Glass Reference Standards for the Trace-Element Analysis of Geological Materials–Compilation of Interlaboratory Data

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ABSTRACT

A set of four artificial glass reference standards, to which were added 46 trace elements, was designed at the U.S. Geological Survey for quality control of trace-element analysis in rocks. This study is a compilation of results from geochemical laboratories of many countries and from three laboratories of the Survey. These standards were made in 180- to 200-pound lots by Corning Glass Works for the Survey. They were designed primarily for monitoring spectrochemical mobile laboratories, as well as for standardizing direct reading spectrometers, or for other similar uses, and are not for sale or distribution outside the U.S. Geological Survey. Medians, instead of the customary arithmetic means, are given for major and minor constituents and for 49 trace elements. Results expressed as medians, obtained by all methods of analyses for lead, rubidium, strontium, and uranium compare favorably with results given for isotope-dilution analyses. Comparisons of quantitative with semiquantitative medians are made with the overall medians for 10 elements; the comparison shows the quantitative medians are in better agreement with the overall medians. The spread of the quantitative data for the three Survey laboratories are compared with each other as well as with the data from the outside laboratories; one Survey laboratory showed the least spread, whereas all the Survey laboratories showed a medium spread of results as compared with the larger spread of the outside laboratories. A quantitative spectrochemical study of compositional homogeneity is included as an important part of establishing the final accuracy of results on these standards. Some isotope-dilution data, for different bottles, are presented for lead and uranium as additional evidence for compositional homogeneity.

INTRODUCTION

An interrelated set of five glass standards (Myers, and others, 1970) was prepared to provide quality control of trace-element analyses in the analytical and mobile laboratories of the U.S. Geological Survey. These standards—GSA, GSB, GSC, GSD, and GSE, in 180- to 200-pound lots each—were made by Corning Glass Works, at the following approximate concentration levels, in parts per million: Blank (GSA), 0.5 (GSB), 5.0 (GSC), 50 (GSD), and 500 (GSE) for 46 trace elements in a glass matrix. Preliminary studies indicated that the blank, GSA, was inhomogeneous, and it was therefore eliminated from the set. To avoid an excessive amount of labor and contamination in preparation of these powders, we sieved them through a 60-mesh nylon screen. When a finer particle size powder (100–200 mesh) is required by the analyst, each standard may be reground in agate. These standards are not for sale or distribution outside the U.S. Geological Survey. However, the results of this study are presented as a guide for similar studies in the future.

Preparation of these standards was undertaken with two general aims in mind: (1) To reduce compositional inhomogeneity or "segregation error" to a minimum, by use of a glass matrix, and (2) to obtain a relatively large supply of standard for long-term quality control of trace-element analysis. More immediate needs were for day-to-day use with direct-reading spectrometers and for mobile laboratory or field units.

ANALYTICAL METHODS

Interlaboratory analyses, based on the cooperative work of the many excellent analysts listed herein, are conventional ways to "certify" the accuracy of major- and trace-element composition of the four glass reference standards. As with all interlaboratory investigations of this nature, this cooperative work has also afforded an opportunity to compare several different analytical methods. As a general rule, agreement among different runs for the same instrumental method are less reassuring than agreement among different instrumental methods.

An attempt to obtain "absolute" compositional accuracy for all elements in these glasses, by using a great number of analyses from a great many laboratories, would consume too much time. Instead, we believe it is possible, using the data available, to arrive at a close approximation to the "true" value by choosing the median as the measure of central tendency, rather than the arithmetic mean of the analyses.

We have used the median, because it is a distribution-free measure of central tendency and because it is little affected by unusually high and low values. We view it as the "most probable" value. Ties have been handled by conventional summing, dividing and rounding. The decision to use the median is supported, at least in part, by

the data shown in table 1 for lead, rubidium, strontium, and uranium from which data by the isotope-dilution method have been obtained.

TABLE 1.—*Isotope-dilution analyses, in parts per million, and corresponding medians of glass standards*

[Leaders (...) indicate no determination made; ID, isotope dilution]

Glass standard---		GSB	GSC	GSD	GSE
Pb	ID---------	---	14	50	460
	Median-----	---	15	52	500
Rb	ID---------	---	4.5	39	420
	Median-----	---	6	41	420
Sr	ID---------	---	27	64	516
	Median-----	---	27	64	500
U	ID---------	1	3.9	39	469
	Median-----	---	---	---	470

TABLE 3.—*Isotope-dilution analyses, in parts per million, for* Pb *and* U *on randomly chosen glass standard bottles*

[Asterisk (*) indicates approximate element content (in parts per million) requested of Corning]

Glass standard--------	GSD *50		GSE *500	
	Bottle No.	Result	Bottle No.	Result
Pb----------	1154	50.9	1376	461
	171	49.9	1430	461
	1018	50.3	1276	467
Mean for bottles----	-----	50.4		463
U----------	765	41.0	305	460
	171	39.1	1276	469
	1018	38.6	1430	477
Mean for bottles----	-----	39.6		469

In the present state of the art, isotope dilution methods seem both in theory and in practice to give the most accurate results for those elements to which these methods are applicable. The isotope-dilution data are given in table 2 for lead, rubidium, strontium, and uranium. In table 3, some evidence is also given for homogeneity of these glasses "between" bottles for lead and uranium.

Because analytical trace-element procedures for different instrumental methods are so varied and yet so precise in detail, it seemed important for this study to survey

TABLE 2.—*Isotope-dilution analyses, in parts per million, of glass standards for* Pb, U, Rb, *and* Sr

[Leaders (...) indicate no data. Asterisk (*) indicates approximate element content (in parts per million) requested of Corning]

Glass standard---	GSB *0.5	GSC *5	GSD *50	GSE *500	Bottle No. (respectively)	Analyst(s) and dates of analyses
Pb----------	---	14.2	50.9	461	435, 1154, 1376	R. E. Zartman and M. H. Deleavux, 1971.
	---	---	50.4	---	171	R. E. Zartman and M. Gallego, 1975.
	---	---	49.5	---	171	Do.
	---	---	49.7	---	171	Do.
	---	---	50.3	---	1018	Do.
	---	---	---	461	1430	W. P. Leeman and M. H. Delevaux, 1975.
	---	---	---	467	1276	Do.
Mean---------	---	14.2	50.2	463	----	
U----------	1	3.9	41.0	460	677, 1825, 765, 305	J. R. Dooley, Jr., 1969.
	---	---	---	477	1430	M. H. Delevaux, B. R. Doe, and W. P. Leeman, 1975.
	---	---	---	469	1276	Do.
	---	---	39.3	---	171	R. E. Zartman and M. Gallego, 1975.
	---	---	38.8	---	171	Do.
	---	---	39.1	---	171	Do.
	---	---	38.6	---	1018	Do.
Mean---------	1	3.9	39.0	469	----	
Rb----------	---	4.78	39.7	419	435, 1154, 1376	C. E. Hedge and W. T. Henderson, 1971.
	---	4.20	39.2	420	435, 1154, 1376	Do.
Mean---------	---	4.5	39.4	420		
Sr----------	---	27.4	64.3	516	435, 1154, 1376	C. E. Hedge and W. T. Henderson, 1971.
		27.4	63.3	517	435, 1154, 1376	Do.
Mean---------	---	27.4	63.8	516	----	

TABLE 4.—*Rock analyses, in percent, of glass standard GSB*

[Leaders (...) indicate no determination made; Tr., trace]

Analyst----- (table 8)	1	2	3	4	5	6	7	8	9	10	11	12	Median
SiO_2--------	61.96	62.2	62.20	62.72	61.1	----	----	----	----	----	----	----	62.20
Al_2O_3-------	14.24	14.2	13.90	14.08	14.1	----	----	----	----	----	----	----	14.10
Fe_2O_3-------	5.16	5.4	5.37	-----	5.7	----	----	----	----	----	----	----	5.38
FeO---------	1.69	1.6	1.50	-----	1.6	----	----	----	----	----	----	----	1.60
MgO---------	3.88	3.8	3.95	3.87	----	3.85	----	----	----	----	----	----	3.87
CaO---------	5.06	5.0	5.10	5.06	5.0	4.92	----	----	----	----	----	----	5.03
Na_2O--------	4.06	3.9	4.12	-----	4.6	4.13	4.12	----	----	----	----	----	4.12
K_2O---------	3.64	3.7	3.62	3.49	3.6	3.60	3.65	----	----	----	----	----	3.62
H_2O^+--------	.10	.40	.14	-----	----	----	----	0.28	0.57	----	----	0.29	.28
H_2O^---------	.07	.10	.07	-----	----	----	----	.07	.13	0.09	0.075	.07	.07
TiO_2--------	.01	<.01	<.05	<.01	Tr.	----	----	----	----	----	----	----	-----[1] (0.0010)
P_2O_5--------	.00	.02	.02	-----	----	----	----	----	----	----	----	----	.02
MnO---------	.03	.04	.028	.023	----	----	----	----	----	----	----	----	.03[1] (0.024)
CO_2---------	.03	-----	-----	-----	----	----	----	----	----	----	----	----	.03
Cl----------	.01	-----	-----	-----	----	----	----	----	----	----	----	----	.01
F----------	.01	-----	-----	-----	----	----	----	----	----	----	----	----	.01
Subtotal--	99.95	-----	-----	-----	----	----	----	----	----	----	----	----	-----
[2]Less O---	.00	-----	-----	-----	----	----	----	----	----	----	----	----	-----
Total-----	99.95	100.00	100.07	-----	----	----	----	----	----	----	----	----	100.37
Fe as Fe_2O_3-	7.04	7.2	-----	6.98	7.5	6.80	----	----	----	----	----	----	7.04

[1]Spectrochemical median (as oxide).
[2]Oxygen equivalent of fluorine and chlorine.

the procedures by questionnaire. This effort has been only partly successful, but, still, the response we did obtain has been informative for judging and understanding some of the analytical results. For example, one optical spectrochemist, using two strongly reversed spectral lines for two elements, found the elements to be 20 to 40 percent lower than the accepted median value. In this report, results from different methods and from different analysts are examined and discussed in more detail.

ROCK ANALYSES

Analyses were made on the glass samples by conventional methods similar to those used for analysis of major and minor rock constituents, and the results are shown in tables 4, 5, 6, and 7. The median for each constituent is given in the last column. The analysis for TiO_2, P_2O_5, and MnO are near their lower limits of detection by these methods. In table 8, the analysts cited are given with affiliations and pertinent data by number.

WATER ANALYSES

The results for combined water $(H_2O)^+$ and moisture $(H_2O)^-$ for the glass samples are shown in table 9. The discrepancy in the results for combined water may be attributed to the failure to determine and correct for the moisture content at the time the samples were weighed for determination of the combined water. Our results in table 10 show that from 0.59 to 0.73 percent additional moisture can be absorbed by these samples when they are placed overnight in a humid atmosphere. Thus, the error due to varying moisture content in these glasses can never be more than about 1 percent.

TRACE-ELEMENT ANALYSES

The interlaboratory study of trace-element composition in these glasses gives reasonable agreement for many elements and very acceptable accuracy. Table 11 gives the supporting evidence. Of course, reviewers and users can draw their own conclusions about matters of agreement among laboratories. Much of the data shown in table 11, for each element, represent averages of several determinations, the number of which is indicated in parentheses after each result. Superscripts, like [a] and [b], are explained in the headnote of table 11. In table 12, the analysts are cited and their affiliations are shown.

DISCUSSION OF DATA

The medians of the trace-element analyses of the four glasses composed from both quantitative and semiquantitative data have been collected and combined for convenience in table 13.

Because of the uncertainty of the data for zirconium in the low concentrations, and especially because of its geochemical importance, a spectrographic study was made on the standard samples GSB and GSC. A direct comparison was made with analytical standards on the same plate by use of 15-mg charges instead of the usual 10-mg charge. This comparison showed that GSC was very close to our original determination of 5 ppm, whereas the GSB sample was definitely lower than the 5 ppm standard, showing 4 ppm as an upper limit. Thus, GSB is shown in tables 11 and 13 as having about 4 ppm zirconium.

In table 11, the authors have rated each median result, using the symbols: R for "suggested with reservations," S for "suggested," and A for "accepted." Thus, we believe that medians that are indicated as accepted (A) are the most accurate. Some medians are based on a few analytical results; therefore, rather than use still another category to signify meager data, we rate them simply as R, "suggested with reservations."

Ranges of the analytical results for several of the trace elements are shown in table 14.

The major element composition of the glasses are also shown as medians, in percent, in table 15, a combination of data from tables 4, 5, 6, and 7.

Both semiquantitative and quantitative data were used in table 11 to obtain the median. It is of interest to examine the data by subdividing it for two medians, for standard GSE:

	As	Cd	Ce	Cd	Ga	Hf	Li	Ni	Pd	Y
Semiquantitative median--	450	400	600	420	20	500	600	600	150	690
Quantitative median------	450	460	500	360	28	500	460	500	100	490
Overall median----------	450	420	550	370	20	500	480	500	100	490

For Cd, Ce, Cs, Ga, Li, Ni, Pd, and Y, one of the individual medians can be considerably different from the overall median; Cd and Ga are closer to the semiquantitative value, and Cs, Ni, Pd, and Y are closer to the quantitative value. The overall median for Ce actually falls halfway between the quantitative and the semiquantitative medians. It is an average of the two. The data for As and Hf are really the most interesting because of the apparent match among semiquantitative and quantitative and overall medians. The quantitative data for Hf, however, gave a fairly narrow range.

Considering the state of the art, as well as the number of results contributed for each element, the data for most of the elements in table 11 are, in general, considered to be remarkably good. The elements for which the medians are based on scarce data are Cl, Eu, F, Ru, Se, Te, and Tl.

One interesting aspect of the data in table 11 is that there are four contributors (Conklin, Fletcher, Mays, and Sutton) of optical spectrochemical data, from three U.S. Geological Survey laboratories, who have used the same methods, and two of these analysts (Conklin and Sutton) are from a single laboratory. In all but a few instances, the comparative data from all four analysts are very good

TABLE 5.—*Rock analyses, in percent, of glass standard GSC*

[Leaders (...) indicate no determination made; Tr., trace]

Analyst----- (table 8)	1	2	3	4	5	6	7	8	9	10	11	12	Median
SiO_2--------	62.04	62.6	62.05	62.78	60.9	----	----	----	----	----	----	----	62.05
Al_2O_3-------	14.20	14.2	13.85	14.21	14.6	----	----	----	----	----	----	----	14.20
Fe_2O -------	5.29	5.6	5.53	-----	5.8	----	----	----	----	----	----	----	5.56
FeO---------	1.58	1.5	1.41	-----	1.4	----	----	----	----	----	----	----	1.46
MgO---------	3.89	3.9	3.95	4.03	----	3.80	----	----	----	----	----	----	3.90
CaO---------	5.00	4.8	5.05	4.98	4.2	4.85	----	----	----	----	----	----	4.92
Na_2O--------	4.06	3.8	4.15	-----	4.6	4.08	4.10	----	----	----	----	----	4.09
K_2O---------	3.60	3.6	3.62	3.62	3.5	3.65	3.64	----	----	----	----	----	3.62
H_2O^+--------	.18	.43	.18	-----	----	----	----	0.31	0.50	----	----	0.35	.33
H_2O^---------	.06	.10	.07	-----	----	----	----	.08	.18	0.10	0.075	.08	.08
TiO_2--------	.01	<.01	<.05	<.01	Tr.	----	----	----	----	----	----	----	-----[1](0.0020)
P_2O_5--------	.00	.02	.02	-----	----	----	----	----	----	----	----	----	.02
MnO---------	.03	.04	.028	.023	----	----	----	----	----	----	----	----	.03[1](0.024)
CO_2---------	.04	-----	------	-----	----	----	----	----	----	----	----	----	.04
Cl----------	.01	-----	------	-----	----	----	----	----	----	----	----	----	.01
F-----------	.01	-----	------	-----	----	----	----	----	----	----	----	----	.01
Subtotal--	100.00	-----	------	-----	----	----	----	----	----	----	----	----	-----
[2]Less 0---	.00	-----	------	-----	----	----	----	----	----	----	----	----	-----
Total-----	100.00	100.00	99.96	-----	----	----	----	----	----	----	----	----	100.32
Fe as Fe_2O_3	7.04	7.3	7.17	-----	7.4	6.96	----	----	----	----	----	----	7.17

[1]Spectrochemical median (as oxide).
[2]Oxygen equivalent of fluorine and chlorine.

TABLE 6.—*Rock analyses, in percent, of glass standard GSD*

[Leaders (...) indicate no determination made; Tr., trace]

Analyst----- (table 8)	1	2	3	4	5	6	7	8	9	10	11	12	Median
SiO_2--------	61.61	62.3	61.80	63.08	60.5	----	----	----	----	----	----	----	61.80
Al_2O_3-------	14.44	14.4	14.20	14.27	14.5	----	----	----	----	----	----	----	14.40
Fe_2O_3-------	5.21	5.2	5.37	-----	5.8	----	----	----	----	----	----	----	5.29
FeO---------	1.61	1.7	1.47	-----	1.4	----	----	----	----	----	----	----	1.54
MgO---------	3.89	3.9	4.05	4.02	----	3.85	----	----	----	----	----	----	3.90
CaO---------	5.00	5.0	5.05	5.02	5.1	4.85	----	----	----	----	----	----	5.01
Na_2O--------	4.06	3.9	4.15	-----	4.6	4.07	4.10	----	----	----	----	----	4.08
K_2O---------	3.72	3.7	3.75	3.66	3.7	3.74	3.74	----	----	----	----	----	3.72
H_2O^+--------	.14	.42	.14	-----	----	----	----	0.31	0.25	----	----	0.35	.28
H_2O^---------	.07	.10	.05	-----	----	----	----	.07	.39	0.12	0.105	.07	.08
TiO_2--------	.01	<.01	.06	<.01	Tr.	----	----	----	----	----	----	----	-----[1] (0.0073)
P_2O_5--------	.00	.02	.02	-----	----	----	----	----	----	----	----	----	.02
MnO---------	.04	.04	.038	.031	----	----	----	----	----	----	----	----	.04[1] (0.017)
CO_2---------	.03	-----	-----	-----	----	----	----	----	----	----	----	----	.03
Cl----------	.01	-----	-----	-----	----	----	----	----	----	----	----	----	.01
F----------	.025	-----	-----	-----	----	----	----	----	----	----	----	----	.02
Subtotal--	99.86	-----	-----	-----	----	----	----	----	----	----	----	----	-----
[2]Less O---	.01	-----	-----	-----	----	----	----	----	----	----	----	----	----
Total-----	99.85	100.00	100.15	-----	----	----	----	----	----	----	----	----	100.22
Fe as Fe_2O_3-	7.00	7.1	-----	7.18	7.4	6.70	----	----	----	----	----	----	7.10

[1]Spectrochemical median (as oxide).

[2]Oxygen equivalent of fluorine and chlorine.

TABLE 7.—*Rock analyses, in percent, of glass standard GSE*

[Leaders (...) indicate no determination made; Tr., trace]

Analyst----- (table 8)	1	2	3	4	5	6	7	8	9	10	11	12	Median
SiO_2--------	61.14	62.1	61.50	61.83	60.0	----	----	----	----	----	----	----	61.50
Al_2O_3-------	14.78	13.6	13.25	13.39	14.0	----	----	----	----	----	----	----	13.60
Fe_2O_3-------	4.74	5.2	5.08	-----	5.3	----	----	----	----	----	----	----	5.14
FeO---------	1.57	1.4	1.37	-----	1.4	----	----	----	----	----	----	----	1.40
MgO---------	3.64	3.6	3.77	3.63	----	3.56	----	----	----	----	----	----	3.63
CaO---------	5.28	5.0	5.35	5.24	5.3	5.05	----	----	----	----	----	----	5.26
Na_2O--------	4.67	4.4	4.60	-----	5.0	4.38	4.53	----	----	----	----	----	4.56
K_2O---------	3.06	3.1	3.11	2.94	3.0	3.08	3.05	----	----	----	----	----	3.06
H_2O^+--------	.05	.38	.07	-----	----	----	----	0.19	0.66	----	----	0.24	.22
H_2O^---------	.03	.06	.05	-----	----	----	----	.03	.10	0.07	0.068	.04	.06
TiO_2--------	.12	.13	.17	.10	.08	----	----	----	----	----	----	----	.12[1] (0.082)
P_2O_5--------	.005	.04	.03	-----	----	----	----	----	----	----	----	----	.03
MnO---------	.09	.09	.10	.095	----	----	----	----	----	----	----	----	.092[1] (0.079)
CO_2---------	.02	-----	-----	-----	----	----	----	----	----	----	----	----	.02
Cl----------	.08	-----	-----	-----	----	----	----	----	----	----	----	----	.08
F----------	.03	-----	-----	-----	----	----	----	----	----	----	----	----	.03
Subtotal--	99.30	-----	-----	-----	----	----	----	----	----	----	----	----	-----
[2]Less O---	.03	-----	-----	-----	----	----	----	----	----	----	----	----	-----
Total-----	99.27	99.00	98.45	-----	----	----	----	----	----	----	----	----	[3]98.80
Fe as Fe_2O_3-	6.49	6.8	-----	6.56	6.9	6.20	----	----	----	----	----	----	6.56

[1]Spectrochemical median (as oxide).
[2]Oxygen equivalent of fluorine and chlorine.
[3]This total does not include the relatively large amount (over 1 percent) of trace elements present in this sample.

TABLE 8.—*Analysts' affiliations and data pertinent to analyses given in tables 4-7*

Column (tables 4-7)	Analyst(s)	Affiliations	Year of analysis	Type(s) of analysis	Reference to published method of analyses
1	Brandt, E. L., (formerly E. L. Munson).	U.S. Geol. Survey, Denver, Colo.	1969	Single conventional----------	Peck (1964).
2	Shapiro, Leonard	U.S. Geol. Survey, Reston, Va.	1969	Rapid methods----------	Shapiro and Brannock (1962).
3	Goni, J., and Moal, J. Y.	BRGM, Natl. Geol. Service, Orleans, France.	1972	Single conventional----------	Moal and others (1968).
4	Fabbi, B. P.	U.S. Geol. Survey, Menlo Park, Calif.	1970, 1971	X-ray fluorescence----------	Fabbi (1972).
5	Weijden, C. H. van der	Univ. Utrecht, the Netherlands.	1970	X-ray fluorescence and method of Shapiro and Brannock (1962) for FeO; flame photometer for Na and K.	Weijden (written commun., 1970).
6	Gardner, Johnnie	U.S. Geol. Survey, Denver, Colo.	1969	Single conventional----------	Perkin-Elmer Corp. (1964).
7	Ingamells, C. O., and Schlocker, L. B.	U.S. Geol. Survey, Menlo Park, Calif.	1971, 1975	-----do----------	L. B. Schlocker (oral commun., 1975).
8	Wasik, J., and Kaye, M.	Australian Natl. Univ., Canberra, ACT Australia.	1970	Conventional----------	Riley (1958).
9	Horska, S.	McGill Univ., Montreal, Quebec, Canada, Dept. Geol. Sciences.	1971	-----do----------	S. Horska (written commun., 1971).
10	Myers, A. T.	U.S. Geol. Survey, Denver, Colo.	1969, 1971	Conventional moisture determination.	Peck (1964).
11	Maxwell, J. A.	Geol. Survey, Ottawa, Canada.	1973	Conventional moisture determination (modified).	J. A. Maxwell (written commun., 1973).
12	Coller, Maynard	Indiana Geol. Survey, Bloomington, Ind.	1973	Conventional----------	R. K. Leininger (written commun., 1973).

TABLE 9.—*Determination of combined water and moisture, in percent, in glass standards*

Analysts and affiliations	GSB	GSC	GSD	GSE	Year(s) analyses	Type(s) of analyses	Reference to published method of analyses
			H_2O+ (combined)				
Brandt, E. L.; U.S. Geol. Survey, Denver, Colo---------	0.10	0.18	0.14	0.05	1969	Modified Penfield---	Peck (1964).
Goni, J., and Moal, J. Y.; BRGM-Nancy, Orleans, France-	.14	.18	.14	.07	1972	-----do----------	Moal and others (1968).
Shapiro, L.; U.S. Geol. Survey, Reston, Va----------	.42	.35	.40	.43	1969	-----do----------	Shapiro and Brannock (1962).
	.37	.50	.44	.32			
Wasik, J., and Kaye, M.; Australian Natl. Univ. Dept. Geology, Canberra, ACT, Australia.	.28	.31	.31	.19	1970	-----do----------	Riley (1958).
Horska, S., Geological Sciences, McGill Univ., Montreal, Quebec, Canada.	.57	.50	.25	.66	1971	-----do----------	S. Horska (written commun., 1971).
Coller, Maynard; Indiana State Univ., Bloomington, Ind-	.29	.35	.35	.24	1973	-----do----------	R. K. Leininger (written commun., 1973).
			H_2O- (moisture)				
Brandt, E. L.; U.S. Geol. Survey, Denver, Colo---------	0.07	0.06	0.07	0.03	1969	1 hour at 105°C-----	Peck (1964).
Myers, A. T.; U.S. Geol. Survey, Denver, Colo----------	.09	.10	.12	.07	1969, 1971	-----do----------	Do.
Goni, J., and Moal, J. Y., BRGM-Nancy, Orleans, France-	.07	.07	.05	.05	1972	-----do----------	Moal and others (1968).
Shapiro, L.; U.S. Geol. Survey, Reston, Va----------	.11	.09	.11	.06	1969	Overnight at 110°C--	Shapiro and Brannock (1962).
	.09	.10	.10	.06			
Wasik, J., and Kaye, M.; Australian Natl. Univ. Dept. Geology, Canberra, ACT, Australia.	.07	.08	.07	.03	1970	1 hour at 110°C-----	Riley (1958).
Horska, S., Geological Sciences, McGill Univ., Montreal, Quebec, Canada.	.13	.18	.39	.10	1971	1½ hours at 118°C---	S. Horska (written commun., 1971).
Maxwell, J. A.; Canada Geol. Survey, Ottawa, Canada----	.08	.08	.10	.07	1973	Overnight at 110°C--	J. W. Maxwell (written commun., 1973).
Coller, Maynard; Indiana State Univ., Bloomington, Ind-	.07	.08	.07	.04	1973	1 hour at 105°C-----	R. K. Leininger (written commun., 1973).

TABLE 10.—*Comparative results, in percent, for moisture* (H_2O^-) *under different conditions of exposure for glass standards*

[Analyst: A. T. Myers, Denver, Colo.; method, conventional moisture determination. Leaders (...) indicate no determination made]

Glass standard-----	GSB	GSC	GSD	GSE	Remarks
August 1969--------	0.09	0.10	0.12	0.07	See table 5.
August 1971--------	---	.20	.15	.15	In glass-stoppered bottle--2-year storage.
Overnight (15 hr)--	.68	.82	.85	.68	In desiccator over water.

(interlaboratory) and, in all but a very few instances, are excellent between the two values (from the two analysts) obtained in a single laboratory (intralaboratory). These two values represent more of a controlled situation—same instrument, same lines (except for V), and same preparation techniques. Whatever differences there are among the three Survey laboratories may be due to subtle differences in instruments, in standards, or in judgments of the analysts. In any event, one would expect the spread of data to be better than the data from three different optical spectrochemical laboratories that are unrelated to the U.S. Geological Survey laboratories and that use different methods, perhaps different lines, and different standard powders, and so forth.

If we now compare the quantitative spectrochemical data (OS of table 11) from Survey analysts (Conklin, Fletcher, Mays, and Sutton) with the data from all spectrochemical analysts of the laboratories outside the Survey, we can show the spread of results in the analytical data for 17 elements for standard GSE:

Total range of results shown as parts per million spread

	Ag	B	Ba	Cd	Co	Cr	Cu	Ge	Mn	Mo	Ni	Pb	Sn	Sr	V	Y	Zr
All Survey laboratories...	30	70	100	40	50	50	110	70	160	170	100	60	100	70	130	70	70
One Survey laboratory.....	10	10	70	20	30	10	10	0	50	10	10	60	0	20	130	0	30
Outside laboratories...	70	200	50	170	190	210	90	170	280	160	80	170	50	50	70	120	90

Considering the above 17 elements, we notice that the spread of results for 15 elements was less for the "one Survey laboratory" when compared with the results for "all Survey laboratories." In this same comparison, two elements (Pb and V) showed an equal spread. If we compare the spread of data for "all Survey laboratories" with that shown by "outside laboratories," 10 elements out of 17 for "all Survey laboratories" showed a narrower spread; one element (Mo) gave an equal spread. The "outside laboratories" did show a narrower spread of results than that of "all Survey laboratories" for 6 elements (Ba, Cu, Ni, Sn, Sr, and V) out of the 17. Only 2 elements (Ba and V) out of the 17 gave a decreased spread of results for "outside laboratories," when compared with the spread of "one Survey laboratory."

COMPOSITIONAL HOMOGENEITY

As Flanagan (1969) pointed out, two prime requirements for reference samples are homogeneity from bottle to bottle and a minimum of contamination during the preparation and bottling of the standards. For these glass standards every known precaution was taken to minimize contamination and to achieve homogeneity. An evaluation of homogeneity was made by quantitative spectrographic analyses for 23 elements in each of four bottles chosen at random from each standard (table 16). Two analyses were made of each split by optical emission procedures. The total variation observed for each standard in this experiment can thus be viewed as the sum of two indipendent variations—variation arising from conditions of

measurement (analytical error) and a second reflecting inhomogeneity in the standard.

The statistical model used is

$$\text{Log } X_{ij} = M + A_i + E_{ij}, \quad (1)$$

where X_{ij} represents the concentration of metal X determined in the jth analysis of the ith split. Because line densities in emission spectrography are exponentially related to concentrations, the observed variation is more properly studied on a logarithmic scale. In this model, M is the true (and generally unknown) concentration, measured in logs, of the metal X in the standard; A_i is the difference between M and the true concentration, in logs, in the ith split; and E_{ij} is the difference between the measured concentration, in logs, and the true logarithmic concentration in the ith split.

The total variance of log X_{ij} is the sum of two variances, that variance due to differences among splits (represented by A_i) and that due to differences among analyses (represented by E_{ij}). Thus,

$$S^2_{\log X} = S^2_A + S^2_E, \quad (2)$$

where $S^2_{\log X}$ is the estimate of the total log variance, S^2_A is the estimate of the log variance among splits and S^2_E is the estimate of analytical log variance. Of interest here is S^2_A, which is a property of the glass standard, and not S^2_E, which is dependent on the laboratory method used.

The component of variance reflecting inhomogeneity (S^2_A) is easily estimated using standard procedures of the analysis of variance, but can be computed from:

$$S^2_A = ((n-1)nm^2)^{-1}((2n-1)\sum_{i=1}^{n}(\sum_{j=1}^{m}\log X_{ij})^2 - (n-1)m\sum_{i=1}^{n}\sum_{j=1}^{m}(\log X_{ij})^2 - (\sum_{i=1}^{n}\sum_{j=1}^{m}\log X_{ij})^2), \quad (3)$$

where S^2_A is the estimate, n is the number of splits analyzed (four), and m is the number of analyses of each split (two). A factor useful in predicting the limits of variation induced by imperfect homogenization is derived from S^2_A:

$$F = \text{antilog } S_A. \quad (4)$$

This factor is a geometric deviation and table 17 lists these factors for several trace metals in each of the four standards. The range of chemical variability expected as a result solely of sample inhomogeneity may be estimated in the following way. About two-thirds of the time (68.3 percent), an analysis of a given standard should range from M/F to M·F, where M is the median of the concentrations (from table 13). About 19 times in 20 (95.4 percent), an analysis should range from M/F^2 to $M \cdot F^2$. Over 99 times in 100 (99.7 percent) an analysis should range from M/F^3 to $M \cdot F^3$. These ranges are those expected under conditions of a perfect analytical method (no imprecision).

For example, if we take the median of Ni in standard GSB (table 11) as the mode, the 68-percent range expected because of sample inhomogeneity is computed as 12–16 ppm and the 95 percent range is 11–18 ppm. Of 19 analyses for Ni in GSB (table 11), only 11 (58 percent) fall within the first range and 14 (74 percent) within the second. The difference between 58 percent and 68 percent or 74 percent and 95 percent, reflects analytical error.

For many entries in table 17 the solution to equation 3 is negative, and the inhomogeneity factor cannot be calculated. Under these conditions, we assume that the factor must be very small, and table 17 lists them simply as "less than" 1.01. For example, Ni in standard GSE seems to be very uniformly distributed. The limits of the 68 percent range expected from sample inhomogeneity should not exceed 495–505 and the maximum 95-percent range due to inhomogeneity should not exceed 490–510. Of 23 analyses for Ni in GSE (table 11), only 5 (22 percent) fall within the first range and only 7 (30 percent) fall within the second. The effects of analytical error seem to be more pronounced in this example than in the previous one. In general, standards GSC and GSE seem to be more homogeneous than standards GSB and GSD. The elements least homogenized seem to be Ba, Cu and Sr.

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*

Abbreviations of methods of analyses:
AA, atomic absorption
FA-OS, fire assay-optical spectrochemistry
Fl. Phot., flame photometry
ID, isotope dilution
OS, optical spectrochemistry
OSp, optical spectrochemistry (automated plate reader)
OSdr, optical spectrochemistry (multichannel direct reader)
XRF, X-ray fluorescence
Chem, chemical

Symbols:
R, suggested reservations
S, suggested
A, accepted
∿, about, or approximated number shown
>, greater than number shown
<, less than number shown
Leaders (---), no data available
Asterisk (*), discussion in text
Number in parentheses (), number of replications for each average result.
a, b, c, d, various spectrochemical techniques of Morgan and Swaine (D. J. Swaine, written commun., 1973)

GSB	GSC	GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
					Quantitative	
Ag:						
<1	2 (2)	28 (2)	380 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
<1	4 (4)	33 (4)	360 (4)	OS	Mays, 1969----------	Do.
<1	5 (4)	43 (4)	390 (4)	OS	Sutton, 1969----------	Do.

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

	GSB	GSC	GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
				Quantitative--Continued			
Ag:							
	---	---	---	380 (2)	XRF	Vromen and Rose, 1970-------	Rose and Cuttitta (1968).
	---	<4	28 (2)	260 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
	.5	3.3 (7)	28 (7)	---	OS	-----do----------	Do.
	<1	4 (8)	44 (8)	380 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
	<.5	3 (3)	34 (3)	330 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
	---	<3	33 (9)	290 (9)	OSdr	Scott and Berrow, 1974------	Scott and others (1969).
				Semiquantitative			
	<.5	2 (10)	20 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
	<,7	5 (2)	50 (2)	400 (2)	OS	Heropoulos, 1968----------	Do.
	---	---	---	330	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
	<1	4	40	600	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
	.6 (4)	5 (4)	50 (4)	300 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
	.5 (6)	4 (6)	>10	>10	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
	<1	4 a	40 a	400 a	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
	<1	3 (4)	40 (4)	---	OS	Mitchell, 1974----------	R. L. Mitchell (written commun., 1974).
	.5 R	4 A	37 A	380 A	Median		
				Quantitative			
As:							
	---	---	---	500 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
	---	---	<10	320 (4)	XRF	Espos and Fabbi, 1971-------	Fabbi and Espos (1972).
	0.3	5.5	42	450	Chem	Turner and McHugh, 1974-----	Ward and others (1963).
				Semiquantitative			
	---	---	<700	700 (10)	OS	Conklin, 1968----------	Myers and others (1961).
	---	---	---	520	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
	---	---	---	380	XRF	Wahlberg, 1972----------	Do.
	---	---	<100	340 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
	.3 R	6 R	42 R	450 S	Median		
				Quantitative			
Au:							
	1 (2)	1.5 (2)	14 (2)	45 (2)	AA	Hubert and Lakin, 1968------	Thompson and others (1968).
	---	1.3	14	40 (8)	FA-AA	Thomas and Riley, 1968------	Huffman and others (1967).
	---	---	<40	50 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
	---	---	<30	50 (4)	OS	Mays, 1969----------	Do.
	---	---	<20	60 (4)	OS	Sutton, 1969----------	Do.
	.06	1.2	12	50	FA-OS	Kvalheim, 1970----------	A. Kvalheim (written commun., 1970).
	.1 (2)	1.0 (2)	11 (2)	40 (2)	FA-OS	-----do----------	Do.
				Semiquantitative			
	---	<10	10 (10)	50 (10)	OS	Conklin, 1968----------	Myers and others (1961).
	---	<15	15 (2)	70 (2)	OS	Heropoulos, 1968----------	Do.
	---	∿1 c	15 c	50 c	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
	---	---	---	50 d	OS	-----do----------	Do.
	.1 R	1.2 S	14 S	50 A	Median		
				Quantitative			
B:							
	20 (2)	20 (2)	49 (2)	520 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
	18 (4)	22 (4)	70 (4)	580 (4)	OS	Mays, 1969----------	Do.
	---	<50	60 (4)	520 (4)	OS	Sutton, 1969----------	Do.
	---	---	<100	500 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
	---	<50	54 (8)	510 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
	<20	24 (3)	45 (3)	360 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
	---	---	---	460	OS	Joensuu, 1972----------	O. Joensuu (written commun., 1972).
	---	---	75 (4)	560 (4)	OS	Campbell and Goodrich, 1973-	E. C. Goodrich (written commun., 1973).
				Semiquantitative			
	18 (10)	20 (10)	50 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
	10 (2)	15 (2)	50 (2)	500 (2)	OS	Heropoulos, 1968----------	Do.
	10 (4)	10 (4)	40 (4)	500 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
	21 (6)	20 (6)	52 (6)	>220	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
	18 c	20 c	50 c	>100 c	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
	---	---	---	500 d	OS	-----do----------	Do.
	15 (2)	20 (4)	40 (4)	400 (4)	OS	Mitchell, 1974----------	R. L. Mitchell (written commun., 1974).
	18 R	20 S	50 A	500 A	Median		
				Quantitative			
Ba:							
	30 (2)	40 (2)	85 (2)	470 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
	28 (4)	29 (4)	62 (4)	490 (4)	OS	Mays, 1969----------	Do.
	29 (4)	42 (4)	100 (4)	570 (4)	OS	Sutton, 1969----------	Do.

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

GSB		GSC		GSD		GSE		Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
									Quantitative--Continued	
Ba:										
---		---		---		520	(4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---		---		110	(4)	500	(4)	AA	Weijden, 1970---------------	C. H. van der Weijden (written commun., 1970).
31	(2)	39	(4)	95	(4)	520	(4)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
39	(4)	45	(4)	91	(4)	450	(4)	XRF	Espos and Fabbi, 1971-------	Fabbi and Espos (1972).
54	(5)	62	(5)	100	(5)	500	(5)	OS	Walker, Smith and Slezak, 1971.	Ahrens and Taylor (1961).
29	(4)	31	(4)	90	(4)	500	(4)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
32	(8)	38	(8)	95	(8)	500	(8)	OS	Conklin, 1972---------------	Bastron and others (1960).
33	(3)	40	(3)	90	(3)	550	(4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
31	(2)	37	(2)	86	(2)	540	(2)	OS	Nockolds and Allen, 1973----	Nockolds and Allen (1953).
									Semiquantitative	
50	(10)	60	(10)	95	(10)	500	(10)	OS	Conklin, 1968---------------	Myers and others (1961).
30	(2)	30	(2)	70	(2)	500	(2)	OS	Heropoulos, 1968------------	Do.
---		---		---		430		XRF	Wahlberg, 1969--------------	C. H. Wahlberg (written commun., 1972).
40		40		200		800		OS	Mitchell, 1970--------------	R. L. Mitchell (written commun., 1970).
---		---		50	(4)	500	(4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
35	(2)	37	(2)	86	(3)	320	(2)	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
29	(6)	34	(6)	82	(6)	460	(6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
31	S	39	S	90	A	500	A	Median		
									Quantitative	
Be:										
<2		3	(2)	36	(2)	460	(2)	OS	Fletcher, 1969--------------	Bastron and others (1960).
<1		2	(4)	50	(4)	590	(4)	OS	Mays, 1969------------------	Do.
---		<5		54	(4)	560	(4)	OS	Sutton, 1969----------------	Do.
---		---		47	(2)	450	(2)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
<2		3.7	(4)	36	(2)	420	(2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
<3		3.5	(8)	40	(8)	550	(8)	OS	Conklin, 1972---------------	Bastron and others (1960).
<3		4	(3)	38	(3)	480	(4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
<3		7	(9)	59	(9)	500	(9)	OSdr	Scott and Berrow, 1974------	Scott and others (1969).
									Semiquantitative	
<1		3	(10)	50	(10)	500	(10)	OS	Conklin, 1968---------------	Myers and others (1961).
<1		5	(2)	50	(2)	500	(2)	OS	Heropoulos, 1968------------	Do.
<3		6		100		1000		OS	Mitchell, 1970--------------	R. L. Mitchell (written commun., 1970).
<1		2	(4)	40	(4)	500	(4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
<1		3	(6)	39	(6)	>150		OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---		3.5	R	44	S	500	A	Median		
									Quantitative	
Bi:										
---		<10		30	(2)	490	(2)	OS	Fletcher, 1969--------------	Bastron and others (1960).
---		<10		52	(4)	420	(4)	OS	Mays, 1969------------------	Do.
---		<20		40	(4)	560	(4)	OS	Sutton, 1969----------------	Do.
---		---		---		480	(4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---		---		<50		460	(2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
<0.5		4.4	(7)	41	(7)	460	(7)	OS	-----do---------------------	Do.
<3		3	(3)	40	(3)	440	(4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
									Semiquantitative	
<5		5	(10)	30	(10)	500	(10)	OS	Conklin, 1968---------------	Myers and others (1961).
---		<7		50	(2)	500	(2)	OS	Heropoulos, 1968------------	Do.
---		<30		40		600		OS	Mitchell, 1970--------------	R. L. Mitchell (written commun., 1970).
<2		2	(4)	40	(4)	500	(4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
---		---		---		410		XRF	Wahlberg, 1972--------------	W. H. Wahlberg (written commun., 1972).
---		<1		40	(6)	350	(6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---		---		50	c	>100	c	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
---		---		---		500	d	OS	-----do---------------------	Do.
---		<30		40	(4)	---		OS	Mitchell, 1974--------------	R. L. Mitchell (written commun., 1970).
---		4	R	40	S	480	A	Median		
									Quantitative	
Cd:										
---		---		<100		480	(2)	OS	Fletcher, 1969--------------	Bastron and others (1960).
---		---		<50		460	(4)	OS	Mays, 1969------------------	Do.
---		---		<100		440	(4)	OS	Sutton, 1969----------------	Do.
---		---		---		480	(2)	XRF	Rose, 1970------------------	Rose and Cuttitta (1968).
---		---		---		∿500	(2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
<2		2.4	(7)	30	(7)	330	(7)	OS	-----do---------------------	Do.
---		---		<100		460	(8)	OS	Conklin, 1972---------------	Bastron and others (1960).
---		<6		25	(3)	370	(4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
									Semiquantitative	
---		<20		30	(10)	500	(10)	OS	Conklin, 1968---------------	Myers and others (1961).
---		---		<50		700	(2)	OS	Heropoulos, 1968------------	Do.

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

GSB		GSC		GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
					Semiquantitative--Continued			
Cd:								
---		---		---	340	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
---		---		<300	400	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
---		<10		30 (4)	300 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
---		<15		34 (6)	250 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---		∿6	c	40 c	>100 c	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
---		---		---	400 d	OS	-----do----------	Do.
---		---		<300	400 (4)	OS	Mitchell, 1974----------	R. L. Mitchell (written commun., 1974).
---		3	R	30 S	420 S	Median		
					Quantitative			
Ce:								
---		---		<100	780 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---		---		<100	580 (4)	OS	May, 1969----------	Do.
---		---		---	500 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---		---		30	450	XRF	Nockolds and Hendry, 1971---	Leake and others (1969).
---		---		<500	500 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
					Semiquantitative			
---		<50		50 (10)	700 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---		---		<70	600 (2)	OS	Heropoulos, 1968----------	Do.
---		---		---	460	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
---		---		---	520	XRF	Wahlberg, 1972----------	Do.
---		<20		76 (6)	630 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---		---		50 R	550 S	Median		
					Quantitative			
Cl:								
50		50		120	800	XRF	Newbury and Webber, 1971----	G. R. Webber (written commun., 1971).
					Semiquantitative			
---		---		---	800	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972)
50	R	50	R	120 R	800 R	Median		
					Quantitative			
Co:								
<4		5	(2)	32 (2)	420 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
<5		<5		35 (4)	470 (4)	OS	Sutton, 1969----------	Do.
---		---		---	370 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
5	(4)	7	(4)	40 (4)	440 (4)	AA	Weijden, 1970----------	C. H. van der Weijden (written commun., 1970).
---		6	(4)	39 (4)	460 (4)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
<6		7	(5)	32 (5)	520 (5)	OS	Walker, Smith and Slezak, 1971.	Ahrens and Taylor (1961).
---		<10		27 (2)	370 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
<5		<10		33 (8)	440 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
<5		6	(3)	26 (3)	400 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
<5		6		33	350	OS	Joensuu, 1972----------	O. Joensuu (written commun., 1972).
<4		5	(4)	30 (4)	460 (4)	OS	Mays, 1973----------	Bastron and others (1960).
---		6	(2)	43 (2)	450 (2)	OS	Nockolds and Allen, 1973----	Nockolds and Allen (1953).
2	(9)	4.5	(9)	41 (9)	540 (9)	OSdr	Scott and Berrow, 1974------	Scott and others (1969).
					Semiquantitative			
3	(10)	7	(10)	30 (10)	700 (10)	OS	Conklin, 1968----------	Myers and others (1961).
<2		5	(2)	50 (2)	500 (2)	OS	Heropoulos, 1968----------	Do.
---		---		---	400	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
<1		4		40	600	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
<5		6	(4)	35 (4)	500 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
<2		8	(2)	36 (3)	380 (2)	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
2	(6)	4	(6)	33 (6)	>460 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---		---		40 b	400 b	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
<3		4	(4)	40 (4)	---	OS	Mitchell, 1974----------	R. L. Mitchell (written commun., 1974).
2	R	6	S	35 A	450 A	Median		
					Quantitative			
Cr:								
5	(2)	9	(2)	68 (2)	460 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
<5		9	(4)	50 (4)	490 (4)	OS	Mays, 1969----------	Do.
4	(4)	8	(4)	41 (4)	510 (4)	OS	Sutton, 1969----------	Do.
---		---		---	480 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---		---		---	410 (2)	AA	Suhr, 1970----------	N. H. Suhr (written commun., 1970).
---		13	(2)	30 (2)	520 (2)	AA	Weijden, 1970----------	C. H. van der Weijden (written commun., 1970).
<5		5	(2)	50 (2)	520 (2)	XRF	Newbury and Webber, 1971----	G. R. Webber (written commun., 1971).

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

GSB		GSC		GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
					Quantitative--Continued			
Cr:								
2	(4)	7	(4)	40 (4)	460 (4)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
---		<10		46 (5)	480 (5)	OS	Walker, Smith and Slezak, 1971.	Ahrens and Taylor (1961).
---		<10		42 (2)	470 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
5	(8)	8	(8)	53 (8)	500 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
<5		9	(3)	44 (3)	460 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
<5		6		40	410	OS	Joensuu, 1972----------	O. Joensuu (written commun., 1972).
1	(2)	6	(2)	45 (2)	480 (2)	OS	Nockolds and Allen, 1973----	Nockolds and Allen (1953).
2	(9)	8	(9)	55 (9)	670 (9)	OSdr	Scott and Berrow, 1974------	Scott and others (1969).
					Semiquantitative			
3	(10)	7	(10)	50 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
3	(2)	7	(2)	50 (2)	500 (2)	OS	Heropoulos, 1968----------	Do.
3		6		40	600	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
<5		6	(4)	55 (4)	600 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
12	(2)	11	(2)	48 (3)	530 (2)	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
3	(6)	6	(6)	39 (6)	440 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
1	(4)	6	(4)	60 (4)	---	OS	Mitchell, 1974----------	R. L. Mitchell (written commun., 1974).
3	S	7	A	47 A	490 A	Median		
					Quantitative			
Cs:								
---		4		34	340	Fl.Phot.	Campbell and Wise, 1972-----	D. E. Campbell (written commun., 1972).
<2		4.5	(2)	34 (2)	370 (2)	AA	Mountjoy, 1972----------	W. Mountjoy (written commun., 1972).
<1		3	(2)	35 (2)	360 (2)	AA	-----do----------	Do.
					Semiquantitative			
---		---		---	410	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
<1		4	(2)	54 (2)	---	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
---		---		---	430	XRF	Wahlberg, 1972----------	J. S. Wahlberg (written commun., 1972).
---		4	S	35 S	370 S	Median		
					Quantitative			
Cu:								
5	(2)	10	(2)	56 (2)	480 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
3	(4)	8	(4)	44 (4)	590 (4)	OS	Mays, 1969----------	Do.
3	(4)	8	(4)	58 (4)	520 (4)	OS	Sutton, 1969----------	Do.
---		<20		60 (2)	450 (2)	AA	Gardner, 1969----------	Huffman (1968).
---		---		---	480 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---		---		---	590 (3)	AA	Suhr, 1970----------	N. H. Suhr (written commun., 1970).
11	(4)	12	(4)	45 (4)	500 (4)	AA	Weijden, 1970----------	C. H. van der Weijden (written commun., 1970).
4	(4)	6	(4)	42 (4)	480 (4)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
11		13		38	340	XRF	Nockolds and Hendry, 1971---	Leake and others (1969).
<10		11	(5)	41 (5)	420 (5)	OS	Walker, Smith and Slezak, 1971.	Ahrens and Taylor (1961).
5	(4)	8.6	(4)	41 (2)	510 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
3	(8)	6.4	(8)	48 (8)	530 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
<3		7	(3)	44 (3)	460 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
6		10		40	440	OS	Joensuu, 1972----------	O. Joensuu (written commun., 1972).
2	(2)	5	(2)	40 (2)	470 (2)	OS	Nockolds and Allen, 1973----	Nockolds and Allen (1953).
					Semiquantitative			
3	(10)	7	(10)	50 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
7	(2)	15	(2)	70 (2)	500 (2)	OS	Heropoulos, 1968----------	Do.
10	(4)	10	(4)	45 (4)	500 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
7	(2)	9	(2)	35 (3)	---	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
---		6	(6)	47 (6)	440 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
5	R	9	S	45 A	500 A	Median		
					Quantitative			
Eu:								
---		---		<100	660 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
					Semiquantitative			
---		<70		70 (10)	700 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---		<50		50 (2)	550 (2)	OS	Heropoulos, 1968----------	Do.
<1		3	(6)	40 (6)	380 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---		3	R	50 R	600 R	Median		
					Quantitative			
F:								
100		100		250	300	Chem	Brandt, 1969----------	Peck (1964).
100	R	100	R	250 R	300 R	Median		

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

GSB	GSC	GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
					Quantitative	
Ga:						
5 (2)	6 (2)	5 (2)	30 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
5 (4)	5 (4)	5 (4)	25 (4)	OS	Mays, 1969----------	Do.
---	---	<7	30 (4)	OS	Sutton, 1969----------	Do.
<2	<2	<2	13 (7)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
2 (3)	3 (3)	3 (3)	28 (4)	OS	Goni and Moal, 1972---------	Moal and others, 1968).
					Semiquantitative	
7 (10)	7 (10)	7 (10)	30 (10)	OS	Conklin, 1968----------	Myers and others (1961).
3 (2)	5 (2)	5 (2)	20 (2)	OS	Heropoulos, 1968----------	Do.
3	4	4	20	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
---	---	<5	17 (2)	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
---	---	<2	18 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
2 b	3 b	2 b	15 b	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
3 (4)	4 (4)	3 (4)	20 (4)	OS	Mitchell, 1974----------	R. L. Mitchell (written commun., 1974).
3 R	5 R	5 R	20 R	Median		
					Quantitative	
Ge:						
---	<20	30 (2)	460 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---	<20	42 (4)	520 (4)	OS	Sutton, 1969----------	Do.
---	---	---	530 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---	---	<50	470 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
<0.7	1.6 (7)	34 (7)	410 (7)	OS	-----do----------	Do.
--	<20	41 (8)	520 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
---	<6	38 (3)	440 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
---	---	80 (4)	580 (4)	OS	Campbell and Goodrich, 1973-	E. C. Goodrich (written commun., 1973).
---	<10	31 (4)	450 (4)	OS	Mays, 1973----------	Bastron and others (1960).
---	<10	42 (9)	510 (9)	OSdr	Scott and Berrow, 1974------	Scott and others (1969).
					Semiquantitative	
---	<20	30 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---	<7	50 (2)	600 (2)	OS	Heropoulos, 1968----------	Do.
---	<10	30	400	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
---	<10	50 (4)	>100	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
---	<1	26 (6)	390 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---	5 c	40 c	>100 c	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
---	---	---	500 d	OS	-----do----------	Do.
---	4 R	40 S	500 A	Median		
					Quantitative	
Hf:						
---	---	<100	500 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---	---	<100	540 (4)	OS	Mays, 1969----------	Do.
---	---	<100	500 (4)	OS	Sutton, 1969----------	Do.
---	---	---	510 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
					Semiquantitative	
---	<50	45 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---	<50	50 (2)	600 (2)	OS	Heropoulos, 1968----------	Do.
---	<10	16 (6)	220 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---	---	45 R	500 S	Median		
					Quantitative	
In:						
---	<20	50 (2)	580 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---	<20	70 (4)	560 (4)	OS	Sutton, 1969----------	Do.
---	---	---	420 (2)	XRF	Rose, 1970----------	Rose and Cuttitta (1968).
---	---	---	480	OS	Campbell and Sterlace, 1972-	D. E. Campbell (written commun., 1972).
---	---	---	≈480 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
<0.5	3.4 (7)	39 (7)	490 (7)	OS	-----do----------	Do.
.6 (5)	4.3 (5)	42 (5)	520 (5)	Chem	Hubert and Lakin, 1972------	Thompson and others (1968).
---	---	---	600 (4)	OS	Campbell and Goodrich, 1973-	E. C. Goodrich (written commun., 1973).
---	<10	70 (4)	580 (3)	OS	Mays, 1973----------	Bastron and others (1960).
					Semiquantitative	
---	<10	30 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
<5	5 (2)	50 (2)	500 (2)	OS	Heropoulos, 1968----------	Do.
---	---	---	460	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
<3	3	30	600	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
---	<20	50 (4)	500 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
---	---	---	490	XRF	Wahlberg, 1972----------	J. S. Wahlberg (written commun., 1972).
---	<5	46 (6)	>150 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---	---	50 a	500 a	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
---	---	40 b	500 b	OS	-----do----------	Do.
.3 c	4 c	50 c	>100 c	OS	-----do----------	Do.
---	---	---	500 d	OS	-----do----------	Do.
.5 R	4 R	50 S	500 S	Median		

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

GSB	GSC	GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
					Quantitative	
Ir:						
---	---	<50	150 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---	---	<50	140 (4)	OS	Sutton, 1969----------	Do.
0.1 (2)	1.3 (2)	14 (2)	90 (4)	FA-OS	Dorrzapf, 1970----------	Dorrzapf and Brown (1970).
					Semiquantitative	
---	<30	30 (10)	150 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---	<7	---	61 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
.1 R	1.3 R	20 R	140 S	Median		
					Quantitative	
La:						
---	---	---	690 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---	<50	45 (4)	650 (4)	OS	Sutton, 1969----------	Do.
---	---	---	670 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---	5	45	550	XRF	Nockolds and Hendry, 1971---	Leake and others (1969).
---	<50	~47 (2)	530 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
---	---	<50	680 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
---	---	46	510	OS	Joensuu, 1972----------	O. Joensuu (written commun., 1972).
---	<30	60 (4)	550 (4)	OS	Mays, 1973----------	Bastron and others (1960).
					Semiquantitative	
---	<50	50 (10)	700 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---	<30	50 (2)	500 (2)	OS	Heropoulos, 1968----------	Do.
---	---	---	500	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
---	<20	30 (4)	550 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
---	<15	36 (6)	560 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---	5 R	47 A	550 S	Median		
					Quantitative	
Li:						
---	<10	40 (2)	400 (2)	AA	Gardner, 1969----------	Huffman (1968).
---	---	36 (2)	420 (2)	AA	Mountjoy, 1971----------	W. Mountjoy (written commun., 1972).
1 (2)	5 (2)	50 (2)	460 (2)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
---	4.2	37	490	Fl.Phot.	Campbell and Wise, 1972-----	D. E. Campbell (written commun., 1972).
---	<10	39 (2)	440 (2)	AA	Mountjoy, 1972----------	W. Mountjoy (written commun., 1972).
<4	4.5 (2)	37 (2)	460 (2)	AA	-----do----------	Do.
<1	3 (9)	51 (9)	560 (9)	OSdr	Scott and Berrow, 1974------	Scott and others (1969).
					Semiquantitative	
---	---	<200	600 (2)	OS	Heropoulos, 1968----------	Myers and others (1961).
1	6	60	1000	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
1 (2)	5 (2)	33 (2)	---	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
---	<30	---	560 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
1 (4)	6 (4)	60 (4)	---	OS	Mitchell, 1974----------	R. L. Mitchell (written commun., 1974).
1 R	5 R	40 S	480 A	Median		
					Quantitative	
Mn:						
130 (2)	140 (2)	180 (2)	510 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
190 (4)	200 (4)	210 (4)	620 (4)	OS	Sutton, 1969----------	Do.
---	---	---	530 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---	---	---	450 (3)	AA	Suhr, 1970----------	N. H. Suhr (written commun., 1970).
190 (2)	200 (2)	240 (2)	720 (2)	XRF	Newbury and Webber, 1971----	G. R. Webber (written commun., 1971).
190 (2)	170 (2)	180 (2)	570 (2)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
170	190	210	610	XRF	Nockolds and Hendry, 1971---	Leake and others (1969).
---	---	<200	470 (5)	OS	Walker, Smith and Slezak, 1971.	Ahrens and Taylor (1961).
220	220	260	660	OS	Campbell and Sterlace, 1972-	D. E. Campbell (written commun., 1972).
210 (4)	190 (4)	250 (2)	750 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
190 (8)	210 (8)	240 (8)	670 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
140 (3)	170 (3)	200 (3)	660 (3)	OS	Goni and Moal, 1972---------	Moal and others (1968).
140 (4)	140 (4)	200 (4)	600 (4)	OS	Mays, 1973----------	Bastron and others, 1960).
170 (9)	180 (9)	210 (9)	650 (9)	OSdr	Scott and Berrow, 1974------	Scott and others (1969).
					Semiquantitative	
150 (10)	150 (10)	200 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
200 (2)	200 (2)	200 (2)	600 (2)	OS	Heropoulos, 1968----------	Do.
250	250	250	600	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
200	200	200	800	OS	-----do----------	Do.
110 (4)	140 (4)	190 (4)	700 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
200 (2)	240 (2)	210 (3)	470 (2)	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
200 (4)	200 (4)	250 (4)	---	OS	Mitchell, 1974----------	R. L. Mitchell (written commun., 1974).
190 S	200 S	210 S	600 S	Median		
					Quantitative	
Mo:						
<4	6 (2)	40 (2)	410 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
<5	7 (4)	50 (4)	580 (4)	OS	Mays, 1969----------	Do.
<5	6 (4)	46 (4)	540 (4)	OS	Sutton, 1969----------	Do.

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

GSB		GSC		GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
					Quantitative--Continued			
Mo:								
---		---		---	500 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
∿5		7	(2)	42 (2)	440 (2)	XRF	Newbury and Webber, 1971----	G. R. Webber (written commun., 1971).
---		5	(4)	46 (4)	480 (4)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
<3		7	(8)	46 (8)	530 (8)	OS	Conklin, 1972---------------	Bastron and others (1960).
---		---		<50	480 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
---		<7		44 (3)	420 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
---		<10		52	490	OS	Joensuu, 1972---------------	O. Joensuu (written commun., 1972).
---		5	(2)	47 (2)	550 (2)	OS	Nockolds and Allen, 1973----	Nockolds and Allen (1953).
---		<1		45 (9)	580 (9)	OSdr	Scott and Berrow, 1974------	Scott and others (1969).
					Semiquantitative			
2	(10)	7	(10)	50 (10)	500 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
<2		7	(2)	70 (2)	700 (2)	OS	Heropoulos, 1968------------	Do.
<3		3		40	1000	OS	Mitchell, 1970--------------	R. L. Mitchell (written commun., 1970).
<2		5	(4)	20 (4)	300 (4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
3	(6)	8	(6)	53 (6)	340 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
1.5	a	5	a	50 a	500 a	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
<1		5	(4)	50 (4)	---	OS	Mitchell, 1974--------------	R. L. Mitchell (written commun., 1974).
2	R	6	A	46 A	500 A	Median		
					Quantitative			
Nb:								
---		<20		40 (4)	530 (4)	OS	Fletcher, 1969--------------	Bastron and others (1960).
---		<20		41 (4)	520 (4)	OS	Sutton, 1969----------------	Do.
---		---		---	480 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---		<6		42 (2)	520 (2)	XRF	Newbury and Webber, 1971----	G. R. Webber (written commun., 1971).
---		<50		55 (2)	510 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
---		<10		40 (8)	490 (8)	OS	Conklin, 1972---------------	Bastron and others (1960).
---		<10		46 (4)	500 (4)	OS	Mays, 1973------------------	Do.
					Semiquantitative			
<7		7	(10)	30 (10)	480 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
---		<7		50 (2)	500 (2)	OS	Heropoulos, 1968------------	Do.
---		---		---	450	XRF	Wahlberg, 1969--------------	J. S. Wahlberg (written commun., 1972).
---		<10		30 (4)	500 (4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
<2		4	(6)	26 (6)	---	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---		5	R	40 A	500 A	Median		
					Quantitative			
Ni:								
10	(2)	20	(2)	60 (2)	600 (4)	OS	Fletcher, 1969--------------	Bastron and others (1960).
10	(4)	10	(4)	49 (4)	530 (4)	OS	Sutton, 1969----------------	Do.
---		---		---	500 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---		---		---	510 (2)	AA	Suhr, 1970------------------	N. H. Suhr (written commun., 1970).
15	(4)	18	(4)	54 (4)	440 (6)	AA	Weijden, 1970---------------	C. H. van der Weijden (written commun., 1970).
---		---		66 (4)	500 (4)	XRF	Espos and Fabbi, 1971-------	Fabbi and Espos (1972).
16	(2)	20	(2)	67 (2)	630 (2)	XRF	Newbury and Webber, 1971----	G. R. Webber (written commun., 1971).
11	(2)	15	(2)	54 (2)	480 (2)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
12	(2)	15	(2)	48 (2)	460 (2)	OS	-----do---------------------	Do.
18		19		59	490	XRF	Nockolds and Hendry, 1971---	Leake and others (1969).
14	(5)	18	(5)	46 (5)	540 (5)	OS	Walker, Smith and Slezak, 1971.	Ahrens and Taylor (1961).
---		<10		50 (2)	500 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
10	(8)	11	(8)	50 (8)	540 (8)	OS	Conklin, 1972---------------	Bastron and others (1960).
11	(3)	14	(3)	53 (3)	480 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
---		<10		57	500	OS	Joensuu, 1972---------------	O. Joensuu (written commun., 1972).
10	(4)	13	(4)	45 (4)	500 (4)	OS	Mays, 1973------------------	Bastron and others (1960).
14	(9)	18	(9)	56 (9)	460 (9)	OSdr	Scott and Berrow 1974-------	Scott and others (1969).
					Semiquantitative			
15	(10)	20	(10)	70 (10)	700 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
20	(2)	25	(2)	70 (2)	600 (2)	OS	Heropoulos, 1968------------	Do.
15		20		60	600	OS	Mitchell, 1970--------------	R. L. Mitchell (written commun., 1970).
15	(4)	20	(4)	35 (4)	700 (4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
16	(2)	22	(2)	53 (2)	520 (2)	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
13	(6)	17	(6)	40 (6)	360 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
15	(4)	15	(4)	60 (4)	---	OS	Mitchell, 1974--------------	R. L. Mitchell (written commun., 1974).
15	(10)	20	(10)	70 (10)	700 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
20	(2)	25	(2)	70 (2)	600 (2)	OS	Heropoulos, 1968------------	Do.
15		20		60	600	OS	Mitchell, 1970--------------	R. L. Mitchell (written commun., 1970).
15	(4)	20	(4)	35 (4)	700 (4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
16	(2)	22	(2)	53 (2)	520 (2)	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
13	(6)	17	(6)	40 (6)	360 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
15	(4)	15	(4)	60 (4)	---	OS	Mitchell, 1974--------------	R. L. Mitchell (written commun., 1974).
14	R	18	S	54 A	500 A	Median		

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

GSB	GSC	GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
			Quantitative			
Pb:						
20 (2)	20 (2)	60 (2)	540 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---	<20	78 (4)	600 (4)	OS	Sutton, 1969----------	Do.
---	---	---	500 (4)	XRF	Vromen and Rose, 1969------	Rose and Cuttitta (1968).
14 (2)	18 (2)	52 (2)	450 (2)	XRF	Newbury and Webber, 1971---	G. R. Webber (written commun., 1971).
21 (4)	21 (4)	52 (4)	480 (4)	OS	Nockolds and Allen, 1971---	Nockolds and Allen (1953).
---	14	51	460	I.D.	Zartman and Delevaux, 1971-	Doe and others (1967).
---	---	<300	510 (2)	OS	Champ and Bender, 1972-----	W. H. Champ (written commun., 1972).
11 (7)	15 (7)	55 (7)	540 (7)	OS	-----do----------	Do.
---	<20	46 (8)	540 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
<6	11 (3)	43 (3)	430 (4)	OS	Goni and Moal, 1972--------	Moal and others (1968).
---	<30	58 (9)	600 (9)	OSdr	Scott and Berrow, 1974-----	Scott and others (1969).
---	---	50 (4)	---	I.D.	Zartman and Gallego, 1975--	Doe and others (1967).
---	---	---	460 (2)	I.D.	Leeman and Delevaux, 1975--	Do.
			Semiquantitative			
10 (10)	15 (10)	50 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
12 (2)	15 (2)	70 (2)	600 (2)	OS	Heropoulos, 1968----------	Do.
---	---	---	480	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
---	<13	35	600	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
10 (4)	15 (4)	50 (4)	500 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
8 (6)	11 (6)	54 (6)	470 (6)	OSp	Dorrzapf and Thomas, 1973--	Dorrzapf (1973).
10 c	10 c	40 c	>100 c	OS	Morgan and Swaine, 1973----	D. J. Swamp (written commun., 1973).
---	---	---	500 d	OS	-----do----------	Do.
13 R	15 A	52 A	500 S	Median		
			Quantitative			
Pd:						
---	<6	26 (2)	82 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---	<3	35 (4)	100 (4)	OS	Mays, 1969----------	Do.
0.2 (2)	2.5 (2)	43 (2)	86 (2)	FA-OS	Dorrzapf, 1970----------	Dorrzapf and Brown (1970).
			150 (2)	FA-OS	-----do----------	Do.
<.07	3.5	35	110	FA-OS	Kvalheim, 1970----------	A. Kvalheim (written commun., 1970).
.4 (2)	3.3 (2)	36 (2)	100 (2)	FA-OS	-----do----------	Do.
---	<5	36 (4)	98 (4)	OS	Sutton, 1971----------	Bastron and others (1960).
			Semiquantitative			
<5	5 (10)	50 (10)	100 (10)	OS	Conklin, 1968----------	Myers and others (1961).
<1	5 (2)	50 (2)	200 (2)	OS	Heropoulos, 1968----------	Do.
<.2	4 (6)	45 (6)	<68 (6)	OSp	Dorrzapf and Thomas, 1973--	Dorrzapf (1973).
0.2 R	3.8 S	36 S	100 A	Median		
			Quantitative			
Pt:						
---	---	<20	76 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---	---	<10	92 (4)	OS	Mays, 1969----------	Do.
0.8 (2)	0.7 (2)	1.4 (2)	110 (2)	FA-OS	Dorrzapf, 1970----------	Dorrzapf and Brown (1970).
---	---	1.4 (2)	120 (2)	FA-OS	-----do----------	Do.
---	.56	<5	100	FA-OS	Kvalheim, 1970----------	A. Kvalheim (written commun., 1970).
.6 (2)	.49 (2)	<1.2	120 (2)	FA-OS	-----do----------	Do.
---	---	<50	110 (4)	OS	Sutton, 1971----------	Bastron and others (1960).
			Semiquantitative			
---	---	<50	140 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---	---	<10	120 (2)	OS	Heropoulos, 1968----------	Do.
---	---	<2	77 (6)	OSp	Dorrzapf and Thomas, 1973--	Dorrzapf (1973).
0.7 R	0.6 R	1.4 R	110 A	Median		
			Quantitative			
Rb:						
---	<10	42 (4)	410 (4)	XRF	Espos and Fabbi, 1971------	Fabbi and Espos (1972).
---	5	35	420	XRF	Golde and Leininger, 1971--	R. K. Leininger (written commun., 1973).
---	4.5 (2)	40 (2)	420 (2)	I.D.	Hedge and Henderson, 1971--	C. E. Henderson (written commun., 1971).
---	5 (2)	46 (2)	480 (2)	XRF	Newbury and Webber, 1971---	G. R. Webber (written commun., 1971).
---	---	---	480 (2)	OS	Nockolds and Allen, 1971---	Nockolds and Allen (1953).
8	9	45	420	XRF	Nockolds and Hendry, 1971--	Leake and others (1969).
---	6.2	39	430	Fl.Photo.	Campbell and Sterlace, 1972	D. E. Campbell (written commun., 1972).
5 (2)	8 (2)	40 (2)	420 (2)	AA	Mountjoy, 1972----------	W. Mountjoy (written commun., 1972).
---	---	---	410 (2)	XRF	Rose, 1974----------	Rose and Cuttitta (1968).
			Semiquantitative			
---	---	---	490	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
2 (2)	8 (2)	61 (2)	---	OS	Alcock and Shaw, 1971------	D. M. Shaw (written commun., 1971).
---	---	---	420	XRF	Wahlberg, 1972----------	J. S. Wahlberg (written commun., 1972).
5 R	6 S	41 A	420 A	Median		

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

	GSB	GSC	GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
						Quantitative	
Rh:							
---		<3	24 (4)	54 (4)	OS	Mays, 1969----------	Bastron and others (1960).
---		<10	15 (4)	60 (4)	OS	Sutton, 1969----------	Do.
4	(2)	5 (2)	20 (2)	70 (2)	FA-OS	Dorrzapf, 1970----------	Dorrzapf and Brown (1970).
						Semiquantitative	
<5		5 (10)	15 (10)	64 (10)	OS	Conklin, 1968----------	Myers and others (1961).
3	(6)	4 (6)	18 (6)	47 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
3	R	4 R	18 S	60 S	Median		
						Quantitative	
Ru:							
---		1.4 (2)	12.5 (2)	90 (2)	FA-OS	Dorrzapf, 1970----------	Dorrzapf and Brown (1970).
---		1.4 R	12 R	90 R	Median		
						Quantitative	
Sb:							
---		---	<200	460 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---		---	<500	520 (4)	OS	Sutton, 1969----------	Do.
---		---	---	470 (2)	XRF	Rose, 1970----------	Rose and Cuttitta (1968).
---		---	<70	390 (4)	XRF	Espos and Fabbi, 1971-------	Fabbi and Espos (1972).
---		<10	25 (7)	350 (7)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
---		---	<100	430 (4)	OS	Mays, 1973----------	Bastron and others (1960).
						Semiquantitative	
---		---	<200	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---		---	<100	500 (2)	OS	Heropoulos, 1968----------	Do.
---		---	---	460	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
---		<50	50 (4)	500 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
---		---	---	510	XRF	Wahlberg, 1972----------	J. S. Wahlberg (written commun., 1972).
---		---	<70	330 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---		---	37 R	470 S	Median		
						Quantitative	
Sc:							
---		---	<4	32 (2)	OS	Fletcher, 1969----------	Bastron and others (1960).
---		---	<2	21 (4)	OS	Mays, 1969----------	Do.
---		---	<5	34 (4)	OS	Sutton, 1969----------	Do.
---		---	<4	33 (4)	XRF	Espos and Fabbi, 1971-------	Fabbi and Espos (1972).
---		---	<5	25 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
---		---	<7	34 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
---		<2	3 (3)	27 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
---		---	---	21	OS	Joensuu, 1972----------	O. Joensuu (written commun., 1972).
---		---	---	32 (2)	XRF	Rose, 1974----------	Rose and Cuttitta (1968).
						Semiquantitative	
---		---	<5	30 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---		---	<2	25 (2)	OS	Heropoulos, 1968----------	Do.
---		---	<3	15	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
---		---	<5	20 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
---		---	<1	31 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---		---	---	21 a	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
---		---	<6	30 (4)	OS	Mitchell, 1974----------	R. L. Mitchell (written commun., 1974).
---		---	3 R	30 S	Median		
						Quantitative	
Se:							
<10		<10	<10	<10	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
<.5		<.5	<.5	3	Chem	Burrow, 1970----------	Rader and Grimaldi (1961).
---		---	---	3 R	Median		
						Quantitative	
Sn:							
---		<20	50 (2)	530 (4)	OS	Fletcher, 1969----------	Bastron and others (1960).
<8		8 (4)	44 (4)	430 (4)	OS	Mays, 1969----------	Do.
---		<20	42 (4)	440 (4)	OS	Sutton, 1969----------	Do.
---		---	---	430 (2)	XRF	Rose, 1970----------	Rose and Cuttitta (1968).
---		6 (4)	41 (4)	440 (4)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
---		---	<50	390 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
---		<20	46 (8)	440 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
<2		4 (3)	43 (3)	430 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
---		5 (2)	42 (2)	420 (2)	OS	Nockolds and Allen, 1973----	Nockolds and Allen (1953).

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

GSB	GSC	GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
					Semiquantitative	
Sn:						
<5	5 (10)	50 (10)	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---	<7	50 (2)	500 (2)	OS	Heropoulos, 1968----------	Do.
---	---	---	470	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
<3	<30	30	400	OS	Mitchell, 1970----------	R. L. Mitchell (written commun., 1970).
<5	5 (4)	35 (4)	500 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
<3	---	35 (6)	---	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
∿.6 c	5 c	40 c	>100 c	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973
---	---	---	400 d	OS	-----do----------	Do.
∿0.6 R	5 R	43 S	440 A	Median		
					Quantitative	
Sr:						
33 (2)	40 (2)	100 (2)	470 (4)	OS	Fletcher, 1969----------	Bastron and others (1960).
40 (2)	40 (2)	70 (2)	500 (2)	AA	Gardner, 1969----------	Huffman (1968).
26 (4)	36 (4)	67 (4)	540 (4)	OS	Sutton, 1969----------	Bastron and others (1960).
---	---	---	500 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---	---	---	480 (2)	AA	Suhr, 1970----------	N. H. Suhr (written commun., 1970).
38 (4)	42 (4)	72 (4)	490 (4)	XRF	Espos and Fabbi, 1971-------	Fabbi and Espos (1972).
---	27 (2)	64 (2)	520 (2)	I.D.	Hedge and Henderson, 1971---	C. E. Hedge (written commun., 1972).
24 (2)	27 (2)	65 (2)	520 (2)	XRF	Newbury and Webber, 1971----	G. R. Webber (written commun., 1971).
26 (4)	24 (4)	62 (4)	540 (2)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
33	36	77	510	XRF	Nockolds and Hendry, 1971---	Leake and others (1969).
22 (4)	25 (4)	57 (2)	490 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
22 (8)	31 (8)	74 (8)	520 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
15 (3)	22 (3)	55 (3)	520 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
26 (2)	27 (2)	60 (2)	460 (2)	AA	Mountjoy, 1972----------	W. Mountjoy (written commun., 1972).
28 (2)	26 (2)	58 (2)	490 (2)	AA	-----do----------	Do.
24 (2)	25 (2)	58 (2)	490 (2)	AA	-----do----------	Do.
45 (4)	49 (4)	65 (4)	500 (4)	OS	Mays, 1973----------	Bastron and others (1960).
					Semiquantitative	
20 (2)	30 (2)	100 (2)	700 (2)	OS	Heropoulos, 1968----------	Myers and others (1961).
---	---	---	450	XRF	Wahlberg, 1969----------	J. S. Wahlberg (written commun., 1972).
---	---	<100	500	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
26 (6)	22 (6)	61 (6)	580 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
10 (2)	20 (2)	52 (2)	410 (2)	XRF	Golde and Leininger, 1973---	R. K. Leininger (written commun., 1973).
26 S	27 A	64 A	500 A	Median		
					Quantitative	
Ta:						
---	---	---	<400	OS	Fletcher, 1969----------	Bastron and others (1960).
---	---	---	530 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---	---	<100	420 (4)	OS	Mays, 1973----------	Bastron and others (1960).
					Semiquantitative	
---	---	<500	500 (10)	OS	Conklin, 1968----------	Myers and others (1961).
---	---	<50	400 (2)	OS	Heropoulos, 1968----------	Do.
---	---	---	460	XRF	Wahlberg, 1969----------	J. S. Wahlberg (1972).
---	---	---	490	XRF	Wahlberg, 1972----------	Do.
---	---	---	480 S	Median		
					Quantitative	
Te:						
---	0.3	12	250	Chem	Hubert and Lakin, 1970------	Thompson and others (1968).
---	---	<50	280 (7)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
					Semiquantitative	
---	---	---	<300	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---	0.3 R	12 R	260 R	Median		
					Quantitative	
Ti:						
6 (4)	8 (4)	40 (4)	480 (4)	OS	Mays, 1969----------	Bastron and others (1960).
<10	13 (4)	44 (4)	550 (4)	OS	Sutton, 1969----------	Do.
---	---	---	480 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---	---	---	500 (5)	OS	Walker, Smith & Slezak, 1971	Ahrens and Taylor (1961).
---	<10	43 (2)	460 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
<10	<20	39 (8)	480 (8)	OS	Conklin, 1972----------	Bastron and others (1960).
					Semiquantitative	
---	<10	50 (2)	500 (2)	OS	Heropoulos, 1968----------	Myers and others (1961).
10 (4)	20 (4)	50 (4)	500 (4)	OS	Mosier, 1970----------	Grimes and Marranzino (1968).
---	---	---	420	XRF	Wahlberg, 1970----------	J. S. Wahlberg (written commun., 1972).
6 (6)	9 (6)	70 (6)	550 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
6 R	11 R	44 S	490 A	Median		

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

	GSB	GSC	GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
						Quantitative	
Tl:							
	---	---	---	36 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
	<1	2.0 (7)	15 (7)	22 (7)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
	.5 (5)	1.5 (5)	7.2 (5)	13 (5)	Chem	Hubert and Lakin, 1972------	Thompson and others (1968).
						Semiquantitative	
	---	---	---	<50	OS	Heropoulos, 1968------------	Myers and others (1961).
	<10	<10	<10	<20	XRF	Wahlberg, 1969--------------	J. S. Wahlberg (written commun., 1972).
	<30	<30	<30	<30	OS	Mitchell, 1970--------------	R. L. Mitchell (written commun., 1970).
	0.4 R	1.8 R	11 R	22 R	Median		
						Quantitative	
U:							
	---	---	---	480	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
	1.0	3.9	41	460	I.D.	Dooley, 1969----------------	J. R. Dooley (written commun., 1969).
	---	---	39 (4)	---	I.D.	Zartman and Gallego, 1975---	Doe and others (1967).
	---	---	---	470	I.D.	Delevaux, Doe, & Leeman, 1975	B. R. Doe (written commun., 1975).
	---	---	---	470	Chem.	Fennelly, 1975--------------	Grimaldi and others (1954).
						Semiquantitative	
	---	---	<500	500 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
	---	---	<500	700 (2)	OS	Heropoulos, 1968------------	Do.
	---	---	<220	410 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
	---	---	<500	500 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
	---	---	<500	700 (2)	OS	Heropoulos, 1968------------	Do.
	---	---	<220	410 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
	1 R	4 R	40 R	470 S	Median		
						Quantitative	
V:							
	---	<10	40 (2)	450 (2)	OS	Fletcher, 1969--------------	Bastron and others (1960).
	---	<5	48 (4)	500 (4)	OS	Mays, 1969------------------	Do.
	---	<10	44 (4)	580 (4)	OS	Sutton, 1969----------------	Do.
	---	---	---	500 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
	---	<10	35 (4)	390 (4)	XRF	Espos and Fabbi, 1971-------	Fabi and Espos (1972).
	---	12 (2)	44 (4)	470 (4)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
	---	<10	45 (5)	540 (5)	OS	Walker, Smith, & Slezak, 1971	Ahrens and Taylor (1961).
	---	<20	47 (2)	510 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
	<10	<20	47 (8)	450 (8)	OS	Conklin, 1972---------------	Bastron and others (1960).
	---	<10	42 (3)	500 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
	<3	4.5	45	500	OS	Joensuu, 1972---------------	O. Joensuu (written commun., 1972).
	---	---	42 (2)	500 (2)	OS	Nockolds and Allen, 1973----	Nockolds and Allen (1953).
						Semiquantitative	
	<7	7 (10)	50 (10)	680 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
	---	<3	50 (2)	500 (2)	OS	Heropoulos, 1968------------	Do.
	---	---	---	380	XRF	Wahlberg, 1969--------------	J. S. Wahlberg (written commun., 1972).
	2	6	50	800	OS	Mitchell, 1970--------------	R. L. Mitchell (written commun., 1970).
	<5	7 (4)	55 (4)	600 (4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
	---	---	61 (3)	470 (2)	OS	Alcock and Shaw, 1971-------	D. M. Shaw (written commun., 1971).
	<1.5	3 (6)	34 (6)	360 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
	2 (4)	5 (4)	40 (4)	---	OS	Mitchell, 1974--------------	R. L. Mitchell (written commun., 1974).
	2 R	6 R	45 A	500 A	Median		
						Quantitative	
W:							
	---	---	<100	420 (4)	OS	Sutton, 1969----------------	Bastron and others (1960).
	---	---	---	430 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
	---	---	<100	420 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
						Semiquantitative	
	---	<50	50 (10)	300 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
	---	---	<30	400 (2)	OS	Heropoulos, 1968------------	Do.
	---	---	---	440	XRF	Wahlberg, 1969--------------	J. S. Wahlberg (written commun., 1972).
	---	<50	50 (4)	300 (4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
	---	---	---	420	XRF	Wahlberg, 1972--------------	J. S. Wahlberg (written commun., 1972).
	---	<10	64 (6)	440 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
	---	---	40 c	>100 c	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
	---	---	---	500 d	OS	-----do----------	Do.
	---	---	50 R	420 S	Median		
						Quantitative	
Y:							
	---	<20	71 (2)	500 (4)	OS	Fletcher, 1969--------------	Bastron and others (1960).
	---	<10	45 (4)	430 (4)	OS	Mays, 1969------------------	Do.
	---	<10	46 (4)	490 (4)	OS	Sutton, 1969----------------	Do.

TABLE 11.—*Determination of trace elements (in parts per million) in glass standards*—Continued

GSB	GSC	GSD	GSE	Method	Analyst(s), and year(s) of analysis (table 12)	Reference to published method of analysis
			Quantitative--Continued			
Y:						
---	---	---	490 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
4	10	51	520	XRF	Nockolds and Hendry, 1971---	Leake and others (1969).
---	<20	39 (2)	470 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
<10	<20	47 (8)	490 (8)	OS	Conklin, 1972---------------	Bastron and others (1960).
<10	16 (3)	49 (3)	390 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
<3	4.5	45	510	OS	Joensuu, 1972---------------	O. Joensuu (written commun., 1972).
---	---	42 (2)	490 (2)	OS	Nockolds and Allen, 1973----	Nockolds and Allen (1953).
			Semiquantitative			
<7	7 (10)	70 (10)	680 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
---	<10	50 (2)	700 (2)	OS	Heropoulos, 1968------------	Do.
---	<10	30 (4)	>200	OS	Mosier, 1970----------------	Grimes and Maranzino (1968).
<3	---	44 (6)	>460	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
4 R	8 R	46 A	490 A	Median		
			Quantitative			
Yb:						
---	---	<2	24 (2)	OS	Fletcher, 1969--------------	Bastron and others (1960).
---	---	<1	22 (4)	OS	Mays, 1969------------------	Do.
---	---	<1	26 (4)	OS	Sutton, 1969----------------	Do.
---	---	<4	29 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
---	---	<2	28 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
			Semiquantitative			
---	---	<1	50 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
---	---	<1	35 (2)	OS	Heropoulos, 1968------------	Do.
<0.2	---	.24 (6)	19 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---	---	0.2 R	30 S	Median		
			Quantitative			
Zn:						
---	---	50 (2)	460 (2)	AA	Gardner, 1969---------------	Huffman (1968).
---	---	<100	600 (4)	OS	Mays, 1969------------------	Bastron and others (1960).
---	---	<500	600 (4)	OS	Sutton, 1969----------------	Do.
---	---	---	490 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---	---	---	440 (2)	AA	Suhr, 1970------------------	N. H. Suhr (written commun., 1970).
---	<10	33 (4)	500 (4)	XRF	Espos and Fabbi, 1971-------	Fabbi and Espos (1972).
8 (2)	9 (2)	48 (2)	520 (2)	XRF	Newbury and Webber, 1971----	G. R. Webber (written commun., 1971).
5	6	43	480	XRF	Nockolds and Hendry, 1971---	Leake and others (1969).
---	<10	37 (7)	380 (7)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
---	<20	39 (3)	310 (4)	OS	Goni and Moal, 1972---------	Moal and others (1968).
11 (2)	15 (2)	---	---	AA	Huffman, 1974---------------	Huffman (1968).
---	<30	38 (9)	450 (9)	OSdr	Scott and Berrow, 1974------	Scott and others (1969).
			Semiquantitative			
---	---	<300	500 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
---	---	<100	500 (2)	OS	Heropoulos, 1968------------	Do.
---	---	<200	500 (4)	OS	Mosier, 1970----------------	Grimes and Marranzino (1968).
---	---	43 (6)	360 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
---	---	50 c	>100 c	OS	Morgan and Swaine, 1973-----	D. J. Swaine (written commun., 1973).
---	---	---	500 d	OS	-----do---------------------	Do.
8 R	12 R	43 S	500 A	Median		
			Quantitative			
Zr:						
----	<20	49 (2)	520 (2)	OS	Fletcher, 1969--------------	Bastron and others (1960).
---	<20	40 (4)	490 (4)	OS	Sutton, 1969----------------	Do.
---	---	---	500 (4)	XRF	Vromen and Rose, 1969-------	Rose and Cuttitta (1968).
---	<10	45 (4)	400 (4)	XRF	Fabbi, 1971-----------------	Fabbi (1972).
---	∿5	48 (2)	520 (2)	XRF	Newbury and Webber, 1971----	G. R. Webber (written commun., 1971).
7 (2)	7 (2)	46 (4)	450 (4)	OS	Nockolds and Allen, 1971----	Nockolds and Allen (1953).
4	6	43	430	XRF	Nockolds and Hendry, 1971---	Leake and others (1969).
---	<30	52 (2)	540 (2)	OS	Champ and Bender, 1972------	W. H. Champ (written commun., 1972).
---	<20	48 (8)	460 (8)	OS	Conklin, 1972---------------	Bastron and others (1960).
---	<10	45	500	OS	Joensuu, 1972---------------	O. Joensuu (written commun., 1972).
---	<10	36 (4)	450 (4)	OS	Mays, 1973------------------	Bastron and others (1960).
7 (2)	7 (2)	47 (2)	460 (2)	OS	Nockolds and Allen, 1973----	Nockolds and Allen (1953).
			Semiquantitative			
<5	5 (10)	48 (10)	500 (10)	OS	Conklin, 1968---------------	Myers and others (1961).
<5	7 (2)	50 (2)	450 (2)	OS	Heropoulos, 1968------------	Do.
---	<10	50 (2)	500 (4)	OS	Mosier, 1970----------------	Grimes and Marranzino, 1968).
---	---	---	480	XRF	Wahlberg, 1972--------------	J. S. Wahlberg (written commun., 1972).
5 (6)	10 (6)	53 (6)	360 (6)	OSp	Dorrzapf and Thomas, 1973---	Dorrzapf (1973).
<4	5 (4)	60 (4)	---	OS	Mitchell, 1974--------------	R. L. Mitchell (written commun., 1974).
<5	5 (2)	---	---	OS	Conklin, 1975---------------	Myers and others (1961).
*∿4 R	6 R	48 A	480 A	Median		

*See discussion in text.

TABLE 12.—*Addresses and affiliations of analysts cited in table 11*

Analyst	Address and affiliation
Alcock, F. G----------	McMaster Univ., Ontario Canada.
Allen, R. S----------	University of Cambridge, Cambridge, England.
Bender, G. P----------	Geol. Survey Canada, Ottawa, Canada.
Berrow, M. L----------	Macauley Inst. for Soil Research, Aberdeen, Scotland.
Burrow, G. T----------	U.S. Geological Survey, Denver, Colo.
Campbell, D. E--------	Corning Glass Works, Corning, N.Y.
Champ, W. H----------	Geol. Survey Canada, Ottawa, Canada.
Conklin, N. M---------	U.S. Geol. Survey, Denver, Colo.
Delevaux, M. H--------	Do.
Doe, B. R-------------	Do.
Dooley, J. R., Jr-----	Do.
Dorrzapf, A. F., Jr---	U.S. Geol. Survey, Reston, Va.
Espos, L. F----------	U.S. Geol. Survey, Menlo Park, Calif.
Fabbi, B. P----------	Do.
Fennelly, E. J--------	U.S. Geol. Survey, Denver, Colo.
Fletcher, J. D--------	U.S. Geol. Survey, Reston, Va.
Gallego, M------------	U.S. Geol. Survey, Denver, Colo.
Gardner, J------------	Do.
Golde, M--------------	Indiana Geol. Survey, Bloomington, Ind.
Goni, J---------------	BRGM-Nancy, Orleans, France.
Goodrich, E. C--------	Corning Glass Works, Corning, N.Y.
Hedge, C. E----------	U.S. Geol. Survey, Denver, Colo.
Henderson, W. T-------	Do.
Hendry, G.L----------	University of Cambridge, Cambridge, England.
Heropoulos, C---------	U.S. Geol. Survey, Menlo Park, Calif.
Hubert, A. E----------	U.S. Geol. Survey, Denver, Colo.
Huffman, Claude, Jr---	Do.
Joensuu, O------------	Miami Univ., Miami, Fla.
Kvalheim, A----------	Geol. Survey, Norway, Trondheim, Norway.
Lakin, H. W----------	U.S. Geol. Survey, Denver, Colo.
Leeman, W. P----------	Do.
Leininger, R. K-------	Indiana Geol. Survey, Bloomington, Ind.
McHugh, J. B----------	U.S. Geol. Survey, Denver, Colo.
Mays, R. E------------	U.S. Geol. Survey, Menlo Park, Calif.
Mitchell, R. L--------	Macauley Inst. for Soil Research, Aberdeen, Scotland.
Moal, J. Y------------	BRGM-Nancy, Orleans, France.
Morgan, N. C----------	CSIRO Division of Mineralogy, North Ryde, NSW 2113, Australia.
Mosier, E. L----------	U.S. Geol. Survey, Denver, Colo.
Mountjoy, Wayne-------	Do.
Newbury, L------------	Geol. Sciences, McGill Univ., Montreal, Canada.
Nockolds, S. R--------	University of Cambridge, Cambridge, England.
Riley, L. B----------	U.S. Geol. Survey, Denver, Colo.
Rose, H. J., Jr-------	U.S. Geol. Survey, Reston, Va.
Scott, R. O----------	Macauley Institute for Soil Research, Aberdeen, Scotland.
Shaw, D. M------------	McMaster Univ., Ontario, Canada.
Slezak, T. I----------	Bureau of Mineral Resources, Canberra City, ACT Australia.
Smith, S. E----------	Do.
Sterlace, J. S--------	Corning Glass Works, Corning, N. Y.
Suhr, N. H------------	Pennsylvania State Univ., Mineral Sciences, University Park, Pa.
Sutton, A. L., Jr-----	U.S. Geol. Survey, Denver, Colo.
Swaine, D. J----------	CSIRO Division of Mineralogy, North Ryde, NSW 2113, Australia.
Thomas, C-------------	U.S. Geol. Survey, Reston, Va.

TABLE 12.—*Addresses and affiliations of analysts cited in table 11*—Continued

Analyst	Address and affiliation
Thomas, J. A----------	U.S. Geol. Survey, Denver, Colo.
Turner, R. L----------	Do.
Vromen, A----------	U.S. Geol. Survey, Reston, Va.
Wahlberg, J. S--------	U.S. Geol. Survey, Denver, Colo.
Walker, K. R----------	Bureau of Mineral Resources, Canberra City, ACT Australia.
Webber, G. R----------	Geol. Sciences, McGill Univ., Montreal, Canada.
Weijden, C. H. van der	Vening Meinesz Laboratory, Voor Geofysicaen Geochemie, Univ. Utrecht, the Netherlands.
Wise, W. M----------	Corning Glass Works, Corning, N.Y.
Zartman, R. E---------	U.S. Geol. Survey, Denver, Colo.

TABLE 13.—*Trace-element compositions, in parts per million, of glass standards as medians*

[Asterisk (*) indicates approximate element content (in parts per million) requested of Corning. Leaders (...) indicate no determination made]

	GSB *0.5	GSC *5	GSD *50	GSE *500		GSB *0.5	GSC *5	GSD *50	GSE *500
Ag------	0.5	4	37	380	Nb------	---	5	40	500
As------	.3	6	42	450	Ni------	14	18	55	500
Au------	.1	1.2	14	50	Pb------	13	15	52	500
B-------	18	20	50	500	Pd------	.2	3.8	36	100
Ba------	31	39	90	500	Pt------	.7	.6	1.4	110
Be------	----	3.5	44	500	Rb------	5	7	41	420
Bi------	----	4	40	480	Rh------	3	4	18	60
Cd------	----	3	30	420	Ru------	----	1.4	12	90
Ce------	----	----	50	550	Sb------	----	----	37	470
Cl------	50	50	120	800	Sc------	----	----	3	30
Co------	2	6	35	450	Se------	----	----	----	3
Cr------	3	7	47	490	Sn------	.6	5	43	440
Cs------	----	4	35	370	Sr------	26	27	64	500
Cu------	5	9	45	500	Ta------	----	----	----	480
Eu------	----	3	50	600	Te------	----	.3	12	260
F-------	100	100	250	300	Ti------	6	11	44	490
Ga------	3	5	5	20	Tl------	.5	1.8	11	22
Ge------	----	4	40	500	U-------	1	4	40	480
Hf------	----	----	45	500	V-------	2	6	45	500
In------	.5	4	50	500	W-------	----	----	50	420
Ir------	.1	1.3	20	140	Y-------	4	8	46	490
La------	----	5	47	550	Yb------	----	----	.2	30
Li------	1	5	40	480	Zn------	8	12	43	500
Mn------	190	200	210	600	Zr------	~4	6	48	480
Mo------	2	6	46	500					

TABLE 14.—*Ranges, in parts per million, of several trace elements in glass standards*

[Leaders (...) indicate no determination made]

Glass standard--	GSB	GSC	GSD	GSE
Ag	<0.5 - 0.6	2 - 5	20 - 50	260- 600
Au	.06- 1.0	1.0 - 1.5	10 - 15	40- 70
B	10 - 21	10 - 24	40 - 75	360- 580
Ba	28 - 54	29 - 62	50 -200	430- 800
Be	---	2 - 6	36 -100	420-1000
Bi	---	2 - 5	30 - 52	350- 600
Ce	---	---	30 - 76	450- 780
Co	<1 - 5	4 - 8	26 - 50	350- 700
Cr	1 - 12	5 - 13	30 - 68	410- 600
Cs	---	3 - 4.5	34 - 54	340- 430
Cu	2 - 11	5 - 15	35 - 70	340- 590
Ge	---	<1 - 1.6	26 - 80	390- 580
In	<.5 - .6	3 - 5	30 - 70	420- 600
La	---	---	30 - 60	500- 700
Li	---	4.2 - 6.0	33 - 60	400-1000
Mn	130 -250	140 -250	180 -260	450- 800
Mo	2 - 5	3 - 8	20 - 70	300-1000
Nb	---	4 - 7	26 - 50	450- 530
Ni	10 - 20	10 - 25	35 - 70	360- 700
Pb	<6 - 21	11 - 21	35 - 70	430- 600
Pd	<.07- .4	2.5 - 5.0	26 - 50	82- 200
Pt	.6 - 1.3	.39- .7	<1.2- 1.4	76- 140
Rb	2 - 8	4.5 - 9.0	35 - 61	410- 490
Rh	3 - 4	<3 - 5	15 - 24	47- 70
Sn	---	4 - 8	30 - 50	390- 530
Sr	10 - 45	20 - 49	52 -100	410- 700
Ti	6 - 10	8 - 20	39 - 70	420- 550
V	<1.5 - 2.0	<3 - 12	34 - 61	360- 680
Y	<3 - 4	4.5 - 16	30 - 71	390- 700
Zn	5 - 11	6 - 15	33 - 50	310- 600
Zr	4 - 7	5 - 10	36 - 53	360- 540

TABLE 15.—*Major-element composition, in percent, of glass standards as medians*

[Leaders (...) indicate no determination made]

Element (as oxide)	GSB	GSC	GSD	GSE
SiO_2	62.20	62.05	61.80	61.50
Al_2O_3	14.10	14.20	14.40	13.60
Fe_2O_3	5.38	5.56	5.29	5.14
FeO	1.60	1.46	1.54	1.40
MgO	3.87	3.90	3.90	3.63
CaO	5.03	4.92	5.01	5.26
Na_2O	4.12	4.09	4.08	4.56
K_2O	3.62	3.62	3.72	3.06
H_2O^+	.28	.33	.28	.22
H_2O^-	.07	.08	.08	.06
TiO_2	----	----	----	.12
P_2O_5	.02	.02	.02	.03
MnO	.03	.03	.04	.09
CO_2	.03	.04	.03	.02
Cl	.01	.01	.01	.08
F	.01	.01	.02	.03
Total--	100.37	100.32	100.22	98.80
Fe_2O_3 (Total iron)	7.04	7.17	7.10	6.56

TABLE 16.—*Quantitative spectrographic determinations, in parts per million, of trace elements on four glass standards using four bottles chosen at random for each standard and two determinations per bottle*

[N, not detected at concentration shown; L, less than concentration shown. Analyst: N. M. Conklin]

Glass standard	Bottle No.	Ag	B	Ba	Be	Cd	Co	Cr	Cu	Eu	Ge	La	Mo	Mn	Nb	Ni	Pb	Sc	Sn	Sr	Ti	V	Y	Zr
GSB	272---	N1	N50	30	N3	N100	N5	5	4	N100	N20	N50	N3	180	N10	11	N20	N7	N20	18	N10	N10	N10	N20
		N1	N50	29	N3	N100	N5	5	3	N100	N20	N50	N3	190	N10	9	N20	N7	N20	16	N10	N10	N10	N20
	470---	N1	N50	38	N3	N100	N5	5	3	N100	N20	N50	N3	190	N10	12	N20	N7	N20	20	N10	N10	N10	N20
		N1	N50	34	N3	N100	N5	6	3	N100	N20	N50	N3	180	N10	12	N20	N7	N20	22	N10	N10	N10	N20
	421---	N1	N50	31	N3	N100	N5	5	3	N100	N20	N50	N3	190	N10	8	N20	N7	N20	25	N10	N10	N10	N20
		N1	N50	34	N3	N100	N5	5	2	N100	N20	N50	N3	180	N10	9	N20	N7	N20	25	N10	N10	N10	N20
	827---	N1	N50	29	N3	N100	N5	5	3	N100	N20	N50	N3	190	N10	12	N20	N7	N20	32	N10	N10	N10	N20
		N1	N50	28	N3	N100	N5	2	2	N100	N20	N50	N3	200	N10	10	N20	N7	N20	20	N10	N10	N10	N20
GSC	187---	4	N50	38	4	N100	N10	7	6	N100	N20	N70	6	200	N10	10	N20	N15	N20	28	L20	N20	N20	N20
		3	N50	43	3	N100	N10	14	8	N100	N20	N70	5	210	N10	8	N20	N15	N20	39	L20	N20	N20	N20
	58---	4	N50	40	3	N100	N10	9	6	N100	N20	N70	7	210	N10	9	N20	N15	N20	30	L20	N20	N20	N20
		4	N50	32	3	N100	N10	7	6	N100	N20	N70	4	220	N10	11	N20	N15	N20	33	L20	N20	N20	N20
	1139---	3	N50	38	4	N100	N10	6	6	N100	N20	N70	7	210	N10	12	N20	N15	N20	28	L20	N20	N20	N20
		4	N50	42	3	N100	N10	9	6	N100	N20	N70	10	190	N10	11	N20	N15	N20	34	L20	N20	N20	N20
	294---	4	N50	36	4	N100	N10	8	7	N100	N20	N70	7	210	N10	11	N20	N15	N20	33	L20	N20	N20	N20
		4	N50	38	3	N100	N10	9	6	N100	N20	N70	9	200	N10	14	N20	N15	N20	22	L20	N20	N20	N20
GSD	1356---	43	48	96	42	N100	33	55	46	N100	42	N70	51	230	34	46	44	N15	45	70	35	46	43	51
		42	59	100	36	N100	34	49	46	N100	42	N70	43	240	39	52	46	N15	50	64	39	42	50	46
	171---	44	52	94	35	N100	35	50	42	N100	36	N70	46	260	38	49	44	N15	39	72	42	51	45	46
		41	56	100	45	N100	32	56	46	N100	42	N70	42	230	44	52	54	N15	44	64	41	48	45	47
	777---	47	50	98	38	N100	28	56	50	N100	42	N70	47	240	43	54	47	N15	49	84	35	52	50	51
		44	56	102	38	N100	32	53	50	N100	42	N70	51	270	42	45	43	N15	46	74	39	49	50	45
	1018---	46	58	82	39	N100	36	48	49	N100	40	N70	43	230	40	54	47	N15	44	84	36	50	48	46
		42	54	86	43	N100	34	55	51	N100	44	N70	46	260	42	49	46	N15	49	84	43	41	43	49
GSE	411---	360	510	470	530	480	450	520	550	690	530	630	530	620	460	510	560	21	420	500	470	430	460	430
		380	540	470	520	440	410	530	520	640	500	680	520	690	480	550	500	31	450	540	480	420	480	460
	1430---	380	560	470	540	440	450	480	550	690	540	660	560	660	490	560	530	35	450	490	480	440	450	460
		380	540	530	600	460	460	490	510	680	500	700	510	660	510	520	500	35	410	530	460	520	540	440
	1276---	370	460	460	580	440	420	460	520	660	480	710	520	690	520	570	560	39	470	560	470	440	460	480
		410	480	530	500	490	460	530	540	630	540	690	540	680	480	500	570	36	430	500	500	420	510	450
	1668---	380	500	530	600	450	430	490	500	640	560	660	500	710	520	540	560	37	400	540	510	480	520	480
		380	520	520	520	500	420	510	520	660	510	700	540	650	480	530	520	34	460	540	480	450	480	450

TABLE 17.—*Factors (geometric deviations) reflecting sample inhomogeneity in glass standards*

[Leaders (...) indicate no data; <, less than]

Glass standard---	GSB	GSC	GSD	GSE
Ag----------	----	<1.01	<1.01	<1.01
B----------	----	----	<1.01	1.06
Ba----------	1.10	<1.01	1.08	<1.01
Be----------	----	<1.01	<1.01	<1.01
Cd----------	----	----	----	<1.01
Co----------	----	----	1.05	<1.01
Cr----------	1.09	<1.01	<1.01	<1.01
Cu----------	1.06	<1.01	1.06	<1.01
Ge----------	----	----	<1.01	<1.01
Eu----------	----	----	----	1.01
La----------	----	----	----	<1.01
Mn----------	<1.01	<1.01	<1.01	<1.01
Mo----------	----	1.17	<1.01	<1.01
Nb----------	----	----	1.04	<1.01
Ni----------	1.14	1.11	<1.01	<1.01
Pb----------	----	----	<1.01	1.01
Sc----------	----	----	----	1.15
Sn----------	----	----	1.04	<1.01
Sr----------	1.15	<1.01	1.11	<1.01
Ti----------	----	----	<1.01	<1.01
V----------	----	----	1.03	1.04
Y----------	----	----	1.01	<1.01
Zr----------	----	----	<1.01	<1.01

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REFERENCES CITED

Ahrens, L. H., and Taylor, S. R., 1961, Spectrochemical analysis—A treatise on the d-c arc analysis of geological and related materials [2d ed.]: Addison-Wesley Publishing Co., 454 p.

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.

Doe, B. R., Tatsumoto, Mitsunobu, Delevaux, M. H., and Peterman, Z. E., 1967, Isotope-dilution determination of five elements in G-2 (granite), with a discussion of the analysis of lead, *in* Geological Survey research 1967: U.S. Geol. Survey Prof. Paper 575-B, p. B170-B177.

Dorrzapf, A. F., Jr., 1973, Spectrochemical computer analysis—Argon-oxygen d-c arc method for silicate rocks: U.S. Geol. Survey Jour. Research, v. 1, no. 5, p. 559-562.

Dorrzapf, A. F., Jr., and Brown, F. W., 1970, Direct spectrographic analysis for platinum, palladium, and rhodium in gold beads from fire assay: Applied Spectroscopy, v. 24, no. 4, p. 415-418.

Fabbi, B. P., 1971, X-ray fluorescence determination of barium and strontium in geologic samples: Applied Spectroscopy, v. 25, no. 3, p. 316-318.

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

Fabbi, B. P., and Espos, L. F., 1972, X-ray fluorescence determination of arsenic, antimony, nickel, rubidium, scandium, vanadium, and zinc in rock standards and other rock samples *in* Geological Survey research 1972: U.S. Geol. Survey Prof. Paper 800-B, p. B147-B152.

Flanagan, F. J., 1969, First compilation of data for the new U.S.G.S. rocks, Pt. 2 *of* U.S. Geological Survey standards: Geochim. et Cosmochim. Acta, v. 33, p. 81-120.

Grimaldi, F. S., May, I., Fletcher, M. H., and Titcomb, J., 1954, Collected papers on methods of analysis for uranium and thorium: U.S. Geol. Survey Bull. 1006, 184 p.

Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for semiquantitative analyses of geologic materials: U.S. Geol. Survey Circ. 591, 6 p.

Hubert, A. E., and Lakin, H. W., 1972, Atomic absorption determination of thallium and indium in geologic materials, *in* Proceedings of the Fourth International Geochemical Exploration Symposium, London, April 17-20: Inst. Mining and Metallurgy, p. 458.

Huffman, Claude, Jr., 1968, Copper, strontium, and zinc content U.S.G.S. silicate rock standards: U.S. Geol. Survey Prof. Paper 600-B, p. B110-B111.

Huffman, Claude, Jr., Mensik, J. D., and Riley, L. B., 1967, Determination of gold in geologic materials by solvent extraction and atomic-absorption spectrometry: U.S. Geol. Survey Circ. 544, 6 p.

Leake, B. E., Hendry, G. L., Kemp, A., Plant, A. G., Harrey, P. K., Wilson, J. R., Coats, J. S., Ancott, J. W., Lunel, T., and Howarth, R. J., 1969, The chemical analysis of rock powders by automatic X-ray fluorescence: Chemical geology, v. 5, p. 7-86.

Moal, J. Y., Beguinot, J., Ruel, G., and Vannier, M., 1968, The quantitative analysis of trace elements in natural materials: Nancy, France, Colloque, C.N.R.S. Nancy 4-6 Dec, p. 107-132.

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.

Myers, A. T., Havens, R. G., and Niles, W. W., 1970, Glass reference standards for trace element analysis of geologic materials, *in* Developments in applied spectroscopy, Mid-America Spectroscopy Symposium, 20th Ann., 1969, Selected Papers: Plenum Press, v. 8, p. 132-137.

Nakagawa, H. M., and Thompson, C. E., 1968, Atomic absorption determination of tellurium, *in* Geological Survey research 1968: U.S. Geol. Survey Prof. Paper 600-B, p. B123-B125.

Nockolds, S. R., and Allen, R. S., 1953, The geochemistry of some igneous rock series, Pt. 1: Geochim. et Cosmochim. Acta, v. 4, p. 105-142.

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

Perkin-Elmer Corp., 1964, Analytical methods for atomic absorption spectrometry: Norwalk, Conn.

Rader, L. F., and Grimaldi, F. S., 1961, Chemical analyses for selected minor elements in Pierre Shale: U.S. Geol. Survey Prof. Paper 361-A, 45 p.

Riley, J. P., 1958, Simultaneous determination of water and carbon dioxide in rocks and minerals: Analyst, v. 83, no. 1, p. 42–47.

Rose, H. J., Jr., and Cuttitta, Frank, 1968, X-ray fluorescence spectroscopy in the analysis of ores, minerals, and waters, *in* Advances in X-ray analysis, 16th Ann. Conf., Denver Univ., 1967, Proc., v. 11: New York, Plenum Press, p. 23–29.

Scott, R. O., Burridge, J. C., and Mitchell, R. L., 1969, Geochemical analysis with a multi-channel direct reader employing direct current arc excitation: Madrid, Spain, Boletin Geologico y Minero, v. 42, no. 5, p. 446–451.

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

Thompson, C. E., Nakagawa, H. M., and VanSickle, G. H., 1968, Rapid analysis for gold in geologic materials, in Geological Survey research 1968: U.S. Geol. Survey Prof. Paper 600–B, p. B130-B132.

Ward, F. N., Lakin, H. W., Canney, F. C., 1963, Analytical methods used in geochemical exploration by the U.S. Geological Survey: U.S. Geol. Survey Bull. 1152, 40 p.

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