RC. 957

U.S. GEOLOGICAL SURVEY CIRCULAR 957

Mineralogy and Instrumental Neutron Activation Analysis of Seven National Bureau of Standards and Three Instituto de Pesquisas Tecnológicas Clay Reference Samples

Mineralogy and Instrumental Neutron Activation Analysis of Seven National Bureau of Standards and Three Instituto de Pesquisas Tecnológicas Clay Reference Samples

By J.W. Hosterman, F.J. Flanagan, Anne Bragg, M.W. Doughten, R.H. Filby, Catherine Grimm, J.S. Mee, P.J. Potts, *and* N.W. Rogers

---

U.S. GEOLOGICAL SURVEY CIRCULAR 957

1987

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

Library of Congress Cataloging in Publication Data

Mineralogy and instrumental neutron activation analysis of seven National Bureau of Standards and three Instituto de Pesquisas Technológicas clay reference samples.
(U.S. Geological Survey circular ; 957)
Bibliography: p.
Supt. of Docs. no.: I 19.4/2:957
1. Clay—Analysis. 2. Radioactivation analysis. I. Hosterman, John W. (John Wallace), 1923– . II. Series.
TP811.M48 1987 549'.6 87-600172

Free on application to the Books and Open-File Reports Section,
U.S. Geological Survey, Federal Center, Box 25425, Denver, CO 80225

CONTENTS

FIGURES

TABLES

[Tables follow References Cited]

7. Instrumental neutron activation determinations of elements in NBS–97b and NBS–98b by the Department of Earth Sciences, The Open University.
8. Instrumental neutron activation determinations of elements in NBS–679 by the U.S. Geological Survey.
9. Instrumental neutron activation determinations of elements in NBS–679 by the Nuclear Radiation Center, Washington State University.
10. Instrumental neutron activation determinations of elements in NBS–679, IPT–28, IPT–32, and IPT–42 by the Department of Earth Sciences, The Open University.
11. Instrumental neutron activation determinations of elements in IPT–28 and IPT–32 by the U.S. Geological Survey.
12. Instrumental neutron activation determinations of elements in IPT–28 and IPT–32 by the Nuclear Radiation Center, Washington State University.
13. Instrumental neutron activation determinations of elements in IPT–42 by the U.S. Geological Survey.
14. Instrumental neutron activation determinations of elements in IPT–42 by the Nuclear Radiation Center, Washington State University.
15. Instrumental neutron activation determinations of elements in NBS–97a by the U.S. Geological Survey, 1976 and 1985.
16. Instrumental neutron activation determinations of elements in NBS–98a by the U.S. Geological Survey, 1976 and 1985.
17. Determinations of lithium in clay reference samples by inductively coupled plasma spectroscopy and flame atomic absorption spectroscopy by the U.S. Geological Survey.
18. Averages of laboratory means for NBS–97 and NBS–97b.
19. Averages of laboratory means for NBS–98 and NBS–98b.
20. Averages of laboratory means for NBS–679 and IPT–28.
21. Averages of laboratory means for IPT–32 and IPT–42.
22. Provisional averages for the 10 clay reference samples.
23. Elemental ratios for averages for the 10 clay reference samples.
24. Provisional means for samples normalized to the grand mean for an element.
25. Certified values of the major and minor oxide contents from Certificates of Analysis for four NBS and three IPT clay reference samples.

Mineralogy and Instrumental Neutron Activation Analysis of Seven National Bureau of Standards and Three Instituto de Pesquisas Tecnológicas Clay Reference Samples

By J.W. Hosterman,[1] F.J. Flanagan,[1] Anne Bragg,[2] M.W. Doughten,[1] R.H. Filby,[2] Catherine Grimm,[2] J.S. Mee,[1] P.J. Potts,[3] *and* N.W. Rogers[3]

Abstract

The concentrations of 3 oxides and 29 elements in 7 National Bureau of Standards (NBS) and 3 Instituto de Pesquisas Tecnológicas (IPT) reference clay samples were determined by instrumental neutron activation analysis. The analytical work was designed to test the homogeneity of constituents in three new NBS reference clays, NBS–97b, NBS–98b, and NBS–679. The analyses of variance of 276 sets of data for these three standards show that the constituents are distributed homogeneously among bottles of samples for 94 percent of the sets of data.

Three of the reference samples (NBS–97, NBS–97a, and NBS–97b) are flint clays; four of the samples (NBS–98, NBS–98a, NBS–98b, and IPT–32) are plastic clays, and three of the samples (NBS–679, IPT–28, and IPT–42) are miscellaneous clays (both sedimentary and residual). Seven clays are predominantly kaolinite; the other three clays contain illite and kaolinite in the approximate ratio 3:2. Seven clays contain quartz as the major nonclay mineral. The mineralogy of the flint and plastic clays from Missouri (NBS–97a and NBS–98a) differs markedly from that of the flint and plastic clays from Pennsylvania (NBS–97, NBS–97b, NBS–98, and NBS–98b).

The flint clay NBS–97 has higher average chromium, hafnium, lithium, and zirconium contents than its replacement, reference sample NBS–97b. The differences between the plastic clay NBS–98 and its replacement, NBS–98b, are not as pronounced. The trace element contents of the flint and plastic clays from Missouri, NBS–97a and NBS–98a, differ significantly from those of the clays from Pennsylvania, especially the average rare earth element (REE) contents. The trace element contents of clay sample IPT–32 differ from those of the other plastic clays. IPT–28 and IPT–42 have some average trace element contents that differ not only between these two samples but also from all the other clays. IPT–28 has the highest summation of the average REE contents of the 10 samples. The uranium content of NBS–98a, 46 parts per million, is very much higher than that of the other clays.

Plots of average REE contents of the flint and plastic clays, normalized to chondritic abundances, show that the clays from Missouri differ from the same types of clay from Pennsylvania. The plot of REE contents for the miscellaneous clays shows that the normalized means for the elements lanthanum through samarium for IPT–28 are much greater than those for the other miscellaneous clays. The means for the elements europium through lutetium are similar for all three miscellaneous clays.

INTRODUCTION

The trace element contents of clays have been published only sporadically since 1950. Kerr and others (1950), in their reports on the American Petroleum Institute Reference Clay Minerals Research Project 49, gave spectrographic determinations of 24 trace elements in 4 kaolins from Arkansas, Georgia, South Carolina, and New Mexico. Hinckley (1961) determined boron, gallium, and manganese contents in several kaolin samples from Georgia and South Carolina. Erickson (1963) analyzed several flint clays from Pennsylvania for K, Fe, Ti, Zr, Cr, and Ca, and Keller (1968) reported that Fe, Mg, Ca, Ba, Sr, Ti, V, Zr, Mn, Cu, Ni, Zn, Ga, Cr, and B are present in detectable amounts in flint clays from Missouri. Flanagan and

[1] U.S. Geological Survey, Reston, Va.
[2] Washington State University, Pullman, Wash.
[3] The Open University, Milton Keynes, United Kingdom.

others (1977, table 1) summarized published data on some trace element contents of U.S. National Bureau of Standards (NBS) samples (flint clay NBS–97 and plastic clay NBS–98) by Shimp and others (1957), Grabowski and Eunice (1958), Turekian and Carr (1961), Clark and Swaine (1963), Filby (1964), Taylor and Kolbe (1964), and Ball and Filby (1965).

The first two clay samples from Pennsylvania (NBS–97 and NBS–98), of primary interest to an expanding refractory industry, were certified in 1931 for their major and minor oxide contents. When the supplies of these two samples were depleted, they were replaced in 1959 by NBS–97a and NBS–98a from Missouri. In 1983, Hosterman and Flanagan collected two more clay samples, now NBS–97b and NBS–98b, from the same area in Pennsylvania as the original NBS clay samples (NBS–97 and NBS–98). They also collected in the same year a sample of common brick clay, NBS–679, to be added to the roster of NBS reference samples. All NBS samples have or will have certificates of analysis listing their major and minor oxides.

Among the available reference samples are three samples from Brazil whose major and minor oxide contents are certified. The Agrupamento de Materials de Referência (Reference Materials Group) of the Instituto de Pesquisas Tecnológicas do Estado de São Paulo, Brazil (IPT), was formed in 1975 with technical support from the NBS. Since then, more than 30 different reference materials have been certified, including metals, minerals, cements, and the three reference clays from Brazil, IPT–28, IPT–32, and IPT–42. Certificates of analysis for these samples were issued in 1979–81. Data for the IPT clays have been included in this report for comparison with data for the NBS clay samples.

The chemistry and mineralogy of the seven NBS samples and of the three IPT samples are discussed in this report. The 10 samples were analyzed by instrumental neutron activation (INAA) at 3 separate laboratories. All samples were analyzed at the U.S. Geological Survey (USGS) analytical laboratory, Reston, Va.; eight samples were analyzed at the Nuclear Radiation Center, Washington State University (WSU), Pullman, Wash., and six samples were analyzed at the Department of Earth Sciences, The Open University (TOU), Milton Keynes, United Kingdom. The mineralogy was determined by X-ray diffraction at the USGS.

In addition to confirming previous estimates (Flanagan and others, 1977, tables 3 and 4) of some trace element contents of the flint and plastic clays from Pennsylvania and Missouri, the data in this report increase our knowledge of the trace element contents of clays from different geologic settings. Because of the potential distribution of the NBS and IPT clays, the samples may serve as reference materials for studies of the trace element contents of other clays.

GEOLOGIC SETTING AND LOCATION

NBS–97, NBS–97a, and NBS–97b are samples of flint clays used in the manufacture of refractory brick. Material for NBS–97 was taken from the Mercer flint clay bed, the Pottsville Formation of Pennsylvanian age, from a mine located on Morgan Run, Decatur Township, Clearfield County, Pa. NBS–97a was taken from the Cheltenham fire clay bed, Cheltenham Formation of Pennsylvanian age. The sample was supplied by the A.P. Green Fire Brick Co., Mexico, Mo. NBS–97b is a sample of the Mercer flint clay bed from a Harbison-Walker Refractories Co. mine on Anderson Creek, Pike Township, Clearfield County, Pa. The material for NBS–97b was sampled from a stockpile near the mine. The mine was not accessible because it had been backfilled to conform to the environmental regulations of the State of Pennsylvania.

NBS–98, NBS–98a, and NBS–98b are samples of plastic underclays used in the manufacture of refractory and face brick. NBS–98 is a sample of underclay of the Clarion coal bed, Allegheny Formation of Pennsylvanian age, collected from a mine located at Templeton, Pine Township, Armstrong County, Pa. Sample NBS–98a, taken from the Cheltenham fire clay bed, Cheltenham Formation of Pennsylvanian age, was supplied by the A.P. Green Fire Clay Co., Mexico, Mo. NBS–98b is a sample of the underclay of the Clarion coal bed obtained at the Harbison-Walker Refractories Co. plant at Clearfield, Clearfield County, Pa.

The clay for sample NBS–679 was collected from the Maryland Clay Products, Inc. (formerly the Washington Brick Co.), pit at Muirkirk, Prince Georges County, Md. The clay is used for making red building and face brick. The very plastic brown clay, which is more than 11 m thick (Knechtel and others, 1961), occurs in the Arundel Formation, Potomac Group of Cretaceous age. Iron ore was mined from the Arundel Formation from colonial times until about 1911, and a furnace at Muirkirk was operated almost continuously from 1847 to 1912 (Miller, 1911). The iron ore is primarily siderite, $FeCO_3$, which occurs as balls and irregular nodules that are removed when the clay is mined.

Reference sample IPT–28 is from Ananindeua, Pará, Brazil, near Belém (lat 1°13′ S., long 48°17′ W.)

in the Amazon Delta. The clay deposit occurs in an unnamed unit of Tertiary age that contains clastic sediments, claystones, sandstones, conglomerates, and laterite. Approximately 2 million metric tons of clay is mined annually from this deposit (Azevedo Branco, 1984).

Sample IPT–32 is from near São João de Meriti, Rio de Janeiro, Brazil (lat 22°44′ S., long 43°27′ W.). The clay occurs in alluvium of an unnamed formation of Holocene age. The alluvium consists of fluvial, marine, and eolian deposits. A small amount of this plastic clay is mined annually from this area.

Sample IPT–42 is from near São Simão, São Paulo, Brazil (lat 21°28′ S., long 47°36′ W.). The clay is in the Pirambóia Formation of Triassic age. The formation consists of sandstones, minor claystones, siltstones, and conglomerates. Approximately 3 million metric tons of the clay, which also contains some ball clay, is mined annually (Azevedo Branco, 1984).

ANALYTICAL DATA AND HOMOGENEITY

Some of the analytical work on the 10 reference clay samples was designed to test whether elements in the new samples, NBS–97b, NBS–98b, and NBS–679, were distributed homogeneously among bottles of samples. The remaining data were obtained so that meaningful comparisons could be made of the trace element contents of the types of clays from different geologic settings and geographic areas.

Hosterman and Flanagan prepared the new clay samples for the NBS by the same method used to prepare USGS rock standards (Flanagan, 1986, p. 31). After the entire bulk of a powdered clay sample was mixed thoroughly in a "V" blender, a portion of about 10 kg was split from the bulk material. Approximately one-half of the 10-kg portion was then subsampled into 60-mL bottles that were labeled, numbered, and distributed to the USGS, WSU, and TOU laboratories for analysis. The other half of the 10-kg portion was reserved for future chemical and mineralogical work. The remaining powdered bulk of the three new samples was delivered to the NBS.

To determine the homogeneity of elements in the three new NBS samples, the USGS, WSU, and TOU laboratories were asked to analyze two portions from two bottles of each sample. Not all laboratories reported four determinations for every element in each sample. Some determinations are missing because the counts for an element were lost during data processing or because the value calculated from the counts for an element was below the lower limit of estimation. INAA data were obtained by the method described by Baedecker and others (1977) for the USGS, by Filby and others (1985) for WSU, and by Potts and others (1981, 1985) for TOU. In addition to the four determinations for an element, the mean, the F ratio (see below), and the error (within bottle) standard deviation calculated during each analysis of variance were computed (see tables 4–10).

For comparison, some USGS data obtained in 1976 for the four older NBS clay samples (NBS–97, NBS–98, NBS–97a, and NBS–98a) have been included in this report. These 1976 data consist of six determinations for each sample (data for two portions from each of three bottles). Because the tests for homogeneity described here would be based on determinations on four portions of any new NBS sample, data for bottles 1 and 2 of NBS–98a (Flanagan and others, 1977, table 3) and data for bottles 1 and 2 of NBS–97, NBS–97a, and NBS–98 (Flanagan and others, 1977, table 4; USGS unpublished data, 1977) were randomly selected for inclusion in this report. To furnish more data for the older samples, the three laboratories were requested also to irradiate four sample portions from bottles of the older NBS samples so that comparisons could be made with approximately the same number of determinations per element for each sample.

Hosterman and Flanagan received from Brazil only one bottle of each of the three clay samples IPT–28, IPT–32, and IPT–42. They divided the contents of each bottle into approximately equal amounts and sent a subsample of each clay to the three laboratories. The laboratories were requested to irradiate four portions from each of their subsamples.

The analytical work to test for the homogeneity of elements among bottles of the three new NBS samples corresponds to an experimental design having a single variable of classification—the bottles of a sample. The calculations of the analysis of variance for this design are discussed in many textbooks on statistics (for example, Dixon and Massey, 1951). The test used for homogeneity of an element is the F ratio calculated during the analysis of variance. If the calculated F ratio for an element equals or exceeds the value in statistical tables at some preselected probability, it may be concluded that the element is distributed heterogeneously among the bottles.

Two hundred and seventy-six F ratios, having degrees of freedom (d.f.) of 1 for the numerator and 2 for the denominator, were calculated for the elements in the new NBS samples (NBS–97b, NBS–98b, and NBS–679) (see tables 4–10). Excluding six F ratios

that exceed $F_{0.95}$ (d.f., 1,2)=18.5 and that are marginally significant (see tables 5, 6, and 9), seven F ratios exceed $F_{0.975}$ (d.f., 1,2)=38.5, and four ratios exceed $F_{0.99}$ (d.f., 1,2)=99 (see tables 5 and 9). Normally, these 11 F ratios that equal or exceed the value for $F_{0.975}$ or for $F_{0.99}$ might be considered evidence that the constituents (elements) are distributed heterogeneously among the bottles. However, these constituents were measured by two different spectroscopy systems at the WSU laboratory. Data measured by one system yielded significant F ratios, whereas data for the same element measured by the other system yielded ratios that were not significant. Such conflicting conclusions about the heterogeneity of an element may have resulted because the WSU laboratory irradiated and counted 100-mg sample portions (Filby and others, 1985). The USGS laboratory customarily irradiates 500-mg samples in the TRIGA reactor in Denver, Colo., because the larger sample portion yields more activity and the data are more reproducible.

The significant F ratios calculated from data for chromium, thorium, scandium, and samarium measured by WSU spectroscopy system 1 for NBS–97b (see table 5) indicate that these elements are distributed heterogeneously. These conclusions may be due, however, to the relatively small differences between duplicate determinations for an element in each bottle. If one squares the differences and then sums the squares, the error mean square obtained is very much less than the mean square for the variation due to bottle means, and a significant F ratio is obtained. However, the percentage differences between averages of the elements by the two systems are 2.3 percent for chromium, 1.1 percent for thorium, 1.3 percent for scandium, and 1.0 percent for samarium. These small differences may be accepted as evidence that the four elements are distributed homogeneously.

MINERALOGY

The 10 clay reference samples were analyzed by X-ray diffraction using copper (CuK_{α_1}) radiation. Small portions of the clay samples were reground in a mortar and pestle to ensure a uniform 200-mesh size and were made into wafers having random orientation. Each wafer was mounted in the sample holder and rotated at a rate of approximately 60 rpm during exposure to X-ray radiation. A goniometer traversed at a speed of 1° 2 θ per minute with a counting time of 1 second, thus resulting in a digital count every 0.02° 2 θ. An X-ray trace was made from 3° to 70° 2 θ for each clay sample (figs. 1–3).

Figure 1 shows the X-ray diffraction patterns of flint clays NBS–97, NBS–97a, and NBS–97b. NBS–97 and NBS–97b are from the Mercer flint clay bed (Pennsylvania), and NBS–97a is from the Cheltenham fire clay bed (Missouri). The X-ray patterns show that these samples contain more than 95 percent kaolinite and only traces of boehmite, illite, and chlorite (aluminous). The major difference among the clay samples is that the Missouri sample, NBS–97a, has a slightly lower degree of crystallinity than the samples from Pennsylvania. This difference is evident by comparing the area between 20° and 25° 2 θ of the three X-ray diffraction patterns. The peaks in this area for NBS–97 and NBS–97b are much sharper and more clearly resolved than those for NBS–97a.

Figure 2 shows the X-ray diffraction patterns of plastic clays NBS–98, NBS–98a, and NBS–98b. NBS–98 and NBS–98b are from the underclay of the Clarion coal bed (Pennsylvania), and NBS–98a is from the Cheltenham fire clay bed (Missouri). The X-ray patterns for NBS–98 and NBS–98b are almost identical. They both contain about 50 percent kaolinite, 35 percent illite, and 15 percent quartz. NBS–98a contains approximately 75 percent kaolinite, 15 percent quartz, 10 percent illite, and a trace of chlorite. The mineralogy is consistent with the chemical analysis data presented in this report (see table 25). NBS–98 contains 25.54 percent Al_2O_3 and 3.17 percent K_2O, whereas NBS–98a contains 33.19 percent Al_2O_3 and 1.04 percent K_2O.

Figure 3 shows the X-ray diffraction patterns for the three Brazilian clay samples, IPT–28, IPT–32, and IPT–42, and for the common brick clay sample from Maryland, NBS–679. The X-ray diffraction pattern of IPT–28 indicates that the sample contains 95 percent kaolinite and 5 percent quartz. Chemical data presented in this report (see table 25) agree with this mineral composition. The diffraction pattern for IPT–32 shows about 80 percent kaolinite, 10 percent quartz, 5 percent illite, 5 percent feldspar, and a trace of smectite. Chemical data in this report (see table 25) are consistent with this mineralogy. The X-ray diffraction pattern of IPT–42 indicates that the clay contains 80 percent kaolinite, 15 percent quartz, and 5 percent illite. Again chemical data presented in this report (see table 25) are consistent with this mineralogy.

The major components of sample NBS–679 are kaolinite (30 percent), illite (25 percent), mixed-layer clay (25 percent), and quartz (20 percent) (Knechtel and others, 1961). A minor amount of goethite is present, and smectite and feldspar are present in trace

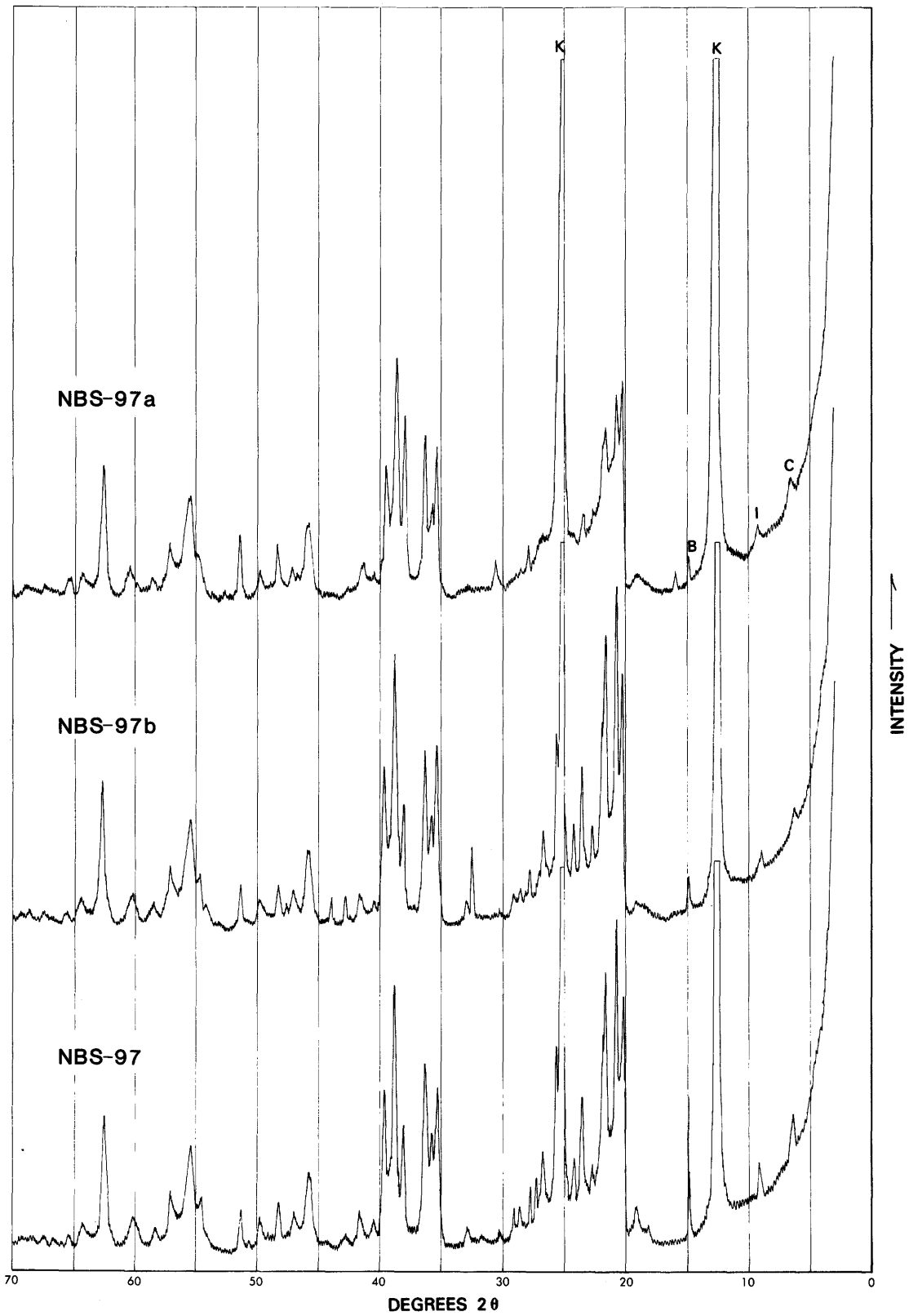

FIGURE 1.—X-ray diffraction traces of flint clays NBS–97 and NBS–97b from the Mercer flint clay bed (Pennsylvania) and of NBS–97a from the Cheltenham fire clay bed (Missouri). C, chlorite; I, illite; K, kaolinite; B, boehmite.

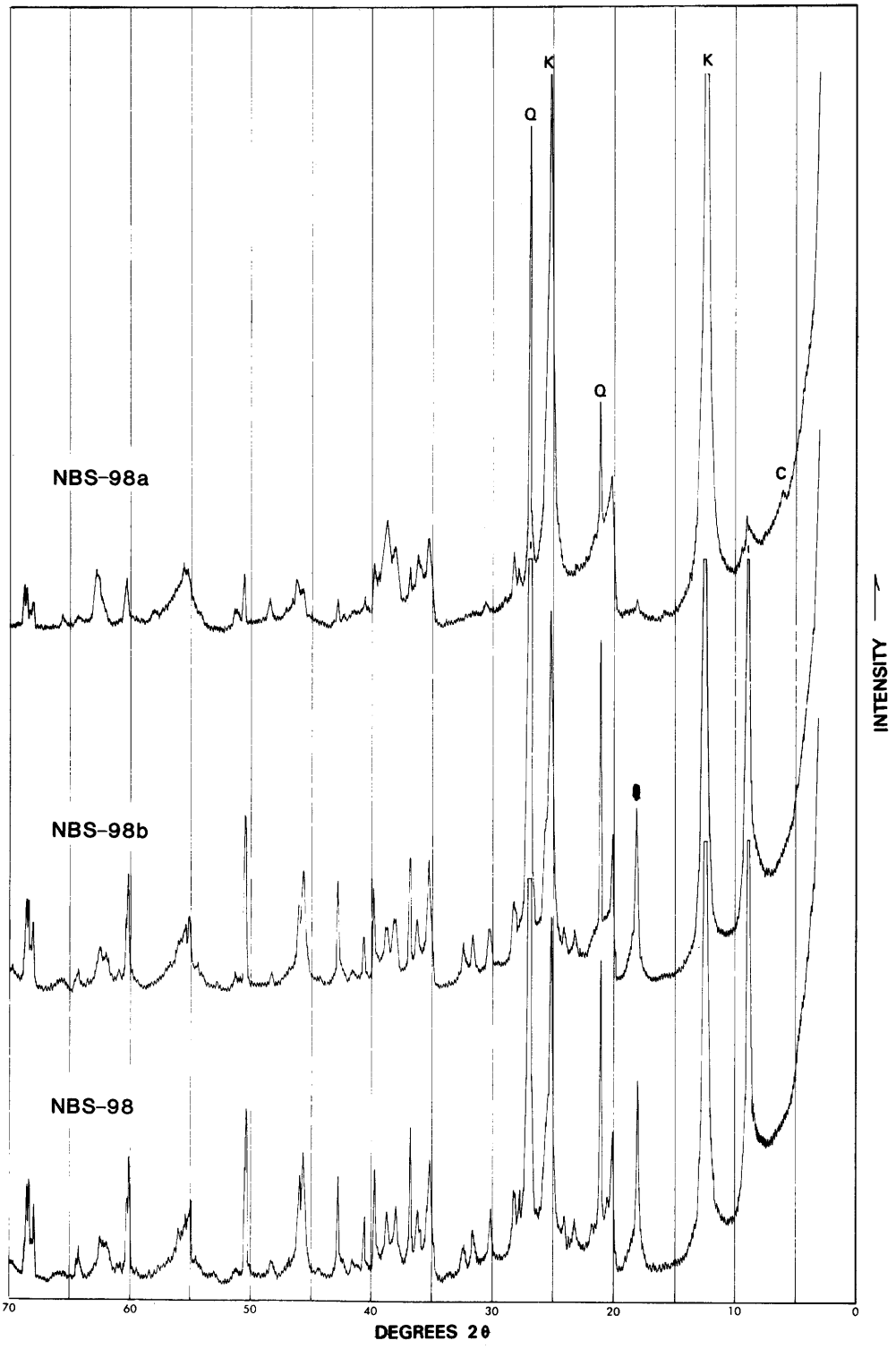

FIGURE 2.—X-ray diffraction traces of plastic clays NBS–98 and NBS–98b from the Clarion coal bed underclay (Pennsylvania) and of NBS–98a from the Cheltenham fire clay bed (Missouri). C, chlorite; I, illite; K, kaolinite; Q, quartz.

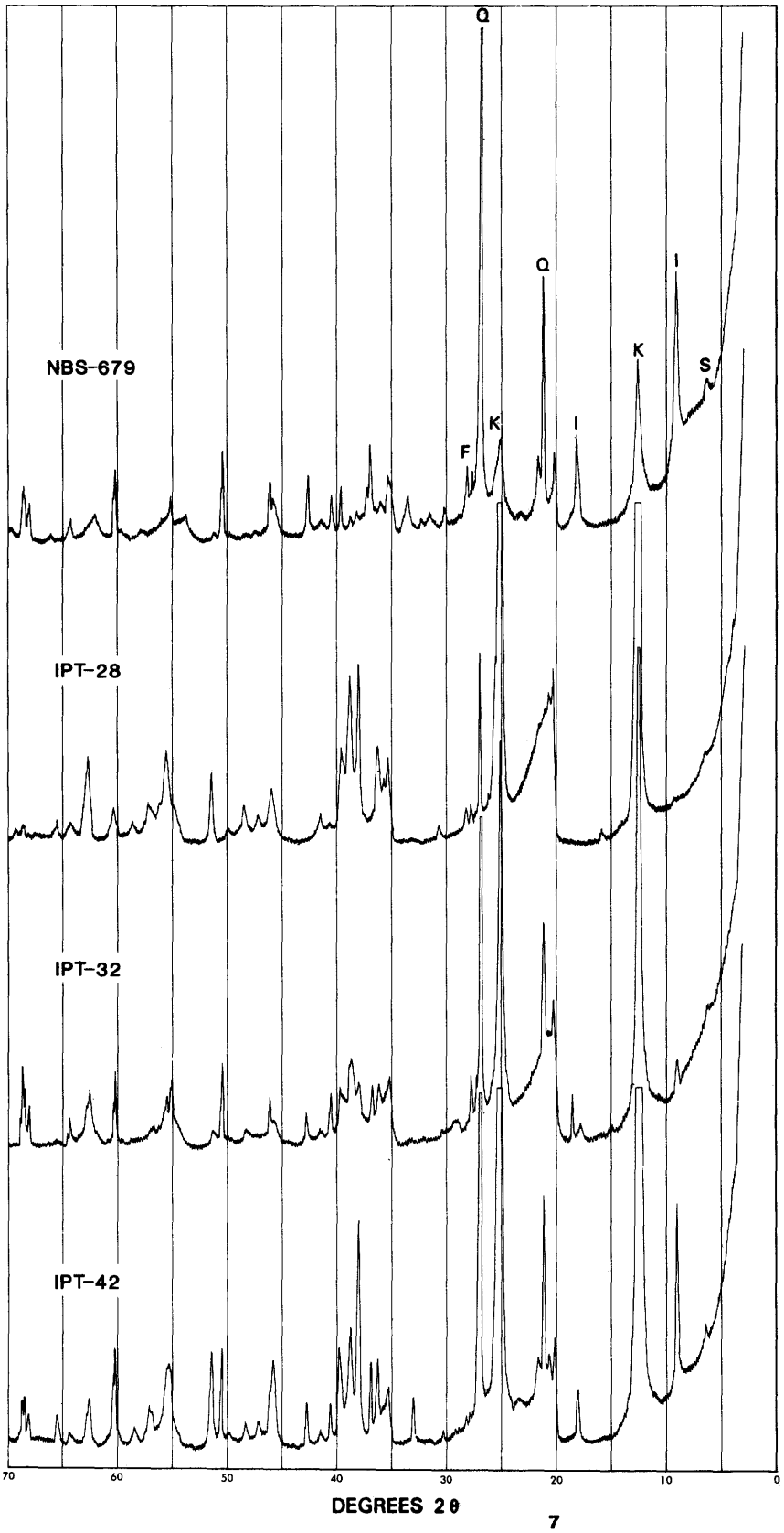

FIGURE 3.—X-ray diffraction traces of three Brazilian clay samples, IPT–28, IPT–32, and IPT–42, and a common brick clay, NBS–679, from Maryland. S, smectite; I, illite; K, kaolinite; Q, quartz; F, feldspar.

amounts. The chemical analysis for the major and minor oxides is not yet available.

TRACE ELEMENT CONTENTS

INAA data reported for all samples by the three laboratories are given in tables 1–16. Table 17 contains data for lithium determined in the USGS laboratory by inductively coupled plasma spectroscopy and by flame atomic absorption spectroscopy.

The tables are arranged so that data for the old NBS samples from Pennsylvania (NBS–97 and NBS–98) in tables 1–3 precede data for the new NBS samples from Pennsylvania (NBS–97b and NBS–98b) in tables 4–7. Data for the new NBS common brick clay sample from Maryland (NBS–679) are given in tables 8–10, and data for the samples from Brazil (IPT–28, IPT–32, and IPT–42) are found in tables 10–14. The USGS was the only laboratory to report data for flint clay NBS–97a (table 15) and plastic clay NBS–98a (table 16) and the lithium content for all samples (table 17).

Laboratory means of sets of data for the samples, except NBS–97a and NBS–98a, are summarized in tables 18–21. Laboratory means and their averages for NBS–97 and NBS–97b are given in table 18, those for NBS–98 and NBS–98b in table 19, those for NBS–679 and IPT–28 in table 20, and those for IPT–32 and IPT–42 in table 21. The conversion from elements in parts per million to oxide in percent was made, where necessary, in tables 18–21. Because of the unequal number of determinations for some elements in tables 1–16, the averages of laboratory means in tables 18–21 were obtained by weighting each laboratory mean by the number of determinations for the mean.

Table 22 lists the weighted averages for 3 oxides and 29 elements for the samples (from tables 18–21). The average lithium content of each sample (from table 17) and the weighted averages for NBS–97a (from table 15) and NBS–98a (from table 16) also are included in table 22. In addition, table 22 contains summations of the average rare earth element contents (ΣREE) for all samples. All the averages in table 22 are considered to be provisional because they may change as more data from other laboratories become available. Table 23 lists 14 elemental ratios for the 10 reference samples. Potassium was converted from K_2O (table 22), and magnesium was converted from MgO (see table 25) to be used in several elemental ratios in table 23. Table 24 lists the provisional means for the samples normalized to the grand mean for 14 elements and for ΣREE. These normalized means make comparisons among samples more obvious than the use of the averages of table 22. Table 25 gives the average major and minor oxide contents of four NBS samples and of three IPT samples from the Certificates of Analysis.

The K/Rb and the K/Ba ratios in table 23 show that the samples from Missouri, NBS–97a and NBS–98a, differ from their Pennsylvania counterparts, NBS–97, NBS–97b, NBS–98, and NBS–98b, as might be expected because of the different geologic environment. The Rb/Cs ratio for the plastic clay from Missouri, NBS–98a, is much lower than the Rb/Cs ratios for the plastic clays from Pennsylvania, and the Rb averages of the three plastic clays NBS–98, NBS–98a, and NBS–98b are greater by factors of 3 or more than the Rb contents of the flint clays from the same areas (table 22).

One striking ratio in table 23, Th/U=0.54 for NBS–98a, is due to the uranium content of 46 ppm for that sample. This value is almost 5 times greater than the next highest uranium content, 9.6 ppm for NBS–97b. The uranium was probably introduced into the clay bed at the time of deposition from an unknown source. The Hf/Ta ratios of the 10 samples are fairly similar (see table 23), except for the high Hf/Ta ratios of 9.93 for NBS–97 and 7.70 for IPT–28, which are due to high Hf contents of 40.9 ppm and 30.8 ppm, respectively. The high Zr and Hf averages of NBS–97 and IPT–28 yield Zr/Hf ratios (35.8 and 34.1, respectively) that fall within the range of such ratios for the 10 samples (32.1 for NBS–97b to 45.7 for IPT–42).

The averages in table 22 and the means normalized to the grand mean in table 24 for some elements in the 10 samples show many of the differences among the samples. The flint clay NBS–97 has higher chromium, hafnium, lithium, and zirconium contents than its current replacement, NBS–97b, from the same area. The differences between the plastic clays NBS–98 and NBS–98b, also from the same area, are not as evident. Some of the trace element contents of the flint and plastic clays from Missouri, NBS–97a and NBS–98a, differ significantly from those of their counterparts from Pennsylvania, especially ΣREE. The averages for elements such as Cs, Li, Ta, Sc, La, Tb, and Tm, when considered individually or in combination, can distinguish NBS–98a from all the other clay samples.

Differences among the REE contents of the clay samples are shown in figures 4, 5, and 6. The average REE contents were normalized by the data of Anders and Ebihara (1982) for C1-chondrites, multiplied by

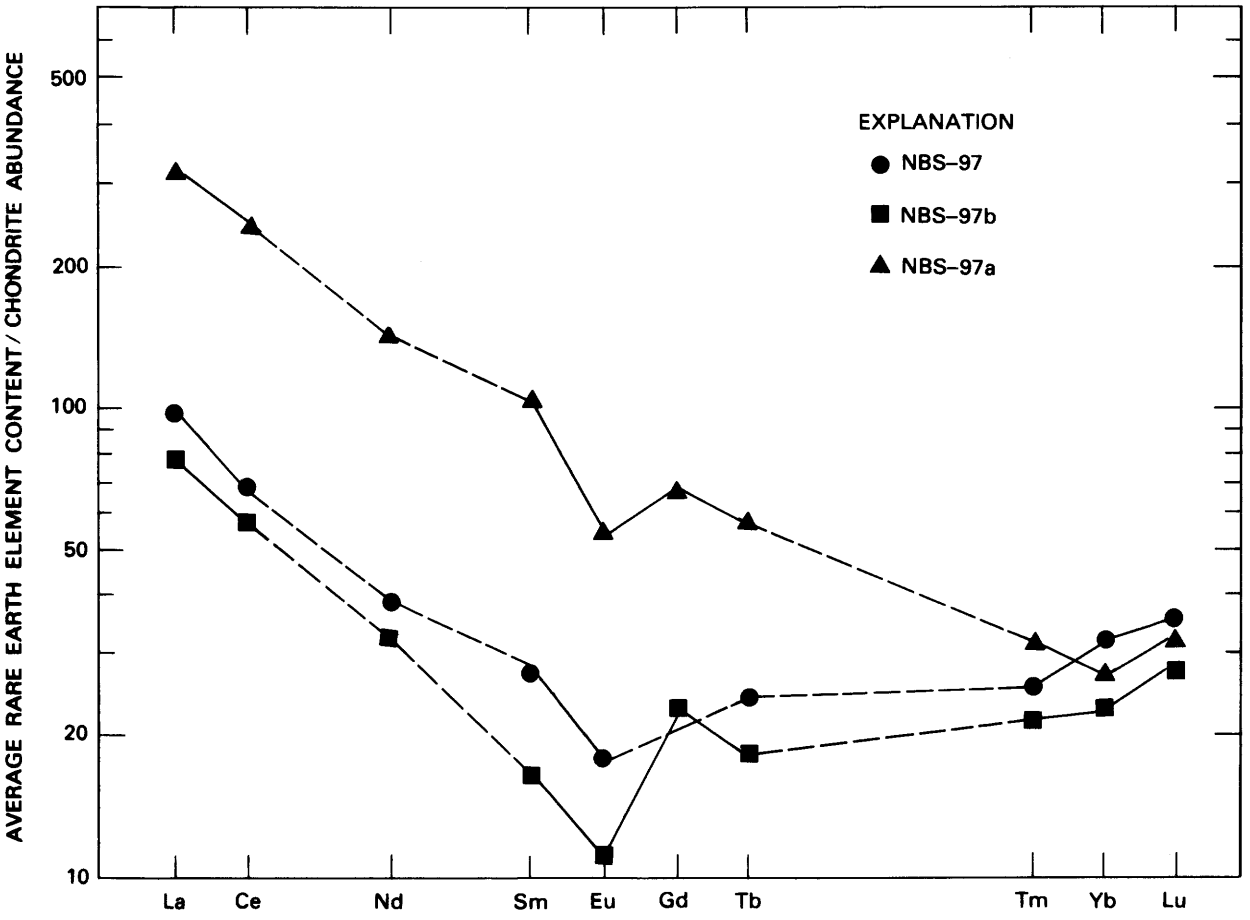

FIGURE 4.—Average rare earth element contents of the flint clays (NBS–97, NBS–97a, and NBS–97b) normalized to chondritic abundances.

1.31. The plot for flint clays (fig. 4) shows that the flint clay from Missouri, NBS–97a, has REE contents that are distinctly different from those of the two flint clays from Pennsylvania. NBS–97 and NBS–97b show plots that are essentially the same except that the data points for NBS–97 are slightly greater.

The plot for the plastic clays (fig. 5) shows that the Missouri plastic clay, NBS–98a, has high REE contents throughout the entire range from lanthanum to lutetium. However, unlike the plots for the flint clays, the normalized means for thulium, ytterbium, and lutetium are significantly higher than the normalized means of the same elements for NBS–98 and NBS–98b. The plastic clay from Brazil, IPT–32, has the second highest means for lanthanum, cerium, and neodymium and the low.est means for thulium, ytterbium, and lutetium.

The plot for the miscellaneous clays (fig. 6) shows that the Maryland clay NBS–679 and the Brazilian clay IPT–42 have very similar REE contents for all elements normalized to chondritic abundances. The other Brazilian clay, IPT–28, has high REE contents throughout the range from lanthanum to samarium.

The plastic clay from Brazil, IPT–32, has a number of trace element contents that differ markedly from those of the other plastic clays. The lithium contents of the other two clays from Brazil, IPT–28, from the Amazon Delta, and IPT–42, from São Simão, are about equal, but the averages of many other trace elements in these two clays differ significantly. The averages for cobalt, thorium, uranium, and zinc not only differ between the two clays, but also, individually or in combination, show that IPT–28 and IPT–42 differ from all the other clay samples.

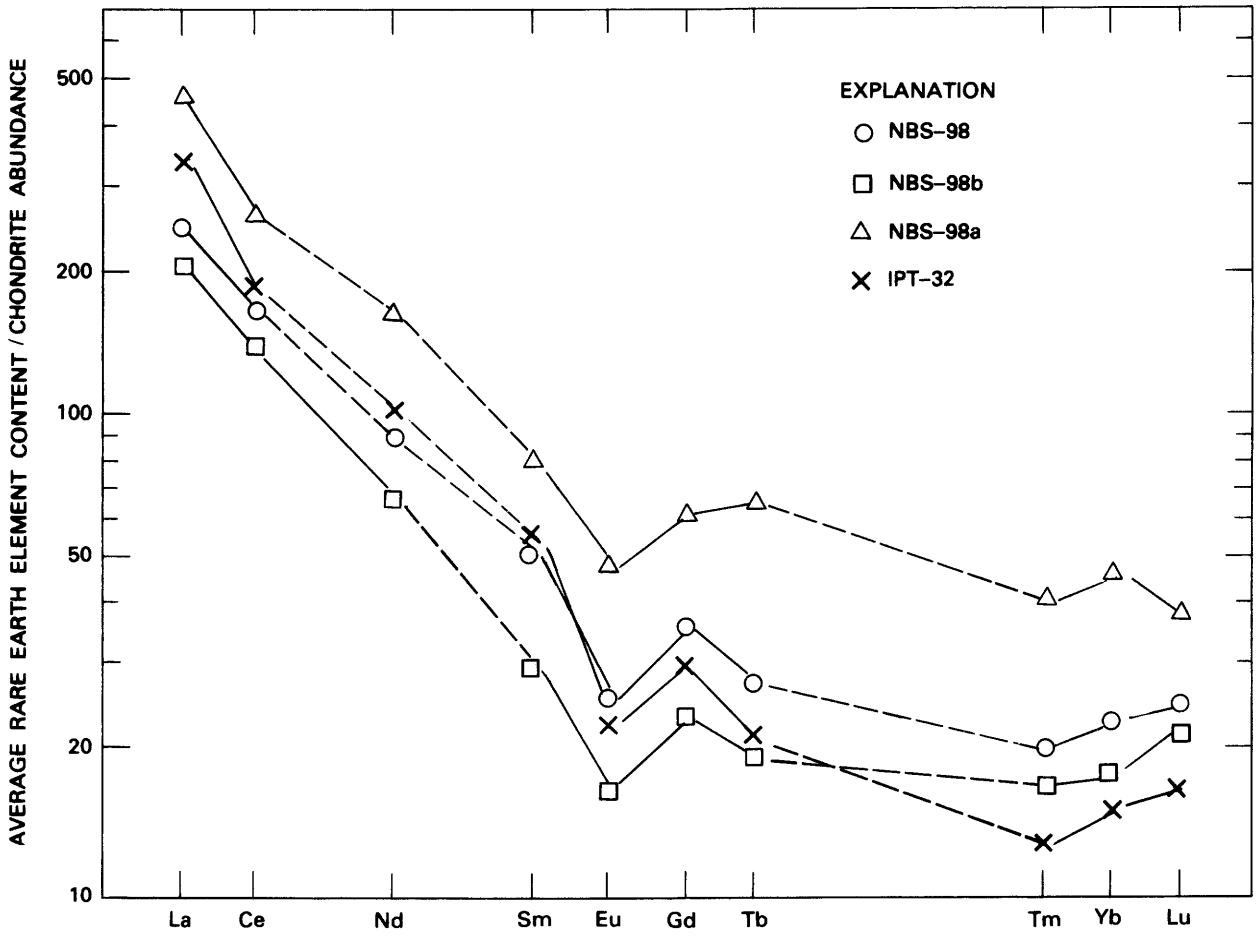

FIGURE 5.—Average rare earth element contents of the plastic clays (NBS–98, NBS–98a, NBS–98b, and IPT–32) normalized to chondritic abundances.

SUMMARY

Mineralogically, the three flint clays, NBS–97, NBS–97a, and NBS–97b, differ very little (fig. 1), except that NBS–97a has much greater normalized ΣREE contents than NBS–97 and NBS–97b have (fig. 4). These three clays are composed of kaolinite and traces of boehmite, illite, and chlorite (aluminous). The kaolinite in NBS–97a (from Missouri) has a slightly lower degree of crystallinity than the kaolinite in NBS–97 or NBS–97b (from Pennsylvania). This difference in crystallinity could be due to the different geologic settings of the two areas.

The flint clay sample NBS–97 (Pennsylvania) has higher average contents of chromium, hafnium, lithium, and zirconium than its replacement, NBS–97b (Pennsylvania), whereas differences between the plastic clays from Pennsylvania, NBS–98 and NBS–98b, are not as evident. Some of the trace element contents of the flint and plastic clays from Missouri, NBS–97a and NBS–98a, differ significantly from trace element contents of similar clays from Pennsylvania, especially the average REE contents normalized to chondritic abundances (figs. 4 and 5).

The plastic clay from Missouri, NBS–98a, is distinguished by its high uranium content (46 ppm), and it has the greatest ΣREE contents of the four plastic clays (fig. 5). The average contents of elements such as Cs, Li, Ta, Sc, La, Ce, Tb, and Tm distinguish NBS–98a from the other plastic clays. The Pennsylvania plastic clays contain kaolinite, illite, and quartz, whereas the Missouri clay contains kaolinite, quartz, illite, and traces of chlorite. The different geologic settings of the two areas may account for the mineral-

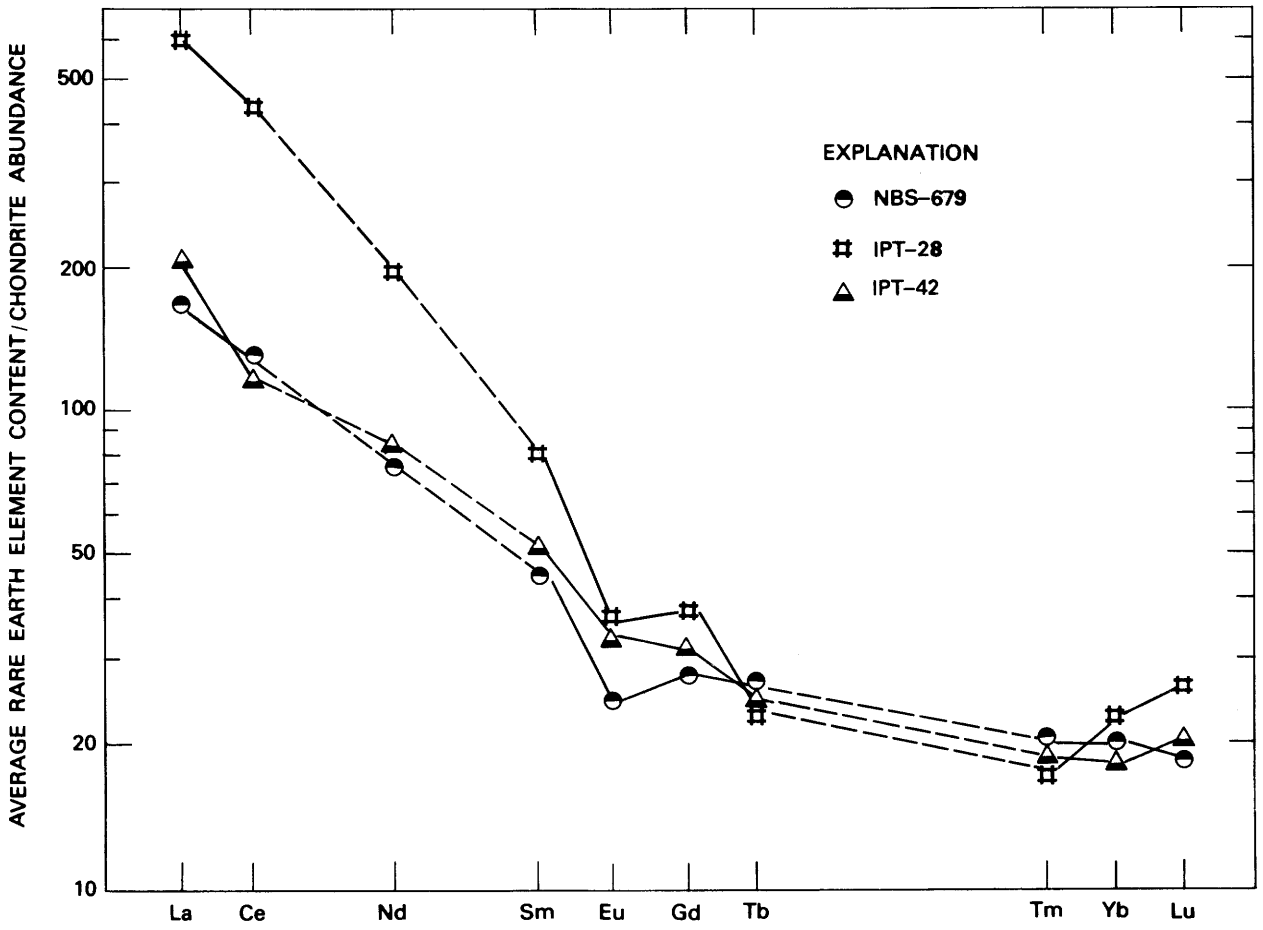

FIGURE 6.—Average rare earth element contents of the miscellaneous clays (NBS–679, IPT–28, and IPT–42) normalized to chondritic abundances.

ogical differences. The plastic clay IPT–32 is similar to NBS–98a in mineralogical content, but most of the trace element contents of IPT–32 differ from those of the other plastic clays.

The miscellaneous clay samples, NBS–679, IPT–28, and IPT–42, are all from different geologic environments, and so no mineralogical relationship was expected. The normalized ΣREE contents (fig. 6) show that the light rare earth elements lanthanum, cerium, neodymium, and samarium are enriched in sample IPT–28. Only minor differences occur in the rare earth element plots for NBS–679 and IPT–42.

The lithium contents of the two Brazilian clays IPT–28 and IPT–42 are about equal, but the averages of many of the trace elements in these two clays differ significantly. The averages for cobalt, thorium, uranium, and zinc differ between IPT–28 and IPT–42, and these averages also distinguish IPT–28 and IPT–42 from the other clays.

REFERENCES CITED

Anders, Edward, and Ebihara, Mitsuru, 1982, Solar-system abundances of the elements: Geochimica et Cosmochimica Acta, v. 46, no. 11, p. 2363–2380.

Azevedo Branco, P.C., 1984, Principais depósitos minerais: Conceitos, metodologia e listagem, *in* Schobbenhaus, Carlos, Almeida Campos, Diogenes, Derze, G.R., and Asmus, H.E., eds., Geologia do Brasil: Departamento Nacional da Producão Mineral, Ministério das Minas e Energia, p. 359–428.

Ball, T.K., and Filby, R.H., 1965, The zinc contents of some geochemical standards by neutron activation and X-ray fluorescence analysis: Geochimica et Cosmochimica Acta, v. 29, no. 7, p. 737–740.

Baedecker, P.A., Rowe, J.J., and Steinnes, E., 1977, Application of epithermal neutron activation in multielement analysis of silicate rocks employing both coaxial Ge(Li) and low energy photon detector systems: Journal of Radioanalytical Chemistry, v. 40, p. 115–146.

Clark, M.C., and Swaine, D.J., 1963, Some trace element contents of National Bureau of Standards reference samples numbers

1a, 98, and 99: Geochimica et Cosmochimica Acta, v. 27, no. 11, p. 1139–1142.

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

Erickson, E.S., 1963, Mineralogy, petrographic, and geochemical relationships in some high-alumina and associated claystones: Unpublished Ph.D. thesis, Pennsylvania State University, 190 p.

Filby, R.H., 1964, The contents of several trace elements in some rock samples: Geochimica et Cosmochimica Acta, v. 28, no. 2, p. 265–269.

Filby, R.H., Nguyen, Son, Grimm, C.A., Markowski, G.R., Ekambaram, Vanavan, Tanaka, Tsuyoshi, and Grossman, Lawrence, 1985, Evaluation of geochemical standard reference materials for microanalysis: Analytical Chemistry, v. 57, p. 551–555.

Flanagan, F.J., 1986, Reference samples in geology and geochemistry: U.S. Geological Survey Bulletin 1582, 70 p.

Flanagan, F.J., Schwartz, L.J., Rowe, J.J., and Dorrzapf, A.F., Jr., 1977, Available clay and feldspar reference samples as standards for archaeological pottery studies: Geostandards Newsletter, v. 1, no. 1, p. 61–66.

Grabowski, R.J., and Eunice, R.C., 1958, Quantitative spectrochemical determination of barium and strontium: Analytical Chemistry, v. 38, no. 8, p. 1374–1379.

Hinkley, D.N., 1961, Mineralogy and chemical variation in the kaolin deposits of the Coastal Plain of Georgia and South Carolina: Unpublished Ph.D. thesis, Pennsylvania State University, 215 p.

Flanagan, F.J., 1986, Reference samples in geology and geochemistry: U.S. Geological Survey Bulletin 1582, 70 p.

Flanagan, F.J., Schwartz, L.J., Rowe, J.J., and Dorrzapf, A.F., Jr., 1977, Available clay and feldspar reference samples as standards for archaeological pottery studies: Geostandards Newsletter, v. 1, no. 1, p. 61–66.

Grabowski, R.J., and Eunice, R.C., 1958, Quantitative spectrochemical determination of barium and strontium: Analytical Chemistry, v. 38, no. 8, p. 1374–1379.

Hinckley, D.N., 1961, Mineralogy and chemical variation in the kaolin deposits of the Coastal Plain of Georgia and South Carolina: Unpublished Ph.D. thesis, Pennsylvania State University, 215 p.

Keller, W.D., 1968, Flint clay and a flint-clay facies: Clays and Clay Minerals Bulletin, v. 16, no. 2, p. 113–128.

Kerr, P.F., Hamilton, P.K., Pill, R.J., Wheeler, G.V., Lewis, D.R., Burkhardt, W., Reno, Duane, Taylor, G.L., Meilenz, R.C., King, M.E., and Schieltz, N.C., 1950, Analytical data on reference clay materials: American Petroleum Institute, Preliminary Report No. 7, 160 p.

Knechtel, M.M., Hamlin, H.P., Hosterman, J.W., and Carroll, Dorothy, 1961, Physical properties of nonmarine Cretaceous clays in the Maryland Coastal Plain: Maryland Geological Survey Bulletin 22, 11 p.

Miller, B.L., 1911, The geology of Prince George's County, Maryland and the District of Columbia: Maryland Geological Survey, The Johns Hopkins Press, 151 p.

Potts, P.J., Thorpe, O.W., and Watson, J.S., 1981, Determination of the rare-earth element abundances in 29 international rocks-tandards by instrumental neutron activation analysis: A critical appraisal of calibration errors: Chemical Geology, v. 34, no. 1, p. 331–352.

Potts, P.J., Thorpe, O.W., Isaacs, M.C., and Wright, D.W., 1985, High-precision instrumental neutron-activation analysis of geological samples employing simultaneous counting with both planar and coaxial detectors: Chemical Geology, v. 48, p. 145–155.

Shimp, N.F., Conner, Jane, Prince, A.L., and Bear, F.E., 1957, Spectrochemical analysis of soils and biological materials: Soil Science, v. 82, no. 1, p. 51–64.

Taylor, R.S., and Kolbe, P., 1964, Geochemical standards: Geochimica et Cosmochimica Acta, v. 28, no. 4, p. 447–454.

Turekian, K.K., and Carr, M.H., 1961, Chromium, cobalt, and strontium in some National Bureau of Standards rock reference samples: Geochimica et Cosmochimica Acta, v. 24, nos. 1–2, p. 1–9.

TABLES

TABLE 1.—*Instrumental neutron activation determinations of elements in NBS–97 by the U.S. Geological Survey, 1976 and 1985*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; —, no data. Four portions from a bottle were used for 1985 data]

	1985				1976			
	Determinations		$\bar{x}$	sd	Bottle 1	Bottle 2	$\bar{x}$	sd
Fe	0.634	0.660	0.664	0.023	0.65	0.64	0.658	0.015
	.674	.688			.67	.67		
Na	.052	.061	.057	.0038	--	--	--	--
	.055	.058			--	--		
Ba	190	216	205	13.4	290	250	258	25
	217	198			260	230		
Co	3.24	3.36	3.34	.067	3.2	3.4	3.32	.10
	3.38	3.38			3.4	3.3		
Cr	639	659	664.2	20.6	557	572	576	14.9
	671	688			584	591		
Cs	2.13	2.34	2.24	.088	2.3	2.3	2.40	.12
	2.21	2.26			2.5	2.5		
Hf	40.8	40.9	40.42	.59	38.4	37.7	38.72	.83
	40.4	39.6			39.3	39.5		
Rb	24	21.7	23.05	1.14	23	22	24.5	2.4
	24	22.5			26	27		
Sb	1.29	1.51	1.46	.14	1.2	1.3	1.40	.18
	1.43	1.63			1.6	1.5		
Ta	4.66	4.19	4.34	.22	4.02	4.15	4.18	.15
	4.25	4.25			4.17	4.39		
Th	36.5	38.4	38.02	1.03	36.5	36.2	36.9	.74
	38.8	38.4			37.9	37.0		
U	7.0	7.3	7.22	.17	--	--	--	--
	7.4	7.2			--	--		
Zn	75	82.1	79.8	3.33	100	104	101.5	1.7
	80	82			101	101		
Zr	1,890	1,760	1,788	68.5	1,380	1,340	1,368	22
	1,750	1,750			1,360	1,390		
Sc	19.1	19.9	19.7	.41	21.4	20.3	20.8	.45
	20.0	19.8			20.7	20.8		
La	26.6	28.7	27.9	.93	32	33	33.2	.96
	28.4	28.0			34	34		
Ce	46.8	50.3	49.95	2.20	57	56	57.0	.82
	51.9	50.8			58	57		
Nd	17	21	[1]20.7	[1]3.5	18	20	[1]19.3	[1]1.2
	<40	24			20	--		
Sm	4.89	5.13	5.10	.14	5.8	5.8	5.8	--
	5.20	5.18			5.8	5.8		
Eu	1.22	1.28	1.26	.03	1.16	1.26	1.24	.05
	1.29	1.27			1.28	1.26		
Tb	1.11	1.19	1.16	.04	1.24	1.25	1.258	.017
	1.18	1.18			1.28	1.26		
Tm	.82	.71	.80	.06	--	--	--	--
	.85	.82			--	--		
Yb	6.20	6.4	6.20	.22	6.4	6.6	6.72	.28
	5.9	6.3			6.9	7.0		
Lu	.96	.98	.97	.01	.94	.94	.95	.02
	.98	.97			.98	.94		

[1] $\bar{x}$ or sd of three data.

TABLE 2.—*Instrumental neutron activation determinations of elements in NBS–98 by the U.S. Geological Survey, 1976 and 1985*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; —, no data. Four portions from a bottle were used for 1985 data]

	1985				1976			
	Determinations		$\bar{x}$	sd	Bottle 1	Bottle 2	$\bar{x}$	sd
Fe	1.52	1.47	1.495	0.035	1.41	1.42	1.402	0.018
	1.53	1.46			1.38	1.40		
Na	.189	.213	.204	.015	--	--	--	--
	.193	.220			--	--		
Ba	631	670	652.8	20.2	660	670	655.0	17
	670	640			660	630		
Co	15.0	14.5	14.65	.37	13.8	13.8	13.75	.06
	14.9	14.2			13.7	13.7		
Cr	139	134	135.8	3.3	110	113	112	3.2
	138	132			109	116		
Cs	10.9	10.4	10.65	.29	10.6	10.5	10.82	.58
	10.9	10.4			10.5	11.7		
Hf	7.82	7.52	7.60	.31	7.5	6.3	7.1	.54
	7.87	7.20			7.2	7.5		
Rb	159	153	165.8	2.87	153	155	152.8	2.1
	159	156			150	153		
Sb	1.48	1.50	1.70	.43	1.4	1.3	1.22	.15
	2.34	1.48			1.1	1.1		
Ta	2.22	2.23	2.22	.04	2.23	2.19	2.22	.04
	2.27	2.16			2.18	2.27		
Th	21.6	20.9	21.2	.54	19.5	19.1	19.4	.32
	21.7	20.6			19.2	19.8		
U	4.7	5.2	5.02	.24	--	--	--	--
	5.2	5.0			--	--		
Zn	107	107	104	4.2	127	126	124.2	2.8
	104	98			123	121		
Zr	418	[1]278	[2]355	[2]55	320	310	335	26.4
	327	320			340	370		
Sc	23.5	22.9	23.1	.60	22.9	22.9	22.85	.17
	23.6	22.3			22.6	23.0		
La	73.4	73.4	73.32	.30	79	77	78.5	2.64
	72.9	73.6			82	76		
Ce	133	130	130	3.56	135	133	134.8	1.26
	132	125			135	136		
Nd	57	48	51.5	3.87	46	50	48.0	1.63
	51	50			48	48		
Sm	9.90	9.90	9.89	.02	10.1	10.0	9.98	.12
	9.85	9.90			10.0	9.8		
Eu	1.79	1.77	1.78	.04	1.76	1.74	1.73	.03
	1.83	1.73			1.70	1.72		
Gd	9.3	8.6	9.08	.33	--	--	--	--
	9.3	9.1			--	--		
Tb	1.33	1.29	1.31	.05	1.39	1.37	1.33	.07
	1.37	1.25			1.32	1.24		
Tm	.62	.64	.63	.03	--	--	--	--
	.59	.67			--	--		
Yb	4.46	4.31	4.51	.26	4.7	4.8	4.88	.17
	4.88	4.38			5.1	4.9		
Lu	.71	.72	.70	.02	.66	.62	.645	.04
	.69	.69			.60	.70		

[1] Correction for fission product interference exceeds 20 percent of the reported value.
[2] $\bar{x}$ or sd of three data.

TABLE 3.—*Instrumental neutron activation determinations of elements in NBS–97 and NBS–98 by the Nuclear Radiation Center, Washington State University*

[In parts per million. Sample portions were counted by two spectroscopy systems. $\bar{x}$, mean; sd, standard deviation; —, no data]

	NBS-97				NBS-98			
	Spectroscopy System				Spectroscopy System			
	1	2	$\bar{x}$	sd	1	2	$\bar{x}$	sd
Fe	6,547	5,999	6,680	523	12,690	14,820	13,368	1,036
	7,146	7,031			12,560	13,400		
Na	573.5	561.7	581	20	1,814	1,971	1,934	99
	608.7	579.3			1,905	2,048		
K	4,499	4,517	4,633	240	24,690	24,730	25,062	409
	4,992	4,524			25,370	25,460		
As	4.722	4.461	4.88	.35	4.648	5.140	4.78	.28
	5.136	5.202			4.863	4.487		
Ba	224.9	299.9	281	38	671.5	703.1	731	61
	309.1	290.0			737.0	813.3		
Co	3.481	3.209	3.40	.22	12.98	13.27	13.35	.34
	3.676	3.255			12.81	13.36		
Cr	683.4	601.9	624	51.2	123.1	121.4	123.9	6.4
	644.6	565.4			133.0	118.2		
Cs	2.388	2.367	2.46	.16	10.20	10.33	10.46	.44
	2.700	2.395			11.11	10.21		
Ba	51.81	55.75	54.87	2.1	32.12	33.66	33.90	2.15
	56.67	55.25			32.84	36.99		
Hf	43.92	39.11	43.58	3.23	7.222	7.964	7.67	.30
	46.80	44.49			7.852	7.755		
Ni	35.99	38.24	34.31	3.37	53.31	44.73	44.42	6.4
	31.66	31.34			40.82	28.82		
Rb	22.69	25.89	24.85	1.88	145.5	150.8	151.4	4.3
	26.87	23.96			154.7	154.5		
Sr	143.2	73.0	[1]121	—	262.5	100.4	263	71.4
	144.8	<100			360.0	237.9		
Sb	1.684	1.589	1.63	.15	1.539	1.284	1.59	.63
	1.794	1.440			2.021	1.511		
Ta	3.962	3.475	3.84	.48	2.064	1.840	2.00	.20
	4.459	3.449			2.261	1.853		
Th	40.05	39.13	40.24	1.82	19.74	21.09	20.80	.77
	42.88	38.92			21.56	20.83		
U	8.529	7.718	8.73	1.0	7.651	6.006	7.06	.93
	10.11	8.565			8.017	6.572		
Zr	1,405	979.4	1,256	224	243.4	217.2	262	55
	1,469	1,172			342.2	245.9		
Sc	20.14	19.22	20.11	1.19	21.17	21.74	21.80	.68
	21.79	19.30			22.76	21.52		
La	29.61	31.63	30.34	.95	67.08	73.51	71.53	3.70
	29.63	30.51			70.09	75.45		
Ce	57.03	53.39	56.63	3.86	127.3	127.8	129.7	4.9
	61.92	54.17			137.1	126.7		
Nd	18.67	19.12	28.9	11.7	43.42	63.97	57.00	9.8
	41.5	36.29			56.19	64.40		
Sm	4.952	5.173	5.44	.62	8.865	8.410	8.81	.36
	6.349	5.268			9.283	8.698		
Eu	1.375	1.295	1.36	.07	1.735	1.849	1.81	.06
	1.462	1.316			1.856	1.799		
Tb	.990	1.165	1.07	.07	1.027	1.245	1.15	.10
	1.059	1.076			1.213	1.128		
Yb	6.612	6.418	6.85	1.14	4.282	4.156	4.37	.22
	8.500	5.878			4.675	4.379		
Lu	1.434	1.266	1.38	.23	.810	.728	.90	.20
	1.675	1.132			1.184	.859		

[1] $\bar{x}$ of three data.

TABLE 4.—*Instrumental neutron activation determinations of elements in NBS–97b and NBS–98b by the U.S. Geological Survey*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; —, no data. Error sd and F ratio are from the analysis of variance of the data. F ratios were not significant at $F_{0.05}$ (d.f., 1,2)=18.5]

	NBS-97b					NBS-98b				
	Bottle No.			Error	F	Bottle No.			Error	F
	1	2	$\bar{x}$	sd	ratio	1	2	$\bar{x}$	sd	ratio
Fe	0.863	0.882	0.871	0.007	1.75	1.260	1.180	1.217	0.032	1.13
	.869	.869				1.209	1.220			
Na	.058	.062	[1].063	--	--	.169	.136	.151	.012	1.95
	.069	<.1				.150	.150			
Ba	213	217	223.5	12.7	<1	690	670	652.5	40	<1
	224	240				620	630			
Co	3.67	3.66	3.62	.071	<1	16.0	15.3	15.58	.32	<1
	3.53	3.64				15.43	15.59			
Cr	227	235	230.8	3.2	1.22	123	114	118.8	2.5	4.62
	231	230				120	118			
Cs	3.26	3.40	3.34	.043	5.97	16.0	15.3	15.55	.27	1.84
	3.34	3.37				15.47	15.43			
Hf	12.58	12.9	12.62	.17	2.16	6.80	6.46	6.53	.16	1.97
	12.42	12.6				6.49	6.38			
Rb	34.2	28.2	32.3	3.5	<1	168	168	169.5	3	1.00
	32.2	34.7				168	174			
Sb	2.06	2.14	2.13	.047	1.91	1.62	1.59	1.60	.016	6.40
	2.14	2.19				1.61	1.56			
Ta	3.97	4.01	3.97	.057	<1	2.02	1.95	1.98	.029	1.06
	4.00	3.90				1.97	1.98			
Th	36.2	36.8	36.4	.30	<1	20.7	19.5	20.1	.46	1.42
	36.3	36.2				20.0	20.1			
U	7.4	7.6	7.4	.15	<1	3.5	3.0	3.5	.7	(=)
	7.4	7.3				3.5	4.0			
Zn	73.8	84.8	78.9	5.7	<1	101.9	92.6	95.0	3.7	3.11
	81.0	76				94.7	91			
Zr	530	506	500	30	2.31	270	275	287.8	35	<1
	515	448				340	266			
Sc	23.1	23.6	23.2	.25	<1	22.7	21.6	22.1	.36	2.77
	23.2	23.1				22.1	22.0			
La	24.5	24.7	24.8	.27	<1	68.8	65.7	67.6	1.56	<1
	25.0	24.9				67.4	68.5			
Ce	43.2	43.4	43.2	.18	<1	109	102	104.9	2.35	2.75
	43.0	43.1				104.7	103.9			
Nd	28	24	[2]26	--	--	39	38	39.5	2.1	<1
	<40	<40				38	42			
Sm	3.24	3.31	3.30	.055	<1	6.10	6.49	6.34	.17	<1
	3.35	3.31				6.41	6.34			
Eu	.735	.762	.742	.013	<1	1.09	1.14	1.12	.025	<1
	.737	.736				1.13	1.11			
Gd	5.1	5.6	5.7	.60	<1	6.1	5.6	5.8	.39	<1
	6.3	5.7				5.5	6.1			
Tb	.75	.78	.80	.06	<1	.86	.89	.85	.05	<1
	.81	.88				.87	.79			
Tm	.72	.69	.67	.049	1.22	.349	.50	.475	.100	<1
	.68	.60				.55	.50			
Yb	4.35	4.6	4.58	.155	4.81	3.22	3.37	3.33	.177	<1
	4.46	4.89				3.53	3.2			
Lu	.741	.80	.754	.032	<1	.540	.572	.554	.014	<1
	.741	.735				.555	.547			

[1] $\bar{x}$ of three data.

[2] No F ratio because of a zero mean square for bottles.

[3] $\bar{x}$ of two data.

TABLE 5.—*Instrumental neutron activation determinations of elements in NBS-97b by the Nuclear Radiation Center, Washington State University*

[In parts per million. Samples were counted by two spectroscopy systems. $\bar{x}$, mean; sd, standard deviation]

	Spectroscopy System 1					Spectroscopy System 2				
	Bottle No.			Error	F	Bottle No.			Error	F
	1	2	$\bar{x}$	sd	ratio	1	2	$\bar{x}$	sd	ratio
Fe	7,981	8,284	8,116	110	1.84	7,734	9,919	9,300	1040	1.04
	8,102	8,099				9,806	9,745			
Na	496.3	512.6	511.4	9.9	2.34	524.3	512.0	520	18	<1
	511.4	525.4				502.7	541.1			
K	4,887	4,895	4,946	107	1.06	4,831	4,669	4,775	146	<1
	4,896	5,108				4,680	4,920			
As	9.225	10.78	10.76	1.12	3.48	7.908	8.190	8.34	.46	1.57
	10.14	12.91				8.195	9.063			
Ba	245.4	268.4	279	32	[1]	301.2	283.8	275	33	<1
	307.8	283.8				236.1	277.9			
Co	3.545	3.449	3.56	.16	<1	3.491	3.526	3.50	.07	3.35
	3.497	3.770				3.379	3.618			
Cr	213.0	220.4	217	1.1	[2]46.46	206.8	211.6	212	3.5	2.23
	214.0	222.2				211.3	217.0			
Cs	3.528	3.412	3.56	.14	<1	3.305	3.826	3.50	.19	2.12
	3.615	3.675				3.422	3.460			
Ga	52.36	51.86	52.1	1.2	<1	57.38	56.21	56.9	2.4	<1
	50.76	53.52				54.21	59.81			
Hf	13.13	13.83	13.4	.22	5.39	13.28	13.69	13.5	.14	2.51
	13.10	13.40				13.42	13.45			
Ni	42.22	25.97	34.5	11.5	[1]	24.24	21.62	22.0	1.97	<1
	26.91	43.02				20.31	21.98			
Rb	31.50	31.38	31.8	.95	1.21	26.91	32.04	29.7	1.8	1.97
	31.00	33.21				29.94	29.97			
Sr	62.21	99.59	105	35	<1	98.52	157.0	127	7.8	[2]37.3
	121.1	136.8				107.7	144.4			
Sb	2.170	2.267	2.16	.08	<1	1.929	2.200	2.06	.06	12.47
	2.074	2.127				2.009	2.119			
Ta	3.644	3.682	3.64	.06	4.05	3.157	3.189	3.20	.06	2.62
	3.556	3.698				3.152	3.300			
Th	35.73	36.73	36.3	.10	[4]125	36.12	36.76	36.7	.47	4.09
	35.79	36.91				36.39	37.67			
U	12.63	10.76	11.3	.83	1.32	11.25	9.935	10.3	.61	1.10
	10.98	10.94				10.02	10.04			
Zr	440.1	446.8	429	20	<1	290.0	356.4	329	50	<1
	411.3	418.2				372.3	298.1			
Sc	22.34	22.90	22.7	.06	[2]79.2	22.11	22.38	22.4	.18	3.34
	22.44	22.97				22.30	22.68			
La	22.42	22.91	22.7	.18	14.82	24.14	23.31	23.6	.68	<1
	22.34	23.27				22.94	23.97			
Ce	44.75	46.28	46.1	1.0	5.89	46.41	46.47	46.3	.49	2.00
	44.90	48.31				45.50	46.82			
Nd	17.18	13.59	17.1	3.3	<1	21.00	17.95	20.2	1.8	<1
	17.65	20.15				20.43	21.58			
Sm	2.601	3.543	3.09	.04	[4]730	3.163	3.065	3.12	.11	<1
	2.620	3.612				3.028	3.239			
Eu	.771	.818	.79	.05	[1]	.760	.825	.79	.02	<1
	.809	.762				.783	.800			
Tb	.792	.794	.81	.02	<1	.948	.931	.92	.03	<1
	.813	.827				.889	.909			
Yb	3.930	4.815	4.58	.30	8.25	4.477	4.521	4.55	.08	<1
	4.382	5.197				4.578	4.638			
Lu	.976	1.204	1.12	.11	<1	.815	.870	.86	.02	4.27
	1.185	1.132				.854	.897			

[1] No F ratio because of a zero mean square for bottles.

[2] Significant at $F_{0.975}$ (d.f., 1,2)=38.5.

[3] Significant at $F_{0.95}$ (d.f., 1,2=)18.5.

[4] Significant at $F_{0.99}$ (d.f., 1,2)=99.

TABLE 6.—*Instrumental neutron activation determinations of elements in NBS–98b by the Nuclear Radiation Center, Washington State University*

[In parts per million. Samples were counted by two spectroscopy systems. $\bar{x}$, mean; sd, standard deviation; S, F ratio significant at $F_{0.05}$ (d.f., 1,2)=18.5]

	Spectroscopy System 1					Spectroscopy System 2				
	Bottle No.			Error	F	Bottle No.			Error	F
	8	18	$\bar{x}$	sd	ratio	8	18	$\bar{x}$	sd	ratio
Fe	10,940	12,550	11,610	433	5.49	10,600	13,410	12,038	381	35.64 S
	11,220	11,730				11,200	12,940			
Na	1,169	1,230	1,225	37	3.73	1,278	1,335	1,328	37.2	<1
	1,210	1,291				1,351	1,350			
K	22,030	22,450	22,752	842	1.48	22,840	24,080	23,805	670	<1
	22,450	24,080				24,180	24,120			
As	5.788	5.939	6.33	.67	<1	5.839	7.507	6.92	.90	<1
	6.521	7.061				7.507	6.819			
Ba	654.9	772.7	709	20	19.56 S	806.4	739.5	773	28	14.65
	671.9	735.4				845.1	699.8			
Co	14.23	15.13	15.0	.40	4.81	13.82	14.94	14.6	.52	<1
	14.82	15.66				14.83	14.66			
Cr	109.2	115.9	114	1.6	22.28 S	99.82	109.0	107	5.9	<1
	110.5	118.8				111.6	107.5			
Cs	15.22	16.36	16.0	.26	17.74	14.70	16.11	15.7	.69	<1
	15.63	16.68				16.05	15.78			
Ga	24.43	24.87	25.1	.74	1.88	28.27	29.82	29.6	.79	2.09
	24.73	26.31				29.72	30.46			
Hf	6.539	6.989	6.85	.13	15.69	6.427	7.030	6.78	.28	<1
	6.631	7.240				6.920	6.751			
Ni	49.19	66.72	57.6	3.2	16.84	42.84	37.18	46.1	8.9	<1
	52.97	61.59				52.50	52.03			
Rb	160.6	172.4	169	3.5	6.97	155.8	164.8	133	6.0	1.65
	167.4	174.1				165.5	172.0			
Sr	202.5	203.9	208	10.4	1.60	154.5	178.1	205	58	<1
	199.6	224.4				258.6	228.3			
Sb	1.520	1.582	1.63	.14	<1	1.435	1.680	1.79	.36	1.61
	1.783	1.648				1.687	2.345			
Ta	1.786	1.869	1.87	.07	2.28	1.557	1.640	1.63	.27	<1
	1.861	1.979				1.688	1.647			
Th	19.18	20.75	20.2	.40	12.82	18.78	20.65	20.1	.9	<1
	19.86	21.19				20.56	20.31			
U	10.30	7.584	8.58	.74	7.09	8.396	7.460	8.19	.44	1.83
	8.822	7.620				8.568	8.319			
Zr	243.2	223.5	243	17.8	3.79	229.2	180.7	193	38	<1
	278.4	228.8				157.0	206.1			
Sc	20.78	22.25	21.7	.30	16.34	19.92	21.53	21.10	.87	<1
	21.37	22.29				21.65	21.32			
La	54.33	55.96	55.6	1.0	7.18	57.16	61.52	60.5	2.2	1.03
	54.14	58.00				61.62	61.79			
Ce	102.9	113.2	109.4	2.6	9.56	96.67	108.7	105.2	6.1	<1
	108.0	113.5				108.8	106.7			
Nd	34.94	37.26	33.5	4.2	<1	31.15	37.99	39.3	7.1	<1
	32.71	29.09				44.08	43.99			
Sm	4.764	4.899	4.97	.23	1.70	4.218	4.707	4.61	.28	<1
	4.881	5.338				4.788	4.719			
Eu	1.127	1.161	1.16	.03	1.86	1.047	1.200	1.15	.06	1.40
	1.162	1.209				1.172	1.171			
Tb	.708	.960	.80	.11	1.09	.809	.900	.89	.09	<1
	.790	.762				.986	.849			
Yb	3.824	4.109	4.07	.63	<1	3.124	3.300	3.41	.29	<1
	4.905	3.454				3.634	3.594			
Lu	.958	.682	.99	.24	<1	.660	.840	.71	.08	1.28
	1.185	1.117				.662	.672			

TABLE 7.—*Instrumental neutron activation determinations of elements in NBS–97b and NBS–98b by the Department of Earth Sciences, The Open University*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; —, no data. Error sd and F ratio are from the analysis of variance of the data. F ratios were not significant at $F_{0.95}$ (d.f., 1,2)=18.5]

	NBS-97b					NBS-98b				
	Bottle No.			Error	F	Bottle No.			Error	F
	17	22	$\bar{x}$	sd	ratio	2	21	$\bar{x}$	sd	ratio
Fe[1]	1.16	1.15	1.165	0.02	<1	1.68	1.68	1.652	0.041	<1
	1.19	1.16				1.61	1.64			
Co	3.53	3.47	3.54	.065	2.12	15.5	15.2	15.08	.43	<1
	3.65	3.52				14.7	14.9			
Cr	232	231	231.2	1.12	<1	125	123	123.0	2.0	[2]
	230	232				121	123			
Cs	3.32	3.37	3.37	.036	1.23	16.7	16.5	16.28	.49	<1
	3.38	3.41				15.8	16.1			
Hf	12.9	12.9	13.02	.18	<1	7.03	6.97	6.930	.11	1.38
	13.2	13.1				6.9	6.96			
Rb	31	35	32.5	2.2	<1	185	183	178.0	8.6	[2]
	33	31				171	173			
Ta	3.67	3.64	3.68	.038	<1	2.03	1.99	1.977	.05	1.33
	3.70	3.71				1.98	1.91			
Th	36.6	36.5	36.6	.05	1.20	21.4	21.2	21.02	.40	<1
	36.6	36.6				20.7	20.8			
U	9.6	9.6	9.4	.25	<1	4.9	4.5	4.80	.16	3.60
	9.3	9.2				5.0	4.8			
Sc	23.5	23.4	23.45	.07	8.00	23.2	23.1	22.98	.27	<1
	23.6	23.3				22.7	22.9			
La	23.6	23.7	23.4	.50	<1	65.3	65.2	64.62	1.07	<1
	23.5	22.7				63.2	64.8			
Ce	47.7	46.8	47.4	.49	<1	119	118	117.2	3.6	2.29
	47.3	47.7				121	111			
Nd	16.1	16.8	16.75	.60	<1	39.0	38.7	38.50	.51	<1
	17.3	16.8				38.5	37.8			
Sm	3.20	3.21	3.18	.04	<1	6.66	6.59	6.635	.05	7.40
	3.14	3.16				6.75	6.54			
Eu	.82	.81	.815	.007	[2]	1.26	1.26	1.250	.016	<1
	.81	.82				1.25	1.23			
Tb	.81	.81	.832	.04	<1	.92	.91	.915	.007	8.00
	.88	.83				.93	.90			
Ho	--	--	--	--	--	--	--	--	--	--
	--	--				--	--			
Tm	.70	.72	.72	.03	<1	.56	.58	.575	.022	<1
	.75	.71				.60	.56			
Yb	4.94	4.90	4.925	.01	9.00	3.95	3.86	3.858	.07	3.30
	4.94	4.92				3.90	3.72			
Lu	.83	.82	.828	.005	1.20	.64	.65	.640	.016	<1
	.83	.83				.65	.62			

[1] Total Fe as Fe_2O_3.

[2] No F ratio because of a zero mean square for bottles.

TABLE 8.—*Instrumental neutron activation determinations of elements in NBS–679 by the U.S. Geological Survey*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; —, no data. Error sd and F ratio are from the analysis of variance of the data. F ratios were not significant at $F_{0.95}$ (d.f., 1,2)=18.5]

	Bottle No.			Error	F		Bottle No.			Error	F
	4	1	$\bar{x}$	sd	ratio		4	1	$\bar{x}$	sd	ratio
Fe	9.52	9.19	9.35	0.085	6.08	Zr	202	148	184	25	<1
	9.39	9.30					188	196			
Na	.144	.147	.143	.013	1.25	Sc	22.7	21.7	22.4	.27	2.83
	.156	.124					22.5	22.4			
Ba	510	411	464	34	2.29	La	51.0	50.1	50.6	.36	1.23
	470	466					50.6	50.7			
Co	25.6	25.0	25.25	.16	6.40	Ce	98	94	94.5	2.1	3.56
	25.3	25.1					95	91			
Cr	106	102	103.2	1.5	2.89	Nd	41	43	43.8	2.7	<1
	103	102					46	45			
Cs	9.41	9.18	9.33	.44	<1	Sm	9.14	8.74	8.91	.16	1.39
	9.35	9.40					8.87	8.90			
Hf	4.20	4.06	4.18	.10	<1	Eu	1.67	1.61	1.66	.06	<1
	4.20	4.27					1.64	1.72			
Rb	189	181	184	4.5	<1	Gd	7.8	7.4	7.3	.46	<1
	181	185					7.1	6.8			
Sb	.76	.82	.81	.025	6.80	Tb	1.19	1.16	1.175	.007	8.00
	.79	.86					1.18	1.17			
Ta	1.37	1.30	1.34	.022	3.20	Tm	.47	.51	[1].49	--	--
	1.35	1.34					<1	.49			
Th	14.3	13.4	13.85	.35	1.28	Yb	3.3	3.3	3.35	.07	[2]
	13.8	13.9					3.4	3.4			
U	2.42	1.82	2.17	.35	<1	Lu	.55	.54	.54	.011	4.00
	2.03	2.40					.53	.53			
Zn	114	109	113	3.5	<1						
	113	116									

[1] $\bar{x}$ of three data.

[2] No F ratio because of a zero mean square for bottles.

TABLE 9.—*Instrumental neutron activation determinations of elements in NBS–679 by the Nuclear Radiation Center, Washington State University*

[In parts per million. Samples were counted by two spectroscopy systems. $\bar{x}$, mean; sd, standard deviation; —, no data]

	Spectroscopy System 1					Spectroscopy System 2				
	Bottle No.			Error	F	Bottle No.			Error	F
	2	24	$\bar{x}$	sd	ratio	2	24	$\bar{x}$	sd	ratio
Fe	78,760	89,690	83,460	8,420	<1	83,940	86,710	84,330	2,050	<1
	89,050	76,360				84,070	82,610			
Na	1,158	1,322	1,252	47	4.66	1,214	1,327	1,282	18.5	[1]45.26
	1,245	1,285				1,226	1,362			
K	20,280	23,290	21,852	752	6.76	21,820	22,840	21,960	405	[1]39.06
	21,470	22,370				20,570	23,610			
As	8.706	10.14	9.37	.27	14.93	8.356	9.483	8.98	.10	[2]105
	8.980	9.665				8.557	9.510			
Ba	471.2	542.4	480	66	<1	574.4	498.9	506	49	<1
	492.8	412.2				481.3	467.4			
Co	21.98	24.87	23.15	2.20	<1	23.01	23.82	23.15	.57	<1
	24.5	21.25				23.09	22.69			
Cr	89.88	101.7	94.5	9.9	<1	93.76	95.23	92.9	2.7	<1
	101.0	85.26				92.59	89.87			
Cs	8.649	9.939	9.27	.82	<1	9.325	9.230	9.17	.16	<1
	9.757	8.732				9.147	8.970			
Ga	31.25	39.91	36.5	2.3	6.83	33.24	42.89	38.9	1.3	[1]44.72
	35.62	39.06				35.59	43.82			
Hf	3.940	4.282	4.09	.37	<1	4.217	4.293	4.21	.07	<1
	4.407	3.719				4.172	4.164			
Ni	40.56	45.94	48.6	7.8	<1	58.8	43.37	52.3	2.4	[3]30.13
	53.95	53.88				58.9	48.14			
Rb	209.3	204.1	195	16.5	<1	212.3	198.2	194	16	<1
	183.1	184.1				185.2	181.2			
Sr	<80	112.1	[4]102	—	—	118.3	<110	[4]99	—	—
	92.3	102.8				84.78	94.08			
Sb	.957	.767	.82	.07	6.15	.742	.871	.80	.02	[1]54.50
	.841	.706				.756	.845			
Ta	1.273	1.254	1.30	.05	1.05	1.174	1.222	1.18	.05	<1
	1.376	1.285				1.192	1.121			
Th	12.98	14.47	13.4	1.3	<1	13.64	13.79	13.54	.27	<1
	14.09	12.13				13.49	13.26			
U	5.264	5.434	4.88	.82	<1	6.452	4.177	5.19	1.36	<1
	4.995	3.811				4.297	5.837			
Ir	160.3	161.8	181	28	<1	165.0	130.2	139	12	6.62
	200.5	200.5				144.7	116.5			
Sc	19.97	22.48	21.06	2.00	<1	21.10	21.75	21.07	.59	<1
	22.44	19.33				20.84	20.60			
La	44.96	50.08	48.14	1.59	4.16	48.22	52.83	50.85	.81	[1]46.66
	48.08	49.45				47.92	54.43			
Ce	90.47	102.5	95.5	8.9	<1	97.72	101.5	98.1	2.6	<1
	100.8	88.09				96.91	96.37			
Nd	37.34	44.35	40.5	2.56	1.80	51.62	47.07	46.9	4.3	<1
	40.24	40.12				43.11	45.89			
Sm	7.521	8.593	8.16	.26	8.72	6.836	7.733	7.34	.07	[2]149.3
	8.032	8.496				6.942	7.834			
Eu	1.605	1.750	1.67	.10	<1	1.713	1.809	1.73	.06	<1
	1.725	1.600				1.697	1.688			
Tb	.863	1.106	1.04	.08	8.62	1.218	1.253	1.15	.13	<1
	.985	1.207				.982	1.136			
Yb	4.872	7.572	5.43	1.29	1.92	3.499	3.220	3.32	.07	[3]22.15
	4.200	5.079				3.448	3.096			
Lu	.942	1.839	1.21	.26	8.80	.893	.494	.60	.18	1.59
	.706	1.369				.534	.480			

[1] Significant at $F_{0.975}$ (d.f., 1,2)=38.5

[2] Significant at $F_{0.99}$ (d.f., 1,2)=99.

[3] Significant at $F_{0.95}$ (d.f., 1,2)=18.5

[4] $\bar{x}$ of three data.

TABLE 10.—*Instrumental neutron activation determinations of elements in NBS–679, IPT–28, IPT–32, and IPT–42 by the Department of Earth Sciences, The Open University*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; —, no data. Error sd and F ratios from the analysis of variance of the data. F ratios were not significant at $F_{0.95}$ (d.f., 1,2)=18.5]

	NBS-679					IPT-28		IPT-32		IPT-42	
	Bottle No.			Error	F	Data	$\bar{x}$	Data	$\bar{x}$	Data	$\bar{x}$
	1	2	$\bar{x}$	sd	ratio						
Fe[1]	12.75	12.83	12.89	0.15	(2)	0.78	0.76	3.33	3.42	1.15	1.12
	13.03	12.94				.75		3.52		1.09	
Co	24.8	25.0	25.08	.27	<1	.55	.52	4.57	4.59	2.87	2.77
	25.3	25.2				.48		4.61		2.67	
Cr	111	112	110.5	1.4	<1	140	140	59	62	80	80
	111	108				141		64		80	
Cs	9.73	9.82	9.86	.14	(2)	--	--	2.96	3.06	1.59	1.56
	9.99	9.90				--		3.15		1.53	
Hf	4.53	4.62	4.528	.067	1.58	31.3	31.6	18.4	18.55	6.11	5.88
	4.44	4.52				31.8		18.7		5.65	
Rb	197	198	196.2	2.1	1.48	--	--	38	39	29	26
	193	197				--		40		23	
Ta	1.40	1.36	1.365	.002	5.00	4.11	4.10	3.79	3.80	1.42	1.40
	1.38	1.32				4.10		3.82		1.37	
Th	14.7	14.7	14.75	.07	(2)	50.5	50.2	33.8	35.0	14.7	14.6
	14.8	14.8				50.0		36.3		14.6	
U	3.1	2.9	2.95	.07	8.00	4.1	4.2	7.5	7.8	1.8	1.8
	3.0	2.8				4.3		8.2		1.9	
Sc	23.7	23.5	23.6	0	(2)	17.9	18.0	16.2	16.8	19.6	19.5
	23.7	23.5				18.0		17.3		19.4	
La	50.7	50.5	50.22	.56	<1	181	181	101	106	64.9	64.6
	50.2	49.5				181		110		64.2	
Ce	112	113	111.8	1.5	<1	376	378	160	160	111	110
	112	110				380		161		109	
Nd	50.0	47.4	49.0	.94	2.40	129	129	66.6	66.4	56.3	56.8
	49.5	49.2				129		66.1		57.2	
Sm	9.72	9.61	9.59	.11	<1	17.2	17.4	10.5	10.8	10.9	10.9
	9.51	9.52				17.6		11.0		10.9	
Eu	1.92	1.89	1.91	.007	12.00	2.82	2.80	1.71	1.74	2.81	2.78
	1.92	1.90				2.78		1.78		2.75	
Tb	1.26	1.23	1.27	.05	(2)	1.19	1.21	1.01	1.06	1.33	1.33
	1.28	1.32				1.23		1.12		1.33	
Ho	1.9	1.6	1.75	--	--	1.6	--	--	--	1.9	--
	--	--				--		--		--	
Tm	.59	.63	.61	.03	<1	.68	.70	.35	.38	.66	.66
	.64	.59				.71		.42		.67	
Yb	4.00	3.94	3.96	.02	6.40	5.22	5.22	2.94	3.09	4.10	4.07
	3.97	3.95				5.23		3.24		4.04	
Lu	.63	.63	.635	.007	(2)	.89	.90	.45	.49	.68	.66
	.64	.64				.92		.53		.65	

[1] Total Fe as Fe_2O_3.

[2] No F ratio because of a zero mean square for bottles.

TABLE 11.—*Instrumental neutron activation determinations of elements in IPT–28 and IPT–32 by the U.S. Geological Survey*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; —, no data]

	IPT-28				IPT-32			
	Determinations		$\bar{x}$	sd	Determinations		$\bar{x}$	sd
Fe	0.545	0.535	0.549	0.017	2.35	2.46	2.45	0.074
	.542	.573			2.46	2.53		
Na	<.07	.041	<.2	--	.123	.133	.126	.029
	<.1	<.2			.088	.159		
Ba	275	280	275.5	6.9	356	350	366	17.3
	281	266			370	389		
Co	.41	.40	.41	.022	4.26	4.30	4.42	.17
	.44	.39			4.57	4.57		
Cr	130	130	132.5	3.32	52.7	56.5	56.1	2.5
	133	137			56.5	58.6		
Cs	<.2	<.2	<.2	--	2.83	2.87	2.89	.05
	<.2	.4			2.89	2.96		
Hf	29.8	29.4	29.82	.31	16.4	16.8	16.65	.24
	30.1	30.0			16.5	16.9		
Rb	<16	<17	<16	--	30.0	32.8	34.4	3.68
	<17	<19			38.0	36.8		
Sb	.94	1.07	1.04	.073	.31	.46	.46	.11
	1.11	1.05			.49	.57		
Ta	4.14	4.22	4.19	.078	3.54	3.75	3.74	.15
	4.12	4.29			3.77	3.91		
Th	47.6	47.8	48.1	.57	31.3	33.0	32.6	.87
	48.2	48.9			33.0	33.1		
U	3.4	3.5	3.42	.41	4.9	5.4	5.45	.49
	3.9	2.9			5.4	6.1		
Zn	12.8	<6	[1]14.1	[1]2.3	56.4	59.6	58.0	1.91
	16.7	12.7			56.4	59.8		
Zr	1,280	1,230	1,258	20.6	660	670	685	26.5
	1,260	1,260			720	690		
Sc	17.0	17.0	17.15	.24	15.15	15.67	15.62	.35
	17.1	17.5			15.68	16.00		
La	179	183	182.2	2.22	100.2	105.0	104.3	2.77
	183	184			106.0	106.0		
Ce	314	319	327.0	12.6	135	141	140	3.46
	334	341			141	143		
Nd	102	108	111.0	10.4	59	59	59.8	2.2
	108	126			58	63		
Sm	15.8	16.1	16.35	.56	9.50	10.01	9.86	.24
	16.4	17.1			9.95	10.00		
Eu	2.47	2.43	2.48	.04	1.47	1.49	1.51	.04
	2.49	2.54			1.52	1.56		
Gd	8.9	9.5	9.85	.89	7.2	7.5	7.65	.42
	10.0	11.0			8.2	7.7		
Tb	1.01	1.04	1.06	.04	.91	.99	.97	.04
	1.07	1.11			.98	.99		
Tm	.63	.52	.588	.050	.35	<.1	[1].40	[1].06
	.62	.58			.40	.46		
Yb	4.2	4.5	4.45	.17	2.71	2.84	2.80	.06
	4.6	4.5			2.79	2.84		
Lu	.73	.75	.752	.021	.421	.470	.428	.032
	.75	.78			.393	.430		

[1] $\bar{x}$ or sd of three data.

TABLE 12.—*Instrumental neutron activation determinations of elements in IPT–28 and IPT–32 by the Nuclear Radiation Center, Washington State University*

[In parts per million. Two sample portions were counted by two spectroscopy systems. $\bar{x}$, mean; sd, standard deviation; —, no data]

	IPT-28				IPT-32			
	Spectroscopy System				Spectroscopy System			
	1	2	$\bar{x}$	sd	1	2	$\bar{x}$	sd
Fe	5,240	5,982	5,243	519	22,930	22,940	23,065	298
	4,632	5,199			22,880	23,510		
Na	164.5	153.9	183.5	28.4	1,337	1,285	1,316	52
	208.5	207.2			1,263	1,379		
K	260.3	302.7	366	117	6,591	6,510	6,562	89
	373.6	527.6			6,475	6,674		
As	1.675	2.655	1.99	.45	8.213	6.778	7.48	.59
	1.789	1.825			7.568	7.364		
Ba	383.5	348.9	358	36	478.6	481.6	480	8.9
	389.4	311.3			469.1	490.7		
Co	.461	.599	.522	.085	4.132	4.355	4.36	.18
	.436	.591			4.584	4.379		
Cr	131.9	137.7	129	10.9	53.18	59.81	59.23	4.31
	113.2	133.9			60.57	63.35		
Cs	<.3	<.3	<.3	--	3.046	3.158	3.06	.08
	<.3	<.4			3.088	2.953		
Ga	39.76	46.76	44.8	3.5	38.40	42.29	39.47	1.98
	45.22	47.45			37.83	39.36		
Hf	32.42	33.30	31.3	2.2	17.34	17.47	17.77	.43
	28.22	31.41			18.09	18.19		
Ni	<30	<35	30	--	21.75	<235	[1]25.6	--
	30	<35			29.43	<35		
Rb	2.819	<6	[1]4.3	--	38.52	35.40	37.45	1.60
	5.735	<7			38.91	36.98		
Sr	213.1	271.7	271	42.9	146.8	72.50	108	44
	285.8	315.2			67.04	145.0		
Sb	.403	1.039	.94	.093	.555	.643	.60	.07
	.832	.995			.558	.479		
Ta	4.150	3.579	3.76	.28	3.675	3.086	3.42	.36
	3.766	3.553			3.778	3.140		
Th	50.26	51.19	48.5	3.7	32.11	33.35	33.37	.95
	42.99	49.63			33.65	34.38		
U	7.912	7.317	7.14	.80	8.330	8.584	8.21	.65
	6.008	7.318			8.679	7.260		
Zr	968.2	811.2	837	93.8	523.7	474.0	503	33
	820.7	746.3			538.7	475.3		
Sc	17.34	17.28	16.63	1.11	15.29	15.36	15.46	.17
	14.98	16.92			15.53	15.67		
La	180.9	196.1	197.8	7.9	109.0	110.6	110.9	3.3
	197.3	196.7			108.4	115.6		
Ce	339.0	355.3	339.8	26.7	146.1	153.3	146.6	4.6
	301.0	344.1			143.0	144.1		
Nd	106.9	128.7	118.8	14.3	51.27	63.67	58.4	5.4
	106.0	133.4			57.66	61.17		
Sm	14.89	14.36	15.0	1.03	10.34	8.712	9.23	1.11
	16.52	14.31			9.957	7.927		
Eu	2.621	2.707	2.58	.16	1.570	1.588	1.59	.02
	2.341	2.644			1.594	1.610		
Tb	1.112	1.039	1.03	.11	.852	.989	.88	.075
	.873	1.101			.828	.842		
Yb	5.135	4.665	4.72	.32	3.286	3.115	3.36	.36
	4.353	4.741			3.147	3.880		
Lu	1.226	.859	.94	.20	.781	.563	.63	.12
	.782	.876			.513	.665		

[1] $\bar{x}$ of two data.

TABLE 13.—*Instrumental neutron activation determinations of elements in IPT–42 by the U.S. Geological Survey*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; — no data]

	Determinations		$\bar{x}$	sd		Determinations		$\bar{x}$	sd
Fe	0.690	0.723	0.715	0.019	Zn	24.0	26.2	24.6	1.05
	.712	.736				24.4	24.0		
Ba	213	220	226	24.2	Zr	194	232	230	27
	262	210				260	235		
Co	2.25	2.41	2.38	.083	Sc	16.6	17.2	17.1	.32
	2.42	2.42				17.2	17.3		
Cr	66.0	67.4	68.5	2.19	La	57.1	59.4	59.7	1.96
	70.6	70.1				60.5	61.7		
Cs	1.23	1.43	1.32	.09	Ce	87	92.2	90.3	2.5
	1.28	1.35				90	92.2		
Hf	4.93	5.08	5.11	.16	Nd	44	49.3	48.1	3.0
	5.09	5.33				48	51		
Ni	--	--	<100	--	Sm	9.4	10.15	9.95	.48
	--	--				9.73	10.51		
Rb	22.5	24.2	22.2	1.51	Eu	2.15	2.31	2.27	.08
	21.5	20.7				2.28	2.33		
Sb	.58	.64	[1].57	[1].061	Gd	7.2	--	[2]8.2	--
	.52	<1				9.3	--		
Sr	--	--	<300	--	Tb	1.06	1.17	1.13	.05
	--	--				1.15	1.13		
Ta	1.22	1.36	1.34	.01	Tm	.61	--	[2].48	--
	1.32	1.45				.34	--		
Th	12.6	12.9	12.8	.14	Yb	3.59	3.71	3.68	.06
	12.8	12.9				3.70	3.73		
U	1.20	1.43	1.34	.12	Lu	.522	.522	.524	.003
	1.26	1.45				.523	.529		

[1] $\bar{x}$ or sd of three data.

[2] $\bar{x}$ of two data.

TABLE 14.—*Instrumental neutron activation determinations of elements in IPT–42 by the Nuclear Radiation Center, Washington State University*

[In parts per million. Two sample portions were counted by two spectroscopy systems. $\bar{x}$, mean; sd, standard deviation; —, no data]

	Spectroscopy System					Spectroscopy System			
	1	2	$\bar{x}$	sd		1	2	$\bar{x}$	sd
Fe	6,999	6,985	6,864	184	Sb	0.990	0.751	0.80	0.13
	6,601	6,872				.782	.696		
Na	216.8	213.8	216.6	18.2	Ta	1.422	1.188	1.25	.12
	240.1	195.8				1.154	1.235		
K	4,560	4,471	4,244	408	Th	14.01	13.98	13.49	.79
	4,291	3,656				12.33	13.64		
As	1.827	1.944	1.67	.26	U	4.192	4.105	3.27	1.07
	1.562	1.376				2.006	2.760		
Ba	256.9	268.9	234	41	Zr	287.9	290.1	266.2	34
	232.8	177.3				271.6	215.4		
Co	2.420	2.471	2.43	.14	Sc	18.08	17.74	17.26	.81
	2.235	2.583				16.26	16.97		
Cr	72.13	69.32	68.18	3.28	La	70.27	71.16	69.12	3.08
	64.52	66.74				70.02	64.56		
Cs	1.453	1.464	1.48	.083	Ce	98.57	101.5	96.2	5.54
	1.409	1.601				88.57	96.37		
Ga	33.76	36.48	33.46	2.54	Nd	49.46	47.10	49.74	4.99
	33.35	30.27				45.58	56.81		
Hf	5.786	5.509	5.53	.18	Sm	10.80	9.094	9.56	1.48
	5.388	5.422				10.67	7.668		
Ni	32.09	<30	32.09	--	Eu	2.564	2.554	2.47	.11
	<30	<30				2.338	2.433		
Rb	27.31	25.57	24.76	2.99	Tb	1.121	1.179	1.090	.076
	20.44	25.72				1.005	1.053		
Sr	142.4	136.4	128.3	13.0	Yb	3.731	3.937	3.66	.22
	117.1	117.3				3.460	3.522		
					Lu	.994	.734	.82	.13
						.858	.715		

TABLE 15.—*Instrumental neutron activation determinations of elements in NBS–97a by the U.S. Geological Survey, 1976 and 1985*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; —, no data]

	1985				1976			
					Bottle			
	Determinations		$\bar{x}$	sd	1	2	$\bar{x}$	sd
Fe	0.319	0.318	0.320	0.002	0.31	0.30	0.298	0.012
	.322	--			.30	.28		
Na	.040	.038	.039	--	--	--	--	--
	<.1	--			--	--		
Ba	500	540	527	23	650	670	667.5	12.6
	540	--			680	670		
Co	4.35	4.41	4.39	.04	4.3	4.1	4.08	.21
	4.42	--			4.1	3.8		
Cr	215	216	217	2.1	180	180	182.5	5.0
	219	--			190	180		
Cs	1.56	1.56	1.59	.06	1.6	1.4	1.58	.13
	1.66	--			1.7	1.6		
Hf	12.57	12.50	12.66	.21	12.0	11.9	11.52	.95
	12.90	--			12.1	10.1		
Rb	11.8	15.0	12.2	3.7	--	--	--	--
	13.5	--			--	--		
Sb	.97	.87	.91	.05	.9	.7	.78	.10
	.90	--			.8	.7		
Ta	3.01	2.99	3.01	.02	3.16	3.16	3.21	.063
	3.02	--			3.23	3.29		
Th	34.1	34.2	34.2	.1	31.7	31.1	31.3	.09
	34.3	--			32.2	30.2		
U	6.8	6.8	6.9	.2	--	--	--	--
	7.1	--			--	--		
Zn	44.0	45.5	45.2	1.0	--	--	--	--
	46.0	--			--	--		
Zr	530	430	507	68	550	580	582.5	28.7
	560	--			620	580		
Sc	31.7	32.1	32.0	.3	32.3	31.2	31.35	1.21
	32.3	--			32.2	29.7		
La	91.7	94.3	93.7	1.8	102	100	102.8	3.0
	95.1	--			102	107		
Ce	190	192	190	2.5	207	200	205.8	3.9
	187	--			209	207		
Nd	76	88	83	6.4	86	84	88.2	4.3
	86	--			94	89		
Sm	18.8	18.7	18.8	.1	21.4	20.4	21.45	1.24
	18.9	--			23.2	20.8		
Eu	3.67	3.67	3.69	.04	3.85	3.77	3.82	.037
	3.74	--			3.80	3.84		
Gd	18.1	18.0	18.0	.1	--	--	--	--
	17.9	--			--	--		
Tb	2.72	2.77	2.78	.07	2.81	2.68	2.77	.10
	2.86	--			2.90	2.69		
Tm	.95	.99	1.00	.05	--	--	--	--
	1.05	--			--	--		
Yb	6.89	7.00	6.93	.06	7.8	7.5	7.7	.39
	6.90	--			8.2	7.3		
Lu	1.001	.973	.986	.014	.98	.93	.995	.052
	.984	--			1.05	1.02		

TABLE 16.—*Instrumental neutron activation determinations of elements in NBS–98a by the U.S. Geological Survey, 1976 and 1985*

[In parts per million, except Fe and Na in percent. $\bar{x}$, mean; sd, standard deviation; —, no data]

	1985				1976			
					Bottle			
	Determinations		$\bar{x}$	sd	1	2	$\bar{x}$	sd
Fe	0.940	0.935	0.940	0.006	0.89	0.90	0.888	0.010
	.946	--			.88	.88		
Na	.057	<.1	.057	--	--	--	--	--
	<.2	--			--	--		
Ba	470	460	467	5.8	530	460	492	29
	470	--			490	490		
Co	12.20	11.95	12.04	.34	11.4	11.7	11.6	.18
	12.26	--			11.8	11.5		
Cr	254	252	253	1.2	214	214	211	3.6
	254	--			209	207		
Cs	6.19	6.06	6.16	.09	6.2	6.3	6.28	.06
	6.23	--			6.3	6.3		
Hf	8.10	7.98	8.06	.07	7.2	7.6	7.42	.17
	8.10	--			7.5	7.4		
Rb	37.8	38.0	35.7	3.8	37	36	34.2	2.6
	31.4	--			32	32		
Sb	2.68	2.63	2.64	.03	2.5	2.3	2.35	.13
	2.62	--			2.4	2.2		
Ta	2.42	2.36	2.40	.03	2.43	2.53	2.48	.04
	2.42	--			2.47	2.49		
Th	26.3	26.0	26.2	.17	23.7	23.9	23.8	.129
	26.3	--			24.0	23.8		
U	46	46	46.3	.6	--	--	--	--
	47	--			--	--		
Zn	42.9	50.2	46.7	3.6	--	--	--	--
	47.0	--			--	--		
Zr	[1]362	[1]265	321	50	690	790	738	50
	[1]336	--			770	700		
Sc	35.1	34.5	34.9	.35	34.8	35.2	34.85	.25
	35.1	--			34.8	34.6		
La	108	110	109	1.2	160	167	162.5	3.7
	110	--			159	164		
Ce	189	200	196	5.8	219	222	219.5	1.73
	198	--			218	219		
Nd	104	89	94	9.0	99	103	98.8	5.4
	88	--			102	91		
Sm	16.6	15.9	16.4	.44	12	13	14.0	3.4
	16.7	--			19	12		
Eu	3.13	3.10	3.13	.04	3.11	3.18	3.18	.06
	3.17	--			3.20	3.25		
Gd	15.6	14.4	15.4	.92	--	--	--	--
	16.2	--			--	--		
Tb	2.89	2.92	2.91	.02	2.96	2.83	2.91	.06
	2.91	--			2.92	2.93		
Tm	1.21	1.23	1.24	.04	--	--	--	--
	1.28	--			--	--		
Yb	8.1	8.2	8.4	.38	9.6	9.1	9.25	.37
	8.8	--			8.8	9.5		
Lu	1.25	1.23	1.25	.02	1.13	1.11	1.12	.04
	1.28	--			1.16	1.08		

[1] Correction for fission product interference exceeds 20 percent of the reported value.

TABLE 17.—*Determinations of lithium in clay reference samples by inductively coupled plasma spectroscopy (ICPS) and flame atomic absorption spectroscopy (FAAS) by the U.S. Geological Survey*

[In parts per million. $\bar{x}$, mean; sd, standard deviation; —, no data]

	Determinations by ICPS						Determinations by FAAS						
	1	2	3	4	x	sd	1	2	3	4	x	sd	Average
NBS-97	990	960	960	960	968	15	860	850	870	880	865	12.9	916
NBS-97b	500	500	480	480	490	11.5	450	440	450	450	448	5	469
NBS-97a	520	500	510	510	510	8.2	450	460	470	460	460	8.2	485
NBS-98	100	100	100	100	100	--	84	84	91	90	87.2	3.8	93.6
NBS-98b	180	190	190	190	188	5	150	160	160	160	158	5	173
NBS-98a	320	320	320	320	320	--	300	290	300	300	298	5	309
NBS-679	61	60	63	62	61.5	1.3	51	54	53	52	52.5	1.3	57
IPT-28	<5	<5	6.7	6.4	6.6	--	<5	<5	<5	<5	<5	<5	6.6
IPT-32	46	47	47	47	46.8	.5	41	41	40	42	40.8	.5	43.8
IPT-42	<5	<5	7.4	7.6	7.5	--	<5	<5	6.6	6.6	6.6	--	7.0

TABLE 18.—*Averages of laboratory means for NBS–97 and NBS–97b*

[Oxides in percent. Trace elements in parts per million. SS, spectroscopy system; —, no data]

	NBS-97				NBS-97b				
	USGS 1976	USGS 1985	WSU	Average	USGS	WSU SS-1	WSU SS-2	TDU	Average
Fe_2O_3	0.941	0.949	0.955	0.948	1.245	1.160	1.330	1.165	1.225
Na_2O	--	.077	.078	.078	.085	.069	.070	--	.075
K_2O	--	--	.558	.558	--	.596	.575	--	.586
As	--	--	4.88	4.88	--	10.8	8.34	--	9.57
Ba	258	205	281	248	224	279	275	--	259
Co	3.32	3.34	3.40	3.35	3.62	3.56	3.50	3.54	3.56
Cr	576	664	624	621	231	217	212	231	223
Cs	2.40	2.24	2.46	2.37	3.34	3.56	3.50	3.37	3.44
Ga	--	--	54.9	55	--	52.1	56.9	--	54.5
Hf	38.7	40.4	43.6	40.9	12.6	13.4	13.5	13.0	13.1
Ni	--	--	34.3	34	--	34.5	22.0	--	28
Rb	24.5	23.0	24.8	24.1	32.3	31.8	29.7	32.5	31.6
Sb	1.40	1.46	1.63	1.50	2.13	2.16	2.06	--	2.12
Sr	--	--	121	121	--	105	127	--	116
Ta	4.18	4.34	3.84	4.12	3.97	3.64	3.20	3.68	3.62
Th	36.9	38.0	40.2	38.4	36.4	36.3	36.7	36.6	36.5
U	--	7.22	8.73	7.98	7.4	11.3	10.3	9.4	9.6
Zn	101.5	79.8	--	90.6	78.9	--	--	--	79
Zr	1,368	1,788	1,256	1,470	500	429	329	--	420
Sc	20.8	19.7	20.1	20.2	23.2	22.7	22.4	23.4	22.9
La	33.2	27.9	30.3	30.5	24.8	22.7	23.6	23.4	23.6
Ce	57.0	50.0	56.6	54.5	43.2	46.1	46.3	47.4	45.8
Nd	[1]19.3	[1]19.7	28.9	23.3	[2]26	17.1	20.2	16.8	19.2
Sm	5.8	5.10	5.44	5.45	3.30	3.09	3.12	3.18	3.17
Eu	1.24	1.26	1.36	1.29	.742	.79	.79	.815	.784
Gd	--	--	--	--	5.7	--	--	--	5.7
Tb	1.26	1.16	1.07	1.16	.80	.81	.92	.83	.84
Tm	--	.80	--	.8	.67	--	--	.72	.70
Yb	6.72	6.20	6.85	6.59	4.58	4.58	4.55	4.92	4.66
Lu	.95	.97	1.38	1.10	.754	4.12	.859	.828	.890

[1] Three data in the laboratory mean.

[2] Two data in the laboratory mean.

TABLE 19.—*Averages of laboratory means for NBS–98 and NBS–98b*

[Oxides in percent. Trace elements in parts per million. SS, spectroscopy system; —, no data]

	NBS-98				NBS-98b				
	USGS 1976	USGS 1985	WSU	Average	USGS	WSU SS-1	WSU SS-2	TOU	Average
Fe_2O_3	2.004	2.137	1.911	2.017	1.739	1.660	1.721	1.652	1.693
Na_2O	--	.275	.261	.268	.204	.165	.179	--	.183
K_2O	--	--	3.019	3.019	--	2.741	2.868	--	2.804
As	--	--	4.78	4.78	--	6.33	6.92	--	6.62
Ba	655	653	731	680	652	709	773	--	710
Co	13.8	14.6	13.4	13.9	15.6	15.0	14.6	15.1	15.1
Cr	112	136	124	124	119	114	107	123	115.8
Cs	10.8	10.6	10.5	10.6	15.6	16.0	15.7	16.3	15.9
Ga	--	--	33.9	34	--	25.1	29.6	--	27.4
Hf	7.1	7.6	7.67	7.46	6.53	6.85	6.78	6.93	6.77
Ni	--	--	44.4	44	--	57.6	46.1	--	51.8
Rb	153	157	151	154	170	169	133	178	162
Sb	1.22	1.70	1.59	1.50	1.60	1.63	1.79	--	1.67
Sr	--	--	263	263	--	208	205	--	206
Ta	2.22	2.22	2.00	2.15	1.98	1.87	1.63	1.98	1.86
Th	19.4	21.2	20.8	20.5	20.1	20.2	20.1	21.0	20.4
U	--	5.02	7.06	6.0	3.5	8.58	8.19	4.80	6.3
Zn	124	104	--	114	95	--	--	--	95
Zr	335	[1]335	262	320	288	243	193	--	240
Sc	22.8	23.1	21.8	22.6	22.1	21.7	21.1	23.0	22.0
La	78.5	73.3	71.5	74.4	67.6	55.6	60.5	64.6	62.1
Ce	135	130	130	132	104.9	109.4	105.2	117.2	109.2
Nd	48.0	51.5	57.0	52.2	39.5	33.5	39.3	38.5	37.7
Sm	9.98	9.89	8.81	9.56	6.34	4.97	4.61	6.64	5.6
Eu	1.73	1.78	1.81	1.77	1.12	1.16	1.15	1.25	1.17
Gd	--	9.08	--	9.1	5.8	--	--	--	5.8
Tb	1.33	1.31	1.15	1.26	.85	.80	.89	.92	.86
Ta	--	.63	--	.63	.475	--	--	.575	.52
Yb	4.88	4.51	4.37	4.59	3.33	4.07	3.41	3.86	3.67
Lu	.645	.70	.90	.75	.554	.99	.71	.64	.72

[1] Three data in the laboratory mean.

TABLE 20.—*Averages of laboratory means for NBS–679 and IPT–28*

[Oxides in percent. Trace elements in parts per million. SS, spectroscopy system; n, number of determinations; —, no data]

	NBS-679					IPT-28			
	WSU SS-1	WSU SS-2	USGS	TOU	Average	TOU n=2	WSU n=4	USGS n=4	Average
Fe_2O_3	11.93	12.06	13.37	12.89	12.56	0.76	0.750	0.785	0.766
Na_2O	.169	.173	.193	--	.178	--	.025	.2	.025
K_2O	2.63	2.64	--	--	2.64	--	.044	--	.044
As	9.37	8.98	--	--	9.18	--	1.99	--	1.99
Ba	480	506	464	--	483	--	358	276	320
Co	23.15	23.15	25.25	25.08	24.16	.52	.522	.41	.48
Cr	94.5	92.9	103.2	110.5	100.3	140	129	132	132
Cs	9.27	9.17	9.33	9.86	9.41	--	.3	.2	.2
Ga	36.5	38.8	--	--	37.7	--	44.8	--	45
Hf	4.09	4.21	4.18	4.53	4.25	31.6	31.3	29.8	30.8
Ni	48.6	52.3	--	--	50.4	--	[1]30	--	30
Rb	195	194	184	196	192	--	[2]4.3	<16	4.3
Sb	.82	.80	.81	--	.81	--	.942	1.04	.99
Sr	[3]102	[3]99	--	--	100	--	271	--	271
Ta	1.30	1.18	1.34	1.36	1.30	4.10	3.76	4.19	4.0
Th	13.4	13.54	13.85	14.75	13.88	50.2	48.5	48.1	48.7
U	4.88	5.19	2.17	2.95	3.8	4.2	7.14	3.42	5.1
Zn	--	--	113	--	113	--	--	[3]14.1	14
Zr	181	139	184	--	168	--	837	1,258	1,050
Sc	21.06	21.07	22.4	23.6	22.0	18.0	16.63	17.15	17.1
La	48.14	50.85	50.6	50.22	50.0	181	197.8	182	188
Ce	95.5	98.1	94.5	111.8	100	378	339.8	327	342
Nd	40.5	46.9	43.8	49.0	45.0	129	118.8	111	118
Sm	8.16	7.34	8.91	9.59	8.5	17.4	15.0	16.4	16.0
Eu	1.67	1.73	1.66	1.91	1.74	2.80	2.58	2.48	2.58
Gd	--	--	7.3	--	7.3	--	--	9.85	9.8
Tb	1.04	1.15	1.18	1.27	1.16	1.21	1.03	1.06	1.08
Ho	--	--	--	[2]1.75	1.75	--	--	--	--
Tm	--	--	[3].49	.61	.56	.70	--	.59	.63
Yb	5.43	3.32	3.35	3.96	4.02	5.22	4.72	4.45	4.71
Lu	[4]1.21	.60	.54	.64	.59	.90	.94	.75	.86

[1] One datum in the laboratory mean.
[2] Two data in the laboratory mean.
[3] Three data in the laboratory mean.
[4] Not included in the average.

TABLE 21.—*Averages of laboratory means for IPT–32 and IPT–42*
[Oxides in percent. Trace elements in parts per million. n, number of determinations; —, no data]

	IPT-32				IPT-42			
	TOU n=2	WSU n=4	USGS n=4	Average	TOU n=2	WSU n=4	USGS n=4	Average
Fe_2O_3	3.42	3.30	3.50	3.40	1.12	0.98	1.02	1.02
Na_2O	--	.18	.17	.18	--	.03	--	.03
K_2O	--	.79	--	.79	--	.51	--	.51
As	--	7.48	--	7.48	--	1.67	--	1.67
Ba	--	480	366	420	--	234	226	230
Co	4.59	4.36	4.42	4.43	2.77	2.43	2.38	2.48
Cr	62	59.2	56.1	56.5	80	68.2	68.5	70.7
Cs	3.06	3.06	2.89	2.99	1.56	1.48	1.32	1.43
Ga	--	39.5	--	40	--	33.5	--	34
Hf	18.6	17.8	16.6	17.5	5.76	5.53	5.11	5.41
Ni	--	[1]25.6	--	26	--	32.1	100	32
Rb	39	37.4	34.4	36.5	26	24.8	22.2	24.0
Sb	--	.60	.46	.53	--	.80	[2].57	.70
Sr	--	108	--	108	--	128.3	<300	128
Ta	3.80	3.42	3.74	3.62	1.40	1.25	1.34	1.32
Th	35.0	33.4	32.6	33.4	14.6	13.5	12.8	13.4
U	7.8	8.21	5.45	7.0	1.8	3.27	1.34	2.2
Zn	--	--	58.0	58	--	--	24.6	25
Zr	--	503	685	590	--	266	230	248
Sc	16.8	15.46	15.62	15.8	19.5	17.3	17.1	17.7
La	106	110.9	104.3	107.3	64.6	69.1	59.7	64.4
Ce	160	146.6	140	146.6	110	96.2	90.3	96.6
Nd	66.4	58.4	59.8	60.6	56.8	49.7	48.1	50.5
Sm	10.8	9.23	9.86	9.80	10.9	9.56	9.95	9.98
Eu	1.74	1.59	1.51	1.59	2.78	2.47	2.27	2.45
Gd	--	--	7.65	7.6	--	--	[1]8.2	8
Tb	1.06	.88	.97	.95	1.33	1.09	1.13	1.15
Tm	.38	--	[2].40	.39	.66	--	[1].48	.57
Yb	3.09	3.36	2.80	3.08	4.07	3.66	3.68	3.75
Lu	.49	.63	.43	.52	.66	.82	.52	.67

[1] Two data in the laboratory mean.
[2] Three data in the laboratory mean.

TABLE 22.—*Provisional averages for the 10 clay reference samples*

[Oxides in percent. Trace elements in parts per million. —, no data; ΣREE, summation of average rare earth element contents]

	Flint			Plastic				Miscellaneous		
	NBS-97	NBS-97b	NBS-97a	NBS-98	NBS-98b	NBS-98a	IPT-32	NBS-679	IPT-28	IPT-42
Fe_2O_3	0.95	1.22	0.44	2.02	1.69	1.3	3.40	12.56	0.77	1.02
Na_2O	.08	.08	.05	.27	.18	.08	.18	.18	.02	.03
K_2O	.56	.59	--	3.02	2.80	--	.79	2.64	.04	.51
As	4.88	9.57	--	4.78	6.62	--	7.48	9.18	1.99	1.67
Ba	248	259	607	680	710	481	420	483	320	230
Co	3.35	3.56	4.21	13.9	15.1	11.8	4.43	24.16	.48	2.48
Cr	621	223	197	124	116	229	58.5	100	132	70.7
Cs	2.37	3.44	1.58	10.6	15.9	6.23	2.99	9.41	.2	1.43
Ga	55	54.5	--	34	27	--	40	37.7	45	34
Hf	40.9	13.1	12.0	7.46	6.77	7.69	17.5	4.25	30.8	5.41
Li	9.16	4.69	4.85	93.6	173	309	43.8	57	6.6	7.0
Ni	34	28	--	44	52	--	26	50	30	32
Rb	24.1	31.6	12.2	154	162	34.8	36.5	192	4.3	24
Sb	1.50	2.12	.84	1.50	1.67	2.47	.53	.81	.99	.70
Sr	121	116	--	263	206	--	108	100	271	128
Ta	4.12	3.62	3.12	2.15	1.86	2.45	3.62	1.30	4.0	1.32
Th	38.4	36.5	32.5	20.5	20.4	24.8	33.4	13.88	48.7	13.4
U	7.98	9.6	6.9	6.0	6.3	46	7.0	3.8	5.1	2.2
Zn	90.6	79	45	114	95	47	58	113	14	25
Zr	1,470	420	550	320	240	320	590	168	1,050	248
Sc	20.2	22.9	31.6	22.6	22.0	34.9	15.8	22.0	17.1	17.7
La	30.5	23.6	98.9	74.4	62.1	140	107.3	50.0	188	64.4
Ce	54.5	45.8	199	132	109.2	209	146.6	100	342	96.6
Nd	23.3	19.2	86	52.2	37.7	96.7	60.6	45.0	118	50.5
Sm	5.45	3.17	20.3	9.56	5.6	15.0	9.80	8.5	16.0	9.98
Eu	1.29	.78	3.76	1.77	1.17	3.16	1.59	1.74	2.58	2.45
Gd	--	5.7	18	9.1	5.8	15.4	7.6	7.3	9.8	8
Tb	1.16	.84	2.77	1.26	.86	2.91	.95	1.16	1.08	1.15
Ho	--	--	--	--	--	--	--	1.8	--	--
Tm	.8	.70	1.0	.63	.52	1.24	.39	.56	.63	.57
Yb	6.59	4.66	7.37	4.59	3.67	8.9	3.08	4.02	4.71	3.75
Lu	1.10	.89	.99	.75	.72	1.18	.52	.59	.86	.67
ΣREE	124.69	105.34	483.09	286.26	227.34	493.49	338.43	218.87	683.66	238.07

TABLE 23.—*Elemental ratios for averages for the 10 clay reference samples*

[Trace elements in parts per million. Fe, K, and Mg in percent used for ratio. —, no data]

	Flint			Plastic				Miscellaneous		
	NBS-97	NBS-97b	NBS-97a	NBS-98	NBS-98b	NBS-98a	IPT-32	NBS-679	IPT-28	IPT-42
Large cations										
K/Rb[1]	1.91	1.55	3.44	1.63	1.43	2.47	1.81	1.14	0.77	1.75
K/Cs	.20	.14	.26	.24	.15	.14	.22	.23	.16	.30
K/Ba[2]	1.88	1.89	.68	3.69	3.27	1.79	1.57	4.53	.10	1.84
Rb/Cs	10.17	9.19	7.72	14.53	10.19	5.58	12.21	20.40	21.5	16.78
Rb/Sr	.20	.27	--	.59	.79	--	.34	1.92	.02	.19
High-valence elements										
Zr/Hf	35.8	32.1	45.1	42.1	35.4	41.6	33.7	39.5	34.1	45.7
Th/U	4.81	3.80	4.71	3.42	3.24	.54	4.77	3.65	9.55	6.09
Th/Ta	9.32	10.08	10.42	9.53	10.97	10.12	9.23	10.68	12.18	10.15
Hf/Ta	9.93	3.62	3.85	3.47	3.64	3.14	4.83	3.27	7.70	4.11
Ferromagnesian elements										
Co/Fe	5.08	4.19	13.58	9.79	12.80	12.97	1.86	2.75	.89	3.49
Co/Mg	21.3	--	46.8	32.0	--	5.06	18.8	--	20.0	207
Ni/Co	10.15	7.86	--	3.16	3.44	--	5.87	2.07	62.5	12.90
Ni/Mg	216	--	--	101	--	--	111	--	1,250	2,667
Li/Mg[3]	58.3	--	53.9	2.16	--	12.2	1.86	--	2.75	5.83

[1] $\times 10^3$.
[2] $\times 10^3$.
[3] $\times 10^{-2}$.

TABLE 24.—*Provisional means for samples normalized to the grand mean for an element*

[ΣREE, summation of average rare earth element contents; —, no data]

	Flint			Plastic				Miscellaneous		
	NBS-97	NBS-97b	NBS-97a	NBS-98	NBS-98b	NBS-98a	IPT-32	NBS-679	IPT-28	IPT-42
Ba	0.56	0.58	1.37	1.53	1.60	1.08	0.95	1.09	0.72	0.52
Co	.40	.43	.50	1.66	1.81	1.41	.53	2.89	.06	.30
Cr	[1]3.32	1.19	1.05	.88	.62	1.22	.31	.53	.71	.38
Cs	.44	.63	.29	1.96	2.93	1.15	.55	1.74	.04	.26
Hf	[1]4.41	1.41	1.29	.80	.73	.83	1.89	.46	[1]3.32	.58
Li	[1]5.00	2.56	2.65	.51	.94	1.69	.24	.31	.04	.04
Rb	.36	.47	.18	2.28	2.40	.51	.54	2.84	.06	.36
Sb	1.14	1.62	.69	1.14	1.27	1.88	.40	.62	.76	.53
Sr	.74	.71	--	1.60	1.26	--	.66	.61	1.65	.78
Ta	1.35	1.18	1.02	.70	.61	.80	1.18	.42	1.31	.43
Th	1.36	1.29	1.15	.73	.72	.88	1.18	.49	1.73	.48
U	1.31	1.57	1.13	.98	1.03	[1]7.54	1.15	.62	.84	.36
Zn	1.33	1.16	.66	1.67	1.40	.69	.85	1.66	.21	.37
Zr	[1]4.12	1.18	1.54	.88	.67	.90	1.66	.47	[1]2.95	.70
ΣREE	.40	.33	1.39	.91	.72	1.57	1.07	.69	2.17	.76

[1]Provisional mean for this element not included in the grand mean.

TABLE 25.—*Certified values of the major and minor oxide contents from Certificates of Analysis for four NBS and three IPT clay reference samples*

[In percent. Samples dried for 2 hours at 140 °C. LOI, loss on ignition at 1,000 °C. n.d., not determined]

	NBS-97	NBS-97a	NBS-98	NBS-98a	IPT-28	IPT-32	IPT-42
SiO_2	42.87	43.67	59.11	48.94	45.1	51.8	51.9
Al_2O_3	38.77	38.79	25.54	33.19	37.6	28.5	32.2
Fe_2O_3	.98	.45	2.05	1.34	.83	3.46	1.09
MgO	.26	.15	.72	.42	.04	.39	.19
CaO	.10	.11	.21	.31	.09	.17	.05
Na_2O	.07	.037	.26	.082	.02	.16	.02
K_2O	.54	.50	3.17	1.04	.03	.80	.47
TiO_2	2.38	1.90	1.43	1.61	2.04	1.49	.96
P_2O_5	.08	.36	.08	.11	.15	.13	.07
MnO	.002	n.d.	.005	n.d.	n.d.	n.d.	n.d.
LOI	13.35	13.32	7.28	12.44	13.9	12.6	12.9

☆U.S. G.P.O. 1987-181-407:60027