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STUDIES IN "STANDARD SAMPLES" FOR USE IN THE
GENERAL ANALYSIS OF SILICATE ROCKS AND MINERALS

PART 5: 1977 EDITION OF "USABLE" VALUES

SYDNEY ABBEY





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FOREWORD

The numerical data in this paper supersede all data published in earlier reports of this series. "Usable values" listed in all of the following should therefore be considered obsolete:

1. Canadian Spectroscopy (1970), v. 15, p. 10-16.
2. Geological Survey of Canada (1972), Paper 72-30
3. Geological Survey of Canada (1973), Paper 73-36
4. Geological Survey of Canada (1975), Paper 74-41

Although some of the values listed in the earlier references also appear in this paper, others have been changed. Many additional values have been added.

In order to avoid possible misunderstandings, readers are advised to read the text of this report before using the values listed in the tables. In some cases, the latest reports issued by the originators of the samples should be consulted as well. All are listed in the references at the end of the main text of this paper.

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Abstract

Reviews already published on the state of international reference samples of silicate rocks and minerals have been updated by the addition of new data and correction of errors. This review includes some samples which contain certain elements at levels considerably different from those in ordinary rocks, but which may be useful in calibrations. Usable values of varying degrees of reliability, calculated on the "dry" basis, are suggested for major, minor and trace constituents in 75 samples.

Résumé

On a mis à date les études sommaires déjà publiées sur l'état actuel d'échantillons de roches et de minéraux silicatés proposés comme matériaux de référence internationaux, en ajoutant des données nouvelles et en corrigeant des erreurs. Cette étude comprend quelques échantillons desquels les teneurs de quelques éléments sont bien différentes de celles dans les roches ordinaires, mais qui peuvent être utiles pour l'étalonnage. On suggère des valeurs utilisables à divers niveaux de certitude, basées sur la condition "sèche", pour des composants majeurs, mineurs et en traces dans 75 échantillons.

INTRODUCTION

In the course of the last 30 years, many geological agencies in a number of countries have prepared selected samples of typical silicate rocks and minerals for use as "standard samples". Generally, the originators have distributed portions of the samples to many laboratories, most of which have contributed analytical results. The originators have then published compilations of the data.

Two unfortunate features have characterized most of these programs:

(a) An extraordinarily wide range of values has been reported by different laboratories for individual constituents of individual samples. For example Flanagan (1969) listed 45 results for silica in sample USGS-GSP-1, ranging from 64.69 to 69.88 per cent. About two-thirds of the values clustered between 66.9 and 67.5.

(b) There has been essentially no co-ordination between different institutions regarding the selection and preparation of such samples, the means of attaining and verifying homogeneity, and the processing of the resulting highly incoherent analytical data.

With the increasing demand for reference materials to calibrate instruments, to test new analytical methods and to correlate analytical data produced by different laboratories, there is a great need for reliable concentration values for as many constituents as possible in as many samples of varied composition as possible. Within the last year or two, tentative steps have been taken toward more worldwide co-operation in the production of "standard samples" of geological materials. Thus, T.W. Steele, of the National Institute for Metallurgy, in South Africa, has set up an "International Study Group on Reference Materials" (ISGRM), and enlisted the participation of many active workers in the field. Almost simultaneously, K. Govindaraju, of the Centre de Recherches Pétrographiques et Géochimiques, in France, has established a new publication "Geostandards Newsletter", whose board of "Regional Editors" includes many of the same workers as the ISGRM. Plenary lectures, round-table discussions and individual papers on the general topic of reference samples have been featured in the programs of the Colloquium Spectroscopicum Internationale, at Grenoble, France, in 1975; the INTERAN '76 Conference on Analysis of Geological Materials, at Prague, Czechoslovakia, in 1976; and the International Symposium on Analytical Chemistry in the

Exploration, Mining and Processing of Materials, at Johannesburg, South Africa, also in 1976.

Faced with so many discrepancies in the available analytical data on each sample, many originators of proposed "standard samples" have been understandably reluctant to assign dependable fixed values. In most cases, published compilations of data have listed all reported results, along with arithmetic averages and standard deviations for each component of each sample. Some reports also included "adjusted" or "preferred" means, which were arithmetic averages of values remaining after eliminating those that differed from the crude average by more than one, two or three standard deviations. Occasionally such modified means have been recommended as "best values", although a certain degree of knowledgeable subjective judgment by the originators has occasionally been involved.

Various workers have directed their attention to the discrepancies in the analytical data emanating from collaborative programs. Ingamells and Switzer (1973) emphasized the correlation of the analytical results with sub-sample weight and particle size; Jaffrezic (1976) performed actual experiments to show quantitatively the effects of particle size on variability of results. The "Community Reference Bureau" (1975) proposed overcoming the effects of sample heterogeneity by preparing fused glass samples for use as primary standards. Maessen et al. (1976) suggested that contributors to collaborative analyses provide statistical data on their methods as an aid in processing the data. Flanagan (1976) mentioned the on-going debate on whether sample heterogeneity or inter-laboratory variability is the greater cause of incompatible results. His data on several new reference samples from the U.S. Geological Survey suggest that sample heterogeneity, at most, is a minor factor. On the other hand, Ridley et al. (1976) reported experimental data emphasizing the effect of particle size on homogeneity. Unfortunately, their work was done in only one laboratory, so it was not possible to compare their observed effects of sample inhomogeneity with effects resulting from inter-laboratory factors.

On the basis of this writer's studies of the data emanating from collaborative programs originating in the U.S.A. (Flanagan, 1969), the United Kingdom (Poole, 1972), France (Roubault et al., 1970; de La Roche and Govindaraju, 1973a, b), the Soviet Union (Kukharenko et al., 1968), Japan (Ando et al., 1971, 1974), South Africa (Russell et al., 1972) and Canada (Abbey, et al., 1975a) the bulk of the evidence

points to inter-laboratory factors as the major source of discordant data. That is not to deny the importance of sample homogeneity, sub-sample weight, fineness of grinding, the need to perform controlled replicate analyses nor the usefulness of statistical data on methods. However, practical considerations often necessitate some compromise in keeping a collaborative program in a reasonable time-frame and within reasonable cost. Collaborating analysts generally work on proposed reference samples only when time can be taken from their normal activities. Where demands for such work involve too much time, many analysts regretfully decline to participate.

It follows that the concentration values eventually assigned to the many constituents of interest in a silicate rock or mineral reference sample can seldom attain the degree of reliability of those for many other materials. It is therefore inadvisable to depend on a single sample for any reference purpose – e.g. for calibration, for comparison of results from different analysts, for verifying proposed new methods, etc. Instead, such samples should be used in groups of at least four, where the uncertainties would tend to "average out". Where possible, such groups should include samples originating in different institutions.

Observations made in the course of studying compilations of analytical data on many different "standard samples" (Abbey, 1970, 1972, 1973, 1975a) have led to certain conclusions which have met with varying degrees of acceptance by others working in the same field. These conclusions follow:

(i) It is very difficult, if not impossible to treat the data by rigorous statistical methods. In the collaborative analysis of proposed standard reference samples of many commercial materials, the number of laboratories involved is relatively small, as is also the number of constituents of interest. Every participating laboratory can be expected to determine most, if not all, of the desired constituents, using a controlled number of replicates, even though analytical methods may vary. The resulting data lend themselves readily to statistical interpretation, providing not only reliable "certificate values" but also such useful information as inter-bottle and inter-laboratory variance, confidence limits and the like. With rock samples, essentially all constituents are of importance, from the dozen-odd "major and minor" components to the long list of "trace elements" which can encompass nearly the entire Periodic Table. Few laboratories are equipped to fulfill all requirements. In an effort at obtaining replicate results for all components, organizers of collaborative analytical programs are obliged to enlist the participation of large numbers of institutions. Because of the great volume of work required, it is seldom possible to obtain controlled replication of analyses, each participant being depended upon merely to report on as many elements as possible by all possible methods. As a result, uncontrolled variables tend to proliferate and statistical treatment of the data becomes increasingly questionable.

(ii) The average value of all available results is not always a good approximation of the best value for a particular constituent of a particular sample. This rule is often inapplicable, but it does assume major importance where available data are limited in number or widely scattered, where components occur at unusual concentration levels and where interfering elements occur at unusually high levels. Although some of the difficulties may ensue from the use of unsuitable analytical methods, many additional factors are frequently involved. There is, for example, an unfortunate tendency in some circles to think of analytical methods in "blanket" terms, describing them in one- or two-word expressions, without mentioning details which may have a great bearing on the quality of results reported. There is substantial evidence to suggest that the identity of the

analyst is of more importance than the method used, leading to the next conclusion:

(iii) The "best" value for a particular constituent in a particular sample should be calculated from the data reported by a small, select group of laboratories whose results show the greatest overall consistency. This is the most controversial conclusion. It has the advantage of attempting to find the few "best" results in a mass of data, rather than concentrating on eliminating a small number of bad ones, as is so commonly done in other systems. This conclusion is applicable only where a large number of results are available, hence mainly for the more commonly determined constituents.

(iv) The summation of derived values should be close to 100 per cent. Such a conclusion would seem to be axiomatic, but there are complications in its use. Part of the difficulty lies in the traditional categorization of analytical data on rocks into "major", "minor", and "trace" elements. Further, many so-called "rock analyses" are performed without regard to the possibility that some "trace elements" may be present at higher levels than usual. Thus chromium, normally a trace in most rocks, can be a minor element in a dunite. Potassium, a major element in most rocks, can be a trace in the same dunite. Strontium, if present to the extent of 100 ppm or more, should be included in the summation – unless it has already been included as part of the calcium result obtained by a chemical method that does not distinguish between the two. The traditional reporting of rock components as oxides can lead to errors where some elements occur in the metallic state, a condition which can also lead to significant errors in determining ferrous and ferric iron.

(v) There appears to be no reliable means of testing the validity of assigned values derived from a large volume of discordant data. This conclusion applies to all proposed schemes for deriving "best" values, be they based on rigorous statistical procedures, empirical mathematical operations, subjective judgment or a combination of any of those approaches. Tentative proposals to overcome this difficulty are outlined below.

Special Problems

Disparities tend to occur in results reported for most constituents of rocks, but they appear more pronounced with such components as ferrous iron, "combined" water and carbon dioxide. With increasing use of instrumental methods of analysis, comparatively fewer determinations are done for those components as for such things as silica, alumina, total iron, etc. With carbon dioxide, matters are further complicated by the failure of many laboratories to distinguish "total carbon", as determined by a combustion method, from "carbonate carbon", as determined by acid evolution. Noticeable differences have been observed between results obtained by the two approaches, even with samples that are not expected to contain significant quantities of non-carbonate carbon.

Even more pronounced are the discrepancies in results reported for the so-called "trace elements", even with such relatively abundant elements as barium, strontium, rubidium, etc. With less abundant elements or those less easily determined, such as silver, arsenic, germanium, etc., the problem is not only one of incoherent results, but also one of limited available data.

It is therefore not surprising that large gaps remain in our knowledge of the composition of many reference samples. For example, sample USGS-W-1 was first introduced over a quarter century ago, but there is still considerable doubt about its content of boron, bismuth, tungsten, molybdenum, hafnium, germanium, thallium, indium, niobium, etc. Selenium is one element for which sufficient data are

available on only one reference sample. With tellurium, there are not enough reported values for any sample to justify listing the element in the tables.

DERIVATION OF "USABLE" VALUES

Various terms have been used by others to describe assigned compositional values derived from large masses of incoherent data. These have ranged from the hesitant "provisional", "proposed" or "tentative" to the more assertive "recommended", "certified" or "guaranteed". There has also been inconsistency in the significance attached to each of those terms. Thus where some (e.g. Roubault et al., 1970) imply that "recommended values" are superior to merely "proposed values", others (e.g. Valcha, 1972) describe well-established values as "guaranteed", in contrast to merely "recommended". Still others (Beyers, 1974) have issued "certificates of analysis" that listed only "average" or "magnitude" values.

In this report as in earlier work (Abbey, 1972, 1973, 1975a), the term "usable values" signifies values that can be used for most purposes. However, varying degrees of uncertainty persist (see below), and therefore changes in "usable values" may be expected as more analytical data become available.

The values listed in Tables 2, 3 and 4 were arrived at in several different ways, as indicated, in part, in the descriptive notes about the various issuing agencies. The procedures used were as follows:

- (1) Values recommended by the originators of a particular group of samples were merely converted to the "dry basis", where necessary, by use of the recommended value for H_2O^- . Where no H_2O^- value was given, it was assumed that all values were already on the dry basis. Where the originators gave no recommended values, or where the originators' recommended values led to inconsistencies, the following steps were used. Those steps are based on a general method first applied (Abbey, 1970) to Flanagan's (1969) raw data on six samples from the U.S. Geological survey, but subsequently modified in order to improve the results.
- (2) All raw data were converted to the dry basis, where possible, using the individual H_2O^- values reported with each analysis.
- (3) For each constituent of each sample, any outlying value that differed from its nearest neighbor by as much as, or more than that neighbor differed from the opposite extreme, was rejected before any further calculations were done. For example, if the results reported were 2, 3, 4, 4, 5 and 10 ppm, the 10 ppm value was immediately rejected.
- (4) The median value of the available results was determined. Where the number of results was less than 10, the median was listed as a usable value, but with a question mark to indicate uncertainty. Question marks were also used at later stages in the method where uncertainty was suspected. Where only three or four results were available, the median was listed only where those results originated in different laboratories, using different methods, and were in acceptable agreement.
- (5) Where 10 or more results were available, they were plotted in a "numerical histogram" (Abbey, 1970; Abbey et al., 1975a). Because of the manner in which the histograms were subsequently used, the choice of class intervals was not based on statistical rules, but was made in a manner to accentuate modal peaks, and preferably to provide seven or more intervals.
- (6) The arithmetic mean of the results was calculated.

(7) Twenty per cent of the available results (those farthest removed from the mean) were rejected, and the remainder used to calculate an "adjusted mean". In some cases where there was reason to doubt values derived in subsequent steps, the adjusted mean was listed as a usable value, but again with a question mark.

(8) All results falling within the same class interval as the adjusted mean, or within the two immediately adjacent intervals, were arbitrarily defined as "good". Those eliminated in (7) were categorized as "poor" (as were also any far outliers eliminated in (3)). Other results were considered "fair".

(9) For each collaborating laboratory, the numbers of good, fair and poor results were listed, and recalculated as percentages of the total of the three types of results from that laboratory. The difference between the percentage of good results and percentage of poor results was taken as a "laboratory rating". That value can vary from plus 100 to minus 100.

(10) Results ("select values") from laboratories whose ratings exceeded an arbitrary level (generally 50) were used to calculate a "select mean" for each constituent. Subject to the constraints of the following items, the select means were listed as "usable values".

(11) Step (3) above was applied to all select values before calculating the select mean.

(12) If the number of select values was less than five, either their median or the adjusted mean (see (7) above) was listed as a usable value, with a question mark.

"Verification" of Usable Values

Two rough criteria were used as a test of the validity of derived values. These were the summation, where sufficient data were available for so-called "complete analysis", and also what has been labelled the "mutual compatibility" of iron oxides. Neither of these criteria is foolproof. All that can be said is that failure to meet them suggests that at least some of the derived values are questionable, but success in meeting the requirements merely serves to support such values, not to confirm them.

The summation criterion has been described above (item iv). The iron oxide compatibility test depends on the fact that all laboratories that determine major components normally report total iron content, expressed as Fe_2O_3 . Some laboratories also determine ferrous iron, expressed as FeO, and hence calculate ferric iron (as Fe_2O_3) by difference, reporting the two as separate components. From the values reported for those components, it is possible to calculate each laboratory's total iron value by means of the simple formula:

$$Fe_2O_3T = 1.1113 FeO + Fe_2O_3, \dots (a)$$

where Fe_2O_3T is the total iron content, expressed as ferric oxide. Thus in a large quantity of data for a given sample, there will in general be a relatively large number of values for total iron, and somewhat smaller numbers of values for ferrous and ferric iron. In the subsequent processing of the data to derive assigned values, the three iron oxides may be treated as separate constituents. However, when the assigned values are finally produced, they should come as close as possible to satisfying equation (a). For purposes of comparison, two additional notations are therefore introduced in Table 2. These are: Fe_2O_3TR , which is the value derived for Fe_2O_3T from the reported values for Fe_2O_3T ; and Fe_2O_3TC , which is calculated by applying equation (a) to the separate assigned values for FeO and Fe_2O_3 , derived from the individual reported values for each of them. Thus a large difference between Fe_2O_3TR and Fe_2O_3TC would indicate questionable derivations.

Unfortunately, some of the originators who published recommended values did not derive a value for Fe_2O_3 as such. Instead, they derived recommended values for $\text{Fe}_2\text{O}_3\text{T}$ and FeO ; then they calculated a value for Fe_2O_3 by using equation (a). In such cases, of course, the "iron oxide compatibility" test no longer applies.

Examples of cases where so-called "best" or "certified" values have failed to meet both of the above criteria have been cited in the literature (Abbey, 1973, 1975b, 1976).

PRESENTATION OF THE DATA

In Table 1, all of the samples in this compilation are listed alphabetically, identified by type of material, issuing agency and country of origin, and also indexed to the appropriate descriptive notes.

In earlier work (Abbey, 1972, 1973, 1975a), the samples included were restricted to actual rocks or compositionally similar minerals, such as micas and feldspars. This time, it was decided to include a carefully selected, limited number of additional samples for which dependable values are available for the common rock constituents, but in which a few of those constituents are present at higher or lower levels than usual. The samples thus selected to provide "high" and "low" points for calibrations include clays, ores, refractories, slags, glasses, etc. Because those samples differ considerably in their compositions from silicate rocks, special care should be taken in using them, to guard against possible interferences from those elements that are present at higher concentration levels than usual.

Reference samples which are suitable only for specialized purposes (e.g. K-Ar dating), or whose published values are based entirely on the work of one laboratory, are not included in this report.

Table 2 lists the samples and their general compositions in roughly the geographic order of country of origin. Because of the increasing variety of "unusual" constituents among the available samples, the manner of presentation has been changed from that used in earlier compilations. Usable values are listed for major and minor constituents, in the order SiO_2 , Al_2O_3 , Fe_2O_3 , FeO , MgO , CaO , Na_2O , K_2O , H_2O^+ , CO_2 , TiO_2 , P_2O_5 , F, S and MnO , as recommended by Maxwell (1968). To provide a realistic summation, the Table includes an additional item, "Others", representing the sum of so-called "trace elements", converted to oxides, where appropriate. The items $\text{Fe}_2\text{O}_3\text{TR}$ and $\text{Fe}_2\text{O}_3\text{TC}$, explained above, are also included.

Only those samples for which reasonably reliable values have been established for most of the usual major and minor rock constituents are listed in Table 2.

In Table 3, the usable values for major and minor elements are listed under the components, with the samples given in descending order of their content of each component.

Some additional samples are listed in Table 3, their concentration values with question marks. Such samples are not considered sufficiently well established to justify their inclusion in Table 2.

In Table 4, the "trace elements" are arranged in much the same way as the major and minor components in Table 3. Usable values for trace elements have been rounded to not more than two significant figures, except where the initial digit is unity, in which case a zero or a five may be shown in the third place. For some elements, the concentration is expressed both as "ppm, element", and "per cent, oxide" (where appropriate), provided the latter value is 0.01 or more. The sum of the latter values for each sample is used as the "Others" in Table 2.

CCRMP – CANADIAN CERTIFIED REFERENCE MATERIALS PROJECT

(Contact: Chairman, Canadian Certified Reference Materials Project, c/o Canada Centre for Mineral and Energy Technology, 555 Booth St., Ottawa, Ontario, Canada, K1A 0G1).

This group, operating originally under the then Canadian Association for Applied Spectroscopy, is now an activity of the Canada Centre for Mineral and Energy Technology, but also involves a number of other Canadian government bodies and some private industries. A catalog of all of their samples is available (Faye, 1976).

Syenite sample SY-1 and sulphide ore sample SU-1 were issued some years ago, and a compilation of available analytical data published most recently by Sine et al. (1969). However, neither of those samples ever attained the status of a reliable reference material for rock analysis. SY-1 is now exhausted. SU-1 is now available as an ore standard, certified for a few selected base metals.

"Ultramafic rock" samples UM-1, UM-2 and UM-4 are available for use as standards for certain components by means of specific tests. They are not intended for use as reference samples in general rock analysis.

Syenite samples SY-2 and SY-3, and gabbro MRG-1 became available some years ago as "uncertified standards". Results of a world-wide program of collaborative analysis are given in a note, a detailed report and a supplement (Abbey et al., 1975a, b; Abbey, 1976). The data in the tables in this publication are based on the supplement.

USGS – UNITED STATES GEOLOGICAL SURVEY

(Contact: F.J. Flanagan, Liaison Officer, Geological Survey, U.S. Department of the Interior, Reston, Va. 22092, U.S.A.).

United States Geological Survey samples G-1 and W-1 are probably the best known reference samples of silicate rocks, early work on them having been published in 1951. The supply of G-1 has long been exhausted and has therefore not been included in the work of this series. W-1 was available until relatively recently, and is included here to provide continuity with earlier reports in the series. Most of the listed values for W-1 in this report are based on those of Flanagan (1973).

A large compilation of data was published on six later samples, andesite AGV-1, basalt BCR-1, dunite DTS-1, granite G-2, granodiorite GSP-1 and peridotite PCC-1 (Flanagan, 1969), but no values were recommended. A later publication (Flanagan, 1976) included additional results and some "recommended", "average" and "magnitude" values. Those values were the same as those listed (along with similar values for many other samples) in an earlier publication by Flanagan (1973).

Some contradictions arose between Flanagan's (1973) values and Abbey's (1972) values, resulting in a Critical Comment and Reply (Abbey, 1975b; Flanagan, 1975). In the most recent report in this series (Abbey, 1975a), Flanagan's values were given precedence, except where these were apparent errors, omissions or other discrepancies. The same policy has applied to this paper.

In recent years, eight additional rock samples were prepared: basalt BHVO-1, marine sediment MAG-1, quartz latite QLO-1, rhyolite RGM-1, schist SDC-1, shales SCo-1 and SGR-1, and syenite STM-1. A recent report (Flanagan, 1976) gives background information for seven of the samples, but unfortunately none for the most unusual one of all, SGR-1, which apparently contains major amounts of carbonate and

organic matter (petroleum?). The report contains a great mass of analytical data, but the latter is unfortunately grossly imbalanced, in terms of the amounts of work done on the various samples, for the various constituents and by various methods in many different laboratories. Values are listed for many constituents of these latter eight samples in this report, but most of them must be regarded as only preliminary. However, the data in Flanagan (1976) clearly indicate that the samples are sufficiently homogeneous for most practical purposes.

Another report (Myers et al., 1976) lists individual results and median values for certain trace elements and most major and minor constituents on four synthetic glasses of rock-like composition, GSB, GSC, GSD and GSE. These samples are intended for use only in U.S. Geological Survey laboratories and are not available for general distribution. Their compositions are therefore not given in this paper.

Flanagan (1973) reported that supplies of samples W-1 and DTS-1 were exhausted.

NBS – NATIONAL BUREAU OF STANDARDS (U.S.A.)

(Contact: Office of Standard Reference Materials, Room B311, Chemistry Building, National Bureau of Standards, Gaithersburg, Md. 20234, U.S.A.).

Of the many standard reference materials issued by this agency, only the potash feldspar 70a and the soda feldspar 99a fall within the composition range of silicate rocks. Meinke (1965a, b) gave their compositions as "provisional", but NBS Special Publication 260 (1975-76 Edition) gives the same data without qualification. Certificate values are given for most of the major and minor elements, but no information is available on trace elements.

In addition to the two feldspars, this compilation includes two clays, a bauxite, a glass and a fly ash from NBS. The additional samples were selected from the many others available from the same source because of their potential usefulness in the analysis of silicate rocks and minerals. They are certified (Cali, 1969a, b; Wichers, 1951; Burgess, 1931) mainly for major and minor components, except for the fly ash, which is certified for certain trace elements (Cali, 1974) of particular interest in environmental studies. Additional analytical work on that sample, done in four different laboratories (Ondov et al., 1975), has served to confirm some "uncertified" values and has provided much useful data for a number of additional elements.

NBS also offers some "Trace Element Standards". Of those, feldspar 607 is certified only for rubidium and strontium. Glass samples 610 to 617 inclusive have been spiked with some 36 trace elements, but certified values have been established for only four to eight elements per sample. There is also some disadvantage in the fact that one sample contains the maximum concentration of all the trace elements, while the others appear to be mere dilutions with the "pure" base materials. Further, the samples are available only as wafers, one or three millimetres thick. They therefore appear to be of little value for general rock analysis, except in special techniques which can use samples in that shape.

BCS – BRITISH CHEMICAL STANDARDS

(Contact: Bureau of Analysed Samples, Newham Hall, Newby, Middlesbrough, Teesside TS8 9EA, England).

As is the case with NBS, this agency offers a variety of reference samples of many different types, including some "Eurostandards", originating in several continental European countries. Details are given in their List 452, published in 1975, which also lists the compositions of all of their samples.

Two BCS samples, soda feldspar 375 and potash feldspar 376 fall within the composition range of silicate rocks. Their Certificates of Analysis (Ridsdale, 1970a, b) list all analytical data reported by the collaborating laboratories. In this case, the number of components determined and the number of participating analysts are both small. The results are in excellent agreement with one another, so there need be no hesitation in accepting arithmetic means as usable values. The analysts involved were evidently expert in feldspar analysis, and the data produced were therefore more coherent than those usually obtained with rock samples, where the need for results for many additional components necessitates the participation of many laboratories with variable backgrounds.

Several additional BCS samples have been included in this compilation because of their possible usefulness in silicate rock and mineral analysis. They include a sillimanite, an iron ore, a silica brick, a "high purity" silica and a blast furnace slag (Ridsdale, 1955, 1961, 1965, 1970a, 1974).

An unfortunate feature of all BCS samples is the absence of information on trace elements.

QMC – QUEEN MARY COLLEGE (U.K.)

(Contact: Dr. A.B. Poole, Department of Geology, Queen Mary College, University of London, Mile End Road, London E1 4NS, England).

This group produced four reference samples several years ago, but is apparently no longer involved with such materials. Available analytical data were listed in a "Third Report" (Poole, 1972), from which usable values have been derived as described earlier in this report.

The samples are aplitic granite I-1, dolerite I-3, pelitic schist M-2 and calcsilicate M-3. Relatively small quantities of these samples were prepared and it is not known whether they are still available.

The analytical data on these samples include very few results for H_2O^- . Analyses which did not include that determination were therefore taken as being on the dry basis. The resulting uncertainty would affect only those constituents present at relatively high levels. Question marks have therefore been used with all usable values exceeding 10 per cent. Usable values have been re-calculated since the last report in this series was prepared, and some errors have been corrected. Some differences from earlier tabulated values may therefore be observed in this report.

ASK – ANALYTISK SPORELEMENT KOMITE (Scandinavia)

(Contact: Dr. Olav H.J. Christie, Mass Spectrometric Laboratory, University of Oslo, Box 1048, Oslo 3, Norway).

Two samples from this group, larvikite ASK-1 and schist ASK-2 fall within the composition range of silicate rocks. A third, ASK-3, is an iron sulphide, of more interest in ore analysis.

The three samples were analysed for a selected number of trace elements in a small number of laboratories, all located in the "Nordic" countries. Recommended values, arrived at by the highly commendable procedure of a round-table discussion by the collaborating analysts, were published by Christie (1975), and those values are listed in Table 4. "Uncertified" values for major and minor elements were also listed by Christie, but are not included in this compilation.

ANRT – ASSOCIATION NATIONALE DE LA RECHERCHE TECHNIQUE (France) CRPG – CENTRE DE RECHERCHES PÉTROGRAPHIQUES ET GÉOCHIMIQUES (France)

(Contact for both groups: K. Govindaraju, Centre de Recherches Pétrographiques et Géochimiques, Case officielle n° 1, 54500 Vandoeuvre-lès-Nancy, France).

The first reference sample produced by CRPG was the experimental granite GR, long since exhausted, and never included among the samples studied in this series of papers. Subsequently, CRPG also produced granites GA and GH, and basalt BR, three of the best-established reference samples. Later, two mica samples were issued, biotite Mica Fe and phlogopite Mica Mg.

More recently, the reference sample program of CRPG has been integrated with that of ANRT, resulting in diorite sample DR-N, serpentine UB-N, synthetic glass VS-N, and most recently, granite GS-N and feldspar FK-N.

The most recent data on the CRPG samples were given by Roubault et al. (1970) for major and minor components, and for trace elements by Govindaraju and de la Roche (1977). Data on the ANRT samples were reported by de la Roche and Govindaraju (1973a, b). For major and minor elements, these groups have followed the general practice of recommending a value that is the mean of the remaining values after eliminating all values that differ from the overall mean by more than one standard deviation. However, they have on occasion applied some subjective judgment in interpreting such data.

Sample Mica Fe was given recommended values by Roubault et al. (1970). However, the number of individual analyses upon which those values were based was rather small, and agreement was not very good. For those reasons no usable values are given in Table 2. The listings in Tables 3 and 4 are intended to show merely where this sample is expected to fit in the concentration "ladder" for each constituent.

For Mica Mg, Roubault et al. (1970) gave only "proposed values", presumably based on preliminary analyses in the originators' laboratories. The limited analytical data from other sources are not in good agreement with the proposed values. Accordingly, this sample is listed in Tables 3 and 4 in the same manner as is Mica Fe. In a recent announcement (Govindaraju, 1977), additional analytical data were solicited for the two mica samples.

Both ANRT samples, DR-N and UB-N, are well-established, except for the MgO value in the latter. The recommended MgO value of de la Roche and Govindaraju (1973a) differs noticeably from the adjusted mean of the available data, being based on a subjective interpretation of results produced by a select group of laboratories. Because of that discrepancy, the MgO value for UB-N is given to only one decimal place, with a question mark, in Tables 2 and 3.

Sample VS-N contains high concentrations (hundreds of parts per million) of many "trace elements". With so many elements present at a maximum level in the same sample, questions may arise regarding its usefulness. Usable values given in Table 4 are rounded versions of elemental equivalents of the oxide contents recommended by de la Roche and Govindaraju (1973b). Similarly, values with question marks are based on their "proposed values". Values for major and minor components of VS-N are not intended for standards use, and are therefore not given in Tables 2 and 3.

The two newest samples, GS-N and FK-N, are now listed for the first time in this series. The values are those of de la Roche and Govindaraju (1976a).

Two additional ANRT samples, bauxite BX-N and kyanite DT-N, were not included in earlier papers in this series because their compositions are far removed from those of silicate rocks. In this work, it was decided to include them among the "non-rock" samples that may prove useful in providing "high" and "low" points for calibrations for certain elements.

A glauconite sample, GL-O (de la Roche et al., 1976b) has been prepared in limited quantity, mainly as a reference standard in geochronology. However, much analytical work

has been done for many constituents of this sample. The originators have assigned a number of "recommended" and "proposed" values, all of which are listed in the tables in this paper.

IRSID – INSTITUT DE RECHERCHES DE LA SIDÉRURGIE (France)

(Contact: G. Jecko, Station d'Essais, Maizières-lès-Metz (57), France).

This institute has produced many reference samples of value in metallurgical industries. Of those, only two have been selected for inclusion in this compilation, because their compositions may prove useful in the analysis of silicate rocks and minerals. They are blast furnace slag LOI-1 and ferrous marl MO8-1. It will be noted that the sum of available data on both samples falls significantly short of 100 per cent, and that should be borne in mind in using the samples.

The values listed in Tables 2 and 3 are those given by the originators as "most probable" on the certificates provided with the samples (Jecko, 1970; undated).

ZGI – ZENTRALES GEOLOGISCHES INSTITUT (East Germany)

(Contact: Prof. K. Schmidt, Direktor, Zentrales Geologisches Institut, Invalidenstrasse 44, 104 Berlin, Deutsche Demokratische Republik).

Three silicate samples from this source are well established: granite GM, basalt BM and slate TB. Values for major and minor elements were given by Grassmann (1972) and for trace elements by Schindler (1972). Grassmann gave means, numbers of determinations, standard deviations and 95-per cent confidence limits, with actual recommended values only for silica and alumina. Individual results were not given. However, Grassmann's confidence limits are such that his values may be considered "usable" and they are therefore listed in Tables 2 and 3.

Similarly, Schindler (1972) gave means, some recommended values and numbers of determinations for trace elements. Because no individual results were given, Schindler's tabulated values are shown in Table 4 as "usable", where 10 or more results were reported. Where five to nine results were involved, the value is shown with a question mark. In several cases where the confidence limits appear to justify doing so, Schindler's means are included even though only three or four determinations were done. Otherwise, no values are listed.

Of the other reference samples issued by ZGI, anhydrite AN and limestone KH are not included here because their compositions are far removed from those of silicate rocks. At this writing, no compilation of data has appeared for four later samples, feldspar sand FK, greisen GnA, serpentine SW and black shale TS, but some average values have appeared in studies on the processing of data for reference samples (Schindler and Scheutzow, 1975; Schindler, private communication). The few tentative values for those samples in Tables 3 and 4 are from those sources.

ZGI is the co-ordinating agency of an Eastern European collaborative program on reference samples of geological materials, involving the Czechoslovak institute mentioned below, among others. That program is expected to prepare samples, within the next few years, of gabbro, nepheline syenite, fireclay, monzonite, slate, skarn, kieselguhr and a number of other "mining materials", of less direct interest in silicate rock and mineral analysis.

UNS – ÚSTAV NEROSTNÝCH SUROVIN (Czechoslovakia)

(Contact: RN Dr. Václav Zýka, Director, Institute of Mineral Raw Materials, 28403 Kutná Hora, Czechoslovakia).

Two samples, a glass sand and a magnesite, have been available from this source for several years. The sand sample, hereafter referred to as SS (for the Czech designation Sklářský Písek, Strěleč) is included in this work for the same reason as were the additional samples of NBS and BCS. The magnesite sample, whose composition is far removed from that of silicate rocks, is not included. However, this report does include data on KK (for Kaolin, Karlovy Vary), for which recommended values have not been published at this writing. The information was made available to the author by the staff of the Institute at Kutná Hora. Similar information about SS is based on a report by Valcha (1972).

The listed values for KK have two apparent shortcomings: the summation is somewhat low, and there is no way of checking the compatibility of iron oxides because no separate values for ferrous and ferric iron are given. Conceivably, the summation might be improved if more data on trace elements were available.

LEN – LENGOSUNIVERSITET (U.S.S.R.)

(Contact: Prof. A.A. Kukharenko, Department of Mineralogy, Leningrad State University, Leningrad V-164, U.S.S.R.).

The only sample from this source, nepheline syenite NS-1, was originally identified as "Khibiny-Generalnaya", and has been referred to elsewhere by various other designations. Because only one sample was involved in this case, no attempt was made to apply the full selective procedure outlined above. All of the values listed in Tables 2, 3 and 4 are based on "adjusted means" derived from the original compilation by Kukharenko et al. (1968). The trace-element values are based on a limited number of reported values.

The summation for NS-1 appears to be high, thus throwing some doubt on the validity of the individual usable values, possibly as a result of the use of the "adjusted means". As it is uncertain whether this material is still available, it is not likely that more data for it will be published. Little can therefore be done to improve the situation.

IGI – INSTITUT GEOKHIMII, IRKUTSK (U.S.S.R.)

(Contact: Prof. L.V. Tauson, Institute of Geochemistry, P.B. 701, Irkutsk 33, U.S.S.R.).

Three samples from this source were issued originally as trap 2001, gabbro 2003 and albitized granite 2005. No compilation of reported data has been published at this writing. However, Tauson et al. (1974) reported a set of "attested" values for three samples identified as trap ST-1A, gabbro SGD-1A and albitized granite SG-1A. Comparison of those values with results obtained in the laboratories of the Geological Survey of Canada indicated that the two sets of samples were identical.

The values listed in the tables in this report are those of Tauson et al. (1974). Those authors did not list individual results nor did they give details of the method used in deriving their tabulated values from the raw data.

GSJ – GEOLOGICAL SURVEY OF JAPAN

(Contact: Dr. Atsushi Ando, Geochemical Research Section, Geological Survey of Japan, 135 Hisamoto-cho, Kawasaki-shi, Japan).

Analytical data for basalt JB-1 and granodiorite JG-1 were compiled and published by Ando et al. (1971, 1974), recommended values being given for only four elements in a later publication (Ando et al., 1975). "Estimated values" for a number of trace elements were also reported by Ando (private communication, 1975). Some of the values in Tables 2, 3 and 4 are based on those recommended and estimated values; others were derived by the procedures outlined above.

Some difficulty was encountered in arriving at a usable value for silica in JB-1. Our most recent compilation (Abbey, 1975a) listed a value of 52.49 per cent (dry basis), but that value was based only on Ando's 1971 data. When his 1974 data were included, the same procedure yielded a value of 52.72 per cent. Changes for other components were less conspicuous. The higher silica value brought about a rather high summation, 100.31, although the availability of additional trace-element data may have been a factor in that case. However, it was felt that an increase from 52.49 to 52.72 was too great. It was therefore decided to reject the "select mean" and to use the "adjusted mean" as a usable value, but to emphasize the uncertainty by adding a question mark. This was an example where failure to satisfy one of the "validity tests" mentioned above was considered sufficient grounds for departure from the established procedure.

The relatively high values for H_2O^- reported in Ando's compilations, averaging close to one per cent, may have been a source of discrepancy in the silica results reported by the collaborating analysts.

MRT – MINERAL RESOURCES, TANZANIA

(Contact: Commissioner, Mineral Resources Division, P.O. Box 903, Dodoma, Tanzania).

The values listed for tonalite T-1 in the tables are derived from the compilation by Thomas and Kempe (1963), being the means of remaining values after eliminating those which were more than one standard deviation removed from the gross mean. Thomas and Kempe originally suggested that procedure for arriving at "tentative recommended values".

The results in the compilation were in good agreement, with much lower standard deviations for individual components than has been the case with other rock samples. However, relatively little information was reported on trace elements.

The data in Table 2 reveal a discrepancy between the two "total iron" values, casting some doubt on the listed values. With reference to T-1, Bowden and Luena (1966) rightly warned against the dangers entailed in indiscriminate use of insufficiently well-established values.

Flanagan (private communication, 1975) reported that the sample is no longer available and that no replacement is contemplated.

NIM – NATIONAL INSTITUTE FOR METALLURGY (South Africa)

(Contact: H.P. Beyers, South African Bureau of Standards, Private Bag 191, Pretoria, South Africa).

Russell et al. (1972) listed the then available results on the six rock samples, dunite NIM-D, granite NIM-G, lujavrite NIM-L, norite NIM-N, pyroxenite NIM-P and syenite NIM-S. They calculated means, standard deviations and adjusted means, but did not give recommended values. Later (Beyers, 1974), the originators issued a set of "certificates of analysis", listing values that are apparently means of values remaining after removal of those differing from the overall mean by more than three standard deviations. Several contradictions in those "certified" values have been pointed out elsewhere (Abbey, 1977). Although the certificates indicate that most of the listed values are mere "averages" or "magnitudes", the fact that they are referred to as "certified" can lead to erroneous conclusions on the part of some users.

In earlier work (Abbey, 1973, 1975a) usable values for these samples were calculated by the methods outlined above, but it was pointed out that some of the samples were of unusual composition, some of the collaborating analysts had apparently ignored that fact, and hence that considerably more subjective judgment than usual was used in arriving at

the tabulated values. Considerably less confidence was therefore placed in those values than in those listed for other samples.

Subsequent work in the Geological Survey of Canada laboratories cast further doubt on the earlier tabulated values for these samples. Through the kindness of T.W. Steele, of the National Institute for Metallurgy of South Africa, the author was provided with a computer printout of all available results on these samples to the end of 1975. The entire derivation procedure was repeated, using a more refined procedure than before. The results, listed in the tables of this report, are in general closer to the NIM "certified" values than before, but are, as a rule, free from most of the objections to the latter values.

The values tabulated in this report are believed to be superior to those listed by Flanagan (1973), which appear to be essentially the same as the NIM "certified" values.

PRECAUTIONARY NOTES REGARDING THE TABLES

A number of citations of values from various compilations have strongly suggested an unfortunate tendency by some workers to accept any tabulated value without attempting to understand how it was derived, or its degree of reliability. It would appear that the time, effort and money going into the establishment of reliable values for reference samples is not universally appreciated or even understood. Although lack of understanding by users may be blamed in some cases, even the originators and the compilers of data are not entirely innocent. For example, it does not help the situation when samples are offered as "standards" with little or no supporting analytical data, or with data from only the originating laboratories, or where the data are presented without sufficient emphasis on the degree of reliability involved.

For the above reasons, footnotes on every page of the Tables in this paper direct the readers' attention to these notes. The presence or absence of question marks in the Tables should be regarded only as a rough guide to the reliability of individual values listed. Better understanding can be attained only by careful study of the original compilations for each group of samples.

Another unfortunate tendency has become apparent in some papers where reference samples have been used in verifying new analytical methods. Some workers consider their results acceptable merely because they fall "within the range" of values listed in a compilation. In fact, such a situation merely indicates that the results in question are not as bad as the worst in the compilation. How bad that can be is clearly indicated in many of the original compilations.

Readers are therefore strongly urged to read the entire text of this paper before using any of the Tables. They are also requested to inform the author of any errors they may observe. Such errors are almost inevitable where so large a volume of numerical data is involved.

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TABLE 1. Alphabetical Listing of Samples

Sample No.	Type	Source	Country	Ref. Page
AGV-1	Andesite	USGS	U.S.A.	4
ASK-1	Larvikite	ASK	Scandinavia	5
ASK-2	Schist			
BCR-1	Basalt	USGS	U.S.A.	4
BCS-267	Silica Brick	BCS	U.K.	5
BCS-302/1	Iron Ore			
BCS-309	Sillimanite			
BCS-313	Pure Silica			
BCS-367	Blast Furnace Slag			
BCS-375	Soda Feldspar			
BCS-376	Potash Feldspar			
BHVO-1	Basalt	USGS	U.S.A.	4
BM	Basalt	ZGI	East Germany	6
BR	Basalt	CRPG	France	5
BX-N	Bauxite	ANRT	France	5
DR-N	Diorite			
DT-N	Kyanite			
DTS-1	Dunite	USGS	U.S.A.	4
FK	Potash Feldspar Sand	ZGI	East Germany	6
FK-N	Potash Feldspar	ANRT	France	5
G-2	Granite	USGS	U.S.A.	
GA	Granite	CRPG	France	5
GH	Granite			
GL-O	Glauconite	ANRT	France	5
GM	Granite	ZGI	East Germany	6
GnA	Greisen			
GS-N	Granite	ANRT	France	5
GSP-1	Granodiorite	USGS	U.S.A.	4
I-1	Aplitic Granite	QMC	U.K.	5
I-2	Dolerite			
JB-1	Basalt	GSJ	Japan	7
JG-1	Granodiorite			
KK	Kaolinite	UNS	Czechoslovakia	6
LOI-1	Blast Furnace Slag	IRSID	France	6
M-2	Pelitic Schist	QMC	U.K.	5
M-3	Calc-Silicate			
MAG-1	Marine Mud	USGS	U.S.A.	4
Mica Fe	Biotite	CRPG	France	5
Mica Mg	Phlogopite			
MO8-1	Ferriferous Marl	IRSID	France	6
MRG-1	Gabbro	CCRMP	Canada	4
NBS-69a	Bauxite	NBS	U.S.A.	5
NBS-70a	Potash Feldspar			
NBS-91	Opal Glass			
NBS-97a	Flint Clay			
NBS-98a	Plastic Clay			
NBS-99a	Soda Feldspar			
NBS-1633	Fly Ash			
NIM-D (SARM 6)	Dunite	NIM	South Africa	7
NIM-G (SARM 1)	Granite			
NIM-L (SARM 3)	Lujavrite			
NIM-N (SARM 4)	Norite			
NIM-P (SARM 5)	Pyroxenite			
NIM-S (SARM 2)	Syenite			

TABLE 1 (cont'd.), Alphabetical Listing of Samples

Sample No.	Type	Source	Country	Ref. Page
*NS-1	Nepheline Syenite	LEN	U.S.S.R.	7
PCC-1	Peridotite	USGS	U.S.A.	4
QLO-1	Quartz Latite			
RGM-1	Rhyolite			
SG-1A (2005)	Albitized Granite	IGI	U.S.S.R.	7
SGD-1A (2003)	Gabbro			
SCo-1	Shale	USGS	U.S.A.	4
SDC-1	Mica Schist			
SGR-1	Shale			
SS	Glass Sand	UNS	Czechoslovakia	6
ST-1A (2001)	Trap	IGI	U.S.S.R.	7
STM-1	Syenite	USGS	U.S.A.	4
SW	Serpentine	ZGI	East Germany	6
SY-2	Syenite	CCRMP	Canada	4
SY-3	Syenite			
T-1	Tonalite	MRT	Tanzania	7
TB	Slate	ZGI	East Germany	6
TS	Shale			
UB-N	Serpentine	ANRT	France	5
VS-N	Synthetic Glass			
W-1	Diabase	USGS	U.S.A.	4

*Also known by other designations (KG-1, X-1, etc.)

TABLE 2
Usable values, "complete analysis" (per cent, dry basis)*

	CCRMP					USGS					
	Gabbro MRG-1	Syenite SY-2	Syenite SY-3	Andesite AGV-1	Basalt BCR-1	Dunite DTS-1	Granite G-2	Grano- diorite GSP-1	Perido- tite PCC-1	Diabase W-1	
SiO ₂	39.24	60.09	59.68	59.72	54.85	40.68	69.19	67.31	42.15	52.72	SiO ₂
Al ₂ O ₃	8.56	12.15	11.80	17.22	13.68	0.29	15.35	15.19	0.73	14.87	Al ₂ O ₃
Fe ₂ O ₃	8.23	2.35	2.48	4.57	3.48	0.85	1.01	1.77	2.50	1.40	Fe ₂ O ₃
FeO	8.60	3.55	3.56	2.08	9.05	6.98	1.45	2.31	5.17	8.73	FeO
MgO	13.51	2.69	2.64	1.55	3.49	49.83	0.77	0.96	43.63	6.63	MgO
CaO	14.72	8.00	8.26	5.00	6.98	0.15	1.98	2.02	0.53	10.98	CaO
Na ₂ O	0.71	4.35	4.15	4.31	3.29	0.01	4.06	2.80	0.01	2.15	Na ₂ O
K ₂ O	0.18	4.51	4.24	2.93	1.68	0.00	4.52	5.53	0.00	0.64	K ₂ O
H ₂ O ⁺	0.99	0.46	0.47	0.82	0.73	0.46	0.55	0.57	4.64	0.53	H ₂ O ⁺
CO ₂	1.01	0.46?	0.40	0.01	0.03?	0.06	0.08	0.12	0.16	0.06	CO ₂
TiO ₂	3.75	0.15	0.15	1.05	2.22	0.01	0.50	0.66	0.01	1.07	TiO ₂
P ₂ O ₅	0.07	0.44	0.54	0.50	0.33	0.00	0.14	0.28	0.00	0.14	P ₂ O ₅
F	0.02	0.50	0.70	0.04?	0.05?	0.00	0.13	0.38	0.00	0.02	F
S	0.06	0.01	0.05	0.01?	0.04?	0.00	0.00?	0.04	0.01	0.01?	S
MnO	0.17	0.32	0.33	0.10	0.19	0.11	0.04	0.04	0.12	0.17	MnO
Others	0.35?	0.45?	1.14?	0.36?	0.30?	0.98?	0.42?	0.48?	0.80?	0.21?	Others
Σ	100.17?	100.48?	100.62?	100.27?	100.39?	100.41?	100.19?	100.46?	100.45?	100.34?	Σ
O/F, S, Cl	0.04?	0.22?	0.32?	0.02?	0.04?	0.00	0.05?	0.18	0.00	0.01?	O/F, S, Cl
Σ (corr.)	100.13?	100.26?	100.30?	100.25?	100.35?	100.41?	100.14?	100.28?	100.45?	100.33?	Σ (corr.)
Fe ₂ O ₃ TR	17.80	6.29	6.47	6.84	13.52	8.60	2.67	4.33	8.28	11.11	Fe ₂ O ₃ TR
Fe ₂ O ₃ TC	17.79	6.29	6.44	6.88	13.54	8.61	2.62	4.34	8.24	11.10	Fe ₂ O ₃ TC

*See "Precautionary notes....", p. 8.

TABLE 2 (cont'd.)
Usable values, "complete analysis" (per cent, dry basis)*

	NBS						QMC					
	Bauxite 69a	K-spar 70a	Opal Glass 91	Flint Clay 97a	Plastic Clay 98a	Na-spar 99a	Aplitic Granite I-1	Dolerite I-3	Pelitic Schist M-2	Calc- Silicate M-3		
SiO ₂	6.01	67.1	67.53	43.67	48.94	65.2	75.38?	49.75?	48.88?	55.59?	SiO ₂	
Al ₂ O ₃	55.0	17.9	6.01	38.79	33.19	20.5	13.92?	13.07?	23.97?	17.62?	Al ₂ O ₃	
Fe ₂ O ₃							0.33?	5.09?	2.31?	0.91?	Fe ₂ O ₃	
FeO	0.02		0.01	0.15	0.42	0.02	0.20?	10.04?	6.30?	3.33?	FeO	
MgO	0.29	0.11	10.48	0.11	0.31	2.14	0.11	4.18	2.45	1.21	MgO	
CaO	0.00	2.55	8.48	0.037	0.082	6.2	0.80	8.20	1.75	12.01?	CaO	
Na ₂ O	0.00	11.8	3.25	0.50	1.04	5.2	4.59	2.92	1.40	2.98	Na ₂ O	
K ₂ O	29.55	0.40	0.50?	13.32	12.44	0.26	4.28	1.43	7.90	0.71	K ₂ O	
H ₂ O ⁺							0.13?	1.71?	3.21?	0.78?	H ₂ O ⁺	
CO ₂							?	?	?	2.98?	CO ₂	
TiO ₂	2.78	0.01	0.02	1.90	1.61	0.01	0.05	2.60	0.72	0.83	TiO ₂	
P ₂ O ₅	0.08		0.02	0.36	0.11	0.02	0.02?	0.40?	0.50?	0.36?	P ₂ O ₅	
F	?	?	5.72	?	?	?	?	0.07?	0.10?	0.06?	F	
S	0.02	?	?	?	?	?	0.01?	?	?	?	S	
MnO	0.02	?	0.01	?	?	?	0.03	0.22	0.26	0.28	MnO	
Others	0.27	0.08	0.39	0.46	0.21	0.26	0.11?	0.35?	0.34?	0.16?	Others	
Σ	99.84?	100.02?	102.50?	99.75?	99.69?	99.87?	99.96?	100.03?	100.09?	99.81?	Σ	
O/F,S,Cl	0.01?	0.00?	2.41?	0.00?	0.00?	0.00?	0.00?	0.03?	0.04?	0.03?	O/F,S,Cl	
Σ (cor.)	99.83?	100.02?	100.09?	99.75?	99.69?	99.87?	99.96?	100.00?	100.05?	99.78?	Σ (cor.)	
Fe ₂ O ₃ TR	5.8	0.075?	0.081?	0.45	1.34	0.065	0.54	16.22	9.25	4.55	Fe ₂ O ₃ TR	
Fe ₂ O ₃ TC							0.55?	16.25?	9.31?	4.61?	Fe ₂ O ₃ TC	

*See "Precautionary notes...", p. 8.

TABLE 2 (cont'd.)
Usable values (per cent, dry basis), "complete analysis"*

	BCS							CRPG			
	Silica Brick 267	Iron Ore 302/1	Sillimanite 309	"Pure" Silica 313	Slag 367	Na-Spar 375	K-Spar 376	Basalt BR	Granite GA	Granite GH	
SiO ₂	95.9	17.8	34.1	99.6	34.4	67.1	67.1	38.39	69.96	75.85	SiO ₂
Al ₂ O ₃	0.85	10.5	61.1	0.16	20.0	19.8	17.7	10.25	14.51	12.51	Al ₂ O ₃
Fe ₂ O ₃								5.61	1.36	0.41	Fe ₂ O ₃
FeO					1.00?			6.60	1.32	0.84	FeO
MgO	0.06	1.45	0.17	0.00	7.1	0.05	0.03	13.35	0.95	0.03	MgO
CaO	1.75	4.05	0.22	0.02	32.4	0.89	0.54	13.87	2.45	0.69	CaO
Na ₂ O	0.06	0.09	0.34	0.00	0.44	10.4	2.83	3.07	3.55	3.85	Na ₂ O
K ₂ O	0.14	0.56	0.46	0.04	1.17	0.78	11.2	1.41	4.03	4.76	K ₂ O
H ₂ O ⁺	?	10.4			?	?	?	2.31	0.87	0.46	H ₂ O ⁺
CO ₂	?	5.4	0.10?	0.14?	?	?	?	0.86	0.11	0.14	CO ₂
TiO ₂	0.17	0.49	1.93	0.02	0.75	0.38	<0.02	2.61	0.38	0.08	TiO ₂
P ₂ O ₅	?	2.02	?	?	0.14?	?	?	1.05	0.12	0.01	P ₂ O ₅
F	?	?	?	?	?	?	?	0.10	0.05	0.35	F
S	?	0.10	?	?	0.94	?	?	0.04?	?	?	S
MnO	0.15	0.28	0.03?	0.00	1.16	?	?	0.20	0.09	0.05	MnO
Others	?	?	?	?	0.19	?	?	0.51?	0.24?	0.13?	Others
Σ	99.87?	100.74?	99.98?	100.01?	99.69?	99.52?	99.50?	100.23?	99.99?	100.29?	Σ
O/F,S,Cl		0.05			0.40			0.06?	0.03?	0.15?	O/F,S,Cl
Σ (cor.)	99.87?	100.69?	99.98?	100.01?	99.29?	99.52?	99.50?	100.17?	99.96?	100.14?	Σ (cor.)
Fe ₂ O ₃ TR	0.79	47.6	1.53	0.025	1.11?	0.12	0.10	12.90	2.77	1.36	Fe ₂ O ₃ TR
Fe ₂ O ₃ TC		?						12.94	2.83	1.34	Fe ₂ O ₃ TC

*See "Precautionary notes...", p. 8 .

TABLE 2 (cont'd.)
Usable Values (per cent, dry basis), "complete analysis"*

	ANRT							IRSID	
	Bauxite BX-N	Diorite DR-N	Kyanite DT-N	K-Spar FK-N	Glauconite GL-O**	Granite GS-N	Serpentine UB-N	Slag LOI-I	Ferr. Marl MO8-I
SiO ₂	7.39	52.88	36.52	65.11	52.22	65.98	39.93	33.65	60.39
Al ₂ O ₃	54.53	17.56	59.21	18.64	7.75	14.71	2.97	16.15	9.94
Fe ₂ O ₃	22.98	3.78	0.55	0.02?	17.61	1.93	5.46		3.08?
FeO	0.26	5.32	0.10	0.06?	2.25	1.65	2.69		2.38?
MgO	0.11	4.47	0.04	0.01?	4.58	2.31	35.4 ?	9.55	1.34
CaO	0.17	7.09	0.04	0.11	0.98	2.51	1.18	35.65	8.70
Na ₂ O	0.06	3.00	0.04	2.58	0.04?	3.78	0.10	?	?
K ₂ O	0.07	1.73	0.12	12.83	8.16	4.64	0.02	?	?
H ₂ O ⁺	11.69	2.20	0.98	0.32?	5.72	1.07	11.28	?	?
CO ₂	0.48	0.15	?	0.08?	?	0.18?	0.44	?	?
TiO ₂	2.41	1.10	1.40	0.02?	0.07?	0.68	0.12	0.62	0.71
P ₂ O ₅	0.13	0.25	0.09	0.02?	0.38	0.28	0.03	0.03?	0.12
F	?	?	?	?	?	?	?	?	?
S	?	?	?	?	?	?	?	0.81	0.46
MnO	0.05	0.21	0.01	0.00?	0.01?	0.06	0.12	1.27	0.06
Others	0.13?	0.26?	0.67?	0.15?	?	0.32	0.77?	?	?
Σ	100.46?	100.00?	99.77?	99.95?	99.77?	100.10?	100.51?	98.59?	87.18?
O/F,S,Cl	?	0.01?	?	?	0.08?	?	0.02	0.40?	0.23?
Σ (corr.)	100.46?	99.99?	99.77?	99.95?	99.69?	100.10?	100.49?	98.19?	86.95?
Fe ₂ O ₃ TR	23.27	9.69	0.66	0.09?	20.11	3.75	8.45	0.86	5.72
Fe ₂ O ₃ TC	23.27	9.69	0.66	0.09?	20.11	3.75	8.45		5.72?

*See "Precautionary notes....", p. 8 .

**Dried 15 hr.

TABLE 2 (cont'd.)
Usable Values (per cent, dry basis), "complete analysis"

	ZGI			UNS			LEN		IGI		
	Basalt BM	Granite GM	Slate TB	Glass Sand SS	Kaolinite KK	Neph. Syenite NS-1	Albit. Granite SG-1A	Gabbro SGD-1A	Trap ST-1A		
SiO ₂	49.60	73.55	60.30	99.35	47.06	53.37	73.36	46.39	49.12	SiO ₂	
Al ₂ O ₃	16.20	13.50	20.55	0.25	36.77	21.30	13.84	14.88	14.23	Al ₂ O ₃	
Fe ₂ O ₃	1.60	0.75	0.91			2.41	0.68	3.86	3.92	Fe ₂ O ₃	
FeO	7.28	1.14	5.43			1.61	1.41	6.86	10.26	FeO	
MgO	7.46	0.38	1.94	0.01	0.19?	0.65	0.05	7.09	5.74	MgO	
CaO	6.46	1.04	0.33	0.03	0.24	1.73	0.14	10.97	10.20	CaO	
Na ₂ O	4.64	3.76	1.31	0.04	0.03	9.89	5.46	2.82	2.49	Na ₂ O	
K ₂ O	0.20	4.74	3.85	0.06	1.06	6.51	4.14	2.96	0.69	K ₂ O	
H ₂ O ⁺	3.62	0.35	3.82		12.75	0.67	0.21	0.83	0.97	H ₂ O ⁺	
CO ₂	1.34	0.28	0.13	0.17	0.17?	0.14?	0.07?	0.13	0.10	CO ₂	
TiO ₂	1.14	0.21	0.93	0.04	0.17	1.06	0.07	1.71	1.82	TiO ₂	
P ₂ O ₅	0.10	0.06	0.10	0.01	0.09	0.28	0.01	1.01	0.21	P ₂ O ₅	
F	0.02?	0.07?	0.07?	?	?	0.13	0.30	0.12	0.03?	F	
S	?	?	?	?	0.02	0.01?	0.02	0.02	0.07	S	
MnO	0.14	0.04	0.05	0.00	0.015	0.19	0.19	0.17	0.21	MnO	
Others	0.18?	0.15?	0.29?	0.01?	0.09?	0.46?	0.52?	0.66?	0.31?	Others	
Σ	99.99?	100.02?	100.01?	100.00?	99.64?	100.41?	100.48?	100.48?	100.41?	Σ	
O/F,S,Cl	0.01?	0.03?	0.03?	?	0.01?	0.07?	0.13?	0.07?	0.06?	O/F,S,Cl	
Σ (corr.)	99.98?	99.99?	99.98?	100.00?	99.63?	100.34?	100.35?	100.41?	100.35?	Σ (corr.)	
Fe ₂ O ₃ TR	9.68	2.02	6.92	0.04	0.98	4.20	2.25	11.48	15.32	Fe ₂ O ₃ TR	
Fe ₂ O ₃ TC	9.69	2.02	6.94			4.18	2.25	11.48	15.32	Fe ₂ O ₃ TC	

*See "Precautionary notes...", p. 8 .

TABLE 2 (cont'd.)

Usable Values (per cent, dry basis), "complete analysis"*

	GSI			MRT			NIM					
	Basalt JB-I	Grano- diorite JG-I	Tonalite T-I	Dunite NIM-D	Granite NIM-G	Lujavrite NIM-L	Norite NIM-N	Pyrox- enite NIM-P	Syenite NIM-S			
SiO ₂	52.62?	72.36	62.65	38.88	75.72	52.45?	52.56	51.04	63.65	SiO ₂		
Al ₂ O ₃	14.62	14.20	16.52	0.32	12.09	13.59	16.54	4.19	17.37	Al ₂ O ₃		
Fe ₂ O ₃	2.36	0.37	2.81?	0.90	0.58	8.74	0.76	1.02?	1.07	Fe ₂ O ₃		
FeO	6.02	1.62	2.90?	14.46	1.30	1.08	7.30	10.59?	0.30	FeO		
MgO	7.76	0.76	1.89	43.56	0.04	0.28	7.48	25.29	0.46	MgO		
CaO	9.35	2.17	5.19	0.28	0.78	3.24	11.46	2.69	0.66	CaO		
Na ₂ O	2.79	3.39	4.39	0.05	3.30	8.30	2.46	0.37	0.42	Na ₂ O		
K ₂ O	1.42	3.96	1.23	0.01	5.00	5.46	0.25	0.09	15.38	K ₂ O		
H ₂ O ⁺	1.01	0.54	1.53	0.30	0.48	2.34	0.32	0.26	0.22	H ₂ O ⁺		
CO ₂	0.18?	0.08?	?	0.42?	0.10?	0.18?	0.11?	0.10?	0.08?	CO ₂		
TiO ₂	1.34	0.27	0.59	0.02	0.09	0.49	0.20	0.20	0.04	TiO ₂		
P ₂ O ₅	0.26	0.09	0.14	0.02?	0.02	0.06	0.03	0.03	0.12	P ₂ O ₅		
F	0.04?	0.05?	0.05?	0.01?	0.42	0.42	0.01?	0.01?	0.01?	F		
S			0.01?	0.02?	0.01?	0.06	0.01?	0.02?	0.02?	S		
MnO	0.15	0.06	0.11	0.22	0.02	0.76	0.18	0.22	0.01	MnO		
Others	0.32?	0.18?	0.21?	0.77?	0.20?	2.51?	0.14?	3.67?	0.38?	Others		
Σ	100.24?	100.10?	100.23?	100.24?	100.15?	99.96?	99.81?	99.79?	100.19?	Σ		
O/F, S, Cl	0.02?	0.02?	0.03?	0.02?	0.19?	0.24?	0.01?	0.02?	0.02?	O/F, S, Cl		
Σ (corr.)	100.22?	100.08?	100.19?	100.22?	99.96?	99.72?	99.80?	99.77?	100.17?	Σ (corr.)		
Fe ₂ O ₃ TR	9.01	2.16	5.93?	16.96	2.02	9.96	8.91	12.76	1.40	Fe ₂ O ₃ TR		
Fe ₂ O ₃ TC	9.05	2.17	6.03?	16.97	2.02	9.94	8.87	12.79?	1.40	Fe ₂ O ₃ TC		

*See "Precautionary notes...", p. 8 .

TABLE 3. Usable values, arranged by major and minor components*

SiO ₂		SiO ₂ (cont'd.)		Al ₂ O ₃ (cont'd.)		Fe ₂ O ₃ (cont'd.)	
99.6	BCS-313	34.1	BCS-309	10.5	BCS-302/1	0.33?	I-1
99.35	SS	33.65	LO1-1	10.25	BR	0.02?	FK-N
95.9	BCS-267	28.3 ?	SGR-1	9.94	MO8-1		
88.2 ?	FK	17.8	BCS-302/1	8.56	MRG-1		
75.85	GH	7.39	BX-N	7.75	GL-O		FeO
75.72	NIM-G	6.01	NBS-69a	6.22?	FK		
75.38?	I-1			6.01	NBS-91		? Mica Fe
73.55	GM			4.19	NIM-P	14.46	NIM-D
73.4 ?	RGM-1	Al ₂ O ₃		2.97	UB-N	10.59?	NIM-P
73.36	SG-1A			0.85	BCS-267	10.26	ST-1A
72.36	JG-1	61.1	BCS-309	0.73	PCC-1	10.04?	I-3
71.5 ?	GnA	59.21	DT-N	0.32	NIM-D	9.05	BCR-1
69.96	GA	55.0	NBS-69a	0.29	DTS-1	8.73	W-1
69.19	G-2	54.53	BX-N	0.25	SS	8.60	MRG-1
67.53	NBS-91	38.79	NBS-97a	0.16	BCS-313	8.6 ?	BHVO-1
67.31	GSP-1	36.77	KK			7.30	NIM-N
67.1	BCS-375	33.19	NBS-98a			7.28	BM
67.1	BCS-376	23.97?	M-2	Fe ₂ O ₃		6.98	DTS-1
67.1	NBS-70a	21.30	NS-1			6.86	SGD-1A
66.1 ?	SDC-1	20.55	TB	22.98	BX-N		? Mica Mg
65.98	GS-N	20.5	NBS-99a	17.61	GL-O	6.60	BR
65.6 ?	QLO-1	20.0	BCS-367	8.74	NIM-L	6.30?	M-2
65.2	NBS-99a	19.8	BCS-375	8.23	MRG-1	6.02	JB-1
65.11	FK-N	?	Mica Fe	6.50?	TS	5.43	TB
63.65	NIM-S	18.64	FK-N	5.92?	GnA	5.32	DR-N
62.9 ?	SCo-1	18.6 ?	STM-1	5.61	BR	5.17	PCC-1
62.80?	TS	17.9	NBS-70a	5.46	UB-N	3.82?	GnA
62.65	T-1	17.7	BCS-376	5.09?	I-3	3.56	SY-3
60.39	MO8-1	17.62?	M-3	4.57	AGV-1	3.55	SY-2
60.30	TB	17.56	DR-N		? Mica Fe	3.33?	M-3
60.09	SY-2	17.37	NIM-S	3.92	ST-1A	2.98?	QLO-1
59.72	AGV-1	17.22	AGV-1	3.86	SGD-1A	2.90?	T-1
59.68	SY-3	16.54	NIM-N	3.78	DR-N	2.69	UB-N
59.5 ?	STM-1	16.52	T-1	3.48	BCR-1	2.38	MO8-1
55.59?	M-3	16.5 ?	MAG-1	3.08	MO8-1	2.31	GSP-1
54.85	BCR-1	16.3 ?	QLO-1	2.88?	STM-1	2.25	GL-O
53.37	NS-1	16.20	BM	2.81?	T-1	2.10?	STM-1
52.88	DR-N	16.15	LO1-1	2.50	PCC-1	2.08	AGV-1
52.72	W-1	16.05?	TS	2.48	SY-3	1.65	GS-N
52.62?	JB-1	16.0 ?	SDC-1	2.41	NS-1	1.62	JG-1
52.56	NIM-N	?	Mica Mg	2.36	JB-1	1.61	NS-1
52.45?	NIM-L	15.35	G-2	2.35	SY-2	1.45	G-2
52.22	GL-O	15.19	GSP-1	2.31?	M-2	1.41	SG-1A
51.04	NIM-P	14.88	SGD-1A		? Mica Mg	1.32	GA
50.9 ?	MAG-1	14.87	W-1	1.93	GS-N	1.30	NIM-G
50.2 ?	BHVO-1	14.71	GS-N	1.77	GSP-1	1.23?	RGM-1
49.75?	I-3	14.7 ?	GnA	1.60	BM	1.14	GM
49.60	BM	14.62	JB-1	1.40	W-1	1.08	NIM-L
49.12	ST-1A	14.51	GA	1.36	GA	1.00?	BCS-367
48.94	NBS-98a	14.23	ST-1A	1.07	NIM-S	0.84	GH
48.88?	M-2	14.20	JG-1	1.02?	NIM-P	0.72?	TS
47.06	KK	13.92?	I-1	1.01	G-2	0.30	NIM-S
46.39	SGD-1A	13.84	SG-1A	0.91	TB	0.26	BX-N
43.67	NBS-97a	13.8 ?	BHVO-1	0.91?	M-3	0.20?	I-1
42.15	PCC-1	13.8 ?	RGM-1	0.90	NIM-D	0.10	DT-N
40.68	DTS-1	13.68	BCR-1	0.85	DTS-1	0.06?	FK-N
39.93	UB-N	13.6 ?	SCo-1	0.76	NIM-N		
39.24	MRG-1	13.59	NIM-L	0.75	GM		
38.88	NIM-D	13.50	GM	0.68	SG-1A		MgO
38.39	BR	13.07?	I-3	0.58	NIM-G		
	? Mica Mg	12.51	GH	0.55	DT-N	49.83	DTS-1
36.52	DT-N	12.15	SY-2	0.50?	RGM-1	43.63	PCC-1
	? Mica Fe	12.09	NIM-G	0.41	GH	43.56	NIM-D
34.4	BCS-367	11.80	SY-3	0.37	JG-1	35.4 ?	UB-N
cont'd...		cont'd...		cont'd...		cont'd...	

*Per cent, dry basis. See "Precautionary notes...", p. 8 .

TABLE 3 (cont'd.). Usable values, arranged by major and minor components*

MgO (cont'd.)		MgO (cont'd.)		CaO (cont'd.)		Na ₂ O (cont'd.)	
25.29	NIM-P	0.01	NBS-91	0.28	NIM-D	0.91?	SCo-1
?	Mica Mg	0.01	SS	0.24	KK	0.71	MRG-1
13.51	MRG-1	0.01?	FK-N	0.22	BCS-309	0.44	BCS-367
13.35	BR			0.18?	TS	0.42	NIM-S
9.55	LO1-1			0.17	BX-N	0.37	NIM-P
7.76	JB-1		CaO	0.15	DTS-1	0.34	BCS-309
7.48	NIM-N			0.14	SG-1A	?	Mica Fe
7.46	BM	35.65	LO1-1	0.12?	FK	0.25?	FK
7.1	BCS-367	32.4	BCS-367	0.11	FK-N	?	Mica Mg
7.1 ?	BHVO-1	14.72	MRG-1	0.11	NBS-70a	0.10	UB-N
7.09	SGD-1A	13.87	BR	0.11	NBS-97a	0.10?	TS
6.63	W-1	12.01?	M-3	?	Mica Mg	0.09	BCS-302/1
5.74	ST-1A	11.46	NIM-N	0.04	DT-N	0.08	NBS-98a
?	Mica Fe	11.4 ?	BHVO-1	0.03	SS	0.08?	GnA
4.58	GL-O	10.98	W-1	0.02	BCS-313	0.06	BCS-267
4.47	DR-N	10.97	SGD-1A			0.06	BX-N
4.42?	SGR-1	10.48	NBS-91		Na ₂ O	0.05	NIM-D
4.18	I-3	10.20	ST-1A			0.04	DT-N
3.49	BCR-1	9.35	JB-1	10.4	BCS-375	0.04	NBS-97a
2.99?	MAG-1	8.70	MO8-1	9.89	NS-1	0.04	SS
2.69	SY-2	8.26	SY-3	8.94?	STM-1	0.04?	GL-O
2.67?	SCo-1	8.20	I-3	8.48	NBS-91	0.03	KK
2.64	SY-3	8.00	SY-2	8.30	NIM-L	0.01	DTS-1
2.45	M-2	7.09	DR-N	6.2	NBS-99a	0.01	PCC-1
2.31	GS-N	6.98	BCR-1	5.46	SG-1A		
1.94	TB	6.46	BM	4.64	BM		K ₂ O
1.89	T-1	5.19	T-1	4.59	I-1		
1.79?	TS	5.00	AGV-1	4.39	T-1	15.38	NIM-S
1.70?	SDC-1	4.05	BCS-302/1	4.35	SY-2	12.83	FK-N
1.55	AGV-1	3.24	NIM-L	4.31	AGV-1	11.8	NBS-70a
1.45	BCS-302/1	3.19?	QLO-1	4.20?	QLO-1	11.2	BCS-376
1.34	MO8-1	2.69	NIM-P	4.15	SY-3	?	Mica Mg
1.21	M-3	2.61?	SCo-1	4.08?	RGM-1	?	Mica Fe
1.00?	QLO-1	2.51	GS-N	4.06	G-2	8.16	GL-O
0.96	GSP-1	2.45	GA	3.85	GH	7.90	M-2
0.95	GA	2.17	JG-1	3.8 ?	MAG-1	6.51	NS-1
0.77	G-2	2.14	NBS-99a	3.78	GS-N	5.53	GSP-1
0.76	JG-1	2.02	GSP-1	3.76	GM	5.46	NIM-L
0.65	NS-1	1.98	G-2	3.55	GA	5.2	NBS-99a
0.46	NIM-S	1.75	BCS-267	3.39	JG-1	5.00	NIM-G
0.42	NBS-98a	1.75	M-2	3.30	NIM-G	4.87?	TS
0.38	GM	1.73	NS-1	3.29	BCR-1	4.76	GH
0.28	NIM-L	1.4 ?	SDC-1	3.07	BR	4.74	GM
0.28?	RGM-1	1.36?	MAG-1	3.00	DR-N	4.64	GS-N
0.19?	KK	1.18	UB-N	2.98	M-3	4.52	G-2
0.17	BCS-309	1.12?	RGM-1	2.92	I-3	4.51	SY-2
0.16?	FK	1.09?	STM-1	2.9 ?	SGR-1	4.36?	RGM-1
0.15	NBS-97a	1.04	GM	2.83	BCS-376	4.30?	STM-1
0.11	BX-N	0.98	GL-O	2.82	SGD-1A	4.28	I-1
0.11	I-1	0.89	BCS-375	2.80	GSP-1	4.24	SY-3
0.10?	STM-1	0.80	I-1	2.79	JB-1	4.15?	FK
0.06	BCS-267	0.78	NIM-G	2.58	FK-N	4.14	SG-1A
0.05	BCS-375	0.69	GH	2.55	NBS-70a	4.03	GA
0.05	SG-1A	0.66	NIM-S	2.49	ST-1A	3.96	JG-1
0.04	DT-N	0.61?	GnA	2.46	NIM-N	3.85	TB
0.04	NIM-G	0.54	BCS-376	2.21?	BHVO-1	3.63?	QLO-1
0.03	BCS-376	0.53	PCC-1	2.15	W-1	3.6 ?	MAG-1
0.03	GH	?	Mica Fe	2.07?	SDC-1	3.27?	SDC-1
0.03?	GnA	0.33	TB	1.40	M-2	3.25	NBS-91
0.02	NBS-69a	0.31	NBS-98a	1.31	TB	2.96	SGD-1A
0.02	NBS-99a	0.29	NBS-69a				
cont'd...		cont'd...		cont'd...		cont'd...	

*Per cent, dry basis. See "Precautionary notes...", p. 8 .

TABLE 3 (cont'd.). Usable values, arranged by major and minor components*

K ₂ O (cont'd.)		H ₂ O ⁺ (cont'd.)		CO ₂ (cont'd.)		TiO ₂ (cont'd.)	
2.93	AGV-1	0.82	AGV-1	0.04?	TS	0.07	SG-1A
2.8 ?	SCo-1	0.78?	M-3	0.03?	BCR-1	0.07?	GL-O
2.65?	GnA	0.73	BCR-1	0.02?	FK	0.06?	FK
1.73	DR-N	0.67	NS-1	0.01	AGV-1	0.05	I-1
1.68	BCR-1	0.57	GSP-1			0.04	NIM-S
1.65?	SGR-1	0.55	G-2			0.04	SS
1.43	I-3	0.54	JG-1	TiO ₂		0.02	BCS-313
1.42	JB-1	0.53	W-1			0.02	NBS-91
1.41	BR	0.48	NIM-G	3.75	MRG-1	0.02	NIM-D
1.23	T-1	0.47	SY-3	2.78	NBS-69a	0.02?	FK-N
1.17	BCS-367	0.46	DTS-1	2.69?	BHVO-1	0.02?	GnA
1.06	KK	0.46	GH	2.61	BR	0.01	DTS-1
1.04	NBS-98a	0.46	SY-2	2.60	I-3	0.01	NBS-70a
0.78	BCS-375	0.41?	FK	?	Mica Fe	0.01	NBS-99a
0.71	M-3	0.35	GM	2.41	BX-N	0.01	PCC-1
0.69	ST-1A	0.32	NIM-N	2.22	BCR-1		
0.64	W-1	0.32?	FK-N	1.93	BCS-309		
0.56	BCS-302/1	0.30	NIM-D	1.90	NBS-97a	P ₂ O ₅	
0.52?	BHVO-1	0.26	NIM-P	1.82	ST-1A		
0.50	NBS-97a	0.22	NIM-S	1.71	SGD-1A	2.02	BCS-302/1
0.46	BCS-309	0.21	SG-1A	?	Mica Mg	1.05	BR
0.25	NIM-N	0.13?	I-1	1.61	NBS-98a	1.01	SGD-1A
0.20	BM			1.40	DT-N	0.54	SY-3
0.18	MRG-1	CO ₂		1.34	JB-1	0.50	AGV-1
0.14	BCS-267			1.14	BM	0.50?	M-2
0.12	DT-N			1.10	DR-N	?	Mica Fe
0.09	NIM-P	5.4 ?	BCS-302/1	1.07	W-1	0.44	SY-2
0.07	BX-N	2.98?	M-3	1.06	NS-1	0.40?	I-3
0.06	SS	1.34	BM	1.05	AGV-1	0.38	GL-O
0.04	BCS-313	1.01	MRG-1	1.02?	SDC-1	0.36?	M-3
0.02	UB-N	0.86	BR	0.93	TB	0.36	NBS-97a
0.01	NIM-D	0.48	BX-N	0.83	M-3	0.33	BCR-1
		0.46?	SY-2	0.75	BCS-367	?	MAG-1
		0.44	UB-N	0.75?	MAG-1	0.28	GS-N
		0.42?	NIM-D	0.73?	TS	0.28	GSP-1
		0.40	SY-3	0.72	M-2	0.28	NS-1
		0.28	GM	0.71	MO8-1	0.28?	BHVO-1
		?	Mica Fe	0.68	GS-N	0.28?	TS
		?	Mica Mg	0.66	GSP-1	0.26	JB-1
		0.18?	GS-N	0.64?	SCo-1	0.26?	QLO-1
		0.18?	JB-1	0.62	LO1-1	0.25	DR-N
		0.18?	NIM-L	0.62?	QLO-1	0.21	ST-1A
		0.17?	KK	0.59	T-1	0.17?	SDC-1
		0.16	PCC-1	0.50	G-2	0.16?	STM-1
		0.15	DR-N	0.49	BCS-302/1	0.14	G-2
		0.14	GH	0.49	NIM-L	0.14	T-1
		0.14?	NS-1	0.38	BCS-375	0.14	W-1
		0.13	SGD-1A	0.38	GA	0.14?	BCS-367
		0.13	TB	0.29?	SGR-1	0.13	BX-N
		0.12	GSP-1	0.27	JG-1	0.12	GA
		0.11	GA	0.27?	RGM-1	0.12	MO8-1
		0.11?	NIM-N	0.21	GM	0.12	NIM-S
		0.10	ST-1A	0.20	NIM-N	0.11	NBS-98a
		0.10?	NIM-G	0.20	NIM-P	0.10	BM
		0.10?	NIM-P	0.17	BCS-267	0.10	TB
		0.08	G-2	0.17	KK	0.09	DT-N
		0.08?	FK-N	0.15	SY-2	0.09	JG-1
		0.08?	JG-1	0.15	SY-3	0.09	KK
		0.08?	NIM-S	0.13?	STM-1	0.08	NBS-69a
		0.07?	SG-1A	0.12	UB-N	0.08?	FK
		0.06	DTS-1	0.09	NIM-G	0.07	MRG-1
		0.06	W-1	0.08	GH		
cont'd...		cont'd...		cont'd...		cont'd...	

*Per cent, dry basis. See "Precautionary notes...", p. 8 .

TABLE 3 (cont'd.). Usable values, arranged by major and minor components*

P ₂ O ₅ (cont'd.)		S		MnO (cont'd.)		Fe ₂ O ₃ T (cont'd.)	
0.06	GM	0.94	BCS-367	0.12	PCC-1	6.92	TB
0.06	NIM-L	0.81	LO1-1	0.12	UB-N	6.9 ?	SDC-1
0.05?	RGM-1	0.46	MO8-1	0.12	SDC-1	6.84	AGV-1
0.03	NIM-N	0.10	BCS-302/1	0.11	DTS-1	6.8 ?	MAG-1
0.03	NIM-P	0.08?	SCo-1	0.11	T-1	6.47	SY-3
0.03	UB-N	0.07	ST-1A	0.10	AGV-1	6.29	SY-2
0.03?	LO1-1	0.06	MRG-1	0.10	MAG-1	5.93?	T-1
?	Mica Mg	0.06	NIM-L	0.09	QLO-1	5.8	NBS-69a
0.02	I-1	0.05	SY-3	0.09	GA	5.72	MO8-1
0.02	NBS-91	0.04	GSP-1	0.06	GS-N	5.19?	STM-1
0.02	NBS-99a	0.04?	BCR-1	0.06	JG-1	5.06?	SCo-1
0.02	NIM-G	0.04?	BR	0.06	MO8-1	4.55	M-3
0.02?	FK-N	0.02	KK	0.05	BX-N	4.33	GSP-1
0.02?	I-2	0.02	NBS-69a	0.05	GH	4.3 ?	QLO-1
0.02?	NIM-D	0.02	SG-1A	0.05	TB	4.20	NS-1
0.01	GH	0.02	SGD-1A	0.05	SCo-1	3.75	GS-N
0.01	SG-1A	0.02?	NIM-D	0.04	G-2	3.2	SGR-1
0.01	SS	0.02?	NIM-P	0.04	GM	2.77	GA
		0.02?	NIM-S	0.04	GSP-1	2.67	G-2
		0.02?	TS	0.04	RGM-1	2.25	SG-1A
F		0.01	PCC-1	0.04	SGR-1	2.16	JG-1
		0.01	SY-2	0.04?	TS	2.02	GM
5.72	NBS-91	0.01?	AGV-1	0.03	I-1	2.02	NIM-G
3.4 ?	GnA	0.01?	I-1	0.03?	BCS-309	1.87?	RGM-1
?	Mica Mg	0.01?	NIM-G	0.02	KK	1.53	BCS-309
?	Mica Fe	0.01?	NIM-N	0.02	NBS-69a	1.40	NIM-S
0.70	SY-3	0.01?	NS-1	0.02	NIM-G	1.36	GH
0.50	SY-2	0.01?	T-1	0.01	DT-N	1.34	NBS-98a
0.42?	NIM-G	0.01?	W-1	0.01	NBS-91	1.11	BCS-367
0.42?	NIM-L			0.01	NIM-S	0.98	KK
0.38	GSP-1			0.01?	FK	0.86	LO1-1
0.35	GH	MnO		0.01?	GL-O	0.79	BCS-267
0.30	SG-1A					0.66	DT-N
0.15?	GL-O	1.27	LO1-1			0.54	I-1
0.13	G-2	1.16	BCS-367	Fe ₂ O ₃ T		0.45	NBS-97a
0.13	NS-1	0.76	NIM-L	47.6	BCS-302/1	0.26?	FK
0.12	SGD-1A	?	Mica Fe	?	Mica Fe	0.12	BCS-375
0.10	BR	0.33	SY-3			0.10	BCS-376
0.10	M-2	0.32	SY-2	23.27	BX-N	0.09?	FK-N
0.10?	STM-1	0.28	BCS-302/1	20.11	GL-O	0.08?	NBS-70a
0.08?	SCo-1	0.28	M-3	17.80	MRG-1	0.08?	NBS-91a
0.07?	GM	0.26	M-2	16.96	NIM-D	0.06	NBS-99a
0.07?	I-3	?	Mica Mg	16.22	I-3	0.04	SS
0.07?	TB	0.22	I-3	15.32	ST-1A	0.02	BCS-313
0.06?	M-3	0.22	NIM-D	13.52	BCR-1		
0.05	GA	0.22	NIM-P	12.90	BR		
0.05?	BCR-1	0.22	STM-1	12.76	NIM-P		
0.05?	JG-1	0.21	DR-N	12.0 ?	BHVO-1		
0.05?	T-1	0.21	ST-1A	11.48	SGD-1A		
0.04?	AGV-1	0.20	BR	11.11	W-1		
0.04?	JB-1	0.19	BCR-1	10.16?	GnA		
0.04?	RGM-1	0.19	NS-1	?	Mica Mg		
0.03?	NIM-N	0.19	SG-1A	9.96	NIM-L		
0.03?	QLO-1	0.18	NIM-N	9.69	DR-N		
0.03?	ST-1A	0.17	MRG-1	9.68	BM		
0.02	MRG-1	0.17	SGD-1A	9.25	M-2		
0.02	W-1	0.17	W-1	9.01	JB-1		
0.02?	BM	0.17	BHVO-1	8.91	NIM-N		
0.01?	NIM-D	0.16?	GnA	8.60	DTS-1		
0.01?	NIM-N	0.15	BCS-267	8.45	UB-N		
0.01?	NIM-P	0.15	JB-1	8.28	PCC-1		
0.01?	NIM-S	0.14	BM	7.30?	TS		

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*Per cent, dry basis. See "Precautionary notes...", p. 8 .

TABLE 4 (cont'd.). Usable values, arranged by "trace elements"

U ppm	pct U ₃ O ₈		V ppm (cont'd.)	pct V ₂ O ₅	Yb ppm	pct Yb ₂ O ₃		
640	SY-3	0.08	50	SY-2	0.01	900	? VS-N	0.10?
280	SY-2	0.03	49	ASK-1	0.01	60	? SY-3	0.01
63	SG-1A	0.01	49	GSP-1	0.01	17	? SY-2	
18	? GH		41	NIM-D	0.01	10	? NIM-G	
15	NIM-G		38	GA	0.01	8	? GH	
13	NIM-L		34	G-2	0.01	6	SG-1A	
12	NBS-1633		31	PCC-1	0.01	5	? STM-1	
4	? GA		24	JG-1		4.3	ASK-1	
4	? NS-1		15	? RGM-1		4	ST-1A	
4	? SGD-1A		13	DTS-1		4	? TB	
3.3	JG-1		11	GM		3.8	BCR-1	
3	? BR		10	NIM-S		3.5?	BM	
2.0	AGV-1		7	? I-1		3.5?	NIM-L	
2.0	G-2		5	SG-1A		3	? GM	
2.0	GSP-1		5	? GH		2.9	SGD-1A	
1.8	BCR-1		2.6?	NIM-G		2.5	GSP-1	
1.8	JB-1					2.1	W-1	
1	? ST-1A					2.1?	JB-1	
0.6?	NIM-S		W ppm	pct WO ₃		2.0	AGV-1	
0.5	W-1		520	? GnA	0.07	2	? BR	
0.4?	BHVO-1		3	? TB		2	? GA	
0.4?	MRG-1		2.3	SG-1A		1.5?	JG-1	
0.4?	NIM-N		2	? GM		1	? MRG-1	
0.4?	NIM-P		1	? BM		0.9	G-2	
			0.5?	W-1		0.6?	NIM-N	
						0.6?	NIM-P	
						0.1?	NIM-S	
ppb								
5	? DTS-1							
5	? PCC-1							
			Y ppm	pct Y ₂ O ₃		Zn ppm	pct ZnO	
V ppm	pct V ₂ O ₅		740	SY-3	0.09		Mica Fe	
600	? VS-N	0.11?	130	SY-2	0.02	800	VS-N	0.10
520	MRG-1	0.09	125	NIM-G	0.02	640	NBS-91	0.08
500	? I-3	0.09	70	GH	0.01	360	? NIM-L	0.04
410	BCR-1	0.07	69	SG-1A	0.01	270	SG-1A	0.03
320	ST-1A	0.06	60	? M-2	0.01	250	SY-2	0.03
310	? BX-N	0.06	50	? I-3	0.01	250	SY-3	0.03
240	BR	0.04	50	? STM-1	0.01	240	? STM-1	0.03
240	NIM-P	0.04	45	? M-3	0.01	210	NBS-1633	0.03
240	SGD-1A	0.04	39	? TB		200	? T-1	0.02
240	W-1	0.04	37	? BCR-1		185	MRG-1	0.02
220	ASK-2	0.04	32	GSP-1		165	ASK-2	0.02
220	DR-N	0.04	32	? DR-N		150	BR	0.02
210	JB-1	0.04	31	? JG-1		150	DR-N	0.02
210	NBS-1633	0.04	30	BR		150	ST-1A	0.02
210	NIM-N	0.04	30	? ST-1A		140	? MAG-1	0.02
180	BM	0.03	27	? BHVO-1		130	? M-2	0.02
170	NBS-69a	0.03	26	AGV-1		120	BCR-1	0.02
	? Mica Fe		26	? BM		120	SGD-1A	0.02
125	AGV-1	0.02	26	? GM		110	? SCo-1	0.01
110	? SCo-1	0.02	26	? JB-1		105	ASK-1	0.01
105	TB	0.02	25	W-1		105	BM	0.01
99	? T-1	0.02	23	NIM-L		105	NIM-P	0.01
80	? M-2	0.01	21	GA		105	? SDC-1	0.01
78	NIM-L	0.01	20	? MRG-1		100	? BHVO-1	0.01
75	UB-N	0.01	17	? NS-1		100	? I-3	0.01
75	? M-3	0.01	13	? FK-N		98	GSP-1	0.01
62	? GS-N	0.01	12	G-2		95	TB	0.01
58	NS-1	0.01	7	NIM-N		91	NIM-D	0.01
55	? QLO-1	0.01	4	? NIM-P		90	? UB-N	0.01
51	SY-3	0.01	3	? NIM-S		89	? TS	0.01

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*See "Precautionary notes...", p. 8.

TABLE 4 (cont'd.). Usable values, arranged by "trace elements"

Zn (cont'd.)		pct ZnO	Zr ppm		pct ZrO ₂	Zr ppm (cont'd.)		pct ZrO ₂
86	W-1	0.01		NIM-L	1.47	160	? BHVO-1	0.02
85	G-2	0.01	1350	NBS-69a	0.18	160	? SCo-1	0.02
85	GH	0.01	1200	? STM-1	0.16?	155	JB-1	0.02
84	AGV-1	0.01	720	SG-1A	0.10	150	GA	0.02
84	JB-1	0.01	700	? VS-N	0.10?	150	GH	0.02
80	GA	0.01	640	NS-1	0.09	145	GM	0.02
80	? SGR-1	0.01	500	GSP-1	0.07	130	ST-1A	0.02
74	SS	0.01	470	NBS-97a	0.06	130	? MAG-1	0.02
74	? GnA	0.01	400	ASK-1	0.05	125	? DR-N	0.02
70	? NS-1	0.01	340	SY-3	0.05	110	? JG-1	0.02
62	NIM-N	0.01	310	NBS-98a	0.04	105	BM	0.01
60	? QLO-1	0.01	300	G-2	0.04	105	W-1	0.01
59	? BX-N	0.01	300	? SDC-1	0.04	100	MRG-1	0.01
53	NIM-G	0.01	290	NIM-G	0.04	100	? M-2	0.01
49	KK	0.01	290	? M-3	0.04	70	NBS-91	0.01
48	? GS-N	0.01	280	? TS	0.04	70	? FK	0.01
45	DTS-1	0.01	270	SY-2	0.04	70	? GnA	0.01
44	? M-3	0.01	250	BR	0.03	60	? I-1	0.01
43	? GL-o	0.01	240	SGD-1A	0.03	45	? NIM-S	0.01
40	GM		240	? GS-N	0.03	30	NIM-P	
40	JG-1		220	AGV-1	0.03	22	? NIM-N	
36	PCC-1		210	? RGM-1	0.03	10	? NIM-D	
32	? RGM-1		190	I-3	0.03			
30	? DT-N		185	BCR-1	0.02			
24	? FK-N		175	TB	0.02			
16	NIM-S		170	ASK-2	0.02			
16	? I-1		170	? QLO-1	0.02			
12	? FK		165	? T-1	0.02			

*See "Precautionary notes. . .", p. 8 .

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