



# GEOLOGICAL SURVEY OF CANADA

## COMMISSION GÉOLOGIQUE DU CANADA

**PAPER 80-14**

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

### PART 6: 1979 EDITION OF "USABLE" VALUES

SYDNEY ABBEY



Energy, Mines and  
Resources Canada

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Ressources Canada

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Available in Canada through

authorized bookstore agents  
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or by mail from

Canadian Government Publishing Centre  
Supply and Services Canada  
Hull, Québec, Canada K1A 0S9

and from

Geological Survey of Canada  
601 Booth Street  
Ottawa, Canada K1A 0E8

A deposit copy of this publication is also available  
for reference in public libraries across Canada

Cat. No. M44-80/14E	Canada: \$3.00
ISBN - 0-660-10609-4	Other countries: \$3.60

Price subject to change without notice

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## FOREWORD

The numerical data in this paper supersede all data published in earlier reports. "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.
5. Geological Survey of Canada (1977), Paper 77-34.
6. X-ray Spectrometry (1978), v. 7, p. 99-121.
7. Geostandards Newsletter (1978), v. 2, p. 141-146.

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.



**STUDIES IN "STANDARD SAMPLES" FOR USE IN THE GENERAL ANALYSIS  
OF SILICATE ROCKS AND MINERALS  
PART 6: 1979 EDITION OF "USABLE VALUES"**

**Abstract**

*Reviews already published on the state of "standard samples" of silicate rocks and minerals, as well as of some samples of other materials that can be used as reference standards for the general analysis of silicate rocks and minerals, have been updated. Usable values of varying degrees of reliability are suggested for major, minor and trace constituents of nearly one hundred different samples. Presentation of the information has been improved with a view to making it more convenient for readers' use.*

**Résumé**

*On a mis à date les études sommaires déjà publiées sur l'état d'échantillons de roches dits "standards" et de minéraux silicatés, ainsi de quelques échantillons d'autres matériaux dont on peut se servir comme standards de référence pour l'analyse générale des roches et des minéraux silicatés. On suggère des valeurs utilisables à divers niveaux de certitude pour des composants majeurs, mineurs et en traces dans presque cent échantillons particuliers. La présentation des renseignements a été améliorée afin de la faire plus convenable pour l'usage des lecteurs.*

**INTRODUCTION**

Increasing use of analytical instrumentation has created a demand for "standard samples" of rocks and minerals for use in calibrations. As a result, geological institutions in a dozen different countries have produced a variety of such materials. Other materials with comparable compositions (glasses, refractories, slags, etc.) have also found use as calibration standards in rock and mineral analysis. In testing new analytical methods and in the comparison of analytical results emanating from different laboratories, such reference materials can be an invaluable tool in the hands of the analyst. (The term "reference materials" is preferred to "standard samples" because the latter name suggests a greater degree of reliability than can realistically be attributed to the derived compositional values.)

Although the originators of rock reference samples have collaborated in providing analytical data for one another's samples, all have gone their separate ways in the selection and preparation of their materials, in their methods for assuring homogeneity and in the manipulation of the highly incoherent results reported by participating laboratories. Recent years have seen a growing trend toward exchange of information, with a view to bringing order out of this chaotic situation. Sessions devoted to the subject of reference samples of geological materials have formed part of several international conferences. An international journal, *Geostandards Newsletter* (K. Govindaraju, editor, c/o CRPG, 54500 Vandoeuvre-Nancy, France) has been established, as has also an International Study Group on Reference Materials (T.W. Steele, chairman, c/o National Institute for Metallurgy, Randburg 2125, South Africa).

This paper presents background information on a large number of geological reference materials and usable numerical values for the concentrations of many constituents in them. Also included is a discussion of possible reasons for the discrepancies in collaborative analytical data and of various schemes that have been proposed for resolving those discrepancies.

**NATURE OF THE RAW DATA**

Among the many collaborative analytical programs for proposed reference samples of rocks that have been conducted over the last 30 years, one feature in common has been the wide dispersal of results reported for essentially all constituents. Various possible explanations for this state of affairs have been proposed. Flanagan (1976a) has referred to the debate between those who hold that sample inhomogeneity is the main culprit and those who consider interlaboratory variability to be more significant. Other ideas put forward concern the use of inadequate subsampling procedures and the absence of information on statistical parameters of analytical methods used.

In an effort designed to compare the possible effects of inhomogeneity with those of interlaboratory factors, Flanagan (personal communication, 1979) has requested that all analyses of three new samples (USGS-BIR-1, -DNC-1 and -W-2) be performed in randomized sequence according to a specified experimental design—i.e. two subsamples from each of three randomly selected bottles. Results were then to be used in analysis-of-variance computations. Incomplete data on the three samples mentioned and on eight earlier ones (Flanagan, 1976b) suggest that inhomogeneity is rarely present to any significant extent, at least among the samples examined.

Ridley et al. (1976) reported experimental data emphasizing the effect of particle size on homogeneity. The validity of their conclusions, however, was limited because the work was done on a single sample in only one laboratory. Ingamells and Switzer (1973) studied the effects of particle size, mineralogical composition, and subsample weight on the scatter of results, concluding that a minimum sample weight ("the sampling constant") could be computed for the determination of each constituent in a particular sample within specified confidence limits. Jaffrezic (1976) demonstrated a linear correlation between particle size and variance when plotted on log-log paper. Maessen et al. (1976) suggested that evaluation of results would be facilitated if collaborating analysts were to provide sufficient statistical information on their analytical methods.



All of the foregoing proposals have merit. Unfortunately, their application in practice is rather difficult. Derivation of sampling constants for each constituent of one sample – let alone a set of two, three or six – would entail a great deal of additional work. Fortunately, most analysts know intuitively what constitutes a safe sample size, as revealed by the low incidence of evidence of inhomogeneity effects in those programs where analysis-of-variance computations have been used. More information on statistical parameters of analytical methods would of course be useful, but again hardly practical. Many contributors to collaborative programs, as well as compilers of the data, have been lax in the information provided on "method used". Too often they have merely listed the technique used in final measurement (XRF, AAS, etc.) in cases where the earlier steps in the procedure may have had a greater bearing on overall reliability than did the measurement technique.

Some programs have endeavored to overcome the homogeneity problem by preparing fused glass samples of controlled composition (e.g. de la Roche and Govindaraju, 1973b). The dispersion of analytical data on such glasses was found to be no better than on the more heterogeneous rock samples, thus pointing once more to the greater importance of interlaboratory factors. In programs involving two or more samples – generally of considerably different compositions – bias in results from a particular laboratory has generally been evident on all of the samples. Thus programs based on a single sample material may well fail to reveal useful information.

Imbalance of available compositional data for the various constituents of reference rocks has reflected the availability and extent of application of suitable analytical methods. Thus comparatively little is known about the concentrations of such "difficult" trace elements as Ag, Au, Bi, Br, Cd, Ge, I, the platinum group, some of the less abundant rare earths, Ta, Th, W, etc. Even with certain more abundant constituents, the fact that they cannot ordinarily be determined by optical or X-ray spectroscopy has meant that comparatively fewer values are available for carbon dioxide, water, and ferrous iron. With carbon dioxide, many contributors have failed to report on whether their results represent total carbon, as determined by combustion methods, or carbonate carbon, as evolved by acid treatment.

#### DERIVATION OF "USABLE VALUES"

Given a highly incoherent set of results for the determination of each constituent of a proposed reference sample, the originator is faced with the difficult problem of estimating the "true" concentration. In the analysis of ores, where a relatively small number of constituents are of interest, where collaborative analysis is done according to a specified replicate sampling design, and where the collaborating analysts are specialists in the handling of similar materials, a systematic and relatively rigorous statistical treatment of the raw data is frequently applied. Thus Sutarno and Faye (1975) have used a scheme in which a few outlying results are rejected according to established statistical rules, and within laboratory and interlaboratory means and variances are computed. From these, it is possible to deduce a "certification factor", indicating whether a particular value has been sufficiently well established to justify certification, to deduce a reliable recommended value, and to assign confidence limits.

With rocks, matters are complicated by the wide variation in composition between samples, by the many constituents (whose contents may range from over 50 per cent to less than 1 ppm) that are of interest, by the varied backgrounds of the participating laboratories, and hence by

the sheer bulk of work required. Few rock programs, therefore, have attempted to organize controlled replicate schemes; those who have done so have found that many contributors fail to live up to the requirements. Inevitably, analytical results on rock samples have displayed greater dispersion than has been the case with ores.

Many procedures have been proposed for deriving "provisional", "preliminary", "tentative", "magnitude", "average", "preferred", "best", "proposed", "recommended", "certified", "attested" or "guaranteed" values, in most cases without definition of the adjective used. Many of the procedures have involved the mean of values remaining after rejection of those lying beyond one, two or three standard deviations from the mean of all the original data. Details of the system used by each originating agency are given below in the notes on the samples they have issued.

A common limitation of most of the above schemes is a failure to account for skewed distributions, a common occurrence with rocks, particularly for some trace elements. Christie and Alfsen (1977) have attempted to overcome the effects of skew by computing a "mode", using a data-transformation calculation, to produce a "Gamma Central Value". Ellis et al. (1977) introduced a "Dominant Cluster Mode" to overcome the effect of skewness. Abbey et al. (1979) proposed a "Moving Histogram Mode" and a "Moving Histogram Transformation Mode" as simplified approximations of the Dominant Cluster and Gamma modes, but also presented evidence to question the value of any "mode" approach to the problem.

Because of the many uncertainties in the final values assigned to the concentrations of constituents in rock reference samples, the term "usable values" has been proposed. Essentially, its meaning is that the value in question may be used with caution, always in combination with values for the same element in other samples and preferably with some understanding of its limitations.

#### THE "SELECT LABORATORIES" METHOD

Assuming that the originators of a particular sample have more information about it than has anyone else, the originators' own recommended values generally were used in compiling the Tables in this paper, except that all values were converted to the "dry basis" where suitable  $H_2O^-$  data were available. In the few cases where the originators' values gave rise to discrepancies, they were replaced by values derived by the "select laboratories" method outlined below. The same method was also used where the originators did not recommend usable values.

Although by no means conclusive, there is a large body of evidence to support the view that interlaboratory bias, or systematic error, is the major cause of incoherent results. It may then be argued that the work of some contributing laboratories is more reliable than that from others and therefore should lead to more dependable values. In an extreme example of that approach, Ingamells (1978) proposed that the evaluation of a reference sample be based on analyses done in only two reputable laboratories, each using mutually independent methods. Only where those two disagree would a third laboratory be called in to resolve the differences. Unfortunately, with rock samples, it would be very difficult to find two, let alone three laboratories that would be dependable for all of the many components of interest.

The select laboratories method has undergone numerous modifications as it has been applied over the years, but the principle remains the same: By some arbitrary set of parameters, all results for each constituent of each sample

are categorized as "good", "fair" and "poor". Each laboratory is given a "rating" on the basis of its relative number of good, fair and poor results. All laboratories with a rating exceeding a specified value are considered "select" and the results reported by them are used to arrive at a usable value.

Details are as follows:

1. All raw data are converted to the dry basis, where  $H_2O^-$  values are reported.
2. Where fewer than three results are available for a particular constituent of a particular sample, no value is assigned.
3. Where three or four results are available, the median is taken as usable value, but only if results are close to one another and three independent methods have been used. Such values are tabulated with question marks.
4. Where five to nine results are available, the median is used, with a question mark, regardless of the methods involved and how closely the results agree.
5. Where ten or more results are available, the mean,  $\bar{x}$ , and standard deviation,  $s$ , are calculated. All results lying below  $\bar{x}-s$  and above  $\bar{x}+s$  are classified as "poor".
6. After setting aside the poor results, the mean of the remainder,  $\bar{x}_1$ , and standard deviation,  $s_1$ , are calculated. All results lying below  $\bar{x}_1-s_1$  and above  $\bar{x}_1+s_1$  are classified as "fair".
7. After setting aside the fair results, those remaining are classified as "good".
8. For each contributing laboratory, the total number of good ( $N_g$ ), fair ( $N_f$ ), and poor ( $N_p$ ) results are determined.
9. Each laboratory is given a rating,  $R$ , where

$$R = \frac{N_g - N_p}{N_g + N_f + N_p} \times 100$$

10. All laboratories with ratings exceeding a specified level are considered "select". Originally, the specified level was 50, but changes introduced in the method since the last paper in this series (Abbey, 1977a) have resulted in a general reduction of rating levels, so the specified level has been reduced, generally to 40, occasionally to 30.
11. For each constituent of each sample, results reported by the select laboratories are examined. Any outlier among the select values that differs from its nearest neighbor by as much as or more than the latter differs from the opposite extreme is rejected.
12. If fewer than five select values are available, a subjective choice is made between their median and the median of all the original data, as usable value, but reported with a question mark.
13. Where five or more select values are available, both their mean and median are calculated. A subjective choice between the two is then made to establish an "unquestioned" usable value. Generally, the median is favoured because it is less affected by the distribution.

It should be noted that the question mark is used in several different circumstances to indicate varying degrees of uncertainty. How it has been applied where usable values are those recommended by the originators is described in the notes for each originating organization. It is inevitable, therefore, that it can have somewhat variable significance in going from one group of samples to another.

## VERIFICATION OF USABLE VALUES

No known test can prove the validity of a concentration value derived from a mass of incoherent data. The fact that different statistically-based selection procedures can produce somewhat different final values casts doubt on the validity of at least some of those procedures. Two rough criteria are used in the Tables in this paper as measures of the validity of listed values: the summation and the "compatibility of the iron oxides".

The summation criterion considers closeness of the total to 100 per cent as a measure of the quality of the listed values, provided all constituents present at a significant level have been included. Unfortunately, compensating errors can result in "good" summations. "Bad" summations can result from adding in certain trace elements that have already been accounted for as part of some major element, if the latter has been determined by a chemical method (e.g. Sr and Ca). Incorrect summations can also result from the reporting of some elements as oxides where they may occur in the metallic state.

The iron-oxide compatibility test can be applied only where usable values for ferrous, ferric and total iron are derived independently from their respective reported values. If the derivation procedure is sound, the derived value for total iron based on individual results reported as such (i.e.  $Fe_2O_3$  TR) should be close to  $Fe_2O_3$  TC (i.e.  $1.1113 FeO + Fe_2O_3$ ), where FeO and  $Fe_2O_3$  are the derived values for those constituents based on individual results reported for them. Because ferric iron is normally determined by difference in an ordinary rock analysis, some originators have derived values only for ferrous and total iron, then obtained a derived value for ferric by difference, instead of deriving a value for  $Fe_2O_3$  from individually reported values, each of which was calculated by difference from individual results for FeO and  $Fe_2O_3$  T. Such a procedure unfortunately renders this test meaningless.

## PRESENTATION OF THE DATA

The Tables have been arranged somewhat differently from those in the preceding paper of this series (Abbey, 1977a) in the hope of making the information more useful to the reader. Table 1 lists the samples alphabetically according to sample type. In Table 2, the samples themselves are listed alphabetically and identified with sample type, source and country of origin, and they are referred to more detailed descriptive notes. Table 3 lists the "complete analyses" of all samples in roughly geographic sequence and in alphabetic order within each issuing institution. The order of presentation of major and minor constituents has been changed from that used previously (Abbey, 1977a), to approximate that used by most other publications, by listing titania between silica and alumina, and manganese between ferrous and magnesium oxides. For the first time in this series, this table also includes samples whose analyses are incomplete or for which firm usable values are not available, in order to give a general idea of overall composition. Table 4 lists essentially the same information as Table 3, but gives the samples in descending order of concentration for each major and minor constituent. In Table 5, the "trace elements" are presented in much the same manner, as ppm ( $\mu g/g$ ), ppb ( $ng/g$ ), ppt ( $pg/g$ ) or ppq ( $fg/g$ ), along with equivalent percentages of appropriate oxides, where they are high enough to affect the summation.

Most of the samples listed in the Tables are silicate rocks; a few are compositionally similar materials such as micas, feldspars and clays. Some additional samples have been arbitrarily selected for inclusion because they contain the same major and minor constituents as do silicate rocks, but in different proportions, and, therefore, may be useful as

Table 1  
Listing of Samples According to Type

Sample Type	Samples
Andesite	AGV-1, JA-1
Anorthosite	AN-G
Ash	NBS-1633
Basalt	BCR-1, BE-N, BHVO-1, BIR-1, BM, BR, JB-1, JB-2
Bauxite	BX-N, NBS-69a, NBS-69b, NBS-697
Biotite	Mica Fe
Calc-silicate	M-3
Clay	KK, NBS-97a, NBS-98a
Diabase	DNC-1, W-1, W-2
Diorite	DR-N
Dolerite	I-3
Dunite	DTS-1, NIM-D
Feldspar	BCS-375, BCS-376, FK-N, NBS-70a, NBS-99a
Gabbro	MRG-1, SGD-1A
Glass	NBS-91, VS-N
Glauconite	GL-O
Granite	G-2, GA, GH, GS-N, I-1, MA-N, NIM-G, SG-1A
Granodiorite	GSP-1, JG-1
Iron Ore	ES-681-1
Jasperoid	GXR-1
Kaolinite	KK
Kyanite	DT-N
Larvikite	ASK-1
Latite	QLO-1
Lujavrite	NIM-L
Marl	MO8-1
Mica	Mica Fe, Mica Mg
Norite	NIM-N
Peridotite	PCC-1
Phlogopite	Mica Mg
Pyroxenite	NIM-P
Rhyolite	RGM-1
Sand	FK, NBS-81a, NBS-165a, SS
Schist	ASK-2, M-2, SDC-1
Sediment	GXR-3, MAG-1
Serpentine	SW, UB-N
Shale	SCo-1, SGR-1, TS
Silica	BCS-267, BCS-313, NBS-81a, NBS-165a, SS
Sillimanite	BCS-309
Slag	BCS-367, ES-878-1, SL-1
Slate	TB
Soil	GXR-2, GXR-5, GXR-6, SO-1, SO-2, SO-3, SO-4, SOIL-5
Syenite	NIM-S, NS-1, STM-1, SY-2, SY-3
Tonalite	T-1
Trap	ST-1A

high or low points in calibrations or because of their trace-element contents. They should, however, be used with caution because their compositions may result in unexpected interferences, some may contain excessive organic matter, others may be difficult to fuse, etc. They include fly ash, bauxite, glass, iron ore, refractories, sand, etc. They have been included because their compositions appear to be close enough to those of silicate rocks to be of value. A number of others are available in the publications of the various issuing agencies.

#### CCRMP - CANADIAN CERTIFIED REFERENCE MATERIALS PROJECT

(Contact: Dr. H.F. Steger, Co-ordinator, CCRMP, c/o Canada Centre for Mineral and Energy Technology, 555 Booth St., Ottawa, Canada, K1A 0G1)

This project, 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 (Steger, in press).

Syenite sample SY-1 and sulphide ore sample SU-1 were issued some years ago, and a compilation of available analytical data was published 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 worldwide program of collaborative analysis are given in a "comprehensive report" (Abbey, in press). The values listed in the Tables were derived by the select laboratories method described above.

Of the many other materials available from this source, four soils and a blast-furnace slag have been included in this paper for possible use in silicate rock and mineral analysis.

The soils, SO-1, SO-2, SO-3 and SO-4, are described by Bowman et al. (1979a,b). Assigned values of varying degrees of confidence for many major, minor and trace elements were derived by the method of Sutarno and Faye (1975), although the authors admitted that "...some subjectivity was required in identifying outliers". They also stated that "...it is evident that the capability of the analyst is the most important factor in determining the reliability of results as both good and poor data were generated by all methods". Their listing of "methods" includes AA, XRF, ES, NAA, COLOR, TITR, GRAV, all of them merely measurement techniques, none of them sufficiently specific. For certain trace elements, the spread of results reported by contributing laboratories is as bad as or worse than what is generally observed with rock samples. There is some evidence that differing chemical pre-treatments were used by different laboratories in methods where solutions were required. The summations show a small but persistent negative bias, suggesting the possibility that the analyses are incomplete, or that the validity of the derivation procedure is open to question. The iron-oxide compatibility test cannot be applied because the presence of major quantities of organic matter precluded the determination of ferrous iron.

Nevertheless, these soil samples may prove useful in rock analysis, particularly because of their usable values for certain trace elements, but caution should be exercised in view of the high organic contents and the other reservations outlined above. The values listed here with question marks are some of those given by Bowman et al. (1979a, b) as "uncertified, for information only".

Individual results for the blast furnace slag, SL-1, are much more coherent than those for the soil samples (Mason and Bowman, 1977), suggesting conditions similar to those that usually apply to ores. The use of the procedure of Sutarno and Faye (1975) therefore can not be questioned in this case. However, the summation is somewhat low, and if an oxygen-for-sulphur correction were applied (assuming all the sulphur to be present as sulphide), the summation would fall under 99 per cent, suggesting that not all constituents have been accounted for. Little information is available on trace elements. Values listed with question marks are those given by Mason and Bowman (1977) as "for information only".

This slag sample may be useful in rock analysis calibrations, particularly where high calcium and low silica points are required. It should be noted that the sample contains appreciable non-carbonate carbon (J. Kelly, Steel Co. of Canada, verbal communication).

## 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, therefore, has 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, 1976c) included additional results and some "recommended", "average" and "magnitude" values. Those values were the same as those listed earlier (along with similar values for many other samples) 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 two recent papers in this series (Abbey, 1975a, 1977a), Flanagan's values were given precedence, except where there were apparent errors, omissions or other discrepancies. Subsequently, because of the appearance of Flanagan's (1976c) second compilation on the six samples, the Editor of *Geostandards Newsletter* suggested that the select laboratories method be applied to all the data now available. This was done and a new set of usable values published by Abbey (1978). The procedure used in that case differed in a few details from that outlined above, and the values listed in this report are those from Abbey (1978) with a few minor corrections.

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. Flanagan (1976b) gave 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 for many constituents of these last eight samples are listed in this report, but most of them must be regarded as only preliminary. However, the data in Flanagan (1976b) clearly indicate that the samples are sufficiently homogeneous for most practical purposes.

An unfortunate feature about the above eight samples is that Flanagan's (1976b) report included no data beyond 1972, and although many additional results have appeared in the literature, no comprehensive compilation nor any recommended values have been published. It is rather surprising that the one institution that has apparently produced more reference samples of rocks than any other organization has not provided more complete compositional information. Absence of recommended values, however tentative, severely limits the usefulness of those samples.

More recently, three additional samples have appeared: basalt BIR-1 and diabbases DNC-1 and W-2. The last of these is an intended replacement for W-1, which was originally reported as exhausted by Flanagan (1973). No replacement for DTS-1, listed as exhausted at the same time, has appeared.

Another report (Myers et al., 1976) listed 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, therefore, are not given in this paper.

## USGS-AEG - U.S. GEOLOGICAL SURVEY AND ASSOCIATION OF EXPLORATION GEOCHEMISTS

(Contact: U.S. Geological Survey, Federal Center, Denver, Colorado 80225, U.S.A.)

Six samples, GXR-1 to GXR-6 inclusive, have been prepared for use as reference materials in geochemical exploration. They represent a variety of compositions, some of which are close to those of silicate rocks. Gladney et al. (1979), having observed the wide scatter of results obtained in U.S.G.S. "in-house" and "round-robin" analyses, attempted to resolve the discrepancies by undertaking repeat analyses, using a variety of analytical techniques, although they relied heavily on neutron-activation methods for most trace elements. On the basis of their own results, Gladney et al. (1979) then listed recommended values for a variable number of constituents of all six samples.

Because of the inevitability of interlaboratory bias, it is difficult to accept the results from one laboratory as a firm basis for recommended values, particularly where only one analytical method was used. As a result, some of the values for the GXR samples tabulated in this report are shown with question marks.

These samples should prove useful in general rock analysis because of the many usable values on certain trace elements. However, it must be remembered that they were designed for use in geochemical exploration and that certain constituents in them (e.g. arsenic, copper, mercury, molybdenum, lead, antimony, selenium, tungsten) could cause problems in analytical procedures for certain other elements.

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

(Contact: Office of Standard Reference Materials, Room B311, Chemistry Building, National Bureau of Standards, Gaithersburg, Md. 20834, 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 presented 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, three bauxites, two sands, 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 mainly for major and minor components, except for the fly ash, which is certified for certain trace elements 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 thorium. 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, whereas 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.

NBS has also issued a set of "mineral glasses for microanalysis", mainly for use in microbeam techniques. They are of little interest in general rock analysis.

There is a rapid turnover of some of the NBS materials, with the result that some of the samples listed here are no longer available. Similarly, new ones may become available before this report is published. NBS Publication 260 is revised frequently, listing only the compositions of available samples. Users of samples no longer available must therefore carefully guard their original certificates or maintain a continuing file of old NBS catalogues.

## 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 461, published in 1977, 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 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. The slag sample suffers from the same summation problems as does CCRMP-SL-1. It will be noticed that the iron ore sample is now a "Eurostandard", ES-681-1. In the most recent paper in this series (Abbey, 1977a), an iron ore sample, BCS 302/1, was listed. Compositions of the two are so nearly the same that it could be concluded that one is a replacement for the other, or even that ES-681-1 represents a more thorough re-analysis of the material previously designated as BCS 302/1. It will be noticed that no summation for that sample is shown in Table 3. Even after correcting for sulphur (assuming it is all present as sulphide), the sum of the values in Table 3 is in excess of 101 per cent, suggesting that some of the assigned values are questionable. If all of the carbon is assumed to be in the non-carbonate form, the total is reduced to about 96 per cent. It may therefore be concluded that some carbonate carbon is present.

A major drawback in most BCS samples is the absence of information on trace elements, but a recent announcement (British Ceramic Research Association, 1979) suggested that steps are being taken to overcome the problem.

## 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 by an earlier version of the select laboratories method.

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  $\text{H}_2\text{O}^-$ . 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. They have also been used where uncertainty exists for the more usual reasons.

## 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 analyzed 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 this paper. "Information values" for some major and minor constituents are listed in Table 3 to give a general idea of composition, but not in Table 4 because they are not usable values. Usable values for certain trace elements are given in Table 5, all without question marks.

#### **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 ES-878-1 (a Eurostandard formerly listed as LO1-1) and ferriferrous marl MO8-1.

Most values given in Tables 3 and 4 are those listed as "most probable" on the certificates provided with the samples. Values shown with question marks were reported by the originators in a private communication; they did not appear on the certificates.

#### **CRPG – CENTRE DE RECHERCHES PÉTROGRAPHIQUES ET GÉOCHIMIQUES (France)**

#### **ANRT – ASSOCIATION NATIONALE DE LA RECHERCHE TECHNIQUE (France)**

(Contact for both: K. Govindaraju, CRPG, C.O. n° 1, 54500 Vandoeuvre-Nancy, France)

The first reference sample produced by CRPG was the experimental granite GR, which has been long since exhausted. Three other rocks, basalt BR and granites GA and GH, were produced subsequently and are generally considered among the best-established reference materials. They were followed by biotite Mica Fe and phlogopite Mica Mg. Later, the CRPG reference materials program was identified with ANRT and produced diorite DR-N, serpentine UB-N and two "non-rock" samples, kyanite DT-N and bauxite BX-N. Still later operations produced a synthetic glass VS-N, a potash feldspar FK-N and a granite GS-N, intended as a replacement for GR. A glauconite sample, GL-O, was prepared in limited quantity, mainly as a reference standard in geochronology, but because much analytical work was done on the sample, the originators assigned a number of values that may prove useful in general rock analysis.

In assigning values, the following general procedure has been used by this group. For each constituent of each sample, a mean and standard deviation of reported values were computed. Results differing from that mean by more than one standard deviation were rejected and the mean of the remainder was taken as "recommended value". However, some subjective factors were also considered in special cases, particularly with trace elements. In cases where there was sufficient uncertainty, the originators have given "proposed" rather than "recommended" values. Their "proposed values" are listed in this paper with question marks.

With samples other than BR, GA, and GH, assigned values for ferric iron appear to be based on the difference between assigned values for total and ferrous, rather than on the actual results reported for ferric. In those cases, the iron-oxide compatibility test no longer applies.

Values in Tables 3 and 4 for BR, GA, and GH are those of Roubault et al. (1970), those in Table 5 are from Govindaraju and de la Roche (1977). Values for Mica Fe and

Mica Mg are from Govindaraju (1979). Those for BX-N, DR-N, DT-N, and UB-N are from de la Roche and Govindaraju (1973a), but an updated compilation is expected in 1980. The most recent information on FK-N and GS-N is that of de la Roche and Govindaraju (1976a); the same authors (1976b) reported on GL-O.

In the report on the two micas, Govindaraju (1979) reported totals of 99.22 and 98.91 per cent respectively for Mica Fe and Mica Mg, but addition of the appropriate oxides of the "trace elements" yields the more acceptable totals of 100.29 and 99.70, as shown in Table 3.

VS-N is a special case, being a synthetic sample. Unfortunately, it contains relatively high concentrations of all the additives, many of them at levels much higher than normally encountered in rock samples. As a result, interferences are possible in some analytical procedures. Further, even if an "additive-free" glass of similar composition was available for preparing dilutions, the additive elements would remain in constant proportion to one another, making it difficult to detect interference effects.

VS-N values listed in Table 5 are rounded versions of elemental equivalents of the oxide concentrations recommended by de la Roche and Govindaraju (1973b); those with question marks are similarly based on their "proposed values".

The latest ANRT samples to become available (and for which no quantitative data are as yet published) are anorthosite AN-G, basalt BE-N (a replacement for BR), and granite MA-N (which contains unusually high concentrations of Ag, Be, Cs, Li, Rb, Sn and W).

#### **IAEA – INTERNATIONAL ATOMIC ENERGY AGENCY**

(Contact: IAEA, Analytical Quality Control Services, Kärntner Ring 11, P.O. Box 590, A-1011 Vienna, Austria)

A soil sample, designated SOIL-5, has been produced, and described by Dybczynski et al. (1979). Their compilation includes "laboratory averages" for each constituent, with from 2 to 60 laboratories reporting, depending on the constituent. The authors used several different statistical tests to identify and eliminate outliers, then utilized means of the remainders and their standard deviations to establish recommended values and confidence limits. Those described as "with a relatively high degree of confidence" are listed in the Tables in this paper without qualification; those "with a reasonable degree of confidence", with question marks. The originators non-certified "information values" are shown as such in Table 3 only.

As was the case with the CCRMP soil samples, the originators of SOIL-5 attempted to correlate results with "method used", but again the "methods" referred to are mere techniques of final measurement. They did indicate which of the reported results involved some chemical pre-treatment of the sample, but did not specify any details of the pre-treatments. It also appears that some of the collaborating analysts did not provide sufficient information on their methods.

#### **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, Střeleč*), 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. This report, however, does include data on KK (for Kaolin, Karlovy Vary), for which recommended values have been made available to the author by the staff of the Institute at Kutna Hora. Similar information about SS is based on a report by Valcha (1972).

No information is available on individual results reported, but the recommended values are believed to have been derived by the method described by Dempir (1978).

#### **ZGI – ZENTRALES GEOLOGISCHES INSTITUT (East Germany)**

(Contact: Prof. K. Schmidt, ZGI, Invalidenstrasse 44, 104 Berlin, Deutsche Demokratische Republik)

This agency acts as co-ordinator of an Eastern European collaborative program of geological materials, involving the Czechoslovak institute mentioned above, among others. In general, collaborative analytical work done under that program involves a multiple-sampling scheme not unlike that of Sutarno and Faye (1975). They also use statistical tests to detect and reject outliers, then report means of the remainders, generally with confidence limits. In one case (Grassman, 1972), silica and alumina values are specifically referred to as "recommended", with no explanation. They do not publish compilations of individual results reported by contributing laboratories.

For basalt BM, granite GM, and slate TB, the tabulated values in this paper are those of Grassman (1972) for major and minor constituents, and of Schindler (1972) for trace elements. Question marks have been added to those values where the number of results reported appear to be too few to support firm values; in extreme cases, Schindler's values have not been listed here.

For feldspar sand FK, greisen GnA, serpentine SW and shale TS, the tabulated values are from certificates supplied with the samples. Question marks are used with values categorized by the originator as "non-certified".

The Eastern European program is expected to prepare, in coming years, a number of rock-like reference materials including gabbro, nepheline syenite, fire clay, monzonite, slate, skarn, and kieselguhr. Details are lacking, mainly because of difficulties in communication.

#### **LEN – LENGOSUNIVERSITET (U.S.S.R.)**

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

The only sample from this source, a nepheline syenite designated here as NS-1, was originally identified as "Khibiny-Generalnaya" by Kukhareno et al. (1968). Unlike other Eastern European authors, they listed individual reported results, but no recommended values. In earlier papers in this series (Abbey, 1972, 1973, 1975a, 1977a), tabulated values were based on "adjusted means" – i.e. the means of values remaining for each constituent after rejecting the 20 per cent of the originally reported results that were farthest removed from the overall mean.

Because the above procedure led to somewhat unsatisfactory values – particularly a rather high summation – it was decided to apply the select laboratories approach for this paper, even though only one sample was involved. As a result of the limited amount of available data, it was necessary to lower the "specified limit" of rating, above

which a laboratory can be considered "select", to 30. The result has been a general slight lowering of most of the usable values and therefore a much improved summation.

Question marks were used according to the outline of the select laboratories method, as given above.

#### **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.

Additional data on these samples were reported by Abbey and Govindaraju (1978).

In this paper, question marks have been added to those values listed by Tauson et al. (1974) in parentheses. It is noteworthy that a small but persistent positive bias appears in all of the summations. The fact that the bias is of similar magnitude and in the same direction for all three samples suggests that it is not due to random errors in the recommended values, but that some systematic error may exist in the method used for deriving those 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 (personal communication, 1975). Some of the values in Tables 3, 4, and 5 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. One 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 per cent, 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 per cent 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  $\text{H}_2\text{O}^-$  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.

Two additional reference samples, andesite JA-1 and basalt JB-2, have been prepared recently. Kato et al. (1978) reported major and minor constituent results as determined by three analysts, but no other information has appeared, to my knowledge.

## MRT – MINERAL RESOURCES, TANZANIA

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

Tonalite sample T-1 was produced some years ago, and a compilation of analytical results published by Thomas and Kempe (1963). Those authors suggested that recommended values for each constituent be computed as the mean of those remaining after eliminating all results that differed from the overall mean by more than one standard deviation. That procedure was used for the values reported for this sample in earlier papers of this series (Abbey, 1972, 1973, 1975a, 1977a). Unfortunately, those values resulted in a somewhat high summation, and in a noticeable discrepancy between the two total-iron values. Because the select-laboratories method had been applied with some success to NS-1, the only other single-sample program, it was decided to do the same in this case.

Results are shown in the Tables. Table 3 reveals that the summation has shown no improvement over that in earlier editions, but the iron-oxide compatibility has been significantly improved (all figures in per cent, dry basis):

	$\text{Fe}_2\text{O}_3\text{TR}$	$\text{Fe}_2\text{O}_3\text{TC}$
Earlier values	5.93?	6.03?
Current values	5.90	5.91

This improvement is noteworthy in view of the fact that the originally reported results for this sample were in closer agreement with one another than has been the case in most other rock programs. It may then be concluded that less satisfactory values may result from the use of "adjusted means", even where the raw data are comparatively coherent.

With reference to T-1, Bowden and Luena (1966) rightly warned against the dangers entailed in indiscriminate use of insufficiently well-established values. Little change may be expected with T-1, as it was reported by Flanagan (personal communication) that supplies of the sample are exhausted and 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, 1977b). 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 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 the immediately preceding paper in this series (Abbey, 1977a) were in general closer to the NIM "certified" values than before, but were, as a rule, free from most of the objections to the latter values.

In apparent recognition of the questionable usefulness of the "certified values", the originators (Steele et al., 1978a, b; Steele and Hansen, 1979a, b) made a more detailed study, using essentially the same raw data as in the computer printout referred to above. They used a number of different tests for outliers, computed several different measures of central tendency (median, mean, dominant cluster mode, gamma central value, etc.), and selected a recommended value by subjective examination of those measures. In view of the thorough work done by Steele et al. (1978a, b) and Steele and Hansen (1979a, b), it was decided to favour their values (where there were differences) over those in Abbey (1977a).

More detailed study of the papers by Steele and Hansen (1979a, b) revealed some minor discrepancies: (a) Their "Others" did not include some trace elements whose oxide equivalents could be rounded to 0.01 per cent. (b) Some contributors of data had given results for only two of the three iron oxides (ferric, ferrous, total-as-ferric) without calculating the third. (c) Their total-iron-oxides compatibilities were not as good as in our own earlier work (Abbey, 1977a).

A comparison was therefore made between the various iron values recommended by Steele and Hansen (1979a, b) and those of Abbey (1977a) and a selection was made to provide the best possible combination of iron-oxide compatibility and summation. Table 6 shows a comparison between the values decided upon and those in the two sources. For all six samples, the values selected in this work provide better iron-oxide compatibility than do those of Steele and Hansen. For four of the six, this work gives summations that are as close to or closer to 100 per cent than are those of Steele and Hansen. For NIM-L, Steele and Hansen give a summation closer to 100 per cent, as they do for NIM-D, but in that case, it should be noted that with dunites and similar rocks high summations are the rule rather than the exception. The presence of small amounts of nickel in the metallic state, although it is reported as NiO, is generally regarded as the reason for high summations. The 100.17 per cent total in this work, therefore, may actually be superior to the 100.13 per cent of Steele and Hansen.



A further complication arose with the NIM samples. In Abbey (1977a), values were reported for certain trace elements for which Steele et al. (1978a, b) considered the available results inadequate to recommend values. Those trace element values therefore should have been omitted from this report. However, to do so would have meant that more information was available in an earlier paper. All values within that category therefore are shown in this paper with question marks, even though some of them appeared in the earlier compilation as unqualified usable values. Thus the quality of some listed values appears to have been "demoted".

Another special case occurred with gallium in NIM-L for which the median of the five available select values was 30 ppm; the mean was 35 ppm. The latter was listed as usable value in the preceding report. However, Steele et al. (1978a, b), after rejecting two extreme outliers, found a mean of 43 ppm, median 49 ppm, and dominant cluster mode 54 ppm. They therefore recommended 54? ppm, a value supported by further results received after the computations were done. Thus, in this case, it was the select laboratories method that produced unsatisfactory results.

## OTHER SOURCES

Ivanov (in press) reports on a Bulgarian granite, G-B. At this writing, no information is available.

Several of the agencies listed above prepare other reference materials that may be of use in general analysis of silicate rocks and minerals. Among the many other institutions that prepare inorganic reference materials, there may be some that could be useful in the analyses of rocks. Every effort has been made to render this compilation as comprehensive as possible, but some potentially useful samples have likely been overlooked.

At this writing, a collaborative effort is underway, involving the British Columbia Department of Energy, Mines and Petroleum Resources, the Canada Centre for Mineral and Energy Technology, and the Geological Survey of Canada, to produce reference samples of stream sediments, lake sediments, and possibly other materials which can be used in geochemical trace analysis. Preparation of reference samples of marine sediments is under study by the National Research Council of Canada.

A novel approach to the preparation of reference samples is that of Date (1978), who proposed a scheme for synthesizing such materials. It involves the preparation of two solutions, one an ethanolic solution of tetra-ethyl orthosilicate, the other a dilute acid solution of such salts of all other elements that can be converted to oxides on ignition. The two solutions are combined, and addition of a controlled amount of ammonium hydroxide results in a "flash hydrolysis", producing a gel in which the dissolved compounds are "frozen" in place. Careful evaporation, drying and ignition results in the production of a powdered mixture of silica and oxides of all other elements added.

The major advantage of such a scheme is the ability to vary composition at will. A disadvantage is that the physical characteristics of the product are very different from those of powdered rocks. Experiments carried out at the Geological Survey of Canada have also revealed that ignition must be carried out at a very high temperature (1200°C?) to minimize hygroscopic properties in the product. Unfortunately, such temperatures can result in the loss of some volatile constituents.

Date's method can produce material which can be applied in some cases, but the usefulness of the product is somewhat limited.

## USE OF 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 have been inserted on every page of Table 3. Readers are strongly urged not to use values from a Table before reading at least the notes concerning the issuing agencies of the samples of interest, or better still, the entire text of this paper. For example, it is important to understand the variation in the significance of the question mark in going from one issuing institution to another. In some cases, it would be advisable to study the compilations published by the originators of particular 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.

The Tables in this paper are arranged in a manner intended to improve their usefulness to the reader. Thus anyone preparing a calibration curve would begin by scanning Tables 4 or 5, then examining Table 3 to learn about the overall composition of potentially useful samples, and finally Table 2 to find where further information may be found in the text. Similarly, anyone interested in a particular sample type would begin with Table 1, and so on.

## ERRATA

★ Readers are requested to draw the author's attention to any errors they may observe in this paper. The preceding paper (Abbey, 1977a) had at least three errors: two different values for As in USGS-W-1, two for Be and two for Mo in NIM-L. One reader noticed the error in W-1; the others came to light only in the preparation of this paper.

## ACKNOWLEDGMENTS

The author is indebted to all of the contact officers under the various originating institutions for the preparation and distribution of the samples listed in this paper. Special thanks are due to Dr. A.R. Date, Josef Dempir, K. Govindaraju, G. Jecko, J.J. Lynch, Dr. Rolf Schindler, T.W. Steele and Dr. Zdenek Valcha for supplying unpublished information and other valuable exchanges, as well as to Dr. J.A. Maxwell for critical reading of the manuscript.

\* See p. 14 ES 681-1 mis-typed.

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Table 2

## Alphabetical Listing of Samples

Sample No.	Type	Source	Country	Ref. Page
AGV-1	Andesite	USGS	U.S.A.	5
AN-G	Anorthosite	ANRT	France	7
ASK-1	Larvikite	ASK	Scandinavia	6
ASK-2	Schist			
BCR-1	Basalt	USGS	U.S.A.	5
BCS-267	Silica Brick	BCS	U.K.	6
BCS-309	Sillimanite			
BCS-313	Pure Silica			
BCS-367	Blast Furnace Slag			
BCS-375	Soda Feldspar			
BCS-376	Potash Feldspar			
BE-N	Basalt	ANRT	France	7
BHVO-1	Basalt	USGS	U.S.A.	5
BIR-1	Basalt			
BM	Basalt	ZGI	East Germany	8
BR	Basalt	CRPG	France	7
BX-N	Bauxite	ANRT	France	7
DNC-1	Diabase	USGS	U.S.A.	5
DR-N	Diorite	ANRT	France	7
DT-N	Kyanite			
DTS-1	Dunite	USGS	U.S.A.	5
ES- <del>871</del> -1	Iron Ore	BCS	U.K.	6
ES-878-1	Blast Furnace Slag	IRSID	France	7
FK	Feldspar Sand	ZGI	East Germany	8
FK-N	Potash Feldspar	ANRT	France	7
G-2	Granite	USGS	U.S.A.	5
GA	Granite	CRPG	France	7
GH	Granite			
GL-O	Glaucinite	ANRT	France	7
GM	Granite	ZGI	East Germany	8
GnA	Greisen			
GS-N	Granite	ANRT	France	7
GSP-1	Granodiorite	USGS	U.S.A.	5
GXR-1	Jasperoid	USGS AEG	U.S.A.	5
GXR-2	Soil			
GXR-3	"Deposit"			
GXR-4	"Mill-head"			
GXR-5	Soil			
GXR-6	Soil			
I-1	Aplitic Granite	QMC	U.K.	6
I-3	Dolerite			
JA-1	Andesite	GSJ	Japan	8
JB-1	Basalt			
JB-2	Basalt			
JG-1	Granodiorite			
KK	Kaolinite	UNS	Czechoslovakia	7
M-2	Pelitic Schist	QMC	U.K.	6
M-3	Calc Silicate			
MAG-1	Marine Mud	USGS	U.S.A.	5
MA-N	Granite	ANRT	France	7
Mica Fe	Biotite	CRPG	France	7
Mica Mg	Phlogopite			

Sample No.	Type	Source	Country	Ref. Page
MO8-1	Ferriferous Marl	IRSID	France	7
MRG-1	Gabbro	CCRMP	Canada	4
NBS-69a	Bauxite	NBS	U.S.A.	6
NBS-69b	Bauxite			
NBS-70a	Potash Feldspar			
NBS-81a	Glass Sand			
NBS-91	Opal Glass			
NBS-97a	Flint Clay			
NBS-98a	Plastic Clay			
NBS-99a	Soda Feldspar			
NBS-165a	Glass Sand			
NBS-697	Bauxite			
NBS-1633	Fly Ash			
NIM-D (SARM 6)	Dunite	NIM	South Africa	9
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			
NS-1 (KG-1,etc.)	Syenite	LEN	U.S.S.R.	8
PCC-1	Peridotite	USGS	U.S.A.	5
QLO-1	Quartz Latite			
RGM-1	Rhyolite			
SG-1A (2005)	Albitized Granite	IGI	U.S.S.R.	8
SGD-1A (2003)	Gabbro			
SCo-1	Shale	USGS	U.S.A.	5
SDC-1	Mica Schist			
SGR-1	Shale			
SL-1	Blast Furnace Slag	CCRMP	Canada	4
SO-1	Soil			
SO-2	Soil			
SO-3	Soil			
SO-4	Soil			
SOIL-5	Soil	IAEA	International	7
SS	Glass Sand	UNS	Czechoslovakia	7
ST-1A (2001)	Trap	IGI	U.S.S.R.	8
STM-1	Syenite	USGS	U.S.A.	5
SW	Serpentine	ZGI	East Germany	8
SY-2	Syenite	CCRMP	Canada	4
SY-3	Syenite			
T-1	Tonalite	MRT	Tanzania	9
TB	Slate	ZGI	East Germany	8
TS	Shale			
UB-N	Serpentine	ANRT	France	7
VS-N	Synthetic Glass			
W-1	Diabase	USGS	U.S.A.	5
W-2	Diabase			

Table 3

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

C C R M P									
	Gabbro MRG-1	Bl. Furn. Slag SL-1	Soil SO-1	Soil SO-2	Soil SO-3	Soil SO-4	Syenite SY-2	Syenite SY-3	
SiO <sub>2</sub>	39.32	35.73	55.02	53.46	33.93	68.5 ?	60.10	59.68	SiO <sub>2</sub>
TiO <sub>2</sub>	3.69	0.38?	0.88	1.43	0.32?	0.57	0.14	0.15	TiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub>	8.50	9.63	17.72	15.24	5.76	10.32	12.12	11.80	Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub>	8.26						2.28	2.44	Fe <sub>2</sub> O <sub>3</sub>
FeO	8.63	0.92 <sup>4</sup>					3.62	3.58	FeO
MnO	0.17	0.86?	0.11	0.09	0.07	0.08	0.32	0.32	MnO
MgO	13.49	12.27	3.83	0.90	8.47?	0.93	2.70	2.67	MgO
CaO	14.77	37.48	2.52	2.74	20.7 ?	1.55	7.98	8.26	CaO
Na <sub>2</sub> O	0.71	0.39?	2.56?	2.35?	1.00	1.31?	4.34	4.15	Na <sub>2</sub> O
K <sub>2</sub> O	0.18	0.51?	3.23	2.95	1.40	2.08	4.48	4.20	K <sub>2</sub> O
H <sub>2</sub> O <sup>+</sup>	0.98						0.43	0.42	H <sub>2</sub> O <sup>+</sup>
CO <sub>2</sub>	1.00		4.4 ? <sup>5</sup>	11.5? <sup>5</sup>	25.3 ? <sup>5</sup>	10.4 ? <sup>5</sup>	0.46	0.38	CO <sub>2</sub>
P <sub>2</sub> O <sub>5</sub>	0.06	0.02?	0.14	0.69?	0.11?	0.21	0.43	0.54	P <sub>2</sub> O <sub>5</sub>
F	0.025	See text	0.07?	0.05?	0.03?	0.03?	0.51	0.66	F
S	0.06	1.26	0.01?	0.03?	0.02?	0.04?	0.011	0.05	S
Others <sup>1</sup>	0.33?	0.01?	0.27?	0.31?	0.10?	0.19?	0.43?	1.18?	Others <sup>1</sup>
Σ	100.18?	99.46?	99.33?	99.69?	99.37?	99.60?	100.35?	100.48?	Σ
O/F, S, Cl			0.03?	0.04?	0.02?	0.03?		0.31?	O/F, S, Cl
Σ (corr.)	100.14?	?	99.30?	99.65?	99.35?	99.57?	100.13?	100.17?	Σ (corr.)
Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>	17.82	1.02	8.57	7.95	2.16	3.39	6.28	6.42	Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>
Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>	17.85						6.27	6.42	Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>

<sup>1</sup>"Trace elements" (see Table 5), converted to oxides, where appropriate.<sup>2</sup>Total iron, expressed as ferric oxide, derived from reported values for total iron.<sup>3</sup>Total iron, expressed as ferric oxide, calculated from values derived for ferric and ferrous, based on reported values for ferric and ferrous.<sup>4</sup>Total iron, expressed as ferrous oxide.<sup>5</sup>Loss on ignition.

## U S G S

	Andesite AGV-1	Basalt BCR-1	Basalt BHVO-1 <sup>4</sup>	Dunite DTS-1	Granite G-2	Grano- diorite GSP-1	Marine Mud MAG-1 <sup>4</sup>	Perid- otite PCC-1	Quartz Latite QLO-1 <sup>4</sup>	Rhyolite RGM-1 <sup>4</sup>	Shale SCo-1 <sup>4</sup>	
SiO <sub>2</sub>	59.61	54.53	49.9 ?	40.61	69.22	67.32	50.9 ?	42.10	65.5 ?	73.4 ?	62.8 ?	SiO <sub>2</sub>
TiO <sub>2</sub>	1.06	2.26	2.7 ?	0.00?	0.48	0.66	0.73?	0.01	0.62?	0.27?	0.64?	TiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub>	17.19	13.72	13.7 ?	0.25	15.40	15.28	16.4 ?	0.73	16.2 ?	13.8 ?	13.6 ?	Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub>	4.56	3.48	2.7 ?	1.02?	1.07	1.70		2.54?	1.0 ?	0.5 ?		Fe <sub>2</sub> O <sub>3</sub>
FeO	2.03	8.96	8.5 ?	6.94?	1.44	2.32		5.17?	3.0 ?	1.2 ?		FeO
MnO	0.10	0.18	0.17?	0.12	0.03	0.04	0.10?	0.12	0.09?	0.04?	0.05?	MnO
MgO	1.52	3.48	7.2 ?	49.80	0.75	0.97	3.0 ?	43.50	1.0 ?	0.28?	2.6 ?	MgO
CaO	4.94	6.97	11.4 ?	0.14	1.96	2.03	1.35?	0.55	3.2 ?	1.1 ?	2.6 ?	CaO
Na <sub>2</sub> O	4.32	3.30	2.3 ?	0.01?	4.06	2.81	3.8 ?	0.01	4.2 ?	4.1 ?	0.9 ?	Na <sub>2</sub> O
K <sub>2</sub> O	2.92	1.70	0.53?	0.00	4.46	5.51	3.6 ?	0.00	3.6 ?	4.3 ?	2.7 ?	K <sub>2</sub> O
H <sub>2</sub> O <sup>+</sup>	0.78	0.67		0.42	0.50	0.58		4.70				H <sub>2</sub> O <sup>+</sup>
CO <sub>2</sub>	0.02	0.02		0.07	0.08?	0.12		0.18				CO <sub>2</sub>
P <sub>2</sub> O <sub>5</sub>	0.51	0.36	0.28?	0.00?	0.13	0.28		0.01				P <sub>2</sub> O <sub>5</sub>
F	0.04	0.05		0.00?	0.12	0.37		0.00?				F
S	0.01?	0.04?		0.00?	0.01?	0.03?		0.01?				S
Others <sup>1</sup>	0.32?	0.27?		0.93?	0.41?	0.42?		0.76?				Others <sup>1</sup>
Σ	99.93?	99.99?		100.31?	100.12?	100.44?		100.39?				Σ
O/F, S, Cl		0.04?		0.00?	0.06?	0.18?		0.01?				O/F, S, Cl
Σ (corr.)	99.90?	99.95?		100.31?	100.06?	100.26?		100.38?				Σ (corr.)
Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>	6.78	13.41	12.0 ?	8.70	2.69	4.30	6.8 ?	8.28	4.3 ?	1.9 ?	5.1 ?	Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>
Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>	6.82	13.44	12.1 ?	8.73?	2.67	4.28		8.29?	4.3 ?	1.8 ?		Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>

<sup>1</sup>"Trace elements" (see Table 5), converted to oxides, where appropriate.<sup>2</sup>Total iron, expressed as ferric oxide, derived from reported values for total iron.<sup>3</sup>Total iron, expressed as ferric oxide, calculated from values derived for ferric and ferrous, based on reported values for ferric and ferrous.<sup>4</sup>Incomplete.

Table 3 (cont'd.)

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

	U S G S				U S G S - A E G						
	Mica Schist SDC-1 <sup>4</sup>	Shale SGR-1 <sup>4,5</sup>	Syenite STM-1 <sup>4</sup>	Diabase W-1	Jasper-oid GXR-1 <sup>4</sup>	Soil GXR-2 <sup>4</sup>	"Deposit" GXR-3 <sup>4</sup>	"Mill-head" GXR-4 <sup>4</sup>	Soil GXR-5 <sup>4</sup>	Soil GXR-6 <sup>4</sup>	
SiO <sub>2</sub>	66.0 ?	28.3 ?	59.5 ?	52.72	49.2	49.2	13.0	67.0	42.1	49.0	SiO <sub>2</sub>
TiO <sub>2</sub>	1.0 ?	0.26?	0.13?	1.07	0.11	0.47	0.17	0.43	0.35	0.83	TiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub>	16.0 ?	6.5 ?	18.5 ?	15.02	6.7	35.1		14.0	39.3	31.4	Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub>			2.9 ?	1.40							Fe <sub>2</sub> O <sub>3</sub>
FeO			2.1 ?	8.73							FeO
MnO	0.12?	0.03?	0.22?	0.17		0.12	2.9	0.02	0.04	0.13	MnO
MgO	1.7 ?	4.5 ?	0.1 ?	6.63	0.35	1.45	1.05	2.7	2.0	1.02	MgO
CaO	1.4 ?		1.1 ?	10.98	1.22	1.15	19.7	1.26	1.05	0.14	CaO
Na <sub>2</sub> O	2.0 ?	3.0 ?	9.0 ?	2.15	0.07	0.75	1.05	0.71	1.04	0.14	Na <sub>2</sub> O
K <sub>2</sub> O	3.3 ?	1.6 ?	4.3 ?	0.64	0.06	1.70		5.2	0.99	2.5	K <sub>2</sub> O
H <sub>2</sub> O <sup>+</sup>				0.53							H <sub>2</sub> O <sup>+</sup>
CO <sub>2</sub>				0.06							CO <sub>2</sub>
P <sub>2</sub> O <sub>5</sub>			0.16	0.14							P <sub>2</sub> O <sub>5</sub>
F				0.025							F
S				0.012?							S
Others <sup>1</sup>				0.21 ?							Others <sup>1</sup>
Σ				100.48?							Σ
O/F, S, Cl				0.02?							O/F, S, Cl
Σ (corr.)				100.46?							Σ (corr.)
Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>	6.9 ?	3.2 ?	5.2 ?	11.11	35.3	2.7	26.6	4.2	4.6	8.0	Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>
Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>			5.2 ?	11.10							Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>

<sup>1</sup>"Trace elements" (see Table 5), converted to oxides, where appropriate.<sup>2</sup>Total iron, expressed as ferric oxide, derived from reported values for total iron.<sup>3</sup>Total iron, expressed as ferric oxide, calculated from values derived for ferric and ferrous, based on reported values for ferric and ferrous.<sup>4</sup>Incomplete.<sup>5</sup>Contains major amounts of petroleum.

	N B S											
	Bauxite 69a	Bauxite 69b	Potash Feldspar 70a	Glass Sand 81a <sup>4</sup>	Opal Glass 91	Flint Clay 97a	Plastic Clay 98a	Soda Feldspar 99a	Glass Sand 165a	Bauxite 697	Fly Ash 1633 <sup>4</sup>	
SiO <sub>2</sub>	6.01	13.4	67.1	(99+) <sup>5</sup>	67.53	43.67	48.94	65.2	(99+) <sup>5</sup>	6.80		SiO <sub>2</sub>
TiO <sub>2</sub>	2.78	2.0	0.01	0.12	0.019	1.90	1.61	0.007	0.011	2.6		TiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub>	55.0	49.3	17.9	0.66	6.01	38.79	33.19	20.5	0.059	45.7		Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub>												Fe <sub>2</sub> O <sub>3</sub>
FeO												FeO
MnO	0.02	0.09			0.008					0.35	0.064	MnO
MgO	0.02				0.008	0.15	0.42	0.02		0.17		MgO
CaO	0.29	0.12	0.11		10.48	0.11	0.31	2.14		0.60		CaO
Na <sub>2</sub> O	0.00	0.03	2.55		8.48	0.037	0.082	6.2		0.046		Na <sub>2</sub> O
K <sub>2</sub> O	0.00	0.80	11.8		3.25	0.50	1.04	5.2		0.07	2.07	K <sub>2</sub> O
L.O.I.	29.55	27.22	0.40		0.50 ?	13.32	12.44	0.26		22.2		L.O.I.
P <sub>2</sub> O <sub>5</sub>	0.08	0.12			0.022	0.36	0.11	0.02		0.90		P <sub>2</sub> O <sub>5</sub>
F					5.72							F
SO <sub>3</sub>	0.04	0.63								0.15		SO <sub>3</sub>
Others <sup>1</sup>	0.27?	0.04?	0.08?		0.38 ?	0.46 ?	0.21 ?	0.49		0.22 ?		Others <sup>1</sup>
Σ	99.86?	100.85?	100.02?		102.49 ?	99.75 ?	99.69 ?	100.04 ?		99.81 ?		Σ
O/F, S, Cl		?	?		2.41 ?	?	?	?				O/F, S, Cl
Σ (corr.)	99.86?	100.85?	100.02?		100.08 ?	99.75 ?	99.69 ?	100.04 ?		99.81 ?		Σ (corr.)
Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>	5.8	7.1	0.075	0.082	0.081	0.45	1.34	0.065	0.012	20.0		Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>
Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>												Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>

<sup>1</sup>"Trace elements" (see Table 5), converted to oxides, where appropriate.<sup>2</sup>Total iron, expressed as ferric oxide, derived from reported values for total iron.<sup>3</sup>Total iron, expressed as ferric oxide, calculated from values derived for ferric and ferrous, based on reported values for ferric and ferrous.<sup>4</sup>Incomplete.<sup>5</sup>Bracketed figures are not usable values; they are given as a mere general indication of composition.



Table 3 (cont'd.)

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

	B C S							Q M C				
	Silica Brick 267	Silli- manite 309	"Pure" Silica 313	Bl. Furn. Slag 367	Soda Feldspar 375	Potash Feldspar 376	Iron Ore ES-681-1	Aplitic Granite I-1	Dolerite I-3	Pelitic Schist M-2	Calc- Silicate M-3	
SiO <sub>2</sub>	95.9	34.1	99.6	34.4	67.1	67.1	17.8	75.36 ?	49.75?	48.88?	55.59?	SiO <sub>2</sub>
TiO <sub>2</sub>	0.17	1.92	0.022	0.75	0.38	0.01?	0.48	0.05	2.60	0.72	0.83	TiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub>	0.85	61.1	0.16	20.0	19.8	17.7	10.6	13.92 ?	13.07?	23.97?	17.62?	Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub>							37.81 ?	0.33 ?	5.09?	2.31?	0.91?	Fe <sub>2</sub> O <sub>3</sub>
FeO				1.00 <sup>b</sup>			8.70 ?	0.20 ?	10.04?	6.30?	3.33?	FeO
MnO	0.15	0.03?	0.00	1.16			0.28	0.03	0.22	0.26	0.28	MnO
MgO	0.06	0.17	0.00	7.1	0.05?	0.03?	1.48	0.11	4.18	2.45	1.21	MgO
CaO	1.75	0.22	0.02	32.4	0.89		3.92	0.80	8.20	1.75	12.01?	CaO
Na <sub>2</sub> O	0.06	0.34	0.00	0.44	10.4	2.83	0.092	4.59	2.92	1.40	2.98	Na <sub>2</sub> O
K <sub>2</sub> O	0.14	0.46	0.04	1.17	0.79	11.2	0.59	4.28	1.43	7.90	0.71	K <sub>2</sub> O
L.O.I.		0.08?			0.39?	0.35?	10.24 ?	0.13 ?	1.71?	3.21?	0.78?	H <sub>2</sub> O <sup>+</sup>
P <sub>2</sub> O <sub>5</sub>							6.60 ? <sup>5</sup>	?	?	?	2.98?	CO <sub>2</sub>
F				0.14 ?			2.02	0.02 ?	0.40?	0.50?	0.36?	P <sub>2</sub> O <sub>5</sub>
S				0.94			0.19		0.07?	0.10?	0.06?	F
Others <sup>1</sup>						0.00?	0.103	0.005?				S
							0.25 ?	0.11 ?	0.30?	0.34?	0.16?	Others <sup>1</sup>
Σ	99.87?	99.93?	99.84 ?	99.50 ?	99.92?	99.32?	See text	99.94 ?	99.98?	100.09?	99.81?	Σ
O/F, S, Cl				See text					0.03?	0.04?	0.03?	O/F, S, Cl
Σ (corr.)	99.87?	99.93?	99.84 ?		99.92?	99.32?		99.94 ?	99.95?	100.05?	99.78?	Σ (corr.)
Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>	0.79	1.51	0.025	1.11	0.12	0.10	47.48	0.54	16.22?	9.25	4.55	Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>
Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>							Note <sup>6</sup>	0.55 ?	16.25?	9.31?	4.61?	Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>

<sup>1</sup>"Trace elements" (see Table 5), converted to oxides, where appropriate.<sup>2</sup>Total iron, expressed as ferric oxide, derived from reported values for total iron.<sup>3</sup>Total iron, expressed as ferric oxide, calculated from values derived for ferric and ferrous, based on reported values for ferric and ferrous.<sup>4</sup>Total iron, expressed as ferrous oxide.<sup>5</sup>Total carbon, expressed as carbon dioxide.<sup>6</sup>Method used to derive Fe<sub>2</sub>O<sub>3</sub> value invalidates comparison.

	A S K		I R S I D		C R P G					
	Larvi- kite ASK-1 <sup>5</sup>	Schist ASK-2 <sup>5</sup>	Bl. Furn. Slag ES-878-1	Ferrf. Marl MO8-1	Basalt BR	Granite GA	Granite GH	Biotite MicaFe	Phlogo- pite MicaMg	
SiO <sub>2</sub>	(59.5) <sup>4</sup>	(54.2)	33.65	60.39	38.39	69.96	75.85	34.55	38.42?	SiO <sub>2</sub>
TiO <sub>2</sub>	(1.1)	(0.92)	0.619	0.714	2.61	0.38	0.08	2.51	1.64?	TiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub>	(18.6)	(18.8)	16.15	9.94	10.25	14.51	12.51	19.58	15.25?	Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub>				3.08	5.61	1.36	0.41	4.66	1.99?	Fe <sub>2</sub> O <sub>3</sub>
FeO				2.38	6.60	1.32	0.84	18.99	6.75?	FeO
MnO	0.13	0.04	1.268	0.057	0.20	0.09	0.05	0.35	0.26?	MnO
MgO	(1.1)	(2.0)	9.55	1.34	13.35	0.95	0.03	4.57	20.46?	MgO
CaO	(3.2)	(0.75)	35.65	8.70	13.87	2.45	0.69	0.43	0.08?	CaO
Na <sub>2</sub> O	(6.5)	(0.8)	0.466	0.54?	3.07	3.55	3.85	0.30	0.12?	Na <sub>2</sub> O
K <sub>2</sub> O	(4.2)	(5.3)	1.288	2.2 ?	1.41	4.03	4.76	8.79	10.03?	K <sub>2</sub> O
H <sub>2</sub> O <sup>+</sup>				3.0 ?	2.31	0.87	0.46	2.92?	2.10?	H <sub>2</sub> O <sup>+</sup>
CO <sub>2</sub>	(8.5) <sup>7</sup>			7.3 ?	0.86	0.11	0.14	0.19?	0.15?	CO <sub>2</sub>
P <sub>2</sub> O <sub>5</sub>			0.034	0.014	1.05	0.12	0.01	0.45	0.01?	P <sub>2</sub> O <sub>5</sub>
F			0.149	0.014	0.10	0.05	0.35	1.59	2.86?	F
S			0.812	0.455	0.039	?	?	?	?	S
Others <sup>1</sup>			?	0.05 ?	0.56 ?	0.25?	0.13?	1.09?	0.80?	Others <sup>1</sup>
Σ			100.50?	100.17 ?	100.28 ?	100.00?	100.16?	100.97?	100.92?	Σ
O/F, S, Cl			1.03?	0.23 ?	0.07 ?	0.03 ?	0.15?	0.68?	1.22?	O/F, S, Cl
Σ (corr.)			99.47?	99.94 ?	100.21 ?	99.97 ?	100.01?	100.29?	99.70?	Σ (corr.)
Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>	(4.6)	(6.9)	0.861	5.72	12.90	2.77	1.35	25.76	9.49?	Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>
Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>			Note <sup>6</sup>		12.94	2.83	1.34	Note <sup>6</sup>		Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>

<sup>1</sup>"Trace elements" (see Table 5), converted to oxides, where appropriate.<sup>2</sup>Total iron, expressed as ferric oxide, derived from reported values for total iron.<sup>3</sup>Total iron, expressed as ferric oxide, calculated from values derived for ferric and ferrous, based on reported values for ferric and ferrous.<sup>4</sup>Bracketed figures are not usable values; they are given as a mere general indication of composition.<sup>5</sup>Incomplete.<sup>6</sup>Method used to derive Fe<sub>2</sub>O<sub>3</sub> values invalidates comparison.<sup>7</sup>Total carbon.

Table 3 (cont'd.)

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

	A N R T								I A E A		U N S		
	Bauxite BX-N	Diorite DR-N	Kyanite DT-N	Potash Feldspar FK-N	Glauc- nite GL-O <sup>6</sup>	Granite GS-N	Serpen- tine UB-N	Synth. Glass VS-N <sup>8</sup>	Soil SOIL-5 <sup>8</sup>		Kaolin- ite KK	Glass Sand SS	
SiO <sub>2</sub>	7.39	52.88	36.52	65.11	52.22	65.98	39.93	(55.50) <sup>5</sup>	(71)		47.06	99.35	SiO <sub>2</sub>
TiO <sub>2</sub>	2.41	1.10	1.40	0.02 ?	0.07 ?	0.68	0.12	(1.08)	(0.8)		0.166	0.036	TiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub>	54.53	17.56	59.21	18.64	7.75	14.71	2.97	(13.44)	15.47		36.77	0.249	Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub>	22.98	3.78	0.55	0.024 ?	17.61	1.93	5.46						Fe <sub>2</sub> O <sub>3</sub>
FeO	0.26	5.32	0.10	0.06 ?	2.25	1.66	2.69						FeO
MnO	0.05	0.21	0.008	0.005 ?	0.008 ?	0.056	0.12	0.09	0.11 ?		0.015	0.001 ?	MnO
MgO	0.11	4.47	0.04	0.01 ?	4.58	2.31	35.4 ?	(4.51)	(2.5)		0.192	0.007	MgO
CaO	0.17	7.09	0.04	0.11	0.98	2.51	1.18	(4.53)	(3.1)		0.236	0.030	CaO
Na <sub>2</sub> O	0.06	3.00	0.04	2.58	0.04 ?	3.78	0.10	(5.95)	2.59		0.032	0.043	Na <sub>2</sub> O
K <sub>2</sub> O	0.07	1.73	0.12	12.83	8.16	4.64	0.02	(8.12)	2.24		1.063	0.057	K <sub>2</sub> O
H <sub>2</sub> O <sup>+</sup>	11.69	2.20	0.95 ?	0.32 ?	5.72	1.07	11.28				12.75		H <sub>2</sub> O <sup>+</sup>
CO <sub>2</sub>	0.45 ?	0.15	0.62 ? <sup>6</sup>	0.085 ?		0.18 ?	0.44				0.174	0.169 <sup>9</sup>	CO <sub>2</sub>
P <sub>2</sub> O <sub>5</sub>	0.13	0.25	0.09	0.024 ?	0.38	0.28	0.05	(0.02)	(0.2)		0.090		P <sub>2</sub> O <sub>5</sub>
F					0.15 ?								F
S											0.019		S
Others <sup>1</sup>	0.15 ?	0.20 ?	0.04 ?	0.14 ?	0.07 ?	0.33 ?	0.63 ?				0.22 ?	0.01 ?	Others <sup>1</sup>
Σ	100.48 ?	99.94 ?	99.73 ?	99.96 ?	99.99 ?	100.12 ?	100.39 ?				99.77 ?	99.99 ?	Σ
O/F, S, Cl					0.06 ?						0.01 ?		O/F, S, Cl
Σ (corr.)	100.48 ?	99.94 ?	99.73 ?	99.96 ?	99.93 ?	100.12 ?	100.39 ?				99.76 ?	99.99 ?	Σ (corr.)
Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>	23.27	9.69	0.66	0.09	20.11	3.76	8.45	(4.14)	6.36 ?		0.982	0.038	Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>
Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>			Note <sup>7</sup>			3.77	Note <sup>7</sup>						Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>

<sup>1</sup>"Trace elements" (see Table 5), converted to oxides, where appropriate.<sup>2</sup>Total iron, expressed as ferric oxide, derived from reported values for total iron.<sup>3</sup>Total iron, expressed as ferric oxide, calculated from values derived for ferric and ferrous, based on reported values for ferric and ferrous.<sup>4</sup>Dried for 15 h.<sup>5</sup>Bracketed figures are not usable values; they are given as a mere indication of composition.<sup>6</sup>Non-carbonate carbon.<sup>7</sup>Method used to derive Fe<sub>2</sub>O<sub>3</sub> values invalidates comparison.<sup>8</sup>Incomplete.<sup>9</sup>Loss on ignition.

	Z G I							L E N		I G I			
	Basalt BM	Feldspar Sand FK	Granite GM	Greisen GnA	Serpen- tine SW	Slate TB	Shale TS	Neph. Syenite NS-1		Albit. Granite SG-1A	Gabbro SGD-1A	Trap ST-1A	
SiO <sub>2</sub>	49.60	88.15 ?	73.55	71.45	39.05	60.30	62.71	53.22		73.36	46.39	49.12	SiO <sub>2</sub>
TiO <sub>2</sub>	1.14	0.059 ?	0.213	0.023	0.016	0.93	0.71	1.05		0.072	1.71	1.82	TiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub>	16.20	6.22 ?	13.50	14.7	0.66	20.55	15.94	21.31		13.84	14.88	14.23	Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub>	1.60		0.75	1.70	5.2 ?	0.91	6.72 ?	2.31		0.68	3.86	3.92	Fe <sub>2</sub> O <sub>3</sub>
FeO	7.28		1.14	3.80	2.0 ?	5.43	0.66 ?	1.60		1.41	6.86	10.26	FeO
MnO	0.145	0.006 ?	0.166	0.083	0.052	0.04	0.006 ?	0.18		0.19	0.17	0.21	MnO
MgO	7.46	0.16 ?	0.377	0.033	38.5	1.94	1.77	0.64		0.054	7.09	5.74	MgO
CaO	6.46	0.12 ?	1.04	0.61	0.18	0.33	0.13	1.70		0.14	10.97 ?	10.24 ?	CaO
Na <sub>2</sub> O	4.64	0.25 ?	3.76	0.08	0.013	1.31	0.09	9.85		5.46	2.82	2.49	Na <sub>2</sub> O
K <sub>2</sub> O	0.203	4.15 ?	4.74	2.63	0.014 ?	3.85	4.88	6.52		4.14	2.96	0.69	K <sub>2</sub> O
H <sub>2</sub> O <sup>+</sup>	3.62	0.41 ?	0.349	1.8 ?	13.6	3.82	4.03	0.66		0.21	0.83	0.97	H <sub>2</sub> O <sup>+</sup>
CO <sub>2</sub>	1.34	0.025 ?	0.278	0.04 ?	0.29 ?	0.13	0.04 ?	0.14 ?		0.073 ?	0.128	0.099	CO <sub>2</sub>
P <sub>2</sub> O <sub>5</sub>	0.105	0.075 ?	0.063	0.016 ?	0.10	0.29	0.075 ?	0.28		0.013	1.01	0.21	P <sub>2</sub> O <sub>5</sub>
F	0.026 ?		0.067 ?	3.36	0.007 ?	0.071 ?	0.118 ?	0.14		0.30	0.12	0.032 ?	F
S				0.016 ?				0.01 ?		0.017	0.020	0.068	S
Others <sup>1</sup>	0.15 ?	0.02 ?	1.13 ?	0.68 ?	0.22 ?	1.89 ?	0.02 ?	0.54 ?		0.48 ?	0.63 ?	0.30 ?	Others <sup>1</sup>
Σ	99.97 ?	99.90 ?	100.00 ?	101.55 ?	100.32 ?	99.94 ?	100.04 ?	100.15 ?		100.44 ?	100.45 ?	100.36 ?	Σ
O/F, S, Cl		0.01 ?	0.03 ?	1.41 ?	0.00 ?	0.03 ?	0.05 ?	0.08 ?		0.13 ?	0.07 ?	0.06 ?	O/F, S, Cl
Σ (corr.)	99.96 ?	99.90 ?	99.97 ?	100.14 ?	100.32 ?	99.91 ?	99.99 ?	100.07 ?		100.31 ?	100.38 ?		Σ (corr.)
Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>	9.68	0.26 ?	2.02	5.92	7.40	6.92	7.45	4.10		2.25	11.48	15.32	Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>
Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>	9.69		2.02	Note <sup>4</sup>		6.94	7.45	4.09		Note <sup>4</sup>			Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>

<sup>1</sup>"Trace elements" (see Table 5), converted to oxides, where appropriate.<sup>2</sup>Total iron, expressed as ferric oxide, derived from reported values for total iron.<sup>3</sup>Total iron, expressed as ferric oxide, calculated from values derived for ferric and ferrous, based on reported values for ferric and ferrous.<sup>4</sup>Method used to derive Fe<sub>2</sub>O<sub>3</sub> values invalidates comparison.

Table 3 (cont'd.)

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

	G S J		M R T		N I M					
	Basalt JB-1	Grano- diorite JG-1	Tonalite T-1	Dunite NIM-D	Granite NIM-G	Lujav- rite NIM-L	Norite NIM-N	Pyroxen- ite NIM-P	Syenite NIM-S	
SiO <sub>2</sub>	52.60?	72.36	62.70	38.96	75.70	52.40	52.64	51.10	63.63	SiO <sub>2</sub>
TiO <sub>2</sub>	1.34	0.27	0.58	0.02	0.09	0.48	0.20	0.20	0.04	TiO <sub>2</sub>
Al <sub>2</sub> O <sub>3</sub>	14.62	14.20	16.69	0.3 ?	12.08	13.64	16.50	4.18	17.34	Al <sub>2</sub> O <sub>3</sub>
Fe <sub>2</sub> O <sub>3</sub>	2.36	0.37	2.71	0.71	0.6 ?	8.74 <sup>4</sup>	0.8 ?	1.02? <sup>4</sup>	1.07 <sup>4</sup>	Fe <sub>2</sub> O <sub>3</sub>
FeO	6.02	1.62	2.88	14.63	1.30	1.13	7.30	10.59	0.30	FeO
MnO	0.15	0.06	0.10	0.22	0.02	0.77	0.18	0.22	0.01	MnO
MgO	7.76	0.76	1.89	43.51	0.06?	0.28	7.50	25.33	0.46	MgO
CaO	9.35	2.17	5.08	0.28	0.78	3.22	11.50	2.66	0.68	CaO
Na <sub>2</sub> O	2.79	3.39	4.39	0.04?	3.36	8.37	2.46	0.37	0.43	Na <sub>2</sub> O
K <sub>2</sub> O	1.42	3.96	1.24	0.01?	4.99	5.51	0.25	0.09	15.35	K <sub>2</sub> O
H <sub>2</sub> O <sup>+</sup>	1.01	0.54	1.52	0.30	0.49	2.31	0.33	0.26	0.22	H <sub>2</sub> O <sup>+</sup>
CO <sub>2</sub>	0.18?	0.08?	0.07?	0.40?	0.10?	0.17	0.10?	0.08?	0.09	CO <sub>2</sub>
P <sub>2</sub> O <sub>5</sub>	0.26	0.09	0.14	0.02?	0.01	0.06	0.03	0.02	0.12	P <sub>2</sub> O <sub>5</sub>
F	0.04?	0.05?	0.05?	0.01?	0.42	0.44	0.03	0.02	0.01	F
S	?	?	0.01?	0.02	0.01	0.065?	0.01	0.02	0.01	S
Others <sup>1</sup>	0.28?	0.15?	0.19?	0.76?	0.19?	2.39 ?	0.12?	3.69?	0.34?	Others <sup>1</sup>
Σ	100.18?	100.07?	100.24?	100.19?	100.20?	99.98 ?	99.95?	99.85?	100.10?	Σ
O/F, S, Cl	0.02?	0.02?	0.03?	0.02?	0.19?	0.25 ?	0.02?	0.02?	0.01?	O/F, S, Cl
Σ (corr.)	100.16?	100.05?	100.21?	100.17?	100.01?	99.73 ?	99.93?	99.83?	100.09?	Σ (corr.)
Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>	9.01	2.16	5.90	16.96 <sup>4</sup>	2.02 <sup>4</sup>	9.96 <sup>4</sup>	8.91 <sup>4</sup>	12.76 <sup>4</sup>	1.40	Fe <sub>2</sub> O <sub>3</sub> TR <sup>2</sup>
Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>	9.05	2.17	5.91	16.97	2.04?	10.00 <sup>4</sup>	8.89? <sup>4</sup>	12.79? <sup>4</sup>	1.40 <sup>4</sup>	Fe <sub>2</sub> O <sub>3</sub> TC <sup>3</sup>

<sup>1</sup>"Trace elements" (see Table 5), converted to oxides, where appropriate.<sup>2</sup>Total iron, expressed as ferric oxide, derived from reported values for total iron.<sup>3</sup>Total iron, expressed as ferric oxide, calculated from values derived for ferric and ferrous, based on reported values for ferric and ferrous.<sup>4</sup>Not originators' values - see text.

Table 4

Usable values, arranged by major and minor components  
(per cent, dry basis)

SiO <sub>2</sub>	SiO <sub>2</sub> (cont'd.)	SiO <sub>2</sub> (cont'd.)	TiO <sub>2</sub> (cont'd.)	TiO <sub>2</sub> (cont'd.)
99.6 BCS-313	55.59 ? M-3	34.55 MicaFe	1.05 NS-1	0.17 KK
99.35 SS	55.02 SO-1	34.4 BCS-367	1.0 ? SDC-1	0.15 SY-3
95.9 BCS-267	54.53 BCR-1	34.1 BCS-309	0.93 TB	0.14 SY-2
88.15 ? FK	53.46 SO-2	33.93 SO-1	0.88 SO-1	0.13 ? STM-1
75.85 GH	53.22 NS-1	33.65 ES-878-1	0.83 GXR-6	0.12 NBS-81a
75.70 NIM-G	52.88 DR-N	28.3 ? SGR-1	0.83 M-3	0.12 UB-N
75.36 ? I-1	52.72 W-1	17.8 ES-681-1	0.75 BCS-367	0.11 GXR-1
73.55 GM	52.64 NIM-N	13.4 NBS-69b	0.73 ? MAG-1	0.09 NIM-G
73.4 ? RGM-1	52.60 ? JB-1	13.0 GXR-3	0.72 M-2	0.08 GH
73.36 SG-1A	52.40 NIM-L <sub>1</sub>	7.39 BX-N	0.71 MO8-1	0.07 SG-1A
72.36 JG-1	52.22 GL-O	6.80 NBS-697	0.71 TS	0.07 ? GL-O
71.45 GnA	51.10 NIM-P	6.01 NBS-69a	0.68 GS-N	0.06 ? FK
69.96 GA	50.9 ? MAG-1		0.66 GSP-1	0.05 I-1
69.22 G-2	49.9 ? BHVO-1		0.64 ? SCo-1	0.04 NIM-S
68.5 ? SO-4	49.75 ? I-3		0.62 ES-878-1	0.04 SS
67.53 NBS-91	49.60 BM	3.69 MRG-1	0.62 ? QLO-1	0.02 BCS-313
67.32 GSP-1	49.2 GXR-1	2.78 NBS-69a	0.58 T-1	0.02 GnA
67.1 BCS-375	49.2 GXR-2	2.7 ? BHVO-1	0.57 SO-4	0.02 NBS-91
67.1 BCS-376	49.12 ST-1A	2.61 BR	0.48 ES-681-1	0.02 NIM-D
67.1 NBS-70a	49.0 GXR-6	2.60 I-3	0.48 G-2	0.02 SW
67.0 GXR-4	48.94 NBS-98a	2.6 NBS-697	0.48 NIM-L	0.02 ? FK-N
66.0 ? SDC-1	48.88 ? M-2	2.51 MicaFe	0.47 GXR-2	0.01 BCS-367
65.98 GS-N	47.06 KK	2.41 BX-N	0.43 GXR-4	0.01 NBS-70a
65.5 ? QLO-1	46.39 SGD-1A	2.26 BCR-1	0.38 BCS-375	0.01 NBS-99a
65.2 NBS-99a	43.67 NBS-97a	2.0 NBS-69b	0.38 GA	0.01 NBS-165a
65.11 FK-N	42.10 PCC-1	1.92 BCS-309	0.38 ? SL-1	0.01 PCC-1
63.63 NIM-S	42.1 GXR-5	1.90 NBS-97a	0.35 GXR-5	
62.8 ? SCo-1	40.61 DTS-1	1.82 ST-1A	0.32 ? SO-3	Al <sub>2</sub> O <sub>3</sub>
62.71 TS	39.93 UB-N	1.61 NBS-98a	0.27 JG-1	
62.70 T-1	39.32 MRG-1	1.43 SO-2	0.27 ? RGM-1	61.1 . BCS-309
60.39 MO8-1	39.05 SW	1.40 DT-N	0.26 ? SGR-1	59.21 DT-N
60.30 TB	38.96 NIM-D	1.34 JB-1	0.21 GM	55.0 NBS-69a
60.10 SY-2	38.42 ? MicaMg	1.14 BM	0.20 NIM-N	54.53 BX-N
59.68 SY-3	38.39 BR	1.10 DR-N	0.20 NIM-P	49.3 NBS-69b
59.61 AGV-1	36.52 DT-N	1.07 W-1	0.17 BCS-267	45.7 NBS-697
59.5 ? STM-1	35.73 SL-1	1.06 AGV-1	0.17 GXR-3	39.3 GXR-5

Table 4 (cont'd.)

Usable values, arranged by major and minor components  
(per cent, dry basis)

Al <sub>2</sub> O <sub>3</sub> (cont'd.)	Fe <sub>2</sub> O <sub>3</sub>	FeO (cont'd.)	MnO (cont'd.)	MgO (cont'd.)
38.79 NBS-97a	37.81 ES-681-1	2.88 T-1	0.07 SO-3	0.93 SO-4
36.77 KK	22.98 BX-N	2.69 UB-N	0.06 GS-N	0.90 SO-2
35.1 GXR-2	17.61 GL-O	2.38 MO8-1	0.06 JG-1	0.76 JG-1
33.19 NBS-98a	8.74 NIM-L	2.32 GSP-1	0.06 MO8-1	0.75 G-2
31.4 GXR-6	8.26 MRG-1	2.25 GL-O	0.06 NBS-1633	0.64 NS-1
23.97 ? M-2	6.72 ? TS	2.1 ? STM-1	0.05 BX-N	0.46 NIM-S
21.31 NS-1	5.61 BR	2.03 AGV-1	0.05 GH	0.42 NBS-98a
20.55 TB	5.46 UB-N	2.0 ? SW	0.05 TB	0.38 GM
20.5 NBS-99a	5.20 SW	1.66 GS-N	0.05? SCo-1	0.35 GXR-1
20.0 BCS-367	5.09 ? I-3	1.62 JG-1	0.04 ASK-2	0.28 NIM-L
19.8 BCS-375	4.66 MicaFe	1.60 NS-1	0.04 GM	0.28? RGM-1
19.58 MicaFe	4.56 AGV-1	1.44 G-2	0.04 GSP-1	0.19 KK
18.64 FK-N	3.92 ST-1A	1.41 SG-1A	0.04 GXR-5	0.17 BCS-309
18.5 ? STM-1	3.86 SGD-1A	1.32 GA	0.04 TS	0.17 NBS-697
17.9 NBS-70a	3.78 DR-N	1.30 NIM-G	0.04? RGM-1	0.16? FK
17.72 SO-1	3.48 BCR-1	1.2 ? RGM-1	0.03 G-2	0.15 NBS-97a
17.7 BCS-376	3.09 MO8-1	1.14 GM	0.03 I-1	0.11 BX-N
17.62 ? M-3	2.9 ? STM-1	1.13 NIM-L	0.03 NIM-G	0.11 I-1
17.56 DR-N	2.71 T-1	0.84 GH	0.03? BCS-309	0.1 ? STM-1
17.34 NIM-S	2.7 ? BHVO-1	0.66? TS	0.03? SGR-1	0.06 BCS-267
17.19 AGV-1	2.54 ? PCC-1	0.30 NIM-S	0.02 GXR-4	0.06? NIM-G
16.69 T-1	2.44 SY-3	0.26 BX-N	0.02 KK	0.05 SG-1A
16.50 NIM-N	2.36 JB-1	0.20? I-1	0.02 NBS-69a	0.05? BCS-375
16.4 ? MAG-1	2.31 NS-1	0.10 DT-N	0.01 DT-N	0.04 DT-N
16.20 BM	2.31 ? M-2	0.06 FK-N	0.01 NBS-91	0.03 GH
16.2 ? QLO-1	2.28 SY-2		0.01 NIM-S	0.03 Gna
16.15 ES-878-1	1.99 ? MicaMg	MnO	0.01? FK	0.03? BCS-376
16.0 ? SDC-1	1.93 GS-N		0.01? GL-O	0.02 NBS-69a
15.94 TS	1.70 Gna	2.9 GXR-3		0.02 NBS-99a
15.47 SOIL-5	1.70 GSP-1	1.27 ES-878-1	MgO	0.01 NBS-91
15.40 G-2	1.60 BM	1.16 BCS-367	49.80 DTS-1	0.01 SS
15.28 GSP-1	1.40 W-1	0.86 SL-1	43.51 NIM-D	0.01? FK-N
15.25 ? MicaMg	1.36 GA	0.77 NIM-L	43.50 PCC-1	
15.24 SO-2	1.07 G-2	0.35 MicaFe	38.5 ? SW	CaO
15.02 W-1	1.07 NIM-S	0.35 NBS-697	35.4 ? UB-N	37.48 SL-1
14.88 SGD-1A	1.02 ? DTS-1	0.32 SY-2	25.33 NIM-P	35.65 ES-878-1
14.71 GS-N	1.02 ? NIM-P	0.32 SY-3	20.46? MicaMg	32.4 BCS-367
14.7 Gna	1.0 ? QLO-1	0.28 ES-681-1	13.49 MRG-1	20.7 ? SO-3
14.62 JB-1	0.91 TB	0.28 M-3	13.35 BR	19.7 GXR-3
14.51 GA	0.91 ? M-3	0.26 M-2	12.27 SL-1	14.77 MRG-1
14.23 ST-1A	0.8 ? NIM-N	0.26? MicaMg	9.55 ES-878-1	13.87 BR
14.20 JG-1	0.75 GM	0.22 I-3	8.47? SO-3	12.01? M-3
14.0 GXR-4	0.71 NIM-D	0.22 NIM-D	7.76 JB-1	11.50 NIM-N
13.92 ? I-1	0.68 SG-1A	0.22 NIM-P	7.50 NIM-N	11.4 ? BHVO-1
13.84 SG-1A	0.6 ? NIM-G	0.22? STM-1	7.46 BM	10.98 W-1
13.8 ? RGM-1	0.55 DT-N	0.21 DR-N	7.2 ? BHVO-1	10.97? SGD-1A
13.72 BCR-1	0.5 ? RGM-1	0.21 ST-1A	7.1 BCS-367	10.48 NBS-91
13.7 ? BHVO-1	0.41 GH	0.20 BR	7.09 SGD-1A	10.24? ST-1A
13.64 NIM-L	0.37 JG-1	0.19 SG-1A	6.63 W-1	9.35 JB-1
13.6 ? SCo-1	0.33 ? I-1	0.18 BCR-1	5.74 ST-1A	8.70 MO8-1
13.50 GM	0.02 FK-N	0.18 NIM-N	4.58 GL-O	8.26 SY-3
13.07 ? I-3		0.18 NS-1	4.57 MicaFe	8.20 I-3
12.51 GH	FeO	0.17 Gna	4.5 ? SGR-1	7.98 SY-2
12.12 SY-2	18.99 MicaFe	0.17 MRG-1	4.47 DR-N	7.09 DR-N
12.08 NIM-G	14.63 NIM-D	0.17 SGD-1A	4.18 I-3	6.97 BCR-1
11.80 SY-3	10.59 NIM-P	0.17 W-1	3.83 SO-1	6.46 BM
10.60 ES-681-1	10.26 ST-1A	0.17? BHVO-1	3.48 BCR-1	5.08 T-1
10.32 SO-4	10.04? I-3	0.15 BCS-267	3.0 ? MAG-1	4.94 AGV-1
10.25 BR	8.96 BCR-1	0.15 JB-1	2.70 SY-2	3.92 ES-681-1
9.94 MO8-1	8.73 W-1	0.14 BM	2.7 GXR-4	3.22 NIM-L
9.63 SL-1	8.70? ES-681-1	0.13 ASK-1	2.67 SY-3	3.2 ? QLO-1
8.50 MRG-1	8.63 MRG-1	0.13 GXR-6	2.6 ? SCo-1	2.74 SO-2
7.75 GL-O	8.5 ? BHVO-1	0.12 DTS-1	2.45 M-2	2.66 NIM-P
6.7 GXR-1	7.30 NIM-N	0.12 GXR-2	2.31 GS-N	2.6 ? SCo-1
6.5 ? SGR-1	7.28 BM	0.12 PCC-1	2.0 GXR-5	2.52 SO-1
6.22 ? FK	6.94? DTS-1	0.12 UB-N	1.94 TB	2.51 GS-N
6.01 NBS-91	6.86 SGD-1A	0.12? SDC-1	1.89 T-1	2.45 GA
5.76 SO-3	6.75? MicaMg	0.11 SO-1	1.77 TS	2.17 JG-1
4.18 NIM-P	6.60 BR	0.11? SOIL-5	1.70 SDC-1	2.14 NBS-99a
2.97 UB-N	6.30? M-2	0.10 AGV-1	1.52 AGV-1	2.03 GSP-1
0.85 BCS-267	6.02 JB-1	0.10 T-1	1.48 ES-681-1	1.96 G-2
0.73 PCC-1	5.43 TB	0.09 GA	1.45 GXR-2	1.75 BCS-267
0.66 NBS-81a	5.32 DR-N	0.09 NBS-69b	1.34 MO8-1	1.75 M-2
0.66 SW	5.17 PCC-1	0.09 SO-2	1.21 M-3	1.70 NS-1
0.3 ? NIM-D	3.80 Gna	0.09 VS-N	1.05 GXR-3	1.55 SO-4
0.25 DTS-1	3.62 SY-2	0.09? QLO-1	1.02 GXR-6	1.4 ? SDC-1
0.25 SS	3.58 SY-3	0.08 Gna	1.0 ? QLO-1	1.35? MAG-1
0.16 BCS-313	3.33? M-3	0.08 SO-4	0.97 GSP-1	1.26 GXR-4
0.06 NBS-165a	3.0 ? QLO-1	0.08 SW	0.95 GA	1.22 GXR-1

Usable values, arranged by major and minor components  
(per cent. dry basis)

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Table 4 (cont'd.)

Usable values, arranged by major and minor components  
(per cent, dry basis)

F (cont'd.)	S (cont'd.)	Fe <sub>2</sub> O <sub>3</sub> T	Fe <sub>2</sub> O <sub>3</sub> T (cont'd.)	Fe <sub>2</sub> O <sub>3</sub> T (cont'd.)
0.06? M-3	0.06 MRG-1	47.48 ES-681-1	8.0 GXR-6	2.69 G-2
0.05 BCR-1	0.06? NIM-L	35.3 GXR-1	7.95 SO-2	2.25 SG-1A
0.05 GA	0.05 SY-3	26.6 GXR-3	7.45 TS	2.16 JG-1
0.05? JG-1	0.04 BR	25.76 MicaFe	7.40 SW	2.16 SO-3
0.05? SO-2	0.04? BCR-1	23.27 BX-N	7.1 NBS-69b	2.02 GM
0.05? T-1	0.03? GSP-1	20.11 GL-O	6.92 TB	2.02 NIM-G
0.04 AGV-1	0.02 GnA	20.0 NBS-697	6.9 ? SDC-1	1.9 ? RGM-1
0.04? JB-1	0.02 NIM-D	17.82 MRG-1	6.8 ? MAG-1	1.51 BCS-309
0.03 NIM-N	0.02 NIM-P	16.96 NIM-D	6.78 AGV-1	1.40 NIM-S
0.03? BM	0.02 SG-1A	16.22? I-3	6.42 SY-3	1.35 GH
0.03? SO-3	0.02 SGD-1A	15.32 ST-1A	6.36 SO-5	1.34 NBS-98a
0.03? SO-4	0.02? KK	13.41 BCR-1	6.28 SY-2	1.11 BCS-367
0.03? ST-1A	0.01 NIM-G	12.90 BR	5.92 GnA	1.02 SL-1
0.02 MRG-1	0.01 NIM-N	12.76 NIM-P	5.90 T-1	0.98 KK
0.02 NIM-P	0.01 NIM-S	12.0 ? BHVO-1	5.8 NBS-69a	0.86 ES-878-1
0.02 W-1	0.01 SY-2	11.48 SGD-1A	5.72 MO8-1	0.79 BCS-267
0.01 MO8-1	0.01? AGV-1	11.11 W-1	5.2 ? STM-1	0.66 DT-N
0.01 NIM-S	0.01? G-2	9.96 NIM-L	5.1 ? SCo-1	0.54 I-1
0.01? DTS-1	0.01? NS-1	9.69 DR-N	4.6 GXR-5	0.45 NBS-97a
0.01? SW	0.01? PCC-1	9.68 BM	4.55 M-3	0.26 FK
	0.01? T-1	9.49? MicaMg	4.30 GSP-1	0.12 BCS-375
	0.01? W-1	9.25 M-2	4.3 ? QLO-1	0.10 BCS-376
		9.01 JB-1	4.2 GXR-4	0.08 NBS-70a
	SO <sub>3</sub>	8.91 NIM-N	4.10 NS-1	0.08 NBS-81a
1.26 SL-1		8.70 DTS-1	3.76 GS-N	0.08 NBS-91
0.94 BCS-367		8.57 SO-1	3.39 SO-4	0.06 NBS-99a
0.81 ES-878-1	0.63 NBS-69b	8.45 UB-N	3.2 ? SGR-1	0.04 SS
0.46 MO8-1	0.15 NBS-697	8.28 PCC-1	2.77 GA	0.02 BCS-313
0.10 ES-681-1	0.04 NBS-69a		2.7 GXR-2	0.01 NBS-165a
0.07 ST-1A				

Table 5

Usable values, arranged by "trace elements"

Ag ppm	As ppm (cont'd.)	pct As <sub>2</sub> O <sub>3</sub> T	B ppm (cont'd.)	pct B <sub>2</sub> O <sub>3</sub>	Ba ppm (cont'd.)	pct BaO
0.4 ASK-2	1.9? SO-1		13? GM		900 VS-N	0.10
0.14? MRG-1	1.2? SO-2		13? MRG-1		900? SO-1	0.10
	0.8? AGV-1		13? NIM-S		850 GA	0.09
	0.8? BCR-1		12? JB-1		780? SO-4	0.09
	0.7 MRG-1		11? GXR-6		760? RGM-1	0.08
	0.25? G-2		10 SG-1A		720 TB	0.08
	0.09? GSP-1		10? BR		690? I-3	0.08
	0.05? PCC-1		8? NIM-G		680 BCR-1	0.08
	0.03? DTS-1		6? AGV-1		670 NBS-97a	0.07
			6? JG-1		670 T-1	0.07
			6? PCC-1		630? SDC-1	0.07
			4 BCR-1		560 GXR-1	0.06
			4? GXR-4		560 SOIL-5	0.06
			4? NIM-D		560? SCo-1	0.06
			2? G-2		550? STM-1	0.06
					490 JB-1	0.05
					480? I-1	0.05
					480? MAG-1	0.05
					460 JG-1	0.05
					460 SY-2	0.05
					450 NIM-L	0.05
					430 SY-3	0.05
					380 DR-N	0.05
					330 GM	0.04
					300? SGR-1	0.03
					290 ST-1A	0.03
					280? SO-3	0.03
					260 BM	0.03
					230 NBS-99a	0.03
					210? FK-N	0.02
					180 NBS-70a	0.02
					160 W-1	0.02
					145 MicaFe	0.02
					130? BHVO-1	0.01
					125? M-3	0.01
					120? NIM-G	0.01
					100 NIM-N	0.01
					90 NBS-69a	0.01
					80 NBS-697	0.01

  

As ppm	pct As <sub>2</sub> O <sub>3</sub> T*	Ba ppm	pct BaO
4000 GXR-3	0.53	4700 GXR-3	0.52
1350 NBS-91	0.18	4000? MicaMg	0.45
460 GXR-1	0.06	2700? NBS-1633	0.30
340 GXR-6	0.04	2400 NIM-S	0.27
110? ES-681-1	0.01	2300 NBS-99a	0.26
98 GXR-4	0.01	2000 GXR-2	0.22
94 SOIL-5	0.01	1950? TS	0.22
61 NBS-1633	0.01	1900 G-2	0.21
47? GnA	0.01	1800 GXR-5	0.20
31 GXR-2		1550? M-2	0.17
30 MO8-1		1400? GS-N	0.16
20 SY-3		1350 GXR-4	0.15
18 SY-2		1300 GSP-1	0.15
14? BM		1300 SGD-1A	0.15
12 GXR-5		1300? QLO-1	0.15
7.1? SO-4		1200 AGV-1	0.13
4? GM		1200 NS-1	0.13
2.6? SO-3		1150 ASK-1	0.13
1.9 W-1		1100 GXR-6	0.12
		1050 BR	0.12
		1000? SO-2	0.11

\*Total arsenic, expressed as As<sub>2</sub>O<sub>3</sub>.

Table 5 (cont'd.)

Usable values, arranged by "trace elements"

Ba ppm (cont'd.)			pct BaO	C (non-carbonate)			Ce ppm (cont'd.)	pct CeO <sub>2</sub>	Co ppm (cont'd.)			pct CoO
50?	MRG-1		0.01	ppm		pct	23?	BM	16	AGV-1		
47?	GnA		0.01		TS	1.39	23?	W-1	16	GXR-4		
46?	NIM-P		0.01	6200	DT-N	0.62	22?	ST-1A	16?	FK-N		
40?	UB-N			1400	KK	0.14	19?	GXR-1	15	SOIL-5		
22	GH			360	ST-1A	0.04	16?	GXR-3	15?	SO-4		
21	SW			280	SGD-1A	0.03	11?	NIM-S	14	GXR-6		
19	SG-1A			270?	SY-2	0.02	10?	NIM-N	14?	DT-N		
10?	NIM-D			250?	MRG-1	0.02			13	TB		
5?	DTS-1			250?	SY-3	0.02	Cl ppm	pct Cl	13?	SO-2		
4?	PCC-1			240?	SG-1A	0.02			13?	T-1		
Be ppm			pct BeO	65?	BCR-1	0.01			12	SY-3		
50?	NIM-P		0.01	C (total)					12?	SO-3		
26?	GXR-3		0.01	ppm		pct	1300	MAG-1	11	SY-2		
23	SY-2		0.01		SO-3	6.6?	800?	NIM-L	11?	SGR-1		
22	SY-3		0.01		SO-2	4.8?	500?	MicaMg	10?	M-3		
20?	NIM-L		0.01		SO-4	4.4?	500?	MicaFe	10?	SCo-1		
12?	KK				ES-681-1	1.8	500?	NS-1	9	GXR-1		
12?	NBS-1633				TS	1.4	430?	RGM-1	9	GXR-2		
11	SG-1A				MRG-1	0.30	400	STM-1	8?	NS-1		
10?	STM-1				SO-1	0.25	370?	ST-1A	7.8	GSP-1		
8?	MicaFe				KK	0.19	340	NIM-D	7?	QLO-1		
7?	NIM-G				SY-2	0.15	300?	BR	6.4?	JG-1		
6?	GH				SY-3	0.13	250?	GSP-1	6	ASK-1		
6?	NS-1				SGD-1A	0.06	220?	GA	6?	NIM-L		
5?	GnA				ST-1A	0.06	200	QLO-1	5	G-2		
4.4?	GM				SG-1A	0.04	200	SGD-1A	5	NIM-G		
4	ASK-1				BCR-1	0.01	200?	NIM-G	4?	GA		
4	ASK-2						200?	NIM-P	3.5	NIM-S		
4?	TB						185	W-1	3?	GM		
3.6	GA						175?	AGV-1	3?	NIM-S		
3.5?	TS						150?	JB-1	3?	RGM-1		
2.4	G-2						140	MRG-1	2.1?	GnA		
2.1	GXR-4						140?	NBS-91	1.5?	GH		
2	SGD-1A						130?	SY-3	1.4	SG-1A		
2?	AGV-1						100	SY-2	1	SGD-1A		
1.6?	BCR-1						100	ASK-1	0.5?	SS		
1.6?	GXR-2						100	G-2				
1.3?	BM						100	NIM-N				
1.2?	GXR-5						100?	GH				
1.1?	GXR-1						100?	NIM-S				
1	ST-1A						80?	PCC-1				
1?	BR						59?	JG-1				
1?	GSP-1						58?	BCR-1				
1?	GXR-6						14	ASK-2				
1?	NIM-N						11?	DTS-1				
1?	NIM-S											
0.8?	W-1											
0.6?	MRG-1											
Bi ppm			pct Bi <sub>2</sub> O <sub>3</sub>	Cd ppm		pct CdO	Co ppm	pct CoO	Cr ppm		pct Cr <sub>2</sub> O <sub>3</sub>	
900?	VS-N		0.10	900?	VS-N	0.10	700	VS-N		NIM-P	3.50	
220	GnA		0.02	3?	SS		210	NIM-D		DTS-1	0.61	
Bi ppb				1.4	NBS-1633		135	DTS-1		NIM-D	0.42	
50?	AGV-1						110	NIM-P		PCC-1	0.41	
50?	BCR-1						110	PCC-1		SW	0.37	
50?	W-1						100	UB-N		UB-N	0.34	
40?	G-2						86	TS		VS-N	0.10	
40?	GSP-1						80?	MRG-1		NBS-697	0.10	
10?	DTS-1						65?	ES-681-1		MRG-1	0.07	
10?	PCC-1						58	GS-N		JB-1	0.06	
Br ppm							50	NIM-N		BR	0.06	
8?	GXR-5						49?	BR		NBS-69a	0.05	
5?	SOIL-5						48	I-3		BHVO-1	0.05	
3?	GXR-2						47?	GXR-3		BX-N	0.04	
1.4?	GXR-6						46	BHVO-1		TS	0.04	
0.6?	PCC-1						45	W-1		DT-N	0.04	
0.5?	AGV-1						44	ST-1A		NBS-97a	0.03	
0.5?	GXR-4						40	SGD-1A		NBS-98a	0.03	
0.4?	GXR-1						40?	BX-N		SO-1	0.02	
0.4?	W-1						40?	NBS-1633		ST-1A	0.02	
0.3?	G-2						39	JB-1		GL-O	0.02	
0.2?	BCR-1						38	TS		NBS-1633	0.02	
0.2?	DTS-1						36	BCR-1		MO8-1	0.02	
							35	DR-N		BM	0.02	
							34	BM		W-1	0.02	
							33?	SO-1		MAG-1	0.02	
							30	GXR-5		GXR-5	0.01	
							30?	M-2		MicaMg	0.01	
							27	ASK-2		GXR-6	0.01	
							20	MicaFe		ASK-2	0.01	
							20?	MicaMg		MicaFe	0.01	
							20?	SDC-1		TB	0.01	
							18?	MAG-1		NBS-69b	0.01	
							17?	GL-O		SDC-1	0.01	
										SCo-1	0.01	
										GXR-4	0.01	
										SO-4	0.01	
										SL-1	0.01	
										M-2	0.01	
										GS-N	0.01	
										M-3	0.01	
										JG-1	0.01	

Usable values, arranged by "trace elements"

Cr ppm (cont'd.)			pct Cr <sub>2</sub> O <sub>2</sub>		Cu ppm			pct CuO		Dy ppm (cont'd.)			pct Dy <sub>2</sub> O <sub>3</sub>		Ga ppm (cont'd.)			pct Ga <sub>2</sub> O <sub>3</sub>	
52	SGD-1A	0.01	6500?	GXR-4	0.81	4?	ST-1A			30?	GXR-6				30?	GXR-6			
45	DR-N	0.01	1300?	GXR-1	0.16	3.5?	AGV-1			29	ASK-1				29	ASK-1			
40	ASK-1	0.01	800	VS-N	0.10	3?	GXR-1			28	SY-2				28	SY-2			
37	GXR-2	0.01	490?	TS	0.06	3?	GXR-2			27	NIM-G				27	NIM-G			
32?	SGR-1		360?	GXR-5	0.05	3?	JG-1			26	SY-3				26	SY-3			
31	NBS-81a		220	ST-1A	0.03	3?	MRG-1			25	ASK-2				25	ASK-2			
30?	NIM-N		165?	I-3	0.02	3?	NIM-L			25	DR-N				25	DR-N			
29?	SOIL-5		135	MRG-1	0.02	2.8?	GXR-6			25	TB				25	TB			
26?	I-3		130	NBS-1633	0.02	2.6?	GXR-4			24?	NS-1				24?	NS-1			
20?	T-1		130?	M-2	0.02	2.3	G-2			23	G-2				23	G-2			
19?	GXR-3		120	ASK-2	0.02	2?	GXR-5			23	GH				23	GH			
16	SO-2		110	W-1	0.01	2?	NS-1			23	GSP-1				23	GSP-1			
15	BCR-1		105?	GXR-6	0.01	0.5?	NIM-D			23?	M-2				23?	M-2			
14	GnA		77	SOIL-5	0.01	0.5?	NIM-S			22	BCR-1				22	BCR-1			
12	GA		72	BR	0.01					22?	TS				22?	TS			
12	GSP-1		68	SGD-1A	0.01					21?	MicaMg				21?	MicaMg			
12	NIM-G		66?	SGR-1	0.01					20	BR				20	BR			
12	NIM-S		61	SO-1	0.01					20?	T-1				20?	T-1			
12	SG-1A		59	AGV-1	0.01					19	AGV-1				19	AGV-1			
12	SY-2		56	JB-1	0.01					19	SGD-1A				19	SGD-1A			
10	AGV-1		52	DR-N	0.01					18	SOIL-5				18	SOIL-5			
10	GM		50	TB	0.01					18?	MRG-1				18?	MRG-1			
10	SY-3		48?	T-1	0.01					17?	I-3				17?	I-3			
10?	GXR-1		45	BM	0.01					17?	JB-1				17?	JB-1			
10?	NS-1		35?	MO8-1	0.01					17?	M-3				17?	M-3			
9.5?	KK		33	GSP-1						16	GA				16	GA			
8	G-2		33?	MAG-1						16	NIM-N				16	NIM-N			
7?	I-1		31	SG-1A						16	ST-1A				16	ST-1A			
6	GH		30	UB-N						16	W-1				16	W-1			
4?	QLO-1		30?	QLO-1						15	BM				15	BM			
3?	RGM-1		30?	SCo-1						15	GM				15	GM			
3?	STM-1		30?	SDC-1						15?	GXR-4				15?	GXR-4			
			25?	M-3						15?	JG-1				15?	JG-1			
			22	SO-4						12?	GXR-1				12?	GXR-1			
			20?	BX-N						11	NIM-S				11	NIM-S			
			20?	GS-N						8?	NIM-P				8?	NIM-P			
			19	NIM-S						7?	UB-N				7?	UB-N			
			18	GnA						1?	DTS-1				1?	DTS-1			
			18	NIM-P						0.7?	PCC-1				0.7?	PCC-1			
			17	SO-3															
			16	BCR-1															
			16	GA															
			16	SY-3															
			14	GH															
			13	GM															
			13	NIM-L															
			12	NIM-G															
			11?	RGM-1															
			10	G-2															
			10	NIM-D															
			10?	DT-N															
			8.8	KK															
			8	PCC-1															
			8?	I-1															
			8?	NS-1															
			8?	SS															
			7	ASK-1															
			7	SO-2															
			7	SW															
			5	DTS-1															
			5	SY-2															
			5?	GL-O															
			4	JG-1															
			4?	MicaFe															
			4?	MicaMg															
			3?	FK-N															
			3?	STM-1															



Usable values, arranged by "trace elements"

[illegible]



Usable values, arranged by "trace elements"

Sc ppm (cont'd)			pct Sc <sub>2</sub> O <sub>3</sub>			Sn ppm (cont'd)			pct SnO <sub>2</sub>			Ta ppm			pct Ta <sub>2</sub> O <sub>5</sub>			Tl ppm		
3.5	G-2					3.2	MRG-1				900?	VS-N		0.11		4?	NBS-1633			
1.7?	GXR-1					3.2	W-1				34?	MicaFe				1.6?	AGV-1			
1?	GH					2.5	BCR-1				29?	GnA				1.3?	GSP-1			
1?	NIM-G					2?	JB-1				26	SG-1A				1.2?	G-2			
0.3?	NIM-L					2?	NIM-D				11?	NS-1A				0.3?	BCR-1			
Se ppm						1.7	BM				1.4?	AGV-1				0.11?	W-1			
19	GXR-1					1.7?	DTS-1				1.2	ST-1A				Tl ppb				
9.4	NBS-1633					1.6?	PCC-1				1.1	SGD-1A				0.8?	DTS-1			
6	GXR-4					1.4?	G-2				1?	GSP-1				0.5?	PCC-1			
1?	GXR-5					Sr ppm			pct SrO			0.8?	BCR-1		Tm ppm					
1?	GXR-6					4600	NIM-L		0.53		0.8?	GXR-2				Tm ppm				
0.7	GXR-2					2300	SGD-1A		0.27		0.8?	GXR-4				8?	SY-3			
0.2	GXR-3					1500	NBS-97a		0.18		0.8?	SOIL-5				2?	NIM-G			
0.1?	BCR-1					1400?	NBS-1633		0.17		0.5?	W-1				2?	SY-2			
0.1?	W-1					1300	BR		0.15		0.5?	GXR-6				0.6?	BCR-1			
Sm ppm						1150	NS-1		0.14		0.3?	GXR-3				0.4?	AGV-1			
100?	SY-3		0.01			1150?	GXR-3		0.14		0.2?	GXR-1				0.3	W-1			
25	GSP-1					800?	VS-N		0.09		Tb ppm					0.3?	G-2			
17	SGD-1A					710?	STM-1		0.08		11?	SY-3				0.1?	MRG-1			
16?	NIM-G					680	ASK-1		0.08		3?	NIM-G				0.1?	NIM-D			
15?	SY-2					660	AGV-1		0.08		2?	NBS-1633				Tm ppb				
12?	BR					570?	GS-N		0.07		2?	SY-2				1?	DTS-1			
12?	NBS-1633					500?	M-3		0.06		1.4?	GSP-1				U ppm				
10?	GH					480	G-2		0.06		1.0	BCR-1				650	SY-3		0.08	
10?	NS-1					440	JB-1		0.05		0.7?	AGV-1				290	SY-2		0.03	
9?	TB					430?	SGR-1		0.05		0.7?	SOIL-5				63	SG-1A		0.01	
7.2	G-2					400?	BHVO-1		0.05		0.65	W-1				60?	MicaFe		0.01	
7	SG-1A					390?	T-1		0.05		0.5?	G-2				35?	GXR-1			
6.5	BCR-1					350?	QLO-1		0.04		0.1?	NIM-S				22?	GnA			
6	GXR-4					350?	SOIL-5		0.04		Tb ppb					22?	TS			
6?	GM					340	SO-2		0.04		3?	DTS-1				18?	GH			
6?	NIM-L					330	BCR-1		0.04		1?	PCC-1				15?	NIM-G			
5.9	AGV-1					330	NBS-98a		0.04		Th ppm			pct ThO <sub>2</sub>			14	NIM-L		
5.4?	SOIL-5					310	GA		0.04		990	SY-3		0.11		11.5	NBS-1633			
5?	GA					306	SY-3		0.04		380?	SY-2		0.04		6.4?	GXR-4			
5?	MRG-1					300?	SO-1		0.04		150?	MicaFe		0.02		4	SGD-1A			
4.8?	JB-1					280	GXR-1		0.03		120	SG-1A		0.01		4?	NS-1			
4.6?	JG-1					275	SY-2		0.03		105	GSP-1		0.01		3.3	JG-1			
4	ST-1A					270	ST-1A		0.03		90?	GH		0.01		3.2?	SOIL-5			
4?	BM					260	I-3		0.03		65	NIM-L		0.01		3.1?	GXR-3			
3.6?	W-1					260	MRG-1		0.03		52	NIM-G		0.01		3?	BR			
3.3	GXR-2					260	NIM-N		0.03		43?	BX-N				3?	GXR-2			
2.9	GXR-5					240	GSP-1		0.03		35?	GM				2.1	G-2			
2.4	GXR-6					230	BM		0.03		25	G-2				2.1	GSP-1			
2?	NIM-D					220	GXR-4		0.03		24?	NBS-1633				2.1?	GXR-5			
1.2?	NIM-S					220	SO-3		0.03		22	GXR-4				1.95	AGV-1			
1?	GXR-3					190	W-1		0.02		19?	TB				1.8	JB-1			
1?	NIM-N					185	JG-1		0.02		17	GA				1.7	BCR-1			
Sm ppb						185?	M-2		0.02		13.5	JG-1				1.6?	GXR-6			
8?	PCC-1					180?	SDC-1A		0.02		12?	BR				1.6?	SW			
4?	DTS-1					175?	SCo-1		0.02		11	SOIL-5				1.0	ST-1A			
Sn ppm						170	I-1		0.02		9	SGD-1A				0.6?	NIM-S			
1900	GnA		0.24			170	SO-4		0.02		9?	JB-1				0.58?	W-1			
70?	MicaFe		0.01			160	GXR-2		0.02		9?	NS-1				0.5?	MicaMg			
33?	KK					155	TB		0.02		8	GXR-2				0.4?	BHVO-1			
11	SG-1A					150?	MAG-1		0.02		6.4	AGV-1				0.4?	NIM-N			
10?	GH					135	GM		0.02		6.1	BCR-1				0.4?	NIM-P			
8?	BR					120	GXR-5		0.01		5.3	GXR-5				0.3?	MRG-1			
7?	NIM-L					105?	RGM-1		0.01		5.2	GXR-6				U ppb				
6.4?	SW					100	ASK-2		0.01		3?	BM				5?	PCC-1			
6?	SY-3					93?	TS		0.01		3?	ST-1A				4?	DTS-1			
5.7	TB					76?	KK		0.01		2.9	GXR-3				V ppm				
5?	GSP-1					62	NIM-S		0.01		2.4	W-1				pct V <sub>2</sub> O <sub>5</sub>				
4.9?	TS					42	GXR-6		0.01		2.3	GXR-1				930?	TS		0.17	
4.6	GM					36?	DT-N		0.01		1?	MRG-1				770	ES-681-1		0.14	
4	SY-2					35?	FK-N		0.01		1?	NIM-N				600?	VS-N		0.11	
4?	GA					32	NIM-P		0.01		1?	NIM-P				520	MRG-1		0.09	
4?	JG-1					20	SG-1A		0.01		0.9?	NIM-S				500?	I-3		0.09	
4?	NIM-G					19	GL-O		0.01		0.6?	NIM-D				420	BCR-1		0.07	
3.7	SGD-1A					19?	GnA		0.01		Th ppb					400?	NBS-165a		0.07	
3.6	AGV-1					10	GH		0.01		10?	DTS-1				320	ST-1A		0.06	
3.5	ST-1A					10	NIM-G		0.01		10?	PCC-1								
3.5?	NS-1					10?	UB-N		0.01											
						5	MicaFe													
						3?	NIM-D													
						0.4	PCC-1													
						0.4?	DTS-1													

Table 5 (cont'd.)

Usable values, arranged by "trace elements"

V ppm (cont'd.)			pct V <sub>2</sub> O <sub>5</sub>			Y ppm			pct Y <sub>2</sub> O <sub>3</sub>			Zn ppm			pct ZnO			Zr ppm			pct ZrO <sub>2</sub>		
310?	BX-N	0.06	800?	VS-N	0.10	1300	MicaFe	0.16															
300?	BHVO-1	0.05	740	SY-3	0.09	800	VS-N	0.10												1350?	NIM-L	1.49	
260	W-1	0.05	180?	TS	0.02	740	GXR-1	0.09												1200?	NBS-69a	0.18	
240	BR	0.04	145	NIM-G	0.02	640?	NBS-91	0.08												800?	STM-1	0.16	
240	SGD-1A	0.04	130	SY-2	0.02	500	GXR-2	0.06												790?	MicaFe	0.11	
230	NIM-P	0.04	70	GH	0.01	400	NIM-L	0.05												720	SO-2	0.11	
220	ASK-2	0.04	69	SG-1A	0.01	370	SOIL-5	0.05												720	NS-1	0.10	
220	DR-N	0.04	60?	M-2	0.01	300?	NBS-165a	0.04												720	SG-1A	0.10	
220	NIM-N	0.04	50?	I-3	0.01	290?	MicaMg	0.04												700?	VS-N	0.09	
210	JB-1	0.04	50?	STM-1	0.01	270	SG-1A	0.03												500	GSP-1	0.07	
210	NBS-1633	0.04	40	BCR-1	0.01	250	SY-2	0.03												470?	NBS-97a	0.06	
180	BM	0.03	40?	SO-2	0.01	240	SY-3	0.03												400	ASK-1	0.05	
180?	GXR-6	0.03	39?	TB		240	STM-1	0.03												320	SY-3	0.04	
170?	NBS-69a	0.03	31?	JG-1		220	GXR-3	0.03												310?	NBS-98a	0.04	
170?	NBS-69b	0.03	30	BR		190	MRG-1	0.02												310?	SO-4	0.04	
140	SO-1	0.02	30	SGD-1A		185?	T-1	0.02												300	G-2	0.04	
140?	MAG-1	0.02	30?	ST-1A		165	ASK-2	0.02												300	NIM-G	0.04	
135	MicaFe	0.02	29	GSP-1		150	BR	0.02												300?	SDC-1	0.04	
130?	MO8-1	0.02	26?	BM		150	DR-N	0.02												290?	M-3	0.04	
130?	SGR-1	0.02	26?	GM		150	ST-1A	0.02												280	SY-2	0.04	
125	AGV-1	0.02	26?	JB-1		145	SO-1	0.02												280?	TS	0.04	
115?	SCo-1	0.02	25	W-1		140?	MAG-1	0.02												250	BR	0.03	
105	TB	0.02	25?	MicaFe		130?	M-2	0.02												250	NBS-81a	0.03	
105?	SDC-1	0.02	25?	NIM-L		125	BCR-1	0.02												240	SGD-1A	0.03	
99?	T-1	0.02	24?	SO-1		125	SO-2	0.02												240?	GS-N	0.03	
92?	GXR-4	0.02	23?	SO-4		120	GXR-6	0.01												230	AGV-1	0.03	
90	SO-4	0.02	23?	SOIL-5		120	SGD-1A	0.01												210	NBS-1633	0.03	
90?	MicaMg	0.02	22?	GnA		120	SGD-1A	0.01												210?	RGM-1	0.03	
88?	GXR-1	0.02	21	GA		110?	SCo-1	0.01												200?	GXR-2	0.03	
81	NIM-L	0.01	19	AGV-1		105	ASK-1	0.01												200?	GXR-4	0.03	
80?	M-2	0.01	17?	NS-1		105	BM	0.01												190?	I-3	0.03	
75	UB-N	0.01	17?	SO-3		105	GSP-1	0.01												185	BCR-1	0.02	
75?	M-3	0.01	16?	MRG-1		105?	SDC-1	0.01												175	TB	0.02	
64	SO-2	0.01	13?	FK-N		100	NIM-P	0.01												175?	QLO-1	0.02	
62?	GS-N	0.01	13?	FK-N		100?	BHVO-1	0.01												170	ASK-2	0.02	
61?	QLO-1	0.01	11	G-2		100?	I-3	0.01												165?	SCo-1	0.02	
60?	GXR-5	0.01	6?	NIM-N		95	TB	0.01												160?	BHVO-1	0.02	
57?	GXR-2	0.01	4?	NIM-P		94	SO-4	0.01												160?	T-1	0.02	
54	GSP-1	0.01	3?	NIM-S		90	NIM-D	0.01												155?	JB-1	0.02	
52	SY-2	0.01	0.05?	DTS-1		89?	TS	0.01												150	GA	0.02	
51	NS-1	0.01				86	AGV-1	0.01												150	GH	0.02	
51	SY-3	0.01				86	W-1	0.01												150?	SO-3	0.02	
49	ASK-1	0.01				85	GH	0.01												145	GM	0.02	
44?	SO-3	0.01				85?	UB-N	0.01												140?	GXR-5	0.02	
40	NIM-D	0.01				84	G-2	0.01												130	ST-1A	0.02	
39?	GXR-3	0.01				84	JB-1	0.01												130?	MAG-1	0.02	
38	GA	0.01				82?	SGR-1	0.01												125?	DR-N	0.02	
36	G-2	0.01				80	GA	0.01												110?	JG-1	0.01	
29	PCC-1	0.01				76	GnA	0.01												105	BM	0.01	
29	W-1	0.01				74	SS	0.01												105	MRG-1	0.01	
24	JG-1					70?	NS-1	0.01												105	W-1	0.01	
20?	SL-1					68	NIM-N	0.01												105?	GXR-6	0.01	
19?	SW					64?	GXR-4	0.01												100?	M-2	0.01	
15?	RGM-1					60?	QLO-1	0.01												81?	SO-1	0.01	
11	DTS-1					59?	BX-N	0.01												70	NBS-91	0.01	
11	GM					58	SW	0.01												70?	FK	0.01	
10	NIM-S					52	SO-3	0.01												70?	GnA	0.01	
7?	I-1					50	NIM-G	0.01												66	GXR-1	0.01	
5	SG-1A					50?	GXR-5	0.01												62?	SGR-1	0.01	
5?	GH					50?	MO8-1	0.01												60?	I-1	0.01	
2?	NIM-G					49	KK	0.01												40?	NBS-165a	0.01	
						48?	GS-N	0.01												33?	NIM-S		
						46	DTS-1	0.01												30?	NIM-P		
						45	GSP-1	0.01												25?	NBS-69b		
						44?	M-3	0.01												23?	NIM-N		
						43?	GL-O	0.01												20?	MicaMg		
						41	PCC-1	0.01												12?	DTS-1		
						40	GM													10?	NIM-D		
						40	JG-1													7?	PCC-1		
						32?	RGM-1																
						29?	DT-N																
						24?	FK-N																
						16?	I-1																
						12?	FK																
						10?	NIM-S																
W ppm			pct WO <sub>3</sub>																				

Table 6

Comparison of recommended iron oxide values on NIM samples

Sample	Per cent	Abbey (1977a)	Steele and Hansen (1979a,b)	This work
NIM-D	Fe <sub>2</sub> O <sub>3</sub>	0.90	0.71	0.71
	FeO	14.46	14.63	14.63
	Fe <sub>2</sub> O <sub>3</sub> TR*	16.96	17.00	16.96
	Fe <sub>2</sub> O <sub>3</sub> TC	16.97	16.97	16.97
	Σ (corr.)	100.22?	100.13?	100.17?
NIM-G	Fe <sub>2</sub> O <sub>3</sub>	0.58	0.6?	0.6?
	FeO	1.30	1.30	1.30
	Fe <sub>2</sub> O <sub>3</sub> TR	2.02	2.00	2.02
	Fe <sub>2</sub> O <sub>3</sub> TC	2.02	2.04	2.04
	Σ (corr.)	99.96?	99.99?	100.01?
NIM-L	Fe <sub>2</sub> O <sub>3</sub>	8.74	8.78	8.74
	FeO	1.08	1.13	1.13
	Fe <sub>2</sub> O <sub>3</sub> TR	9.96	9.91	9.96
	Fe <sub>2</sub> O <sub>3</sub> TC	9.94	10.04	10.00
	Σ (corr.)	99.72?	99.85	99.73?
NIM-N	Fe <sub>2</sub> O <sub>3</sub>	0.76	0.8?	0.8?
	FeO	7.30	7.47	7.30
	Fe <sub>2</sub> O <sub>3</sub> TR	8.91	8.97	8.91
	Fe <sub>2</sub> O <sub>3</sub> TC	8.87	9.10	8.89
	Σ (corr.)	99.80?	100.13?	99.93?
NIM-P	Fe <sub>2</sub> O <sub>3</sub>	1.02?	0.87	1.02?
	FeO	10.59?	10.59	10.59
	Fe <sub>2</sub> O <sub>3</sub> TR	12.76	12.70	12.76
	Fe <sub>2</sub> O <sub>3</sub> TC	12.79?	12.64	12.79?
	Σ (corr.)	99.77?	99.66?	99.83?
NIM-S	Fe <sub>2</sub> O <sub>3</sub>	1.07	1.11	1.07
	FeO	0.30	0.30	0.30
	Fe <sub>2</sub> O <sub>3</sub> TR	1.40	1.40	1.40
	Fe <sub>2</sub> O <sub>3</sub> TC	1.40	1.44	1.40
	Σ (corr)	100.17?	100.13	100.09?
*See Table 3, note 2 for explanation of these terms.				