

AN ESTIMATE OF THE COMPOSITION OF  
PART OF THE CANADIAN SHIELD

AN ESTIMATE OF THE COMPOSITION OF PART OF THE  
CANADIAN SHIELD IN NORTHWESTERN  
ONTARIO

By  
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An attempt has been made to estimate the abundance of trace and major constituents in the Precambrian rocks in a large part (43,000 square miles) of the Red Lake - Lansdowne House area in northwestern Ontario. The area has an average composition which is close to that of granodiorite, more silicic than most estimates of crustal abundance, close to other estimates for continental shield areas, but possibly deficient in  $K_2O$ . The rocks of this area appear to be low in Be, Ti, V, Cu, Y, Sc and Zr, and high in Sr. Analysis of variance techniques have detected significant regional variations of Cr, Mn, Sr and Ba. Significant variation exists between rock types for all trace elements analyzed except Cu.

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### ABSTRACT

An attempt has been made to estimate the abundance of trace and major constituents in the Precambrian surficial rocks in a large part (43,000 square miles) of the Red Lake - Lansdowne House area in northwestern Ontario. The area has an average composition which is close to that of granodiorite, more silicic than most estimates of crustal abundance, close to other estimates for continental shield areas, but possibly deficient in  $K_2O$  relative to Poldervaart's (1955) estimate. The rocks of this area appear to be low in Be, Ti, V, Cu, Y, Sc and Zr, and high in Sr, relative to crustal abundances based on the proportion of exposed rocks on the surface of the continents (Turekian and Wedepohl, 1961). Analysis of variance techniques have detected significant regional variations of Cr, Mn, Sr and Ba. Significant variation exists between rock types for all trace elements analyzed except Cu.

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## Chapter I

### INTRODUCTION

#### General

The aim of this thesis is to estimate the abundance of certain trace and major elements in a large area of the Superior Province of the Canadian Shield. The justification for this research is twofold. Firstly, there is a lack of information as to the abundance of major elements and particularly trace elements in the Canadian Shield. Secondly, estimates of abundance for both the Canadian Shield and other shield areas have been based mainly on the results of specialized geological studies, abundance figures being a by-product of these studies. Averages have been obtained by grouping together analyses of comparable rock types, from several different sources in the literature, with little regard to the suitability of the data. Geographic and geological variations have usually not been considered.

Only one other estimate of the composition of the Canadian Shield is known to the author. Grout (1938) calculated major element averages by collecting analyses of rocks of the Shield and weighting them in proportion to their relative exposure. Unfortunately, only a few scattered analyses were available at that time and no attempt was made to sample systematically.

During the field seasons of 1960 and 1961, about 10,000 bedrock samples were collected by officers of the Geological Survey of Canada in the Red Lake-Lansdowne House area of northwestern Ontario. These samples were originally collected for use in a regional geochemical reconnaissance of copper and zinc in bedrock, conducted by Dr. R.H.C. Holman of the Geological Survey of Canada. Composites have been made from the major part of these samples. Analyses of these composites for both major and trace elements, along with the relative proportions of outcrop for the different rock types in the area, form the basic data used in this study.

#### Red Lake-Lansdowne House Area

##### Location and Description

The area is located in the Canadian Shield in northwestern Ontario (Figure 1) and lies between longitudes 86 and 94 degrees, and latitudes 51 and 53 degrees. It is about 43,000 square miles in area and is contained entirely within the Superior Province, except for a small strip on the eastern edge of the area which is overlain by Palaeozoic sediments (Ordovician and Silurian) of the Hudson Bay Lowlands.

Holman (1963h, p. 30) describes the general geology of the area as follows:

"The most common rocks of this segment of the Precambrian Shield are granodiorites that exhibit varying degrees of foliation. The granodiorites are interrupted by discontinuous belts and irregularly shaped bodies of massive granite. These granites are usually pink but, in the southeast corner of the region, white varieties are common. Porphyritic granitic rocks are extensively developed in the western half of the area. Infolded masses of mixed volcanic rocks (basalts, andesites, rhyolites and tuffs) with minor associated sedimentary

rocks extend throughout the region, often as long, narrow and curving belts. Basic (intrusive) rocks are comparatively uncommon."

The region has been extensively glaciated. Glacial deposits and muskeg obscure large portions of bedrock. Exposure of the bedrock varies from 50 per cent in the northwest corner of the area to 1 per cent in the east. Average exposure of bedrock is about 30 per cent.

#### Previous Work

For purposes of geological mapping, the area was divided into seven map areas of equal size. Each map area is two degrees of longitude by one degree of latitude, including about 6,000 square miles. The key to the location and identification of each map area is given in Figure 2.

Preliminary geological maps (Bostock, 1962; Carruthers, 1961; Donaldson, 1959, 1960; Emslie, 1960, 1962; Jackson, 1961, 1962) have been published on the scale of one inch to four miles. This information has been compiled by Duffel (1963) on the scale of one inch to eight miles.

An investigation of the surficial geology of the whole area was carried out by Prest (1963a). Maps of the surficial geology (Prest, 1963b) and bedrock-drift distribution (Prest and Donaldson, 1963) have been published on a scale of one inch to eight miles.

During the course of geological mapping, in the field seasons of 1960 and 1961, traversing parties collected representative specimens of exposed bedrock at intervals of about one mile. Each specimen was described in the field and its location was recorded. The average

density of sampling is one specimen for every three to four square miles. Coverage varies widely depending on extent of exposure of bedrock. Density of sampling is highest in the northwest part of the area and lowest in the eastern part due to very sparse outcrop.

Some 10,000 bedrock samples were collected, each of which was analyzed for Cu and Zn. Determinations of As were also made on a few samples. The data for Cu in bedrock have been published by Holman (1963a,b,c,d,e,f, and g) in the form of a series of preliminary geochemical maps on the scale of one inch to four miles. Also, a preliminary paper by Holman (1963h) summarizes initial results for Cu and Zn in four of the map areas.

An aeromagnetic survey of the area was carried out during 1959 and 1960, and a geological interpretation of this data was made by MacLaren (1962), on the scale of one inch to eight miles. In addition, the magnetic susceptibility and specific gravity of each geochemical sample were determined, in an attempt to facilitate the interpretation of the aeromagnetic survey and of future gravity surveys in the Precambrian of northern Ontario.

Geological, geochemical and geophysical results have been summarized in a preliminary report by Duffel, MacLaren and Holman (1963).

## Chapter II

### EXPERIMENTAL DESIGN

#### General

The best, but not the most efficient, method of estimating geochemical abundances in the area would be to analyze all 10,000 individual samples of bedrock. This approach is desirable in some respects. It provides information which can be related more directly to the geology of the area. Variations from rock type to rock type, and from area to area, would be more amenable to examination and explanation. Anomalous values could be identified and their causes examined. However, the analytical and statistical work involved would be truly formidable, in the absence of supporting personnel.

Estimates of abundance were obtained in a more efficient manner. Instead of analyzing each individual separately, the samples of bedrock were grouped together as composites. Duplicate composite samples were made to represent each rock type in each map area. Replication of composite samples is necessary in order to provide information as to the stability of any averages derived from the analyses of the composites. Averages were obtained by weighting the analytical results in proportion to the outcrop (estimated by map units) for each rock type.

In this chapter, discussion is limited to trace elements, unless otherwise indicated.



### Map Areas

The area was divided into seven map areas (Figure 2) of equal size (about 6,000 square miles) for purposes of geological reconnaissance. This division has been preserved in this study for two reasons: (a) Such a division is necessary in order to interpret the geochemical results in relation to the geological information which is available at this time; (2) The seven map areas constitute large, separate samples of this section of the Canadian Shield.

### Rock Types

During the reconnaissance, geological mapping of the area, fourteen rock types were recognized. Because of differences in geology and of subjective interpretation of the geology from map area to map area, this number had to be condensed to eight units so that comparisons could be made within the area and with other shield areas. These eight rock types are briefly described in Table I.

Each rock type occurs in each map area, with the exception of rock type 1. Rock type 1 (leucocratic granite) is abundant in map areas 1 and 2, but is very minor or absent in the rest. Composites for rock type 1 have been made only for map areas 1 and 2.

The proportion of outcrop for each rock type was determined by Holman (1963a, b, c, d, e, f, and g) by planimetering the reconnaissance geological map for each map area. This information, as it applies to this research, is given in Tables II and III.

### Representativeness of Sampling

In this study the target population (Krumbein, 1960) consists of the exposed surface rocks of the area. This target population may itself be a biased sample of the crust. Variations with depth may be different in kind from variations over the surface. Only exposed parts of the crust in this area are accessible to sampling. This may introduce bias because of differential erosion and variation in extent of glacial deposits and other debris.

During the primary sampling, no attempt was made to use random sampling techniques. This may have introduced some bias. For instance, one rock type may have been more intensely sampled than another (i.e. a greater proportion of individuals for one rock type than is warranted on the basis of the amount of outcrop for that rock type). Table IV is a comparison of the percentage of exposed bedrock for each rock type with the percentage of all primary individuals for each rock type. (Details of the distribution of primary individuals are given in Appendices I, II, III and IV.) This table indicates that each rock type is represented in the whole group of primary individual samples in proportion to its exposure in the area. Rock type 6 (basic intrusive) is the only exception, and it has been greatly over-sampled. In addition, the reconnaissance geochemical maps for Cu in bedrock (Holman 1963a, b, c, d, e, f, and g) show that the primary individuals are evenly distributed throughout the areas of exposed bedrock. We may conclude that the primary sampling is not seriously biased and that it affords a satisfactory probability sample of the exposed bedrock of the area.

Since it was impracticable to analyze every individual, composites were prepared. These provide an unbiased and efficient representation of the area, since they were made from all of the primary individuals available. The composites contain all of the information that could be derived from the individual primary samples, with the exception of information as to the variation within a rock type for a certain map area.

Engel (1963) determined the approximate percentages of granitic and pre-existing rocks exposed in the geological provinces of North America by point counting geological maps. His values for the relative proportions of different rocks in the Superior-Wyoming-Slave province of North America are shown in Table V. A comparison of Table V with the information contained in Tables III and IV reveals a remarkable similarity between the relative proportions of different rock types in the Red Lake-Lansdowne House area and in the Superior-Wyoming-Slave province of North America. This may mean that the Red Lake-Lansdowne House area could be considered to be a typical segment of this province.

#### Stability

In order to assess the validity of trace element averages, it is necessary to determine whether or not the area constitutes a statistically homogeneous unit. This can be done by testing the significance of regional variations (variations from map area to map area) by the use of analysis of variance techniques.

If, for a certain element, there is no statistically significant regional variation, then any averages derived for the whole area, for that element, can be considered to be "stable". That is, the whole area may be considered to be essentially a homogeneous unit, each map area being a representative sample of the whole. If there is statistically significant regional variation, averages can still be calculated but their meaning is open to question. Significant regional variation may indicate that the experimental design, for that one element, is not suitable for an accurate estimate of a true average because sampling may not have been carried out within a uniform population.

## Chapter III

### METHODS

#### Crushing of Primary Samples

All primary individuals were crushed in the laboratories of the Geological Survey of Canada. Each individual sample of bedrock (weighing two to three pounds) was split. A chip was retained and the remainder was reduced to gravel size (one-quarter inch) by means of a Chipmunk jaw crusher. Then the sample was ground to about -80 mesh with a Braun rotating-disk pulveriser, fitted with ceramic plates. Fifteen to twenty grams of this powder were ground to -200 mesh by mechanical agitation in small ceramic ball mills on a paint shaking machine. All crushing equipment was thoroughly cleaned between samples, so that contamination from sample to sample would be negligible.

#### Preparation of Composite Samples

8,076 of the 10,000 primary samples of bedrock were used in making the composite samples for this study. About 2,000 of the primary samples were collected during a detailed sampling of some greenstone belts in the Lake St. Joseph map area (map area 3). Most of these were not used because their inclusion would over-emphasize the importance of certain small areas of greenstone in the Lake St. Joseph area.

The composites are of two types. The first type was made to represent each rock type in each map area, in duplicate. These have been called "composite samples". The second type was made to represent each rock type in the whole area, for purposes of major element analysis. These have been termed "composites of composite samples".

#### Composite Samples

All primary individuals for each rock type in each map area were randomly divided into two separate groups. Composites were made from each of these groups by weighing out equal portions of the -200 mesh powder for each of the primary samples. Thus, duplicate composite samples exist for each rock type in each map area, with the exception of rock type 1 in map areas 3 through 7, where leucocratic granite is very minor or absent. The total number of composite samples is 102.

Each composite sample is identified as to rock type, map area and duplicate by a sample number. This number is prefixed by the letter "C" and consists of three digits. The first digit indicates the map area; the second, the rock type; the third, the duplicate. For example, C361 refers to the first of the duplicates representing rock type 6 (basic intrusive) in map area 3 (Lake St. Joseph). This scheme has been used whenever reference is made to a specific composite sample.

Appendix V shows the number of primary individuals used in making each composite sample. Each number reflects the amount of outcrop available for sampling as well as the intensity of sampling.

### Composite of Composite Samples

Eight composites of composite samples were prepared for each rock type in the whole area, by weighing out equal portions of powder from each composite representing the rock type. These are identified by the rock type number prefixed by the letters "CC". For example, CC6 refers to the composite of all composite samples representing rock type 6 (basic intrusive).

### Major Element Analysis

Major element analysis was carried out, in duplicate, on CC1 to CC8 by J. Muysson of the Rock Analysis Laboratory, Department of Geology, McMaster University. Rapid silicate analysis methods, similar to those described by Vincent (1960), were employed. The results of these duplicate analyses are given in Appendix VI. Averages of pairs of duplicate analyses are shown in Table VI.

The standard samples G-1, W-1, T-1 and GR were also analyzed to provide a check on the accuracy of the analytical procedures. The results of these analyses are compared with the preferred values for each of the standard samples in Table VII. A close examination of this table indicates that no serious errors exist in the analysis of any of the major constituents with the possible exception of  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  in basic rocks.

### Spectrographic Methods

#### General

102 composite samples and CC1 to CC8 were analyzed quantitatively using emission spectrographic techniques similar to the general quan-

titative schemes described by Ahrens and Taylor (1961, Ch. 13), and Shaw (1960). The method employs Pd as an internal standard. The elements which are sought include Be, Ti, Cr, V, Ni, Co, Cu, Mn, Sc, Zr, Sr, and Ba. Y was usually detectable but not measurable. Each analysis was carried out in triplicate. The trace element data for the composite samples are shown in Appendices VII and VIII. Each value is the geometric mean of triplicate analyses.

#### Procedure

The powders to be analyzed were arranged in random order, using a table of random numbers, in order to nullify any possible effects of systematic variations during the course of analysis. An aliquot of powder for each composite was mixed in the ratio 1:1 with graphite containing 0.025% PdCl<sub>2</sub>. The charge was moistened with acetone and mixed in an agate mortar for five minutes to ensure uniformity.

Burns were made in triplicate under conditions which are described in detail in Table VIII. Each of the triplicate burns was recorded on a different set of spectrographic plates, eight sets to a plate.

Each analysis line, along with its corresponding internal standard line and sensitivity in p.p.m., is listed in Table IX. In cases where an element was not detected (n.d.) or was present in detectable but not measurable amounts (tr.), the values used for statistical purposes were assumed to be one-tenth and one-half, respectively, of the sensitivity limit for that element.



### Computation

Transmission readings were taken on three steps (log intensity ratio of 0.2) of the analysis line and the internal standard line, as well as readings of background on the most intense of the three steps for each. This allows computation to be carried out by a self-calibrating procedure (Ahrens and Taylor, 1961, p. 159) through which background corrections can be applied.

Computation was carried out by the use of a program written by D.M. Shaw for a Bendix G-15 digital computer. This program converts transmission readings to Seidel values  $\sqrt{S} = \log_{10}(100/T - 1)$ , where T = transmission reading in % and then proceeds to calculate an intensity ratio (dY) by solving quadratic polynomials. dY is the  $\log_{10}$  of the ratio of the intensity of the analysis line to the intensity of the internal standard line, each corrected for background.

In a few cases, particularly when the analysis line was unusually light, the computer was unable to complete the calculation because of imaginary roots in the quadratic polynomial. Computation was then done graphically on a Seidel calculating board.

### Working Curves

In order to construct working curves, two different synthetic matrices were prepared, from Johnson-Matthey "Specpure" chemicals. They were made to approximate the composition of a granodiorite and a gabbro (Table X).

Two different sets of standards, having a concentration range of 0.316 to 3160 p.p.m., were prepared with these matrices. These standards were arced under the same conditions as those described

above. Two sets of working curves, relating dY to p.p.m., were plotted on semi-log graph paper. These curves served to convert values of dY to p.p.m. graphically. The "granodiorite" set of working curves was used for the acidic and intermediate rock types, whereas the "gabbro" set was used for the basic rock types. This was necessary in order to reduce matrix effects as much as possible.

The working curve for Ti was prepared in a different manner, so that a larger concentration range could be covered. A series of silicate rocks, having a large range in Ti concentration was selected. These rocks, which had been previously analyzed for Ti by means of wet chemical methods, were arced under the same conditions as those described above. The working curve was constructed by plotting values of dY versus the known concentrations of Ti as given by wet chemical methods. The curve was used for both acidic and basic rock types.

### Precision and Accuracy of Spectrographic Methods

#### Precision

Precision has been calculated using the logarithms of all analytical results for each element in a single classification analysis of variance (Dixon and Massey, 1957, Ch. 10). The logarithmic transformation was necessary because the absolute deviation in p.p.m. varies directly with the level of concentration and serves to homogenize the variances.

By means of a single classification analysis of variance, the within - triplicates (within - cells) mean square is determined. This is the best available estimate of the within - triplicates variance

$(S_p^2)$ , the pooled variance). The standard deviation (S) is found by the relationship:

$$S = (S_p^2/3)^{1/2}$$

The best estimate of the concentration of an element is  $\bar{k}$ , where

$$\bar{k} = \text{antilog}_{10}(\bar{x})$$

and  $\bar{x}$  is the mean of the triplicate analysis in log p.p.m. The interpretation of the standard error S of the mean  $\bar{x}$  is

$$U = \text{upper limit} = \text{antilog}_{10}(\bar{x} + S)$$

$$L = \text{lower limit} = \text{antilog}_{10}(\bar{x} - S)$$

Thus, approximately two-thirds of the analyses of a sample, with a true value of  $\bar{k}$  p.p.m. of an element, should fall between the values of U and L. Precision is expressed as the coefficient of variation (C) in per cent.

$$C (\%) = \frac{(U - L)}{\frac{1}{2}(U + L)} \times 100$$

The values of the coefficient of variation for each element gives an estimate of the relative error for triplicate analysis, and were obtained using a program, prepared by D.M. Shaw and the writer, for an I.B.M. 7040 digital computer. Values of C are included in Table IX.

Precision seems to be satisfactory for all elements, with the possible exceptions of Cu and Zr. The lower precision of Zr (11.7%) may be due to the refractory nature of Zr. The low precision for Cu (17.2%) may be caused by the effects of contamination, particularly at low concentrations of Cu. Cu contamination has been found to be a continuing problem and its elimination is virtually impossible.

### Accuracy

In order to estimate the accuracy of the spectrographic method, both G-1 and W-1 were analyzed. The results of these analyses are compared, in Table XI, with recommended values for G-1 and W-1 as reported by Fleischer and Stevens (1962). This comparison indicates that there are serious deviations of Ba and Zr from the recommended values for G-1, and of Cr, Ni and Sr from the recommended values for W-1. Values for Be in basic rock types may be too high due to a suspected interference between the spectral lines Be  $3130.416 \text{ \AA}$  and V  $3130.267 \text{ \AA}$  at concentrations of V greater than 50 p.p.m.

The trace element data can be adjusted for inaccuracies by applying correction factors. Table XII lists correction factors based on the recommended values for G-1 and W-1. The use of correction factors may not be justified, since it involves, in effect, a shifting of the working curve for each element, to agree with the recommended values for G-1 or W-1. Some of the data presented below has been tabulated in both the corrected and uncorrected forms. Unless stated otherwise, the data is uncorrected.

### Two-Way Analysis of Variance

#### General

Analysis of variance has been employed to determine the statistical significance of variations of each trace element between map areas (regional variation) and between rock types. This is, in effect, testing hypotheses of equal means. In addition, the significance of interactions between map areas and rock types (i.e. any variation not

explained solely by the two-fold classification) has been tested. Tests were carried out on arithmetic data. No transformations were employed.

Analyses of variance for the trace element data (Appendices IX, X, XI, and XII) were carried out in four ways, which are:

(1) rock types 2, 3, 4, 5, 6, 7, and 8 for all map areas.

Rock type 1 has been excluded since it occurs in only two map areas in significant amounts.

(2) rock types 2, 3, 4, and 5 (felsic varieties) for all map areas.

(3) rock types 6, 7, and 8 (basic and sedimentary varieties) for all map areas.

(4) Sc in rock types 6 and 8 for all map areas. This was done because Sc was found, in significant amounts, only in rock types 6 and 8.

These four categories were adopted in order to test for significance of variations for all rock types, for the felsic varieties, and for the basic and sedimentary varieties.

#### Computation

Computational formulae for this type of analysis of variance are given by Bennett and Franklin (1954, Ch. 7), and by Miller and Kahn (1962, Ch. 7). Calculations were carried out using a program prepared by the writer for an I.B.M. 7040 digital computer.

#### Statistical Model

The statistical model used in this study is a two-way crossed analysis of variance, with replication. The model is described by

Bennett and Franklin (1954, Ch. 7), Dixon and Massey (1957, Ch. 10), and Miller and Kahn (1962, Ch. 7). The model may be written:

$$x_{ijk} = u + y_i + z_j + w_{ij} + e_{ijk}$$

$x_{ijk}$  represents a single trace element value for a composite sample.  $u$  is a constant and is the true population mean. The value of  $x_{ijk}$  depends on  $u$  and is affected by contributions from map areas ( $y_i$ ) and rock types ( $z_j$ ).  $w_{ij}$  is the effect of interaction (the effect of  $y_i$  and  $z_j$  taken together, which is not accounted for by their effects taken separately).  $e_{ijk}$  is the random error occurring between duplicate composite samples. A complete analysis of variance table for this model is given in Table XIII.

Assumptions for this model are the following:

- (1) Observations are random with respect to any conditions not systematically varied.
- (2) Means and variances are additive.
- (3)  $u$ ,  $y_i$ ,  $z_j$ , and  $w_{ij}$  are constants. That is, the model presumes fixed effects.
- (4) The errors  $e_{ijk}$  are independent, random and normally distributed, with an expected mean of zero and common variance  $\sigma^2$ .

#### Statistical Tests

The F ratios, shown in Table XIII, were calculated and compared with the appropriate critical values of the F distribution. Two significance levels (5% and 1%) were employed. An effect is termed "significant" if the corresponding F ratio is greater than

the critical value of  $F$  at the 5% significance level and "very significant" if the  $F$  ratio is greater than the critical value of  $F$  at the 1% level. The interaction and within-duplicates sums of squares were pooled, when the interaction effect was found to be nonsignificant, to obtain a pooled error estimate of  $\sigma^2$ . Summaries of the results of these tests are given in Tables XIV, XV, and XVI.

If an hypothesis, that the means for different map areas are not significantly different, is accepted, variation between map areas can be considered to be random. In other words, no significant regional variation exists. However, if the hypothesis is rejected, significant differences are indicated among the means and a regional trend, independent of variations between rock types, is probably present. In a similar fashion, the significance of differences between mean values for the various rock types is assessed, independent of variations between map areas.

The explanation of significant interactions is more difficult. Four explanations are offered by Dixon and Massey (1957). These are:

- (1) They are the result of random fluctuations, with probability  $\alpha$  (0.05 or 0.01).
- (2) The two variables are not independent. Particular combinations of the variables give rise to effects greater than the combination of their separate effects.
- (3) Apparent interactions may result when important variables are left out of the analysis.
- (4) The sampling was not random within each group.

All of these statements of significance are subject to error. A true hypothesis is likely to be rejected, by chance, in 5% or 1% of the cases, depending on which level of significance is used.

#### Calculation of Weighted Averages

All averages derived from the major and trace element data have been weighted according to the proportion of outcrop (Tables II and III) for each rock type. The reasoning behind this procedure is as follows. In order to use all of the primary individuals available and to get an accurate estimate of the composition of each rock type, regardless of its abundance, composites were made to represent each rock type in each map area (except rock type 1). If unweighted averages were calculated, the values for relatively minor rock types (e.g. basic intrusive rocks) would be greatly overemphasized.

Major element averages for the whole area (Tables XVII and XVIII) were calculated by weighting the major element data (Table VI) in proportion to the outcrop for each rock type (Table III).

Trace element averages were calculated for the following:

- (1) each rock type in each map area (unweighted) (Appendix XIII).
- (2) each map area (Table XIX), weighted according to the proportion of outcrop for each rock type in each map area relative to the total outcrop for each map area (Table III).
- (3) each rock type in the whole area (Table XX), weighted in proportion to the outcrop in each map area for each rock type relative to the total outcrop for each rock



type (Table II).

(4) the whole area (Tables XXI and XXII).

## Chapter IV

### DISCUSSION OF RESULTS

#### Major Elements

The results of major element analysis of CC1 to CC8 are given in Table VI. Table XVII shows the major element averages for the whole area, weighted in proportion to the outcrop for each rock type in the whole area (Table III). These figures indicate that the average composition of surficial rocks in this area is very close to that of granodiorite (Barth, 1952, p. 69).

In Table XVIII, these weighted averages are compared with various estimates of crustal abundance and with an estimate of the composition of the continental, crystalline, surface, shield rocks (Poldervaart, 1955). A comparison of this type is difficult since each estimate involves a variety of assumptions. However, the following conclusions may be drawn.

- (1) The average composition of this section of the Canadian Shield agrees very well with Poldervaart's (1955) average composition of the continental, crystalline, surface, shield rocks. However,  $K_2O$  in the Red Lake-Lansdowne House area (2.25%) is low relative to Poldervaart's figure (3.3%).
- (2) Comparisons with the estimates of crustal abundance, given by Vinogradov (1962), Turekian and Wedepohl (1961), and

Poldervaart and Green (1959), indicate that, in general, the surficial rocks of this area are more granitic, in that they contain:

- (a) more  $\text{SiO}_2$ ,  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}(?)$
- (b) less  $\text{TiO}_2$ , total Fe, MnO, MgO, CaO,  $\text{P}_2\text{O}_5$  and S(?).

### Trace Elements

#### Averages

Trace element averages are presented in four forms, which are:

- (1) averages for each rock type in each map area (averages for pairs of duplicate composite samples, in Appendix XIII)
- (2) weighted averages for each map area (Table XIX)
- (3) weighted averages for each rock type (Table XX)
- (4) weighted averages for the whole area:
  - (a) derived from the 102 composite samples (Table XIX)
  - (b) derived from the 8 composites of composite samples representing each rock type in the whole area (Appendix VIII)

These last two sets of averages (Table XXI) agree closely except for Be, V and Ba. The averages derived from the 102 composite samples are preferable since they are the result of a number of independent observations for each rock type and are therefore less subject to the effects of analytical error. Both sets of averages have been corrected to agree with preferred values for W-1 in order to facilitate their interpretation (Table XXII). The

correction factors based on G-1 (Table XII) could not be applied, in conjunction with those based on W-1, since some of them are missing.

#### Significance of Variation

The analysis of variance techniques described in Chapter III have been employed to detect regional variations and variations between rock types. The tests were carried out on three different groupings of rock types. These are:

- (1) all rock types (except rock type 1)
- (2) felsic rock types
- (3) basic and sedimentary rock types.

Table XXIII lists trace elements which vary significantly within these three groupings.

All trace elements, except Cu, vary significantly between rock types (Table XXIII) when all rock types or only the basic and sedimentary rock types are considered. However, in the felsic group, significant variation exists between rock types for the elements Cr, V, Ni, Co, Mn, Sr and Ba. These results are not surprising. They simply reflect known variations in composition (Table VI).

The significant regional variations indicate that the Red Lake-Lansdowne House area cannot be considered to be homogeneous for certain trace elements, and that this heterogeneity varies depending upon which major group of rock types (felsic or basic) is considered. These variations suggest that the map areas cannot be regarded as equivalent samples. For example, the rock types may not be exactly equivalent

from map area to map area. This is supported by the fact that regional variations are almost always accompanied by significant interactions between map areas and rock types (Tables XIV, XV, and XVI). In order to establish more accurate averages, particularly for Cr, Mn, Sr and Ba, an expanded experimental design, with much more well defined rock types, is necessary.

It is interesting to note that Cu is the only trace element which shows no significant variation of any kind, either regional or between rock types, despite the fact that Holman (1963h) found a maximum range of less than 5 to 700 p.p.m. Cu for this area. Holman's weighted averages for the map areas are uniform, with a range of about 14 to 22 p.p.m. Cu.

The significance of variations of Sc in basic intrusive and basic volcanic rock types (6 and 8) was tested separately (Appendix XII). No significant variation is indicated.

#### Comparisons

Trace element averages for the whole area (Table XXIV) are compared with estimates of crustal abundance given by Turekian and Wedepohl (1961), Vinogradov (1962), and Shaw (1964). These estimates are based on many different sources of data and on different assumptions. Nonetheless, some general conclusions may be drawn. The surface rocks of the Red Lake-Lansdowne House area are:

- (1) low in Be, Ti, V, Ni, Co, Cu, Y, Mn, Sc, and Zr
- (2) high in Sr and Ba.

One would think that the trace element averages for this area should agree closely with the crustal abundances based on the proportion of igneous rocks exposed on the surface of the continents (Turekian and Wedepohl, 1961, Model I). An examination of these two sets of data suggests that this area may be:

- (1) low in Be, Ti, V, Cu, Y, Sc, and Zr
- (2) high in Sr.

The low concentration of Cu has been confirmed by the work of Holman (1963h). He quotes an average of 15 to 20 p.p.m. Cu. This agrees very well with the average of 17 p.p.m. Cu given here.

In interpreting the significance of these deviations from crustal abundance, variations of the major constituents must be taken into account. Marked differences were noted above between the major element composition of this area and various estimates of crustal abundance. However, the composition of the surficial rocks in this area is quite similar to the estimates of major element abundance for continental, igneous terrains (Table XVIII) given by Poldervaart (1955), and Turekian and Wedepohl (1961, Model I). Therefore, deviations from the trace element crustal abundances, given by Turekian and Wedepohl (1961, Model I) (Table XXIV) are probably significant, since the comparisons are virtually free from the influence of fluctuations of the major constituents. Thus, the Red Lake-Lansdowne House area may be considered to be low in Be, Ti, V, Cu, Y, Sc and Zr, and high in Sr.

It is instructive to compare trace element averages, for the different rock types in this area, with other averages for similar rock

types. Comparisons are made for the felsic rock types (Table XXV, uncorrected and corrected for G-1), the basic rock types (Table XXVI, uncorrected and corrected for W-1), and for the sedimentary rock type (Table XXVII).

Examination of Table XXV indicates that, even when corrected for G-1, Sr is high and Zr is low in the felsic rocks of this area relative to the other estimates. The other trace elements agree as to the order of magnitude, but the obvious variability from one estimate to another rules out any definite conclusions.

Fair agreement seems to exist between the trace element averages (Table XXVI) for the basic intrusive and basic volcanic rock types (6 and 8) and the other estimates for basic rocks. Some differences are outstanding. Ti, Cu, Sc and Zr appear to be low, even when corrected for W-1. Taking into account that the spectrographic method greatly underestimates Sr, it is high relative to the other estimates.

The sedimentary unit (mainly slate, argillite, quartzite, greywacke, conglomerate and their metamorphic equivalents) can be compared directly with the work of MacPherson (1958) on Canadian Precambrian greywackes, argillites and low grade schists, and of Herz and Dutra (1960) on Precambrian metasedimentary rocks in a part of the Brazilian Shield (Table XXVII). Agreement is not good and the content of trace elements in the Precambrian sediments of the Red Lake-Lansdowne House area is generally low, except for Mn, which is about twice the value given by MacPherson.

### Suggestions for Further Work

No accurate information is available as to the mineralogical variations among the composite samples used in this study. The distribution of the more common mineral species could possibly be determined by means of infrared spectroscopy (Abbey, 1964). The use of activation analysis and more specialized spectrographic methods could provide information as to the abundance and distribution of elements, such as Au, Ag, the platinum group and the rarer alkalis, which have not been considered in this study.



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TABLE I

Description of Rock Types

<u>Rock Type</u>	<u>Symbol</u>
1. Leucocratic, pink and white, massive granite	LGR
2. Massive to slightly foliated granite. Includes undivided granitic rocks.	MGR
3. Massive porphyritic granite. Phenocrysts are potash feldspar.	PGR
4. Foliated granodiorite.	GD
5. Paragneiss, lit-par-lit gneiss, migmatite, mixed rocks, hybrid granitic rocks with abundant amphibolitic inclusions.	GN
6. Basic to ultramafic intrusive rocks. Comprised of diorite, quartz diorite, gabbro, olivine gabbro, anorthositic gabbro, pyroxenite and minor melanocratic granodiorite.	GAB
7. Metasedimentary rocks composed mainly of slate, argillite, quartzite, greywacke, conglomerate and metamorphic equivalents. Also includes minor iron formation.	SED
8. Meta-basalt and meta-andesite, with minor acidic flows, tuff, breccia and agglomerate.	VOL

(Sequence of rock types is believed to be chronological, oldest at the base.)

TABLE II

Outcrop for Each Rock Type in Each Map Area as a Percent  
of Total Outcrop for Each Rock Type

Rock Type	Map Sheet							Total
	1	2	3	4	5	6	7	
1 LGR	66	34	-	-	-	-	-	100
2 MGR	16	17	15	11	13	14	14	100
3 PGR	15	24	46	-	2	4	9	100
4 GD	8	-	15	20	16	24	17	100
5 GN	-	33	-	12	30	14	11	100
6 GAB	-	-	-	31	-	63	6	100
7 SED	10	10	8	22	15	5	30	100
8 VOL	8	11	16	21	22	4	18	100

TABLE III

Outcrop for Each Rock Type in Each Map Area as a Percent  
of Total Outcrop for Each Map Area

Rock Type	Map Sheet							% of Outcrop for Whole Area
	1	2	3	4	5	6	7	
1 LGR	31	16	-	-	-	-	-	7
2 MGR	38	40	35	26	29	33	32	33
3 PGR	7	11	21	-	1	2	4	7
4 GD	13	-	26	34	27	41	28	24
5 GN	-	19	-	7	17	8	6	8
6 GAB	-	-	-	5	-	10	1	2
7 SED	4	4	3	9	6	2	12	6
8 VOL	7	10	15	19	20	4	17	13
TOTAL	100	100	100	100	100	100	100	100

After Holman (1963a, b, c, d, e, f, and g).

Felsic rocks = 79% of total outcrop

Basic rocks = 15% of total outcrop

Sedimentary rocks = 6% of total outcrop



TABLE IV  
Comparison of Number of Primary Samples with  
Per Cent Outcrop for Each Rock Type

<u>Rock Type</u>	<u>Number of Primary Samples *</u>	<u>% of Total Number of Primary Samples</u>	<u>% of Total Outcrop for All Map Areas</u>
1 LGR	456	5.7	7
2 MGR	2603	32.2	33
3 PGR	614	7.6	7
4 GD	1808	22.4	24
5 GN	707	8.7	8
6 GAB	417	5.2	2
7 SED	464	5.7	6
8 VOL	1007	12.5	13
<b>Total</b>	<b>8076</b>	<b>100.0</b>	<b>100</b>

\* These figures were derived from data on the distribution of primary samples given in Appendices I, II, III and IV.

TABLE V

Approximate Percentages of Granitic and Pre-existing  
Rocks Exposed in the Superior - Wyoming - Slave Province  
of North America<sup>1</sup>

<u>Rock Type</u>	<u>%</u>
Granitic rock <sup>2</sup>	76
Peridotite <sup>3</sup>	0.1
Diorite and Quartz Diorite	2
Sedimentary rocks	5
Basic volcanics	12
Felsic volcanics	0.1
Other	4

1: After Engel(1963).

2: Includes quartz-monzonite, granodiorite, quartz porphyry  
and gneisses pervasively veined by granite.

3: Island - arc (Alpine) type.

TABLE VI

Major Constituents in Composites of Composite Samples for Each Rock Type

(wt. per cent of oxide)

	LGR CC-1	MGR CC-2	PGR CC-3	GD CC-4	GN CC-5	GAB CC-6	SED CC-7	VOL CC-8
SiO <sub>2</sub>	72.12	69.85	67.97	68.41	66.73	52.77	63.07	52.63
TiO <sub>2</sub>	0.21	0.29	0.44	0.37	0.52	0.88	0.54	0.88
Al <sub>2</sub> O <sub>3</sub>	14.78	15.67	15.57	15.75	15.83	14.73	14.52	14.33
Fe <sub>2</sub> O <sub>3</sub>	0.76	0.90	1.14	1.06	1.25	2.40	2.10	2.30
FeO	0.99	1.42	1.63	1.99	2.97	7.16	4.95	8.04
MnO	0.03	0.03	0.05	0.05	0.07	0.15	0.11	0.18
MgO	0.55	0.95	1.07	1.41	1.86	6.86	2.82	6.41
CaO	1.84	2.67	2.95	3.44	3.63	8.81	4.62	9.14
Na <sub>2</sub> O	3.89	4.28	4.09	4.38	3.84	2.66	2.92	2.44
K <sub>2</sub> O	3.79	2.78	3.65	1.96	1.75	0.82	1.65	0.68
P <sub>2</sub> O <sub>5</sub>	0.08	0.12	0.24	0.11	0.16	0.18	0.14	0.12
H <sub>2</sub> O+110°C	0.51	0.50	0.43	0.65	0.80	1.78	1.36	1.83
H <sub>2</sub> O-110°C	0.08	0.07	0.06	0.05	0.06	0.06	0.08	0.07
CO <sub>2</sub>	0.04	0.06	0.07	0.07	0.06	0.22	0.27	0.58
Ign	(0.64)	(0.73)	(0.71)	(0.76)	(0.99)	(2.01)	(1.73)	(2.36)
F	0.02	0.03	0.05	0.03	0.03	0.03	0.04	0.03
Cl	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
S	n.d.	n.d.	n.d.	n.d.	0.05	0.06	0.25	0.08
SO <sub>3</sub>	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sum	99.72	99.65	99.45	99.77	99.63	99.60	99.48	99.78
O = F	0.01	0.01	0.02	0.01	0.03	0.03	0.11	0.04
Total	99.71	99.64	99.43	99.76	99.60	99.57	99.37	99.74

All values for SiO<sub>2</sub>, TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, FeO, MnO, MgO, CaO, Na<sub>2</sub>O, K<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub> and H<sub>2</sub>O+ are averages of duplicate analyses (see Appendix VI).

Analyst: J. Muysson

TABLE VII

Major Constituents in the Interlaboratory Standards G-1, W-1, T-1 and GR  
(weight % oxide)

	G-1		W-1		T-1		GR	
	This Paper <sup>a</sup>	Preferred Value <sup>b</sup>	This Paper <sup>a</sup>	Preferred Value <sup>b</sup>	This Paper <sup>a</sup>	Preferred Value <sup>c</sup>	This Paper <sup>a</sup>	Preferred Value <sup>c</sup>
SiO <sub>2</sub>	72.47	72.41	52.27	52.46	62.80	63.08	65.61	65.85
TiO <sub>2</sub>	0.26	0.26	1.10	1.07	0.56	0.56	0.65	0.62
Al <sub>2</sub> O <sub>3</sub>	14.26	14.27	14.87	15.03	16.36	16.31	14.92	14.54
Fe <sub>2</sub> O <sub>3</sub>	0.78	0.87	1.44	1.41	2.58	2.73	1.71	1.68
FeO	0.96	0.98	8.75	8.74	2.93	2.82	2.07	2.12
MnO	0.03	0.03	0.17	0.16	0.11	0.10	0.06	0.06
MgO	0.34	0.41	6.65	6.62	1.82	1.82	2.31	2.34
CaO	1.33	1.39	10.89	10.96	5.06	5.12	2.49	2.47
Na <sub>2</sub> O	3.34	3.32	2.19	2.07	4.39	4.32	3.76	3.73
K <sub>2</sub> O	5.42	5.45	0.60	0.64	1.19	1.23	4.50	4.50
P <sub>2</sub> O <sub>5</sub>	0.09	0.09	0.14	0.14	0.18	0.17	0.34	0.34
H <sub>2</sub> O	0.48	0.40	0.75	0.69	1.50	1.31	0.94	0.87
CO <sub>2</sub>	0.08	0.08	0.06	0.05	0.06	0.08	0.14	0.37 <sup>d</sup>
F	0.06	0.07	-	-	-	-	-	-
O = F	0.03	0.03	-	-	-	-	-	-
Total	99.87	100.00	99.88	100.04	99.54	99.65	99.50	99.49

<sup>a</sup> Analyst: J. Muysson

<sup>b</sup> Fleischer and Stevens (1962). The preferred value for SiO<sub>2</sub> in W-1 may be 52.63%, but this has not been firmly established. After a revision in techniques, J. Muysson obtains 52.63% SiO<sub>2</sub> in W-1 (pers. comm., J. Muysson).

<sup>c</sup> Ingamells and Suhr (1963).

<sup>d</sup> Total carbon by combustion, calculated as CO<sub>2</sub>, not acid soluble CO<sub>2</sub>.

TABLE VIII

Details of Spectrographic Method

Spectrograph:	Jarrell-Ash 21 ft. grating, Wadsworth mount, first order dispersion of 5.2 Å/mm.
Condensing optics:	25 cm. focal length cylindrical lens (horizontal axes) at the slit; 6.7 cm. focal length cylindrical lens (vertical axes) at 16.1 cm. from the slit; 5 mm. diaphragm at 27.5 cm. from the slit; arc 72.5 cm. from slit.
Arc gap:	4 mm.
Slit width:	30 microns
Slit length:	8 mm.
Intensity reduction:	7 step rotating sector (log intensity ratio of 0.2) at the slit. One wire-mesh screen at the diaphragm. No filter.
Voltage:	220 volts D.C. open circuit.
Current:	6.5 amps.
Exposure:	to completion, approximately 110 seconds.
Electrodes:	National Carbon Co. 'special' grade 1/8" graphite rod cathode. United Carbon Products ultrapurity preformed 1/8" graphite anode, 1/16" x 3/8" plain crater.
Charge:	1 part sample to 1 part graphite containing 0.025 % PdCl <sub>2</sub> and 0.125% In <sub>2</sub> O <sub>3</sub> .
Gas jet:	Stallwood jet with 80% argon - 20% oxygen mixture (supplied in mixed tank by Canadian Liquid Air Co.) at flow of 18 s.c.f.h.
Photographic Plates:	Eastman Kodak Type SA1 (2200-3500Å) Eastman Kodak Type IIIIF (3500-4800Å)
Processing:	3 minutes in Kodak D-19 developer at 20°C, 30 second stop bath of 3% acetic acid, 4 minutes in acid fix ('Amfix' fixer), 1 hour water wash.
Photometry:	Jarrell-Ash microphotometer, background correction applied.

TABLE IX  
Data for Analysis Lines

Element	Analysis Line (Å)	Internal Standard Line (Å)	Sensitivity (p.p.m.)	Precision (%)
Be	3130.416	Pd 3242.703	0.1	6.4
V	3183.982	Pd 3242.703	10	5.8
Cu	3273.962	Pd 3242.703	1	17.2
Y	3327.875	Pd 3242.703	30	-
Zr	3391.975	Pd 3242.703	10	11.7
Ni	3414.765	Pd 3242.703		
Ni	3414.765	Pd 3421.240	1	9.5
Co	3453.505	Pd 3242.703		
Co	3453.505	Pd 3421.240	1	8.6
Mn	4034.490	Pd 3609.548	10	4.9
Sc	4246.829	Pd 3609.548	8	7.1
Cr	4254.346	Pd 3609.548	4	7.8
Ti	4305.916	Pd 3609.548	100	5.5
Ba	4554.042	Pd 3609.548	10	6.3
Sr	4607.331	Pd 3609.548	10	7.2

Wavelengths were taken from Harrison (1939).

Precision is expressed as the coefficient of variation in percent  
 (see text)

TABLE X

Compositions of Synthetic Matrices

(weight %)

	Granodiorite Matrix	Gabbro Matrix
SiO <sub>2</sub>	55	43
Al <sub>2</sub> O <sub>3</sub>	15	15
Fe <sub>2</sub> O <sub>3</sub>	6	10
MgO	6	6
CaCO <sub>3</sub>	6	16
NaCl	6	7
KCl	6	3
	<hr/>	<hr/>
	100	100
	<hr/>	<hr/>

TABLE XI

Comparison of Trace Element Values for G-1 and W-1 with Recommended Values

	This Paper <sup>a</sup>	<u>G-1</u>	Recommended Value <sup>b</sup>
Be	3.1		3.3
Ti	1160		1500
Cu	10		13
Mn	240		210
Zr	101		210
Sr	280		280
Ba	1850		1220

	This Paper <sup>a</sup>	<u>W-1</u>	Recommended Value <sup>b</sup>
Be	1.5		0.8
Ti	6200		6400
Cr	76		120
V	213		240
Ni	51		80
Co	41		52
Cu	124		110
Mn	1540		1300
Sc	36		33
Zr	93		100
Sr	85		220
Ba	229		225

All values are in p.p.m.

<sup>a</sup> Each value is the arithmetic mean of a triplicate analysis.

<sup>b</sup> After Fleischer and Stevens (1962).



TABLE XII

Trace Element Correction Factors Based on Values for G-1 and W-1

Element	Correction Factors	
	Based on G-1	Based on W-1
Be	1.06452	0.53333
Ti	1.29310	1.03226
Cr	-	1.57895
V	-	1.12676
Ni	-	1.56863
Co	-	1.26829
Cu	1.30000	0.88710
Mn	0.87500	0.84415
Sc	-	0.91667
Zr	2.07921	1.07527
Sr	1.00000	2.58823
Ba	0.65946	0.98253

TABLE XIII

Analysis of Variance Table  
Two Classifications with Replication

Source of Variation	D.F.	Sums of Squares	Mean Squares	To Test Hypothesis:	Statistic (F)
Map Areas	p-1	$S_i^2 = nq \sum_i (\bar{x}_{i..} - \bar{x})^2$	$s_i^2 = S_i^2 / (p-1)$	$y_1 = y_2 = \dots = y_p$	$s_i^2 / s^2$
Rock Types	q-1	$S_j^2 = np \sum_j (\bar{x}_{.j.} - \bar{x})^2$	$s_j^2 = S_j^2 / (q-1)$	$z_1 = z_2 = \dots = z_q$	$s_j^2 / s^2$
Interaction	(p-1)(q-1)	$S_{ij}^2 = n \sum_{i,j} (\bar{x}_{ij.} - \bar{x}_{i..} - \bar{x}_{.j.} + \bar{x})^2$	$s_{ij}^2 = S_{ij}^2 / (p-1)(q-1)$	$\sigma_w^2 \neq 0$	$s_{ij}^2 / s^2$
Duplicates	pq(n-1)	$S_{k(ij)}^2 = \sum_{i,j,k} (x_{ijk} - \bar{x}_{ij.})^2$	$s^2 = S_{k(ij)}^2 / pq(n-1)$		
Total	npq-1	$S_T^2 = \sum_{i,j,k} (x_{ijk} - \bar{x})^2$	$MS_T = S_T^2 / (npq-1)$		

Model:  $x_{ijk} = u + y_i + z_j + w_{ij} + e_{ijk}$

After Miller and Kahn (1962)

TABLE XIV

Significance of Effects for the Two-Way Analysis of Variance  
of Trace Elements in Rock Types 2, 3, 4, 5, 6, 7, and 8 for All Map Areas

	Between Map Areas	Between Rock Types	Interaction
Be	-	**	-
Ti	-	**	-
Cr	**	**	*
V	-	**	*
Ni	-	**	-
Co	-	**	-
Cu	-	-	-
Mn	*	**	-
Zr	-	**	-
Sr	**	**	**
Ba	**	**	**

- = not significant at the 5% level

\* = significant at the 5% level

\*\* = very significant = significant at the 1% level

TABLE XV

Significance of Effects for the Two-Way Analysis of Variance  
of Trace Elements in Rock Types 2, 3, 4, and 5 for All Map Areas

	Between Map Areas	Between Rock Types	Interaction
Be	-	-	-
Ti	-	-	-
Cr	**	**	**
V	**	**	**
Ni	**	**	**
Co	**	**	**
Cu	-	-	-
Mn	-	**	-
Zr	-	-	-
Sr	**	**	*
Ba	**	**	**

- = not significant at the 5% level

\* = significant at the 5% level

\*\* = very significant = significant at the 1% level

TABLE XVI

Significance of Effects for the Two-Way Analysis of Variance  
of Trace Elements in Rock Types 6, 7, and 8 for All Map Areas

	Between Map Areas	Between Rock Types	Interaction
Be	-	*	-
Ti	-	**	*
Cr	*	**	-
V	-	**	-
Ni	-	**	-
Co	-	**	-
Cu	-	-	-
Mn	-	**	-
Zr	*	*	**
Sr	*	*	*
Ba	**	**	**

- = not significant at the 5% level

\* = significant at the 5% level

\*\* = very significant = significant at the 1% level

TABLE XVII

Weighted Major Element Averages for the Whole Area

(weight % oxide)

	Weighted Average	
SiO <sub>2</sub>	66.30	
TiO <sub>2</sub>	0.47	
Al <sub>2</sub> O <sub>3</sub>	15.37	
Fe <sub>2</sub> O <sub>3</sub>	1.26 <sup>a</sup>	
FeO	2.85	
MnO	0.07	
MgO	2.05	
CaO	3.97	
Na <sub>2</sub> O	3.87	
K <sub>2</sub> O	2.25	
P <sub>2</sub> O <sub>5</sub>	0.13	
H <sub>2</sub> O <sup>+</sup>	0.81	
H <sub>2</sub> O <sup>-</sup>	0.06	
CO <sub>2</sub>	0.15	
F	0.03	
Cl	0.01	
S	0.03	
SO <sub>3</sub>	-	
O=F	0.01	
TOTAL	99.67	

<sup>a</sup> Total Fe  
as Fe<sub>2</sub>O<sub>3</sub>  
is 4.43%

These averages were derived from major element analyses (Table VI) of 8 composites (CC1 to CC8) of the 102 composite samples. The averages were obtained by weighting the data in proportion to the outcrop for each rock type in the whole area (Table III).

TABLE XVIII

Weighted Major Element Averages for the Whole Area Compared with  
Estimates of Crustal Abundance (weight % oxide)

	This Paper <sup>a</sup>	Poldervaart <sup>b</sup> (1955)	Vinogradov <sup>c</sup> (1962)	Turekian & Wedepohl (1961) <sup>d</sup>		Poldervaart and Green (1959)
				Model I	Model II	
SiO <sub>2</sub>	66.30	66.4	63.11	66.74	59.04	55.2
TiO <sub>2</sub>	0.47	0.6	0.75	0.68	1.30	1.7
Al <sub>2</sub> O <sub>3</sub>	15.37	15.5	15.21	14.49	14.74	15.3
Fe <sub>2</sub> O <sub>3</sub>	1.26 <sup>e</sup>	1.8 <sup>f</sup>	6.65 <sup>g</sup>	5.00 <sup>g</sup>	8.58 <sup>g</sup>	2.9
FeO	2.85	2.8	-	-	-	5.8
MnO	0.07	0.1	0.13	0.08	0.13	0.3
MgO	2.05	2.0	3.10	1.97	3.93	5.1
CaO	3.97	3.8	4.14	6.13	6.94	8.4
Na <sub>2</sub> O	3.87	3.5	3.37	3.26	2.47	3.0
K <sub>2</sub> O	2.25	3.3	3.01	3.52	1.93	1.9
P <sub>2</sub> O <sub>5</sub>	0.13	0.2	0.21	0.18	0.22	0.2
H <sub>2</sub> O <sup>+</sup>	0.81	-	-	-	-	-
H <sub>2</sub> O <sup>-</sup>	0.06	-	-	-	-	-
CO <sub>2</sub>	0.15	-	0.08	-	-	0.4
F	0.03	-	0.07	0.06	0.05	-
Cl	0.01	-	0.02	0.01	0.01	-
S	0.03	-	0.05	0.10	0.15	-
SO <sub>3</sub>	-	-	-	-	-	-
O=F	0.01		0.05	0.06	0.07	
TOTAL	99.67	100.0	99.85	102.16	99.42	100.2

TABLE XVIII Continued

- a These averages were derived from major element analyses of 8 composites (CC1 to CC8) of the 102 composite samples. The averages were obtained by weighting the data in proportion to the outcrop for each rock type in the whole area.
- b Average composition of continental shield crystalline surface rocks.
- c Crustal abundance obtained by assuming that the crust is composed of two parts of granite and one part of basalt.
- d Model I: Crustal abundance based on the proportion of exposed igneous rocks on the surface of the continents.  
Model II: Crustal abundance based on the assumption of a crust composed primarily of equal parts of high-calcium granitic rocks and basaltic rocks.
- e Total Fe as  $\text{Fe}_2\text{O}_3$  is 4.43%.
- f Total Fe as  $\text{Fe}_2\text{O}_3$  is 4.9%.
- g Total Fe as  $\text{Fe}_2\text{O}_3$ .



TABLE XIX

Weighted Trace Element Averages for Each Map Area and for Whole Area

	Map Area							Weighted Averages for Whole Area <sup>a</sup>
	1	2	3	4	5	6	7	
Be	1.01	1.13	1.23	0.98	1.04	0.89	1.27	1.08
Ti	2210	2300	2610	3130	2490	2760	2900	2630
Cr	47	44	39	93	60	40	54	54
V	52	54	61	88	80	62	81	68
Ni	16	15	16	34	24	20	26	22
Co	7.2	10	11	15	14	10	15	12
Cu	11	14	14	21	21	17	24	17
Y	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30
Mn	600	614	686	974	881	672	921	764
Sc	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8
Zr	64	47	53	67	56	60	62	58
Sr	532	450	668	445	437	636	436	515
Ba	793	611	824	538	451	910	415	649

All values are in p.p.m.

Weighting factors in Table III

<sup>a</sup> Average of columns 1 to 7

TABLE XX

Weighted Trace Element Averages for Each Rock Type (uncorrected)

	Rock Type							
	1 (LGR)	2 (MGR)	3 (PGR)	4 (GD)	5 (GN)	6 (GAB)	7 (SED)	8 (VOL)
Be	1.07	1.04	1.00	0.99	0.95	1.25	1.20	1.39
Ti	1350	1870	2320	2510	2850	4580	3250	4800
Cr	< 4	6.0	6.0	16	36	279	122	239
V	19	28	37	47	70	179	98	215
Ni	3.3	3.5	5.0	8.7	14	115	38	91
Co	< 1	4.2	5.3	5.2	9.4	37	16	47
Cu	4.0	8.5	10	13	22	43	22	48
Y	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30
Mn	358	402	481	508	718	1740	1270	2140
Sc	< 8	< 8	< 8	< 8	< 8	16	< 8	19
Zr	49	48	52	57	62	68	93	80
Sr	459	539	788	645	464	363	342	234
Ba	858	771	1200	606	510	358	394	272

All values are in p.p.m.

Derived from the 102 composite samples

TABLE XXI

Comparison of Weighted Trace Element Averages  
for the Whole Area (uncorrected)

	Composite Samples <sup>a</sup>	Composites of Composite Samples <sup>b</sup>
Be	1.08	0.64
Ti	2630	2590
Cr	54	63
V	68	82
Ni	22	23
Co	12	11
Cu	17	13
Y	< 30	< 30
Mn	764	735
Sc	< 8	< 8
Zr	58	44
Sr	515	549
Ba	649	494

All values are in p.p.m.

<sup>a</sup> These averages were derived from trace element data for 102 composite samples (from Table XIX).

<sup>b</sup> These averages were derived from trace element data for 8 composites (CC1 to CC8) of the 102 composite samples (from Table III and Appendix VIII).

TABLE XXII

Comparison of Weighted Trace Element Averages for the Whole Area, Corrected to Agree with Preferred Values for W-1

	Composite Samples <sup>a</sup>	Composites of Composite Samples <sup>b</sup>
Be	0.58	0.34
Ti	2710	2670
Cr	85	99
V	77	92
Ni	35	36
Co	15	14
Cu	15	12
Y	< 30	< 30
Mn	645	620
Sc	< 8	< 8
Zr	62	47
Sr	1330	1420
Ba	638	485

All values are in p.p.m.

<sup>a</sup> These averages were derived from trace element data for 102 composite samples.

<sup>b</sup> These averages were derived from trace element data for 8 composites (CC1 to CC8) of the 102 composite samples.

TABLE XXIII

Summary of Significant VariationsSignificant Regional Variations

All Rock Types	Felsic Rock Types	Basic and Sedimentary Rock Types
Cr	Cr	Cr
Mn	V	Zr
Sr	Ni	Sr
Ba	Co	Ba
	Sr	
	Ba	

Significant Variations Between Rock Types

All Rock Types	Felsic Rock Types	Basic and Sedimentary Rock Types
Be	Cr	Be
Ti	V	Ti
Cr	Ni	Cr
V	Co	V
Ni	Mn	Ni
Co	Sr	Co
Mn	Ba	Mn
Zr		Zr
Sr		Sr
Ba		Ba

Cu shows no significant variations of any kind.

TABLE XXIV

Comparison of Trace Element Averages for Whole Area with  
Estimates of Crustal Abundance

	This Paper <sup>a</sup>		Turekian & Wedepohl(1961) <sup>b</sup>		Vinogradov <sup>c</sup>	Shaw <sup>d</sup>
	A	B	Model I	Model II	(1962)	(1964)
Be	1.08	0.58	2.2	1.5	3.8	2
Ti	2630	2710	4100	7800	4500	-
Cr	54	85	65	111	83	90
V	68	77	99	169	90	100
Ni	22	35	37	75	58	80
Co	12	15	12	28	18	27
Cu	17	15	35	64	47	70
Y	< 30	< 30	34	28	29	40
Mn	764	645	650	970	1000	1000
Sc	< 8	< 8	14	22	10	15
Zr	58	62	160	130	170	156
Sr	515	1330	300	450	340	450
Ba	649	638	611	377	650	250

All values are in p.p.m.

<sup>a</sup> A: Weighted trace element averages for the whole area, derived from data for 102 composite samples.

B: Weighted trace element averages for the whole area, derived from data for 102 composite samples and corrected to agree with preferred values for W-1.

<sup>b</sup> Model I: Crustal abundance based on the proportion of exposed igneous rocks on the surface of the continents.  
Model II: Crustal abundance based on the assumption of a crust composed primarily of equal parts of high-calcium granitic rocks and basaltic rocks.

<sup>c</sup> Crustal abundance obtained by assuming that the crust is composed of two parts of granite and one part of basalt.

<sup>d</sup> Estimates of crustal abundance taken from various sources in the literature.

TABLE XXV

Comparison of Trace Element Averages for  
Felsic Rock Types

	This Paper <sup>a</sup>		Turekian & Wedepohl (1961) <sup>b</sup>		Vinogradov <sup>c</sup>	Herz & Dutra <sup>d</sup>	Shaw <sup>e</sup>
	A	B	A	B	(1962)	(1960)	(1964)
Be	1.02	1.09	2	3	5.5	4.1	3.2
Ti	2150	2780	3400	1200	2300	-	-
Cr	12	-	52	26	25	7.7	2
V	38	-	88	44	40	29	(67)?
Ni	6.2	-	15	4.5	8	8.3	5.8
Co	4.8	-	7	1	5	3.8	3.0
Cu	8.9	12	40	10	20	11	16
Y	<30	-	35	40	34	82	~68
Mn	469	410	540	390	600	-	390
Sc	<8	-	14	7	3	6.5	11
Zr	63	131	140	175	200	220	140-175
Sr	579	579	440	100	450	160	440-1000
Ba	742	489	420	840	800	860	430

All values are in p.p.m.

a A: Trace element averages for felsic rock types (rock types 1, 2, 3, 4, and 5) weighted in proportion to their relative outcrop in the whole area. These values have not been corrected to agree with G-1.

B: Same as A but corrected to agree with preferred values for G-1 (Table XII).

b A: High - calcium granitic rocks.

B: Low - calcium granitic rocks.

c Felsic rocks (granites, granodiorites, etc.).

d Granitic rocks in a part of the Brazilian Shield.

e Averages for felsic rocks, derived from various sources in the literature.

TABLE XXVI

Comparison of Trace Element Averages for Mafic Rock Types

	This Paper <sup>a</sup>				Vinogradov <sup>b</sup> (1962)	Turekian and <sup>c</sup> Wedepohl(1961)	Shaw <sup>d</sup> (1964)
	Rock Type 6 (GAB)		Rock Type 8 (VOL)				
	A	B	A	B			
Be	1.25	0.67	1.39	0.74	0.4	1	1.0
Ti	4580	4730	4800	4960	9000	12200	-
Cr	279	441	239	378	200	170	340
V	179	202	215	242	200	250	220
Ni	115	180	91	143	160	130	97
Co	37	47	47	60	45	48	32
Cu	43	38	48	43	100	87	149
Y	< 30	-	< 30	-	20	21	~ 40
Mn	1740	1470	2140	1810	2000	1390	1160
Sc	16	15	19	17	24	30	37
Zr	68	73	80	86	100	110	110
Sr	363	940	234	606	440	465	465
Ba	358	352	272	267	300	333	280

All values are in p.p.m.

a A: Weighted trace element averages for each of the mafic rock types. These values have not been corrected to agree with preferred values for W-1.

B: Same as A for corrected to agree with W-1 (Table XII).

b Mafic rocks (basalts, gabbros, etc.).

c Basaltic rocks.

d Averages for basic rocks derived from various sources in the literature.



TABLE XXVII

Comparison of Trace Element Averages for  
Sedimentary Rock Type

	<u>This Paper</u> <sup>a</sup> Rock Type 7	MacPherson <sup>b</sup> (1958)	Herz and Dutra <sup>c</sup> (1960)
Be	1.20	-	1
Ti	3250	-	-
Cr	122	212	300
V	98	175	200
Ni	38	108	100
Co	16	-	9
Cu	22	47	20
Y	<30	-	30
Mn	1270	626	-
Sc	<8	-	9
Zr	93	-	200
Sr	342	-	400
Ba	394	441	900

All values are in p.p.m.

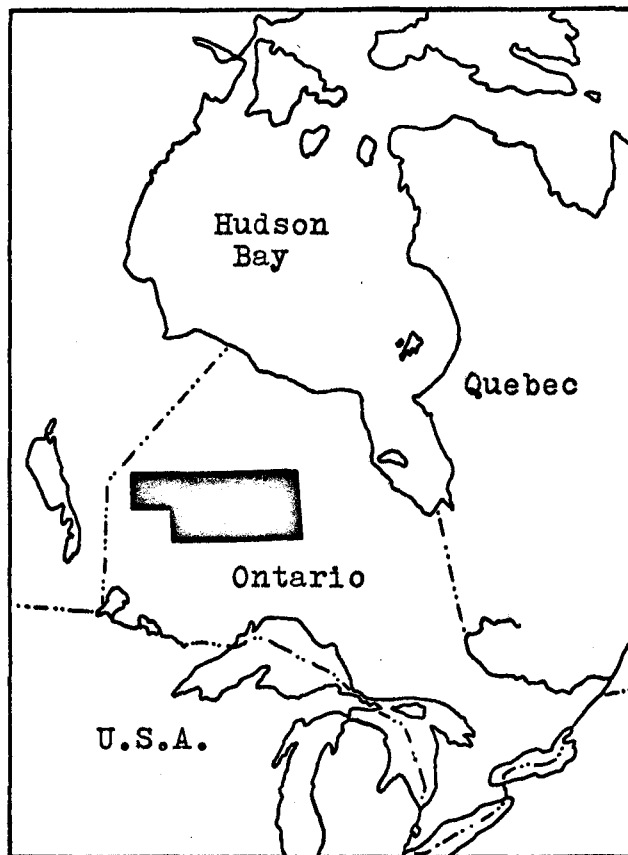
<sup>a</sup> Weighted trace element averages for the sedimentary unit. These values have not been corrected to agree with preferred values for W-1.

<sup>b</sup> Averages for Canadian Pre-Cambrian greywackes, argillites and low grade schists.

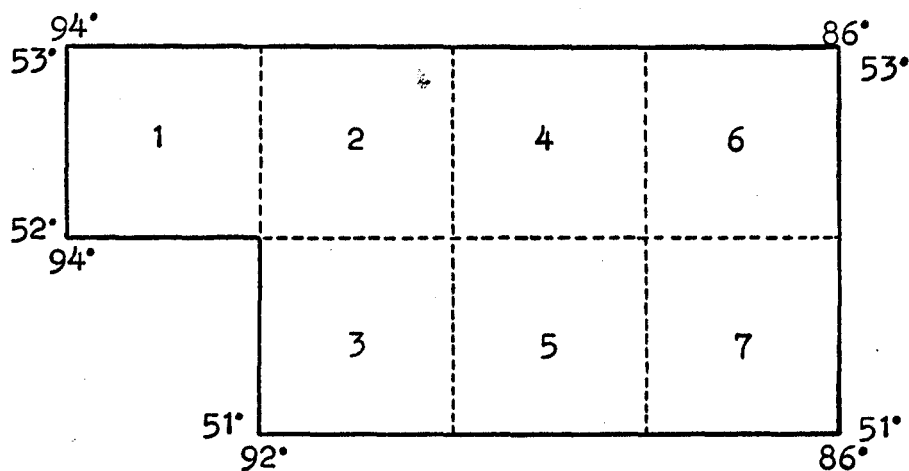
<sup>c</sup> Averages for Pre-Cambrian metasedimentary rocks in a part of the Brazilian Shield.

Figure 1

Location of Area



Scale: 1 inch to 400 miles

Figure 2Key to Location of Map Sheets

- 1 North Spirit Lake (53C)
- 2 North Caribou Lake (53B)
- 3 Lake St. Joseph (520)
- 4 Wunnummin Lake (53A)
- 5 Miminiska (52P)
- 6 Lansdowne House (43D)
- 7 Fort Hope (42M)

**APPENDICES**

APPENDIX I

Number of Primary Samples for Each Rock Type and Map Area

	Rock Type								Total
	1	2	3	4	5	6	7	8	
1	297	480	90	251	4	51	93	89	1355
2	159	326	49	13	245	29	29	106	956
3	-	662	364	390	2	40	87	251	1796
4	-	183	11	400	130	61	52	140	977
5	-	216	28	234	160	37	100	160	935
6	-	272	22	223	39	71	12	35	674
7	-	464	50	297	127	128	91	226	1383
Total	456	2603	614	1808	707	417	464	1007	8076

APPENDIX II

Number of Primary Samples as Percentage of the Grand Total for  
All Map Areas and Rock Types

	Rock Type							
	1	2	3	4	5	6	7	8
1	3.678	5.943	1.114	3.108	0.049	0.631	1.152	1.102
2	1.969	4.037	0.607	0.161	3.034	0.359	0.359	1.312
3	-	8.197	4.507	4.829	0.025	0.495	1.077	3.108
4	-	2.266	0.136	4.953	1.610	0.755	0.644	1.733
5	-	2.675	0.347	2.897	1.981	0.458	1.238	1.981
6	-	3.368	0.272	2.761	0.483	0.879	0.149	0.433
7	-	5.745	0.619	3.678	1.573	1.585	1.127	2.798

Grand Total is 8076 (100.000%)

APPENDIX III

Percentages of Total Number of Primary Samples for Each Rock Type  
in Each Map Area

Map Area	Rock Type							
	1	2	3	4	5	6	7	8
1	65.13	18.44	14.66	13.88	0.57	12.23	20.04	8.84
2	34.87	12.52	7.98	0.72	34.65	6.95	6.25	10.53
3	-	25.43	59.28	21.57	0.28	9.59	18.75	24.93
4	-	7.03	1.79	22.12	18.39	14.63	11.21	13.90
5	-	8.30	4.56	12.94	22.63	8.87	21.55	15.89
6	-	10.45	3.58	12.33	5.52	17.03	2.59	3.48
7	-	17.83	8.14	16.43	17.96	30.69	19.61	22.44
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

%

APPENDIX IV

Percentages of Total Number of Primary Samples for Each Map Area  
in Each Rock Type

Map Area	Rock Type								Total
	1	2	3	4	5	6	7	8	
1	21.92	35.42	6.64	18.52	0.29	3.76	6.86	6.57	100.00
2	16.63	34.10	5.13	1.36	25.63	3.03	3.03	11.09	100.00
3	-	36.86	20.27	21.71	0.11	2.23	4.84	13.97	100.00
4	-	18.73	1.13	40.94	13.31	6.24	5.32	14.33	100.00
5	-	23.10	2.99	25.03	17.11	3.96	10.69	17.11	100.00
6	-	40.36	3.26	33.09	5.79	10.53	1.78	5.19	100.00
7	-	33.55	3.61	21.47	9.18	9.25	6.58	16.34	100.00



## APPENDIX V

Number of Primary Individuals used to  
Make Each Composite

<u>Composite</u>	<u>Number in Composite</u>		<u>Composite</u>	<u>Number in Composite</u>
C111	149		C442	199
C112	148		C451	65
C121	240		C452	65
C122	240		C461	31
C131	45		C462	30
C132	45		C471	26
C141	126		C472	26
C142	125		C481	70
C151	2		C482	70
C152	2		C521	108
C161	26		C522	108
C162	25		C531	14
C171	47		C532	14
C172	46		C541	117
C181	45		C542	117
C182	44		C551	80
C211	80		C552	80
C212	79		C561	19
C221	163		C562	18
C222	163		C571	50
C231	25		C572	50
C232	24		C581	80
C241	7		C582	80
C242	6		C621	136
C251	123		C622	136
C252	122		C631	11
C261	15		C632	11
C262	14		C641	112
C271	15		C642	111
C272	14		C651	20
C281	53		C652	19
C282	53		C661	36
C321	331		C662	35
C322	331		C671	6
C331	182		C672	6
C332	182		C681	18
C341	195		C682	17
C342	195		C721	232
C351	1		C722	232
C352	1		C731	26
C361	20		C732	24
C362	20		C741	150
C371	44		C742	147
C372	43		C751	64
C381	126		C752	63
C382	125		C761	64
C421	93		C762	64
C422	90		C771	46
C431	6		C772	45
C432	5		C781	113
C441	201		C782	113
		Total Number of Individuals = 8076		

APPENDIX VI

Duplicate Major Element Analyses of Composites of Composite Samples (CC-1 to CC-8)  
(weight % of oxide)

	CC-1 (LGR)		CC-2 (MGR)		CC-3 (PGR)		CC-4 (GD)		CC-5 (GN)		CC-6 (GAB)		CC-7 (SED)		CC-8 (VOL)	
SiO <sub>2</sub>	71.96	72.28	69.80	69.90	67.91	68.03	68.42	68.41	66.79	66.67	52.74	52.80	63.02	63.12	52.69	52.57
TiO <sub>2</sub>	0.21	0.22	0.29	0.29	0.44	0.44	0.37	0.37	0.52	0.53	0.88	0.88	0.54	0.54	0.88	0.88
Al <sub>2</sub> O <sub>3</sub>	14.81	14.76	15.70	15.64	15.49	15.66	15.80	15.70	15.89	15.77	14.78	14.68	14.48	14.57	14.32	14.34
Fe <sub>2</sub> O <sub>3</sub>	0.78	0.75	0.90	0.91	1.16	1.12	1.05	1.08	1.25	1.25	2.38	2.42	2.06	2.15	2.33	2.28
FeO	0.99	0.99	1.43	1.42	1.64	1.63	1.99	1.99	2.97	2.97	7.18	7.14	4.99	4.91	8.02	8.06
MnO	0.03	0.03	0.03	0.04	0.06	0.05	0.05	0.05	0.07	0.07	0.15	0.15	0.11	0.11	0.18	0.18
MgO	0.56	0.54	0.95	0.95	1.06	1.08	1.35	1.47	1.86	1.86	6.87	6.85	2.84	2.81	6.38	6.45
CaO	1.82	1.86	2.67	2.68	2.96	2.95	3.45	3.44	3.61	3.66	8.77	8.86	4.62	4.62	9.16	9.13
Na <sub>2</sub> O	3.90	3.89	4.27	4.29	4.08	4.11	4.40	4.37	3.83	3.86	2.64	2.68	2.94	2.91	2.47	2.42
K <sub>2</sub> O	3.81	3.78	2.77	2.79	3.68	3.63	2.00	1.93	1.73	1.77	0.81	0.84	1.64	1.67	0.67	0.69
P <sub>2</sub> O <sub>5</sub>	0.08	0.08	0.12	0.12	0.24	0.24	0.11	0.12	0.16	0.16	0.17	0.19	0.14	0.14	0.12	0.13
H <sub>2</sub> O <sup>+110°C</sup>	0.57	0.45	0.49	0.51	0.45	0.42	0.61	0.70	0.74	0.86	1.78	1.78	1.32	1.41	1.81	1.86
H <sub>2</sub> O <sup>-110°C</sup>	0.08		0.07		0.06		0.05		0.06		0.06		0.08		0.07	
CO <sub>2</sub>	0.04		0.06		0.07		0.07		0.06		0.22		0.26	0.28	0.58	0.59
Ign	(0.64)		(0.73)		(0.71)		(0.76)		(0.99)		(2.01)		(1.73)		(2.36)	
F	0.02		0.03		0.05		0.03		0.03		0.03		0.04		0.03	
Cl	0.01		0.01		0.01		0.01		0.01		0.02		0.01		0.01	
S	n.d.		n.d.		n.d.		n.d.		0.05		0.06		0.25		0.08	
SO <sub>3</sub>	n.d.		n.d.		n.d.		n.d.		n.d.		n.d.		n.d.		n.d.	
Sum	99.67	99.78	99.59	99.71	99.36	99.55	99.76	99.79	99.63	99.64	99.54	99.66	99.34	99.62	99.80	99.77
O=F	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.03	0.03	0.03	0.03	0.11	0.11	0.04	0.04
Total	99.66	99.77	99.58	99.70	99.34	99.53	99.75	99.78	99.60	99.61	99.51	99.63	99.23	99.51	99.76	99.73
Total Fe as Fe <sub>2</sub> O <sub>3</sub>	1.88	1.85	2.49	2.49	2.98	2.93	3.26	3.29	4.55	4.55	10.33	10.39	7.61	7.61	11.24	11.24

H<sub>2</sub>O-, CO<sub>2</sub>, Ign, F, Cl, S, and SO<sub>3</sub> were not analyzed in duplicate except for CO<sub>2</sub> in CC-7 and CC-8.

Analyst: J. Muysson

## APPENDIX VII

Trace Element Analyses for Composite Samples

Sample	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
C111	0.93	1190	tr	18	tr	tr	2.9	n.d.	295	n.d.	51	340	954
C112	0.71	1310	tr	23	3.3	tr	3.5	tr	429	n.d.	54	592	896
C121	1.08	2400	7.4	40	2.4	3.5	9.0	n.d.	440	n.d.	64	592	761
C122	1.17	2550	8.2	48	6.1	tr	12	tr	474	n.d.	72	646	803
C131	1.02	2080	tr	36	tr	tr	4.6	n.d.	518	n.d.	77	563	1090
C132	0.85	3090	4.3	52	5.0	7.0	4.0	n.d.	680	n.d.	65	806	1100
C141	1.19	2300	13	48	10	5.4	14	tr	546	n.d.	48	631	863
C142	0.85	2540	7.3	47	5.3	6.3	9.9	tr	563	n.d.	81	638	682
C151	1.24	5350	97	136	19	27	6.4	tr	1120	tr	38	204	140
C152	0.75	6170	102	129	19	26	2.8	n.d.	1390	n.d.	52	227	147
C161	1.19	6570	269	143	123	36	19	tr	1220	11	122	617	648
C162	1.50	6030	173	181	45	35	28	tr	1520	15	130	569	804
C171	0.94	2460	241	103	70	20	32	n.d.	1350	18	69	133	289
C172	1.27	3490	276	152	56	23	25	tr	1320	tr	70	272	317
C181	1.19	3480	453	187	147	52	53	tr	2120	15	63	196	246
C182	1.31	4250	467	216	139	50	40	tr	2090	19	105	195	340
C211	2.17	1520	n.d.	14	4.3	tr	5.4	n.d.	364	n.d.	47	444	792
C212	0.93	1560	n.d.	13	2.0	tr	5.6	tr	337	n.d.	33	446	661

## APPENDIX VII (Continued)

Sample	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
C221	0.67	1970	7.5	28	5.3	6.5	9.8	n.d.	377	n.d.	48	309	634
C222	1.43	1960	tr	22	2.9	tr	9.5	n.d.	443	n.d.	35	592	657
C231	1.02	3040	tr	50	3.8	6.7	18	tr	496	n.d.	44	779	1060
C232	0.91	1910	4.7	30	2.3	3.5	5.3	tr	413	n.d.	43	682	993
C241	0.68	1660	n.d.	22	n.d.	n.d.	6.4	n.d.	367	n.d.	34	670	703
C242	1.02	1920	tr	29	6.4	7.7	10	tr	451	n.d.	46	328	327
C251	0.97	2330	12	55	7.3	tr	10	tr	495	n.d.	49	436	453
C252	0.71	2370	25	62	10	8.2	15	n.d.	655	n.d.	58	473	443
C261	1.26	4800	255	219	73	40	27	tr	1580	17	114	288	505
C262	1.10	3560	619	152	261	40	25	n.d.	1290	17	51	106	193
C271	0.70	2870	409	101	101	21	22	n.d.	1080	9.9	64	136	176
C272	1.07	3070	100	118	30	11	23	tr	1110	7.4	42	341	434
C281	1.57	4240	181	210	65	42	44	tr	1990	15	49	242	285
C282	1.71	4360	353	227	105	51	47	tr	1840	19	75	196	218
C321	0.91	1770	tr	25	1.8	2.3	4.5	tr	310	n.d.	52	631	809
C322	1.59	1790	tr	17	tr	tr	4.3	n.d.	363	n.d.	44	646	955
C331	0.94	2150	6.6	37	3.9	5.6	11	n.d.	447	n.d.	45	750	1150
C332	1.20	2310	tr	37	8.5	tr	9.8	n.d.	497	n.d.	57	1020	1580

## APPENDIX VII (Continued)

Sample	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
C341	1.01	2610	10	49	7.5	6.0	11	n.d.	513	n.d.	57	646	541
C342	1.46	2310	11	43	7.6	tr	17	n.d.	580	n.d.	39	869	749
C351	0.73	3320	20	65	13	11	13	n.d.	580	tr	89	374	802
C352	0.93	4200	29	88	19	16	11	tr	645	tr	113	728	727
C361	1.16	4600	1193	155	97	29	29	n.d.	1300	16	66	159	365
C362	1.77	4280	321	170	102	50	55	n.d.	2180	22	48	249	219
C371	1.09	2670	68	79	35	14	15	tr	818	n.d.	81	465	426
C372	1.35	4080	86	126	30	21	28	tr	991	tr	96	612	569
C381	1.43	5090	199	193	71	47	37	tr	2180	18	63	361	402
C382	1.39	5240	219	216	74	44	38	tr	1810	24	80	237	197
C421	0.87	2200	7.4	35	3.1	3.5	12	tr	453	n.d.	49	700	857
C422	0.76	1610	7.0	32	4.8	6.2	8.5	n.d.	373	n.d.	63	390	761
C431	1.39	15800	n.d.	95	4.5	7.6	102	37	1500	n.d.	287	2270	458
C432	0.56	3020	4.3	20	4.3	6.1	17	tr	476	n.d.	55	1300	442
C441	0.94	2400	tr	50	7.7	tr	13	tr	503	n.d.	48	546	506
C442	0.86	2450	12	37	7.7	tr	12	tr	440	n.d.	72	476	472
C451	0.54	3300	47	61	13	8.1	22	n.d.	802	n.d.	80	577	730
C452	0.65	2180	17	55	9.9	9.0	19	n.d.	628	n.d.	49	482	509

## APPENDIX VII (Continued)

Sample	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
C461	1.02	4620	355	171	124	37	57	n.d.	2860	17	54	280	398
C462	1.14	5070	569	145	264	43	51	n.d.	1840	23	69	141	209
C471	1.75	4050	165	108	42	19	17	n.d.	1390	tr	80	374	465
C472	0.71	4630	101	115	31	16	15	n.d.	1420	tr	87	446	515
C481	1.49	5130	222	216	75	57	42	tr	2270	17	100	235	360
C482	1.23	5270	303	225	103	40	44	tr	2070	16	78	242	253
C521	0.71	1020	tr	17	1.6	2.5	3.2	n.d.	416	n.d.	29	481	570
C522	0.91	1130	n.d.	13	2.6	tr	8.2	tr	419	n.d.	30	456	533
C531	0.79	1290	9.1	26	5.7	n.d.	7.9	n.d.	293	n.d.	40	496	1230
C532	1.02	1950	9.7	28	4.2	tr	18	tr	447	n.d.	67	527	572
C541	0.99	2150	24	48	9.9	6.0	11	tr	453	n.d.	48	663	530
C542	0.85	2030	6.7	36	5.6	6.6	10	n.d.	436	n.d.	52	633	548
C551	1.25	2960	63	98	21	12	32	tr	652	tr	82	372	400
C552	1.01	3100	62	82	22	11	28	n.d.	648	tr	60	362	378
C561	1.27	4490	194	182	61	42	82	tr	1750	21	53	268	268
C562	1.25	5080	207	175	83	42	43	tr	2150	20	68	256	232
C571	1.56	2920	99	93	29	15	19	tr	793	tr	123	247	275
C572	1.50	2730	101	83	26	12	15	tr	993	n.d.	99	280	378

## APPENDIX VII (Continued)

Sample	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
C581	1.45	4430	208	219	80	55	51	tr	2640	18	78	274	255
C582	1.20	4660	176	215	79	36	50	n.d.	2080	22	71	150	253
C621	0.74	1570	5.8	24	4.6	5.0	10	n.d.	354	n.d.	53	420	1270
C622	0.51	2100	8.8	30	3.6	tr	10	n.d.	423	n.d.	50	768	1280
C631	1.05	1940	n.d.	27	tr	tr	5.8	n.d.	442	n.d.	53	596	1350
C632	0.99	3400	tr	32	1.5	tr	20	tr	426	n.d.	75	1250	2120
C641	0.95	2470	7.6	37	4.3	4.4	14	tr	496	n.d.	52	682	679
C642	1.03	2990	9.8	54	7.6	6.8	15	tr	577	n.d.	70	810	886
C651	0.65	2740	19	55	10	7.4	10	n.d.	846	n.d.	56	655	888
C652	0.73	3560	19	70	10	6.8	19	n.d.	807	n.d.	59	573	655
C661	1.41	4310	162	192	71	39	28	tr	1430	tr	80	613	424
C662	1.23	4310	225	178	86	32	51	n.d.	1480	14	60	298	375
C671	0.80	4590	106	72	23	7.8	4.0	tr	763	13	133	283	829
C672	0.90	3530	47	65	20	8.8	11	tr	913	n.d.	149	625	791
C681	1.28	6830	387	229	294	40	96	n.d.	2280	21	68	288	424
C682	1.38	4140	214	203	81	49	42	tr	2060	16	56	286	263
C721	1.87	1850	9.6	27	5.2	4.9	6.7	n.d.	380	n.d.	35	418	459
C722	1.25	2000	tr	37	5.5	tr	10	tr	396	n.d.	38	488	449

APPENDIX VII (Continued)

Sample	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
C731	0.62	2200	15	34	4.1	6.2	10	n.d.	483	n.d.	45	729	940
C732	0.82	1710	6.8	22	2.1	3.6	8.6	n.d.	415	n.d.	33	496	763
C741	0.99	2790	30	57	14	7.1	17	tr	523	tr	65	607	453
C742	0.86	2780	45	60	17	8.7	15	tr	506	tr	50	521	436
C751	0.64	4200	41	79	17	11	40	n.d.	1710	n.d.	68	468	522
C752	2.42	2950	57	64	20	9.0	43	n.d.	685	tr	50	509	615
C761	1.39	6630	184	190	88	38	>1000	tr	1570	29	82	141	211
C762	1.26	5430	260	258	89	42	28	tr	1610	16	90	201	164
C771	1.28	2440	49	86	29	20	34	tr	1170	tr	104	318	279
C772	1.09	2940	64	77	31	15	24	n.d.	1990	tr	104	365	358
C781	1.57	5240	176	225	86	51	54	n.d.	2310	27	112	214	232
C782	1.25	4520	154	206	78	48	62	tr	1890	16	76	209	200

All values are the geometric means of triplicate analyses and are listed in p.p.m.

n.d. = not detected

tr. = trace



APPENDIX VIII

Trace Element Analyses for Composites of Composite Samples (CC-1 to CC-8)

Sample	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
CC1	0.53	1340	n.d.	28	3.6	n.d.	5.4	n.d.	380	n.d.	39	510	580
CC2	0.53	1870	tr	39	6.1	tr	6.8	n.d.	460	n.d.	33	590	480
CC3	0.61	2700	tr	45	5.0	6.4	9.3	tr	540	n.d.	61	1240	1640
CC4	0.54	2270	17	50	8.6	9.2	8.3	n.d.	570	n.d.	35	620	450
CC5	0.57	3300	49	93	25	15	14	n.d.	790	n.d.	44	400	350
CC6	1.11	4500	360	241	95	41	29	tr	1610	17	76	310	245
CC7	0.65	3200	150	119	43	20	18	tr	1110	tr	70	330	285
CC8	1.16	4600	290	254	89	41	35	tr	1690	20	65	194	173
Weighted Average for Whole Area	0.64	2590	63	82	23	11	13	<30	735	<8	44	549	494

All values are the arithmetic means of triplicate analyses and are listed as p.p.m.

n.d. = not detected

tr. = trace

APPENDIX IX

Results for the Two-Way Analysis of Variance of Trace Elements in Rock  
Types 2, 3, 4, 5, 6, 7 and 8 for All Map Areas

Element	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Be	6	0.846368 (Between Map Areas)	0.141061	1.65	NS
	6	2.62697 (Between Rock Types)	0.437828	5.11	VS
	36	2.87830 (Interaction)	0.0799527	0.89	NS
	49	4.39369 (Between Duplicates)	0.0896670		
	97	10.7453 (Total)			
Ti	6	24,295,400	4,049,240	1.76	NS
	6	109,979,000	18,329,900	7.96	VS
	36	100,285,000	2,785,690	1.43	NS
	49	95,274,900	1,944,390		
	97	329,834,000			
Cr	6	84,182.6	14,030.4	3.53	VS
	6	1,277,950	212,992	53.55	VS
	36	288,150	8,004.16	2.01	S
	49	194,896	3,997.48		
	97	1,845,179			
V	6	3,152.85	525.475	1.81	NS
	6	444,228	74,038.1	254.42	VS
	36	20,583.7	571.770	1.96	S
	49	14,259.5	291.010		
	97	482,224			

APPENDIX IX (Continued)

Element	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Ni	6	5,051.64	841.940	0.67	NS
	6	192,518	32,086.4	25.45	VS
	36	49,490.5	1,374.74	1.17	NS
	49	57,731.8	1,178.20		
	97	304,792			
Co	6	289.954	48.3257	2.17	NS
	6	27,585.7	4,597.62	207.01	VS
	36	922.446	25.6235	1.30	NS
	49	965.763	19.7094		
	97	29,763.9			
Cu	6	66,221.7	11,037.0	1.16	NS
	6	105,550	17,591.7	1.85	NS
	36	329,018	9,139.40	0.93	NS
	49	479,469	9,785.08		
	97	980,259			
Mn	6	1,101,610	183,601	2.53	S
	6	36,249,600	6,041,600	83.18	VS
	36	3,192,580	88,682.8	1.46	NS
	49	2,981,330	60,843.4		
	97	43,525,100			

APPENDIX IX (Continued)

Element	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Zr	6	7,432.06	1,238.68	1.32	NS
	6	19,779.1	3,296.5	3.51	VS
	36	43,332.7	1,203.7	1.62	NS
	49	36,437.5	743.622		
	97	106,981			
Sr	6	732,161	122,027	4.57	VS
	6	4,055,780	675,963	25.34	VS
	36	2,385,740	66,270.7	2.48	VS
	49	1,307,150	26,676.4		
	97	8,480,830			
Ba	6	2,025,160	337,526	16.16	VS
	6	6,014,160	1,002,360	48.00	VS
	36	2,455,350	68,204.1	3.27	VS
	49	1,023,270	20,883.1		
	97	11,517,900			

NS = not significant at 5% level    S = significant at 5% level    VS = very significant = significant at 1% level

Critical values of the F-distribution (Dixon and Massey, 1957) for this table are:

$$F_{6,49,0.99} = 3.29 \quad F_{6,49,0.95} = 2.34 \quad F_{36,49,0.99} = 2.11 \quad F_{36,49,0.95} = 1.69$$

$$F_{6,85,0.99} = 3.12 \quad F_{6,85,0.95} = 2.25$$

APPENDIX X

Results for the Two-Way Analysis of Variance of Trace Elements in Rock Types 2, 3, 4, and 5 for All Map Areas

Element	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Be	6	0.864043 (Between Map Sheets)	0.144007	1.30	NS
	3	0.0770340 (Between Rock Types)	0.0256780	0.25	NS
	18	1.85473 (Interaction)	0.103040	0.89	NS
	28	3.25334 (Between Duplicates)	0.116191		
	55	6.04915 (Total)			
Ti	6	26,151,900	4,358,660	1.20	NS
	3	24,528,900	8,176,290	2.24	NS
	18	81,006,100	4,500,340	1.45	NS
	28	86,679,400	3,095,690		
	55	218,366,000			
Cr	6	4,055.98	675.997	15.96	VS
	3	14,378.9	4,792.97	113.17	VS
	18	8,296.75	460.930	10.88	VS
	28	1,185.89	42.3531		
	55	27,917.5			
V	6	4,374.43	729.071	4.62	VS
	3	20,196.3	6,732.11	42.62	VS
	18	7,617.29	423.183	2.68	VS
	28	4,422.50	157.946		
	55	36,610.6			

APPENDIX X (Continued)

Element	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Ni	6	216.194	36.0324	8.12	VS
	3	1,246.84	415.615	93.72	VS
	18	312.261	17.3478	3.91	VS
	28	124.175	4.43481		
	55	1,899.48			
Co	6	187.134	31.1889	5.54	VS
	3	660.863	220.288	39.13	VS
	18	679.978	37.7765	6.71	VS
	28	157.625	5.62946		
	55	1,685.60			
Cu	6	1,799.38	299.897	1.61	NS
	3	1,002.51	334.172	1.79	NS
	18	4,549.84	252.769	1.76	NS
	28	4,026.93	143.819		
	55	11,378.7			
Mn	6	481,532	80,255.4	1.66	NS
	3	1,458,640	486,214	10.05	VS
	18	1,053,280	58,515.3	1.40	NS
	28	1,171,310	41,832.4		
	55	4,164,760			

APPENDIX X (Continued)

Element	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Zr	6	9,953.93	1,658.99	1.45	NS
	3	4,464.34	1,488.11	1.30	NS
	18	21,909.8	1,217.21	1.11	NS
	28	30,655.5			
	55	66,983.6			
Sr	6	833,589	138,932	3.52	VS
	3	1,370,310	456,771	11.59	VS
	18	1,769,720	98,317.6	2.49	S
	28	1,103,560			
	55	5,077,180			
Ba	6	2,148,600	358,100	12.08	VS
	3	2,351,090	783,696	26.44	VS
	18	1,525,160	84,730.9	2.86	VS
	28	829,792			
	55	6,854,640			

NS = not significant at 5% level    S = significant at 5% level    VS = very significant = significant at 1% level

Critical values of the F-distribution (Dixon and Massey, 1957) for this table are:

$$\begin{array}{lllll}
 F_{6,28,0.99} = 3.47 & F_{3,28,0.99} = 4.51 & F_{18,28,0.99} = 2.55 & F_{6,46,0.99} = 3.29 & F_{3,46,0.99} = 4.31 \\
 F_{6,28,0.95} = 2.42 & F_{3,28,0.95} = 2.92 & F_{18,28,0.95} = 1.93 & F_{6,46,0.95} = 2.34 & F_{3,46,0.95} = 2.84
 \end{array}$$

APPENDIX XI

Results for the Two-Way Analysis of Variance of Trace Elements in Rock Types 6, 7, and 8 for all Map Areas

Element	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Be	6	0.216668 (Between Map Sheets)	0.0361114	0.62	NS
	2	0.424935 (Between Rock Types)	0.212468	3.63	S
	12	0.789229 (Interaction)	0.0657691	1.21	NS
	21	1.14035 (Between Duplicates)	0.0543023		
	41	2.57118 (Total)			
Ti	6	4,055,340	675,891	1.65	NS
	2	23,022,700	11,511,300	28.12	VS
	12	13,366,900	1,113,910	2.72	S
	21	8,595,550	409,312		
	41	49,040,500			
Cr	6	198,538	33,090	3.08	S
	2	180,926	90,463	8.41	VS
	12	161,442	13,453	1.46	NS
	21	193,711	9,224.3		
	41	734,616			
V	6	1,591.91	265.318	0.44	NS
	2	97,598.7	48,799.4	80.53	VS
	12	10,153.0	846.079	1.81	NS
	21	9,837.00	468.429		
	41	119,181			



APPENDIX XI (Continued)

Element	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Ni	6	14,541	2,423.57	0.82	NS
	2	44,963	22,481.7	7.66	VS
	12	39,472	3,289.36	1.20	NS
	21	57,608	2,743.22		
	41	156,585			
Co	6	169.984	28.3307	0.95	NS
	2	7,351.80	3,675.90	123.35	VS
	12	175.308	14.6090	0.38	NS
	21	808.139	38.4828		
	41	8,505.23			
Cu	6	139,306	23,217.7	1.06	NS
	2	55,874.5	27,937.2	1.27	NS
	12	249,585	20,798.7	0.92	NS
	21	475,442	22,640.1		
	41	920,207			
Mn	6	1,143,090	190,516	1.83	NS
	2	6,571,090	3,285,550	31.59	VS
	12	1,594,820	132,901	1.52	NS
	21	1,836,500	87,452.2		
	41	11,145,500			

APPENDIX XI (Continued)

Element	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Zr	6	4,413.95	735.659	2.67	S
	2	2,321.29	1,160.64	4.22	S
	12	14,487.0	1,207.25	4.38	VS
	21	5,782.00	275.333		
	41	27,004.3			
Sr	6	156,155	26,025.8	2.68	S
	2	88,524.4	44,262.2	4.57	S
	12	358,444	29,870.3	3.08	S
	21	203,583	9,694.43		
	41	806,706			
Ba	6	335,621	55,936.9	6.07	VS
	2	168,640	84,320.2	9.15	VS
	12	471,126	39,260.5	4.26	VS
	21	193,481	9,213.4		
	41	1,168,870			

NS = not significant at 5% level    S = significant at 5% level    VS = very significant = significant at 1% level

Critical values of the F-distribution (Dixon and Massey, 1957) for this table are:

$$\begin{array}{ccccc}
 F_{6,21,0.99} = 3.81 & F_{2,21,0.99} = 5.78 & F_{12,21,0.99} = 3.17 & F_{6,33,0.99} = 3.47 & F_{2,33,0.99} = 5.39 \\
 F_{6,21,0.95} = 2.57 & F_{2,21,0.95} = 3.47 & F_{12,21,0.95} = 2.25 & F_{6,33,0.95} = 2.42 & F_{2,33,0.95} = 3.32
 \end{array}$$

APPENDIX XII

Results for the Two-Way Analysis of Variance of Sc in Rock Types 6 and 8  
for All Map Areas

Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
6	148.429 (Between Map Sheets)	24.7381	1.68	NS
1	4.32143 (Between Rock Types)	4.32143	0.29	NS
6	49.4286 (Interaction)	8.23810	0.47	NS
14	244.500 (Between Duplicates)	17.4643		
27	446.679 (Total)			

NS = not significant at 5% level

\* Critical values of the F-distribution (Dixon and Massey, 1957) for this table are:

$$F_{6,20,0.99} = 3.87 \quad F_{6,14,0.99} = 4.46 \quad F_{1,20,0.99} = 8.10$$

$$F_{6,20,0.95} = 2.60 \quad F_{6,14,0.95} = 2.85 \quad F_{1,20,0.95} = 4.35$$

APPENDIX XIII

Trace Element Averages for Pairs of Composite Samples Listed in Order of

Rock Type

Rock Type 1 (IGR)

Map Area	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
1	0.82	1250	tr	21	3.3	tr	3.2	tr	362	n.d.	53	466	925
2	1.55	1540	n.d.	14	3.2	tr	5.5	tr	351	n.d.	40	445	727

Rock Type 2 (MGR)

Map Area	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
1	1.12	2470	7.8	44	4.2	3.5	11	tr	457	n.d.	68	619	782
2	1.05	1960	7.5	25	3.4	6.5	9.6	n.d.	410	n.d.	42	451	646
3	1.25	1780	tr	21	1.8	2.3	4.4	tr	337	n.d.	48	639	882
4	0.81	1910	7.2	34	3.9	4.8	10	tr	413	n.d.	56	545	809
5	0.81	1080	tr	15	2.1	2.5	5.7	tr	418	n.d.	30	469	552
6	0.62	1840	5.6	27	4.1	5.0	10	n.d.	389	n.d.	52	594	1280
7	1.56	1920	9.6	32	5.3	4.9	8.4	tr	388	n.d.	37	453	454

All values are in p.p.m.

APPENDIX XIII (Continued)

Rock Type 3 (PGR)

Map Area	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
1	0.93	2580	4.3	44	5.0	7.0	4.3	n.d.	599	n.d.	71	685	1090
2	0.96	2480	4.7	40	3.1	5.1	12	tr	455	n.d.	44	731	1030
3	1.07	2230	6.6	37	6.6	5.6	11	n.d.	472	n.d.	51	885	1370
4	0.98	9390	4.3	58	4.4	6.9	60	37	988	n.d.	171	1790	450
5	0.90	1620	6.4	27	4.9	tr	13	tr	370	n.d.	54	512	902
6	1.02	2670	tr	30	1.5	tr	13	tr	434	n.d.	64	924	1730
7	0.72	1960	11	28	3.1	4.9	9.4	n.d.	449	n.d.	39	613	852

Rock Type 4 (GD)

Map Area	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
1	1.02	2420	10	48	7.7	5.8	12	tr	555	n.d.	65	635	773
2	0.85	1790	tr	26	6.4	7.7	8.3	tr	409	n.d.	40	499	515
3	1.23	2460	11	46	7.6	6.0	14	n.d.	547	n.d.	48	758	645
4	0.90	2420	12	44	7.7	tr	13	tr	472	n.d.	60	511	489
5	0.92	2090	15	42	7.7	6.3	11	tr	445	n.d.	50	648	539
6	0.99	2730	8.7	46	5.9	5.6	14	tr	537	n.d.	61	746	783
7	0.92	2790	37	59	16	7.9	16	tr	515	tr	58	564	445

## APPENDIX XIII (Continued)

Rock Type 5 (GN)

Map Area	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
1	0.99	5760	99	133	19	26	4.6	tr	1260	tr	45	216	144
2	0.84	2350	18	59	8.7	8.2	13	tr	575	n.d.	54	455	448
3	0.83	3760	24	77	16	14	12	tr	613	tr	101	551	765
4	0.59	2740	32	58	11	8.5	20	n.d.	715	n.d.	65	530	620
5	1.13	3030	62	90	22	12	30	tr	650	tr	71	367	389
6	0.69	3150	19	63	10	7.1	14	n.d.	827	n.d.	58	614	772
7	1.53	3570	49	72	18	10	42	n.d.	1200	tr	59	489	569

Rock Type 6 (GAB)

Map Area	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
1	1.34	6300	221	162	84	36	23	tr	1370	13	126	593	726
2	1.18	4180	437	186	167	40	26	tr	1430	17	83	197	349
3	1.46	4440	256	163	99	39	42	n.d.	1740	19	57	204	292
4	1.08	4840	462	158	194	40	54	n.d.	2350	20	62	211	304
5	1.26	4790	201	179	72	42	62	tr	1950	20	61	262	250
6	1.32	4310	194	185	79	36	39	tr	1450	14	70	456	400
7	1.33	6030	222	224	88	40	28	tr	1590	22	86	171	188

APPENDIX XIII (Continued)

Rock Type 7 (SED)

Map Area	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
1	1.10	2980	258	128	63	22	29	tr	1330	18	70	203	303
2	0.88	2970	255	110	65	16	23	tr	1100	8.6	53	239	305
3	1.22	3370	77	103	32	18	21	tr	905	tr	89	539	498
4	1.23	4340	133	112	37	17	16	n.d.	1400	tr	84	410	490
5	1.53	2830	100	88	28	13	17	tr	893	tr	111	264	327
6	0.85	4060	77	69	21	8.3	7.4	tr	838	13	141	454	810
7	1.19	2670	56	82	30	17	29	tr	1580	tr	104	342	319

Rock Type 8 (VOL)

Map Area	Be	Ti	Cr	V	Ni	Co	Cu	Y	Mn	Sc	Zr	Sr	Ba
1	1.25	3870	460	202	143	51	46	tr	2100	17	84	196	293
2	1.64	4300	267	219	85	46	45	tr	1910	17	62	219	252
3	1.41	5170	209	205	72	45	38	tr	2000	21	72	299	300
4	1.36	5200	262	221	89	48	43	tr	2170	16	89	239	307
5	1.33	4540	192	217	79	45	50	tr	2360	20	75	212	254
6	1.33	5490	300	216	188	45	69	tr	2170	18	62	287	344
7	1.41	4880	165	216	82	49	59	tr	2100	21	94	212	216