Trend Surface and Factor Analysis of Geochemical Data from the Mount Nansen Area

R. Saager

MOUNT NANSEN PROPERTY

TREND SURFACE AND FACTOR ANALYSIS OF GEOCHEMICAL DATA FROM THE MOUNT NANSEN AREA

by

R. Saager

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CONTENTS

I INTRODUCTION

The following statistical evaluations are based on geochemical data collected in the stream sampling survey of July 1970 (report "Stream Sampling Survey 1970, Mount Nansen Property, Yukon T." by F. Bianconi and R. Saager, dated September 10, 1970) and in the soil survey of September 1970 (report "Geochemical Soil Survey 1970, Mount Nansen Property, Yukon T." by F. Bianconi and R. Saager, dated October 26, 1970). The stream sampling survey - in which the elements Cu, Mo, Pb, Zn, Ag, Sb, and Ni were investigated - revealed the presence of two Cu-Mo anomalies and of three Pb-Zn-Ag anomalies in the northern half of the Mount Nansen Property. The subsequent soil survey - Cu, Mo and Pb - delineated the approximate position and extent of the Cu-Mo anomalies.

The geological setting and the patterns of the Cu-Mo anomalies indicate that they might be caused by underlying porphyry ore mineralizations. The Pb-Zn-Ag anomalies - in analogy to the Mount Nansen deposit - are interpreted as being caused by narrow sulphide veins.

The trend analyses of the soil survey data and the factor analyses of the stream survey data are an expansion of the two earlier mentioned reports. They were undertaken with the aim to "filter" the vast amount of data and to make the complex system more comprehensible. By doing this, it was hoped to find trends and anomalies which would underpin and/or expand previously made statements on the geochemical distribution patterns.

Lead did not show distinct anomalies in the soil survey investigation and nickel showed a relative erratic distribution in the stream sample data. Both elements were, therefore, not included in the present investigations.

II GEOLOGICAL SETTING (Fig. 10)

The geology of the Mount Nansen area has been dealt with extensively in the report of September 10, 1970. Some additional mineralogical and structural data were given in the report of October 24, 1970.

Discussing the present investigation, it is important, however, to recall that, lithologically, the area in a general way can be divided into three parts. The northern part, where the Cu-Mo anomalies and one minor Pb-Zn-Ag anomaly occur, is underlain by a north-west trending porphyry of Cretaceous to early Tertiary age. The central part is underlain by the Jurassic Nansen Volcanics which, to the east, partially make way to early Cretaceous granodioritic to granitic intrusions. The remaining Pb-Zn-Ag anomalies lie in this central part. The southern part of the area is covered by the metamorphic rocks of the Yukon Group, of Precambrian to Paleozoic age. No persistent anomalous values were obtained from this area.

III SAMPLING AND ANALYTICAL METHODS

The sampling and the analytical methods employed are explained in detail in the two previous reports. Conventional sampling techniques were used and with the exception of Sb, all elements were determined by atomic absorption. Sb was analysed colorimetrically following fusion with HN_4Cl.

The limits of detection were 0.2 ppm for Ag, 2 ppm for Pb, and 1 ppm for all other elements. The analytical precision lies between 15 and 25 per cent for the atomic absorption determinations, and between 10 and 50 per cent for Sb, at a 95 per cent level of confidence.

IV STATISTICAL EVALUATION

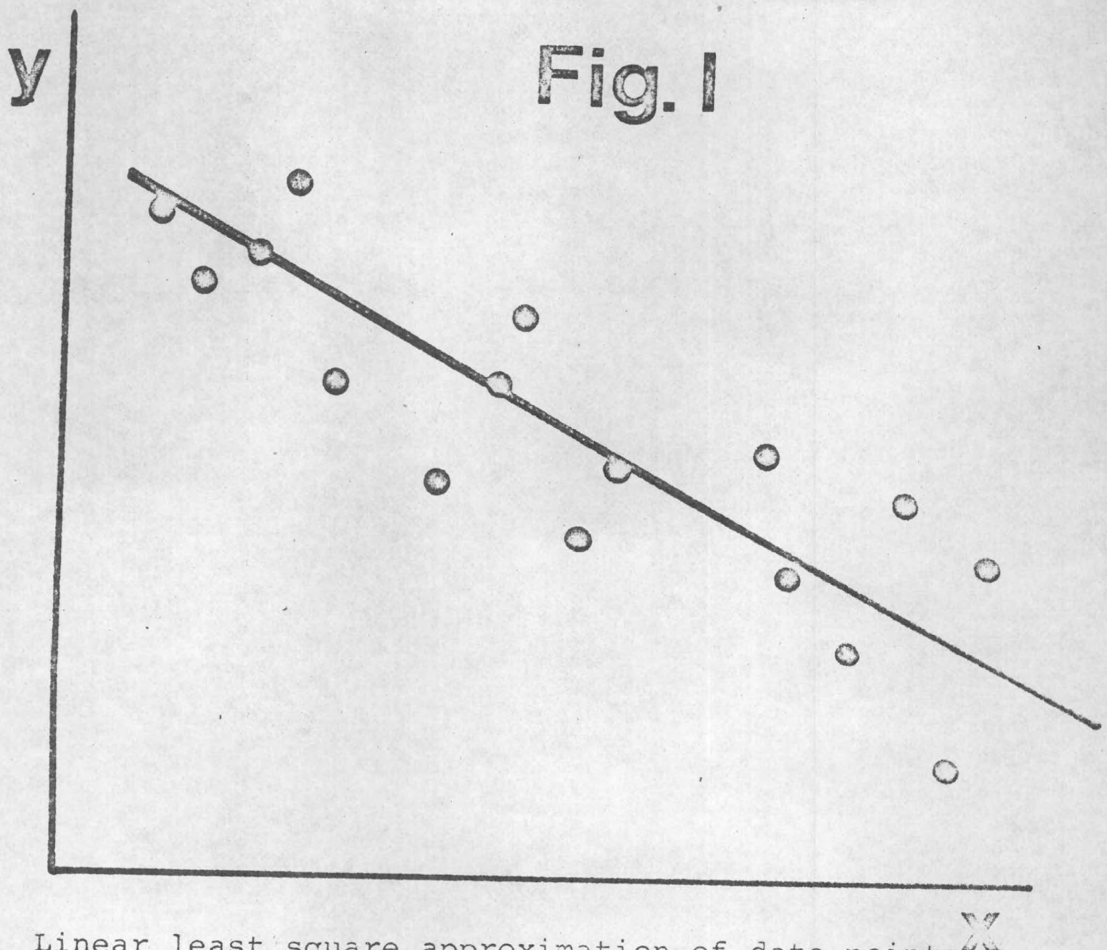
For the processing of the geochemical data various statistical methods, including linear regression analyses, Chi-square tests, polynomial trend surface analyses, Q- and R-mode factor analyses were employed. The programs used were written in FORTRAN for the IBM 360 model 67 computer at the University of British Columbia by the staff of the Computing Centre and by the Kansas State Geological Survey.

A. Polynomial Trend Surface Analysis

Only the soil sample data were investigated by trend surface analysis, as the method fits a polynomial surface to a set of data for which exact coordinate values are known. Stream sediment data cannot be used for such an investigation, since they do not represent the geochemical composition within the narrow limits of the sampling point, but are composite samples of the upstream drainage areas of the streams from which the samples were obtained.

Trend surface analyses applied to geochemical and geological data have been discussed extensively by Whitten (1961), Merriam and Harbaugh (1964), Harbaugh (1964), and more recently by Sinclair (1969). Trend surfaces are described by arithmetic equations in which the geochemical values are the dependent variable stated as a function of two independent variables, which are the coordinates of the sample locations. The mathematical procedure consists of finding the constants to the arithmetic equations in a way that the least square criterion is satisfied.

A simple two dimensional linear trend analysis, thus, would be the fitting of a set of data points on a scatter diagram with a straight line, using the least square method (Fig.1). This straight line is the simplest type of an approximating curve. By using higher order polynomials a better approximating of the data can usually be attained.



Linear least square approximation of data points

Returning to the three dimensional problem one sees, that according to their order, trend surfaces are more complex as the number of components in the equation describing them increases, and as their fit with the given set of data becomes better. The first order, or linear surface, is a plane and contains linear terms; the second order, or quadratic surface, consists of bowl-shaped paraboloids and contains linear and quadratic terms; the third order, or cubic surface, is even more complex and contains linear, quadratic and cubic terms, etc.

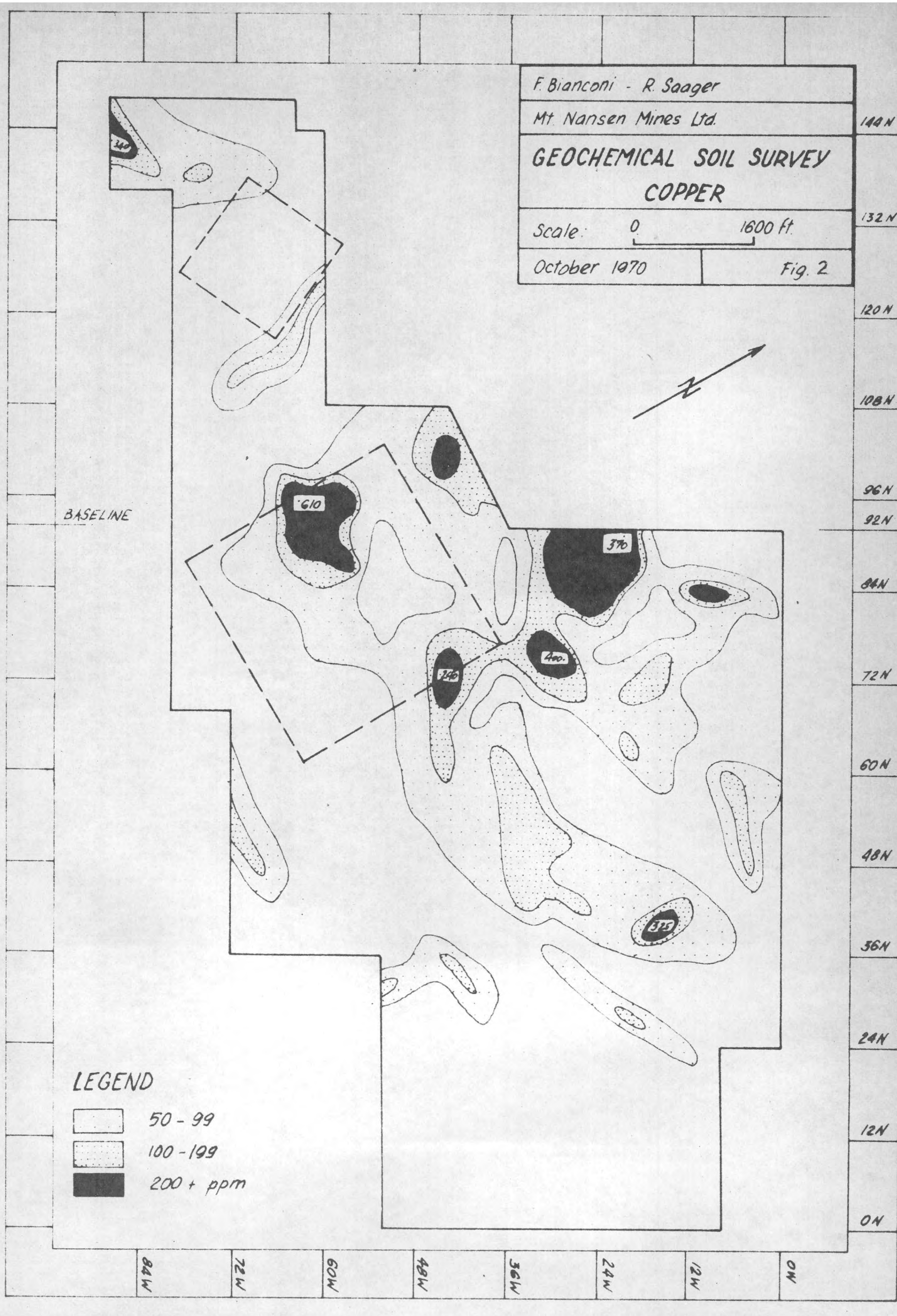
An important factor of trend surface analysis is that it breaks a set of data into two components without loss of information: firstly into a general trend map, and secondly into residual values, which represent the difference between the original data and the data of the trend map. Residual values can be contoured and the resulting maps, thus, represent data from which regional gradients or background have been removed. High order trend surface analyses further can be used to provide filtered, unbiased approximations of hand contoured raw data.

It is sometimes difficult to determine whether certain trends obtained are significant, or to decide which surface to use for the problem investigated. Further limitations of the method are the necessity of a meaningful distribution of the control points, and the unreliability of the trend surfaces in the statistically badly controlled marginal zones of the investigated areas.

Discussion of Results

Copper (Fig. 2, 3, 4).

Hand contouring of the raw data revealed the presence of two distinct high Cu-anomalies (Fig. 2). One has its


F. Bianconi - R. Saager
Mt. Nansen Mines Ltd.
GEOCHEMICAL SOIL SURVEY
COPPER
Scale: 0 1600 ft.
October 1970
Fig. 2
BASELINE
610
370
400
240
325
144 N
132 N
120 N
108 N
96 N
92 N
84 N
72 N
60 N
48 N
36 N
24 N
12 N
0 N
84W
72W
60W
48W
36W
24W
12W
0W
LEGEND
50 - 99
100 - 199
200 + ppm

maximum at about 300W/860N, in terrain underlain by a porphyry stock. The maximum of the other anomaly lies at about 650W/920N and does not occur on outcropping rock.

Using the computer program written by the Kansas State Geological Survey (Sampson and Davies, 1966) the first to fourth order trend surfaces were determined and the corresponding residual values calculated. (See Table 1)

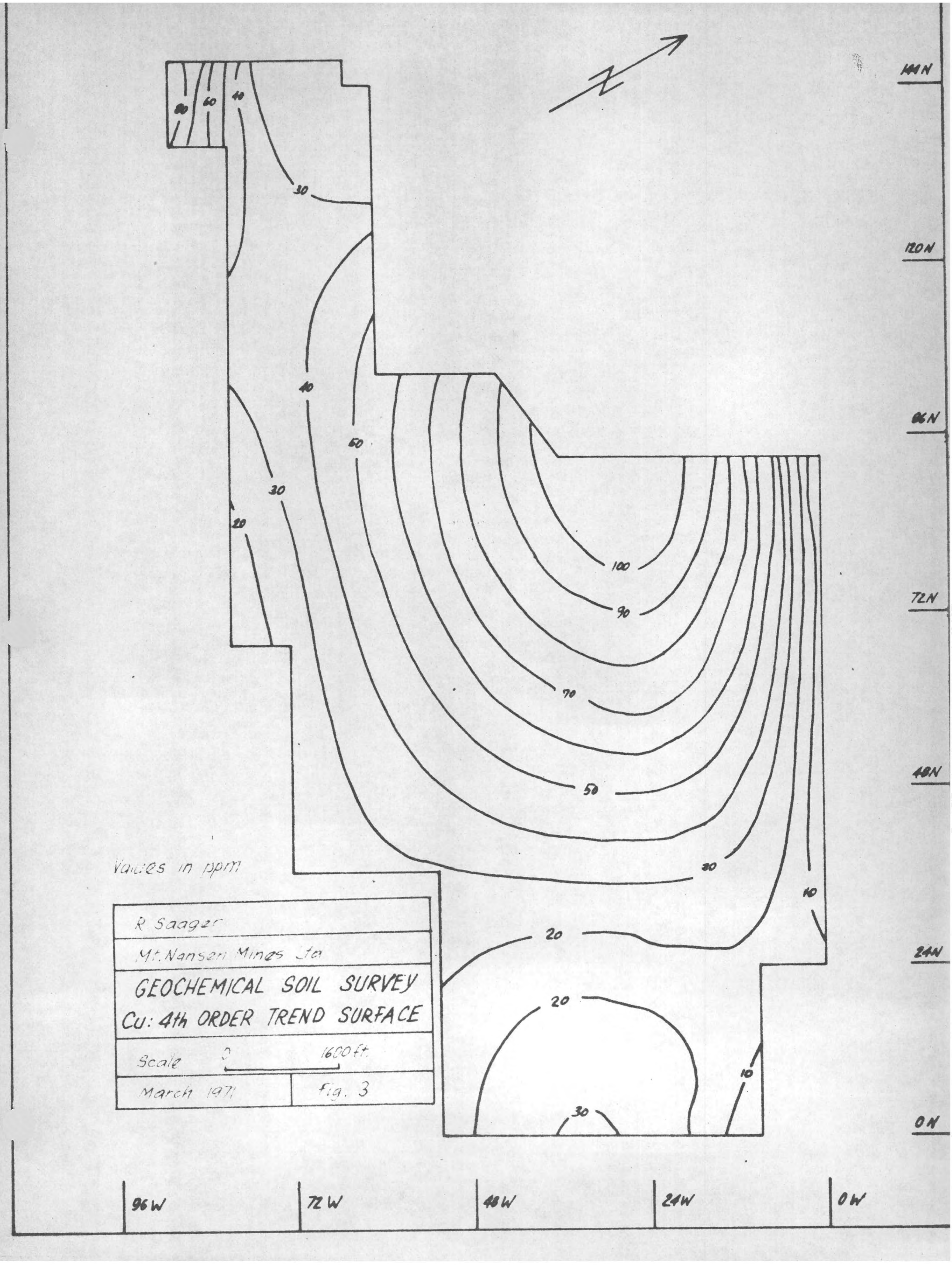
Table 1: Standard Deviations and Coefficients of Determination of 407 Cu values

	Stand. Dev.	Coeff. of Det.
1st order surface	65.72 ppm	0.03
2nd order surface	63.67 ppm	0.09
3rd order surface	62.48 ppm	0.13
4th order surface	61.42 ppm	0.16

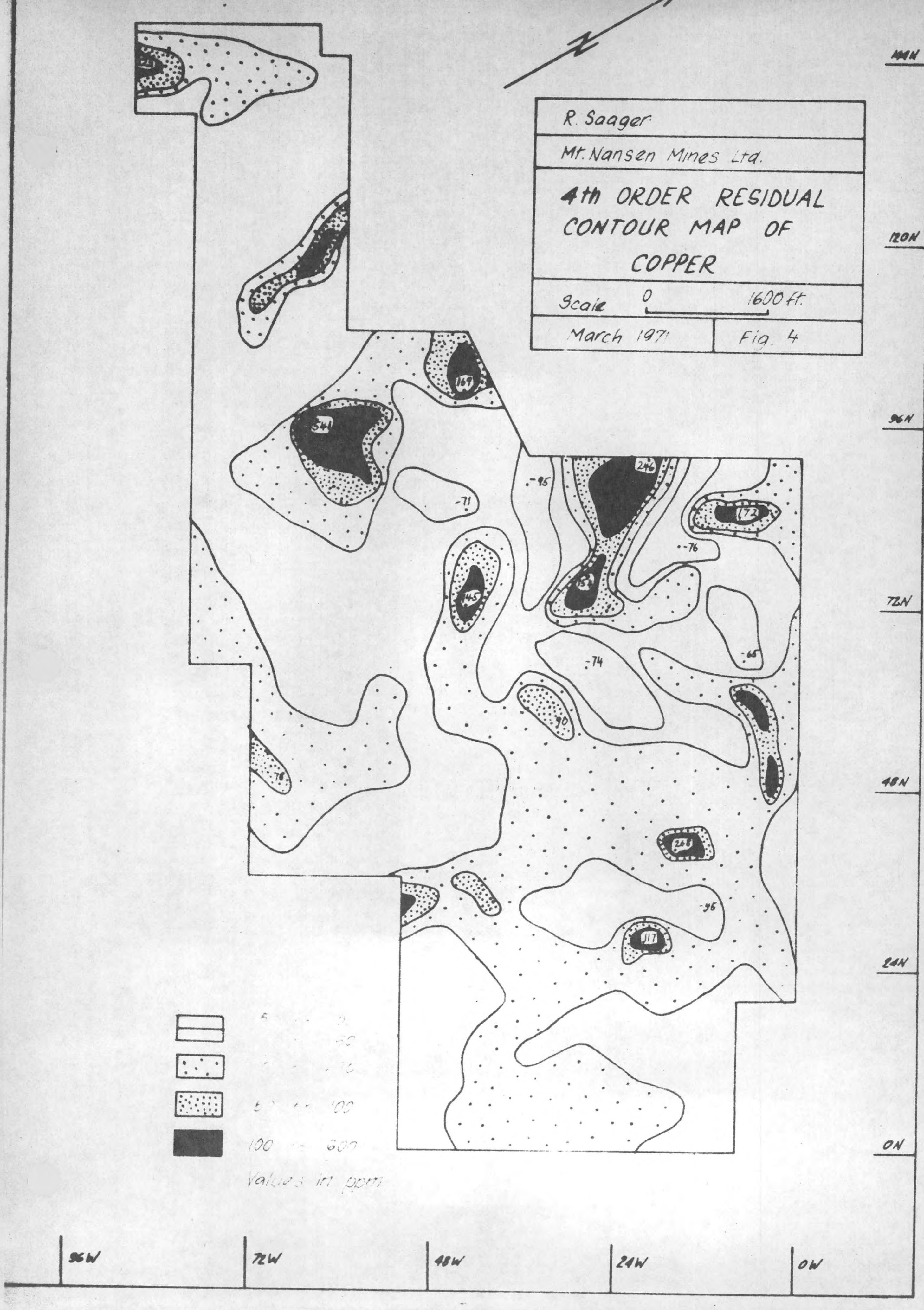
The linear surface shows a gradient in the south-north direction with an increase towards north from 20 ppm Cu to 100 ppm Cu.

The quadratic and cubic surfaces exhibit a distinct dome in the northern part of the investigated area. The main axis of the dome in both cases trend northwest, and are conformable to the trend of the underlying porphyry.

The quartic surface, given in Fig. 3, is very similar to the quadratic and cubic trend surfaces. It also indicates a distinct dome-shaped pattern for Cu, with a maximum at about 720W/900N and the main axis trending northwest. The maximum of the dome coincides, to a large extent, with one of the maxima of the raw data shown in Fig. 2.



144N
120N
96N
72N
48N
24N
0N
96W
72W
48W
24W
0W
80
60
40
30
40
50
30
20
100
90
70
50
30
10
20
20
30
10
Values in ppm
R Saager
Mt. Nansen Mines Ltd
GEOCHEMICAL SOIL SURVEY
Cu: 4th ORDER TREND SURFACE
Scale 0 1600 ft.
March 1971
Fig. 3


R. Saager
Mt. Nansen Mines Ltd.
4th ORDER RESIDUAL CONTOUR MAP OF COPPER
Scale 0 1600 ft.
March 1971
Fig. 4
Values in ppm
144N
120N
96N
72N
48N
24N
0N
96W
72W
48W
24W
0W

The hand contoured 4th order residual map shows the distribution of Cu in the soil samples with the 4th order regional trend removed from the original data (Fig. 4). The patterns obtained in the residual contour map do not deviate strongly from the patterns obtained for the hand contour map of the raw data (Fig. 2).

Molybdenum (Fig. 5, 6, 7)

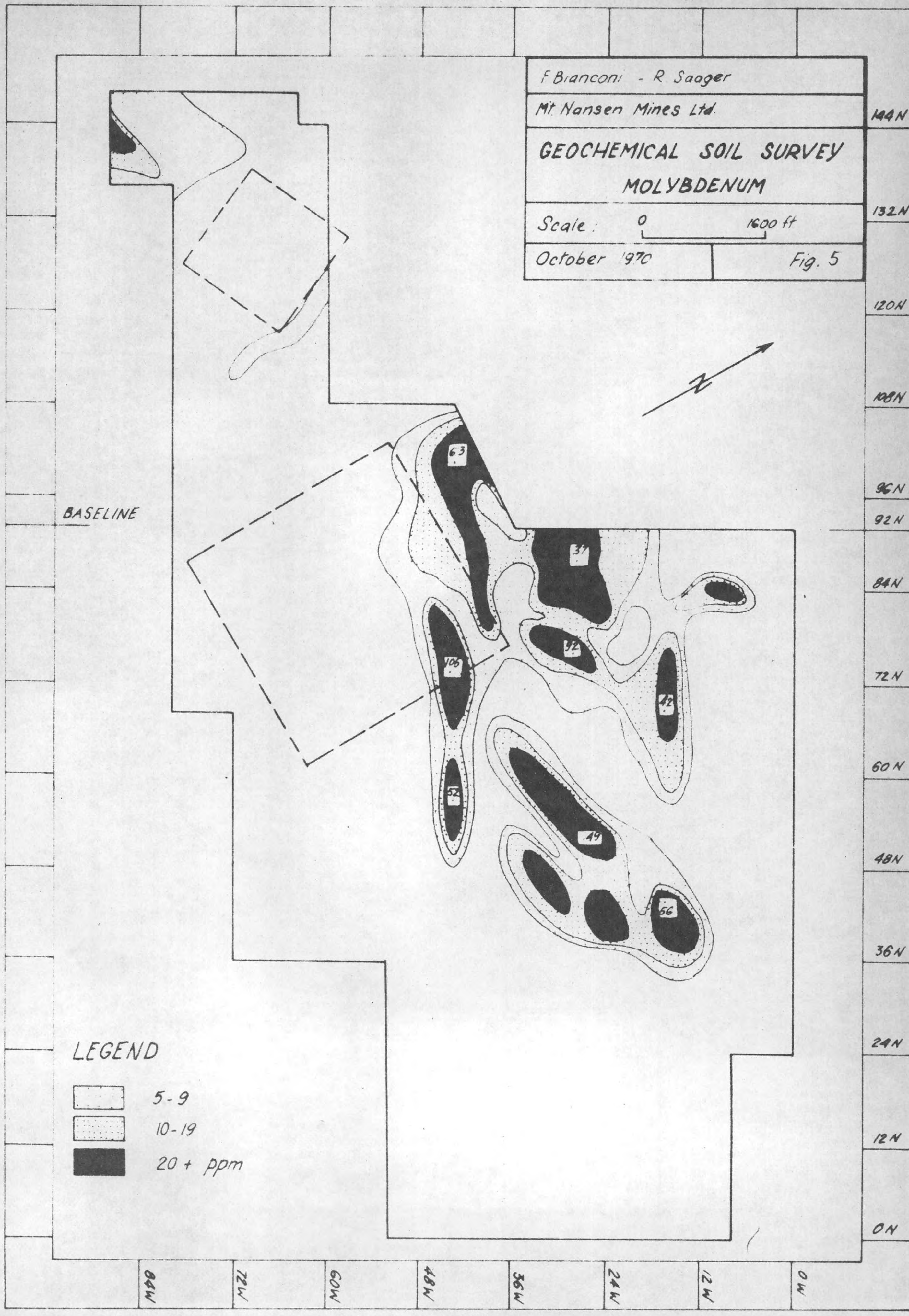
The map of the hand contoured raw data (Fig. 5) shows similar patterns as for Cu, but the anomalies are distinctly larger and somewhat better defined. It is interesting to note, that the Cu anomaly at 650W/920N is not accompanied by high Mo values. The 1st to 4th order surfaces were fitted for Mo (Table 2).

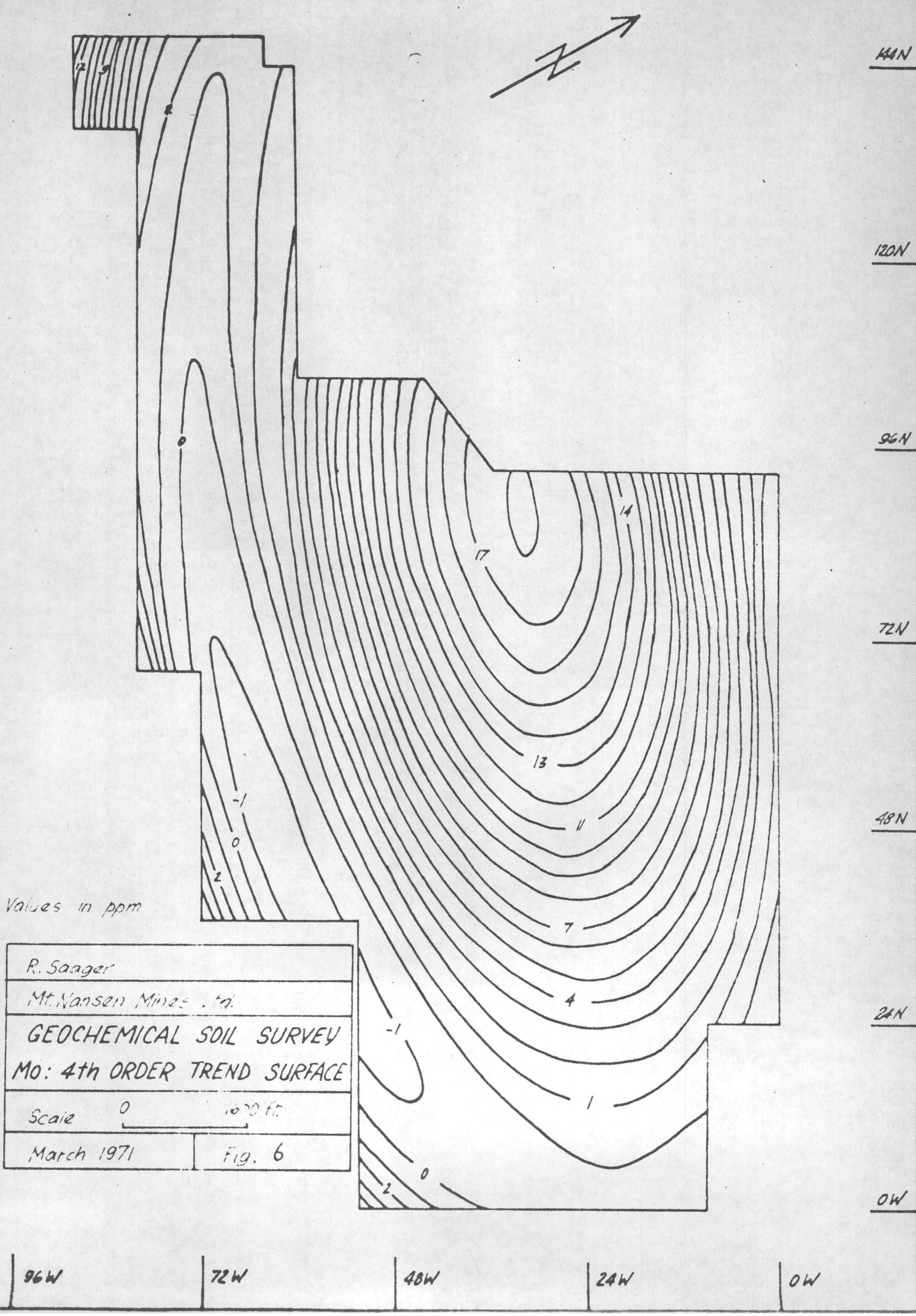
Table 2: Standard Deviations and Coefficients of Determinations of 407 Mo values

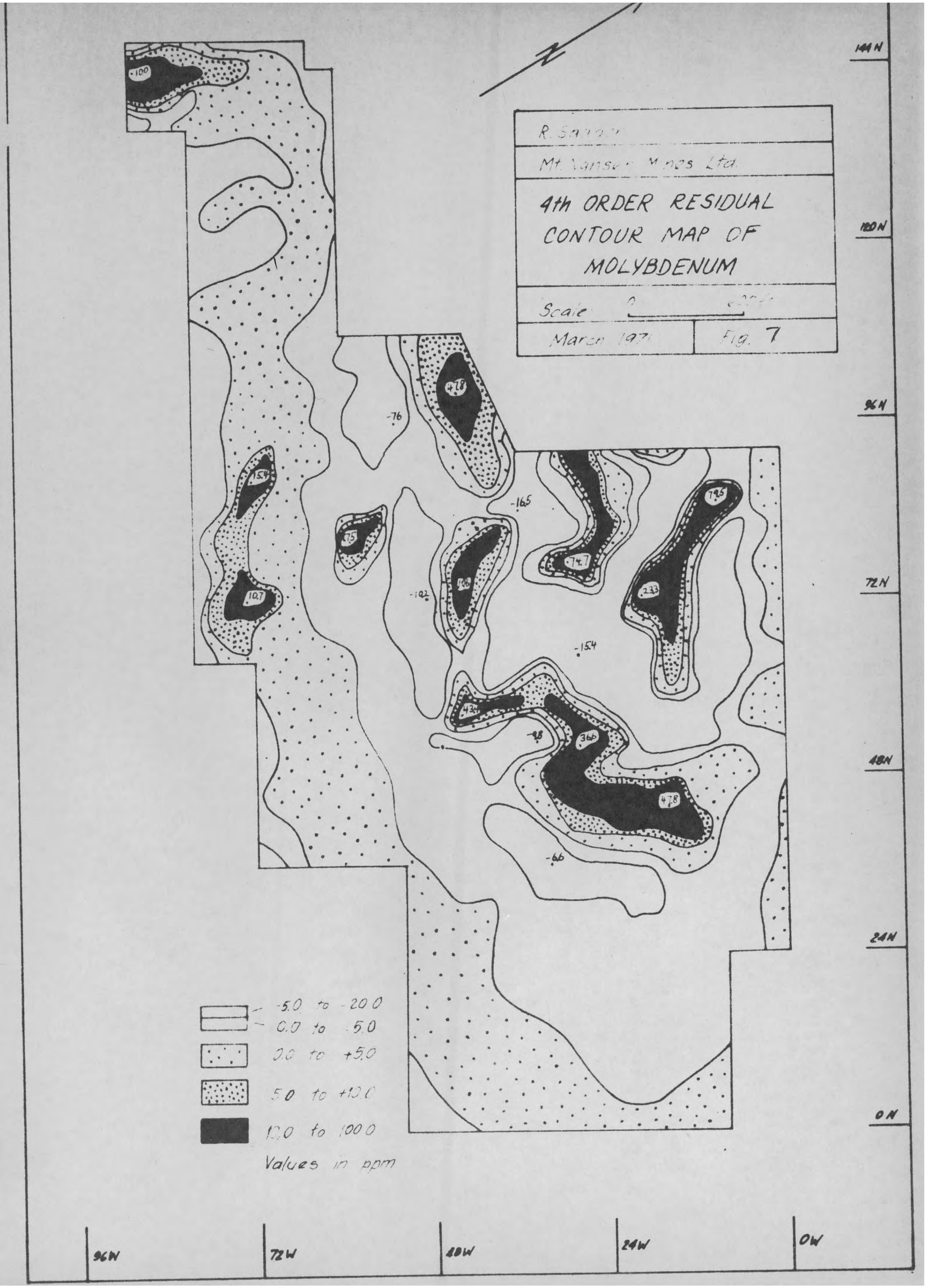
	Stand. Dev.	Coeff. of Det.
1st order surface	10.83	0.05
2nd order surface	10.36	0.13
3rd order surface	9.83	0.21
4th order surface	9.67	0.24

All trend surfaces show extremely similar patterns as the surfaces of Cu. The linear surface displays a south-north gradient with an increase towards north from 0 ppm to 14 ppm Mo. The quadratic and cubic surfaces show a dome-shaped pattern, with the major axis trending northwest.

The quartic surface (Fig. 6) displays a distinct and somewhat narrower and more elongated dome than the one obtained in the quartic surface of Cu. This can be


F Bianconi - R. Saager
Mt. Nansen Mines Ltd.
GEOCHEMICAL SOIL SURVEY
MOLYBDENUM
Scale: 0 1600 ft
October 1970
Fig. 5
N
BASELINE
63
37
92
106
42
52
49
56
LEGEND
5-9
10-19
20 + ppm
144N
132N
120N
108N
96N
92N
84N
72N
60N
48N
36N
24N
12N
0N
84W
72W
60W
48W
36W
24W
12W
0W


Values in ppm
R. Saager
Mt. Nansen Mines Ltd.
GEOCHEMICAL SOIL SURVEY
Mo: 4th ORDER TREND SURFACE
Scale 0 1600 ft.
March 1971
Fig. 6
144N
120N
96N
72N
48N
24N
0W
96W
72W
48W
24W
0W
17
14
13
11
7
4
1
0
-1
2


N
4th ORDER RESIDUAL
CONTOUR MAP OF
MOLYBDENUM
Scale
March 1971
Fig. 7
-5.0 to -20.0
0.0 to -5.0
0.0 to +5.0
5.0 to +10.0
10.0 to 100.0
Values in ppm
144N
120N
96N
72N
48N
24N
0N
96W
72W
48W
24W
0W

explained by the fact that the southern one of the two major Cu anomalies is not accompanied by high Mo values. The 4th order residual contour map is conspicuously similar to the raw data contour map of Mo, as it also was the case for the Cu maps.

Conclusions

The trend surfaces for Cu and Mo display almost identical patterns with an increasing south-north gradient for the linear surfaces and dome-shaped patterns for the quadratic to quartic surfaces. The major axes of the trends are for all surfaces parallel, trending northwest, and superimposed on the trend of the underlying porphyry. The trend surfaces, thus, indicate the presence of a geologically significant regional trend, which must be caused by the underlying porphyry. A genetical relationship between the Cu-Mo anomalies and the porphyry, therefore, must be regarded as highly probable.

The 4th order residual contour maps for Cu and Mo are extremely similar to the corresponding contour maps of the raw data. This indicates that even after removal of the regional trends the same anomalies are obtained. One can, therefore, regard the anomalous soil values as "true". This means that they are caused by underlying mineralizations - probably of the porphyry ore type - and do not just represent reflections of the regional geological setting.

B. R-mode Factor Analysis

Factor analysis is a branch of multivariate statistics and was developed largely by psychologists to analyse results from psychological tests. The method and its application to geological problems has been described among others by Imbrie and Purdy (1962), Imbrie and van Andel (1964), Krumbein and Graybill (1965), and more recently by Saager and Esselaar (1969) and Sinclair (1969).

The principal goal of factor analysis is to make a complex set of data more comprehensible, by expressing the total variance of the original set of variables in as few factors as possible. The number of factors accounting for a given percentage of the variance is less than the number of variables, if the original variables possess a high correlation, or it is equal to the number of variables, if the variables are extremely poorly correlated. The factors are thus linear combinations of variables which reflect correlation in data.

Factor analysis may proceed by two distinct different ways. The R-mode analysis studies the relationship between all pairs of variables by analysing the matrix of the product moment correlation coefficients. The correlation coefficient is a measure of the linear relationship which exists between variables. It has a value between +1 and -1 depending on whether the values are sympathetically or antipathetically related. The Q-mode analysis proceeds by examining the relationship between samples and is discussed later.

Problems involving factor analysis usually do not deal with three-component systems and a restriction to ordinary Euclidean space is impossible. Algebraic vector models must be employed which allow to make use of the techniques of vector and matrix algebra.

The method of principal components described by Harman (1967) is generally used to relate each variable to the statistically independent, hypothetical factors. This method , which produces the initial factor matrix, is rather difficult to explain and involves calculation of eigenvalues and eigenvectors. The magnitude of the eigenvalues expresses the proportion of the overall data variability which is contained in each factor and thus indicates the importance of each factor.

Dimensional reduction is carried out by approximation in a least square sense. The first factor is so chosen that it accounts for as much of the variance as possible. Each successive factor is then chosen in such a way that it lies orthogonal to the preceding factor and accounts for as much of the remaining variance as possible. If the first few factors account for a large amount of the total variation it may be possible to ignore the rest.

The initial factors or principal components can be geometrically visualized as orthogonal axes around which variable vectors cluster in the space of dimension determined by the number of factor axes (Fig. 8).

Once the minimum number of dimensions or factors has been determined, the factors are usually orthogonally rotated, so that they correspond as closely as possible to any definite grouping of the variable vectors. This so-called Varimax rotation (Kaiser, 1959) is necessary as the principal factor axes in the n-dimensional space are

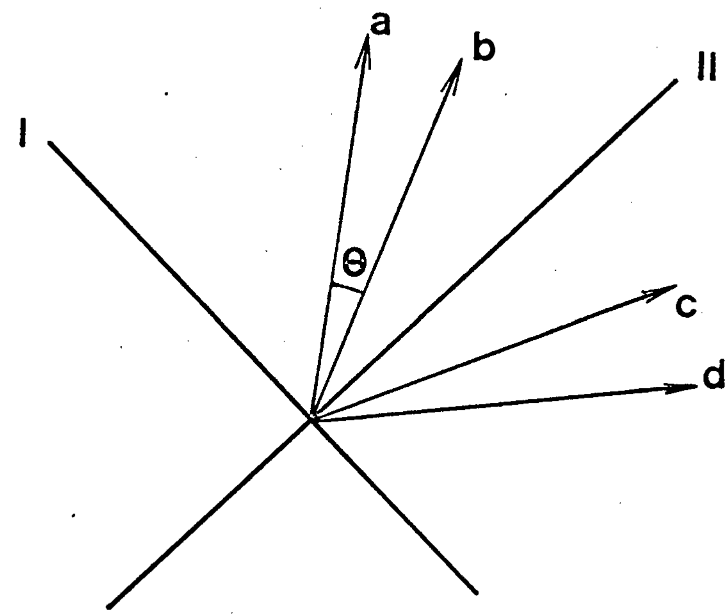


Fig. 8: Two-dimensional plot of 4 variable vectors (a,b,c,d) with two initial factor axes (I,II). The variable vectors are of unit length. The cosine theta of the angle between a vector pair is equal to the value of the correlation coefficient between them. After Imbrie and Van Andel (1964).

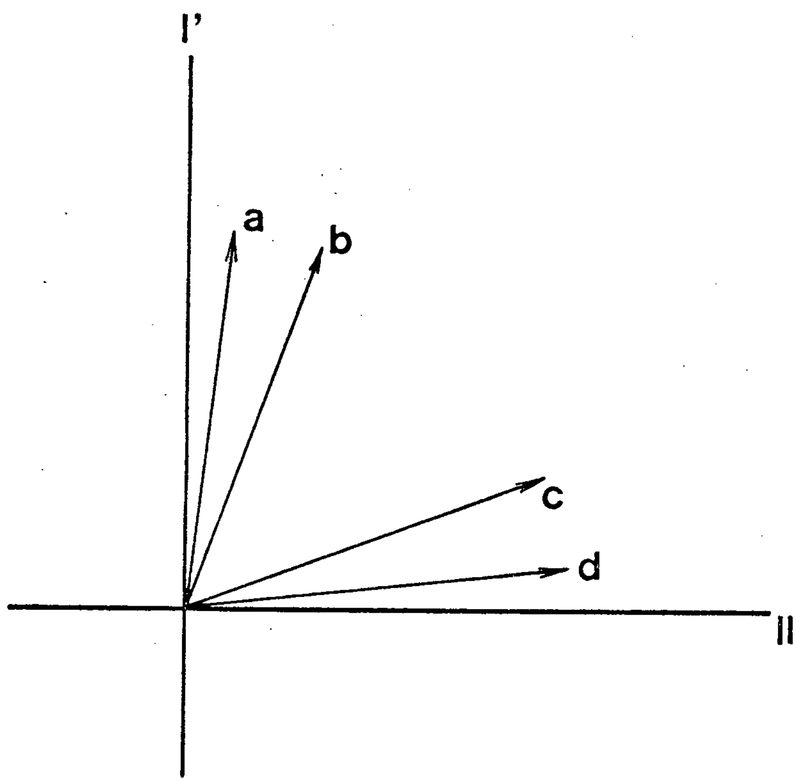


Fig. 9: Two-dimensional plot of the same four variable vectors with the factor axes (I', II') orthogonally rotated. The Varimax axes correspond more closely to the four vectors.

located according to a mathematical criterion, which makes geological interpretations of the initial factors difficult. The result of the rotation is the Varimax factor matrix (Fig. 9).

Using regression equations, factor scores have been calculated for each sample locality in order to express the variable content of each sample in terms of the factors extracted by the analysis. In other words each factor can be regarded as a "new" variable. Each sample now contains certain amounts of these new variables, which are given by the factor scores. They are in standard deviation units and lie above and below the zero mean of score.

Treatment of Data

As pointed out earlier only stream sediment data, involving the six geochemical variables Cu, Mo, Pb, Zn, Ag, and Sb, were investigated by factor analysis. For Mo, Ag, and Sb, the raw data; and for Cu, Pb and Zn - which tend to be lognormally distributed - the logarithmically transformed

Table III: Correlation Coefficients of Cu, Mo, Pb, Zn, Ag, Sb

	Cu	Mo	Pb	Zn	Ag	Sb
Cu	1.0000	0.5001	0.2724	0.0469	0.3605	0.0921
Mo	0.5001	1.0000	0.2197	-0.0309	0.1956	0.1993
Pb	0.2724	0.2197	1.0000	0.7333	0.5640	0.0761
Zn	0.0469	-0.0309	0.7333	1.0000	0.3787	0.0517
Ag	0.3605	0.1956	0.5640	0.3787	1.0000	0.2680
Sb	0.0921	0.1993	0.0761	0.0517	0.2680	1.0000

data were used for the computation of the product moment correlation coefficients. The interrelation of all pairs of samples were computed and are given on Table III.

For calculating the initial factor matrix (principal components) from the correlation matrix unities have been left in the main diagonal of the matrix. The factor space so obtained accounts for a greater percentage of the total variance than the one obtained if communality estimates are placed in the main diagonal. Three factors explaining approximately 80 per cent of the total variation in the data have been extracted. The proportion of the overall data variability contained in each factor is explained by the magnitude of the eigenvalues (Table IV) which are ranked in decreasing order. According to Harman (1967) only factors explained by eigenvalues greater than one should be used when unities are left in the main diagonal of the correlation matrix.

Table IV:				
	Eigenvalues	2.424	1.407	0.961
	Proportion of Eigenvalues	0.404	0.235	0.160
	Cumulative Proportion of Eigenvalues	0.404	0.639	0.799

Subsequent to the computation of the initial factor matrix the system has been rotated by the Varimax method so that three independent factors correspond with groupings present in the geochemical data (Table V). Finally, the factor score of each sample locality was computed, and the results plotted into the factor score maps (Figs. 11, 12, 13).

The UBC FACTO package developed at the Computing Centre of the University of British Columbia (Bjerring, 1969) and the IBM 369 Scientific Subroutine Package were used to compute the correlation matrix and the R-mode factor analysis.

Table V: Varimax Factor Matrix

	Factor 1	Factor 2	Factor 3	Communality
Cu	0.16188	-0.86173	-0.01738	0.76909
Mo	0.00589	-0.83989	0.14307	0.72592
Pb	0.90861	-0.20470	-0.00733	0.86752
Zn	0.90099	0.13360	0.03028	0.83054
Ag	0.65549	-0.31188	0.33563	0.63959
Sb	0.04699	-0.07155	0.97543	0.95880

Discussion of Results

The main object of the present investigation has been to simplify the complex set of six geochemical variables and to find underlying geological causes of variation in the stream sediment measurements. As indicated in Tables IV and V, three significant factors explaining 79.9 per cent of the total variation in the data could be extracted with the R-mode analysis. Scanning the "factor columns" in Table V for the highest factor loadings allows to determine which variables correspond most closely to one of the three independent factor axes:

Factor 1	Pb (0.90861)	Zn (0.90099)	Ag (0.65549)
Factor 2	Cu (-0.86173)	Mo (-0.83989)	
Factor 3	Sb (0.95880)		

The communality is the sum of the squared factor loadings in a row of the factor matrix, and explains the

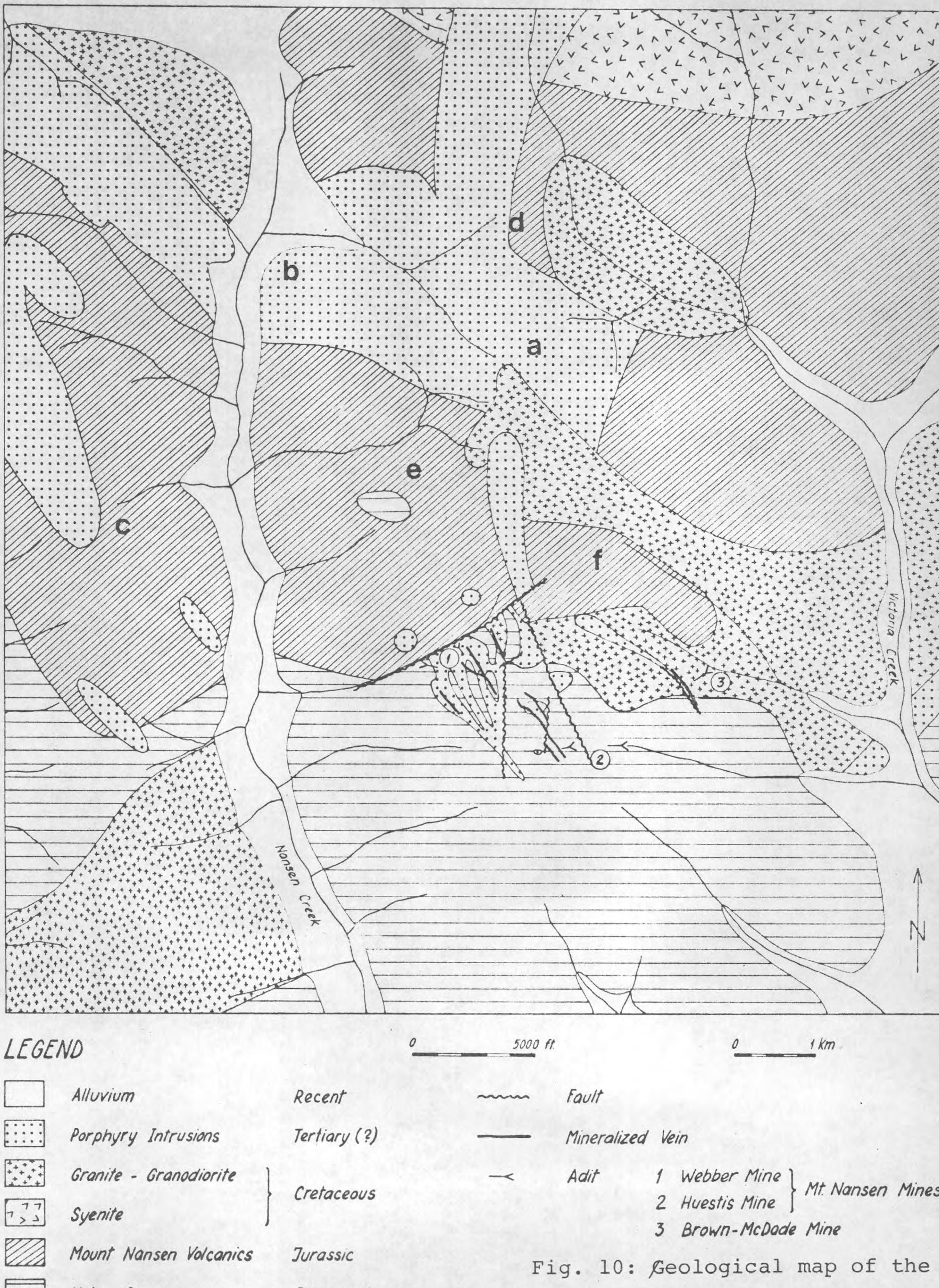


Fig. 10: Geological map of the Mount Nansen area

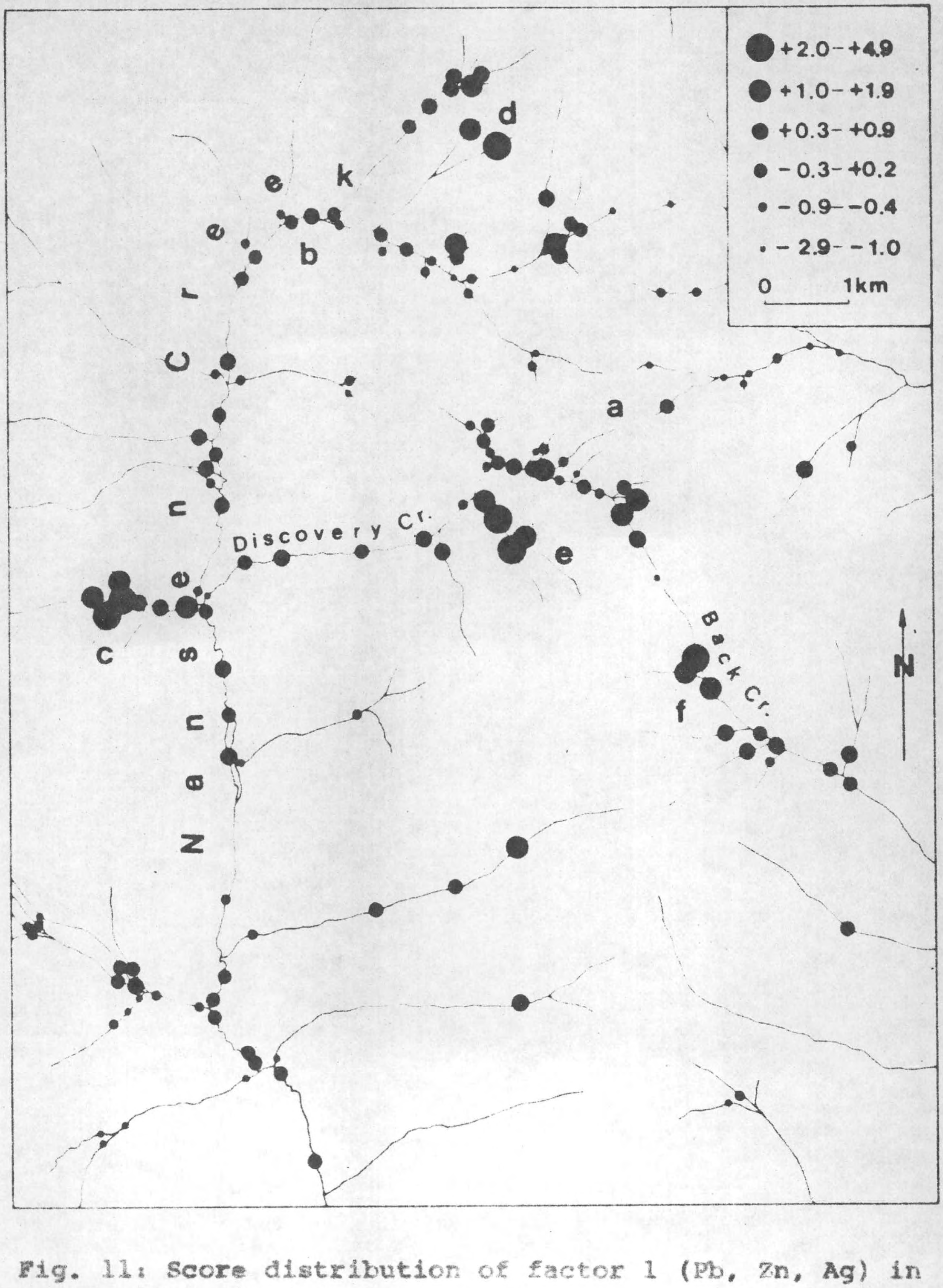


Fig. 11: Score distribution of factor 1 (Pb, Zn, Ag) in standard deviation units.

proportion of the variability of any particular variable which has gone into all three factors; for instance, for Cu this value is 0.76909 or 76.909 per cent of its variability.

Factor 1 (Pb, Zn, Ag) represents lead-zinc-silver vein deposits probably of a similar nature as the Mount Nansen ore deposit (Saager and Bianconi, 1971). Figure 11 gives the distribution of the scores of factor 1 at each sample locality and delineates areas in which the occurrence of such vein deposits can be expected. Anomalous factor score values occur in c, d, e, and f, which agrees extremely well with the three distribution maps of Pb, Zn, and Ag given in the stream sampling report of Bianconi and Saager (1970).

The four anomalies occur on the flanks of the large northwest trending porphyry body (Fig. 10) and, thus, might be interpreted as peripheral vein deposits, which are genetically related to porphyry mineralizations (Lowell and Guilbert, 1970).

Factor 2 (Cu, Mo) can be caused by disseminated porphyry ore type mineralizations, since factor scores occur exclusively on ground underlain by porphyry. In fact the distribution patterns delineate quite sharply the outlines of the porphyry rocks. In accordance with the elemental distribution patterns of Cu and Mo, the highest factor score values occur at a and b (Fig. 12). This is the area where the soil survey (Bianconi and Saager, 1970) delineated several Cu and Mo anomalies, and which was examined by means of trend surface analysis (Figs. 2-7).

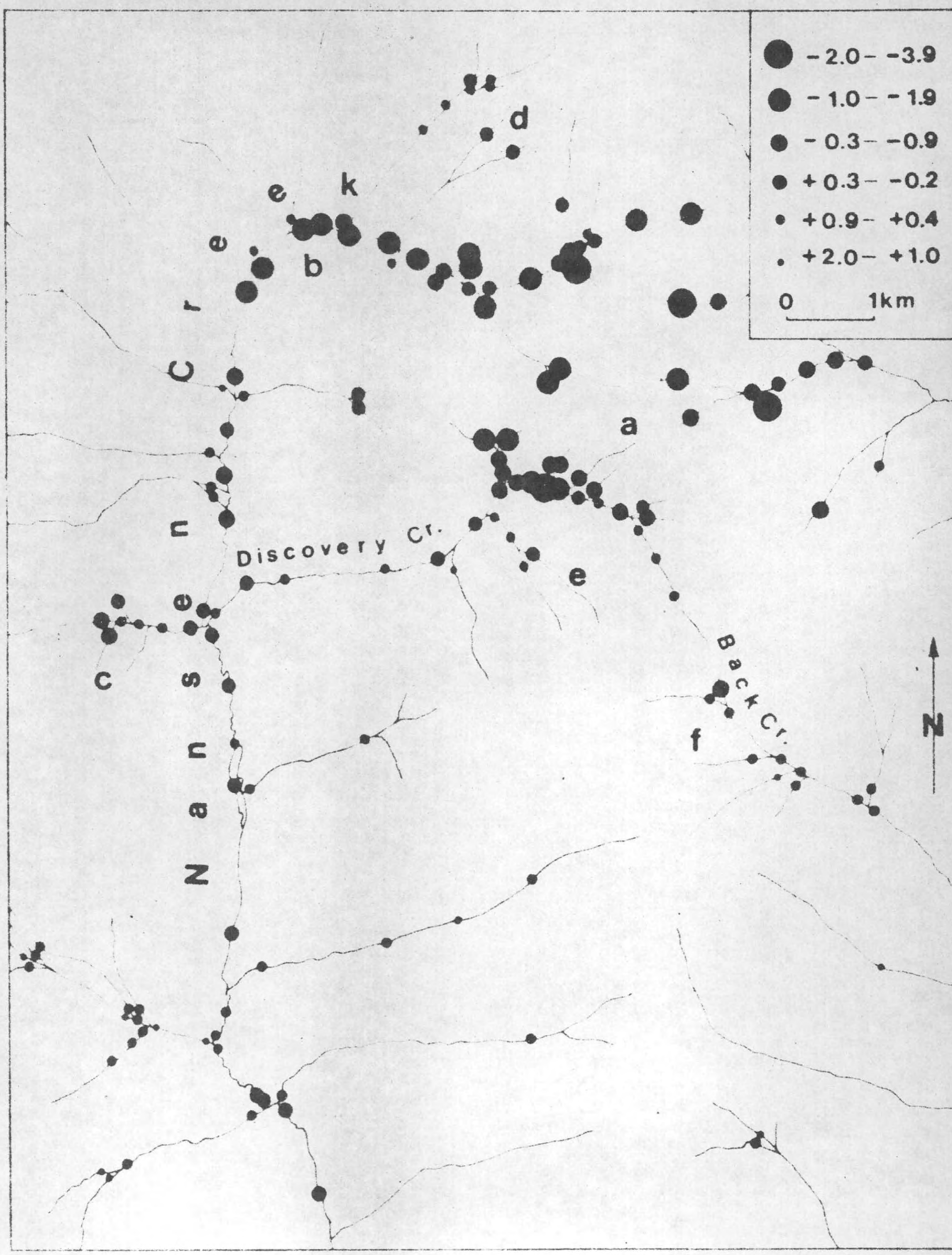


Fig. 12: Score distribution of factor 2 (Cu, Mo) in standard deviation units.

A somewhat less pronounced anomaly exists at c, indicating the presence of Cu and/or Mo? in this strong Pb-Zn-Ag anomaly, which would be in agreement with the mineralogy of some of the Mount Nansen ore material, where minor amounts of chalcopyrite, valleriite and other Cu-bearing minerals were found (Saager and Bianconi, 1971).

Factor 3 (Sb) is statistically the least important factor and its geological significance is not completely understood. In the area Sb has been found as a chemical constituent in freibergite and a number of others, mostly silver bearing sulphosalts (Saager and Bianconi, 1971). The presence of a low, but relatively significant loading of Ag (0.33563) in factor 3 seems to indicate that these geochemical relationships might be, to a certain extent, the cause of these factors. The distribution of the factor scores (Fig. 13), however, shows rather unclear patterns. Some anomalous values occur together with high score values of factor 1 at c, other anomalous values were found in the Cu-Mo anomaly at a. The anomalous values in the southwest corner of Figure 13 cannot be interpreted at the moment, since no other indications of mineralizations are known for this area.

Conclusions

Factor 1 and factor 2 obtained in the present R-mode analysis must be regarded as significant since they can be geologically and geochemically correlated with two distinctly different, but possibly genetically related, types of mineralizations; i.e. Pb-Zn-Ag veins in lithologically different host rocks (Nansen volcanics,

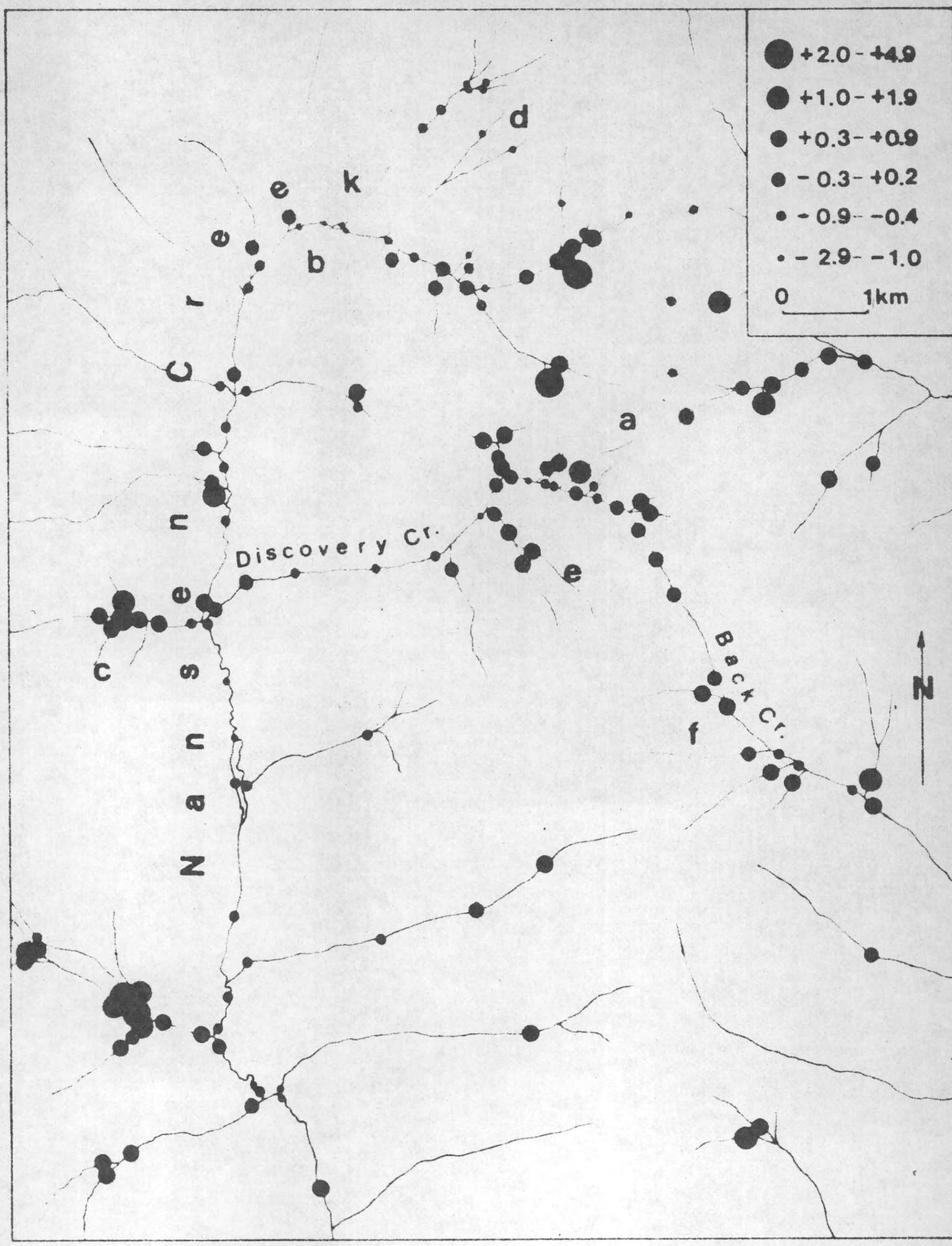


Fig. 13: Score distribution of Factor 3 (Sb) in standard deviation units.

Mesozoic intrusives, Yukon schists) and disseminated Cu-Mo mineralizations in porphyries.

The score map of factor 1 (Fig.11), therefore, can be regarded as a pointer to zones of Pb-Zn-Ag mineralization and the score map of factor 2 (Fig.12) indicates areas of high Cu-Mo potential; at the same time it approximately delineates areas underlain by porphyry rock.

Factor 3, which has the smallest eigenvalue of all three factors, presently cannot be related in such an evident way with a geological and geochemical concept. In comparison with the other two factors it also displays a less significant and less distinct distribution pattern of the factor scores (Fig. 13). The relatively high loading of Ag in this factor, and some high factor score values as well in Pb-Zn-Ag as in Cu-Mo anomalies point to the possibility that this factor is evoked by antimony-and silver-bearing sulphosalts, which can be present in both the Cu-Mo porphyry mineralizations and the Pb-Zn-Ag veins.

From the exploration point of view the great advantage of the present investigation is the fact, that factor analysis deals with many variables at one time. It successfully has helped to reduce the number of maps to be interpreted from six to three. Two of the maps (Figs. 11 and 12) are particularly interesting since they delineate target areas either for vein type ores, or for disseminated porphyry ore mineralizations.

From the three factor score maps it also becomes apparent that the most promising exploration areas for both types of mineralization lies either in terrain underlain by porphyries,or in the direct vicinity of such porphyry intrusions. The results of the factor analysis seem, therefore, to underpin earlier made conclusions that the silver-lead-zinc bearing vein-deposits are peripheral phenomena of a large disseminated porphyry ore type mineralization. Since these genetical conclusions were obtained solely by the investigation of a relatively small number of geochemical data, it is felt,that such an approach is not only useful to interpret the measurements of exploration surveys but, in certain cases, could also assist to formulate initial concepts of the genesis of ore deposits.

C. Q-Mode Factor Analysis

The Q-mode analysis proceeds by examining the relationship between samples. The variables determined in each sample may vary from sampling point to sampling point for a number of causes, and each cause will produce variations in the variables. The measured variations from sampling point to sampling point are, thus, not independent, but interlocked in some way. If the underlaying causes are similar for two sampling points, the variable values obtained for these two samples must be similar. Sample pairs with similar variable values possess a high similarity coefficient between them,and sample pairs that bear little relationship with each other have a low similarity coefficient.

Since the samples are expressed as vectors of unit length, the cosine theta of the angle between two sample vectors can be used as an angular measure of the proportional similarity between the two samples. The Q-mode study, therefore, proceeds by analysing the cosine theta similarity matrix of the relationships between all pairs of samples, as opposed to the R-mode analysis, which is based on the decomposition of the product moment correlation matrix of the variables.

The method of principal components is also used to find the minimum number of dimensions, in which the object vectors can be explained without distorting their positions relative to one another. Subsequently, the initial factor axes are orthogonally rotated by the Varimax rotation and the Varimax factor loadings obtained for each sample. The squared sum of the factor loadings obtained for each sample are its communality which indicates what proportion of any sample variability has been explained by the corresponding factor loadings. The Varimax factor score matrix indicates in standard deviation units how much of each variable is represented in each factor, and is used to determine which variables contribute predominantly to a certain factor.

An attractive feature of the Q-mode analysis is the fact, that it determines the extent to which the various factors are represented in the composition of each sample. In geochemical surveys, involving a vast number of samples, Q-mode analysis, however, is limited by the fact that only a certain number of samples can be examined, owing to the necessity of storing the entire cosine theta similarity matrix in the memory of computers.

Treatment of Data

The same values as in the R-mode analysis were used, i.e.

raw data for Mo, Ag, and Sb, and logarithmically transformed data for Cu, Pb, and Zn. The cosine theta matrix, the initial factor matrix, the Varimax factor matrix, and the Varimax factor score matrix (Table VI) were computed, employing a FORTRAN program, which was developed at the Department of Geology of the University of British Columbia (Wilson, 1969).

Table VI: Varimax Factor Score Matrix

	Factor 1	Factor 2	Factor 3
Cu	-1.8875	0.8714	0.3393
Mo	-0.7677	0.2859	0.5019
Pb	-0.8596	-1.2698	-0.4064
Zn	-0.3578	-1.6254	-0.6305
Ag	-0.8433	-0.6526	0.7523
Sb	0.5117	-0.7052	2.1199

Discussion of Results

Three significant factors accounting for 80.3 per cent of the total variance could be extracted by the Q-mode analysis. Factor 1 explaining 31.9 per cent of the data is predominantly a Cu factor (factor score -1.8875) with minor contributions from Pb (-0.8596) and Ag (-0.8433). Factor 2 explaining 27.5 per cent of the variance consists predominantly of Zn (-1.6254) and Pb (-1.2698) with a minor contribution of Cu (-0.8714). Factor 3 is essentially an Sb factor (2.1199) accounting for 20.9 per cent of the data.

The three factors, thus, correspond to a certain extent with the factors obtained in the R-mode analysis, which, though less distinct, seems to indicate similar underlying

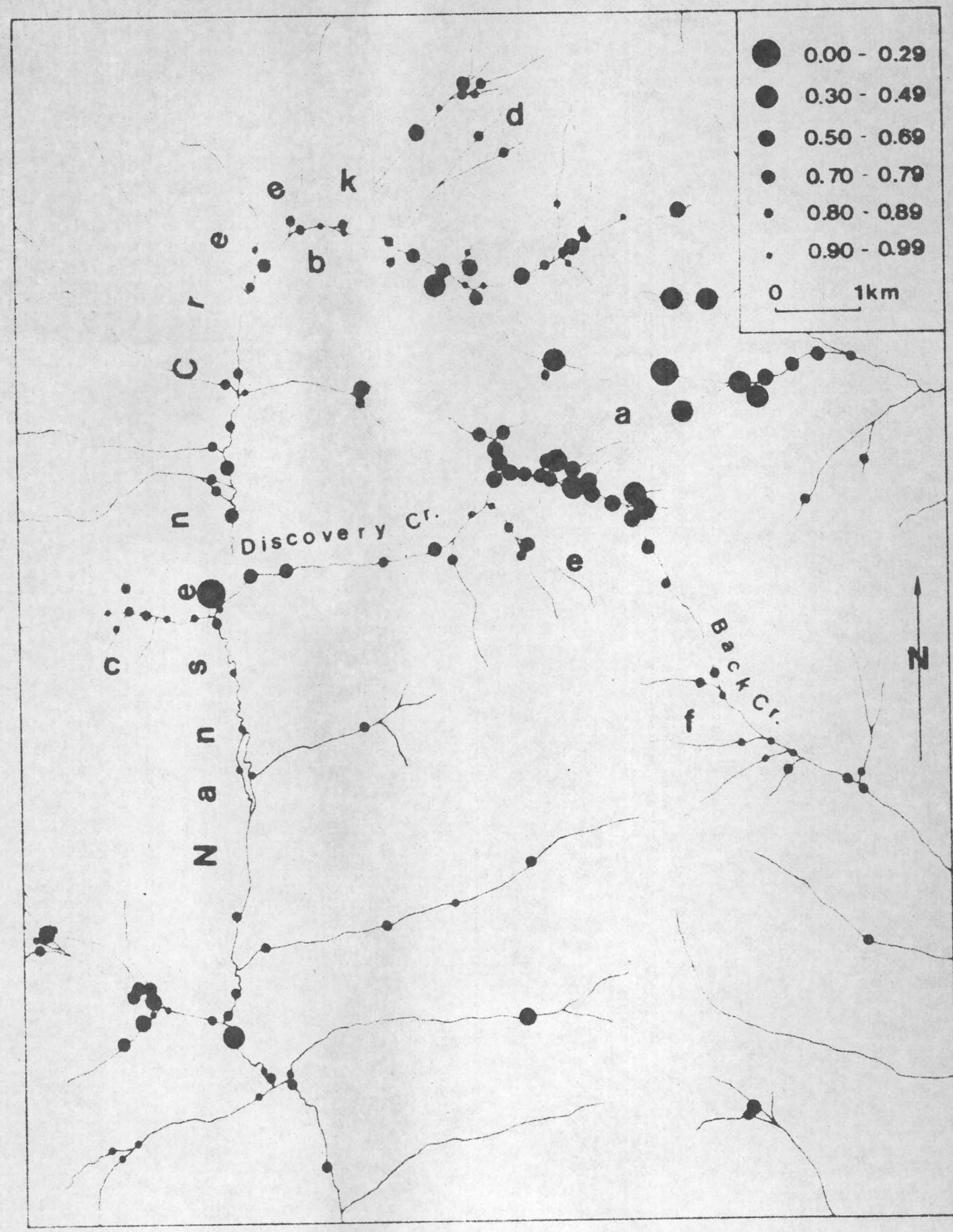


Fig. 14: Distribution of Q-mode communalities with 3 factors extracted; in proportions of the total variability.

causes for the variation in data, i.e. different types of mineralization. It is evident that not exactly the same factors are obtained in the two studies, as the R-mode investigates relationships between the variables of geochemical samples, whereas in the Q-mode the relationships between the geochemical samples are inspected.

No distribution maps of the three factors are given here, since the anomalies found were somewhat indistinct, and, generally, did not give new or additional informations to the distribution patterns obtained in the R-mode study (Figs. 11, 12 and 13).

An attempt was therefore made to plot the distribution patterns of the communality values (Fig. 14) which indicate the extent to which the data variability of each sample is accounted for by the three factors. At the same time such a plot comprehends the original six variables obtained for each sampling point into one map, which, if carefully evaluated, must certainly be considered an aid in interpreting the vast amount of geochemical data obtained in this investigation. From Figure 14 it can be seen, that most of the samples with a low communality value occur in the area of the Cu-Mo anomaly at a. All other geochemical anomalies detected in the stream sediment survey do not exhibit such an evident correlation. These samples generally possess high communality values, and are, thus, relatively well explained by the three factors. It is felt that this distinct distribution pattern of samples, poorly explained by the three factors, is an indication that the Cu-Mo anomaly a is the most significant anomaly detected in the course of the present studies.

Conclusions

The three factors obtained in the Q-mode analysis are similar to the ones found in the R-mode investigation, but cannot be correlated in such a distinct way with a geological concept. The distribution patterns of the factors correspond in a broad sense with those of the R-mode factors, which seems to indicate that the previously made statements regarding the causes of the factors were justified.

The plot of the areal communality distribution (Fig. 14) allows to correlate and interpret the entire geochemical data on one map. It shows an interesting relationship between the geochemical Cu-Mo anomaly a and low communality values, which quite distinctly indicates the significance of this anomaly. Most of the other sample values show high communality values and, therefore, must be considered to fall within the system defined by the three factor axes.

From this, as well as from the other statistical interpretations, the Cu-Mo anomaly at a must be considered the most interesting and most promising exploration target in the area investigated by the geochemical stream sediment survey.

R. Saager

420-475 Howe St
Vancouver 1, B.C.

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