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EXPLORATION DIVISIONWESTERN DISTRICTREPORT ON ROCK GEOCHEMISTRY AT THE KOOTENAY KING MINE
OCTOBER 1974

826/12E

SUMMARY

A sampling experiment to test for a rock geochemical halo around the Kootenay King Mine in the southern Rocky Mountains shows that no such halo exists in the elements Cu, Pb, Zn, Mo, Ni, Co, Mn, or V.

Variation in the amount of iron sulphide in the sediments appears to control variation in Ni and Co, and to partly control variation in Mn. Variation in the carbonate minerals is suggested as a control for the distribution for the remainder of the Mn and all of the V. Cu, Pb, and Zn are distributed about equally into iron sulphides and carbonate minerals.

The black argillites of the hanging wall to the orebody do not differ from the brown siltstones of the footwall in any of the above elements.

INTRODUCTION

During August 1974 a rock sampling program was undertaken at the Mineral King Mine property in the Hughs Range of the Rocky Mountains. The purpose of the program was to test the hypothesis that bedded sulphide deposits of the Kootenay King type are associated with an extensive halo in the chemistry of the trace elements in the host rocks. The object of the test is purely empirical: that is, to discover any spatial relation that exists between the position of the orebody in the stratigraphy, and variation in the elements for which analyses were made. This is because it is the way in which the results would be used in further prospecting. No attempt is made here to account for variation in relation to the orebody in terms of geologic processes, and especially genetic processes, unless these have a clear application to prospecting.

This report is written to accompany data submitted for assessment requirements. Since June, 1974 it has not been possible to group Mining Leases with Mining Claims for assessment. Consequently, data from Mining Lease 52, which contains the orebody, are neither reported nor interpreted here.

PROPERTY, LOCATION, ACCESS

The Kootenay King Mine property consists of 5 mineral claims, KK1-4, KK9, registered with the Fort Steele Mining District on November 12, 1970; and Mineral Lease (M52). It lies 16 miles NE of Cranbrook, on the southeast side of Lakit Mountain, between elevations 6000 and 8300

M-53? Department of
Mines and Petroleum Resources

ASSESSMENT REPORT

NO. 5245 MAP

feet. It is approached by a dirt road along the east side of the ridge containing Lakit Mountain that branches from the Wildhorse Creek road 3.9 miles from Highway 95 at Fort Steele.

SAMPLING

Samples of argillite were taken at approximately 100 foot separations along eight traverses across the strike of the formation. The strike length so covered amounts to about 5,000 feet, extending 2,500 feet north and south of the orebody, and situated principally in the footwall.

Samples were collected up to 5 lbs. in weight in the field, with care being taken to avoid excessive weathering, zones of shearing, and quartz veining. The samples were reduced in the office, by hammering them, to between 1/2 lb. and 1 lb. of rock as fresh as possible for shipment to the analyst, Bondar-Clegg and Company Ltd., 1500 Pemberton Avenue, North Vancouver, B. C.

The samples were pulverized, and sieved to -100 mesh size. Atomic Absorption analyses were made on digestions of hot H_2SO_4 for vanadium (V), and hot aqua regia for Cu, Pb, Zn, Mo, Co, Ni, and Mn.

The above elements were chosen as a first exploratory step in searching for variables that might display a halo, because they are a selection from that portion of the Periodic Table of Elements that contains Pb and Zn. Thus they might be expected to be transported, concentrated and distributed in a manner similar to, but not exactly the same as, Pb and Zn.

The locations of 80 samples occurring within the Mineral Claims are shown on the attached map, and the values reported by Bondar-Clegg are tabulated in the appendix to this report.

RESULTS

A study of the raw values for Cu, Pb, Zn, Ni, Co, Mn, and V shows immediately that there is no strong and obvious zonation of these variables that is related to the position of the Kootenay King orebody.

It is necessary, before commencing analyses, to examine the data matrix to see if it represents one population of samples within which the variables are related in a consistent manner. No valid conclusions about variable relationships will be forthcoming from a population within which some of the samples display variables related in a manner that is different from the relationships displayed by the remainder. If this occurs, the two groups need identification. In this case it is expected that some of the samples will display the effects of a process responsible for the regional distribution of the trace elements (back-

ground), while other samples will display a superimposed process related to the emplacement of the orebody (anomaly).

The statistical technique chosen for this operation is factor analysis in Q-mode. The technique is described by Imbrie, J., and Purdy, E.G. in "Classification of Modern Bahamian Carbonate Sediments", Am. Assoc. Petrol. Geol., Mem.1, pp. 253-272. It is a cluster analysis technique based on similarities of covariance among the variables. Appendix 2 contains graphic output from a computer application of the technique to the Kootenay King samples. Three dimensions are examined, amounting to 99.353% of the variation in the matrix: in other words, all of it. The diagram shows the samples plotted in the plane of the second and third dimensions, which is the one showing the greatest spread. The samples describe a tight, homogeneous group, with four outliers, giving no indication of heterogeneity of variance within the population. Thus there is only one population. This condition is suggested by a study of the frequency distributions: if there had been more than one population it should have been evidenced by multi-(bi-)modal frequency plots, and difficulty in transformation to an approximation of the normal (see below).

A useful expedient when dealing with chemical compositional variables, especially with trace values, is to convert the raw data to logarithms before subjecting them to analysis. Frequency distributions of trace variables are commonly highly skewed towards low values, so the log transformation produces a distribution that is more nearly symmetrical, and more nearly approximating the normal. The advantages of working with the (transformed) normal distribution are great: basically, most of the procedures of statistical analysis (for example, analysis of dispersion, correlation, and regression) are efficient to the extent that the variable is normally distributed. Bias in statistical estimators is reduced as the variable approximates the normal distribution.

Logarithmic transforms of the variables considered here provide the following moment statistics:

<u>Variables*</u>	<u>Mean</u>	<u>S.D.</u>	<u>Skewness</u>	<u>Kurtosis</u>
Cu	0.8216	0.4677	-0.285	2.163*
Pb	1.2575	0.2456	0.874**	4.895**
Zn	1.6593	0.3372	0.548*	3.787
Ni	1.0171	0.4853	not available	but large
Co	0.9564	0.4241	-0.883**	4.419*
Mn	2.5940	0.5338	-1.394**	4.532**
V	1.5152	0.1048	-0.180	2.503

*The variable Mo was not detected in 35 samples. Substituting a value of zero or 0.1 ppm for this observation in the data matrix so distorts bi-variate and multi-variate exercises that Mo was dropped from the

analysis. The determinations are obviously qualitative in comparison to those of the other variables, and should not be included in the same data matrix.

The standard deviation statistics (S.D.) are all small compared to mean values, indicating an approach to a satisfactory reduction in variation. The estimators for skewness and kurtosis (peakedness) differ to a greater or lesser extent from 0 and 3 respectively, indicating departure from the normal distribution. In particular, Ni should be rejected as representing one homogeneous parent population with (log) normal distribution.

Although the multivariate relationships appear to indicate a single population, there is one obvious source of difference that requires testing. The footwall brown siltstones can be expected to differ chemically from the black argillites of the hangingwall. Subdividing the 80 samples into two groups representing the argillites and the siltstones provides two sets of means that can be compared by t-test. There is no element showing a difference between the two sub-populations that is significant at the 5% level of confidence or greater.

With one homogeneous population of randomly selected samples it is safe to examine the relationships of variables, one with another. The technique for so doing is simple linear correlation. There follows the matrix of simple linear correlation coefficients.

	<u>Cu</u>	<u>Pb</u>	<u>Zn</u>	<u>Ni</u>	<u>Co</u>	<u>Mn</u>
Pb	0.338**					
Zn	0.331**	0.318**				
Ni	0.335**	0.178	0.266*			
Co	0.539**	0.356**	0.413**	0.730**		
Mn	-0.014	0.100	0.119	0.635**	0.544**	
V	0.145	0.097	0.122	-0.057	-0.026	-0.275**

There are 10 positive values significant at the 5% level of confidence (**), and one positive and one negative value significant at the 1% level of confidence (*), for a total of 12 out of a possible twenty-one.

Within this matrix there can be distinguished three blocks of relationships. Cu-Pb-Zn-Ni-Co form one group of significant inter-correlations between +0.3 and +0.5. Mn-Ni-Co represent a group inter-correlated between +0.5 and +0.8. The third group, consisting of

Mn and V, are negatively related at a lower level of significance. Solid groups of positive trace element intercorrelations can frequently be explained when they all occur within one mineral.

Blocking the correlation matrix by eye, as has been done above, amounts to identifying the major elements of covariation in the data set. The operation can be performed mathematically by the technique of factor analysis in R-mode. The major elements of covariation are the factors: really they are dummy variables that correlate highly with different groups of real variables. The effect is the simplification of the message contained in the data, and the purpose is interpretation: it is common practice to identify the factors as independent causes of variation (see Harman, H.J., Modern Factor Analysis, Chicago Press, 1960).

In the factor analysis table that follows three factors are extracted amounting to 73.5% of the variation in the data. Three are presented because there are three apparent axis of covariation in the correlation matrix. Additional variation may be regarded as noise. The factor loadings represent the extent to which each variable correlates with the respective factors (dummy variables).

<u>Factor Loading</u>				
<u>Variable</u>	<u>Factor 1</u>	<u>Factor 2</u>	<u>Factor 3</u>	<u>Communalities</u>
Cu	0.602	-0.473	0.004	0.5858
Pb	0.500	-0.416	-0.534	0.7081
Zn	0.555	-0.372	-0.176	0.4785
Ni	0.824	0.295	0.288	0.8489
Co	0.916	0.048	0.088	0.8392
Mn	0.626	0.639	0.093	0.8003
V	-0.026	-0.687	0.632	0.8714
Σ	2.825	1.506	0.815	5.1322
$\Sigma\%$ cum.	40.368	61.885	73.534	73.534

The Ni,Co,Mn axis stands out clearly as the highest loadings on the first factor, and the Mn inverse V axis is represented as factor 2. The Cu,Pb,Zn,Ni,Co association is represented also on factor 1 as a set of lower loadings for Cu,Pb,Zn: it is not separated from the Ni,Co,Mn axis by this analysis. The third factor presents an inverse relationship between Pb and V, not suspected from the correlation matrix. The low communalities on Cu and Zn mean that more factors must be extracted to account for their variation. For instance, only 47.85% of the variation in Zn is accounted for in the analysis above. Extracting further factors to improve the explanation of Zn and Cu results in low loadings difficult to interpret: probably they represent an attempt to explain noise.

INTERPRETATION

The data matrix of 80 samples x 7 variables has been reduced by factor analysis to three vectors, or dimensions. This simplification is an interpretive device that can be used to identify independent sources of variation, and, where applicable, causes of variation.

The variables group as follows in terms of the factors:

F1	Mn, Ni, Co (Cu, Pb, Zn)
F2	Mn, -V (-Cu, -Pb, -Zn)
F3	v, -Pb

There is, however, no comparable grouping of samples. Differences in rock type, or in geographic location do not appear to be a source of variation.

Trace elements as a class commonly occur as substitutions, defects, or minor regular constituents in the major and accessory minerals that comprise the rock. The samples are composed of quartz, feldspar, ferromagnesian silicates (micas and clays), iron sulphides, and carbonates. In the absence of further data on mineral or major oxide composition it is impossible to do any more than to suggest that the three factors recognized above are explained in terms of variation in the three mineral groups that commonly incorporate them. These are the FeMg silicates, the carbonates, and the iron sulphides. It is unlikely, however, that the first of these, the FeMg silicates, will appear as a factor in this data matrix. This is because the silicates probably withstood the hot aqua regia digestion much better than either the sulphides or the carbonate minerals, and little of the trace elements contained report in the analyses.

Factor 1: The main loadings are on Mn, Ni, and Co. It is suggested that these data represent variation in the iron sulphides within which these elements are incorporated. The main reason for so doing is because Cu appears as a minor loading. Cu very seldom occurs as a regular substitution in the ferromagnesian minerals (silicates), and hence the alternate candidate for factor 1, variation in biotite and chlorite, is less favoured. This conclusion is supported by the comment about the analysis of silicates in the previous paragraph.

Factor 2: This factor describes the inverse relation of Mn and V. Variation in the small amount of carbonate is suggested as the control. This is because carbonates are typically low in V, whereas manganese readily substitutes for Ca in the carbonate lattice, both in the Aldridge formation, and universally.

Cu, Pb, and Zn all appear under both factors 1 and 2 with about equal loadings. The distribution of these elements is thus interpreted as being independently controlled by the variation in sulphides and the carbonate minerals to about an equal extent.

The above conclusions regarding the correct identification of factors 1 and 2 are tentative hypotheses. They can be tested, however, by the further analysis of the samples for CO_2 , S, FeO , and Fe_2O_3 . If factor 2 is correctly identified, it should load heavily on CO_2 .³ Factor 1 should load on Fe_2O_3 and S, or on FeO , depending on whether it represents iron sulphide variation, as suggested here, or silicate variation.

Factor 3: This factor accounts for the rest of the meaningful variation in Pb and V, but the relationship is inverse. It is unaccountable with the data presently available.

CONCLUSIONS

The sampling and analysis experiment described here shows that there is no strong dispersion halo in the elements Cu, Pb, Zn, Mo, Ni, Co, Mn, or V surrounding the Kootenay King orebody. This conclusion is not affected by the fact that no sampling close to the mine is reported: a halo restricted to the area of Mining Lease 52 would be too small to use on an exploration basis.

A second conclusion is the rather surprising one that no trace element difference appears between the brown, cross-bedded, footwall siltstones, and the black, hangingwall argillites.

As a third conclusion, it appears that variation in the amount of iron sulphide may account for the Ni and Co, and about half the Mn. Variation in the amount of carbonate in the sediment appears to control variation in the rest of the Mn, and about half the V. The elements Cu, Pb, and Zn appear dependent on both the distribution of iron sulphides, and of carbonate minerals in approximately equal amounts.



F. R. Edmunds
Sr. Project Geologist
Sullivan Mine
Cominco Ltd.

FRE/dp
November 8, 1974

STATEMENT OF QUALIFICATIONS

1. This certifies that I, Frederick R. Edmunds, of Kimberley, B. C. have practised my profession of geologist for 17 years; and that I am a graduate of Keele University, England (B.A. hons., 1958) and of the University of Toronto, Canada (M. Sc. 1964); and that I am qualified to submit the foregoing report.



F. R. Edmunds
Senior Project Geologist
Sullivan Mine
Cominco Ltd.

2. This certifies that I, F. L. Goodwin, of Kimberley, B. C. have known F. R. Edmunds for 1 year; and that to the best of my knowledge the contents of paragraph 1 are true.

 P. Eng.

F. L. Goodwin
Manager, Kimberley Operations
Sullivan Mine
Cominco Ltd.

**BONDAR-CLEGG & COMPANY LTD.**

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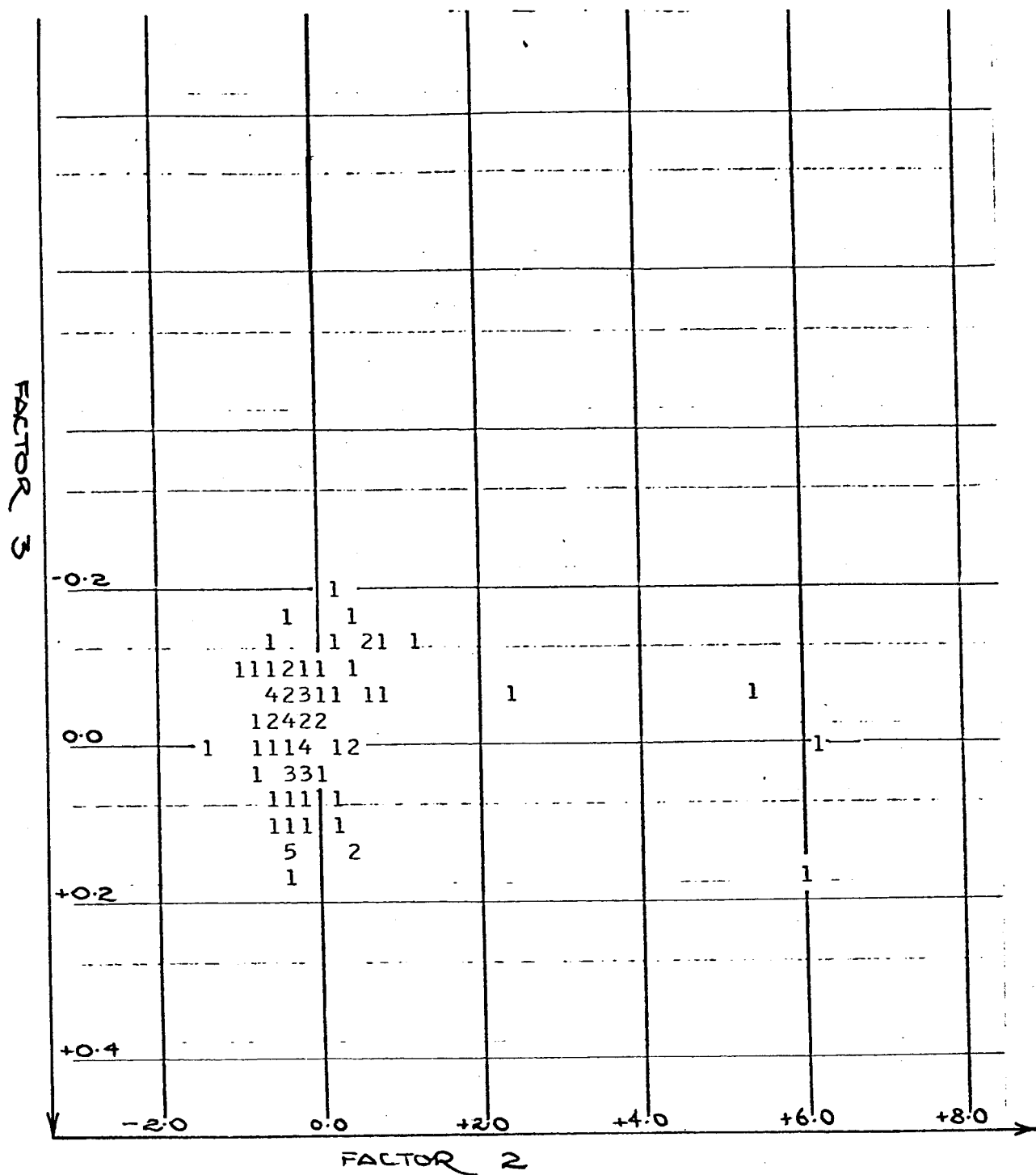
Geochemical Lab Report

Extraction V; Hot H₂SO₄
Cu, Pb, Zn, Mo, Co, Ni, Mn; Hot Aqua Regia Report No. 24 - 715 PROJECT: L 0549Method Atomic Absorption From Cominco Ltd.Fraction Used -100 mesh Date October 8 19 74

SAMPLE NO.	Cu ppm	Pb ppm	Zn ppm	Mo ppm	Ni ppm	Co ppm	Mn ppm	V ppm	REMARKS
1	3	7	39	1	10	9	350	38	
2	12	98	140	3	19	14	960	34	
3	24	11	27	1	23	16	985	22	
4	13	11	182	9	10	9	50	45	
5	13	32	52	ND	7	5	20	42	
6	8	33	46	ND	17	14	765	30	
7	10	20	38	1	30	15	1345	34	
8	6	26	36	1	14	9	590	32	
9	1	33	28	ND	12	10	645	30	
10	8	16	40	5	7	13	55	36	
11	14	19	33	8	6	8	65	37	
12	4	17	48	ND	12	10	390	33	
13	1	16	36	ND	11	10	920	40	
14	3	18	460	ND	10	10	870	40	
15	16	20	180	1	26	17	1085	41	
16	6	23	28	1	13	10	775	41	
17	8	22	31	1	20	15	1300	38	
18	6	14	99	ND	16	11	300	41	
19	8	21	195	1	10	9	480	41	
20	36	29	68	2	25	17	1020	39	
21	3	10	48	ND	10	10	270	39	
22	27	27	100	1	39	18	980	25	
23	4	23	30	1	24	16	695	28	

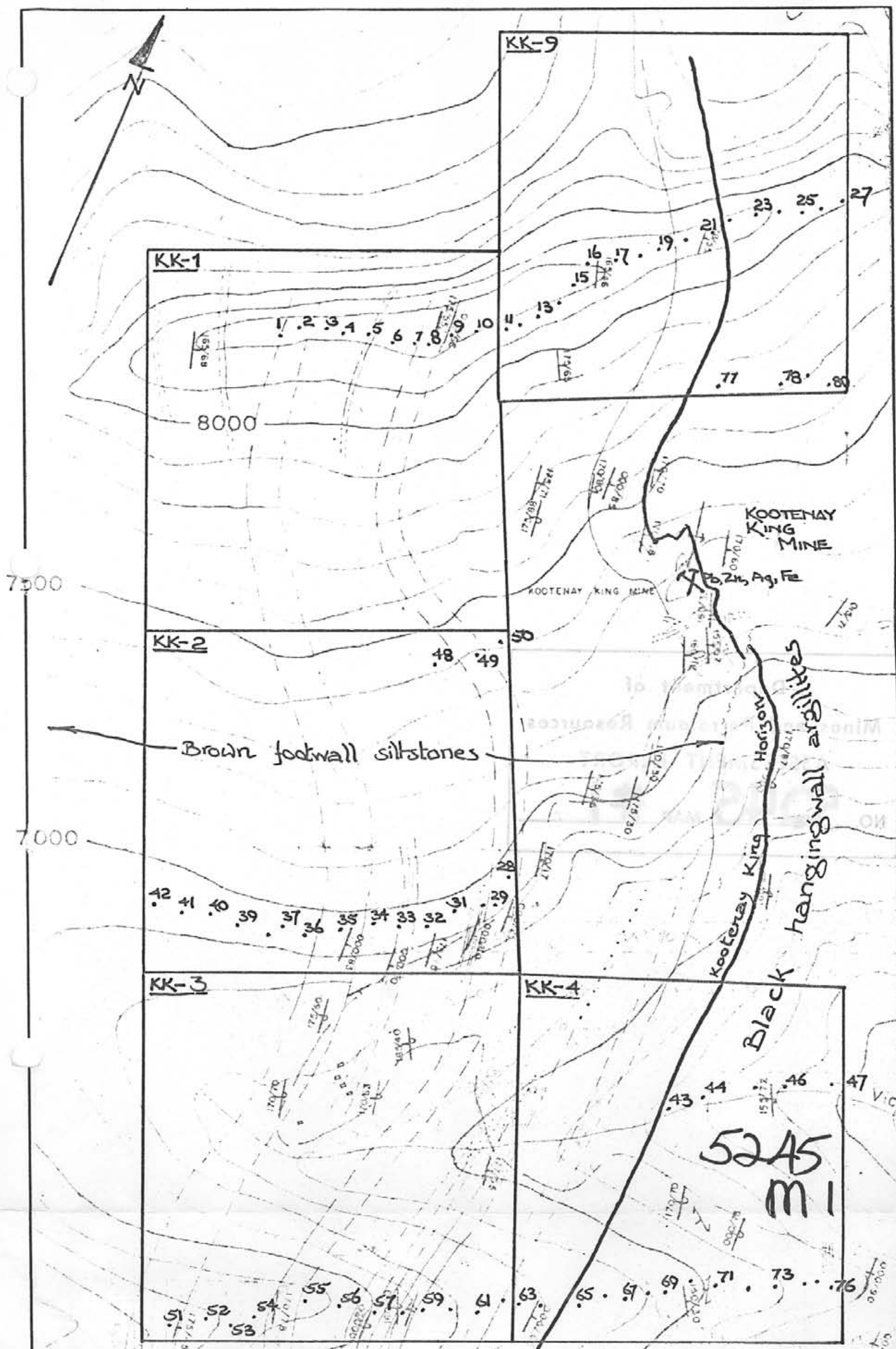
SAMPLE NO.	Cu ppm	Pb ppm	Zn ppm	Mo ppm	Ni ppm	Co ppm	Mn ppm	V ppm
24	13	16	34	1	12	10	60	40
25	26	30	90	2	30	20	1015	27
26	6	20	30	1	16	14	1685	23
27	4	14	14	ND	8	3	125	24
28	9	12	52	ND	10	10	285	23
29	1	6	114	ND	4	4	350	26
30	30	72	250	2	28	20	685	28
31	5	22	30	1	10	8	965	25
32	6	9	28	ND	5	6	90	29
33	1	25	44	ND	9	13	780	30
34	1	20	42	ND	4	7	465	30
35	13	16	41	1	16	12	345	30
36	2	10	14	ND	5	7	970	21
37	1	11	21	ND	4	8	1095	19
38	15	34	56	ND	18	21	2650	32
39	28	20	53	ND	23	16	1690	38
40	6	9	48	ND	5	6	365	37
41	2	8	23	ND	4	7	755	42
42	14	16	62	1	ND	5	25	41
43	14	128	134	ND	10	10	155	52
44	4	21	80	1	7	8	1000	30
45	3	16	23	2	1	5	15	46
46	42	18	148	2	23	17	180	22
47	8	21	46	1	8	9	735	21
48	10	9	15	1	14	11	445	31
49	6	12	58	1	14	11	410	19
50	5	17	42	1	14	11	490	28
51	2	57	14	1	ND	3	5	28
52	16	17	12	ND	10	6	515	31
53	22	19	51	1	8	8	75	38
54	30	13	43	2	10	26	50	40
55	10	15	40	3	24	13	405	30
56	2	16	49	1	10	8	555	29

[illegible]



PLOT OF FACTOR ANALYSIS IN Q-MODE : FACTOR 2
VERSUS FACTOR 3

APPENDIX 2



Drawn by:		Traced by: FRE	
Revised by	Date	Revised by	Date

PLAN OF ROCK GEOCHEMISTRY
SAMPLE LOCATIONS

to accompany report by F. R. Edmunds
November, 1974

Scale: 1" To 500'

Date: NOV, 1974

Plate: