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Rapportarkivet

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Falconbridge	Sul 415-76-17	Sulfidmalm A/S		

Tittel

Evaluation of factor Analysis results, Masi till data.

Forfatter	Dato	Bedrift
R B Band	1976	Sulfidmalm A/S

Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
Kautokeino	Finnmark	Finnmark	18342 18331 19343 19334	Nordreisa

Fagområde	Dokument type	Forekomster
Geokjemi	Rapport	
Råstofftype	**Emneord**	
Malm/metall	Si Al Fe Mg Ca Na K Ti V Cr Co Ni Cu Zn, Ag Mo	

Sammendrag

I 1974 ble et større moreneprøvetakingsprogram gjennomført i Masiområdet som en hjelp til å plukke ut de mest lovende flybårne Mag og EM anomaliene. Prøvene ble samlet med 100m avstand i profiler som ble lagt med 500m avstand. Prøvene ble tatt på ca 70cm dyp. Totalt ble ca 7000 prøver samlet.

Hver 5 av disse prøvene ble analysert slik at man fikk et 500m x 500m nett med prøver som ble spektrografisk analysert på 18 elementer (Si, Al, Fe, Mg, Ca, Na, K, Ti, V, Cr, Co, Ni, Cu, Zn, Ag, Mo) ved den finske geologiske undersøkelsen i Helsinki.

Factor analyse ble utført av Tuomo Alipetti ved Universitetet i Oulo som en del av egen forskning.

Rapporten er en kritisk gjennomgang av dette arbeidet hvor det hevdes at metoden med "four factor scores" som er plottet på kartene trekker ut faktorer som er relatert til prøvetype og berggrunn i stedet for til mineraliseringer.
Faktor I: Prøvetype, for det meste jordlagstype.
Faktor II: Basiske bergarter.
Faktor III: Albitiseringsprosesser.
Faktor IV: Al innhold. Leirinnhold i morene (prøvetype) eller glimmerskifer i grunnen.

A/S SULFIDMALM

INTER-OFFICE MEMORANDUM

Date: 16th February, 1977

To: W. D. Harrison

cc: H. T. Berry, R. Jahnsen, T. Alapieti, I. Elliot, E. Kreivi, R. B. Band

From: J. B. Gammon

Subject:

Report No. 415/76/17. Masi till data.

Please find attached Bands erudite (lærde!) commentary on the finnish output of a computer-run factor analysis of spectrographic data from Masi till samples.

I think I am correct in concluding that the procedure applied has not been particularly succesful in classifying samples anomalous for copper in terms of possible sources. Band comments that it would have been more interesting to run all samples for more than 5 factors. Perhaps Oulu University would be interested in pursuing this as a research project?

J. B. Gammon

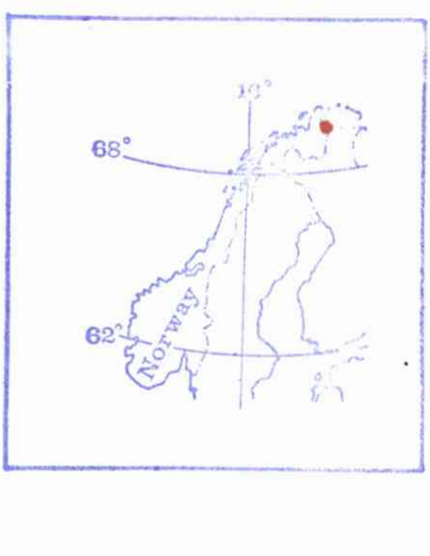
FOR FALCONBRIDGE NIKKELVERK A/S
A/S SULFIDMALM

Project 905-17

EVALUATION OF FACTOR ANALYSIS RESULTS
MASI

By

R. B. Band



Report no. 415/76/17

EVALUATION OF FACTOR ANALYSIS RESULTS, MASI

1. DATA BASE:

In 1974 a reconnaissance till sampling programme was carried out in the Masi area as an aid in evaluating airborne- Mag-EM data and as one phase of a systematic prospecting programme. Till samples were collected from an average depth of 70 cms, at intervals of 100 m, along lines spaced 500 m apart. A total of ca. 7000 samples were collected in this way.

At a later stage every fith sample was analysed spectrographically for a total of 18 elements (Si, Al, Fe, Mg, Ca, Na, K, Ti V, Cr, Co, Ni, Cu, Zn, Ag, Mo), giving a new 500m x 500m sample net. Samples were analysed by direct reading spectrograph at Finnish Geological Survey, Helsinki.

2. FACTOR ANALYSIS METHOD:

Factor analysis was carried out by Tuomo Alipetti at the University of Oulu. Alipetti requested permission to use the data, but carried out the computer work at the University's expense and himself decided the methodology to be followed.

The spectrographic data was available on magnetic tape, as output from the direct reading spectrograph. The first step in processing was to convert values quoted as metal oxides to percent or ppm metal values. This data was then listed. The second step was to calculate mean and standard deviation figures. I am not sure whether he used a log transform for any or all of the metals.

The data was also screened for values lying outside "acceptable ranges" (presumably negative values, and arbitrary limits) and these were then replaced by the relevant mean value(Mo was particularly effected by this). Having assembled a complete and acceptable data set (1210 samples) he set up a correlation matrix for <u>all</u> samples.

The first run at the factor analysis programme was based on selecting out samples with > 135 ppm Cu only. For some reason this programme did not work. The second attempt was made using all values > 100 ppm Cu, which also corresponds to exactly the upper ten percent of the copper values (121 samples).

A first-run was made using splits into 3-factor, 4-factor, 5-factor and 6-factor models, using the Varimax solution. He then selected the 4-factor model and re-ran the programme calculating factor scores for the 121 samples.

In essence therefore the factor analysis has taken samples with <u>anomalous</u> copper values (> 100 ppm) and attempted to classify them into various groups, based on spectrographic 18 element data.

3. FACTOR MODELS:

It might be interesting first to compare the development of the various factor models as the programme tries to account for the variation of the data in terms of a progressively smaller number of groups (see table 1). The following can intuitively be said:

<u>Factor 1</u> appears in this run <u>consistently as a basic rock indicator</u>.

Factor 2 is heavily influenced by a non-sympathetic variation in Fe and Si contents. Note change in sense of this factor between 5- and 6-factor model and the 4- and 3-factor models.

Factor 3 is always influenced by Na K Ti; V and Pb come in as the number of factors is reduced.

Factor 4 is not as consistent as the other factors, but Al is significant in it.

Factor 5 is a Ca Mo factor - surprisingly Cr drops out when the number of factors is reduced.

(NB. Usually for an 18 variable data set one would expect to run more factors than this, often as many factors as variables, and then dropping down until a grouping is forced on the variables).

4. THE FOUR FACTOR MODEL:

The four factor model was selected to calculate factor scores. In the re-run interestingly there was a reversal of the importance of factors I and II, i.e. in the re-run factors were as follows:

Factor I	+ Si (Ca, Mg, Na) - ve Fe (Pb, Cu)
Factor II	Ni, Co, Mn, Mg, Cr, Cu
Factor III	Na, K, Ti, Mg, Ca, V
Factor IV	Al, Ag (negative factor loadings)

This may indicate that factors 1 and 2 are of roughly equal importance in accounting for the variability in the 121 samples processed.

Factor scores for this model have been plotted up on the Masi reconnaissance base map.

5. SIGNIFICANCE OF FACTORS:

To assess the significance of the various factors 14 samples having either high or low scores for the factors (i.e."Factor series end-members") were compared. Table 2 shows data and factor scores for the various end members. Unfortunately the samples are not clear-cut end members for one factor only, e.g. samples 1241 and 5791 are high for both Factors 1 and 2; sample 5556 is a low end-member for factor 1 and a high end member for factor 2. Because of this it is not possible to isolate and identify end members of the various factor series with complete confidence.

Table 3 summarizes the information from Table 2, giving the ranges of the various elements making up each factor, which are present in low and high end-members of the factor series.

For Factor I high scores have 25-30% Si and only 2-11% Fe. Low scores have 13-17% Si and 28-32% Fe, they also have ca. twice the Mn content of silica rich samples. Interesting samples with medium scores for factor I have 23-26% Si and 6-18% Fe, i.e. Si-content is similar for medium and high factor I samples, and it appears that variations in Fe-content are more significant in determining the actual factor score (NB. Fe has a negative loading for factor I).

For Factor II the determining factor is clearly high Ni (300-800 ppm), Co (35-130 ppm) and Cr (300-2000 ppm) values. Mn and Mg are also significantly higher.

For Factor III high factor score samples show Na, K, Mg and Ca values which are 10-fold higher than values in low-score samples. Ti and V values are ca. double in high-score samples compared with low.

Despite the factor loading picture Factor IV is entirely an Al-factor. Low factor score samples show double the Al content of High-score samples (ca. 20% vs ca. 10%). Silver on the other hand shows a minimal increase, taking into account analytical error i.e. 0.9-1.0 ppm Ag for low score samples vs 0.7 ppm Ag for high (NB. both Al and Ag have negative loadings on factor IV).

5. INTERPRETATION OF FACTORS:

Because of the way the factor analysis was set-up, taking only samples with > 100 ppm Cu, the samples are widely and almost randomly scattered over the Masi reconnaissance grid. This makes it difficult to interpret the significance of the factors, since they are generally too widespread for any geographical grouping to come through. Based on the element-make-up of the factors I would suggest the following interpretation.

Factor I:

Si is relatively constant in most samples (ca. 25%) and it is variation in Fe which is the determining factor in factor score values. In the low-score end-member excessively high Fe content (ca. 30% Fe) would naturally dilute the Si content down to lower levels (ca. 15% Si).

A plausible interpretation of this is that Factor I is reflecting sampling depth, or more precisely the location within the soil profile from which individual till samples were collected. Till samples are nominally collected from a constant depth, 70 cms, which should ensure sampling from the C horizon. In practise however samples are certainly collected from varying depths, and it is most probable that soil profile development and the depth of the different soil horizons will vary from location to location. This is not to imply criticism of the sampling technique, since a) it is recognized as compromise between the needs for rapid sampling and a constant sampling material and b) the Fe-enrichment process in the lower B or B/C soil horizons can progress quite far before it is obvious on the basis of colour change.

The Fe-rich, Si-poor end member of this factor-grouping may well represent gossanous soils, as for instance are developed at Ingajokka.

Factor II:

is the classic "basic bedrock factor", characterized by high Ni, Co, Mg, Cr, Mn values. Low scores could indicate acid bedrock, but more probably an excess of some other factor.

Factor III:

Based on the element association in this factor it could represent an albitised (Na, K, Ca) basic bedrock (Mg, Ti, V) factor.

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This is to some extent backed up by the fact that scores for Factors II and III often seem to follow each other, to a certain extent. Certainly there is field evidence for extensive albitisation of the basic volcanics in the Masi area.

Factor IV:

As already mentioned this is really only reflecting variations in Al content. It could in this case be reflecting variations in clay content of the till sample, either as a reflection of bedrock composition (mica schists?) or resulting from glacial or post-glacial processes (fluvial-sorting).

6. SUCCESS OF FACTOR MODELS:

The success of the factor Model accounting for the variation in metal contents in the sample/variable mass is expressed in the programme output by the table of communalities. This indicates for each element the proportion of the total variability accounted for by the factors used.

Most of the variation in the data is explained by the four-factor model for the following elements:
Si, Al, Fe, Mg, Na, Ni, Ag, Pb.

A "moderate" portion of the variation is explained for: Ca, K, Ti, Cr, Cu.

Very little of the variation is explained for: V, Mn, Zn, Mo.

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7. APPLICATION OF FACTOR SCORE FIGURES:

As already pointed out the pre-selection of samples with > 100 ppm Cu for the factor analysis run gives a very irregular and widely-spaced grid (on average 1 sample per 2.5 m^2). Because of this irregular spacing and also because of the special nature of the samples, the factor score results can not be used to map the distribution of bedrock types or surficial deposits, as may have been possible had all the data been included.

Since only samples with "anomalous" copper values were included in the test, it should be possible to use the factor scores to classify the copper anomalies, and possibly to say something about their origin. For example a copper anomaly with a low score on factor I should be in a gossan area, and may be related to massive pyrrhotite horizons, as for example at Ingajokka (score of ca. 200 on Factor I for 1 sample from Ingajokka). Similarly a high score on Factor II would indicate association with basic bedrock (eg. east shore of Suolojavrre and Salggan East Grid) and a high score on factor III association with albitised bedrock.

This is true for "end-member samples" but high proportion of samples seem, on scanning through the factor scores, to fall in the "middle ground", with medium values on all factors, indicating of course a contribution from multiple sources, as would be expected in till samples.

A further draw-back is that only a "moderate" proportion of the total copper variation has been accounted for by the four factors used in this investigation (see section 6).

The part not-accounted for is the "odd ball" part that could well represent a mineralization source. This is the advantage of running with more factors, because then a much higher proportion of the total variation is accounted for and there is a chance of obtaining a "mineralization factor". In the present investigation the factors used have explained "most" of the variation in the major elements. They are therefore "bedrock" and soil/till type parameters and it is possible that this "major element" variation has swamped the minor variations due to mineralization, sample environment etc.

8. CONCLUSIONS:

1) The 4-factor model factor analysis seems to have pulled out factors which are related to sample type and bedrock geology rather than to mineralization types as such.

2) The factors are interpreted as representing

<u>Factor I</u>: sample type, particularly soil horizon sampled. Very low score probably represents gossan and therefore possibly proximity to massive sulphide formations.

<u>Factor II:</u> basic bedrock

<u>Factor III</u>: Albitisation processes

<u>Factor IV</u>: Al content. Low values indicate high clay content in till (sample type) or possibly mica schist bedrock.

3) A similar run including all samples might be a useful supplement in mapping the distribution of basic and albitised bedrock areas.

4) Factor scores could be used to classify some of the anomalous copper samples as to probable bedrock association. A high proportion of the samples will be "multiple source" however and not readily classifiable.

5) The 4-factor model does not account for all of the variation in Cu content in the samples. This "unexplained" variation could well be the most significant.

Table 2: METAL VALUES FOR FACTOR-SCORE END MEMBERS, WITH FACTOR SCORES, MASI TILL DATA, RUN 2.

Sample No.	I	II	III	IV	Si	Al	Fe	Mg	Ca	Na	K	T	V	Cr	Mn	Co	Ni	Cu	Zn	Pb	Ag	Mo
3306	272	486	355	607	14.6	10.8	32.0	.5	.8	.1	.2	1970	7	155	2080	10	109	114	20	37	.7	-
6439	234	481	414	558	17	11.3	28	.8	.08	.2	.2	2510	375	186	1840	24	35	594	12	43	.8	11
1241	632	1149	440	416	26.5	7.9	11.6	6.1	.78	.24	.18	4500	188	2000	2900	47	771	197	115	27	1	.4
4216	689	456	392	463	32	10.8	1.9	1.6	2.7	1.2	.3	3800	126	569	421	13	51	120	38	16	1	14
5791	654	710	410	458	28.6	11.3	4.6	3.3	2.7	.7	.4	3540	195	669	995	34	324	185	8	21	.9	14
5556	204	1008	429	397	13.4	6.6	10.7	.2	.8	.7	.06	1970	260	290	2000	129	522	1130	17	64	.7	21
5001	428	405	400	574	24.7	9.4	18.0	1.0	.3	.7	.5	2870	720	272	385	6	39	152	0	25	.7	3
1196	367	406	601	297	22.7	16	10	1	1.5	1.5	.3	14700	700	208	651	19	33	113	10	29	1	15
3501	454	518	776	525	25.6	8.7	7.4	2.9	2.7	5.3	2.0	7700	435	622	1140	29	108	113	29	38	1	27
7571	553	417	291	96	23.7	24.5	1.0	.4	.4	.2	.1	2850	58	450	234	10	27	140	-	11	1	1
7831	537	454	301	471	25.5	13.8	11.6	.8	.6	.3	.05	2520	153	190	1700	30	41	110	-	20	.8	-
3406	483	530	744	503	26	9.9	6.6	2.9	2.3	5.1	1.0	8000	394	735	1280	33	104	112	15	43	1	22
7576	560	379	251	268	26	20.6	3.6	.2	.2	.1	0	1070	-	128	37	6	16	112	0	11	.9	2
3076	519	532	716	570	28	7.9	8.3	2.1	3.8	3.5	.2	6090	441	914	1430	25	45	136	44	22	.7	-

Table 1. PROGRESSIVE MODIFICATION TO FACTOR MAKE-UP WITH DECREASING NUMBER OF FACTORS MASI DATA, RUN I.

	I	II	III	IV	V	VI
SIX FACTORS	Co Ni Cu Mg Mn	+Fe (V) Pb Sn -ve Si	Na K Ti	+Fe -ve Al Ag	Mo Cr	Ti V
FIVE FACTORS	Co Ni Cu Mg Mn	tve -m Fe Si V (Ca) Pb(Na) Sn(Cr)	Na K Ti V	-ve Al Ag	Ca Mo	-
FOUR FACTORS	Mn Co Ni Cu Fe Mg	+vd -m Si Fe Na	Na K Ti V	Ag (Mo Sn)		
THREE FACTORS	Fe tve Mn Co Ni Cu (Mg) Al -ve (Ag)	+ve -ve Si Fe Na Al (Ca)Sn (Cr)	Na K Ti V Pb (Sn)			

Table 3: ELEMENT RANGES FOR FACTOR END MEMBERS, MASI DATA, RUN 2

FACTOR 1: Elements involved

Si (Ca, Mg, Na)
Fe negative, (Pb, Cu)

	Si	Ca	Mg	Na	Fe Fe
High Scores show:	25-30%	0.8-3.0%	2-3%	.2-1.2%	2-11%
(NB. 1 sample w. 6% Mg also has very high score in Factor 2)					
Low scores show:	13-17%	.1-.8%	.2-.8%	.1-.7%	28-32%
(low scores also have ca. 2 times Mn content of high scores)					
Med. scores show:	23-26%	.3-2.7%	1-2.9%		6-18%

FACTOR 2: Elements involved

Ni, Co, Mn, Mg, Cr, Cu

	Ni	Co	Mn	Mg	Cr	Cu
High Scores:	300-800	35-130	1000-3000	.2-6.1	300-2000	200-1130
Low scores:	20-40	6-20	40-700	.2-1.0	130-450	

FACTOR 3: Elements involved

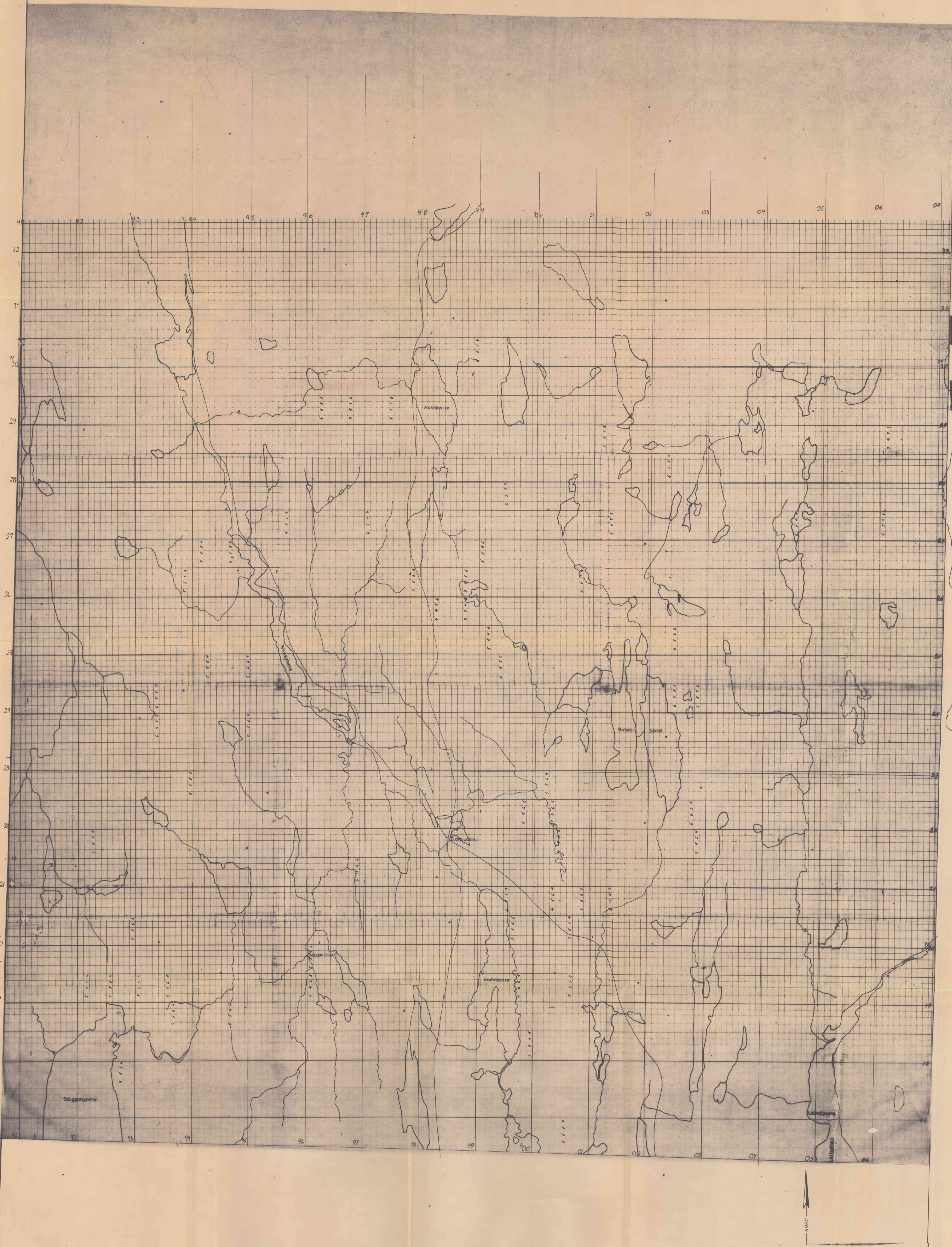
Na, K, Ti, Mg, Ca, V

	Na	K	Ti	Mg	Ca	V
High scores:	3.5-5.3	.2-2.0	6000-8000	2.1-2.9	2.3-3.7	400
Low scores:	.2-.3	.1	1000-3000	.2-.8	.2-.6	50-150

FACTOR 4: Elements involved

Al, Ag

	Al	Ag
High scores:	7.9-10.8	.7 ppm
Low scores:	16-25%	.9-1.0



MASI 17	SCALE 1 20000	OBS. DRAW. TRAC. CHK.	
A/S SULFIDMALM	MAP NO.		
	MAP SHEET 1834 II 1934 III		


Salggonjavrre
Ruoddojavrre
Suolojavrre
Sodnajavrre
Salvvajavrre
Masijokka
Masi
MASI 17
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A/S SULFIDMALM
MAP NO.
MAP SHEET