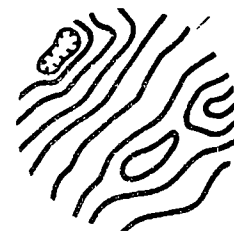


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914 Industrial Avenue
Palo Alto, California 94303

Telephone: (415) 321-7610
Cable: "GEOMETRICS, Palo Alto

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Remote Sensing and
Interpretation

COMPUTER ANALYSIS OF GEOCHEMICAL DATA FROM KENO HILL AREA YUKON TERRITORY, CANADA

D. P. O'Brien*, R. O. Prindle** & J. S. Burns***

Introduction

This report discusses computer techniques applied to geochemical data that has been published by the Geological Survey of Canada (G.S.C.) in Bulletin III, entitled Geology, Geochemistry & Origin of the Lead, Zinc, Silver Deposits of the Keno Hill-Galena Hill Area, Yukon Territory, in 1965 by R. W. Boyle.

This presentation is not intended as a definitive study of this very complex area, but rather as an illustration of the uses of computer analysis and graphical display in the treatment of geochemical data.

Our first objective was to take a small portion of the area, approximately 16 miles by 20 miles, that contained about 2000 analyzed stream samples and produce a computer/machine contoured map of lead and zinc concentrations. By shading these maps at the threshold and again at the anomalous levels, it enables them to be used both qualitatively and quantitatively in geological interpretation. We will have a look at these shortly.

The second objective was to digitize five other elements all having the same locations as the two just mentioned and place all of these on punched cards. Once these data were in this format, it was then easy to perform multivariate statistical analysis utilizing a digital computer. In this multivariate study, we performed a factor analysis on the geochemical variables. Factor analysis, a technique developed primarily for the field of psychology, has of late, begun to be

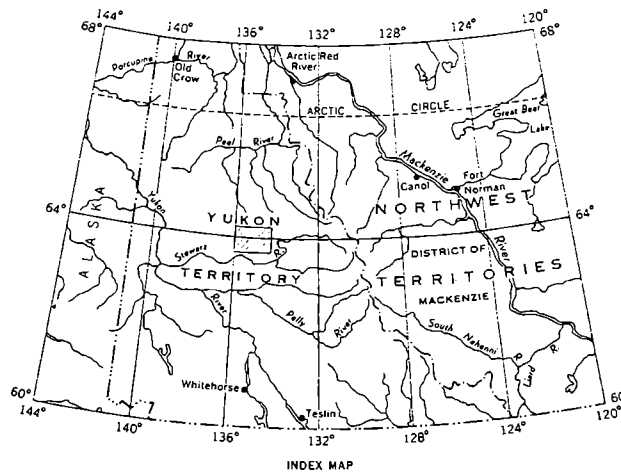
GeoMetrics, Palo Alto, California
GeoMetrics, Palo Alto, California - Presented at the 76th Annual
Convention of the Northwest Mining Association, Spokane, Wash.,
December 4-5, 1970.
Abacus Geographics, Ltd., Vancouver, Canada

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employed in analysis of the large amounts of data, typically generated in a geochemical investigation. Factor analysis is concerned with deciding how many underlying processes or factors are operating on a geological region to produce the variations in concentrations of different elements observed in the survey.

Location and Geology

We will now go to the first slide that shows the general location of the Keno-Galena Hill area in the pink square, located in the Yukon Territory, approximately 220 miles north of Whitehorse.



The second slide shows the geologic map published by the G.S.C. The study area related to this paper is located in the upper left hand corner of the map. The significant locations in the area of interest are Mt. Halvdane in the lower left, Dublin Gulch and the Potato Hills in the center of the area. The geological and structural description from Bulletin III is extracted as follows:

1. Slates, phyllites, graphitic sericitic schists, quartz-mica schists, thick and thin bedded schistose quartzites, with interbedded calcareous units, comprise approximately 80% of the terrain. These metamorphic rocks called the Yukon Group are Precambrian and/or Lower Paleozoic in age.

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2. During Mesozoic time, these rocks were intruded by gabbroic and "diabasic" sills which were subsequently converted to "greenstone lithologies" similar to those which crop out north of Galena Hill.
3. Granitic stocks and small plugs of probable Cretaceous age, intruded this sequence of rocks and crop out in the central portion of the area of interest. These rocks are numbered #10 on the map.
4. Skarn and hornfels lithologies occur within the thermal imprint zone of the intrusive bodies. Also a number of quartz-feldspar porphyry sills and dikes are exposed in the southern portion of the area.
5. Two principal systems of faults occur in the district-- a northeast striking system and a north-northeast to north-west trending series. Two types of faults occur in the area; those that contain veins and lodes of economic minerals are designated by the term vein faults, and those that contain only small amounts of economic minerals are called cross faults, bedding faults, etc.
6. The most favorable host rocks for the formation of epigenetic metal deposits are thick-bedded quartzites and greenstones. The economic lodes are located at a) the junction of two or more vein faults, b) in contact zones where quartzites or greenstones grade into schists, and c) in fault veins existing in thick-bedded quartzites between schist units.

Stream Sampling & Topography

The next slide is of the same general area and is a photo of the sample locations and the zinc concentrations at these locations in the many stream channels where they were collected. It should be noted that samples were collected every 1500 feet along the stream channels and indicate extensive coverage in the area of interest. Mineral occurrences and deposit locations are designated by red letters and as you will notice, it is very difficult to interpret the concentrations in the Dublin Gulch area because of these many symbols. This map and six other elements maps like it were digitized by John Burns of Abacus Graphics Ltd., Vancouver

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Zinc Contour Map

The next slide (slide 4) is a machine contoured variable density map of the same area produced by GeoMetrics (see GeoMetrics Data Services brochure). It is a contour map of the concentration of zinc values from stream samples. On this map the values represent the logarithm (x100) of the values of zinc in PPM. However, on future maps these values will be directly in PPM. Observe the semi-circular feature near Dublin Gulch, and fan-shaped dispersion pattern north of Mt. Halldane. We shall refer to these features later.

The selection of the shaded areas on the contour map was based upon the following criterion. The cumulative distribution curve for zinc (slide 5) (parts per million versus cumulative percentage) exhibited discontinuities in slope at certain concentration levels. These levels served as the transition contours between shaded portions of the map. The darkest levels (1000 PPM or greater) indicate the very few high concentration areas, while light grey areas (300-1000 PPM) serve to delineate the threshold level and the white areas are 100 PPM or less.

If this map is overlain on the geological map, it is seen that the northeast trending light grey area roughly follows the semi-circular pattern of the contact zone of the granite intrusives, although it might not be directly related to them. The areas of greatest concentrations of zinc are in the NE vein faults occurring in terrain composed of pyrite-rich slates, phyllites and schists. Some of these high concentrations are, of course, due to contamination and/or located near known lead and zinc outcrops. However, the map shown has a very diffuse and spread-out appearance for those values above threshold. This, we feel, is indicative of the high mobility of zinc in an acidic regional environment. Indeed, some of the zinc anomalies may have been displaced many hundreds of feet downstream.

This migratory tendency is quite pronounced north of Mt. Halldane, where the anomaly pattern is a broad, fan-like feature extending into the McQuesten River valley. A broad, northwest trending anomalous area north of Eagle Ridge is, as yet, unexplained in terms of the geology of that area. The broad, dispersed features of this map are in striking contrast to the next slide which displays the anomaly pattern of lead.

Lead Contour Map

The lead contour map (slide 6) was produced in the same manner as the zinc map. Notice that the shaded areas are not as extensive as they were for zinc.

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Electrostatic Plotter

The next slide (slide 7) shows the plotter we used in making these maps. The electrostatic plotter pictured in this slide operates on a principal similar to that of Xerography and was controlled off-line by plotting commands generated on a digital magnetic tape. These plotting commands produce an electrostatic charge on a dielectrically coated paper running continuously under a series of 1024 electrostatic styli. This paper then passes through a fluid which deposits particles at the point of electrical charge, thus producing a pattern on the paper. This pattern may be controlled by the computer so as to produce the level shaded contour map as shown. Maps such as these can be run off the plotter in about 3 minutes which incidentally, is about 5 to 10 times faster than other machine plotters.

Factor Analysis

Slides 8 and 9 show selected computer output from a factor analysis of seven variables utilizing a modified R-mode approach. These are lead (Pb), zinc (Zn), copper (Cu), cobalt (Co), manganese (Mn), arsenic (As), boron (B) and, in addition, the ratios Pb:Zn, Cu:Zn, Mn:Zn, As:Zn were selected for analysis. The following steps were performed: Table I entitled, Correlation Matrix displays the computed degree of correlation (or lack of it) between these variables. Table II entitled, Factor Matrix, is computed next for the 11 variables. At this stage, 11 factors are assumed. Note, however, that the last 4 of the factors have all zero entries. This is due to the linear dependence of the log of the ratios to the log of the elements. From this matrix, it is seen that B and Co are associated with factors 6 and 7, respectively, and are both only slightly associated with the other factors. Table III entitled, Rotated Factor Matrix, has now reduced the number of factors to 5 (this was determined by removing statistically non-significant factors). Note that Co is now "shifted" to factor 2 in the rotated factor matrix (along with Mn), while B is more or less uniformly distributed over all the factors or does not correlate well with any of these particular elements. Unfortunately, tin (Sb) was not analyzed. If it had been, it would have probably shown a high correlation in the Dublin Gulch area where known placer cassiterite deposits are located. The association between Mn and Co will be discussed later. Table IV entitled, Factor Scores, helps determine the effect of a particular factor at that sample location. We multiply each measurement by a "weight" or "score" appropriate for that factor, and sum over all the variables. The result is a number which is proportional to the "strength" of the factor at that location. The weights needed for this analysis are tabulated in this table. Strictly speaking, the series of steps outlined in these slides are referred to as "Analysis of Principal Components", a sub-category of "Factor Analysis".

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To return to our discussion of factor 2 and its significance, we note it is associated with Mn and Co. This is a familiar association where co-precipitation of a dissolved metal such as Co with hydrous Mn Oxides takes place under an oxidization environment that has a high Eh value. Thus, we call the factor operative in factor 2, an oxidization factor. If we form the product of the factor 2 (or oxidation) weights with each variable, and sum these products, we have a number which is proportional to the Eh, or oxidization potential of that sample locale.

Some of the other factors present have been previously discussed. Thus, factor 1 is associated with lead but has a large negative score for Zn. We interpret this as the inverse of the highly dispersed pattern shown for Zn and this factor points to the geology of the area, since Pb, as we have seen is relatively non-mobile. Similarly, factor 3, a high Zn correlation, is related to precipitation factors for zinc and most importantly, water acidity. Factors 4 and 5 are related to Cu and As, respectively.

In summary then, we postulate the following factor representation of these processes:

<u>Factor</u>	<u>Element</u>	<u>Factor Representation</u>
1	+Pb -Zn	Geological rock units
2	+Mn +Co	Oxidizing - reducing conditions
3	+Zn	Solution
4	+Cu	Indicative of alkaline and neutral pH conditions
5	+As	

We feel, however, that further work could help clarify some of these factors by adding tin, nickel, iron and other elements to the correlation matrix.

The next slide (slide 10) is a contour of factor 2 for the Mt. Halldane area. From the previous discussion, we postulate that the contour enclosing factor score $(F) > 1$ indicates a highly oxidizing area, and that contour enclosing $F < 1$ points to an area of reducing conditions. It is interesting to note that the Pb, Zn (veins) on Mt. Halldane occur in areas of moderate oxidation (i.e., greater than zero and less than 1). The high reducing conditions northeast of the mountain may point to poor water drainage conditions in this area.

Conclusions

In concluding, we feel that:

1. Patterns of dispersion can be made easier and faster when you contour values utilizing variable density for threshold an anomalous levels by computer/machine techniques.

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2. Complex interrelationships such as between Mn and Co can be only recognized quickly on a computer.

These, in turn, can help the mining companies to follow those areas of interest that have the greatest probability first.

LEGEND

CENOZOIC

TERTIARY
Eocene or later

12 *Andesite, trachyte (flow rocks)*

MESOZOIC

CRETACEOUS (?)

11 *Quartz-feldspar porphyry, granite porphyry*

10 *Granodiorite, granite, diorite*

9 *Meta-diorite, meta-gabbro (greenstone)*
(only the larger bodies are shown)

PALAEZOIC

ORDOVICIAN TO SILURIAN

8 *Dolomite, minor limestone*

YUKON GROUP (1-7)

7 *Pebbly quartzite, phyllitic quartzite, slate, phyllite, minor limestone (age uncertain)*

6 *Slate, schist, quartzite, minor limestone*

5 *Quartzite, quartz-mica schist, slate, minor limestone*

4 *Quartz-mica schist, pebbly quartzite, minor limestone, skarn in vicinity of 10*

3 *Quartz-mica schist, graphitic schist, phyllitic quartzite, minor limestone, skarn in vicinity of 10*

2 *Thick-bedded quartzite, thin-bedded quartzite, graphitic schist, minor limestone, skarn in vicinity of 10*

1 *Graphitic schist, thin-bedded quartzite, quartz-mica schist, phyllite, calcareous schist and quartzite*

PRECAMBRIAN AND/OR PALAEZOIC

Drift-covered area

Bedding (horizontal, inclined, vertical)

Bedding inclined (direction of dip known, top of bed unknown)

Schistosity, foliation (inclined, vertical)

Syncline (arrow indicates plunge)

Anticline (arrow indicates plunge)

Anticline and syncline (overturned)

Glacial striae

Late fault (approximate, assumed)

Geology compiled by R. W. Boyle, from published Geological Survey of Canada maps, 890A, 1105A, 43-9, 5-1956, 8-1958, 9-1958 and 15-1962, with additional field surveys by R. W. Boyle

To accompany G. S. C. Bulletin 111, by R. W. Boyle

Geological cartography by the Geological Survey of Canada, 1964

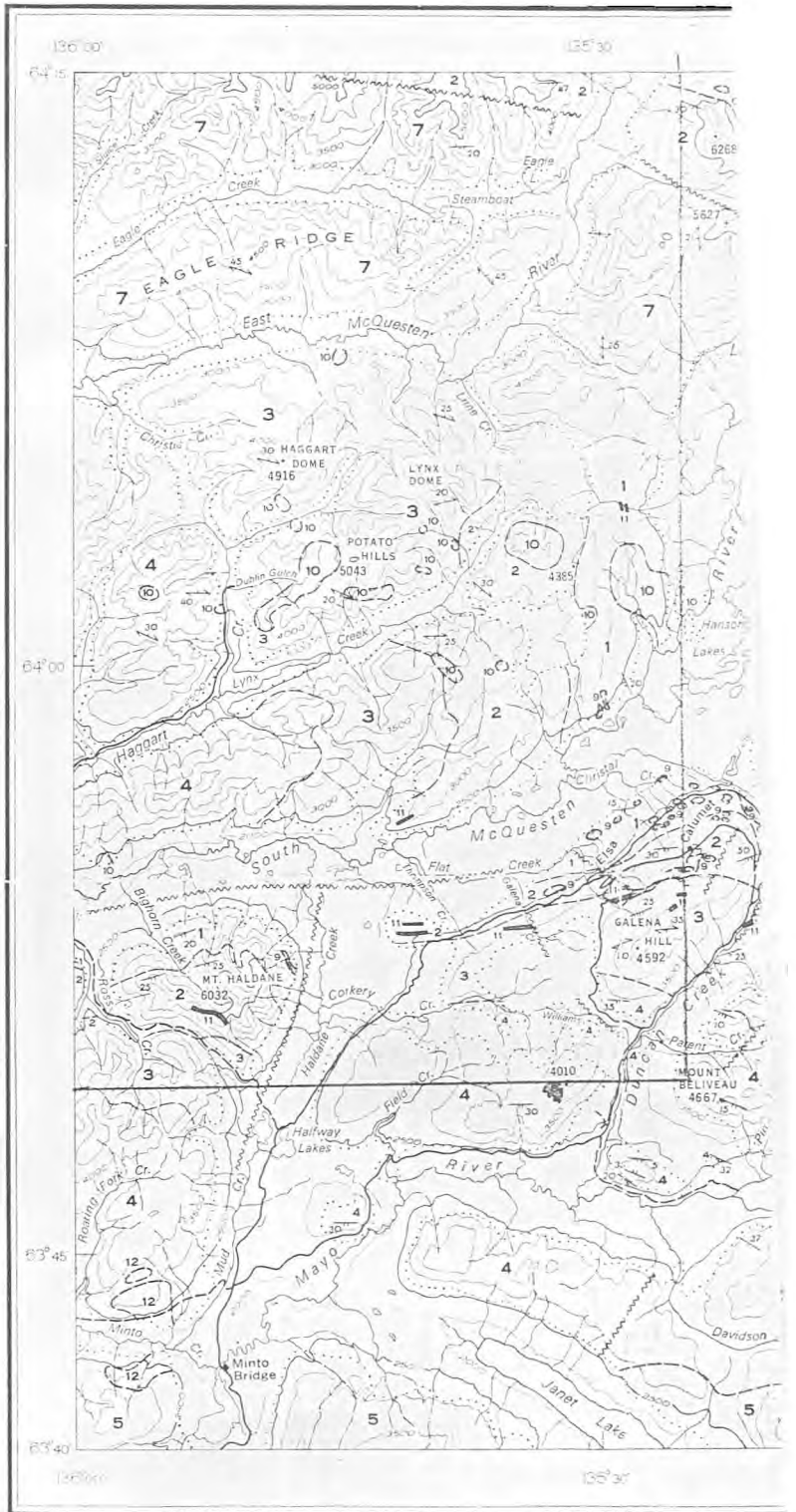
Road, all weather

Other roads

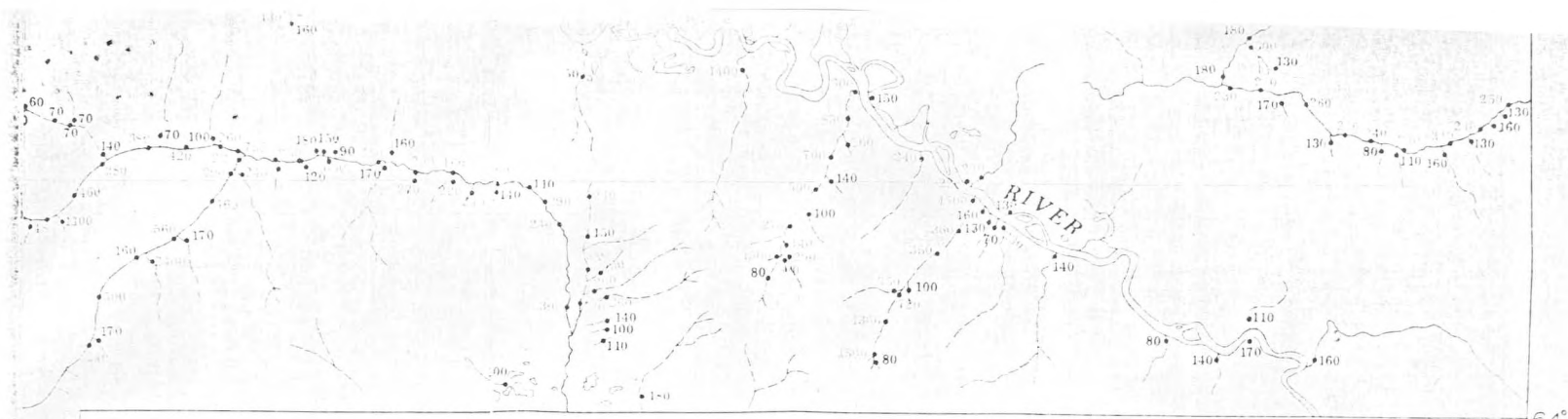
Contours (interval 500 feet)

Height in feet above mean sea-level

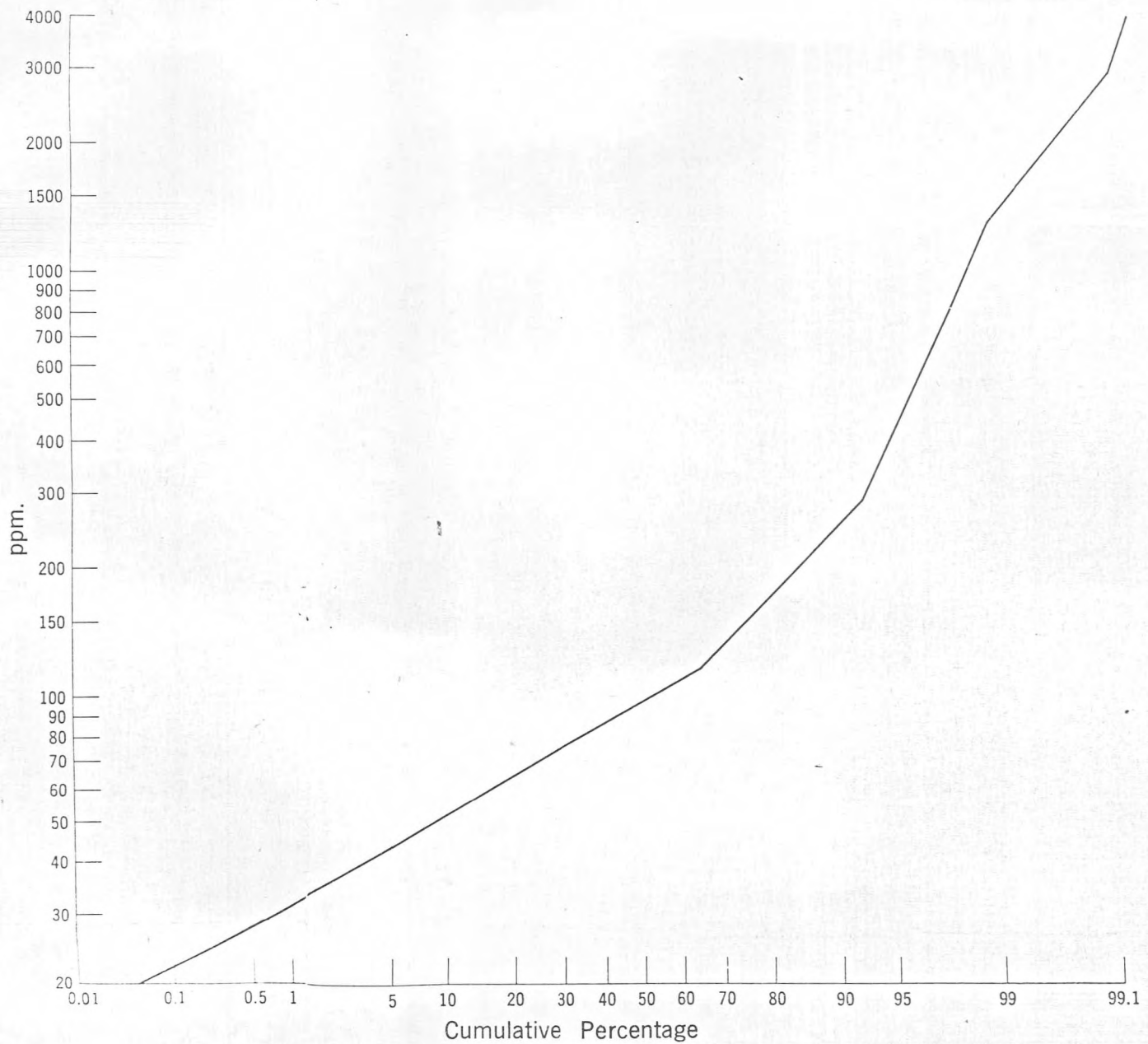
Base-map cartography by the Geological Survey of Canada, from maps published by the Surveys and Mapping Branch and the Army Survey Establishment, R. C. E., with minor revisions by the Geological Survey of Canada



PUBLISHED 1964
COPIES OF THIS MAP MAY BE OBTAINED FROM THE
DIRECTOR, GEOLOGICAL SURVEY OF CANADA, OTTAWA

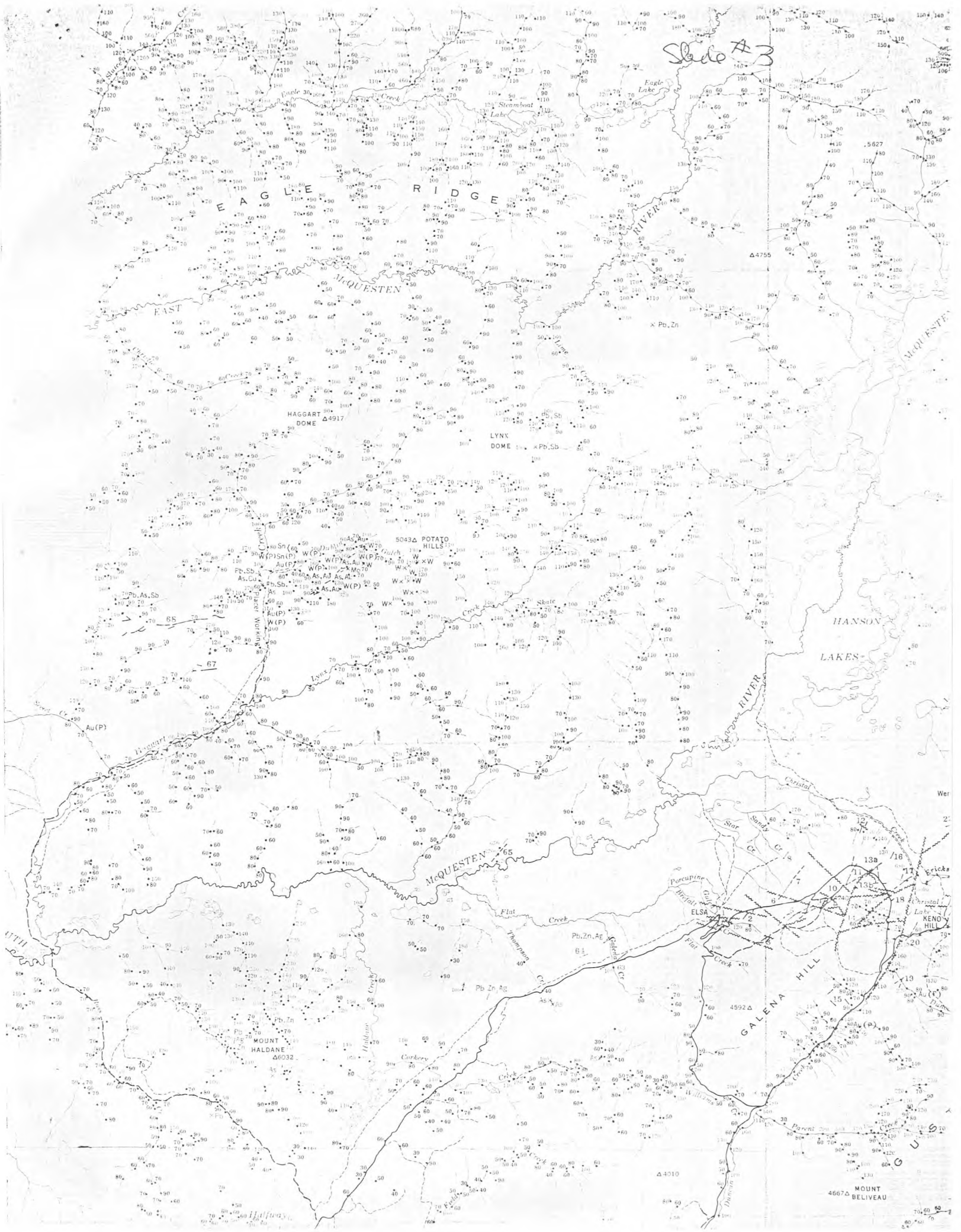


64°



5

Cumulative distribution curve for zinc in stream and spring sediments



CORRELATION MATRIX

PB	ZN	AS	CU	CO	MN	B	PB/ZN	MN/ZN	CU/ZN	AS/ZN
1,000	,252	,295	,098	,196	,040	,186	,828	-,165	-,121	,215
,252	1,000	,291	,452	,233	,347	,240	-,334	-,477	-,419	-,065
,295	,291	1,000	,153	,130	,009	,231	,119	-,225	-,099	,936
,098	,452	,153	1,000	,181	,185	,261	-,166	-,190	,621	-,007
,196	,233	,130	,181	1,000	,336	,251	,056	,128	-,021	,049
,040	,347	,009	,185	,336	1,000	,141	-,162	,658	-,117	-,119
,186	,240	,231	,261	,251	,141	1,000	,042	-,061	,054	,152
,828	-,334	,119	-,166	,056	-,162	,042	1,000	,116	,124	,247
-,165	-,477	-,225	-,190	,128	,658	-,061	,116	1,000	,226	-,059
-,121	-,419	-,099	,621	-,021	-,117	,054	,124	,226	1,000	,051
,215	-,065	,936	-,007	,049	-,119	,152	,247	-,059	,051	1,000

FACTOR MATRIX

,671	-,317	-,201	-,266	-,549	,174	,082	-,001	-,001	-,001	-,001
,530	,691	,358	-,189	-,172	,207	,072	-,000	-,000	,002	,003
,822	-,152	,105	,061	,522	,116	-,006	-,001	,001	,000	-,000
,363	,522	-,174	,678	-,223	,236	,017	,000	,001	-,002	,000
,363	,348	-,396	-,203	-,063	-,280	-,683	-,000	-,000	,000	,000
,072	,595	-,588	-,403	,190	,245	,192	,000	-,000	,001	-,003
,480	,259	-,177	,103	-,053	-,712	,389	-,000	-,000	-,000	-,000
,346	-,709	-,402	-,150	-,435	,050	,038	-,001	,001	,002	,001
-,358	,002	-,838	-,226	,316	,064	,122	-,000	-,000	-,001	,003
-,096	-,076	-,491	,856	-,076	,058	-,046	-,000	-,001	,002	-,000
,662	-,413	-,022	,134	,608	,045	-,032	,001	-,001	-,000	,000

Bo associated alone with factor 6

Co associated alone with factor 7

ROTATED FACTOR MATRIX

.932				
-.071	.108	.257		
.091	.275	.932	-.011	
-.058	.049	.229	-.006	.132
.190	.150	.389	.015	.049
-.126	.601	.299	.876	.961
.153	.939	.019	.115	.025
.148	.296	.301	-.035	.067
-.061	-.034	.289	.302	-.059
.004	.659	.730	-.006	.222
.121	-.069	.423	-.026	.100
	-.050	.105	.898	-.094
			.018	-.019
				.984

Go now associated
with Mm in factor 2

Bo now distributed uniformly
over 5 factors

FACTOR SCORES

.515	.043	.132	-.017	
-.030	.111	.449	-.035	-.079
-.079	.023	.030	-.027	-.042
-.026	.023	.171	.513	.499
.099	.308	.072	.036	-.040
-.070	.505	-.025	-.065	-.006
.061	.133	.117	.156	-.008
.519	-.023	-.132	.004	.068
-.041	.384	-.383	-.033	-.053
.001	-.074	-.220	.553	.026
-.071	-.017	-.134	-.016	-.004
				.535

FACTOR 2

