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DISCOVERY AND EXPLORATION OF ASHNOLA PORPHYRY COPPER DEPOSIT, NEAR KEREMEOS, B.C.: A GEOCHEMICAL CASE HISTORY

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ABSTRACT

The Ashnola copper prospect, a typical porphyry copper deposit, was discovered by regional stream sediment sampling. Subsequent geochemical studies included additional stream sediment sampling, soil sampling of A and B horizons, biogeochemical sampling, and rock sampling. The results of the geochemical studies are compared to geology and geophysical expression of the deposit.

Important results of the study are:

(1) B-horizon Cu and Mo provide a sound basis for a soil geochemical survey in the general area of Ashnola prospect because of close correlation of their sub-populations with geological features including those of economic importance.

(2) A-horizon Zn is more useful than B-horizon Zn but neither appears necessary in this particular case.

(3) Biogeochemical analyses for copper and zinc correlate best with A-horizon soil analyses.

(4) Zinc is concentrated preferentially relative to copper in the vegetation analyzed. The Zn/Cu ratio in A-horizon soils is about 2/1, whereas the ratio in ash of lodgepole pine needles is 10/1.

(5) The method of data analysis utilizing thresholds estimated from partitioned probability plots of all variables aided the interpretation immeasurably and appears a useful general procedure in the routine analysis of geochemical survey data.

INTRODUCTION

This geochemical case history deals with sequential exploration of a porphyry Cu—Mo deposit, the Ashnola prospect, in southern British Columbia. Sampling of stream sediments, soil horizons, vegetation and rock was undertaken over a period of years by several different groups. Consequently, there are some gaps in available data. The history encompasses a period from the discovery of the property in 1966 by a regional stream sediment sampling program up to diamond drilling in 1973.

The Ashnola Cu—Mo prospect is about 30 miles southeast of Princeton, British Columbia, in Osoyoos Mining Division (Fig.1). The area is characterized by rugged terrain with steep-walled glaciated valleys. Local relief is about

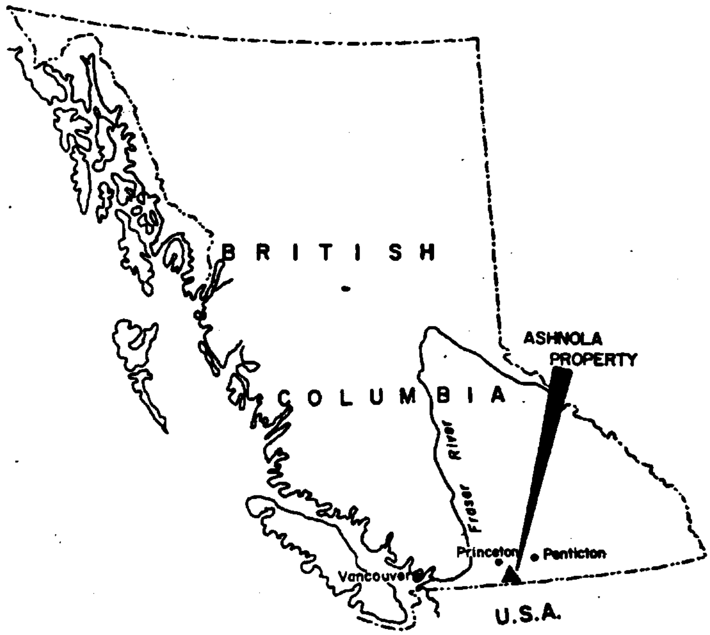

Fig.1. Location map, Ashnola porphyry Cu—Mo prospect.

1500 ft. The region is abundantly forested, particularly in valleys and lower slopes, with lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*) and sparse underbrush.

Soils have formed in three distinct but overlapping environments. On the upper part of the area, glacial deposits are absent and residual soils have developed with little or no transport. On the steep slopes, the parent material is composed of fluvio-glacial deposits and talus characterized by rapid transport which, in some places, has caused two levels of soil development. Apparently, an earlier soil profile has been buried by downward-moving material and the new profile developed above it. Valley bottoms are covered with fluvio-glacial deposits. The upper part of Cat Creek valley resembles a miniature flood plain and an alluvial fan has formed at the mouth of Cat Creek.

General geology of Ashnola prospect is shown in Fig.2. The area is underlain by a series of silicic porphyries and pyroclastic rocks with a small intrusive quartz monzonite boss and associated dykes.

Mineralization which accompanied the intrusion, consists of chalcopyrite, molybdenite and abundant pyrite. It occurs almost entirely in fracture-fillings in rhyolite but disseminated sulphides are common within the quartz monzonite. Leaching of sulphides has taken place in surface rocks to depths of about 100 ft. Oxidation is evident to 300 ft. Supergene minerals, such as chalcocite, cuprite and native copper are present in trace amounts but enrichment is only local and poorly developed.

Alteration is widespread and typical of that found associated with porphyry

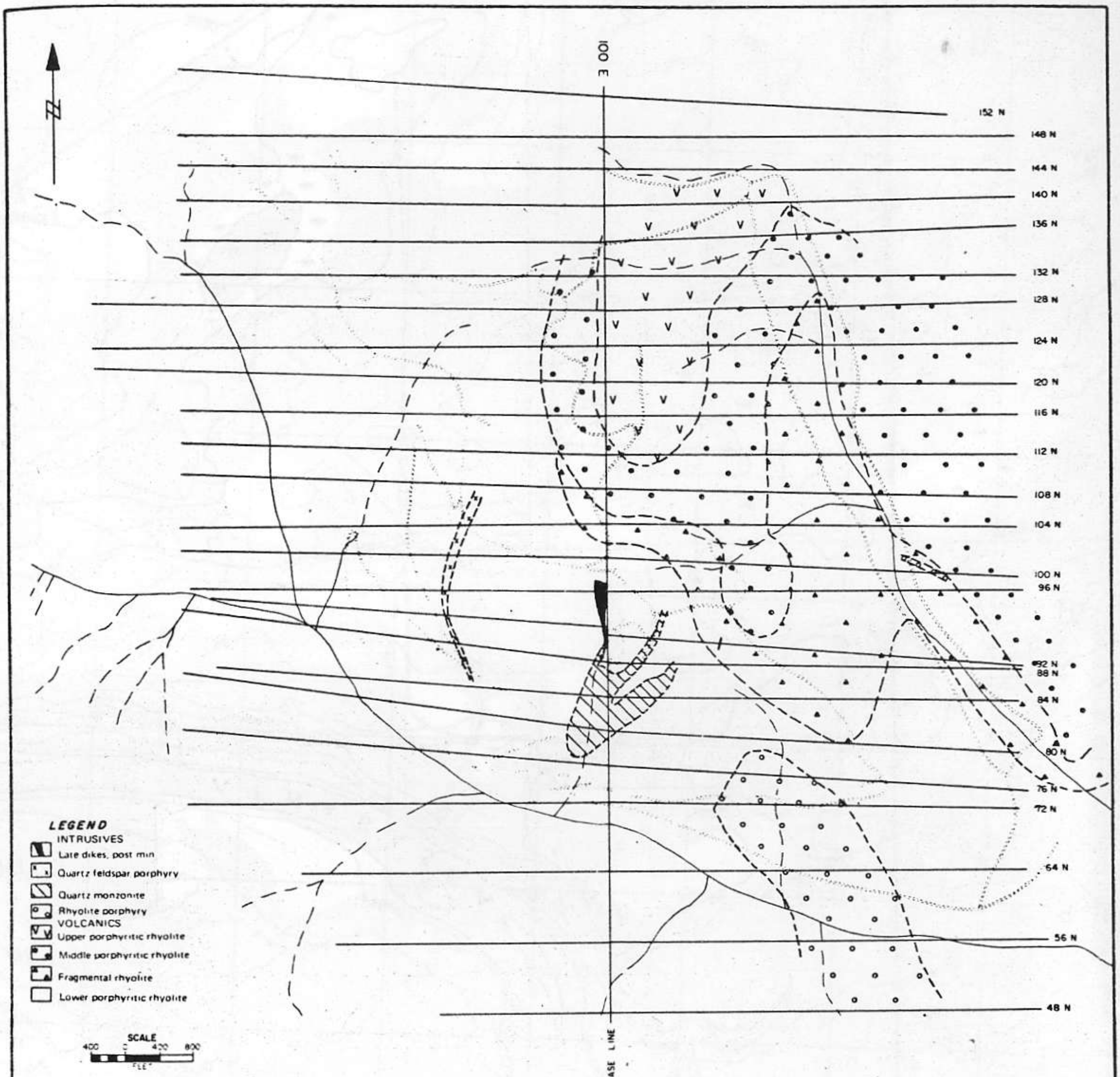

Fig.2. General geology, Ashnola property.

copper deposits. Fig.3 is a composite map showing the relationship between alteration and chargeability as determined by an induced polarization survey. An alteration zone about 1.8 miles in diameter, is characterized by quartz veining with silification and sericitization. Pyrite mineralization accompanies this "phyllic zone" alteration and is distributed in a semi-circle as outlined by anomalous chargeability. A zone of argillic alteration is coincident with part of the quartz sericite alteration as shown in Fig.3. A small zone of potassic alteration (biotite and K-feldspar) is virtually coincident with the quartz diorite boss.

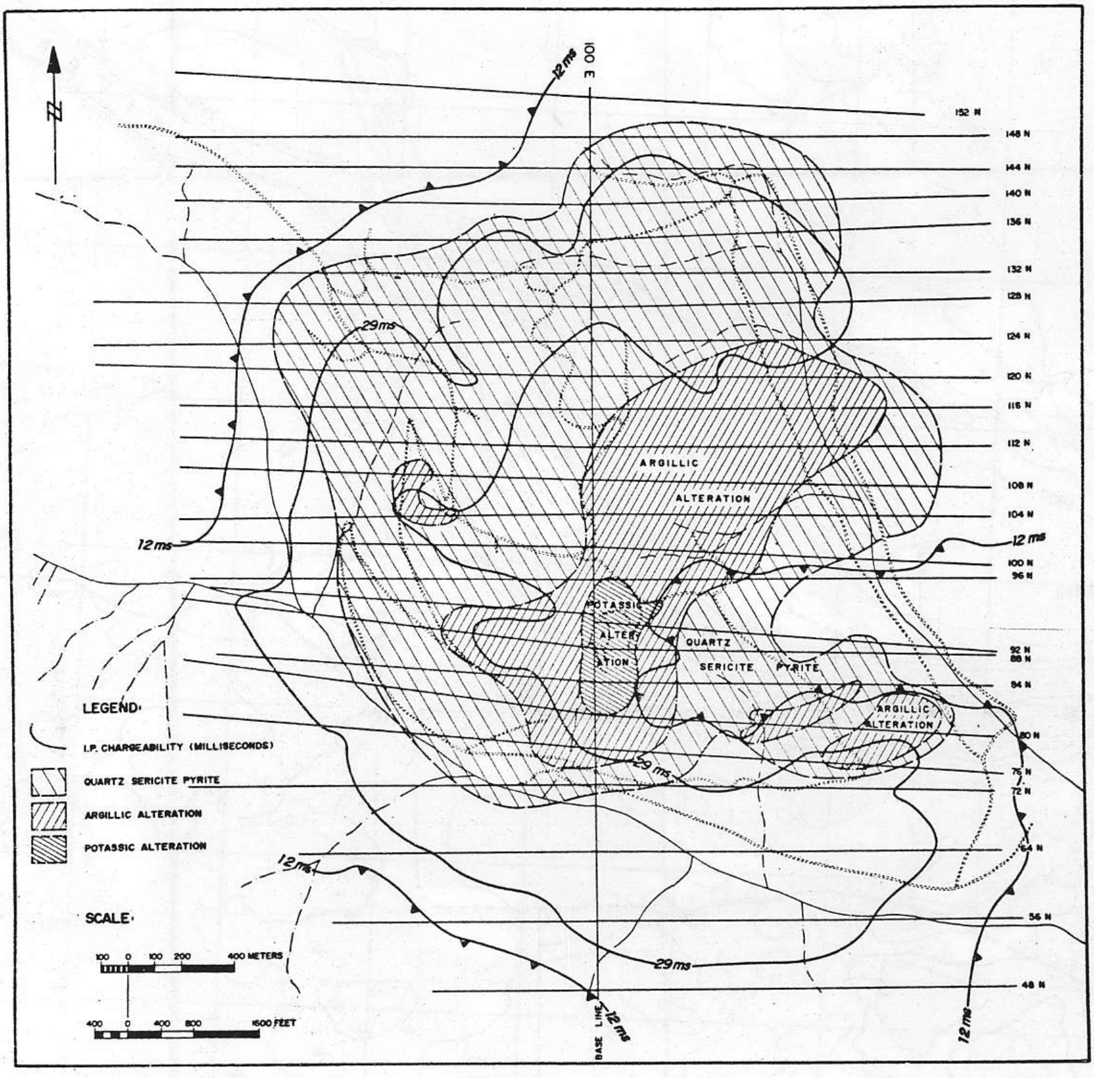

Fig.3. Relationship of alteration to an induced polarization (I.P.) chargeability high that coincides with a zone of abundant pyrite.

In summary, the geology, mineralization and alteration, closely resembles a high-level part of Lowell's porphyry model (Lowell and Guilbert, 1970).

HISTORY

Ashnola prospect was discovered many years ago but was rediscovered independently in 1966 by a regional stream sediment sampling program. Since that time, work on the project has included geological mapping, soil geochemistry, rock geochemistry, biogeochemistry, magnetometer and induced polarization surveys and drilling. In all, forty holes, including rotary, percussion and diamond-drill holes, have been completed. Approximately $300,000 has been expended to date on the deposit.

STREAM SEDIMENT SURVEY

In 1966, a regional stream sediment survey was conducted over parts of southern British Columbia, mainly south of Highway 3 from Princeton to Osoyoos. The only streams significantly anomalous in copper and molybdenum were McBride and Cat Creeks, both easterly flowing tributaries of Ashnola River. Sediment samples from these creeks contained Mo — 12 ppm, Cu — 550 ppm, and Zn — 150 ppm.

The anomalous creeks were sampled in detail with stream sediments taken at intervals of roughly 500 ft, and soil samples taken from several adjoining areas. Fig.4 shows sample locations and anomalous areas for copper in stream sediments. Results for molybdenum were comparable.

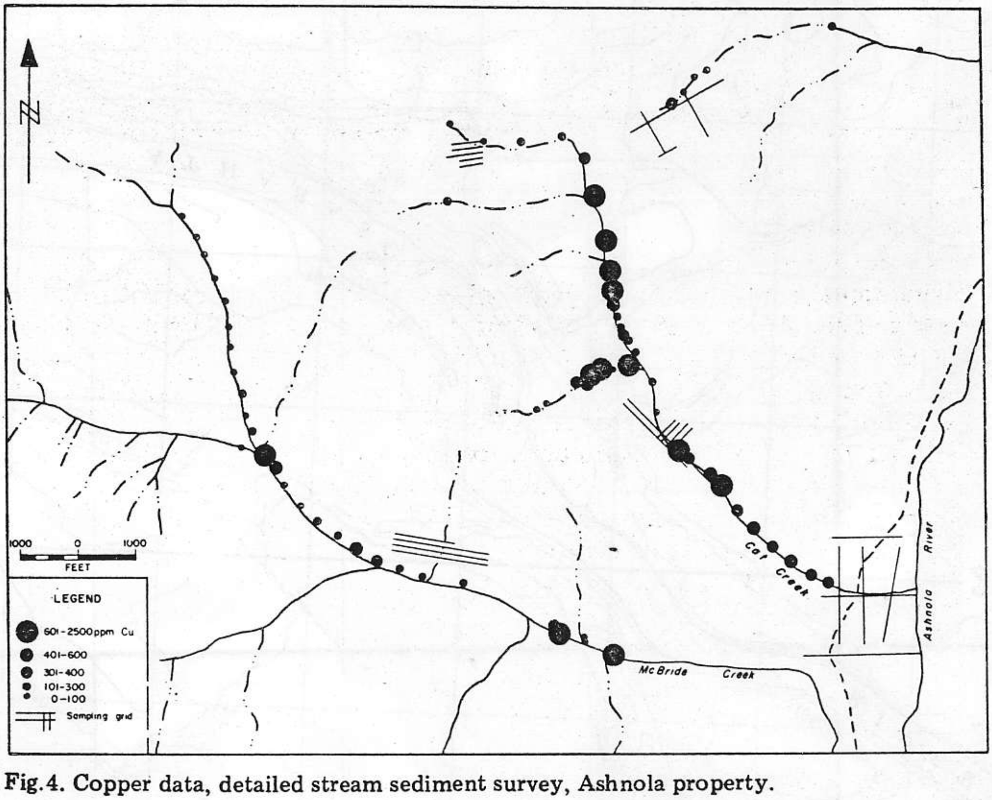

Fig.4. Copper data, detailed stream sediment survey, Ashnola property.

SOIL SURVEY

As a result of detailed stream sediment sampling, several small areas were soil sampled (B horizon). Numerous high values led to a more extensive grid-controlled B-horizon survey in 1966. A number of detailed profile studies show that copper and molybdenum are depleted in the upper few inches to 1 ft and increase in amount at depth by several fold or as much as an order of magnitude. Zinc commonly shows the reverse pattern, being much enriched near surface.

The grid was extended in 1970 and samples from both A and B horizons were analyzed, as were a limited number of biogeochemical samples.

DATA ANALYSIS — DETAILED SOIL SURVEY

Map plots with arbitrary contour intervals were prepared for all geochemical variables to permit intercomparison of patterns and relationships to geology, geophysical data, etc. A more informative procedure based on analysis of probability plots of each variable was also undertaken. In each case polymodal, lognormal models seemed applicable and each probability graph was partitioned on that basis (see examples in Figs.5 and 8). Thresholds separating the partitioned populations as efficiently as practicable were chosen, as described by Sinclair (1974). Resulting groups of data for each variable were coded on maps to aid the interpretation. Isopleths on these maps represent thresholds that discriminate populations relatively efficiently. Parameters of all partitioned populations are listed in Table I. The method of listing these parameters is to give the antilogarithms of the mean logarithm (b), the mean logarithm plus one standard deviation ($b + s_L$), and the mean logarithm minus one standard deviation ($b - s_L$).

A limited correlation study was done for data from 203 stations, each having values for 8 variables (5 geochemical and 3 geophysical). The resulting matrix of simple correlation coefficients is given in Table II. A total of 12 of the 28 correlation coefficients are significant at the 1% level. Six of these result from intercorrelations among the 4 variables A-horizon Cu, B-horizon Cu, A-horizon Zn, and B-horizon Zn. Two additional significant correlations exist between B-horizon Mo on one hand and A-horizon Cu, and B-horizon Cu on the other hand. Equally important is the clear absence of correlation between molybdenum and zinc in soils. The only other significant correlation coefficient involving a geochemical variable is the barely significant one between chargeability and B-horizon Cu.

DISCUSSION OF RESULTS

In 1966, part of the area was sampled (B horizon) and in 1970 the grid was extended and both A and B horizons were sampled in the extension. B-horizon Cu results in the original central area are considerably higher than

TABLE I

Parameters of partitioned populations, geochemical variables

Variable*	Population	Proportion (%)	Values (ppm)		
			b	$b + s_L$	$b - s_L$
ACU	I	5	62	123	31
	II	95	5.3	12.3	2.3
BCU (1966)	I	6	222	268	184
	II	6.5	120	142	103
	III	97.5	26	51	13.3
BCU (1970)	I	2.4	316	—	—
	II	33.6	26	37	20
	III	64	5.4	7.9	3.7
AMO	I	2.4	8.8	12.3	6.3
	II	97.6	0.69	1.6	0.34
BMO (1966)	I	3.5	62	77	50
	II	8.5	24.5	33.1	18.0
	III	88	2.6	4.9	1.4
BMO	I	7	20	43	9.6
	II	93	1.1	2.5	0.51
AZN	I	4.5	380	490	295
	II	85.5	58.9	123	28.9
	III	10	9.6	13.5	6.8
BZN	I	5	363	490	275
	II	65	74.1	123	43.6
	III	30	23.4	33.9	16.0
BIO-CU	I	15	182	199	166
	II	85	117	140	98
BIO-ZN	I	8	2090	2320	1850
	II	92	1080	1370	840

*ACU = A-horizon Cu, BCU = B-horizon Cu, AMO = A-horizon Mo, BMO = B-horizon Mo, AZN = A-horizon Zn, BZN = B-horizon Zn, BIO-CU = biogeochemical copper, BIO-ZN = biogeochemical zinc.

TABLE II

Correlation coefficients for arithmetic data*

Variable**	CH	MAG	ACU	AZN	BCU	BZN	BMO	RES
CH	1.0							
MAG	*−0.279*	1.0						
ACU	0.105	−0.081	1.0					
AZN	−0.023	−0.039	0.582	1.0				
BCU	*0.183*	−0.138	*0.863*	*0.490*	1.0			
BZN	0.118	−0.142	*0.740*	*0.779*	*0.806*	1.0		
BMO	0.138	−0.170	*0.332*	0.083	*0.374*	0.132	1.0	
RES	*−0.583*	*0.558*	−0.066	0.082	−0.084	−0.018	−0.091	1.0

*Absolute values greater than 0.181 are significant at the 1% level and are italicized.
**CH = chargeability, MAG = ground magnetometer values, RES = apparent resistivity, ACU = A-horizon Cu, AZN = A-horizon Zn, BCU = B-horizon Cu, BZN = B-horizon Zn, BMO = B-horizon Mo.

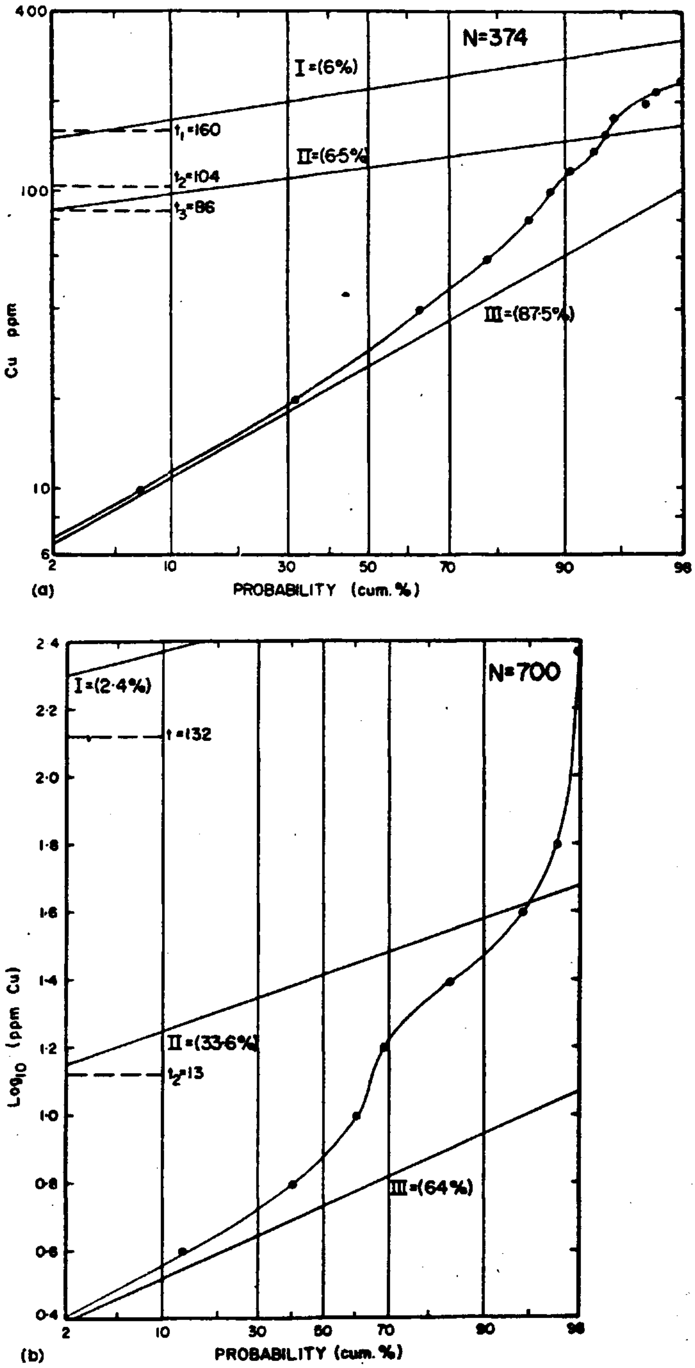

Fig.5. Probability plots: (a) B-horizon Cu data for 1966; (b) B-horizon Cu data for 1970. Each plot is partitioned into populations shown by straight lines. Thresholds (in ppm) separating populations are indicated by t_1, t_2, etc.

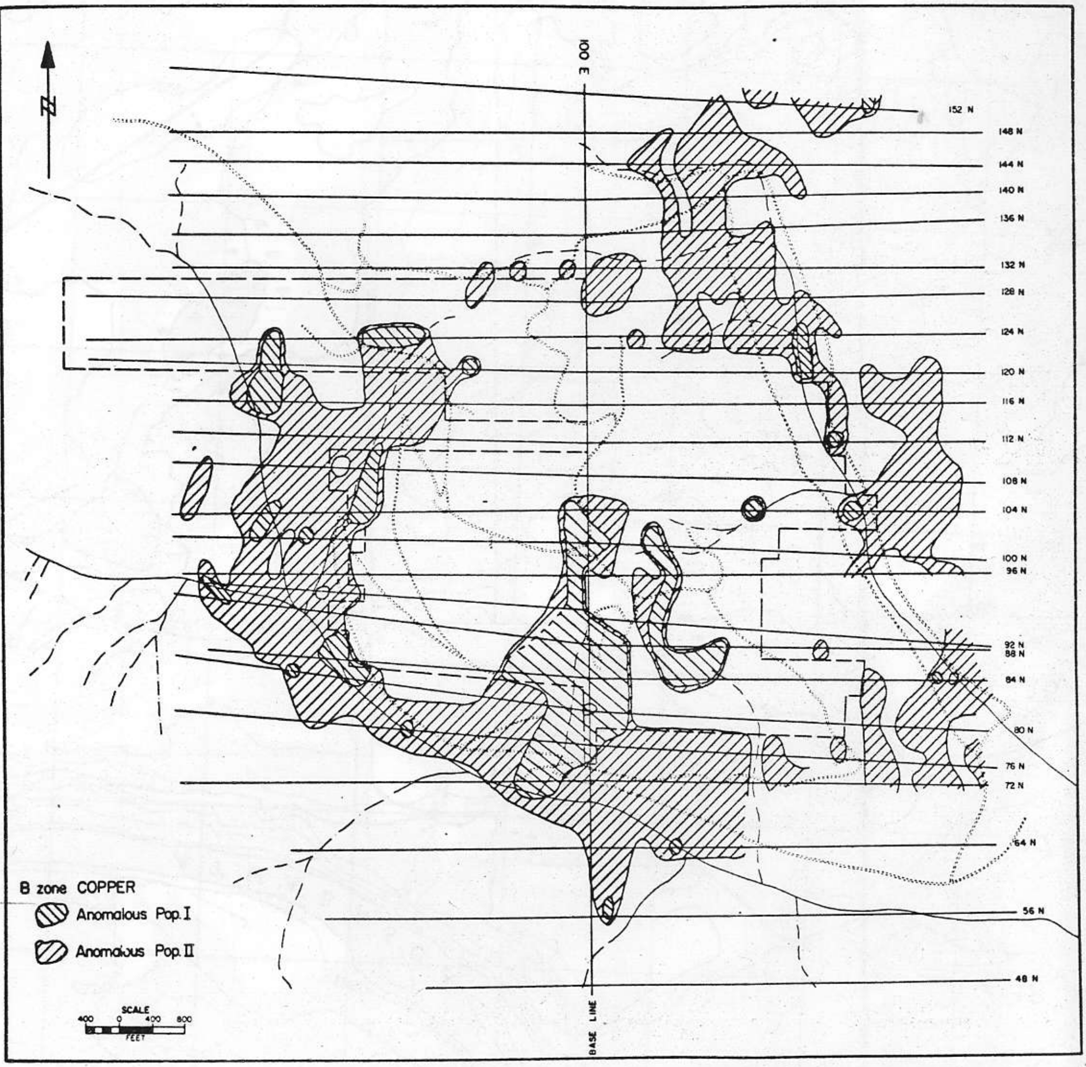

Fig.6. B-horizon Cu populations. Hachured areas show high and low anomalous populations. Isopleths are thresholds between populations (see Fig.5).

in the extension. This is probably the result of different analytical procedures. The two sets of data, however, are statistically similar. They are both made up of three populations: I — related to mineralization, mainly in the quartz monzonite boss; II — related to the pyrite halo; III — background. Fig.5a, b shows probability plots of B-horizon Cu data for original and extended areas respectively. Fig.6 is a geochemical plan combining both sets of data.

A-horizon Cu data is composed of two populations: I — a series of localized highs that correspond erratically to the pyrite halo; II — background. The third upper population corresponding to that for B-horizon Cu is missing,

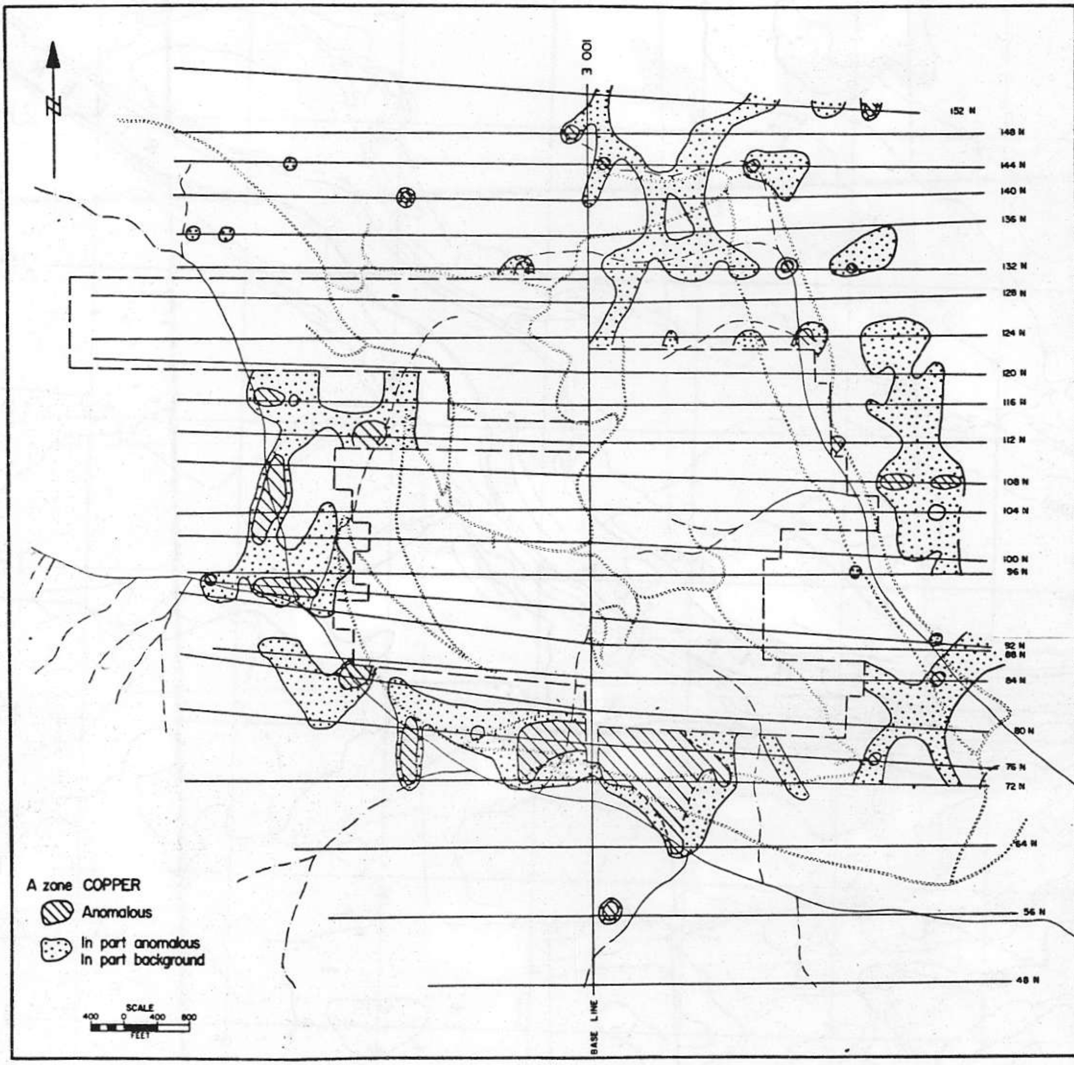

Fig.7. A-horizon Cu populations. Hachured area is anomalous. Dots show overlap of anomalous and background values. Isopleths are thresholds chosen from probability plots.

probably because the quartz monzonite boss is not exposed in the extended area for which A-horizon data are available. Fig.7 is a geochemical plan of A-horizon Cu populations. A comparison of A-horizon Cu with B-horizon Cu shows that good correlation exists between the two (see Table II) but that, in the type of environment found at Ashnola, the B-horizon Cu is diffused over a much larger area.

A limited area, mantled by overburden of unknown depth, was sampled for biogeochemical analysis. Second year growth from lodgepole pines were collected, ashed and analyzed for copper and zinc. Both data sets contain

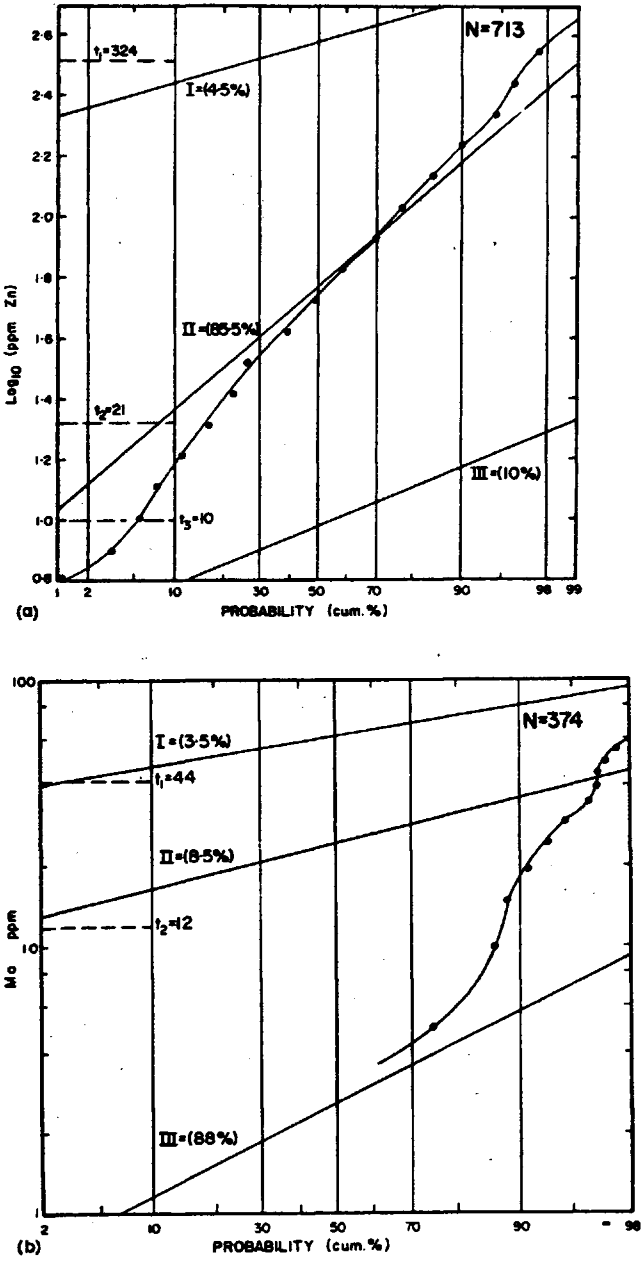

Fig.8. Probability plots: (a) A-horizon Zn; (b) B-horizon Mo, 1966. Each plot is partitioned into populations shown by straight lines. Thresholds (in ppm) separating populations are indicated by t_1, t_2, etc.

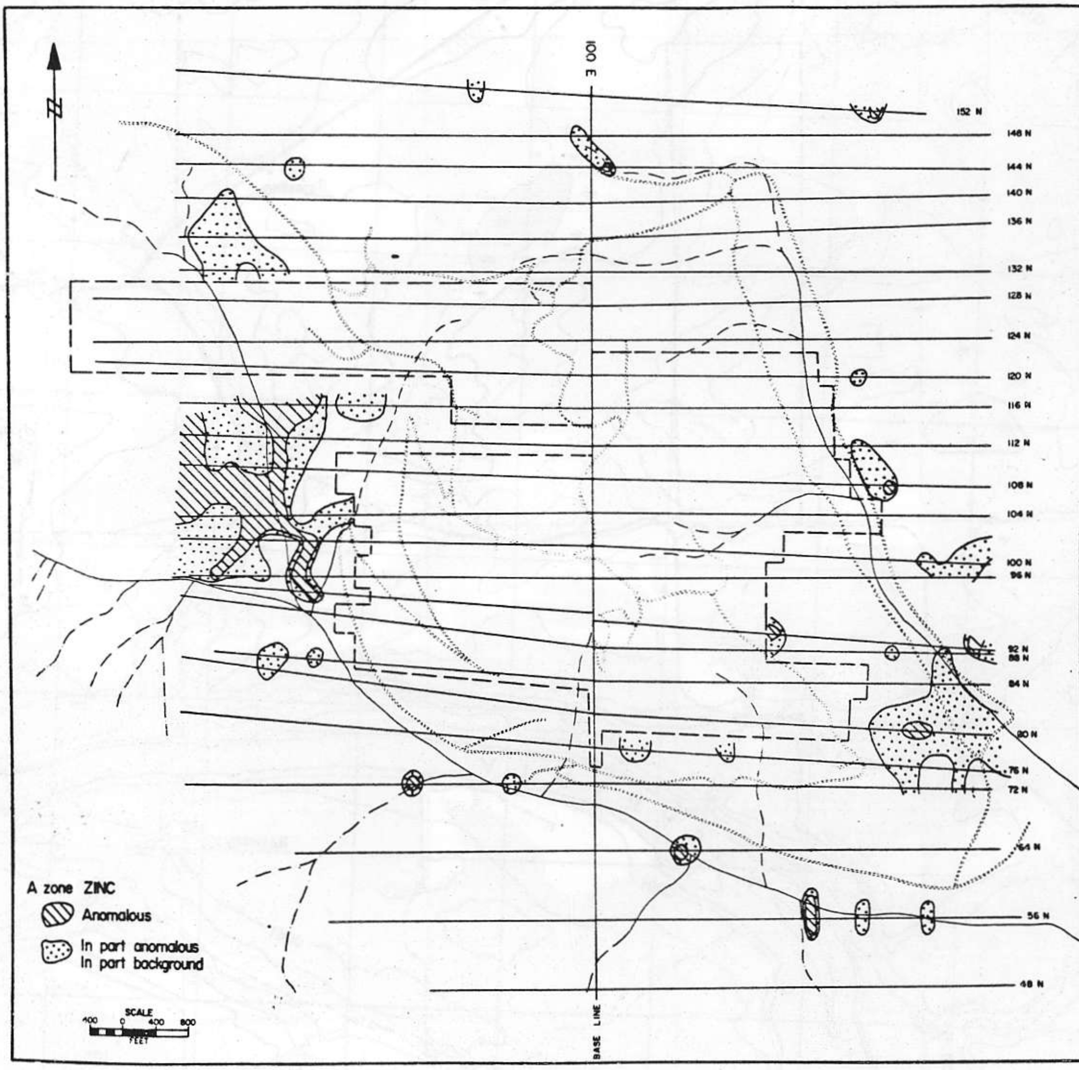

Fig.9. A-horizon Zn plan showing upper population (hachured) and range of overlap (dots) between upper and lower populations.

two populations that overlap somewhat; therefore threshold values, particularly those of copper, are not sharp. In general, there is good correlation between biogeochemical copper and A-horizon Cu but there are some unexplained differences. Figs.10 and 11 show the distribution of copper and zinc, respectively. There is no apparent correlation between biogeochemical copper and zinc.

A-horizon Zn, as shown in Fig.8a, is composed of three populations: I — peripheral to and partly overlapping (in some areas) the pyrite halo (population II in B-horizon Cu); II — background; III — also background but anoma-

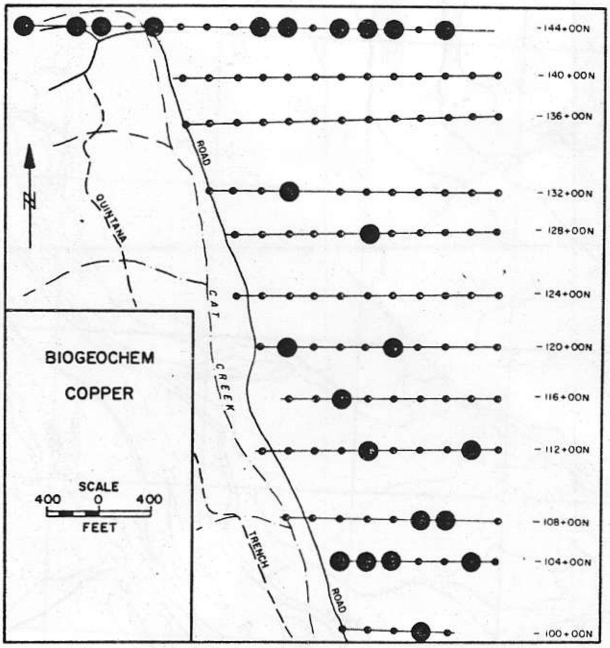

Fig.10. Biogeochemical copper. Large dots are upper population; small dots are lower population.

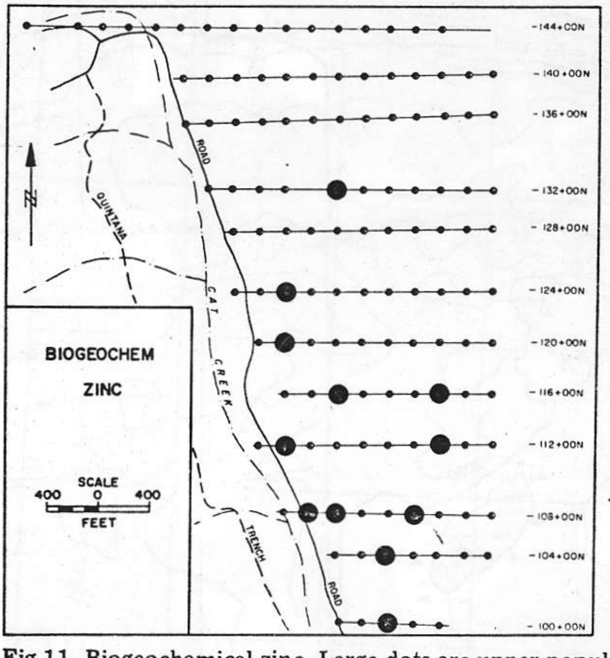

Fig.11. Biogeochemical zinc. Large dots are upper population; small dots are lower population.

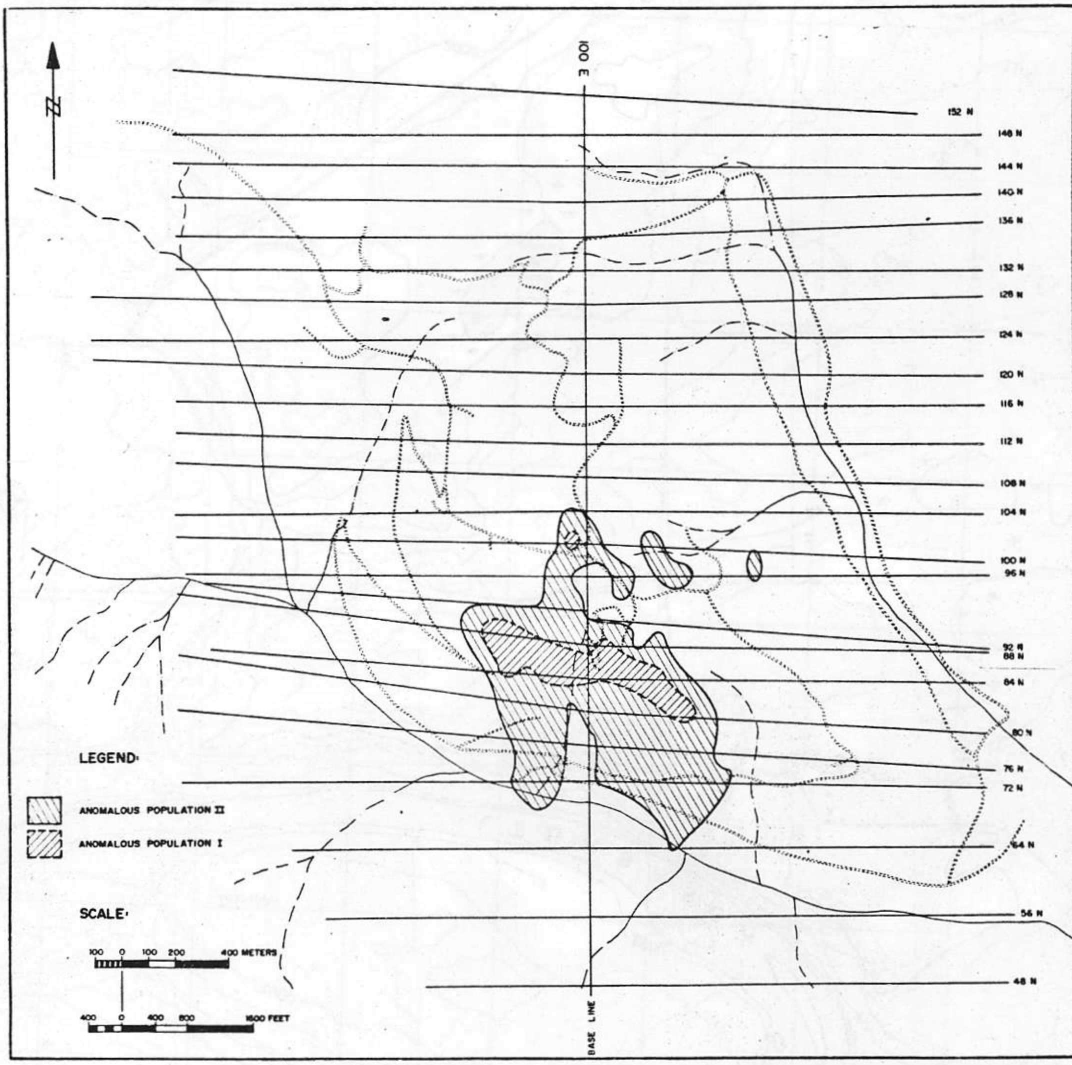

Fig.12. B-horizon Mo populations. Anomalous populations I and II (hachured) are surrounded by background values.

lously low for reasons unknown. Fig.9 shows the distribution of A-horizon Zn. A-horizon Zn and A-horizon Cu show good correlation, whereas no correlation exists between biogeochemical copper and biogeochemical zinc. Biogeochemical zinc and A-horizon Zn have different population compositions but their uppermost populations correlate moderately well.

B-horizon and A-horizon Zn values correlate strongly, not only in terms of calculated correlation coefficient (Table II), but also in terms of individual populations. A comparison of the geochemical plans of the two variables shows that good coincidence is present between A- and B-horizon Zn anomalies but that A-horizon anomalies are, in general, more abundant and larger than B-horizon anomalies.

B-horizon Mo values are composed of three populations (e.g. Fig.9b): I — related to in-place molybdenite mineralization; II — mechanical dispersion and dilution of I (active talus); III — background. A possible exception to the above is that several small scattered areas of population II could be related to molybdenite mineralization with an overburden cover. A geochemical plan for B-horizon Mo is shown in Fig.12. Visual examination suggests that A-horizon Mo correlates strongly with B-horizon Mo.

B-horizon Mo and B-horizon Cu also show good correlation. Comparison of Figs.6 and 12 shows that this correlation stems mainly from a high degree of coincidence of anomalous values of both variables on and near the mineralized quartz monzonite boss.

CONCLUSIONS

(1) The application of data analysis based on partitioning of cumulative probability plots has greatly facilitated the recognition of geochemical populations and their correlation with geological and geophysical information.

(2) A comparison of A- and B-horizon Cu analyses has shown that B-horizon data provided more complete information with respect to population definition with efficient thresholds and correlation with geological features. A horizon anomalies are more erratic and less dispersed than those of B horizon. Little of significance was added to B-horizon information by A-horizon data.

(3) Biogeochemical copper data contributed little additional information to that gained from B-horizon data.

(4) The concentration ratio of zinc in vegetation is very high relative to that of copper and there is no correlation between abundances of the two elements.

(5) A-horizon Zn anomalies are discontinuous and are peripheral to and partly overlapping the pyrite halo. B-horizon Zn data adds little to A-horizon Zn.

(6) B-horizon Mo values are significantly higher than those of A horizon and the threshold values are more useful.

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