GEOPHYSICAL EXPLORATION OF A LEAD-ZINC DEPOSIT IN YUKON TERRITORY

*by Edward O. Chisholm**

Abstract

Self-potential and magnetometer surveys were followed by a gravimetric survey in the northwestern Cordillera to outline successfully a flat-lying lead-zinc sulphide replacement deposit beneath 50 ft. of glacial overburden. This site of the survey is 125 miles northeast of Whitehorse, Yukon Territory, in mountainous terrain. Detailed diamond drilling verified the accuracy of the survey both as to boundaries and estimated tonnage of the deposit. Auxiliary surveys were carried out by aeromagnetic and geochemical methods. Graphitic schists interfered with the self-potential readings, but geochemical and magnetic results were helpful for indicating favourable terrain.

Location, Topography, Etc.

THE lead-zinc sulphide replacement body investigated by geophysical techniques described here is located on the headwaters of Vangorda Creek, a tributary of Pelly River, on the Vangorda Mines property of Prospectors Airways Company Limited. The surrounding country is mountainous but the deposit is in the centre of an intermontane valley approximately 2½ miles wide. Differences of elevation within the area of the survey are less than 100 ft., a feature which facilitated gravity work.

The replacement body lies beneath a glacial sand and boulder ridge varying in thickness from 25 to 80 ft. The ridge is traversed by Vangorda Creek, a small glacial stream, and a smaller tributary. Outcrop is exposed in the area of the survey at one location only on the bank of the stream, and consists of massive sulphides 100 ft. in length, 10 ft. in height. Permafrost, though usual in this latitude, was not encountered. Overlying the glacial material is a persistent layer of volcanic ash approximately 4 inches thick. The climate is sub-arctic and the soil profile is immature with zones of leaching and oxides penetrating less than a foot below surface. This results in a smaller, residual base-metal content of the soil and water than is normal to central latitudes.

The geophysical methods were started in advance of drilling, but were broadened in kind and magnitude as the drilling progressed and as different characteristics of the deposit were revealed. Initially the simplest methods, the self-potential and the magnetometer, were used. When it was apparent that graphitic schist was present, the electrical methods were discarded and magnetometer work was increased. The detail of this method was completed during the second season in time to indicate possible extensions of the deposit.

Further drilling indicated, however, that the magnetometer could not be relied upon solely to indicate sulphides because of the presence of other magnetic zones. At this stage gravimetric work was initiated and was completed over the deposit at the same time as the drill program. The results coincided so well that further drilling to extend the margins of the deposit was considered unnecessary. The excess mass calculation agreed so closely with the tonnage figure arrived at by drilling that it was decided also that further deep holes to explore the possibility of underlying zones were unnecessary.

Geology, Mineralization, Alteration

The deposit comprises an overlapping series of horizontal lenses of sulphides that appear to replace a favourable sedimentary bed; longitudinal section of the body is shown in Figure 1. Seventy-three diamond drill holes indicate a length of 3,200 ft. with an average width of 490 ft., and 9,400,000 tons of sulphide containing 3.16% Pb, 4.96% Zn, 0.27% Cu, 1.76 ozs. Ag, and 0.02 oz. Au; also, an additional 12,600,000 tons of low-grade to barren sulphides. The total mass of sulphides is estimated from diamond drilling to be in the order of 22,000,000 tons. The mineralized body extends from bedrock surface to a depth of 300 ft. Drilling to 1,000 ft. encountered no underlying body.

The host rocks comprise a flat-lying sedimentary assemblage which can be divided into two main zones, namely, one predominantly chloritic sericite schist, and the other predominantly graphitic schist. They are intimately associated with much intercalation at the edges of the graphitic horizon. The graphitic schist is minutely crumpled, breaks easily along cleavage planes, and contains narrow (up to 1 m.m.) quartz stringers

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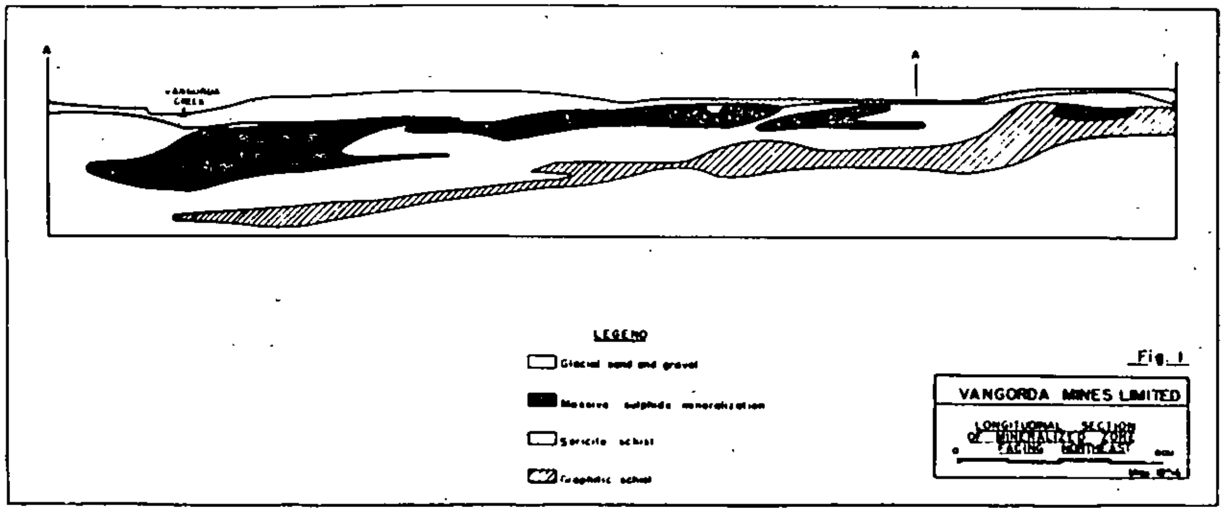

Figure 1.
ongitudinal section
f mineralized zone,
facing northeast.

which often are mineralized with pyrrhotite, with minor chalcopyrite and pyrite. In thin section, it consists of minutely folded bands of white mica (sericite) and black carbonaceous matter intercalated with bands of anhedral, interlocking quartz grains, and isolated siliceous lenses. Sparse mineralization is confined to the siliceous bands, pyrrhotite apparently replacing quartz. This graphitic schist seems to have been produced by strong metamorphism of impure carbonaceous slate interbedded with thin, sandy layers. Calcite is present in small amounts and may have been introduced with the sulphides.

The sericitic zone consists of light greenish-grey, chlorite schist and appears less deformed than the black schist. It is sparsely mineralized in siliceous bands (mainly pyrrhotite with some galena and chalcopyrite). In thin section, it appears to be a succession of thin bands of sericite, alternating with somewhat wider layers of quartz and chlorite containing minor amounts of orthoclase and sericite. The sericite-chlorite schist appears to have resulted from strong regional metamorphism of a succession of thin sedimentary beds, probably of impure sandstone interbedded with shale. Occasional siliceous lenses containing sulphides may originally have been small pebbles in the sediment.

No intrusive rocks were found within the area, although granite, gabbro, diorite and porphyry are present elsewhere on the claims.

The mineralization is a fine-grained aggregate of sulphides in a siliceous matrix. Sulphide content is variable but might average 60 per cent overall. Minerals present in their order of abundance follow:

Pyrite	35%
Sphalerite	25%
Galena	15%
Pyrrhotite	10%
Chalcopyrite	6%
Arsenopyrite	5%
Magnetite	3%
Marcasite	1%
Tennantite	Small amount

The assemblage indicates a hypothermal replacement deposit.

Alteration is predominantly sericitic and chloritic and is intensified in an envelope surrounding the mineralized deposit.

The control of deposition appears to be lithological rather than structural, but at this stage there is insufficient evidence to decide. There is a suggestion that the northwest extremity of the deposit is terminated by a fault along Vangorda Creek. Brecciation and carbonatization of the ore in drill holes in this section indicate faulting. There is also a suggestion that the long axis of the deposit is controlled by faulting and/or folding. No post-ore displacement of the sulphide mass in a horizontal or a vertical plane was indicated in the drilling and it would seem that any structural elements reflected in the magnetometer and gravity surveys may indicate pre-ore controls. It is reasonable to assume that the presence of feeder faults in the area and the displacement of contours in the magnetic and gravity surveys in the vicinity of Vangorda Creek and its tributary to the east near Line 19E, may be caused by this. However, part of the displacement of the gravity contours along the creeks is due to thinning of the overburden in this locality.

Gravimeter Survey

The outline of the residual gravimeter anomaly and its relation to the mineralized zone is shown in Figure 2 (in pocket).

Readings were taken with a Worden gravimeter with sensitivity of 0.10024 mgs. per scale division, at 100-ft. intervals with varying line separation. Gravity and elevation runs were made in closed loops with all errors being adjusted. Elevation misclosures were kept under 0.5 ft. and gravity misclosures under 0.5 milligals. Drift, elevation, latitude and terrain corrections were applied to the gravity readings.

Density measurements on both surface and core specimens gave the following values:

Specimen	*Depth*	*Type of Material*	*Density*
1	Surface	Granite	2.64 gms./cc.
2	139′	Sericite schist	2.69 "
3	188′	Sericite schist	2.75 "
4	393′	Sericite schist	2.76 "
5	188′	Graphite schist	2.78 "
6	45′	Gabbro	2.85 "
7	50′	Gabbro	2.84 "
8	—	Massive sulphides	4.34 "
9	—	Massive sulphides	4.23 "
10	—	Massive sulphides	4.62 "

The schists are of relatively uniform density, with the granite slightly lighter and gabbro slightly heavier.

- **Observations**

The mineralized zone was clearly detected by geophysics and its edges are well defined. The results show a remarkable coincidence with the zone as outlined by drilling.

Tonnage calculations from the residual anomaly (total anomaly minus regional anomaly) gave in excess of 6,000,000 long tons. Transferred into actual tonnage, on the assumption that the schist's average density is 2.8 gms./cc. and the mineralization averages 4.0 gms./cc., a total of 20,000,000 tons is indicated. This is remarkably close to the 22,000,000 tons of sulphides indicated by drilling.

The regional gravity, not shown on the accompanying map, slopes gradually southwest and is caused by a series of gabbro intrusions in this direction.

The shape of the anomaly indicates that the mineralization is banded in parallel zones along its length. The portions of greatest thickness near Vangorda Creek, (as shown on the longitudinal section on Figure 1), are reflected in high-gravity values up to a peak of 2.02 milligals. The lensing out of the deposit to the edges is reflected also in lower-gravity values.

Some of the edges of the deposit indicated by the gravity anomaly are noticeably sharp, others are gradual; this may be a reflection of faulting, especially in the northwest end of the deposit.

Approximately 500 ft. southwest of the mineralized deposit, and parallel to it, is a small, broad low; this appears to be a reflection of a graphitic schist zone which outcrops in this area. Its overall density is lower than surrounding schists.

No anomalous regional effects that might be expected in the disturbed zone of intermontane terrain were noticeable in the gravity survey.

- **Conclusions**

Near-surface deposits of massive sulphides enclosed in light schists that provide a marked density contrast, produced sharp high-gravity anomalies. Values about 0.5 milligals were considered anomalous.

The gravimetric method is a definite tool for outlining sulphide masses in the geological conditions described here.

Self-Potential Survey

The outline of the self-potential survey and its relation to the mineralized zone are shown in Figure 3 (in pocket). Readings were taken at 50-ft. intervals along lines 200 ft. apart.

- **Observations**

The self-potential survey of the mineralized zone showed several large anomalies seemingly caused by graphitic schist. Readings over the deposit itself generally were flat and appeared to be blanketed by overburden where it exceeded 25 ft. in thickness.

- **Conclusions**

The self-potential method, although cheap and fast, would be of use under the present geological association only in tracing the block schist zones under overburden less than 25 ft. thick. Where depth of overburden is unknown, interpretation of results would be difficult and the electrical-magnetic method would offer a more effective technique because of its greater penetration.

Aeromagnetic Survey

A series of lines approximately 5,000 ft. apart were flown over the central part of the claims at a height of 500 ft. to test the effectiveness of this type of instrument for reconnaissance.

- **Observations**

No higher than normal readings were obtained over the mineralized zone, but a generally higher level of readings was noted over the basic intrusive rocks one mile to the southwest of the deposit.

- **Conclusions**

Insufficient lines were run over the zone to test the airborne instrument conclusively; with closely spaced flightlines at a low altitude, results comparative to the ground magnetometer survey might be expected.

Magnetometer Survey

The outline of the magnetometer survey and its relation to the mineralized zone are shown in Figure 4 (in pocket).

Readings were taken by the Askania instrument at 50-ft. intervals on lines 200 ft. apart. Sensitivity was 25.6 gammas per scale division. No magnetic storms or side hill effects from surrounding mountains were noted.

- **Observations**

Six anomalies were found within the area of mineralization, with residual magnetic values ranging from 800 to 2,000 gammas.

Contours are lenticular along the length of the deposit.

The most intense anomalies were obtained where overburden is shallow.

Anomalies of similar magnitude and shape were found outside the mineralized zone.

Certain sections of massive mineralization gave no magnetic anomalies.

Magnetic contours show displacement along Vangorda Creek and its tributary to the east.

Sufficient spot drilling has been done to indicate the cause for most anomalies.

- **Conclusions**

The magnetometer alone would not produce definitive anomalies signifying underlying sulphide mineralization because of the variable magnetite content of the sulphide deposit itself, and because of the presence within the confines of the survey of other factors contributing to a magnetic condition of magnitude similar to that encountered over the mineral deposit. These factors are:

1. Concentration of magnetite in residual gossan material underneath an eroded section of sulphides;

2. Small gabbro intrusive plugs outside the confines of the mineralized zone;

3. Widely disseminated magnetite in certain sections of the graphitic schist zone which, when near surface, produced a mass effect equal in magnitude to the magnetic section of the main mineralized zone.

The magnetometer proved useful in indicating favourable terrain; in determining the strike of mineralized zones; and in pinpointing thick sections of sulphide containing magnetite. It indicated also a possible fault that terminates the deposit abruptly along Vangorda Creek between anomalies 1 and 2; drilling confirmed this fault. A possible pre-ore fault is indicated along the creek at Line 19E.

The magnetometer is best used under the above geological conditions in conjunction with other exploration survey methods.

Geochemical Surveys

The outlines of geochemical heavy-metal surveys in the soil surrounding part of the deposit and in the drainage system cutting through it are shown on Figures 5 and 8 respectively. Geochemical profiles showing the relationship between heavy-metal content in the soil, topography, location of sulphides, gravity and magnetic determinations, are shown in cross-sections 6 and 7.

Soil samples were taken at 100-ft. intervals on lines 200 ft. apart at uniform depth of 2 ft.; this represents the "C" or parent soil zone. It was tested for heavy-metal content by the cold extraction method devised by Bloom*. Surveys were conducted in July after the seasonal run-off had taken place and the water table had reached a state of equilibrium.

The method is a rapid and simple field technique that involves extraction of (Zn, Cu, Pb, Co, Ni) ions from a soil sample with a cold solution of ammonium citrate in the presence of dithizone-xylene solution.

*BLOOM, H. A.: A Field Method for the Determination of Ammonium-Citrate Soluble Heavy Metals in Soils and Alluvium. *Econ. Geol.*, Vol. 50, pp. 533-541.

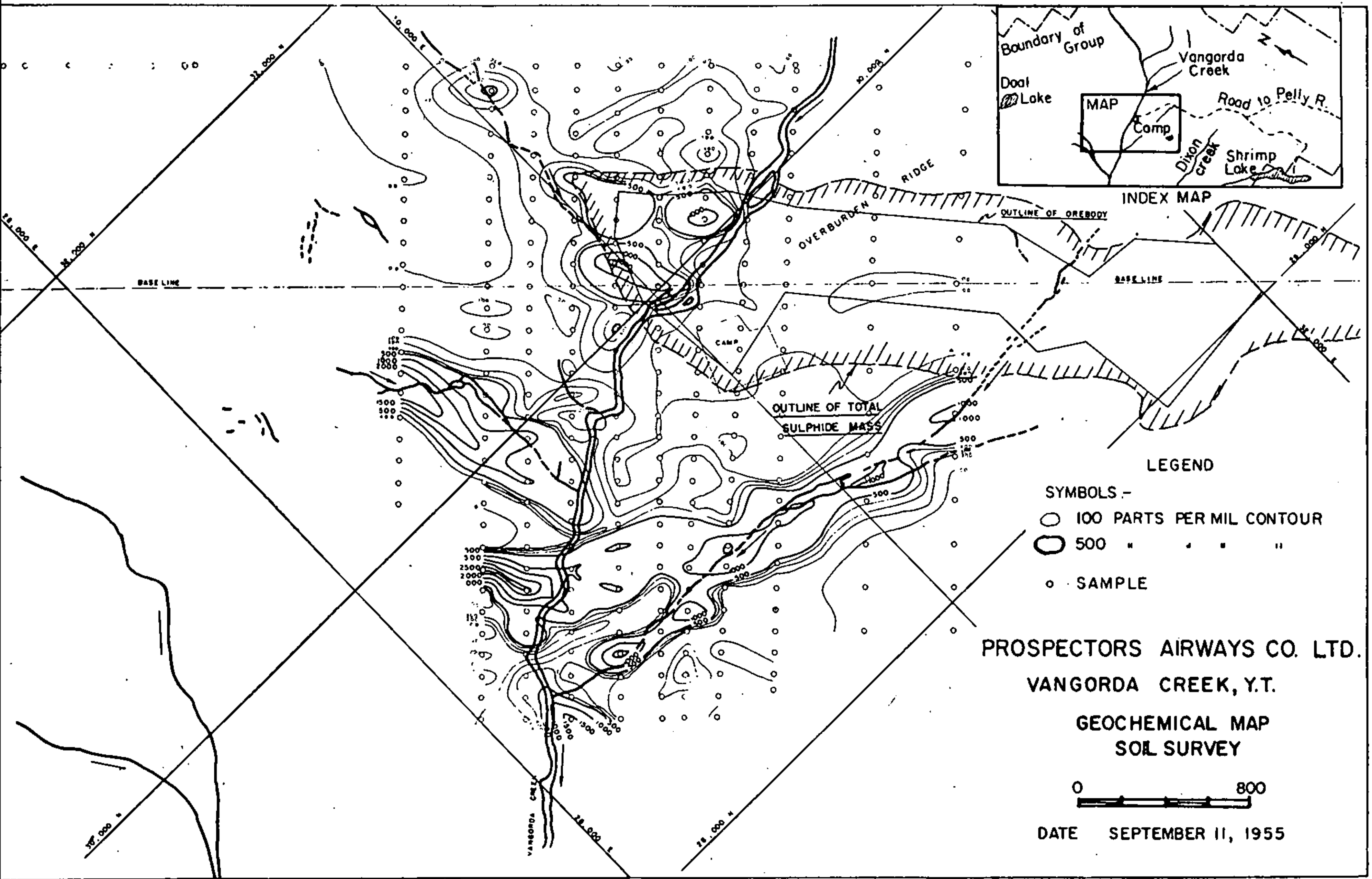

Figure 5. Geological map—soil survey.

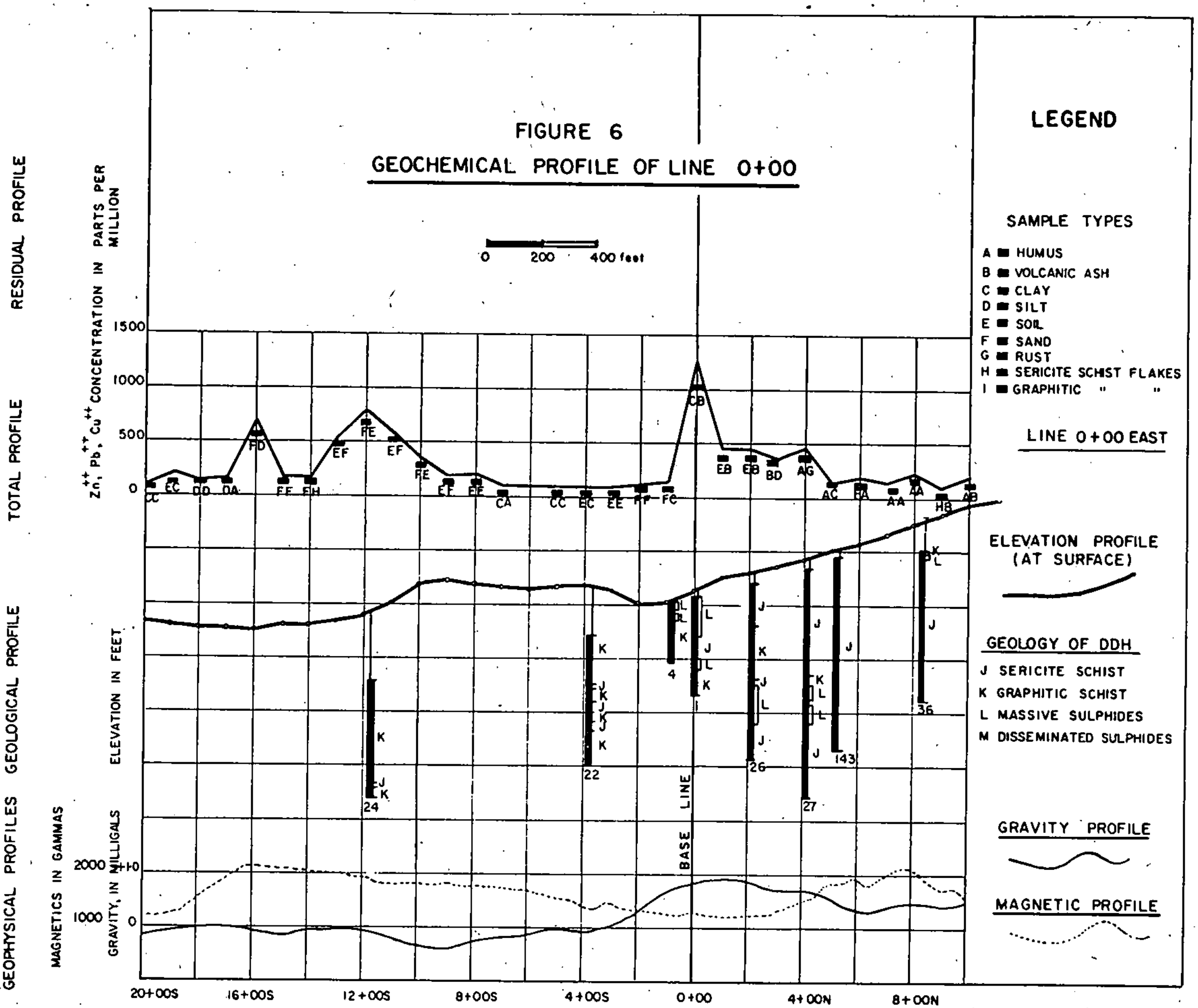

Figure 6. Geochemical profile of line 0+00.

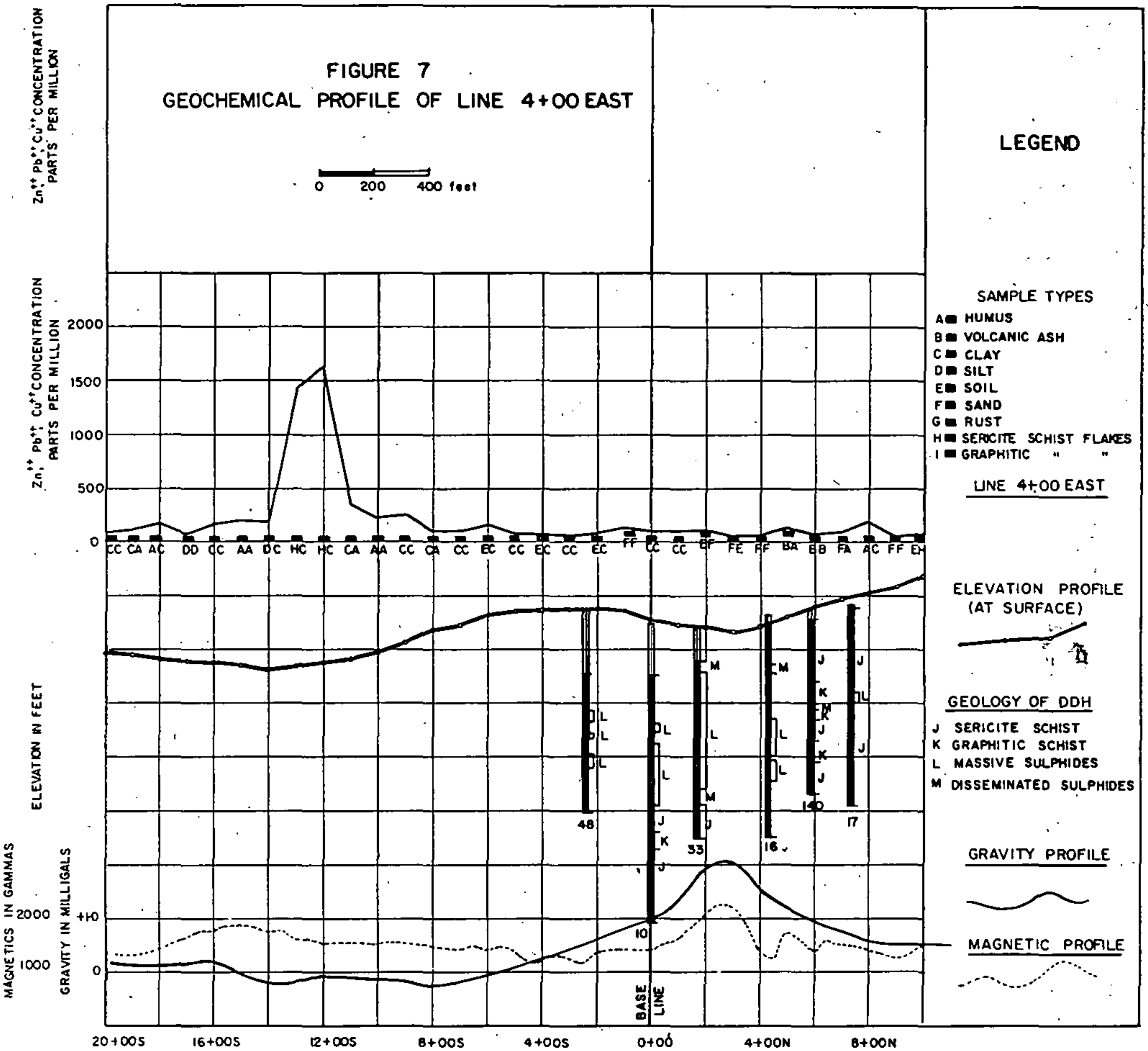

Figure 7. Geochemical profile of line 4 + 00 east.

The method may be used also for water samples taken at regular intervals along streams.

- **Observations**

Figure 5 shows distinct heavy-metal anomalies in the soil near the mineralized zone on the down slope side.

The higher contours generally follow the water channels.

Deep overburden blanketed out anomalies.

Similar results are noted also in Figures 6 and 7 where sharp increases were obtained in the heavy-metal content of the soil on sections 0 plus 00 and 4

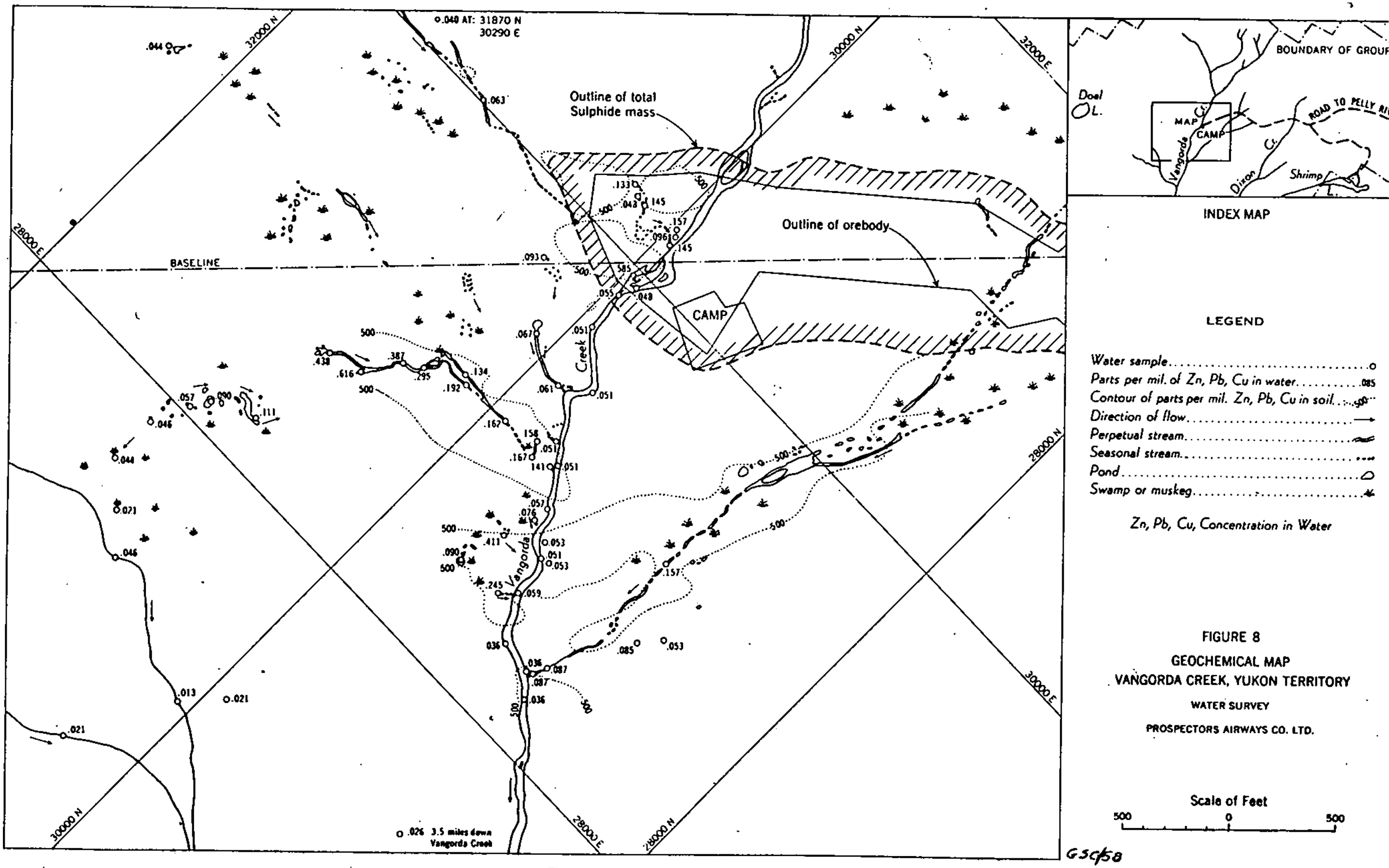

Figure 8. Geochemical map, Vangorda Creek.

plus 00 east at 12 plus 00 south, down-slope from the mineralized zone.

Figure 6 shows a sharp rise in the heavy-metal content of the soil at 0 plus 00 south where the massive sulphides are near surface and where overburden is light. In these conditions a heavy-metal content of over 200 parts per million was considered significant for the soil and over 0.01 part per million for water.

There is a rough correspondence between heavy-metal soil contours and the self-potential contours which trend along water courses. Both may be due in part to the concentration of ions along these channels.

Figure 8 shows a gradual build-up in the heavy-metal content of the water in Vangorda Creek up to the point where it cuts through the mineralized zone. Similar increases in heavy metals were noted in the tributaries of the main creek on proceeding upstream and approaching the mineralized zone.

- **Conclusions**

The geochemical water test is a cheap and useful prospecting method for testing streams and tracing heavy metals to their point of maximum concentration. The soil testing is useful as an auxiliary exploration tool where overburden is light.

The main usefulness of geochemical methods lies in the quick determination of large targets for subsequent exploration by methods other than time-consuming investigation within narrow limits. This is because of the large inherent sampling error in any soil sample.

General Conclusions

The results of geophysical and geochemical surveys over the sulphide deposit at Vangorda Creek indicate that the optimum combination of preliminary exploration techniques elsewhere on the property would consist of a geochemical soil and water reconnaissance followed by electro-magnetic and gravity survey.

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GEOCHEMICAL ANOMALIES RELATED TO SOME BRITISH COLUMBIA COPPER MINERALIZATION

by Harry V. Warren, Robert E. Delavault and Christine H. Cross

Abstract

Geochemical techniques were applied to prospecting for copper in three areas in the south part of British Columbia. Soil and vegetation samples were collected along profiles over strong, medium and weak copper mineralization. The analyses were plotted on profiles, and the mineralization, as determined by various methods, is shown. Large geochemical anomalies were obtained over the areas of significant copper mineralization. The ratios of the p.p.m. of copper to the p.p.m. of zinc present in the samples were computed and plotted as aids in interpretation. The techniques were found to be effective for exploration in the section of British Columbia under study.

RECENT interest in low-grade copper deposits has induced a wave of intensive exploration in the vicinity of Kamloops, Ashcroft, Merritt, and Aspen Grove, British Columbia (Figure 1). Much of this section is geologically favourable and heavily drift-covered, making it a natural setting in which to use geochemical techniques.

The examples which follow were not collected originally with the intention of publication, and some data, which would have served to develop a more complete picture, are not available. However, through the kindness of the companies on whose properties the samples were collected, sufficient results have been released to illustrate the type of anomaly which may be looked for over mineralization of different intensities in some sections of south-central British Columbia. Biogeochemistry and pedogeochemistry, particularly the latter, have been shown to be of value in any search for mineralization buried by overburden less than 20 to 30 ft. thick.