Effectiveness of Geochemical and Biogeochemical Exploration Methods in the Cobalt Area, Ontario

E. H. W. HORNBROOK
Geological Survey of Canada

ABSTRACT

The effectiveness of geochemical and biogeochemical exploration methods in detecting the silver vein deposits at Silverfields Mining Corp. Ltd., Hi Ho Silver Mines Ltd. and Agnico Silver Mines Ltd. was studied during the summer of 1968.

At these mine sites, bark, leaf, spur and/or twig organs of trembling aspen and white birch, together with B-horizons soils and (A_o+A_1) horizons combined, were collected and analyzed for Ag, Co, Ni, Mn, Cu, Pb and Zn. A major part of the study was conducted at the Silverfields Mining Corp. Ltd. mine, because certain geological features of the mine, described as follows, were particularly appropriate for this study.

The principal ore veins occur in the 100- to 200-foot-thick assemblage of Cobalt sedimentary rocks which overlie Keewatin greenstones containing sedimentary interflow bands. The sediments and greenstones are capped by approximately 175 to 200 feet of Nipissing diabase sill.

In the Cobalt sediments, ore veins have the following dimensions: length, 50 to 900 feet; vertical extent, 50 to 200 feet; thickness, seldom more than ½ foot for an individual vein. In some places, ore veins pinch out or swell for several feet along strike, or they frequently horsetail and may or may not continue. They occur in the form of single veins or closely spaced multiple veins comprising a family or vein system. Vein systems may be separated by up to tens of feet from other similar, roughly parallel vein systems. Some of the narrow fractures at the surface of the diabase contain traces of ore elements, suggesting that ore veins extend upward through the diabase as thin, probably discontinuous seams.

Because the principal ore veins being mined at depth have a surface expression, they are amenable to detection by soil or plant exploration methods. Furthermore, the reflection at the surface of the configuration of the near-vertical ore veins at depth facilitates their correlation with the anomalous distribution of ore elements in soils and vegetation.

A rectangular grid (500 feet by 2,000 feet) was established perpendicular to the strike of the roughly parallel, principal ore veins. Samples were collected at 25-foot intervals from six lines, 100 feet apart. The $(A_o + A_1)$ combined horizons, seived to minus 10 plus 80 mesh, were the most effective soil horizons to sample, because they were enriched in most elements compared to the B horizon. Similarly, birch spurs were the most effective plant organ to sample of those studied, followed by aspen twigs. Thus, anomaly maps were constructed from (A_o+A_1) horizons and birch-spur analytical data.

The anomalies developed, particularly for silver in the (A_o+A_1) horizon, not only defined the central anomalous target area where several vein systems occurred as opposed to relatively barren areas within the mine, but established the anomalous expression of an individual ore-vein system within the target area. In addition to determining the proper type of the sample material to be collected and the appropriate indicator elements, the factors responsible for the effectiveness of these methods significantly include sampling density. A method incorporating sample collection at 100-foot intervals in the (A_o+A_1) horizon would detect only the central anomalous target area.

INTRODUCTION

A STUDY OF THE EFFECTIVENESS of geochemical and biogeochemical exploration methods in detecting silver vein deposits at Silverfields Mining Corp. Ltd., Hi Ho Silver Mines Ltd. and Agnico Silver Mines Ltd. was carried out during the summer of 1968. These mines are located a few miles by road southeast of the town of Cobalt, Ontario. Cobalt is 5 miles west of Lake Timiskaming and 95 miles north of North Bay, Ontario, on Highway No. 11. Only the major studies carried out at Silverfields will be reported here; a complete report will be given in a forthcoming Geological Survey of Canada publication.

The objectives of the study were: (1) to detect, by geochemical and/or biogeochemical exploration methods, trace-element leakage halos in the overlying till; (2) to relate anomalous concentration of indicator elements in the halos to the principal ore veins deeply buried in the Coleman Formation sediments under 200 feet of Nipissing diabase sill; and (3) to evaluate the effectiveness of the geochemical and biogeochemical exploration methods used to achieve objectives (1) and (2).

There are many difficult problems associated with geochemical exploration at Cobalt, Ontario, as evidenced by the fact that no major deposits have been discovered by surface geochemical methods for several years. Part of the difficulties originate because individual silver veins constitute thin, vertical, anastomatic, frequently discontinuous, deeply buried targets that do not generate large geochemical halos in the overlying till. Extensive contamination of the landscape often modifies, or completely obliterates, geochemical anomalies over surface 'leakage' halos, enormously complicating the interpretation of geochemical exploration results. Exploration problems are further compounded by glacial deposits of boulder till, glacial clay and glacio-fluvial deposits of poorly sorted sands and gravels. These deposits effectively cover much of the economically interesting bedrock of the Cobalt area, frequently preventing the extension of even known silver veins by conventional geochemical exploration methods. Koehler *et al.* (1954) stated that the cobalt content of glacial deposits near bedrock could be used to successfully outline silver veins where they extend to the bedrock surface, and Boyle (1969) pointed out that, although trace-element analysis of clay and derived soils was not effective in geochemical prospecting for silver veins, the use of the till and derived soils should be effective.

GEOLOGY

The geology of the Cobalt - New Liskard area has been described by several writers, including Miller (1908, 1913), Knight (1924) and Thomson (1957, 1962).

Steeply dipping Archean Keewatin mafic to intermediate lavas with interflow bands of chert, tuff and agglomerate comprise most of the basement rocks of the area. These are overlain in places by steeply dipping greywacke, quartzite and conglomerate of the Archean Timiskaming Group. Granite and hornblende syenite and basic dikes and sills intrude both Keewatin and Timiskaming rocks. The Proterozoic Cobalt Group of sediments, mostly conglomerate, greywacke and quartzite, lie unconformably on Archean basement rocks. A gently dipping Keewenawan quartz diabase sill (Nipissing Sill) has intruded both Archean and Proterozoic rocks. Ordovician and Silurian limestones, shales and dolomites in places overlie all earlier rocks.

The local mine geology at Silverfields Mining Corp. Ltd. is essentially similar to that of most other silver mines in the Cobalt area. At Silverfields, the principal ore veins mainly occur in the 100- to 200-foot-thick sedimentary assemblage of the Coleman Formation, Cobalt Group. The sedimentary rocks overlie unconformably, in an erosional trough, Keewatin lavas containing mineralized sedimentary interflow bands. They are capped by 175 to 200 feet of Nipissing diabase sill.

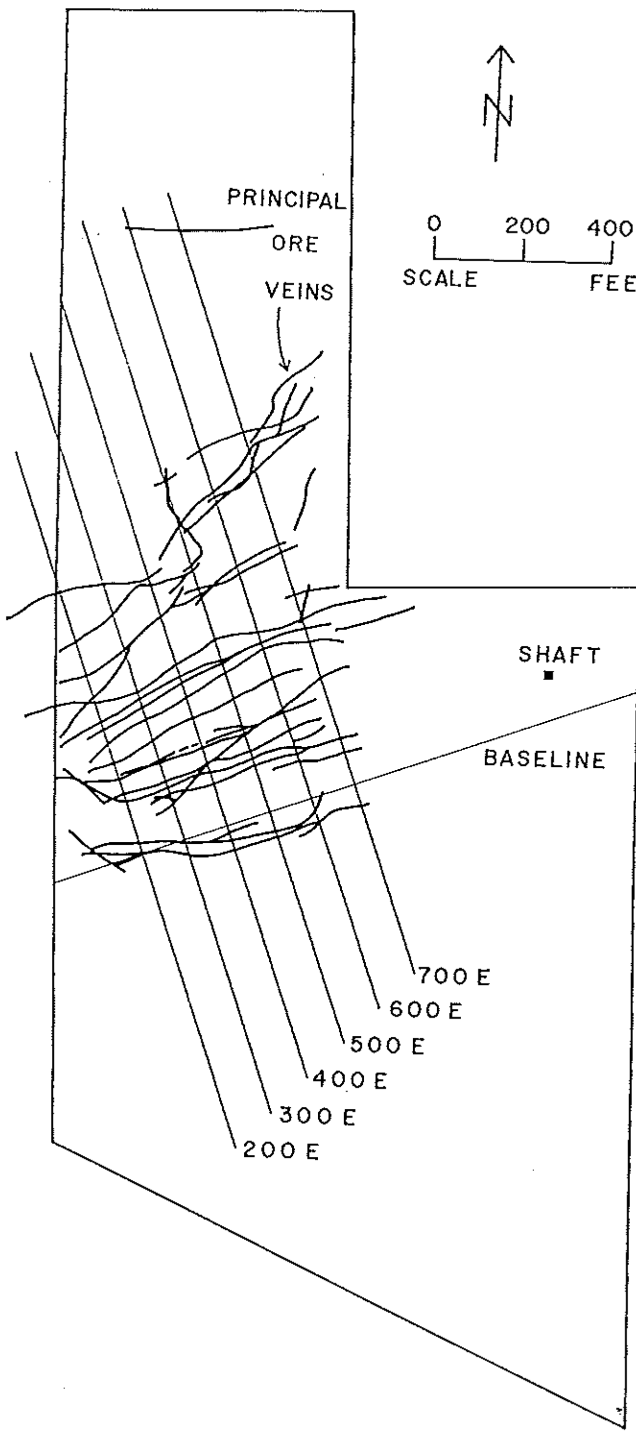

FIGURE 1 — Property Plan, Silverfields Mining Corporation Limited.

Ore veins (see *Figure 1*) characteristically have the following dimensions (Petruck, 1968): length, 50 to 900 feet; vertical extent, 50 to 200 feet; thickness, seldom more than a few inches for an individual vein. In some places, ore veins pinch out or swell for several feet along strike, or they frequently horsetail and may or may not continue. They occur in the form of single veins, or closely spaced multiple veins comprising a family or vein system. Vein systems may be separated by up to tens of feet from other similar, roughly parallel vein systems.

The principal ore veins contain much native silver, Ni-Co arsenides, ruby silver and lesser amounts of galena, sphalerite, chalcopyrite and pyrite in a dolomite gangue.

Some of the narrow fractures at the sub-outcrop surface of the Nipissing diabase sill contain traces of ore elements (Boyle, 1969), suggesting that ore veins extend upward, through the diabase, as thin and probably discontinuous seams.

GENERAL DESCRIPTION OF THE LANDSCAPE

Soils characteristic of the Brown Forest, Grey Wooded, Podzol and Dark Grey Gleisolic Great Soil Groups, dominant in the New Liskard - Englehart area described by Hoffman *et al.* (1952), are also dominant immediately south in the Cobalt area. Commonly, at Silverfields, Podzol soils are developed on better drained till and Dark Grey Gleisolic soils on poorer drained till.

The elevation is highest at the north end of the sample grid (*Figure 1*), with a gentle slope to the southeast. The depth of till is shown on *Figure 2*. Briefly, the thickness of till is 10 feet or less, increasing progressively toward the east and south. The central parts of the grid have continuous coverage, whereas the north and northeast parts have a discontinuous coverage of up to 5 feet of till. There is one deep accumulation of 40 feet of till at 500N on line 700E (*Figures 1* and *2*).

In the Cobalt area, forest vegetation is comprised of an association of: trembling aspen, *Populus tremuloides;* white birch, *Betula papyrifera;* jack pine, *Pinus banksiana;* white spruce, *Picea glauca;* and balsam fir, *Abies balsamea.* Pines are common only on ridges or sandy, rocky sites. The hardwoods, birch and some maple, *Acer saccharum,* have a scattered occurrence. Aspen, spruce and fir are common throughout the area.

The rugged broken topography is typical of the Canadian Shield, with till-covered or rocky hills separated by narrow linear valleys. Local relief is 100 to 200 feet. Soil drainage is good, except in low-lying areas where peaty soils are water-saturated. The temperate climate has a mean summer, winter and annual temperature of 65°F, 10°F and 38°F respectively. Annual precipitation is about 32 inches.

METHODS

The sampling grid (*Figure 1*) is comprised of 452 stations established at 25-foot intervals on six traverse lines oriented perpendicular to the strike of the silver veins. Conventional methods of soil-sample collection were employed; however, the (A_0+A_1)-horizon sample was first collected from over a few square feet at the sample site before digging a soil pit.

Methods of collection and preparation of plant material can be complex and have been extensively described by the writer (Hornbrook, 1969a, 1970). Ideally, the sample tree and soil pit should be close together and immediately adjacent to the grid station, but this is not always possible in a combined geochemical and biogeochemical survey.

Plant ash and (A_o+A_1)-, B- and C-horizon soils were leached with hot nitric acid and Ag, Co, Ni, Cu, Pb, Zn and Mn were determined by atomic absorption spectroscopy (Hornbrook, in press). Analytical and sample processing facilities were set up in two mobile trailer laboratories and in a laboratory room of a building on the Haileybury Campus of the Institute of Applied Arts and Technology, Haileybury, Ontario. All analytical results were produced, compiled and plotted in the field; data processing to produce computer-drawn anomaly maps was done at Ottawa, Ontario.

PILOT STUDIES

Usually, geochemical and/or biogeochemical exploration programs require a preliminary study in a new field area. To achieve optimum results, it is necessary to determine control factors governing the effectiveness of each phase of the total exploration program.

At Silverfields, control-factor studies included: (1) selection of indicator elements; (2) selection of the best mineral or organic soil horizon and size fraction for sampling; (3) selection of the best tree species and organ of that species for sampling; (4) effects on metal distribution patterns of sampling density; (5) effects of environmental contamination; and (6) performance of the analytical methods.

RESULTS

Indicator Elements

The choice of the indicator elements determined in a geochemical and/or biogeochemical program is usually governed by several, often conflicting, matters, not excluding cost of analysis. These matters would include: mineralogy and geology of the deposit; type of sample medium analyzed; and the precision, accuracy and detection limit of the analytical methods for the desired indicator elements.

To measure the response of the arsenide group of minerals, Ag, Co and Ni were determined; similarly, Cu, Pb and Zn were determined for the chalcophile group, and Mn was determined because it is present in the dolomite gangue of the principal ore veins. Some data for As, Sb, Mo, W, Bi and Hg in till in the Cobalt area are given by Boyle (1969).

Comparison of (A_o+A_1)-Horizon and B-Horizon Results

A profile plot of Ag, Co, Ni, Cu, Pb, Zn and Mn concentrations in (A_o+A_1)- and B-horizon soils collected at 50-foot intervals on line 600E is shown in *Figure 3*. It is obvious by comparison that the (A_o+A_1) horizon is significantly enriched in each indicator element. Observations of this type of enrichment are becoming more common (for example, Boyle, 1969; Hornbrook, 1969a, b, 1970; and Warren and Delavault, 1960). The relatively flat profile of the plotted B-horizon concentrations (*Figure 3*) over the principal ore veins (*Figure 1*) demonstrates its failure to develop anomalies over leakage halos. This partly explains why most conventional B-horizon pedogeochemical exploration in the Cobalt area is unsuccessful. Table I shows averaged concentrations of the indicator elements in $(A_o + A_1)$-, and B- and C-horizon soils collected from several stations in both anomalous and background areas.

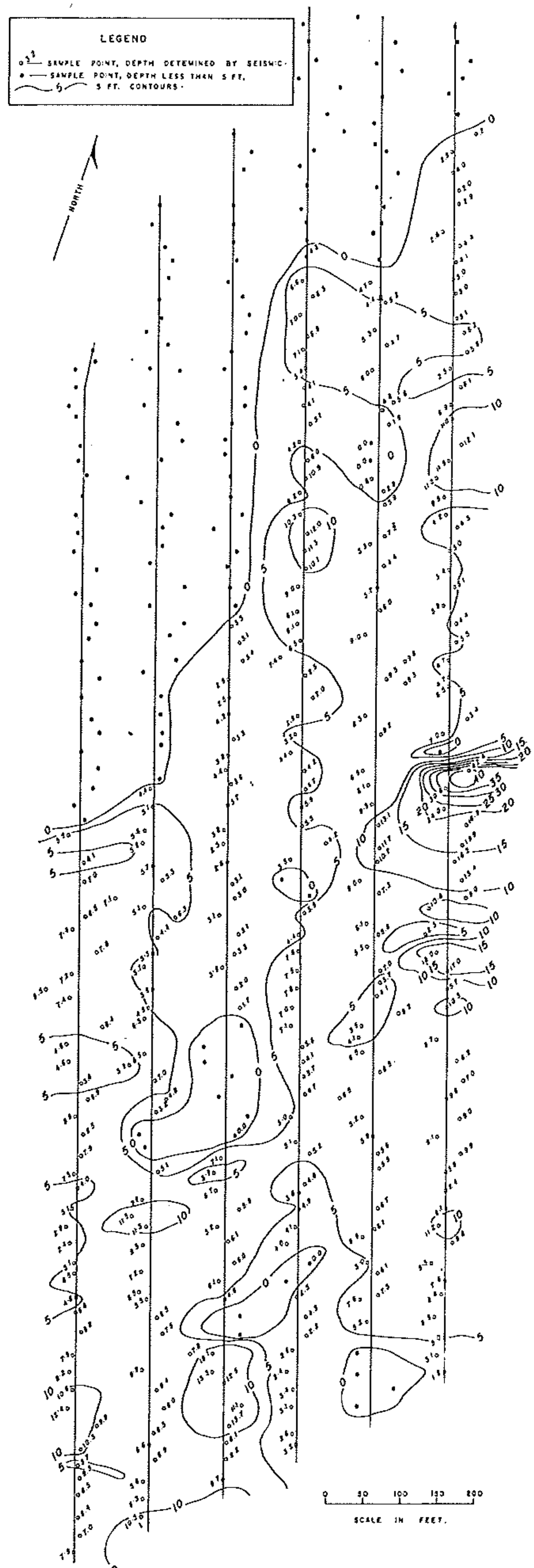

FIGURE 2 — Thickness of Till, Silverfields Property.

The enrichment of indicator elements in the (A_0+A_1) horizon in both areas is again evident. In addition, the C horizon would be even less effective than the B horizon for pedogeochemical exploration, because it has even less of a content of indicator elements. Subsequent studies showed that the minus-10-plus-80-mesh fraction of the (A_0+A_1) horizon contained the highest indicator-element content. Therefore, the (A_0+A_1) horizon is the best sample medium for pedogeochemical exploration in the Cobalt area.

Comparison of Biogeochemical Results

Similar comparative studies were carried out for the following biogeochemical samples: bark, leaf and second-year twig and/or spur organs of white birch and trembling aspen trees on lines 300E and 600E. These were the only tree species which grew in sufficient abundance and uniform density for sampling purposes over the total grid. Comparison of the biogeochemical results showed the following relationships: (1) white birch — spurs were enriched in indicator elements relative to the conventional sample organ, second-year twigs, as well as bark and leaves; (2) trembling aspen — bark had the lowest concentration of indicator elements, and leaves preferentially concentrated Co and Ni, but they had a content of Ag, Mn, Cu and Pb similar to that of second-year twigs; and (3) birch spurs had a higher indicator-element content than either trembling aspen leaves or second-year twigs. Therefore, white birch spurs are the best tree organs to sample for biogeochemical exploration in the Cobalt area. However, where birch is not available, second-year twigs of trembling aspen, rather than leaves, should be sampled, mainly because the younger leaves undergo morphological changes, accompanied by a variation in their element content, during growth. The variation in element content of young relative to older growth has been recognized by Warren *et al.* (1955).

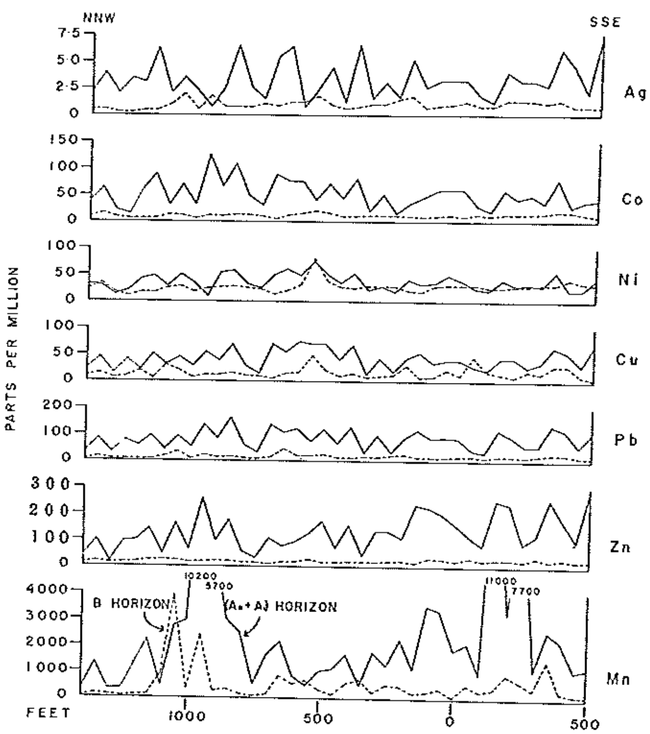

FIGURE 3 — (A_0+A_1)- and B-Horizon Metal Content.

Leakage Halos

Some probable features of the leakage halos and their development are: (1) thin, vertical seams extending upward from principal ore veins through 200 feet of overlying diabase probably do not develop as a continuous fracture along strike at the sub-outcrop surface across the total grid; (2) in fact, probably not all of the principal ore veins have an extension to the sub-outcrop surface; (3) fractures in the sub-outcrop surface of the diabase may only be partly mineralized along their strike length; and (4) the silver veins are very irregular and discontinuous along their strike length.

Therefore, it is unrealistic to expect a long, linear, continuous leakage halo to develop in the till coincident with the silver vein at depth; rather, for many of the veins, a series of disconnected shorter linear halos develop along the projected path of the silver vein. In the shallow till (*Figure 2*), leakage halos probably do not move a significant amount southeast, down the gentle hillslope.

Silver Distribution as a Function of Sample Interval

Computer-drawn anomaly maps (*Figure 4*) show four variations in the anomalous distribution of silver in (A_0+A_1)-horizon soils, produced by altering the sample interval from 25- to 50- and 100-foot spacings. To determine the maximum sample interval permissible, for a detailed program such as this one, the computer program was altered to expand the sample density until the meaningful anomalous pattern deteriorated beyond the necessary requirements for interpretation. Both possible 50-foot sample interval maps are given in *Figure 4* to permit comparison between them.

TABLE I — Comparisons of the Concentrations of Indicator Elements in (A_0+A_1)-, B- and C-Horizon Soils

Indicator Elements (average concentrations in ppm)		Ag	Ni	Co	Cu	Pb	Zn	Mn
ANOMALOUS AREA	(A_0+A_1) horizon	2.5	37.0	22.5	69.0	147.0	215.0	2350
	B horizon	.75	23.0	13.0	14.5	16.0	19.5	350
	C horizon	.40	12.5	6.0	1.5	2.5	12.0	75
BACKGROUND AREA	(A_0+A_1) horizon	.61	15.1	7.6	26.1	31.0	198.0	2080
	B horizon	.22	12.1	6.4	3.7	9.1	18.3	84
	C horizon	.14	10.1	3.7	5.9	6.2	12.0	72

At 25-foot sample intervals, the silver anomaly map (*Figure 4*) shows that closely spaced leakage halos from surface fractures of the Nipissing diabase are individually detected as narrow, strongly linear, disconnected anomalies perpendicular to the traverse lines in the center 'target' area of the grid. At 50-foot intervals (*Figure 4*), the linear character of the silver anomalies is only partly maintained and they do not distinguish individual leakage halos. Significantly, the two 50-foot-interval anomaly maps, in places, show radical differences: (1) the linear character is greater in the topmost of the 50-foot-interval maps; and (2) anomalous zones along the west side are present in only one map. Thus, the anomalous distribution of silver in the 50-foot-interval maps is not only unreliable, it is also not as effective in detecting individual halos as the 25-foot-interval map described above. However, the central part of the grid is still defined as the interesting target area.

The strong narrow linear character of the silver anomalies on the 25-foot-interval map has completely deteriorated on the 100-foot-interval map (*Figure 4*). Furthermore, there is now a possible interpretation of a north-south trend of silver distribution as well as the original east-west trend perpendicular to the sample traverse lines. Although the central anomalous target area is still defined, it is now detected by only nine anomalous samples.

Here it is important to point out that conventional pedogeochemical exploration would have employed a similar net-type grid, but with 100-foot or greater sample intervals between all sample sites. It is debatable, but had B-horizon soils been collected off this sample grid at 100-foot intervals, then the anomalous leakage halos developed in the till over the complex principal ore veins at Silverfields might not have been detected. This conjecture is probably true because of the reduced content of silver in the B horizon compared to the (A_0+A_1) horizon and because, at this expanded 100-foot interval, only nine of the silver-enriched (A_0+A_1)-horizon samples were anomalous, suggesting that an insufficient number of B-horizon samples would be anomalous for positive detection of the central target area.

Thus, the 25-foot-interval silver anomaly map defines individual leakage halos as well as the central target zone and the 50- and 100-foot-interval maps successfully define only the central target zone. Only the 100-foot sample interval scale is sufficiently large to apply over areas greater than the grid or the Silverfields property. The property is approximately 70 acres in size.

Therefore, 100-foot-interval sampling could be carried out in large areas, followed up by detailed 25-foot-interval sampling to detect individual leakage halos, provided that the suspected target is similar in size to the silver vein deposits at Silverfields. If the target is smaller than the Silverfields deposits (i.e., a single narrow silver vein remote from other veins), then 25-foot-interval sampling is necessary to achieve successful detection. The 50-foot-interval scale is not dense enough for detailed work and probably is denser than required for large-scale programs.

Surface Contamination

Surface contamination will frequently produce anomalies equal to, or of greater significance than, those developed from geochemical leakage halos in the till generated by silver veins. Therefore, extreme care must be exercised in the layout of sample traverses and in the interpretation of developed anomalies. Contamination originates from old mine dumps, trenches, pits, tailings ponds and abandoned surface workings, which are common throughout the area as a result of several decades of mining activity.

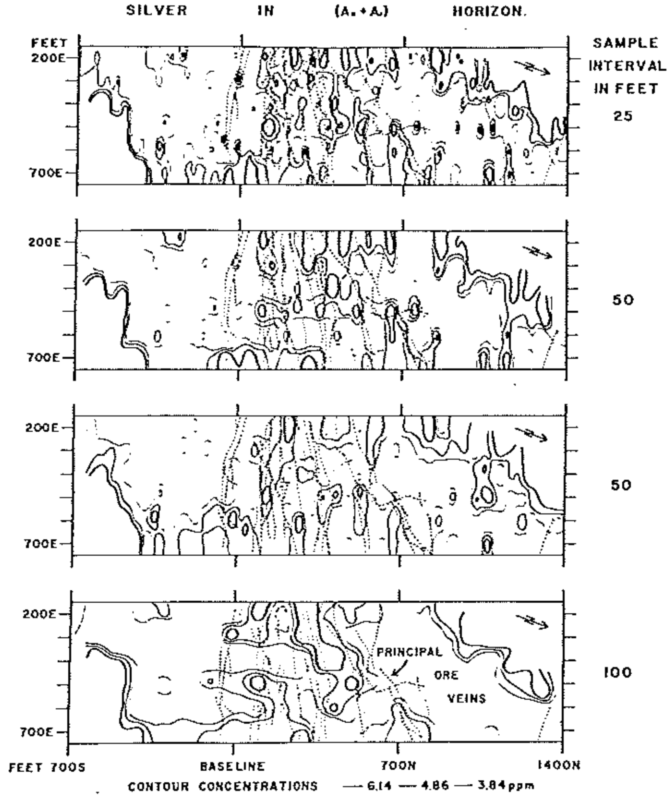

FIGURE 4 — Silver Anomalies as a Function of Sample Interval.

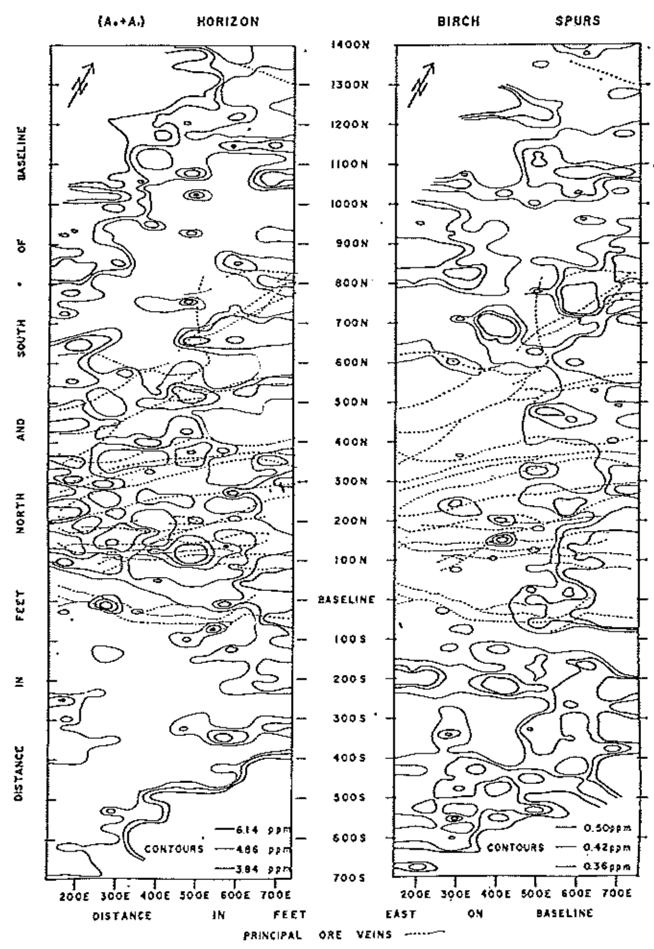

FIGURE 5 — Geochemical Anomaly Map — SILVER.

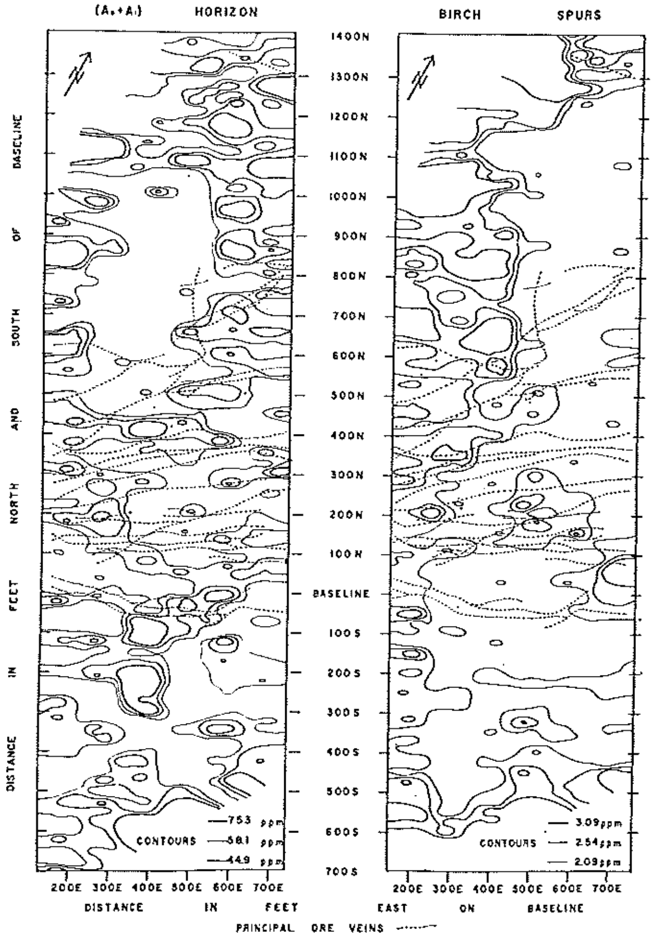

FIGURE 6 — Geochemical Anomaly Map — COBALT.

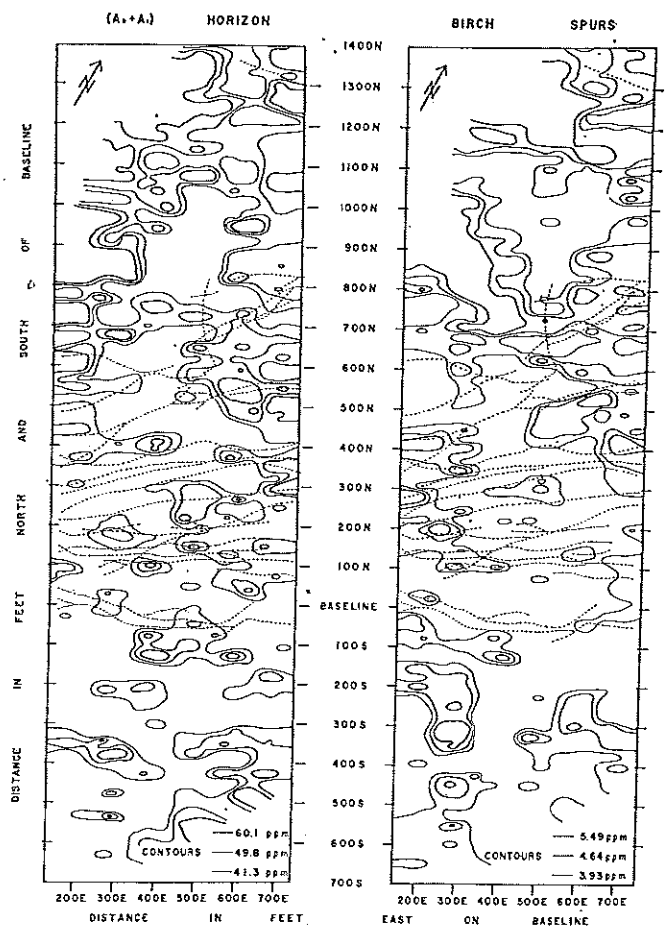

FIGURE 7 — Geochemical Anomaly Map — NICKEL.

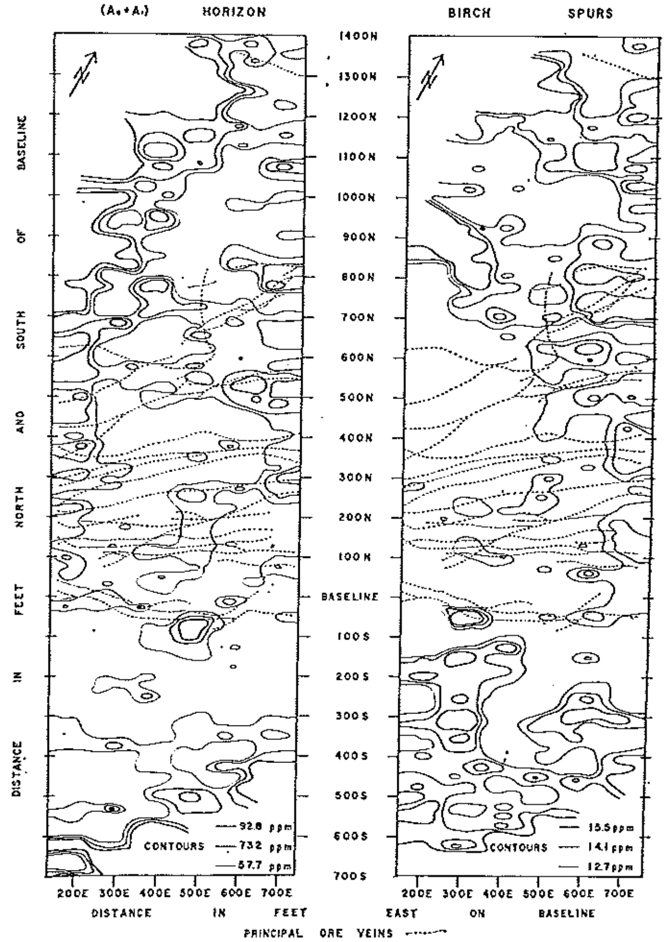

FIGURE 8 — Geochemical Anomaly Map — COPPER.

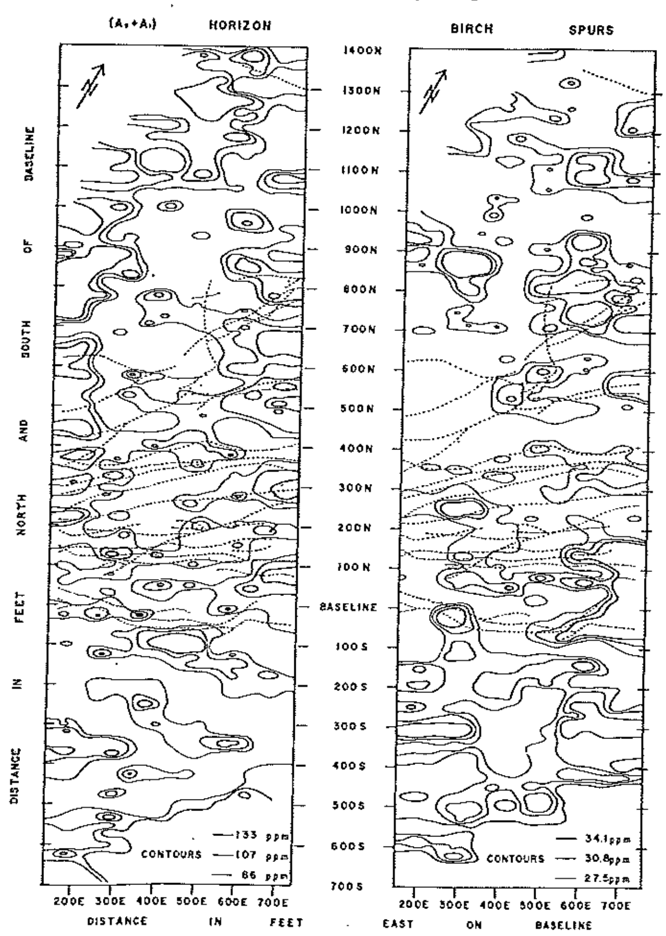

FIGURE 9 — Geochemical Anomaly Map — LEAD.

Many of the mine access roads in the Cobalt area were constructed from mine waste rock which is sufficiently mineralized to contaminate vegetation and soils up to tens of feet from the edge of the road. Lead contamination from car exhaust gases was found in soil up to one hundred yards from arterial highways in British Columbia (Warren *et al.*, 1960).

Contamination of the first type is evident on the Ag, Co, Ni, Cu, Pb and Zn anomaly maps in *Figures 5* to *10* respectively; it has produced a large anomalous zone at the extreme south end of the grid. Here, stations at the south end of traverse lines are coincident with and only several feet from the Silverfields mine access road. Furthermore, the broad character of some element anomalies (Ag, Pb, Zn, *Figures 5, 9, 10*) on the east side of the grid near the baseline, particularly for birch spurs, may be due in part to wind-blown dust contamination from the mineralized waste rock in the adjacent mine parking lot, which begins approximately 200 feet east of line 700E.

A similar strong anomalous zone for Ag, Co, Ni, Cu and Pb (*Figures 5* to *9*) occurs across the northwest and northern part of the grid, but is not to be confused with anomalies generated by contamination. The strong, broad character of this anomalous zone is produced only because the trees, from which the humus is derived, grow in, and receive their nutrients from, patches of soil and humus trapped in crevasses and weathered fractures. There is little or no soil or trees elsewhere in this part of the sample grid (*Figure 2*). Most of the ground at the north end of lines 200E to 500E (*Figure 1*) consists of fractured bedrock and broken rock rubble at the top of a steep hill face. Thus, the element content of trees and humus reflect strikingly the mineralization present in many of these fractures — more so than trees growing above fractures in the southern till-covered part of the grid.

Therefore, contamination or apparent contamination can become very significant, producing anomalies equivalent to those produced by geochemical leakage halos from silver veins.

Anomaly Maps

The following principal observations are warranted after an examination and comparison of the effectiveness of each anomaly map in detecting the silver vein deposits. Each figure shows an anomaly map for the same element in white birch spur organs and in the (A_o+A_1) horizon. *Figures 5* to *11* show anomaly maps for Ag, Co, Ni, Cu, Pb, Zn and Mn respectively.

(1). A given element is not necessarily equally effective in the (A_o+A_1)-horizon and birch-spur anomaly maps; i.e., silver, cobalt or copper in *Figures 5, 6* and *8*. This difference is probably due in part to the complex chemistry of humus, the nature of nutrient uptake in the sample tree and the influence of wind-blown dust contamination.

(2). Silver in the (A_o+A_1) horizon (*Figure 5*) appears to be the most effective. The map shows that individual leakage halos from sub-outcrop fractures are detected and can be related to the projected path of principal ore veins at depth.

(3). Other anomaly maps are also effective: Pb, Zn and Mn in the (A_o + A_1) horizon and birch spurs (*Figures 9, 10* and *11*, respectively); and Co and Ni in (A_o + A_1) horizons (*Figures 6* and *7*).

(4). Copper anomaly maps are not effective.

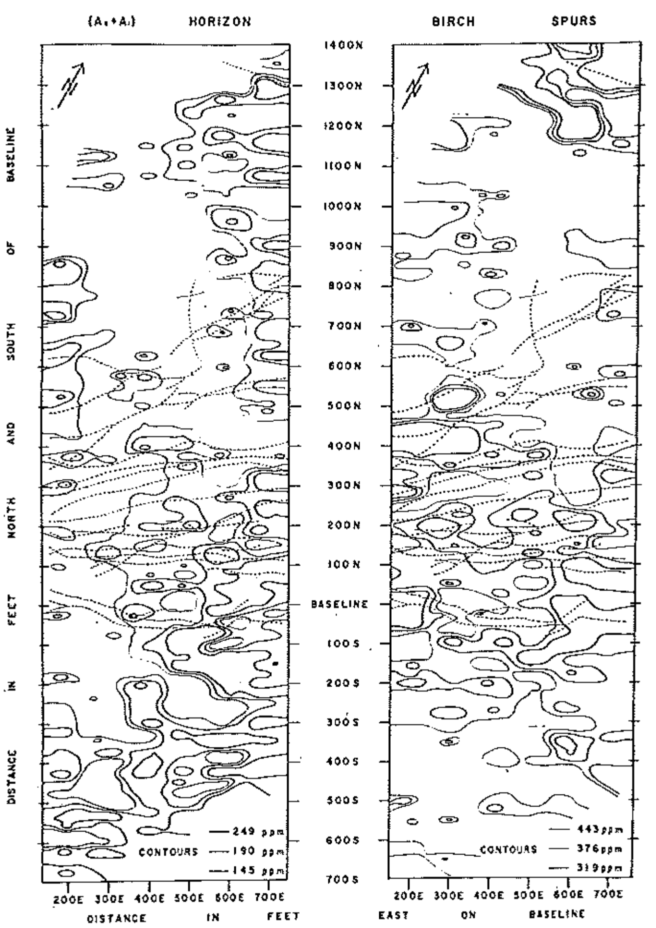

FIGURE 10 — Geochemical Anomaly Map — ZINC.

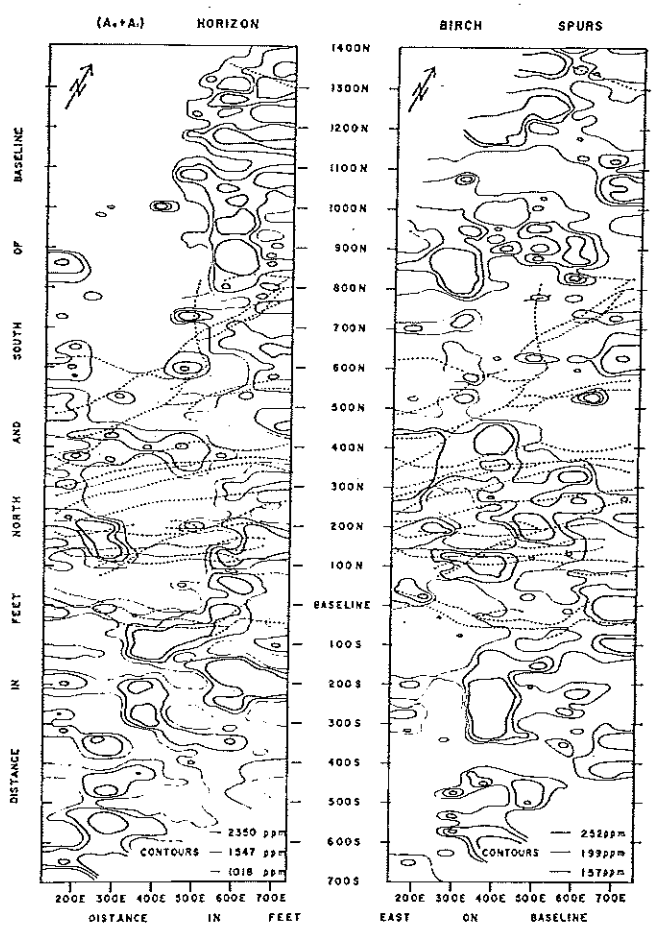

FIGURE 11—Geochemical Anomaly Map—MANGANESE.

(5). Silver veins, such as the one from 200W on the west side to 300N on the east, which is particularly well defined by silver and lead in the (A_o+A_1) horizon (*Figures 5* and *9*), probably have a well-developed and mineralized-related fracture system in the sub-outcrop surface of the diabase and therefore a well-developed leakage halo in the overlying till.

(6). Most of the cobalt anomalies in birch spurs are present along the west side of the anomaly map (*Figure 6*), possibly as a reflection of the zoning in the silver vein deposits. According to Petruck (1968), first the CoNi-As and then the CoAs zones occur successively west of, and below, the upper eastern NiAs zone. This relationship of the zones creates a preferentially cobalt-rich western part while more or less evenly distributing the nickel across the grid. The western preference for cobalt is evident only in birch spurs (*Figure 6*); the even distribution of nickel is evident in both sample materials (*Figure 7*).

(7). The anomalous distribution pattern of most elements tends to be exhibited by a series of disconnected linear blobs, with barren spaces between them, along the projected path of a vein.

(8). On many anomaly maps, and most obvious on the map of silver in birch spurs (*Figure 5*), the most interesting anomalies are coincident with real or apparent contamination and not with the principal ore veins in the central part of the sample grid.

SUMMARY AND CONCLUSIONS

Many of the problems of surface exploration in the Cobalt area have been described: (1) the silver veins are narrow, vertical, frequently discontinuous, deeply buried targets that do not generate large geochemical leakage halos in the till; (2) there is extensive contamination; and (3) there are difficulties because of the bedrock cover of till and glacio-fluvial deposits and the masking effect of clay deposits. Problems inherent in geochemical and biogeochemical exploration programs in the area have been researched: (1) choice of indicator elements; (2) selection of the best sample medium for geochemical and biogeochemical sampling; (3) sample density; and (4) the effect of anomalies generated by real or apparent contamination on the indicator-element distribution in anomaly maps.

A study of these problems and the effectiveness of geochemical and biogeochemical exploration in the Cobalt area reveals the following.

(1). The best indicator elements, in decreasing order of merit, are: Ag, (Pb, Zn and Mn), Co and Ni. Only Cu, of all the indicator elements selected, does not seem to be of some merit.

(2). The best sampling medium for geochemical exploration is the minus-10-plus-80-mesh part of the A_o + A_1) horizon; for biogeochemical exploration, the best media are white birch spurs, or, if white birch is not available, second-year twigs of trembling aspen. For most indicator elements, the best results are obtained in the (A_o+A_1) horizon rather than with white birch spurs.

(3). A given indicator element is not necessarily equally effective in producing (A_o+A_1)-horizon and birch-spur anomaly maps.

(4) A map of silver in the (A_o + A_1) horizon (*Figure 5*) is the most effective anomaly map because it detects most individual leakage halos in the till that are generated from mineralized fractures in the sub-outcrop of the diabase. These leakage halos are related to principal ore veins at depth. A map of silver in white birch spurs (*Figure 5*) is among the least effective of all anomaly maps to the extent that its most interesting anomalies are coincident with real or apparent contamination and not with the principal ore veins.

(5). Therefore, interpretation is difficult, if not impossible, unless only certain effective combinations of indicator elements and sample media are used. These combinations are: in (A_o+A_1) horizons, in decreasing order of effectiveness — Ag, (Pb, Mn and Zn), Co and Ni; in birch spurs, in decreasing order — Mn, Zn and Pb.

(6). Where the (A_o+A_1) horizon is available for sampling, B-horizon soils should not be collected because they have a much lower and insufficient content of silver and associated elements. It is probable that some unsuccessful pedogeochemical programs in the Cobalt area failed only because B-horizon soils were sampled.

(7). There is an important relationship among sampling density, features of the target and the extent of ground to be explored by a geochemical program. Large-scale programs to detect large targets could employ 100-foot-interval sampling to be followed up by detailed sampling. Detailed work on 25-foot intervals would detect individual silver veins after large anomalous target zones are defined within the total program area.

However, if the target is expected to consist of only one or two silver veins, then 25-foot sample intervals are necessary even over the total program area. Otherwise, the detection of one or two small difficult targets may not be possible.

Samples should be collected off a sampling grid comprised of two or more traverse lines rather than a single line, because the discontinuous nature of leakage halos in the till creates barren gaps along the strike of a vein. Because of the gaps, a single traverse line over a target as large as the Silverfields deposits, where even the most effective combination of indicator elements and sample media are used, has only a limited potential for success if samples are collected on intervals of 100 feet or, for some lines, even 25 feet.

(8). It is evident that successful detection is most unlikely if B-horizon soils were collected at 100-foot intervals or less from a single traverse line at Silverfields, and it is doubtful that success would be achieved even if they were collected off a sample grid over the deposit.

(9). Contamination or apparent contamination can become very significant, producing anomalies equivalent to, or greater than, those produced by leakage halos in the till.

(10). The following developed characteristics of the anomalies — a series of short, disconnected, linear-blobs, strung out along the projected path of a silver vein — is expected, considering the features and development of the leakage halos generated in the overlying till from principal ore veins in the Coleman Formation sediments.

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