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GEOCHEMICAL AND BIOGEOCHEMICAL EXPLORATION METHODS RESEARCH IN THE COBALT AREA, ONTARIO

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(with a contribution by G.D. Hobson)

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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CONTENTS

Illustrations

ABSTRACT

A study of the effectiveness of geochemical and biogeochemical exploration methods in detecting silver vein deposits was carried out on the Silverfields, Hi Ho, and Agnico O'Brien properties in the Cobalt area, Ontario. Bark, leaf, twig and spur organs of trembling aspen and white birch, and the $(A_0 + A_1)$, B, and C horizon soils were analyzed for Ag, Co, Ni, Cu, Pb, Zn and Mn by atomic absorption methods. The following conclusions were reached:

1. Ag, Co, Ni, Pb, Zn, and Mn are effective indicator elements. Cu does not seem to be useful.
2. The $(A_0 + A_1)$ horizon is enriched in all indicator elements relative to the B and C horizons, and, with the exception of Zn, all tree organs.
3. The most effective sample medium for geochemical exploration is the minus 10 plus 80 mesh part of the $(A_0 + A_1)$ horizon. For biogeochemical exploration, the most effective is white birch spurs; trembling aspen second year twigs are suitable if white birch is not available.
4. In the $(A_0 + A_1)$ horizon, the most effective indicator elements are Ag, followed by Co, Ni, Pb, Zn and Mn. In birch spurs, Pb, Zn and Mn are effective.
5. There is an important relationship among sampling density, features of the target, and the extent of ground to be explored by a geochemical program.
6. Contamination can produce anomalies equivalent to, or greater than, leakage halos in the till.

RÉSUMÉ

On a effectué une étude sur l'efficacité des méthodes d'exploration géochimiques et biogéochimiques dans la détection des filons d'argent, sur les concessions Silverfields, Hi Ho, et Agnico O'Brien dans la région de Cobalt, en Ontario. Pour reconnaitre la présence de Ag, Co, Ni, Cu, Pb et Mn, on a appliqué les méthodes d'absorption atomique à l'analyse des écorces, des feuilles, des brindilles et des rameaux de tremble et de bouleau blanc, ainsi qu'aux horizons des sols $(A_0 + A_1)$, B et C. L'étude a abouti aux conclusions suivantes:

1. Ag, Co, Ni, Pb, Zn et Mn sont des éléments indicateurs efficaces. Seul Cu semble être inutile.
2. L'horizon $(A_0 + A_1)$ est riche en éléments indicateurs par rapport aux horizons B et C; tous les échantillons prélevés sur les arbres ont les mêmes éléments sauf Zn.
3. Le milieu le plus efficace en ce qui concerne les échantillons nécessaires à l'exploration géochimique est la partie dont les grains passent par les mailles allant de moins 10 à plus 80, dans l'horizon $(A_0 + A_1)$. Pour l'exploration biogéochimique, les rameaux de bouleau blanc fournissent les échantillons les plus efficaces; les brindilles des trembles âgées de deux ans conviennent si l'on ne dispose pas de bouleau blanc.
4. Dans l'horizon $(A_0 + A_1)$, les éléments indicateurs les plus efficaces sont Ag, suivi de Co, Ni, Pb, Zn et Mn. Dans les rameaux de bouleau, Pb, Zn et Mn sont les plus efficaces.
5. Il existe une importante relation entre la densité d'échantillonnage, les caractéristiques de l'objectif et l'étendue de terrain à explorer dans un programme géochimique.
6. La contamination peut provoquer des anomalies d'importance égale ou supérieure à celle des halos dûs aux fuites dans le till.

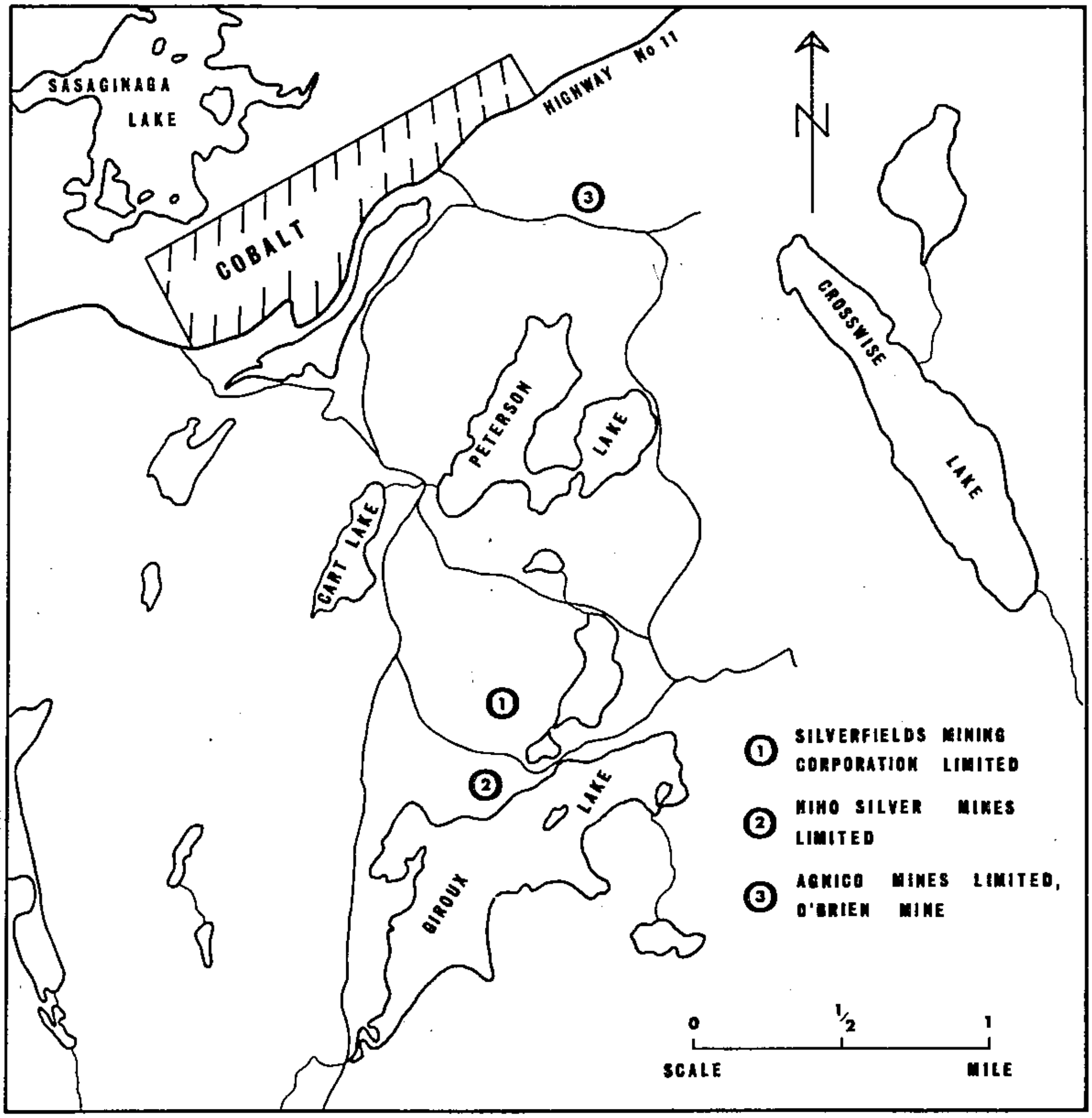

Figure 1. Cobalt area, Ontario: mine location map.

GEOCHEMICAL AND BIOGEOCHEMICAL EXPLORATION METHODS RESEARCH IN THE COBALT AREA, ONTARIO

INTRODUCTION

A study of the effectiveness of geochemical and biogeochemical exploration methods in detecting silver vein deposits at the properties of the Silverfields Mining Corporation Ltd., Hi Ho Silver Mines Ltd., and Agnico Silver Mines Ltd., was carried out during the summer of 1968. The properties are a few miles southeast of the town of Cobalt, Ontario (Fig. 1), which is 5 miles west of Lake Timiskaming and 95 miles north of North Bay, Ontario.

The effectiveness of the methods was determined by detecting anomalous concentrations of trace elements in the glacial till and vegetation, and then relating the anomalous halos to the occurrence of principal ore veins. There are, however, many difficult problems associated with geochemical and biogeochemical exploration at Cobalt. Individual silver veins are thin, vertical, anastomatic, frequently discontinuous, deeply buried targets that do not generate large geochemical halos in the overlying till. Furthermore, extensive contamination of the landscape has commonly modified or completely obliterated geochemical anomalies related to trace element leakage halos, thus complicating the interpretation of element anomaly maps. Surface exploration problems are further compounded by the presence of glacial deposits of boulder till, glacial clay, and glaciofluvial deposits of sands and gravels which cover much of the economically important bedrock. In many cases the glacial deposits effectively mask the surficial extensions of known silver veins so that they cannot be detected by conventional geochemical exploration methods. Koehler et al. (1954) found that the cobalt content of the glacial deposits near bedrock could be used to detect silver veins only when the veins extend to the bedrock surface. Boyle et al. (1969) pointed out that although trace element analyses of clay and derived soils were not effective for geochemical prospecting for silver veins, the till and derived soils should be effective. In the present study the bark, leaf, and twig organs of aspen, poplar, and white birch, the spur organs of the white birch, and the (A_0+A_1), B, and C horizon soils were analyzed for Ag, Co, Mn, Cu, Pb and Zn. All analytical determinations and the initial compilation of the data were completed at the field base camp at Haileybury, a few miles north of Cobalt via Highway No. 11.

Shallow seismic determinations of the depth and nature of the surficial material were carried out by a two-man crew under the direction of G.D. Hobson of the Geological Survey. His report describing their work and results forms Appendix A.

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Acknowledgments

The writer supervised the total project which was divided into field and analytical operations. R.R. Cranston, assisted by D.E. Howe, B.J. Wakeford and R.J. Buchanan, was in charge of the atomic absorption laboratories and sample processing laboratories. W.F. Tuer, assisted by D.M.V. Coombes and D.O. Merriman, was in charge of field operations.

The writer wishes to express his thanks to J.D. Frey, Dean of the Haileybury Campus, Northern Institute of Applied Arts and Technology, for the Institute's permission to use a laboratory in the school for analytical operations, and for a base camp site on the campus to accommodate two mobile trailer laboratories. The writer also wishes to thank the many mine managers and geologists of the Cobalt area for their assistance and co-operation, in particular H. Moore, G. Ninacs, and B. Thorniley of Silverfields Mining Corporation Ltd., Glen Lakes Silver Mines Ltd., and Agnico Mines Ltd. respectively.

The writer appreciates the vital assistance of J.J. Lynch of the Geological Survey for establishing the atomic absorption method of analysis employed, and for training the analytical staff prior to its departure for the field.

General Description of the Landscape

The geology of the Cobalt–New Liskard area has been described by Miller (1908, 1913), Knight (1924), Thomson (1956, 1960a, b, 1962, 1964a, b, c), Boyle et al. (1969) and others. Steeply dipping Archean (Keewatin) mafic to intermediate lavas with interflow bands of chert, tuff and agglomerate make up most of the basement rock of the area. These are overlain in places by steeply dipping greywacke, quartzite, and conglomerate of the Archean Timiskaming Group. Granitic plutons and basic dykes and sills intrude both Keewatin and Timiskaming rocks. The Proterozoic Cobalt Group of sediments, mostly conglomerate, greywacke, and quartzite, lies unconformably on Archean basement rocks. Gently dipping quartz diabase sheets have intruded both Archean and Proterozoic rocks. Ordovician and Silurian limestones, shales and dolomites in places overlie all earlier rocks.

The rugged broken topography of the area is typical of the Canadian Shield. In the vicinity of Cobalt a peneplain has been eroded into steeply rolling till-covered or rocky hills separated by narrow linear valleys. The trends of the valleys were determined by bedrock faults and/or preglacial and glacial erosion. Only a few of the highest hills exceed 1,150 feet in elevation. Silverfields and Hi Ho mines are located on the southern slope of Diabase Mountain, elevation 1,250 feet. Details of the topographic profiles of the outcrop and suboutcrop surfaces, and the nature and depth of surficial material are given in Appendix A for each of the mine properties.

Drainage follows either the gentle northeasterly dipping peneplain to Lake Timiskaming or southwest valleys to Montreal River. Soil drainage is good except in low-lying valleys where peaty soils are water-saturated. The glacial deposits in the Cobalt area consist of sand and gravels, varved clays, and boulder till. Typically, sand and gravel are present west and southwest of Cobalt at Gillies Lake, whereas varved clays are present in the "Little Clay Belt" north of New Liskeard and in some valleys near Cobalt. Boulder till is typically present on bedrock or underlies the other glacial deposits.

The climate of the area is temperate, with mean summer and winter temperatures of 65°F and 10°F respectively. Annual precipitation is approximately 32 inches. Brown Forest, Grey Wooded, Podzol, and Dark Grey Gleisolic soils which are dominant in the New Liskeard-Engleheart area described by Hoffman et al. (1952) are also dominant in the Cobalt area.

The development of a specific soil within this group is determined by the parent soil material, relief, forest cover, and drainage conditions. Boulder till and its derived soils, mainly Podzol, generally occur on the properties studied. Dark grey Gleisolic soils are developed on poorly drained till in valleys.

In Rowe's (1959) Forest Regions of Canada, the Cobalt area is shown as near the north boundary of the Timagami section and adjacent to the Haileybury clay section of the Great Lakes–St. Lawrence forest region. Rowe described the Timagami section as follows:

"This is a large upland area north of Lake Huron, stretching east and west from Lake Timagami, and occupying a generally southward-sloping surface. The northern boundary marks a diffuse transition to forest lands bearing a preponderance of boreal types.

"The typical association of the Section consists of white pine (Pinus strobus) with scattered white birch (Betula papyrifera) and white spruce (Picea glauca), although the spruce frequently rivals the pine in abundance. Another common though variable type is a mixture of the birch, pine and spruce, with balsam fir (Abies balsamea) and the aspens (Populus grandidentata, P. tremuloides). Both red pine (Pinus resinosa) and jack pine (P. banksiana) are present, the former often prominent in bluffs along ridges and the latter generally restricted to the driest sandy or rocky sites. The tolerant hardwoods, yellow birch (Betula lutea) and sugar maple (Acer saccharum), have only a scattered occurrence. The prevalent forest cover on the uplands is clearly a reflection of periodic past fires, and the sandy soils have provided conditions especially favourable for the propagation of white pine, red pine and jack pine. On the lowlands, in poorly drained depressions and in swamps, the black spruce (Picea mariana) with tamarack (Larix laricina) or cedar (Thuja occidentalis), form well-marked communities.

"The topography is gently to moderately rolling in the west, more rugged and broken in the eastern part. A shallow till overburden is usual on the hills, but extensive areas of exposed bedrock – Precambrian granite and gneiss, with local conglomerates and sandstones of the Huronian series – occur in all parts of the Section. Sandy and gravelly soils of glaciofluvial and fluvial origin, relating to the upper levels of glacial Lake Algonquin, contribute to the pine sites in the central and southern portion, and rock-cored drumlins, present in the western and eastern areas, are absent centrally. Podzol and peat soils characterize slopes and depressions, respectively."

In the vicinity of Cobalt, Ontario, a mixture of birch, pine and spruce with balsam fir and the aspens characterizes the forest vegetation. On the properties studied, trembling aspen and white birch are dominant accompanied by a less abundant growth of red pine, jack pine, spruce and balsam fir. Pines are common only on ridges or sandy rocky sites.

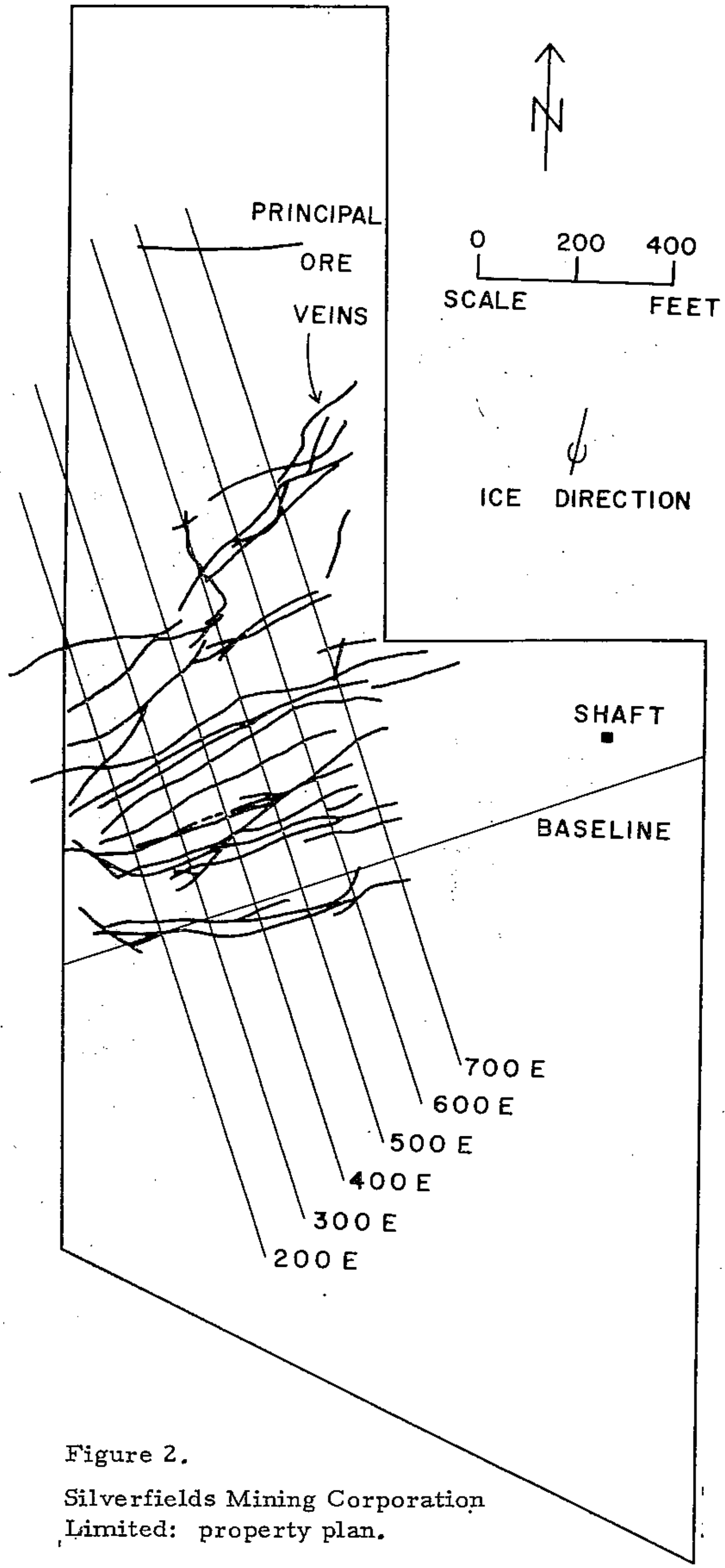


Figure 2.

Silverfields Mining Corporation Limited: property plan.

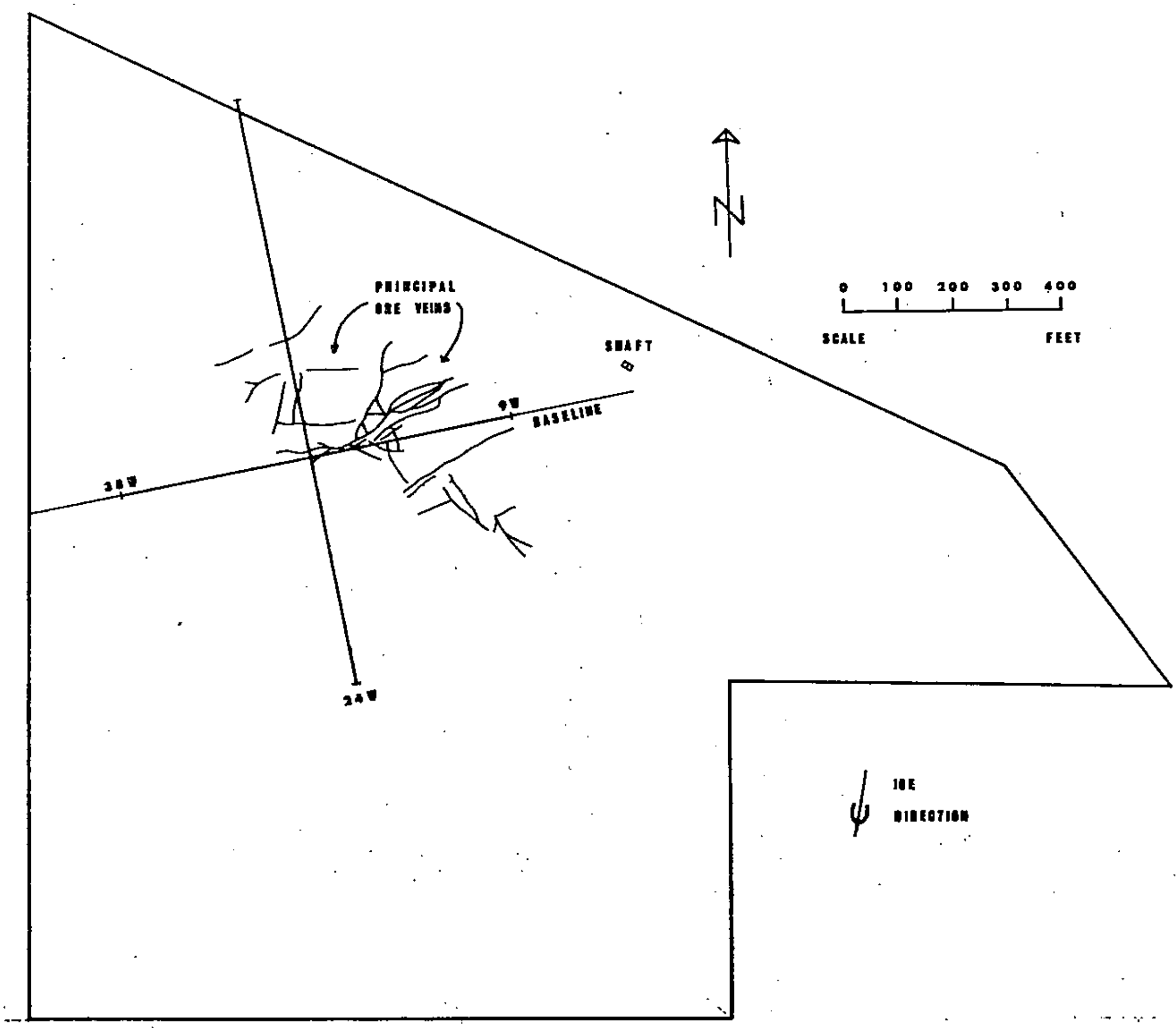


Figure 3. Hi Ho Silver Mines Limited; property plan.

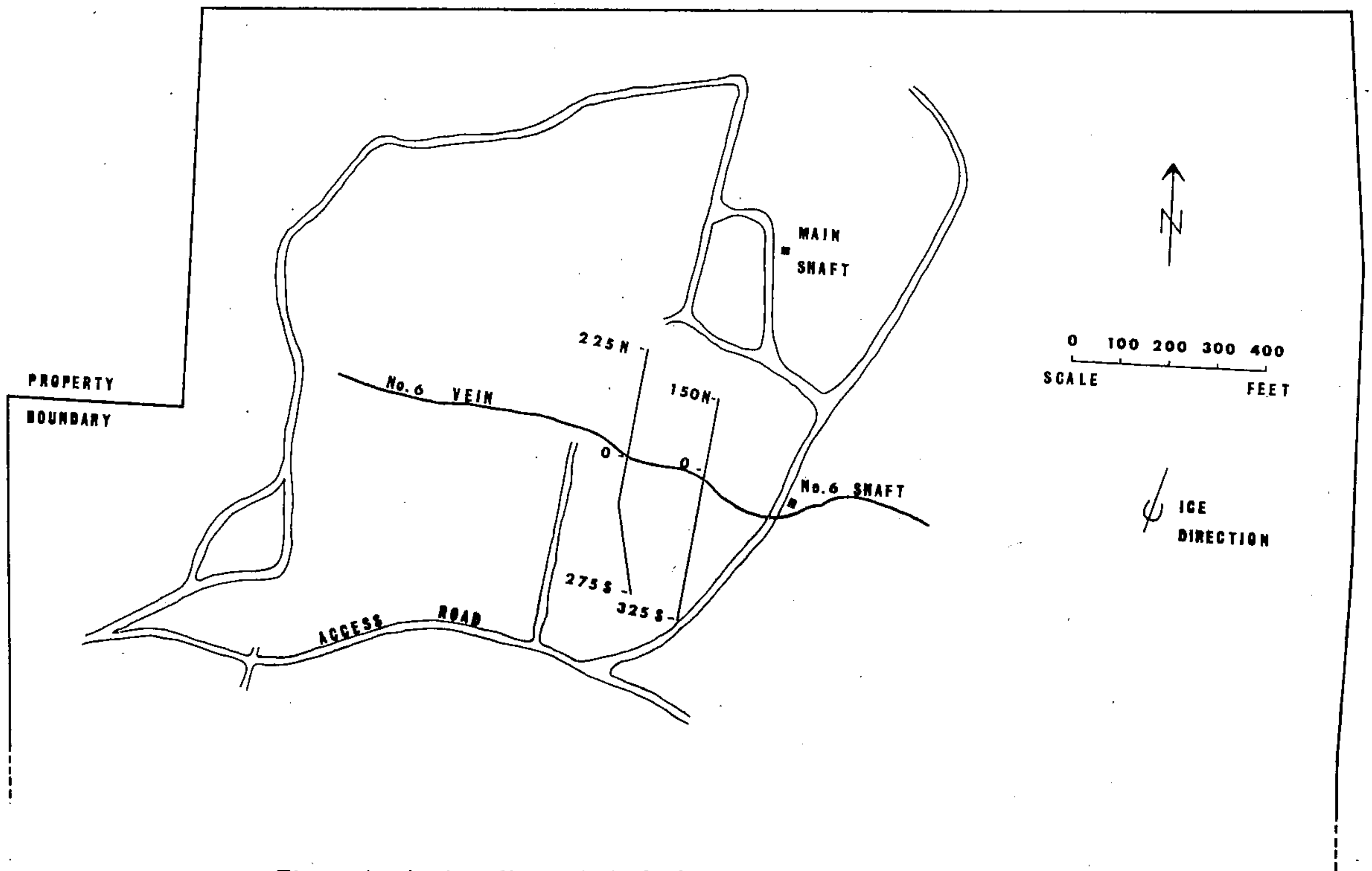


Figure 4. Agnico Mines Limited, O'Brien Mine: property plan.

DISCUSSION OF METHODS

Methods of Establishing Sample Traverses

Contamination of the environment from past and present mining activity is a real problem for biogeochemical and geochemical exploration. More than 50 years of mining and exploration activity at Cobalt has created a landscape replete with pits, trenches, mine shafts and dumps. Most rivers and streams are effectively contaminated from lakes used as tailings ponds. Many of the mine access roads of the area are constructed partly of mine waste rock which is sufficiently mineralized to contaminate significantly the adjacent forest vegetation and soils. Furthermore, relic mine access roads and railway beds constitute a source of contamination barely recognizable due to overgrowth by vegetation. Extreme care must therefore be taken to avoid contamination effects.

Traverse lines originally established in 1966 (Boyle et al., 1969) were partly utilized for this study. Only at the O'Brien No. 6 vein on the Agnico property (Fig. 4) were extensive modifications not required. At the Hi Ho property (Fig. 3) much of the forest vegetation cover on the original traverse lines had been removed prior to 1968 and one line was found unsuitable for sampling. At Silverfields (Fig. 2), the original traverse lines were extended and four new lines were added.

With the exception of the baseline at Hi Ho, traverse lines were established perpendicular to the dominant strike of the principal ore vein or veins at each property. Sample stations were established at 25-foot intervals on every traverse line, but some were initially sampled at 50-foot intervals. The total number of stations was 452 at Silverfields, 74 at Hi Ho, and 42 at Agnico.

Methods of Collection and Preparation of Sample Materials

Trembling aspen and white birch grew in sufficient abundance and with suitable growth density at Silverfields, but only the aspen was adequate for sampling purposes at Hi Ho and Agnico. The following tree organs were collected: birch and aspen bark (at breast height, 4 feet 6 inches from the ground); birch and aspen leaves; aspen second year twigs, birch spurs and second year twigs. Previous experience had shown (Hornbrook, 1969b) that only the above tree organs are necessary to obtain meaningful data on the metal distribution in sample trees. Of the (A_0+A_1), B, and C horizon samples, only the first was collected routinely at all stations.

Measurements of age, height, and breast height diameter of all sample trees were recorded in the field. A later examination of the measurements confirmed previous indications (Hornbrook, 1969a; 1970a) that for this type of study, there is no significant relationship among the measurements and the distribution or absolute concentration of metal elements in the samples. This is not unexpected because trees are deliberately chosen to maintain physical uniformity: aspen sample trees were generally about 35 feet high, 6 inches thick, and 40 years old; birch sample trees were generally about 30 feet high, 5 inches thick, and 45 years old.

Sample collection and preparation methods described by Hornbrook (1970a) were modified as required and are reproduced in Appendix B. Ashing

Figure 4. Agnico Mines Limited, O'Brien Mine: property plan.

techniques and associated problems have been discussed by Fortescue and Hornbrook (1967). Sample drying, subsampling, and ashing operations were carried out in two suitably equipped mobile trailer laboratories at the base camp.

Method of Analysis - Atomic Absorption Spectrophotometric

Prepared plant ash, mineral, and organic soils were analyzed in an atomic absorption laboratory set up in a spare laboratory room in the main building on the Haileybury campus. Briefly, the atomic absorption analyses involve the following operational procedures:

1. 200 mg of plant ash or soil are placed in a test tube and 3 ml of HNO_3 are added.
2. Each test tube is shaken and placed in a water bath at 90°C. The sample material is leached for one hour and the tubes are shaken every 10 minutes.
3. Tubes are removed and the sample solution diluted up to 10 ml with metal-free water. The tubes are again shaken, and the solution is allowed to stand for about three hours to permit suspended particles to settle to produce a clear solution.
4. The sample solution is aspirated into the flame of the atomic absorption unit and absorption percentage is recorded.
5. Element concentration in ppm is obtained from percentage absorbance by use of a standard curve showing percentage absorbance versus concentration in μ/ml.
6. The data for element concentrations in plant ash are converted to ppm on an oven-dry basis by using the previously determined percentage of sample ash for the calculation.

DISCUSSION OF RESULTS

Pilot Studies

A preliminary compilation of analytical results in necessary in the initial stages of biogeochemical and geochemical exploration programs because many control factors affecting the performance of the methods employed must be evaluated if optimum results are to be achieved. These control factors include: (1) selection of the appropriate indicator elements; (2) selection of the best mineral or organic soil horizon and size fraction for analysis; (3) selection of the best tree species and organ of that species for sampling; (4) element distribution patterns as a function of sample density; (5) effect of environmental contamination; and (6) performance of the sample collection, preparation, and analytical methods with respect to precision, accuracy, and element detection limits.

Analytical data obtained from analysis of initial sample suites collected on single-line traverses were compiled, mostly in profile plots, and evaluated. The control factors are described in the sections that follow.

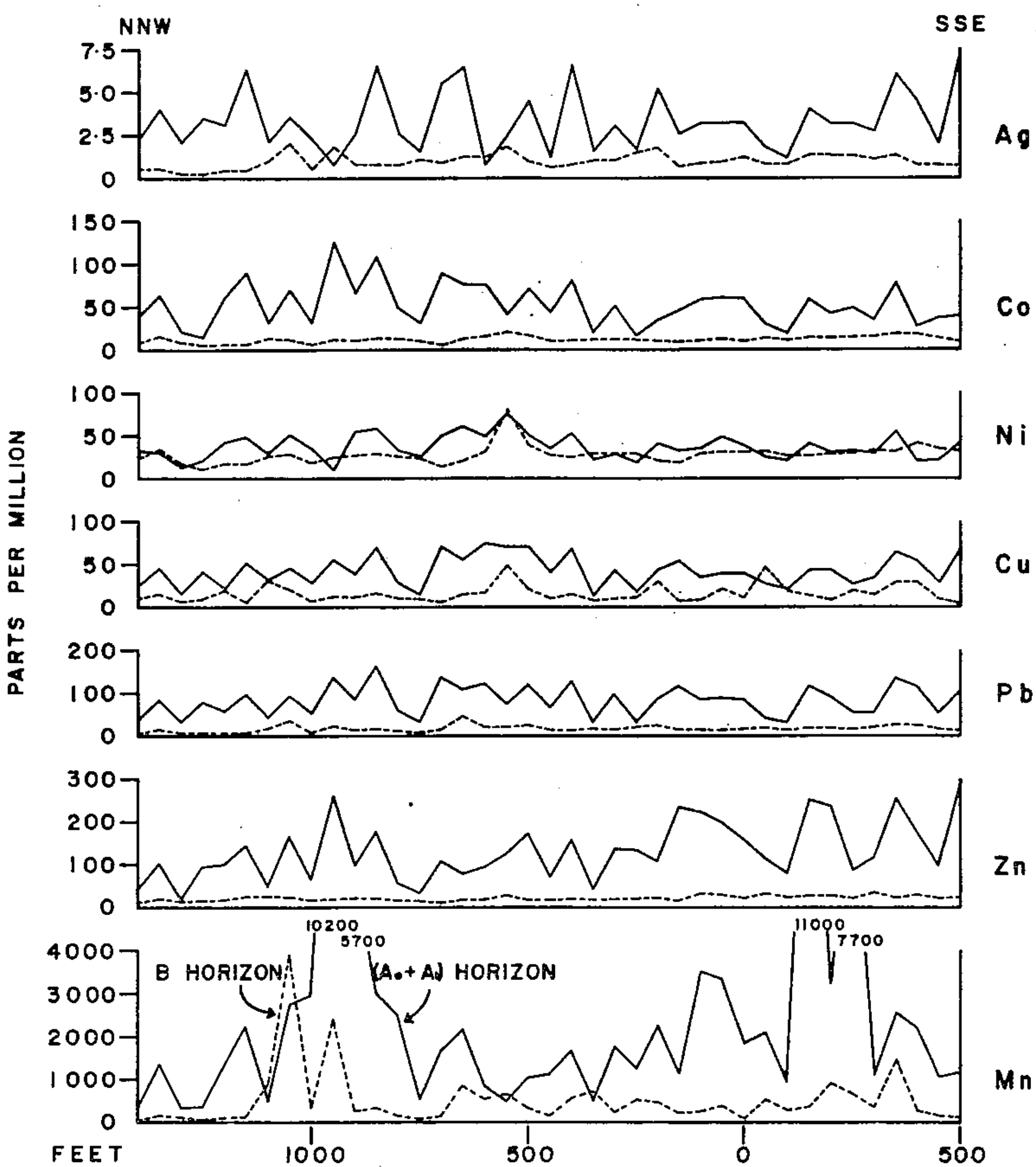


Figure 5. (A_0+A_1) and B horizon soil metal content: Silverfields.

Indicator Elements

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

To measure the response of the arsenide family of minerals, Ag, Co and Ni were determined; similarly Cu, Pb and Zn were determined for the chalcophile family, 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 in Boyle <u>et al.</u> (1969).

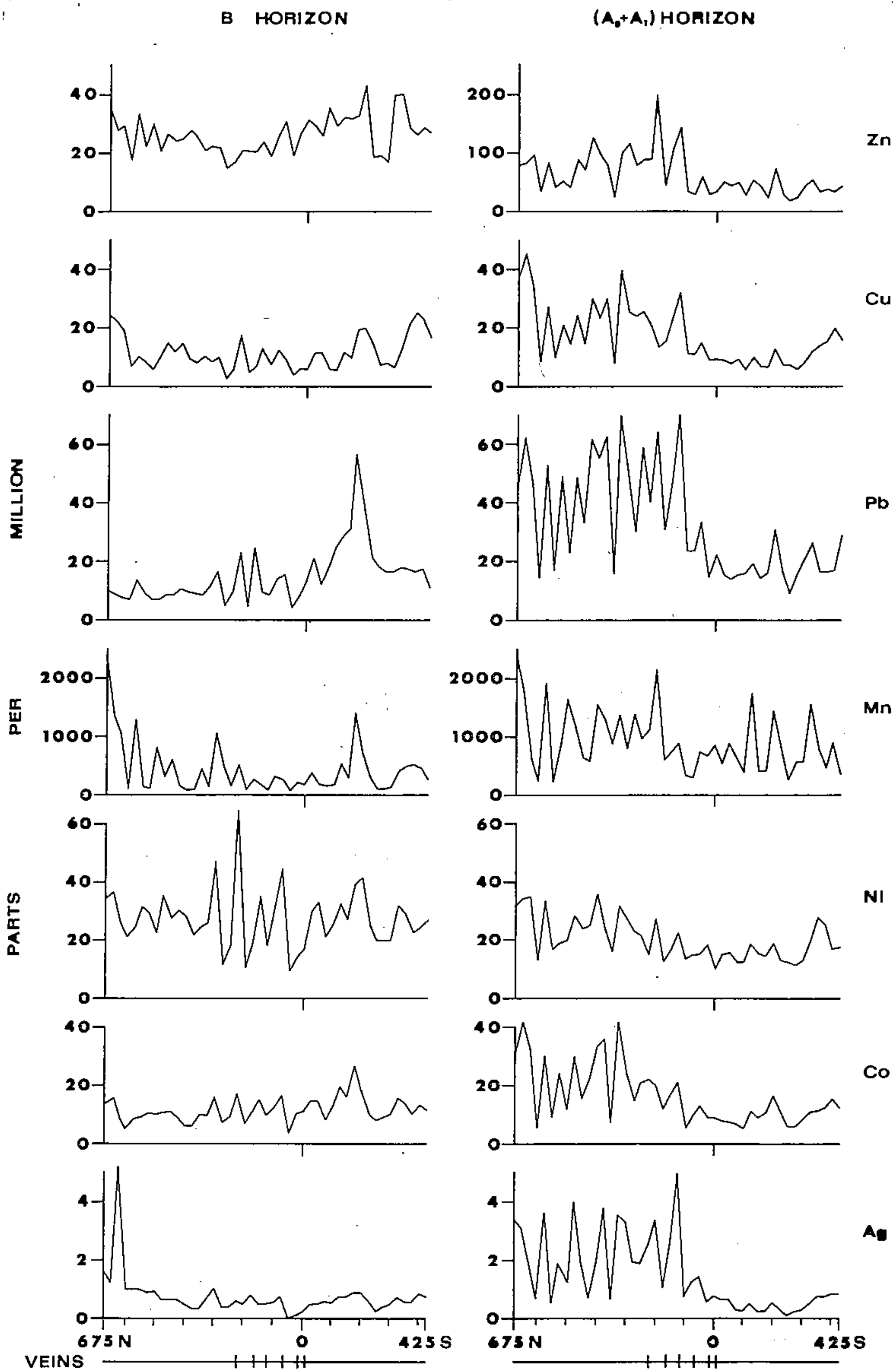


Figure 6. (A_0+A_1) and B horizon soil metal content: Hi Ho.

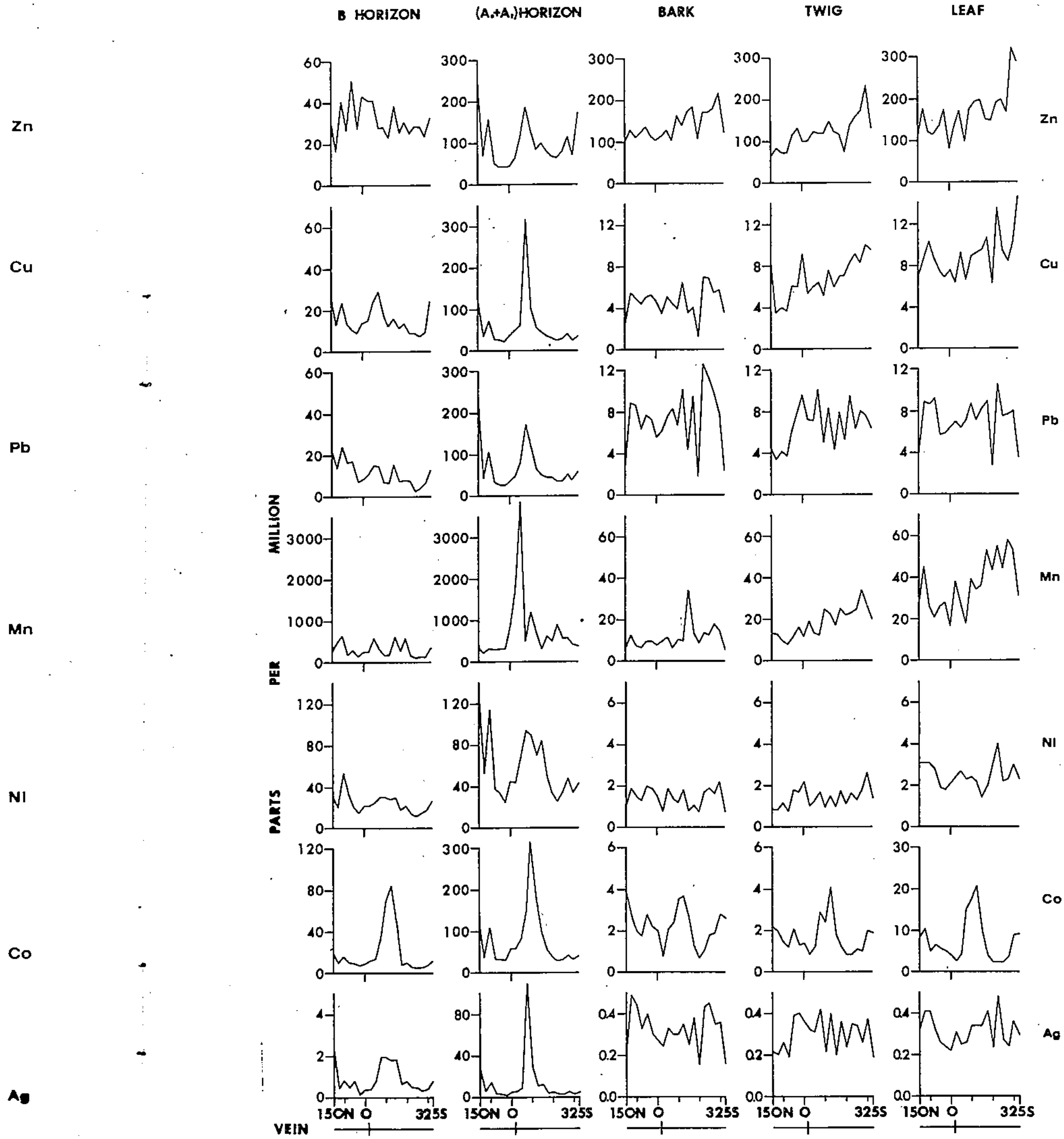


Figure 7. (A_0+A_1) and B horizon soil and trembling aspen metal content: Agnico– O'Brien.

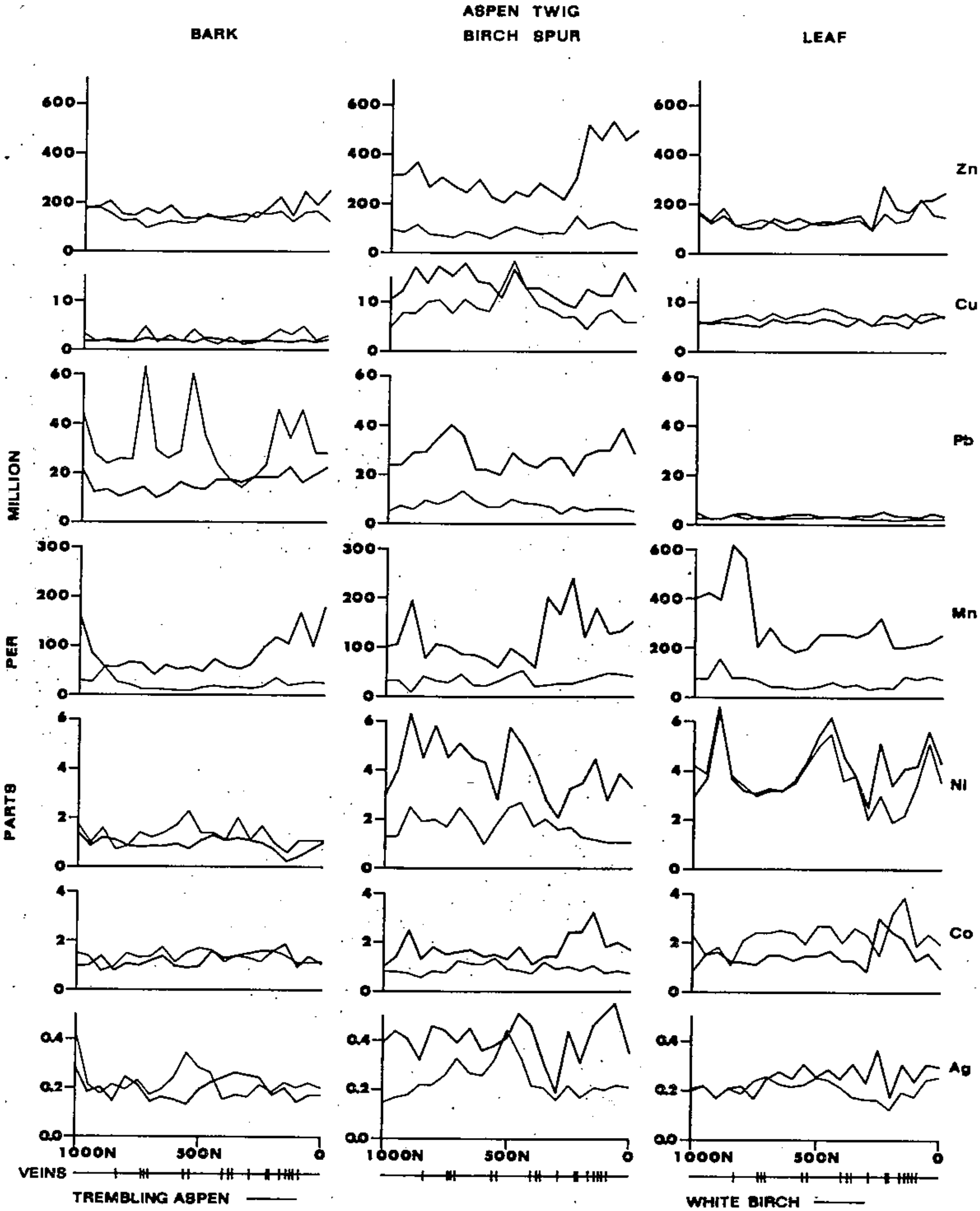


Figure 8. Trembling aspen and white birch metal content: Silverfields.

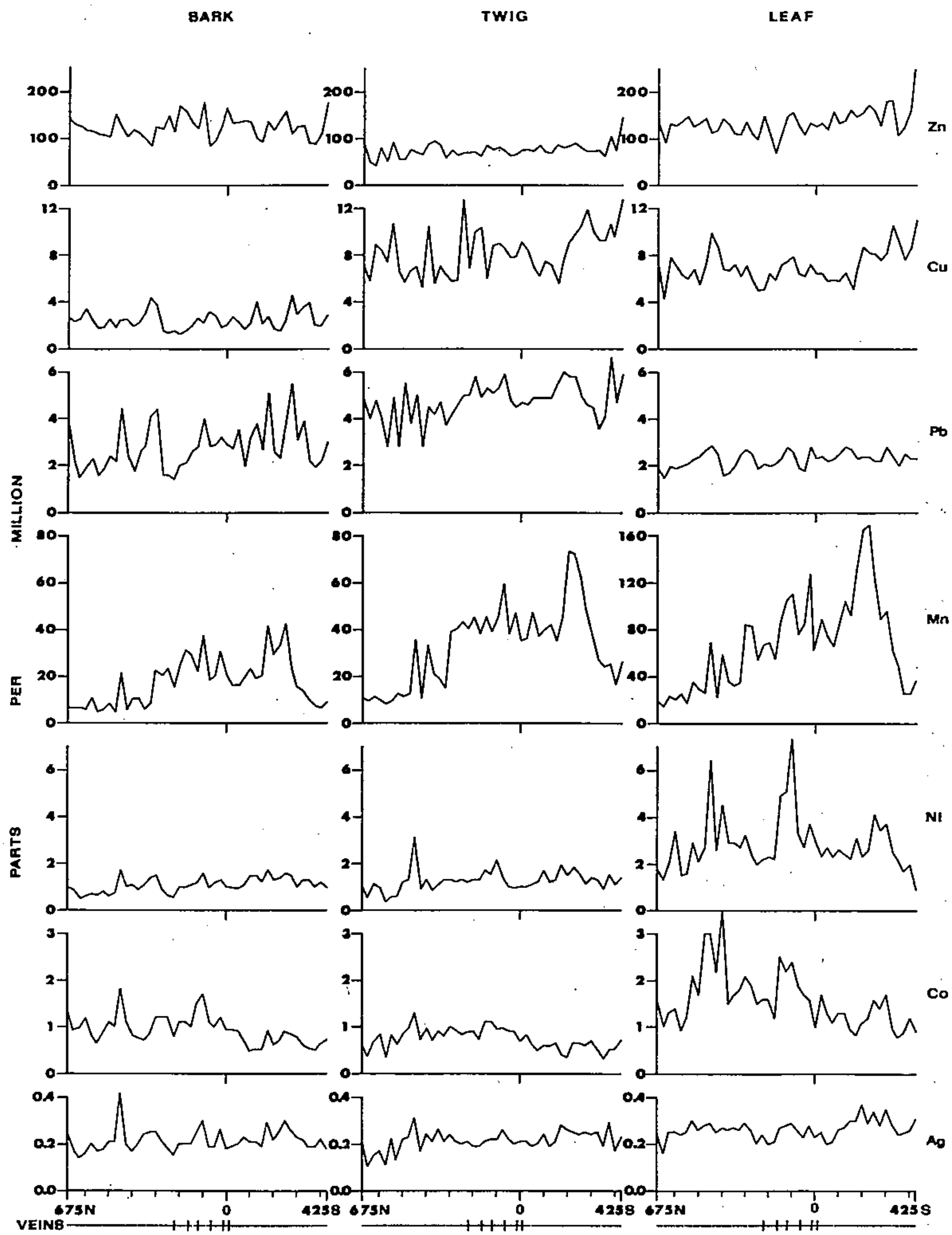


Figure 9. Trembling aspen metal content: Hi Ho.

Table I.

Comparisons among the concentrations of indicator elements in $(A_0 + A_1)$, B and C horizon soils.

Indicator Elements (averaged concentrations in ppm)		Ag	Ni	Co	Cu	Pb	Zn	Mn
anamolous 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

Table II.

Comparison between the concentration of indicator elements in white birch spur and second year twig organs.

Element	Ag		Co		Ni		Cu		Pb		Zn		Mn	
sample material	Spur	Twig	Spur	Twig	Spur	Twig	Spur	Twig	Spur	Twig	Spur	Twig	Spur	Twig
6+50 S	.67	.21	5.1	1.2	4.5	2.2	19	6	46	5	380	110	130	80
6+00 S	.43	.18	2.3	1.0	4.8	2.4	15	7	31	8	220	120	80	70
5+50 S	.55	.22	1.7	1.2	5.6	3.6	14	7	39	11	400	230	110	110
5+00 S	.42	.22	1.9	0.9	4.1	2.4	14	7	24	9	210	130	80	60
4+50 S	.42	.13	1.9	0.7	5.6	3.0	13	5	33	5	290	120	90	70
4+00 S	.43	.24	1.4	0.9	2.8	2.2	13	9	31	9	280	150	60	60
3+50 S	.38	.31	2.0	1.7	5.7	3.8	17	10	26	13	420	280	80	80

Comparison of $(A_0 + A_1)$, B and C Horizon Analytical Data

A profile plot of Ag, Co, Ni, Cu, Pb, Zn and Mn concentrations in $(A_0 + A_1)$ and B horizon soils collected at 50-foot intervals on line 600 E at Silverfields is shown in Figure 5. It is obvious by comparison that $(A_0 + A_1)$ horizon is significantly enriched in each indicator element. Observations of this type of enrichment are becoming more common and are, for example, described in Boyle et al. (1969), Hornbrook (1969a; 1970a, b), and Warren and Delavault (1960). The relatively flat profile of the plotted B horizon data (Fig. 5) over the principal ore veins (Fig. 2) demonstrates its failure to develop anomalies over leakage halos at Silverfields. The failure partly explains why many conventional pedogeochemical exploration programs in the Cobalt area are not successful.

Table 1 shows averaged concentrations of the indicator elements in $(A_0 + A_1)$, B, and C horizon soils collected from several stations in both anomalous and background areas and shows the enrichment of indicator elements in the $(A_0 + A_1)$ horizon. A similar enrichment is also evident in Figures 6 and 7. The C horizon would be the least effective for pedogeochemical exploration because it is lowest in indicator elements. Subsequent studies showed the minus 10 plus 80 fraction of the $(A_0 + A_1)$ horizon contained the highest content of indicator elements. Therefore, the $(A_0 + A_1)$ horizon is the best sample medium for pedogeochemical exploration in the Cobalt area.

Comparison of Biogeochemical Data

Comparative studies similar to those for the soils were carried out on bark, leaf, twig, and spur organs of white birch and trembling aspen. Comparative studies revealed the following relationships:

1. White birch: spur organs are enriched in all indicator elements relative to the second year twigs (Table 2). Spurs are enriched relative to the birch bark and (except for Mn) leaves (Fig. 8).
2. Trembling aspen: bark generally has the lowest concentration of indicator elements (Pb is an exception). Leaves and twigs have similar concentrations, but the leaves show a significant enrichment of Co, Ni and, to a lesser extent, Zn (Figs. 7, 8 and 9).
3. Except for Co and Ni, birch spurs have a higher indicator element concentration than either trembling aspen leaves or second year twigs (Fig. 8).

Therefore, birch spurs are the best tree organ to sample for biogeochemical exploration in the Cobalt area. Where birch is not available, trembling aspen second year twigs rather than leaves should be sampled (mainly because morphological changes in young leaf organs during a growing season may be accompanied by substantial changes in indicator element content). The increased variation in element content of young, actively growing organs relative to older established tree organs has been recognized by Warren et al. (1955). Hence, second year trembling aspen twigs rather than leaves were sampled at Hi Ho and Agnico.

Leakage Halos

Leakage halos are anomalous concentrations of metal elements in the glacial till overlying mineralized fractures or veins. At Silverfields Boyle et al. (1969) have suggested that ore veins extend through the overlying diabase as thin, probably discontinuous, seams. It is unlikely that the seams develop as a continuous fracture at the suboutcrop surface along the total projected strike length of a vein. Certainly not all of the principal ore veins in the underlying sediments have an upward extension to the suboutcrop surface of the diabase. Fractures, where they occur, may only be mineralized along part of their strike length. Silver veins at depth are notoriously irregular and discontinuous along their strike length. Therefore, it is unrealistic to expect a long-linear - continuous-leakage halo anomaly to develop in the till coincident with a silver vein at depth. Rather, a series of disconnected, shorter linear halos along the projected strike length of the vein should be expected. In the shallow till present at Silverfields (Fig. A-5) leakage halos, where developed, probably do not move a significant amount down the gentle southeasterly hillslope.

At Agnico Mines Ltd. (Fig. 4) the O'Brien No. 6 vein in diabase is in contact with overlying till. In places at Hi Ho Silver Mines Ltd. (Fig. 3) the silver veins in sediments have a possible contact at the sediment-till interface. Thus, the leakage halos developed should be more persistent along strike and possibly stronger than at Silverfields because of the absence of a diabase caprock up to 200 feet thick.

Silver Distribution as a Function of Sample Interval

In Figures 5 and 8 most of the anomalous peaks generated by leakage halos occur at an individual station. These stations were established at Silverfields on line 600 E at 50-foot intervals. Because of the narrow widths of the vertical, principal ore veins, their anastomatic character, and their complicated spatial relationship to one another, it is possible that some leakage halo anomalies were either missed entirely or were not fully developed by samples collected at 50-foot intervals. A second suite of samples was collected between the initial stations so that a combined interval of 25 feet between all stations was achieved. Profiles of Ag in $(A_0 + A_1)$ horizon soils are given in Figure 10. The plots show the original and second sample suites each at 50-foot intervals, and then combined to produce a profile of Ag concentration based on a 25-foot sample interval. South of station 0 there is a marked difference in the 50-foot profiles for the same section of traverse line. This is resolved by the 25-foot interval profile into several separate, distinct, and closely-spaced anomalous peaks. In another section of the traverse line, between stations 500 and 1000 N, the 50-foot profiles obviously reinforce each other to produce a strong leakage halo anomaly over several sample stations as is shown in the combined 25-foot interval plot. A completely reliable "picture" of the element distribution is achieved only by sampling on a 25-foot interval basis. Subsequent sampling at the Agnico and Hi Ho properties was carried out at 25-foot intervals.

In Ottawa, using computer processing, a more detailed examination of element distribution as a function of sample interval was carried out to confirm field conclusions because the sample interval constitutes a critical factor upon

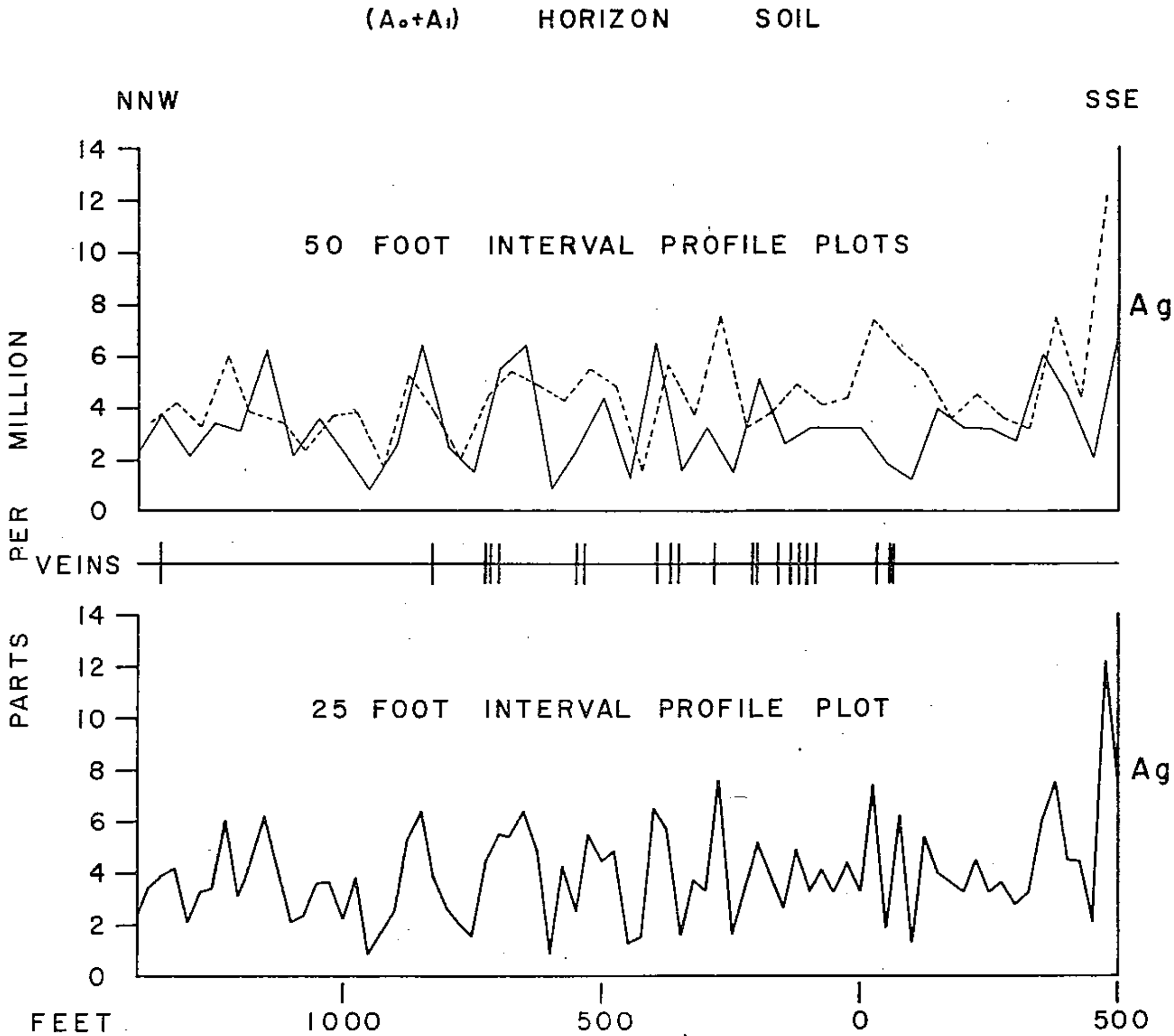
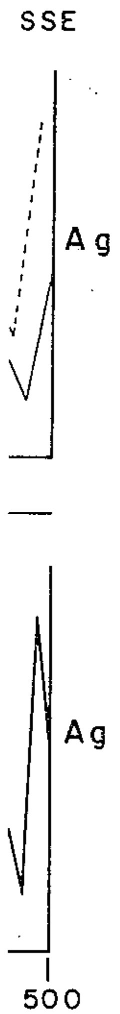


Figure 10. Comparison among 25- and 50-foot interval profile plots of silver distribution.



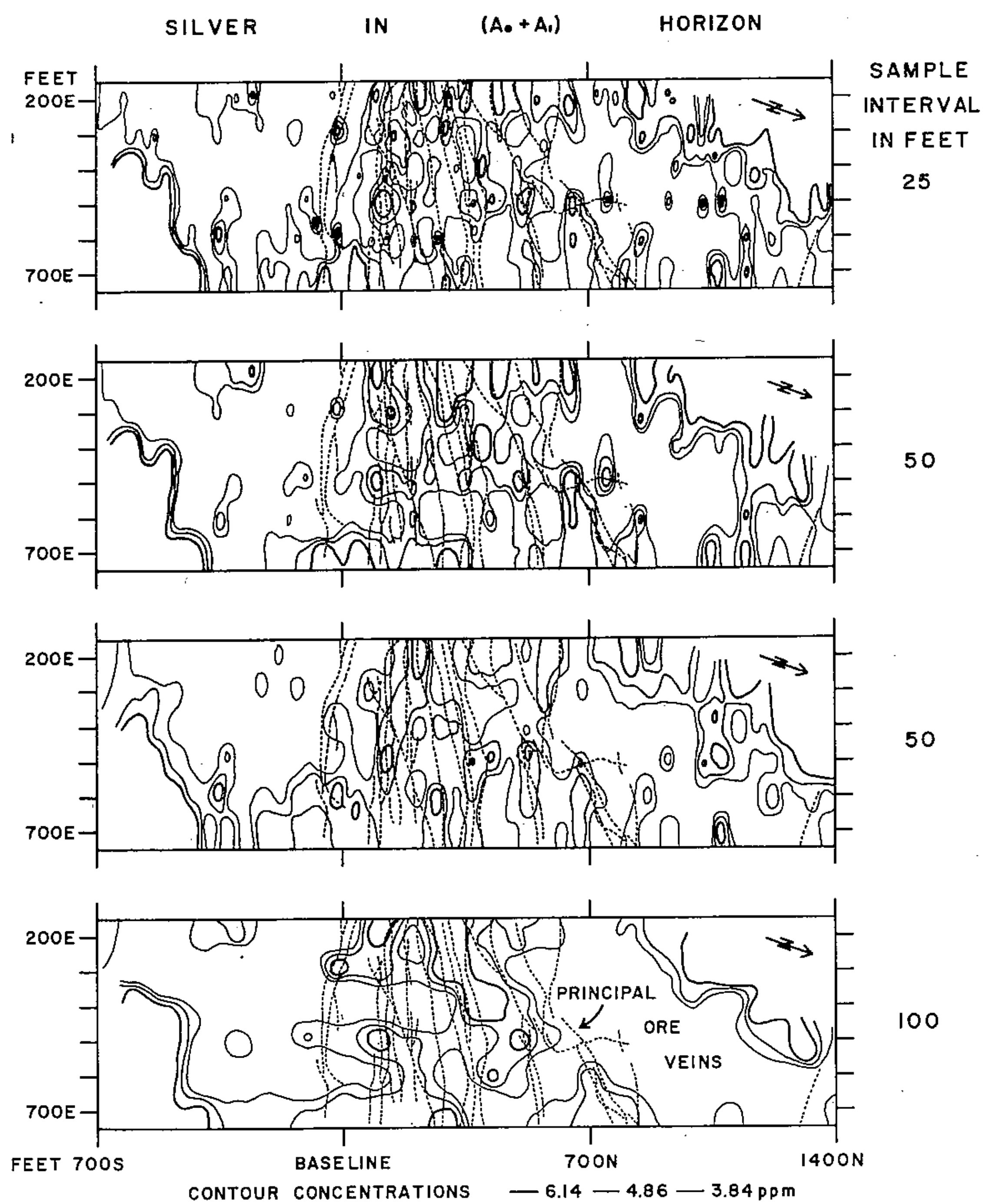


Figure 11. Silver anomalies as a function of sample interval at Silverfields.

which other factors are dependent. Computer-drawn anomaly maps (Fig. 11) 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 study, the computer program was altered to expand the sample density until the anomalous pattern deteriorated beyond interpretation. Both possible 50-foot interval maps are given in Figure 11 to permit comparison of their effectiveness.

At 25-foot sample intervals, the silver anomaly map (Fig. 11a), shows that closely-spaced leakage halos from surface fractures in the Nipissing diabase are individually detected as narrow, strongly linear, disconnected anomalies perpendicular to the traverse lines in the central target area of the grid. At 50-foot intervals (Figs. 11b and c) the linear character of the silver anomalies is only partly maintained and individual leakage halos are not distinguishable. Significantly, the two 50-foot interval anomaly maps show some radical differences: (1) the greater linearity in the Figure 11b anomaly map demonstrates its improved discrimination among individual leakage halos, and (2) anomalous zones of silver at 6.14 ppm or greater along the west side of Figure 11b are not present in Figure 11c. Thus, the anomalous distribution of silver in the 50-foot interval maps is not only unreliable, but is also less effective in detecting individual halos than the 25-foot interval maps 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 have completely deteriorated on the 100-foot interval map (Fig. 11d). Further, 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 target area is still defined, it is detected now by only 9 anomalous samples.

It is important to point out that conventional pedogeochemical exploration would have employed a similar net-type grid, but with 100-foot or greater intervals between all sample stations. Had B horizon soils been collected off the Silverfields sample grid at 100-foot intervals, the anomalous leakage halos developed in the till over the complex principal ore veins might not have been detected.

The 25-foot interval anomaly map defines individual leakage halos in addition to 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 on the Silverfields property. The property is approximately 70 acres in extent.

Therefore, 100-foot interval sampling of the (A_0 + A_1) horizon could be carried out of large areas followed up by 25-foot interval sampling to detect individual leakage halos providing, of course, the suspected target is similar in size to the silver vein deposits at Silverfields. Otherwise, if the suspected target is smaller than that of Silverfields (i.e., a single narrow silver vein remote from other veins) then 25-foot interval sampling on traverse lines 100 feet apart, perpendicular to the expected vein strike is necessary to achieve successful detection. The 50-foot interval scale of sampling is neither dense enough for detailed exploration nor large enough for the extensive coverage required for semiregional programs.

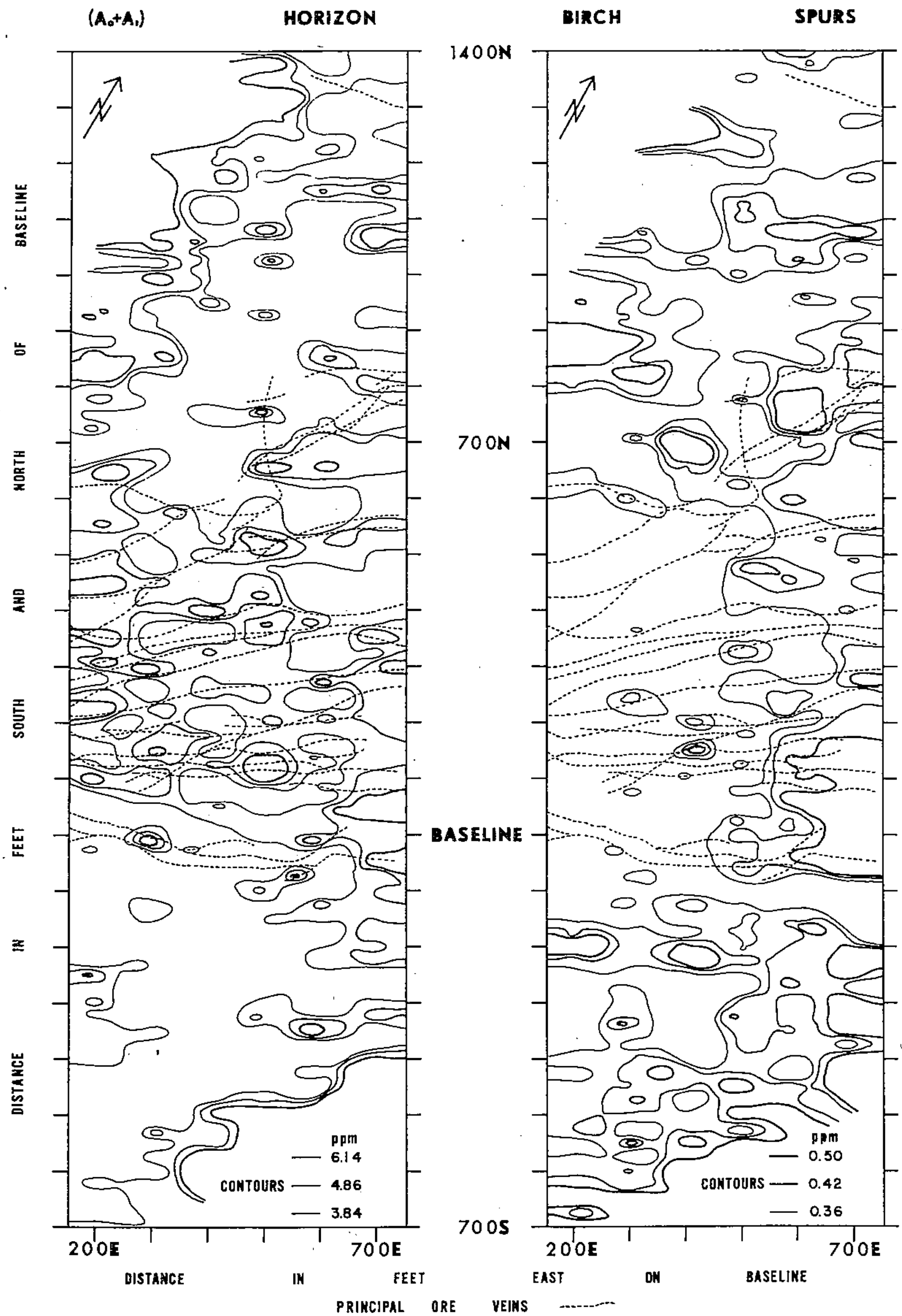


Figure 12. Geochemical anomaly maps: silver.

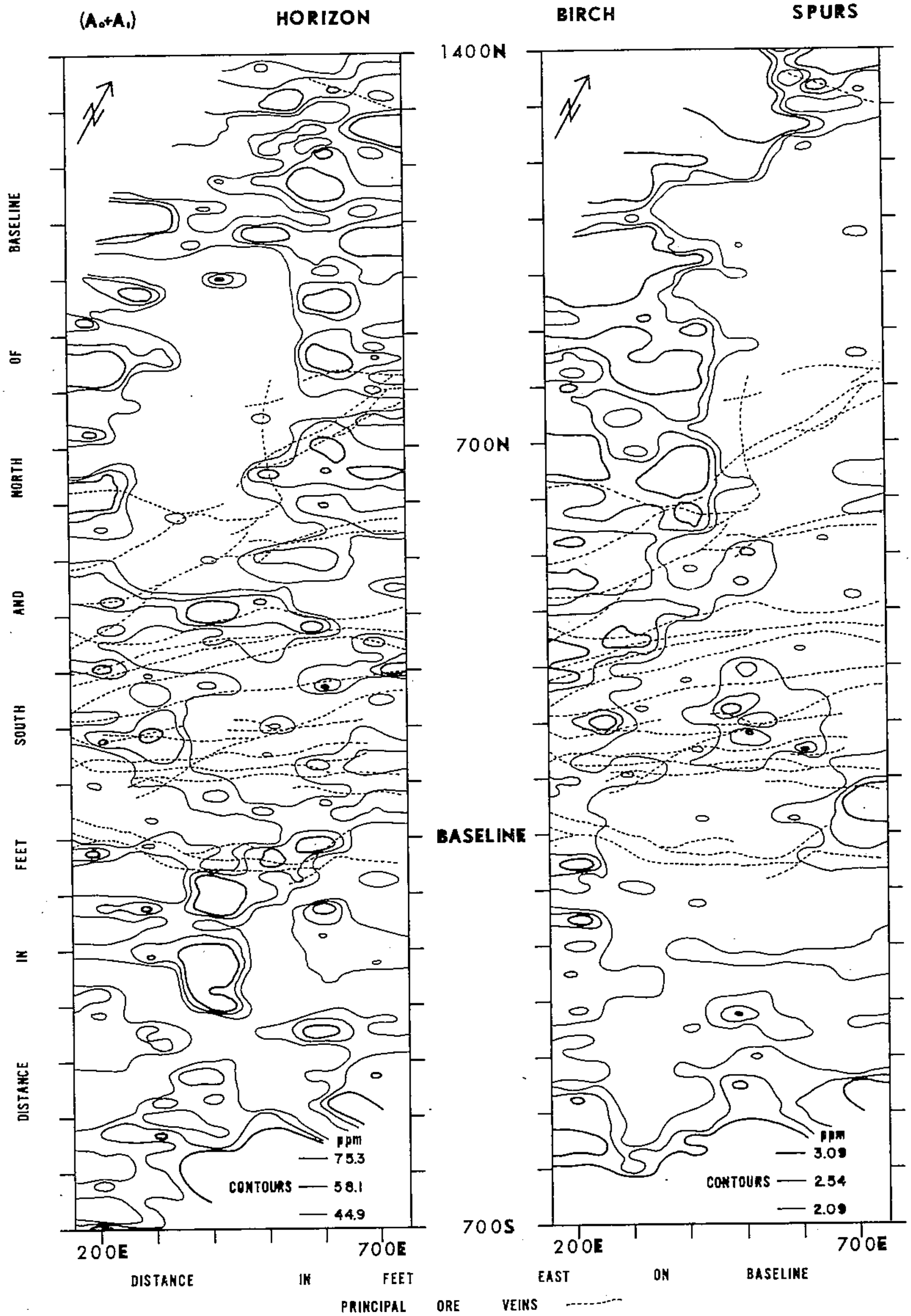


Figure 13. Geochemical anomaly maps: cobalt.

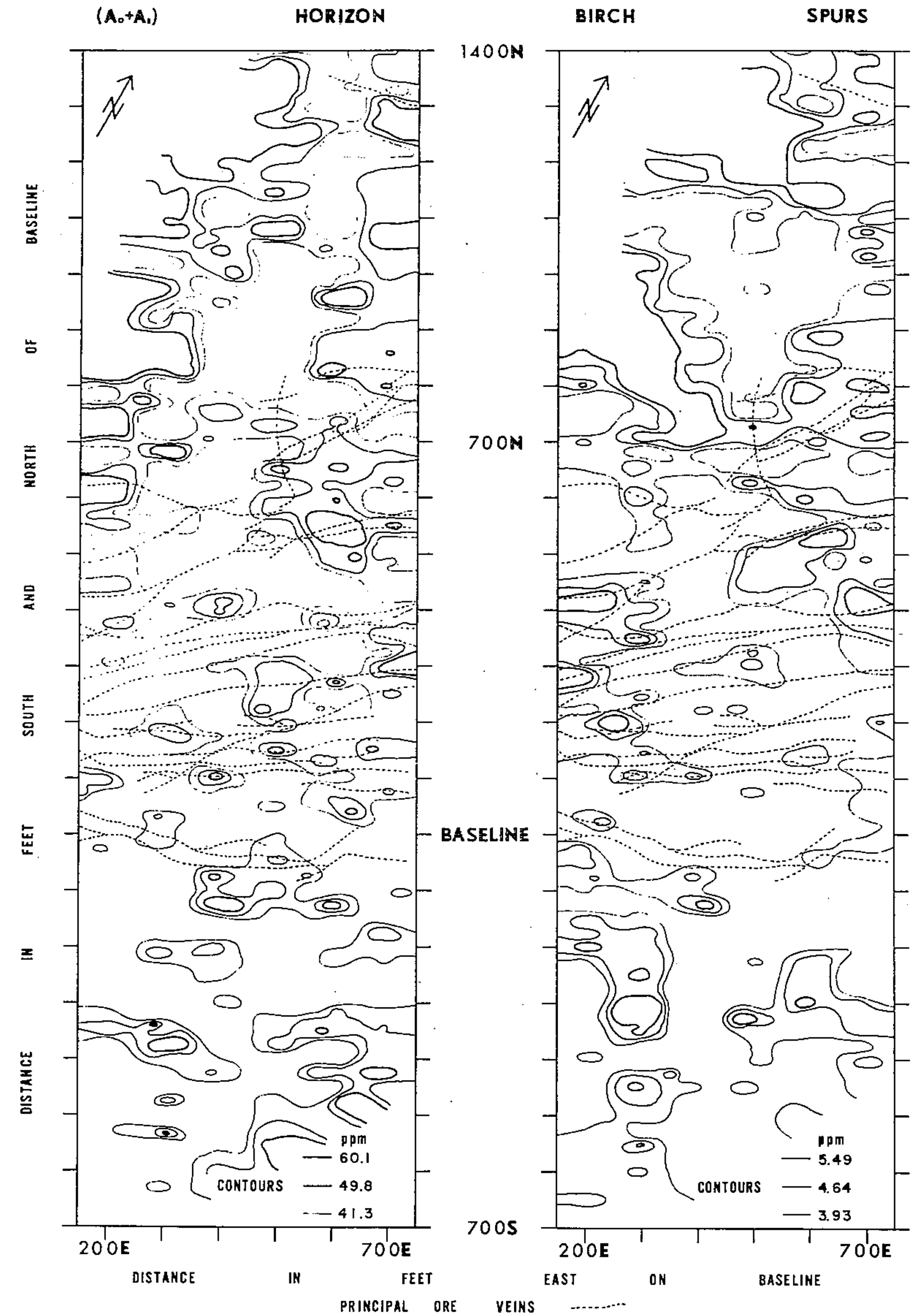


Figure 14. Geochemical anomaly maps: nickel.

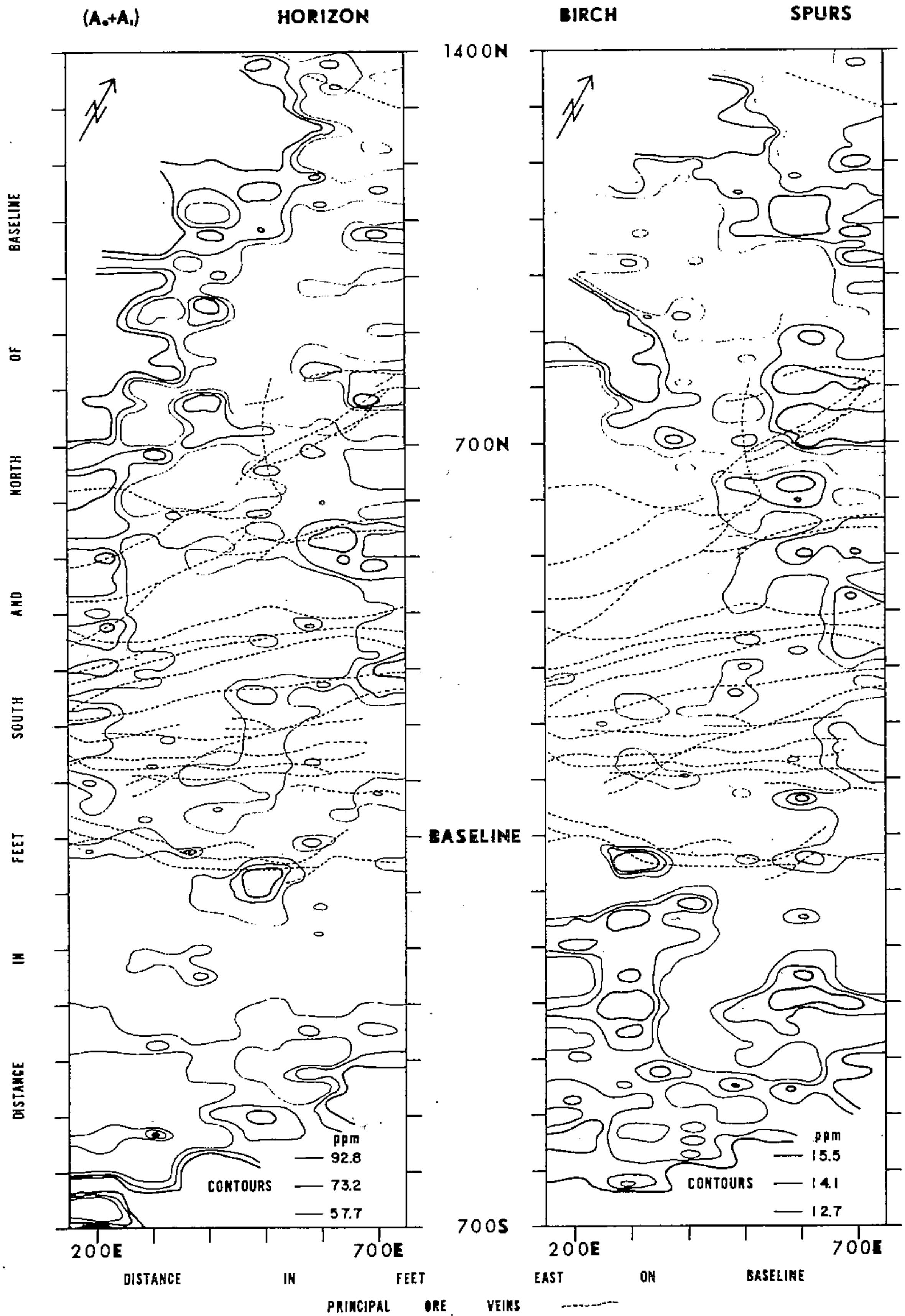


Figure 15. Geochemical anomaly maps: copper.

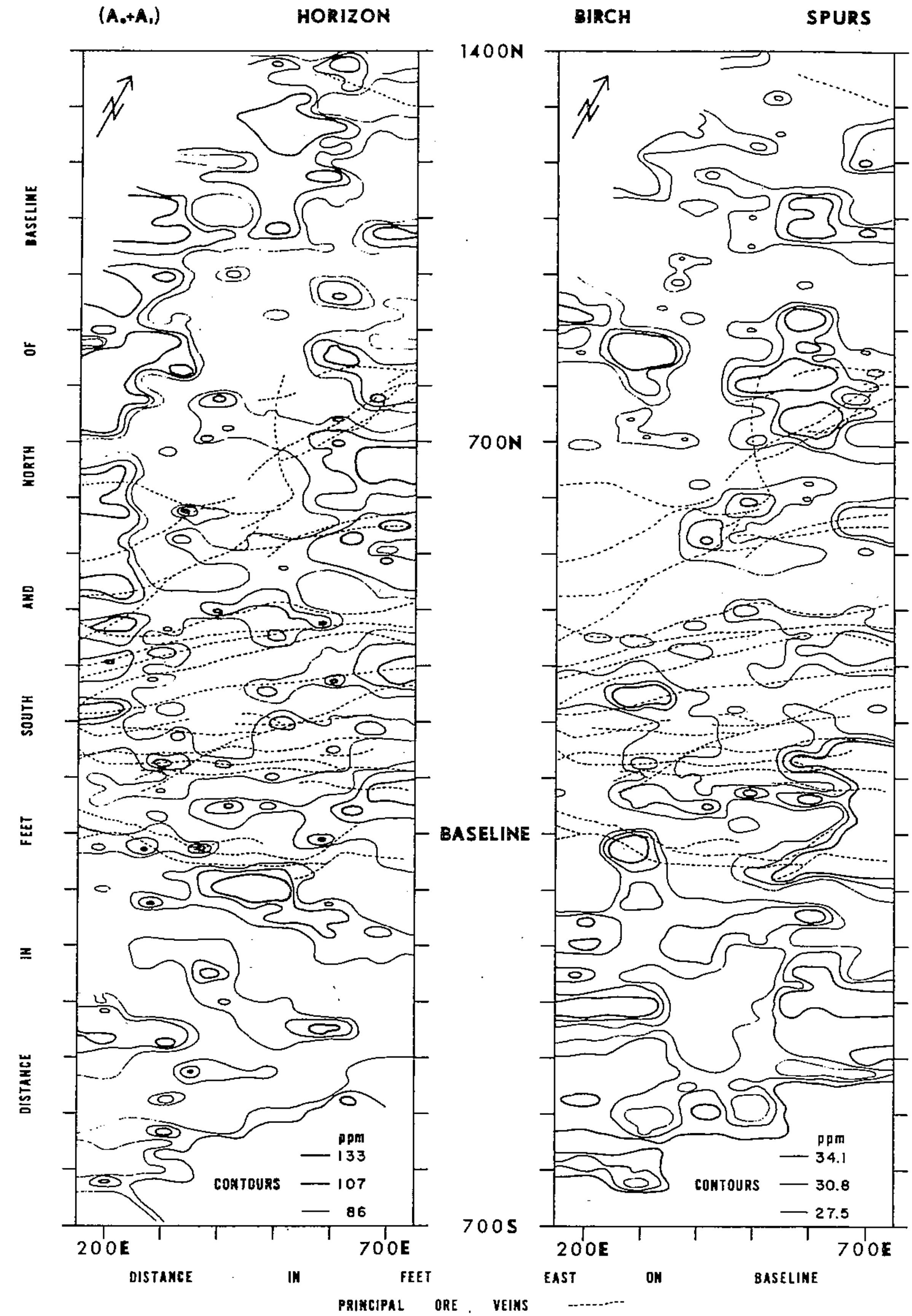


Figure 16. Geochemical anomaly maps: lead.

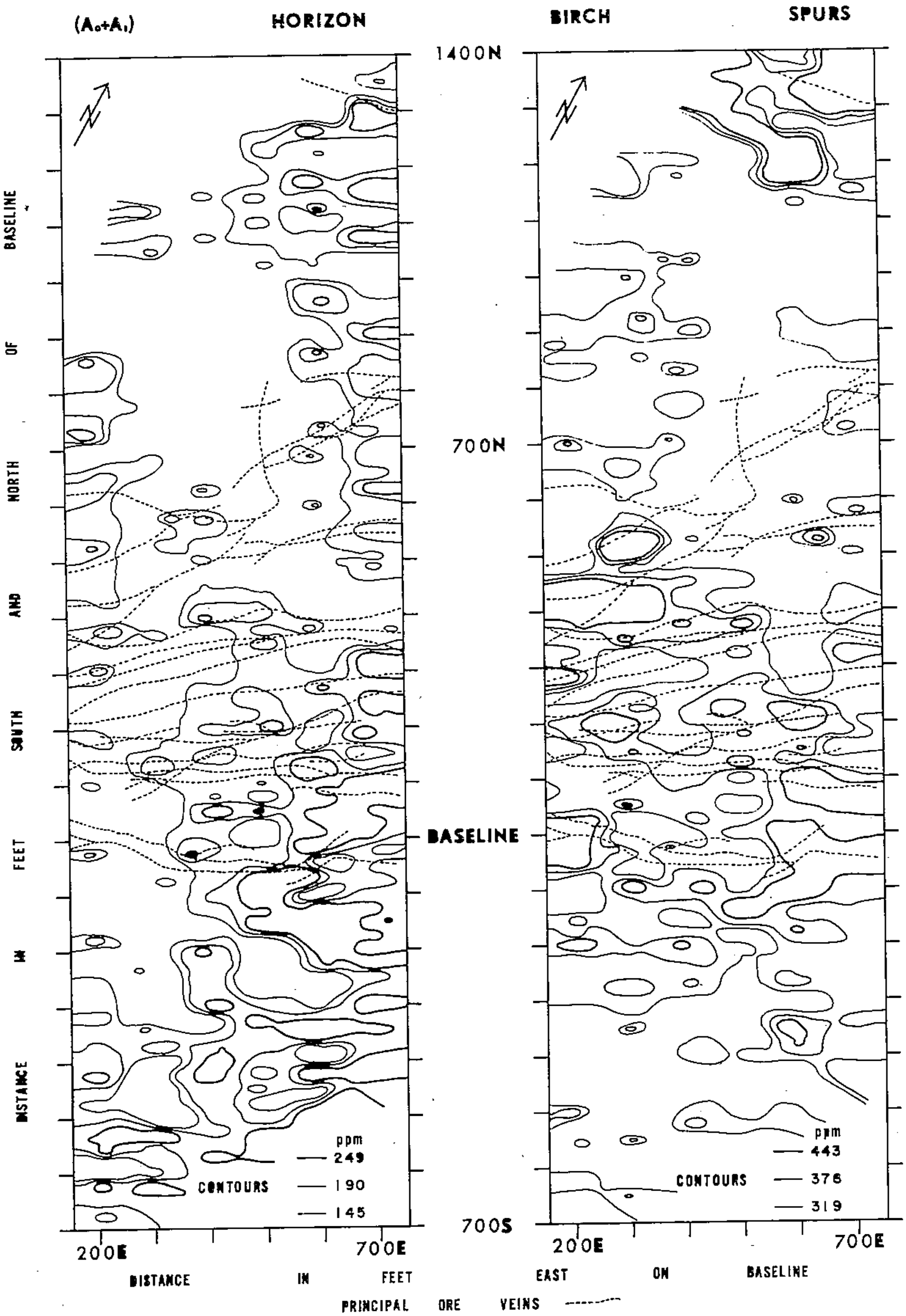


Figure 17. Geochemical anomaly maps: zinc.

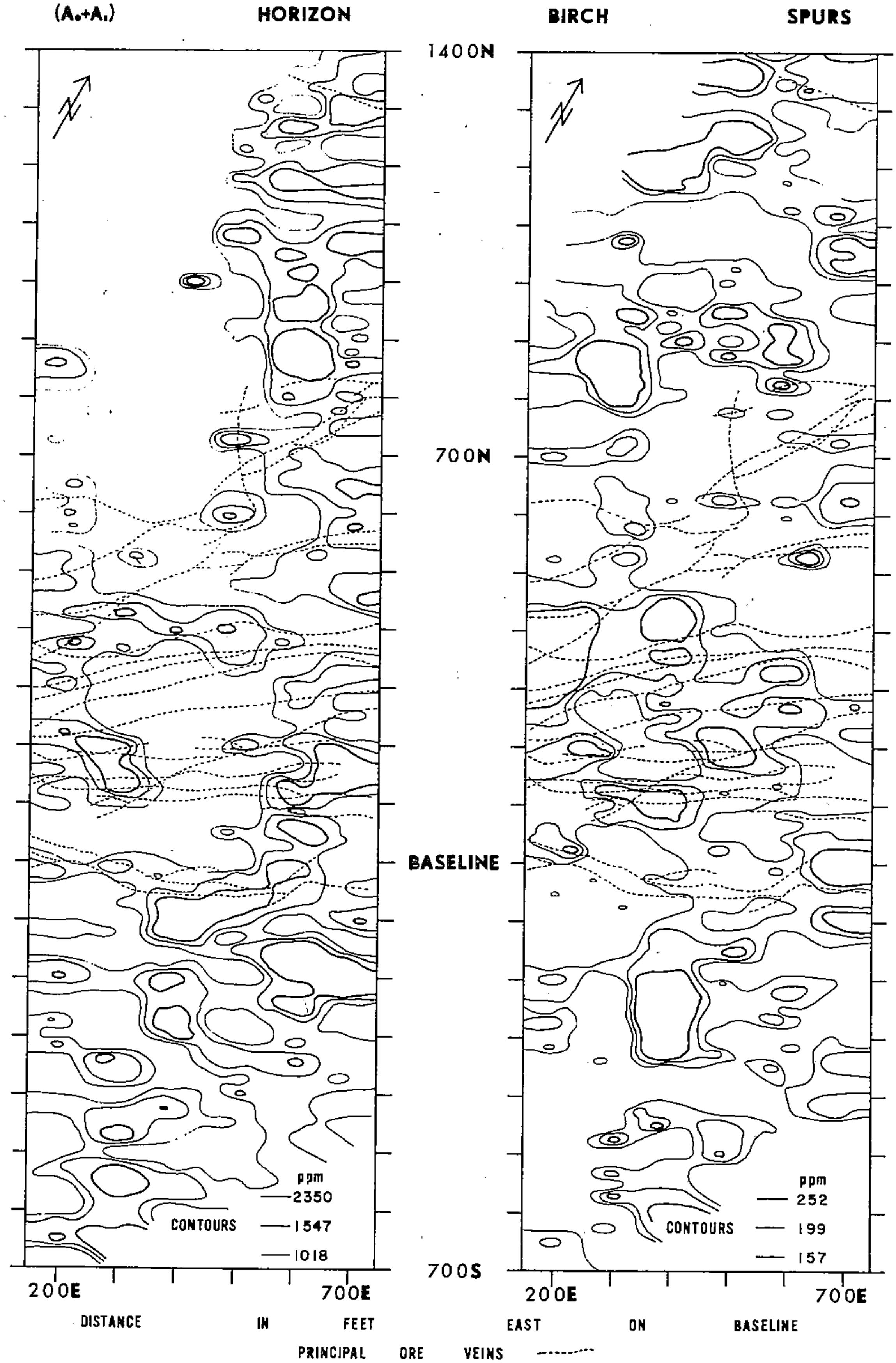


Figure 18. Geochemical anomaly maps: manganese.

Contamination

Contamination is a serious problem for biogeochemical and geochemical exploration in the Cobalt area. As mentioned previously, contamination originates from past and present mining activity in the area, and particularly from mine access roads which are usually constructed from mine waste rock that frequently contains ore minerals.

Warren and Delavault (1960) have shown that lead contamination from car exhaust gases is present in soil up to one hundred yards from an arterial highway in British Columbia. Therefore, it is expected that contamination would also occur adjacent to the Cobalt area access roads, some of which are subject to additional contamination from large trucks hauling ore from the local mines.

Contamination of the Silverfields mine access road is evident principally for Ag, Co, Cu, Pb and Zn (Figs. 12, 13, 15, 16 and 17). At the south end of the sample grid (Fig. 2), all except two traverse lines extend southeast to within 25 feet of the shoulder of the access road. The strong broad anomalous zone in soils and/or vegetation across the south end of the grid is coincident with the curvature of the road and is derived from ore minerals in the crushed rock road base. Further, the broad character of some element anomalies (Ag, Pb and Zn in Figs. 12, 16 and 17 respectively) on the east side of the grid near the baseline, particularly for birch spurs, may be due in part to wind-blown dust from ore minerals in the crushed mine rock covering the adjacent parking lot. The lot begins approximately 200 feet east of line 700E on the baseline.

A similar broad, strong anomalous zone for Ag, Co, Ni, Cu and Pb in Figures 12 to 16 occurs across the north and northwest part of the grid. The strong, broad character of this anomalous zone is produced only because trees, from which the ($A_0 + A_1$) horizon is derived, grow in and receive their nutrients from patches of mineral and organic soil trapped in crevices and weathered fractures. There is little or no soil elsewhere in this part of the sample grid (Fig. A-5). Most of the ground at the north end of lines 200E to 500E (Fig. 2) consists of fractured bedrock and broken rock rubble at the top of a steep hill face. Thus, the element content of birch spurs and ($A_0 + A_1$) horizon soil strikingly reflect the minute traces of any mineralization present in many of these fractures compared to the reflection above mineralized fractures in the southern till-covered part of the sample grid. Significantly, therefore, contamination or apparent contamination can produce anomalies equivalent to those from silver veins beneath shallow till.

Silverfields Property Anomaly Maps

The mine geology at Silverfields Mining Corporation Ltd., is essentially similar to 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. These gently dipping sediments here overlie unconformably, in an erosional trough, Keewatin lavas containing mineralized sedimentary interflow bands (Moore, 1967). Ore veins (Fig. 2) characteristically have the following dimensions (Petruk, 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 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.

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

Some of the narrow fractures at the suboutcrop surface of the Nipissing diabase sill contain traces of ore elements. Boyle et al. (1969) suggested that ore veins extend upward through the diabase as thin, probably discontinuous seams.

The following principal observations are warranted after an examination and comparison of the effectiveness of each anomaly map in detecting silver veins. Each figure shows an anomaly map for the same element in white birch spur organs and in ($A_0 + A_1$) horizon soil. Figures 12 to 18 are anomaly maps for Ag, Co, Ni, Cu, Pb, Zn and Mn respectively.

1. A given element is not necessarily equally effective in ($A_0 + A_1$) horizon soil and white birch spur anomaly maps; e.g. Ag, Co or Cu in Figures 12, 13 and 15 respectively. This difference is probably due in part to the complex chemistry of the ($A_0 + A_1$) horizon soil, the nature of nutrient uptake in the sample tree, and the influence of wind-blown dust contamination.
2. Silver in ($A_0 + A_1$) horizon soil (Fig. 12) seems to produce the most effective anomalies. Individual leakage halos from suboutcrop fractures are not only detected, but can be related to the projected path of the appropriate principal ore vein beneath the diabase.
3. Other anomaly maps are also effective: Pb, Zn and Mn in ($A_0 + A_1$) horizon soil and birch spurs (Figs. 16, 17 and 18 respectively); Co and Ni in only the ($A_0 + A_1$) horizon soil (Figs. 13 and 14 respectively).
4. Copper anomaly maps are not effective.
5. Some silver veins that have a well-developed leakage halo in the overlying till probably have a related fracture system that is unusually well developed and mineralized in the suboutcrop surface of the diabase.
6. Most of the Co anomalies in birch spurs are present along the west side of the anomaly map (Fig. 13), possibly as a reflection of the zoning in the silver vein deposits. According to Petruk (1968), the Co-Ni-As and then the Co-As zones occur successively west of and below the upper eastern Ni-As zone. Thus Co is more abundant in the western part whereas Ni is relatively evenly distributed across the sample grid. The western preference for Co is evident only in the birch spurs anomaly map (Fig. 13) whereas the even distribution of Ni is evident in both anomaly maps (Fig. 14). Thus the data based on 25-foot interval sampling are sufficiently sensitive to reflect a zoning of Co and Ni in the silver veins.
7. Along the projected path of a vein the anomalous distribution of most elements appears as a series of disconnected linear anomalies with concentrations close to background levels between them.
8. The most interesting anomalies are commonly associated with real or apparent contamination and not with the principal ore veins in the central part of the grid. The association is particularly true of Ag in the

8. (cont.) birch spur anomaly map (Fig. 12). Identification of the sources of contamination and their influence on element distribution are a necessary prerequisite to successful interpretation.

Agnico Property, O'Brien No. 6 Vein Profile Plots

The O'Brien No. 6 vein of Agnico Mines Ltd. (Fig. 4) occurs in diabase, but along its strike length it passes into Cobalt Group sediments and eventually into Keewatin greenstones. Near the traverse lines the vein contains ore grade material at the suboutcrop surface.

Important features revealed over the O'Brien No. 6 vein on the east traverse line (Fig. 4) by the element profile plots (Fig. 7) are:

1. The $(A_0 + A_1)$ horizon is enriched in Ag, Co, Ni, Cu, Pb, Zn and Mn relative to the B horizon. Anomalous concentrations for most of these elements were significantly higher than those found at either the Silverfields or Hi Ho properties. The increased element content in the soils at Agnico is due to the fact that the principal ore vein (the O'Brien No. 6 vein) intersects the suboutcrop surface of the diabase.

   Aspen bark is enriched in Pb, but otherwise has an equivalent or lower concentration of elements than twigs or leaves. Twigs and leaves have similar concentrations of elements except for Ni, Mn, Cu and Zn which are concentrated in the leaves.
2. All elements in the $(A_0 + A_1)$ horizon have a strong, narrow anomaly related to the position of the No. 6 vein. High concentrations found for most elements at 150 N remote from the No. 6 vein are due to contamination from the adjacent road which has a mine waste rock base. Useful anomalies were unexpectedly developed in the B horizon for Ag, Co and Cu. Anomalies were also developed in the Co profiles for bark, twig, and leaf plots, but the remaining tree organ profile plots are too erratic for meaningful interpretation on the basis of a single traverse line.
3. Anomalies developed for various elements in different materials are displaced 50 to 100 feet south of the No. 6 vein. The displacement is downslope of the topographic and suboutcrop surfaces whose profiles are shown in Figure A-4.
4. Although profile plots for the west traverse line (Fig. 3) are not presented here, the results are similar to the east traverse line described above.
5. The indicator element profile plots, particularly for the $(A_0 + A_1)$ horizon, demonstrate that the O'Brien No. 6 vein is accurately detected by 25-foot interval sampling. The vein might not be found by a 50-foot or greater sampling interval because the anomaly is narrow and frequently supported by data from a single station.
6. On the basis of single traverse line geochemical and biogeochemical sampling over the O'Brien No. 6 vein the following conclusions may be drawn: (1) The $(A_0 + A_1)$ horizon soil is an effective sampling medium for all indicator elements; (2) B horizon is effective for only Ag, Co and Cu; (3) Tree organs appear to be effective only for Co; (4) Sampling at 25-foot intervals is necessary to ensure detection of thin vertical silver veins; (5) The strongest response is obtained where the silver vein is in direct contact with the overlying till; and (6) Contamination may be responsible for significant anomalies.

Although most of the tree organ data are not effective, this study does not exclude the possibility that such data from several lines in the form of an anomaly map would not be. However, to detect a single silver vein in a similar setting it is necessary only to sample the $(A_0 + A_1)$ horizon soil at 25-foot intervals for some or all of the indicator elements.

Hi Ho Property Profile Plots

Hi Ho Silver Mines Ltd. (Fig. 3) adjoins the south boundary of the Silverfields property, hence their mine geology is similar. However, at the Hi Ho property, the Nipissing diabase sill does not completely cover the Cobalt Group sediments which are present as a northeasterly projecting tongue coincident with the baseline. Presumably, many of the fractures in the suboutcrop surface of the sediments are related to the silver veins at depth.

Important features revealed over several ore veins on line 24W (Fig. 3) by the profile plots (Figs. 6 and 9) are:

1. The $(A_0 + A_1)$ horizon soil is enriched in all indicator elements relative to the B horizon but not to the extent found at the Agnico property.

   B horizon profiles are erratic in that the persistent occurrence of anomalous peaks found north of the baseline in the $(A_0 + A_1)$ horizon soil are not maintained or developed for all indicator elements. Anomalous peaks are present for Co, Mn, Pb and Ni, but are significant only for Ni.

   Generally, the concentration of elements found in aspen bark is equivalent to, or lower than, that of twigs or leaves. Occasionally, for a given element, the concentration in bark may be higher than that of either twigs or leaves but not of both organs. Indicator element concentrations in twigs and leaves are similar except that Co and Ni are concentrated in leaves and Pb in twigs.

   The bark, leaf and twig data are not consistent. Mn shows a steadily increasing concentration downhill to 250 feet south of the baseline where it drops off sharply to near background levels. Other indicator elements do not show this trend but have individual narrow anomalies.
2. All elements in the $(A_0 + A_1)$ horizon soil have several closely spaced anomalous peaks from about 100 feet north of station O to the north end of the line, 675N (Fig. 6). The position of these anomalies is north of, and uphill from, the family of veins located about, and north of, station O. Line 24W is a long southward-sloping suboutcrop ridge where the bedrock slopes off to either side (east and west) as shown by the suboutcrop profile configuration of the baseline (Fig. A-2). In G.D. Hobson's contribution, Appendix A, Figure A-2, stations 18 and 76 correspond to station O on line 24W in Figures 6 and 9. There is a reverse northerly slope that forms a bedrock depression centred 125 feet north of station O (Fig. A-2). The depression extends from 25 feet south to 325 feet north of station O. Most of the vertical projections of the principal ore veins (Fig. 3) in the sediments intersect the suboutcrop surface of the sediments on the reverse slope of the depression or very close to the bottom of the depression. Thus

2. (cont.) leakage halos generated by the vein cluster do not continue downslope, south of the baseline as would normally be expected, but rather move laterally east and west down off the ridge via the bedrock depression north of the baseline. Therefore, there is an abrupt cut-off of anomalous element content in the $(A_0 + A_1)$ horizon soil south of the baseline which is demonstrated in the profile plot (Fig. 6).

   Some of the anomalous peaks north and south of the baseline may be due to mineralized material in the till locally transported south from the Silverfields property.

3. Correlation between indicator element anomalies and the vein cluster at the baseline (station O) is complicated by the reverse slope and a bedrock depression (Figs. 6 and A-2).

4. Vegetation on the baseline from 24W, east toward the mine-shaft (Fig. 3) had been cut prior to 1968 and only very young aspen poplar was available for sampling. Thus, uniformity of aspen poplar sample material was not possible from 9W to 38W and the analytical data east of line 24W are not reliable for interpretive purposes. The suggested lateral transport of leakage halos east and west in the bedrock depression and eventually south downhill across the baseline cannot be established. Transport downhill undoubtedly eventually occurs but it may occur farther east and west respectively of 9W and 38W making detection impossible with the data available. Therefore, baseline analytical data were not presented in this paper.

5. In most of the plots, particularly the $(A_0 + A_1)$ horizon plot, the anomalies developed are narrow and, as at Agnico, frequently supported by data from only one station. Again, it is evident that a 50-foot, or greater interval, would not be satisfactory because many anomalies would be missed entirely.

6. It is evident that single line traverses are not satisfactory here although many significant anomalies were found. They do not provide sufficient information to delineate leakage halos in the overlying till, particularly when unusual bedrock topography is encountered.

7. Based on an evaluation of single traverse line data, the following conclusions may be made: (1) the $(A_0 + A_1)$ horizon soil is the most effective sample medium for all indicator elements; (2) B horizon soil is effective for Ni and possibly the others; (3) Co, Ni, Pb and Mn are effective in plant material; (4) remaining element - material combinations may be effective for interpretation in an anomaly map format; (5) a grid-type sampling program is necessary to obtain anomaly maps where the vein clusters are complex and where unusual suboutcrop topography controls the transport of anomalous element concentrations in till; (6) samples should be collected on lines perpendicular to the expected strike of the vein clusters at 25-foot intervals.

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) extensive contamination is present; (3) bedrock is covered by till and glaciofluvial deposits; and (4) the masking effect produced by 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) effect of anomalies generated by contamination upon indicator element distribution in anomaly maps.

A study of these problems and the effectiveness of geochemical and biogeochemical exploration in the Cobalt area shows the following:

1. Effective indicator elements are: Ag, Co, Ni, Pb, Zn and Mn. Only Cu of all indicator elements tested does not seem to have some value.
2. The $(A_0 + A_1)$ horizon is enriched in all indicator elements relative to the B and C horizons, and with the exception of Zn, all tree organs sampled.
3. The most effective sample medium for geochemical exploration is the minus 10 plus 80 mesh part of the $(A_0 + A_1)$ horizon. Ag in $(A_0 + A_1)$ horizon is the most effective indicator element followed by Co, Ni, Pb, Zn and Mn. For biogeochemical exploration, the most effective sample medium is white birch spurs or trembling aspen second year twigs if white birch is not available. In birch spurs Pb, Zn and Mn are effective.
4. A given indicator element is not necessarily equally effective in $(A_0 + A_1)$ horizon and birch spur anomaly maps. Silver in the $(A_0 + A_1)$ horizon (Fig. 12), is the most effective anomaly map because it detects in till most of the individual leakage halos generated from mineralized fractures in the suboutcrop surface of the diabase. These leakage halos can then be related to the projected path of the principal ore veins at depth. Silver in white birch spurs (Fig. 12), is among the least effective of all anomaly maps because its most interesting anomalies coincide with contamination and not with the principal ore veins. Therefore, interpretation is difficult, if not impossible, unless only certain effective combinations of indicator elements and sample media indicated in (3) above are used.
5. Where the $(A_0 + A_1)$ horizon is available for sampling, B horizon soils should not be collected because they have an insufficient content of Ag and associated elements. It is probable that some pedogeochemical programs in the Cobalt area failed only because B horizon soils were sampled. Exceptions are possible as at the O'Brien No. 6 vein (Fig. 7) but here the productive vein is in contact with the thin overlying till.
6. There is an important relationship among sampling density, features of the target, and the extent of area to be explored by a geochemical program. Large scale programs to detect large targets could employ 100-foot interval sampling to be followed by detailed sampling. Subsequent 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 over the total program area. Otherwise, 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 is used, has only a limited potential for success if samples are collected on intervals of 100 feet, or for some lines, even 25 feet.

7. 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. It is doubtful that success would be achieved even if the samples were collected on a grid pattern over the deposit.
8. Contamination sources may produce anomalies equivalent to, or greater than those produced from leakage halos in the till.

REFERENCES

Boyle, R.W., Dass, A.S., Church, D., Mihailov, G., Durham, C., Lynch, J. and Dyck, W.
1969: Research in geochemical prospecting methods for native silver deposits, Cobalt area, Ontario, 1966; Geol. Surv. Can., Paper 67-35.

Fortescue, J.A.C. and Hornbrook, E.H.W.
1967: Progress report on biogeochemical research at the Geological Survey of Canada, 1963-1966; Geol. Surv. Can., Paper 67-23, Pt. I.

Hoffman, D.W., Wicklund, R.E. and Richards, N.R.
1952: Soil survey of New Liskeard–Engleheart area, Timiskaming district, Ontario; Ontario Soil Survey, Rpt. No. 21; Experimental Farms Service, Canada Dept. Argriculture and Ontario Agricultural College.

Hornbrook, E.H.W.
1969a: Biogeochemical prospecting for molybdenum in west-central British Columbia; Geol. Surv. Can., Paper 68-56.

1969b: A pilot project at the Silvermine lead deposit, Cape Breton Island, Nova Scotia; in Progress report on biogeochemical research at the Geological Survey of Canada, 1963-1966, edited by J.A.C. Fortescue and E.H.W. Hornbrook; Geol. Surv. Can., Paper 67-23, Pt. II.

1970a: Biogeochemical prospecting for copper in west-central British Columbia; Geol. Surv. Can., Paper 69-49.

1970b: Biogeochemical investigations in the Perch Lake area, Chalk River, Ontario; Geol. Surv. Can., Paper 70-43.

Knight, C.W.
1924: Geology of the mine workings of Cobalt and South Lorrain silver areas; Ont. Dept. Mines, vol. XXXI, 1922, Pt. 2.

Koehler, G.F., Hostetler, P.B. and Holland, H.D.
1954: Geochemical prospecting at Cobalt, Ontario; Econ. Geol., vol. 49, pp. 378-388.

Miller, W.G.
1908: The cobalt-nickel arsenides and silver deposits of Timiskaming, 3rd Ed; Ont. Bur. Mines, vol. XVI, 1907, Pt. 2.

1913: The cobalt-nickel arsenides and silver deposits of Timiskaming, 4th Ed; Ont. Bur. Mines, vol. XIX, Pt. 2.

Moore, H.A.
1967: Silverfields Mining Corporation Limited; 1967 C.I.M.M. Centennial field excursion, northwestern Quebec and northern Ontario, pp. 146-149, publ. by Can. Inst. Mining Met.

Petruk, W.
1968: Mineralogy and origin of the Silverfields silver deposit in the Cobalt area, Ontario; Dept. Energy Mines and Resources, Mines Br., Division Report MS - PP. 68-1.

Rowe, J.S.
1959: Forest regions of Canada; Can. Dept. North. Affairs, Natl. Resources, Forestry Br., Bull. 123.

Thomson, R.
1956: Township of Bucke, district of Timiskaming, Ontario; Ont. Dept. Mines, Map No. 1956a.

1957: Cobalt camp; <u>in</u> Structural Geology of Canadian Ore Deposits, vol. 2, Sixth Commonwealth Mining and Metallurgy Congress, 1957, pp. 377-388; Can. Inst. Mining Met., Montreal.

1960a: Geology of the north part of Lorrain Township (Con VII to XII), district of Timiskaming; Ont. Dept. Mines, Prelim. Rept. 1960-1.

1960b: Report on parts of Coleman Township and Gillies Limit to the south and southwest of Cobalt, district of Timiskaming; Ont. Dept. Mines, Prelim. Rept. 1960-3.

1962: Indexes for Preliminary reports issued in 1960 and 1961 covering parts of the Townships of Bucke, Coleman, Gillies Limit, and Lorrain in the vicinity of Cobalt, district of Timiskaming; Ont. Dept. Mines, Prelim. Rept. 1962-2.

1964a: Cobalt silver area, northern sheet, Timiskaming district; Ont. Dept. Mines, Map 2050.

1964b: Cobalt silver area, southwestern sheet, Timiskaming district; Ont. Dept. Mines, Map 2051.

1964c: Cobalt silver area, southeastern sheet, Timiskaming district; Ont. Dept. Mines, Map 2052.

Warren, H.V. and Delavault, R.E.
1960: Observations on the biogeochemistry of lead in Canada; Trans. Roy. Soc. Can., vol. 54, ser. 3, sec. 4.

Warren, H.V., Delavault, R.E. and Fortescue, J.A.C.
1955: Sampling in biogeochemistry; Bull. Geol. Soc. Am., vol. 60, pp. 229-238.

APPENDIX A

HAMMER REFRACTION SEISMIC SURVEY TO ASSIST BIOGEOCHEMICAL PROGRAM NEAR COBALT, ONTARIO

George D. Hobson

Three shallow refraction seismic surveys were conducted over silver mining properties in the Cobalt area, Ontario (35 M/5E) to assist the investigations of a Geological Survey of Canada biogeochemical team. The three properties: Agnico Mines Limited (O'Brien property), located one mile east of Cobalt; and Hi Ho Silver Mines Limited and Silverfields Mining Corporation Limited, located about one and one-half miles south of Cobalt are readily accessible by vehicle (Fig. A-1). The seismic survey was carried out between July 23 and August 20, 1968.

A Huntec model FS-3 portable hammer seismograph was used to record seismic data. A 16-pound sledge hammer struck against a steel plate on the ground provided the seismic energy. Explosives were not used as an energy source.

Thirty-eight reversed refraction seismic profiles were completed over the three properties: 4 on O'Brien, 5 on Hi Ho and 29 on the Silverfields property. These profiles were completed at intervals of approximately 300 feet over cut lines established by the biogeochemical team. Hammer points were located at the actual biogeochemical sampling sites which were approximately 25 feet apart. It will be noted upon inspection of the cross-sections in Figures A-2 and A-4 and of the plan, Figure A-5, that the actual interval between biogeochemical test stations (that is, the availability of a tree) may vary from the 25-foot grid interval. Depth to bedrock was calculated beneath all hammer points resulting in a total of 423 separate depth determinations. All computations were done through a computer using a delay-time concept and the standard time-intercept formulae.

Horizontal survey control was supplied by the biogeochemical team while vertical control at all detector and hammer locations was established by use of a Wild level.

The geology of the project area has been described in detail in the body of this report; a brief geological background to the seismic survey is included in this section. The surficial material in the area is predominantly poorly sorted sand and gravel in recessional till moraines, outwash deposits, and poorly stratified beach, spit, and bar deposits. The bedrock beneath the O'Brien and Silverfields properties is diabase; the bedrock at the Hi Ho property consists of Coleman sediments surrounded by diabase.

Hi Ho Property

Figure A-1 sets out the cut line grid with station locations over the Hi Ho property. Figure A-2 depicts the thickness of overburden overlying the bedrock surface. The surface topography generally reflects that of the bedrock except between stations 20 and 30 on the north-south section. Beneath these stations there is a bedrock depression which is not reflected on the surface. Over this property, two ranges of seismic velocities are recorded and distinguished within the overburden. The uppermost surficial or aerated zone displays a seismic velocity ranging between 600 and 1,150 feet per second while the underlying drift material exhibits a velocity ranging between 2,100 and 4,900 feet per second. These velocities indicate dry materials, probably high in sand content, overlying bedrock. Bedrock velocities vary between 10,000 and 17,000 feet per second. Thickness of overburden on this property varies between 8 feet at both ends of the north-south control line and 76 feet beneath station 23. No outcrop was observed in the vicinity of the grid.

O'Brien Property

Figure A-3 sets out the cut line grid over the O'Brien property while Figure A-4 displays the bedrock topography and thickness of overburden. The four reversed profiles over this property provide very close control on the bedrock topography revealing that the bedrock surface is generally reflected in the overlying terrain relief. On this property the thickness of overburden is generally thin, varying between about 3 feet at station 17 and about 11 feet beneath station 6. Only one velocity layer can be detected overlying bedrock; seismic velocities within this layer range from 500 to 1,050 feet per second while the velocity observed through bedrock varies between 10,900 and 18,200 feet per second. Outcrops of diabase were observed adjacent to the cut grid lines.

Silverfields Property

Figure A-5 depicts the thickness of overburden over the project area of the Silverfields property. Overburden is generally less than 10 feet thick except near station 734, where 42.4 feet of overburden was calculated from seismic data. Extensive areas of diabase outcrop are visible over this area, particularly at the northern ends of the control lines. As on the O'Brien property, only one seismic velocity layer overlies bedrock; this velocity ranges from 750 to 1,150 feet per second. It is worthy of note that exceptionally high values of the seismic energy velocity through bedrock were observed on this property. Velocities in excess of 25,000 feet per second were observed on reversed profiles, thus indicating that the bedrock tends to be very basic or even ultrabasic in its chemical nature.

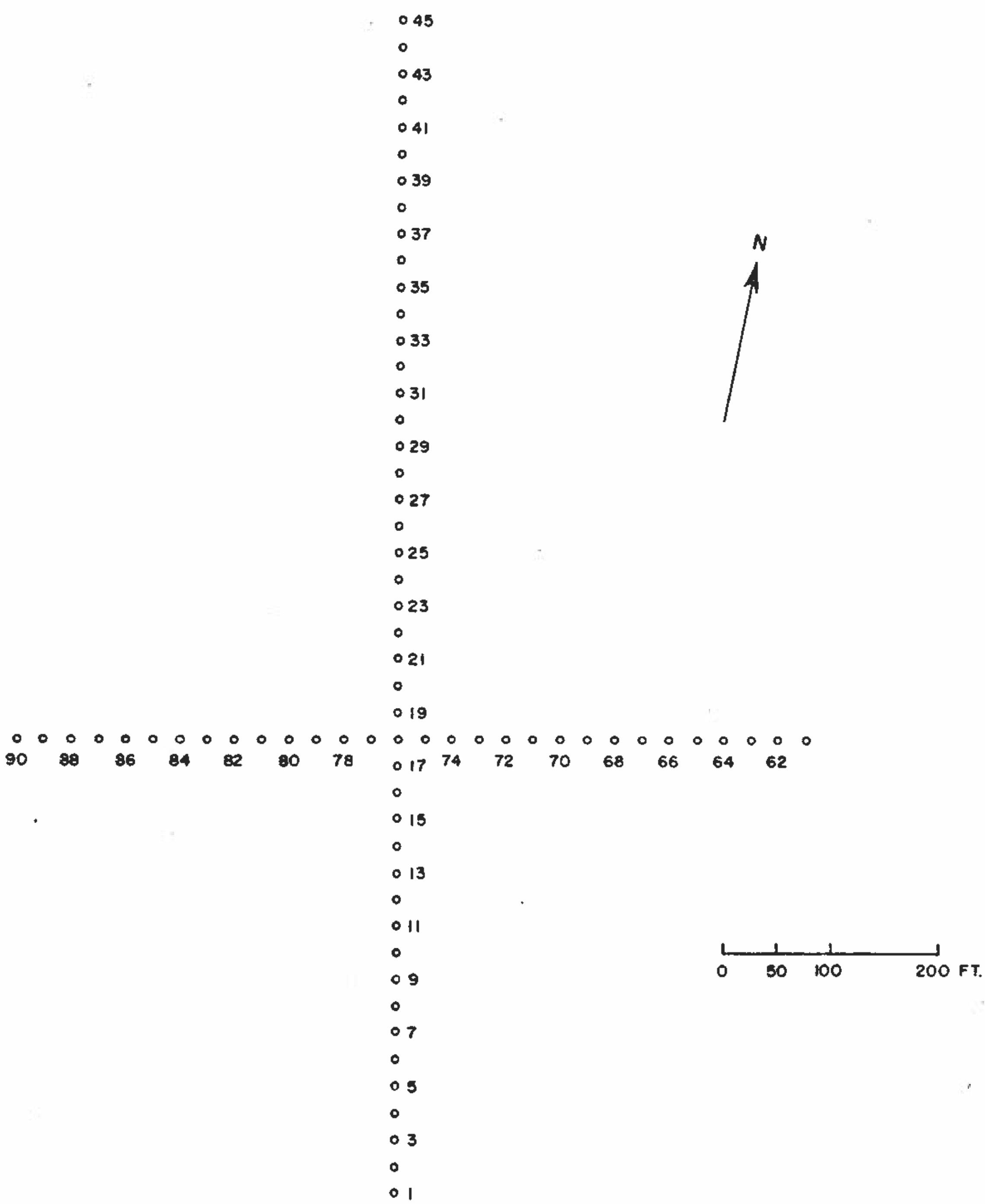


Figure A-1: Seismic locations over cut line grid, Hi Ho property, Cobalt area.

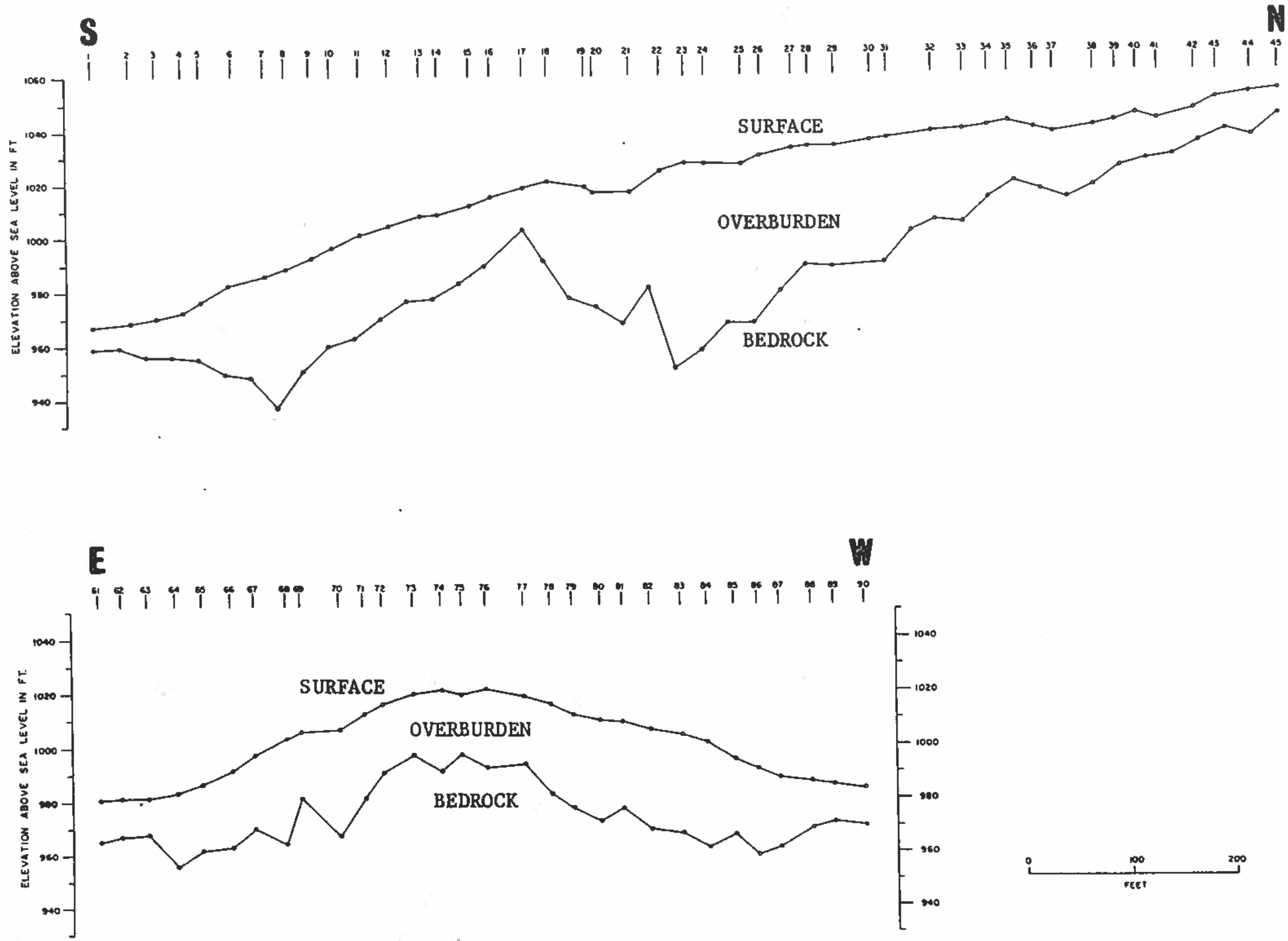


Figure A-2: Seismic sections depicting overburden over bedrock, Hi Ho property, Cobalt area.

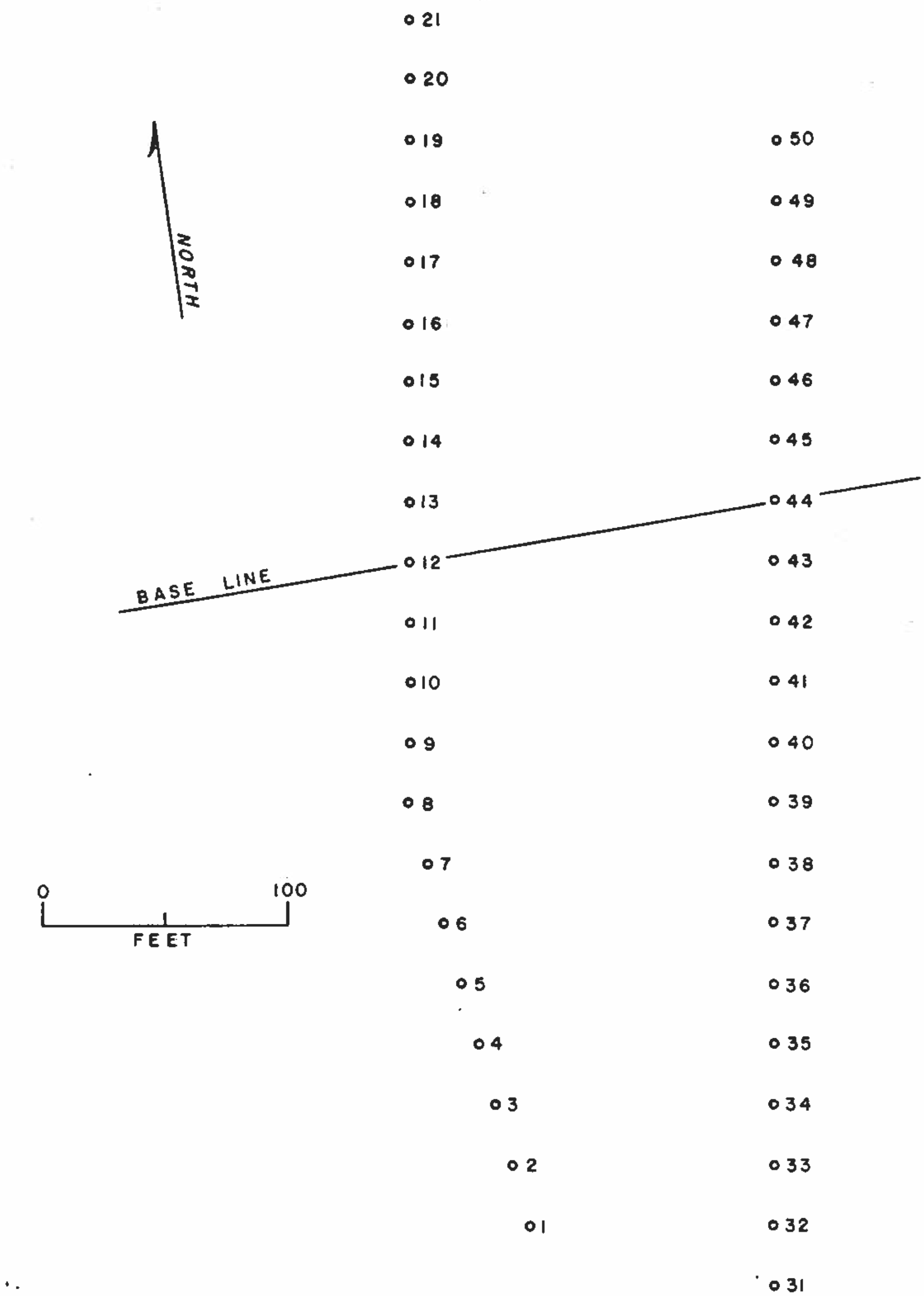


Figure A-3: Seismic locations over cut line grid, O'Brien property, Cobalt area.

Figure A-2: Seismic sections depicting overburden over bedrock, O'Brien property, Cobalt area.

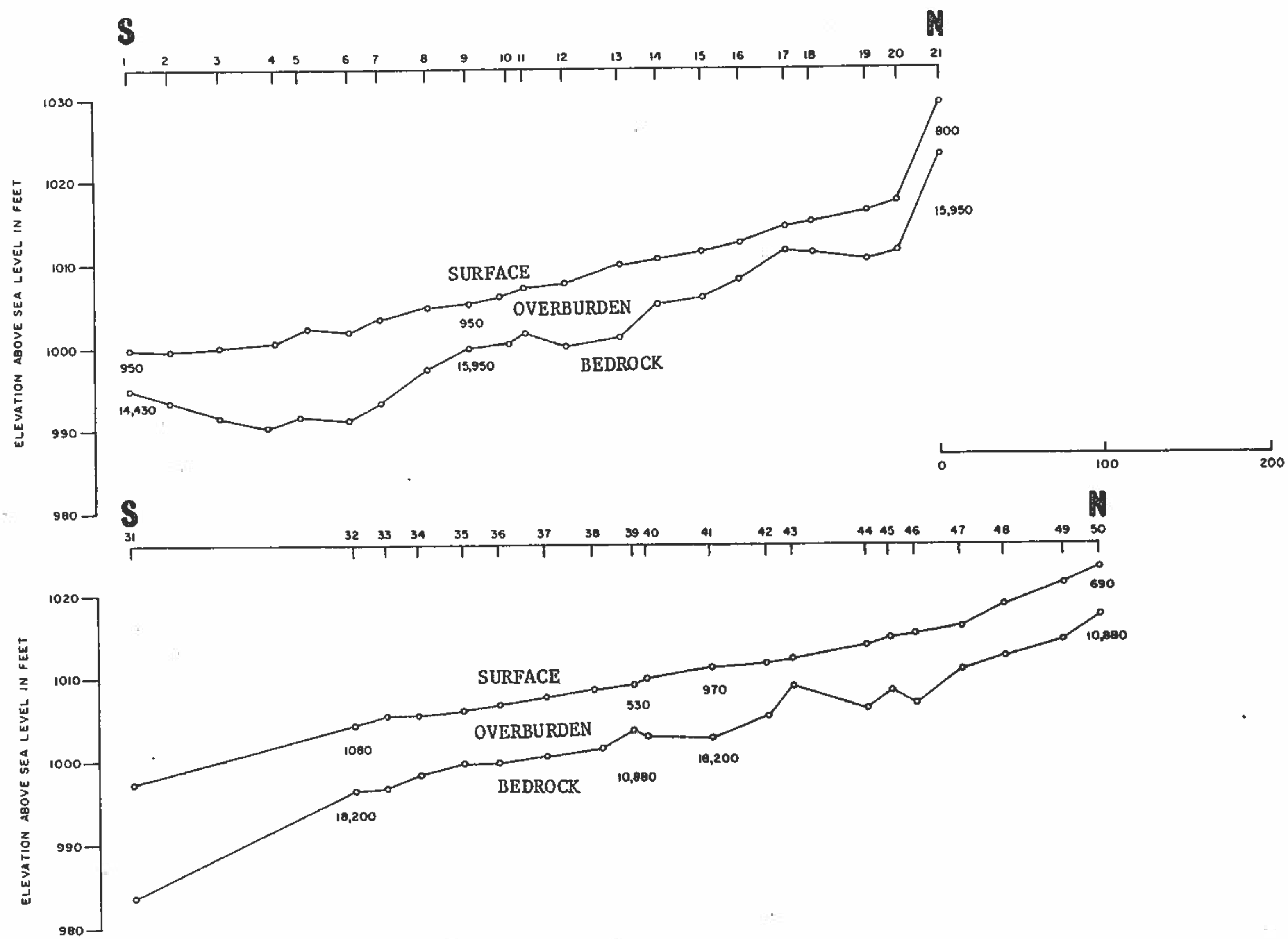


Figure A-4: Seismic sections depicting overburden over bedrock, O'Brien property, Cobalt area.

Figure A-4: Seismic sections depicting overburden over bedrock, O'Brien property, Cobalt area.

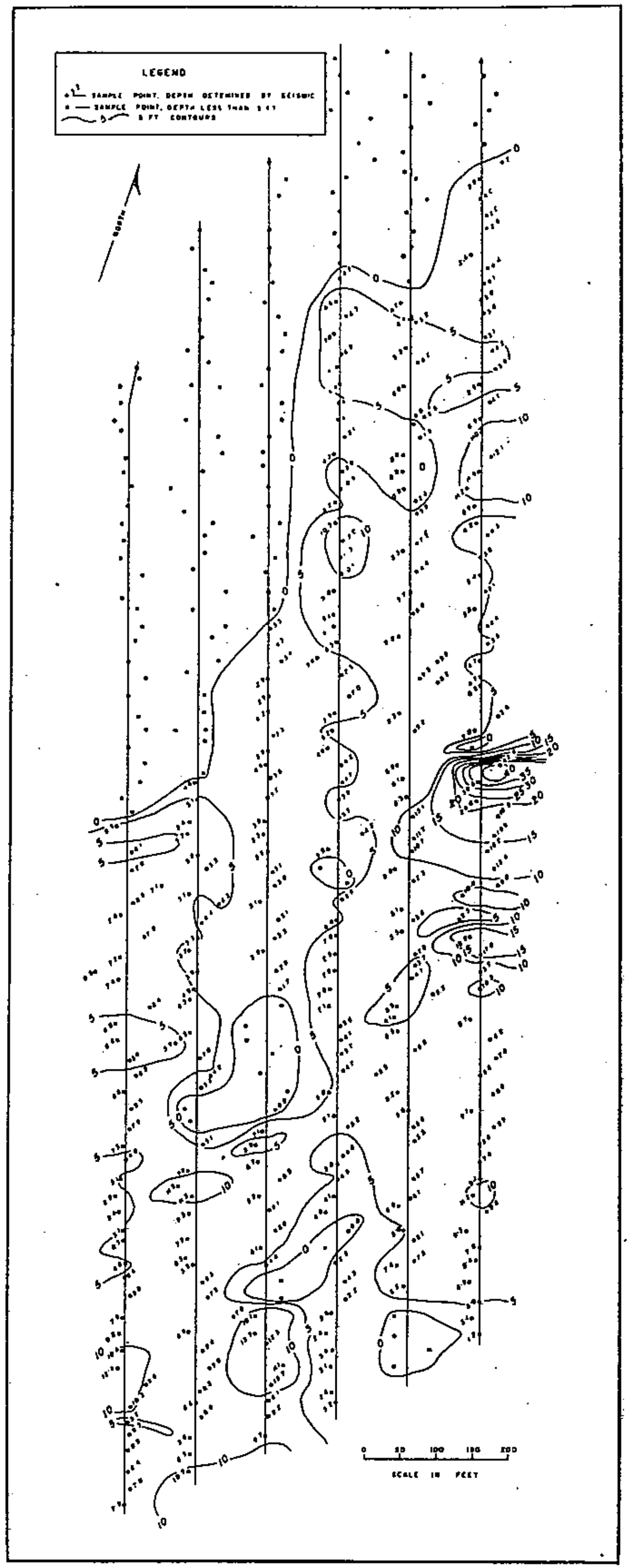


Figure A-5: Thickness of overburden, Silverfields property, Cobalt area.

APPENDIX B

Plant and Soil Collection and Preparation Techniques

At each station, a humus sample was collected from the (A_0+A_1) horizon as close to the previously selected sample tree as possible. Next, the sample tree was cut down, and the foliage sampled using steel secateurs. Bark samples were stripped off 1-inch-thick wood discs sawed off the main stem of the tree at breast height. The discs were used for growth ring count to determine the age of the sample tree. The soil pit was dug with a mattock where the humus was sampled, and representative samples of the B and C horizons were collected using hand tools. All samples were put in paper bags that have a high wet strength to resist sample moisture. The above order of sample collection was found by experience to reduce possible contamination between soil and plant materials.

In the sample preparation laboratory, foliage, bark (A_0 + A_1), B and C horizon soils were air dried in heated cabinets at 50 degrees centigrade for as long as three days in the case of wet humus. All material was then subsampled as follows: foliage separated into leaf, spur and twig organs; bark reduced to small fragments less than 1/4 inch thick; B and C horizon soil sieved to -80 mesh for analyses; and (A_0+A_1) horizon soil sieved to obtain the -10 to +80 mesh fraction. The subsampled bark, twig, spur, and leaf and humus samples were then oven dried at 80 degrees centigrade for 10 hours.

A 10-gram oven-dry amount of each sample of plant organ or humus material was dry-ashed in a muffle furnace on a time-temperature controlled cycle. The cycle permits the temperature to slowly increase to 435 degrees centigrade until all the organic material is thoroughly charred. The temperature is maintained automatically at 435 degrees centigrade for the remainder of the 10-hour cycle. Each ash sample was completely mixed and stored in sealed plastic vials for subsequent analyses.