THE PRIMARY DISPERSION OF CU, ZN, NI, CO, MN, AND NA ADJACENT TO SULFIDE DEPOSITS, SPRINGDALE PENINSULA, NEWFOUNDLAND

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ABSTRACT

An investigation was made of the dispersion patterns of copper, zinc, nickel, cobalt, manganese and sodium in the wall rocks of three sulfide deposits representative of the mineral occurrences found on the Springdale Peninsula, Newfoundland. Whole rock samples from the Lady Pond prospect, the Little Deer Mine and the Little Bay Mine were analyzed by atomic absorption spectrophotometry.

The deposits, consisting of several steeply plunging narrow lenses containing disseminations and impregnations of chalcopyrite and pyrite, occur in chloritic shear zones in Ordovician pillow lavas.

The sodium content of the samples gives a reliable indication of the extent of alteration undergone by the country rocks and the chlorite schist zones in which the deposits occur. Nickel and cobalt dispersion patterns do not show any aureoles surrounding the deposits. Manganese and copper dispersion patterns may exhibit narrow local aureoles. The zinc dispersion patterns suggest the presence of aureoles, approximately twenty five feet wide, around the sulfide deposits for four out of six traverses.

Average background values have been determined for the elements studied and data are presented on the distribution of the elements between different parts of pillows found in the epidotized pillow lavas.

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CHAPTER I. INTRODUCTION

As the search for economic mineralization continues, those deposits which are easily discovered by simple examination of the earth's surface have in large part been located, and new methods of exploration for finding "blind ore bodies" with no visual surface expression are being developed. One such exploration technique which has only been developed in the past two decades is based on the detection of secondary geochemical dispersion patterns and has proved itself in many instances in Canada and other countries (see Hawkes and Webb, 1962). The use of primary geochemical dispersion is not so well developed and in the words of Hawkes and Webb (op. cit.) "the application of primary dispersion patterns to mineral exploration is still strictly in the experimental stage."

The Springdale Peninsula, containing a number of copper bearing sulfide deposits in chlorite schist zones developed from basic volcanic rocks of Ordovician (?) age has been the site of extensive exploration during the last decade. Studies of primary dispersion aureoles around this type of deposit are limited. The area seemed an ideal place in which to make a scientific study and at the same time obtain information which could be useful in exploration for this type of deposit in an area characterized by extensive drift cover.

The present investigation sought to collect basic data concerning the levels of trace element concentrations in the vicinities of the deposits and to determine whether these deposits are characterized by primary dispersion aureoles of sufficient intensity and width to serve as ore guides.

A short review of the available information pertinent to the subject of primary dispersion patterns is given, but the reader is referred to the books by Hawkes and Webb (1962) and Ginzburg (1960) for a full discussion of the theory and uses of all phases of applied geochemistry.

PREVIOUS WORK

Following the classification of Hawkes and Webb (1962), reproduced in Table 1-1, the primary dispersion patterns are divided into two types, syngenetic and epigenetic, each with further sub-divisions. The pattern of interest during the present study is the epigenetic "wall rock anomaly."

Epigenetic Hydrothermal Dispersion Patterns

The term "hydrothermal" is used in its broadest sense to indicate hot aqueous fluids, whatever their source or direction of movement, that served as the medium in which or through which, the ore forming elements are transported. Introduction of the ore elements to the site of deposition may be by diffusion through a stationary hydrothermal fluid permeating the host rocks or by mass movement or flow of the hydrothermal fluids through the site of deposition. In the present study the writer sampled wall rocks adjacent to mineralized zones, i.e. the study concerned wall rock anomalies. The possible existence of leakage anomalies and compositional zoning was not investigated.

Wall Rock Anomalies

If the site of deposition represents part of a channelway through which mineralizing fluids flowed from a distant source it is likely that the difference in composition between the mineralizing fluids in the channelway and the pore fluids in the wall rocks would cause a movement of ore elements from the channelway out into the surrounding wall rocks, producing a trace element dispersion pattern or aureole that decreases in intensity outward from the site of mineralization. These aureoles might be thought of as a type of wall rock alteration even though they might

Table 1 - 1 Classification of the Principal Types of Primary Dispersion Patterns (after Hawkes and Webb, 1962, p.46).

Syngenetic Patterns	Geochemical province	
	Local syngenetic patterns	
Epigenetic Patterns	Hydrothermal dispersion patterns	Wall rock anomalies
		Leakage anomalies
		Compositional zoning
	Pressure Temperature effects in epigenetic minerals	Mineral reconstitution
		Chemical geothermometers
		Isotopic geothermometers

extend beyond the limits of mineralogical alteration. Such aureoles, if sufficiently well developed, could serve as an exploration guide in that they increase the size of the exploration target.

Alternatively, if one assumes that host rocks are the source of at least some of the constituents of ore and gangue minerals (e.g. Boyle, 1961, 1968) one would expect the host rocks in the vicinity of the mineralization to be depleted in the elements concerned.

Regional metamorphism of mineralized rocks might of course, modify preexisting dispersion patterns, possibly enhancing them or possibly destroying them.

Classical investigations into wall rock alterations, which greatly influenced subsequent studies, were carried out by Lovering, (1949) and Sales and Meyer (1948). General reviews were presented by Kerr (1955), who summarized the field and laboratory data on hydrothermal alteration, and by Schawrtz (1955), who discussed altered rocks as guides to ore. Within the last decade considerable effort has been oriented towards the investigation of hydrothermal alteration.

One of the earliest documented studies concerned mainly with trace element aureoles is that of Sandberger (1882, 1885), on the heavy metal content of ore shoots in the mining districts of Central Europe. The disoovery of traces of heavy metals in the wall rocks led him to formulate his famous hypothesis on lateral secretion. Posepny (1902) refuted Sandberger's theory and stated that the minute metallic admixtures detected by Sandberger were derived from the ore deposit.

Curtis (1884) found assayable silver in the shattered and altered limestone wall rocks adjoining high-grade silver replacement deposits in the Eureka mining district of Nevada. The silver content of the limestone decayed from 17 ppm in the wall rocks adjacent to the orebody to 8 ppm 30 feet away from the vein and to 5 ppm in the unaltered wall rocks 100 feet away from the ore bodies.

Interest in the subject appears to have declined in the period 1910 to 1950 and it was not until the publication of the work by Graf and Kerr (1950) on the deposits of Santa Rita, New Mexico that potential industrial applications were recognized. They found lead aureoles 20-30 feet wide and zinc aureoles 60-250 feet wide extending outward from lead-zinc deposits in fractured limestones.

Schwartz (1950) reported that bleached limestones adjacent to lead-zinc deposits at Bisbee and Leadville had been enriched in manganese and iron by as much as 12% near the ore.

Morris and Lovering (1952), working in the Tintic district of Utah, concluded that the movement of ore elements into the wall rocks was due mainly to diffusion from the ore zone. They found that the metal content of the wall rocks fell off logarithmically from the ore deposits, except where cracks permitted greater than normal access to the wall rocks. Along these cracks the metal content generally was found to fall off linearly from the deposit. The width of the anomaly seemed to vary inversely with the chemical reactivity of the wall rock. In the limestone the penetration was found to be very low, sometimes being restricted to as little as five feet. Similar narrow aureoles have been reported by others as characteristic of limestones; e.g. Engel and Engel (1956) and Austin and Nackowski (1958). In less reactive wall rocks, e.g. metamorphic and igneous silicate rocks, Morris and Lovering (1952) reported aureoles up to thousands of feet wide. They were able to predict accurately the existence of a 'blind vein' on the basis of their trace element data in the limestones.

James (1957, as reported on page 56 in Hawkes and Webb, 1962), during his study of arsenic in wall rocks of shear zones containing arsenic and gold in Southern Rhodesia, discovered a logarithmic decay of the arsenic content away from the ore deposits. He found an aureole width of 25 feet in sandstones and 200 feet in greenstones. Stoll (1945) working on the beryllium pegmatites of New England found diffusion of beryllium from the pegmatites into the mica-schist and mica-gneiss country rocks. Although the exact shape of the beryllium anomaly was not established, anomalously high concentrations of beryllium were found several hundred feet away from the pegmatites.

Hawkes and Webb (1962) concluded that the variable width of wall rock anomalies was determined by the chemical activity or permeability of the rock types together with the duration of the period of hydrothermal activity.

Boyle (1961) found that there was a decrease in the concentration of elements from greenstone country rocks towards gold-quartz veins in chlorite schist zones. He concludes that there had been a migration of carbon dioxide, water, sulphur, arsenic, gold, silver and other metallic elements from the greenstones into shear zone systems producing chlorite schists and economic mineral deposits.

Carpenter (1963) was able to correlate the width of copper halos in sandstones at White Pine, Michigan, with the tenor of the veins.

Faults, joints and fractures are other variables which may cause confusing anomalies in wall rocks. Graf and Kerr (1950), during a geochemical survey around a lead-zinc deposit in a limestone formation, New Mexico, found that the lead highs were further away from the ore body than the zinc highs. They found also that the zinc concentration was variable and did not show any correlation with distance away from the deposit and concluded that the distribution of the elements was largely controlled by small scale fractures.

Total Rock Versus Mineral Surveys

It has been clearly demonstrated in the past that elements occuring in trace amounts tend to concentrate in certain minerals, according to their charge, ionic radius and other atomic properties (Goldschmidt, 1954; Wager and Mitchell, 1943 and 1951; and others). Because of this effect, if total rock is analyzed, quite large differences in the recorded level of concentration could be caused simply by a change in the mode of the rock. For example, nickel is known to occur almost entirely in the ferromagnesian and sulfide phases and if the mode of these phases double an apparently significant change in nickel concentration will occur. In order to remove this effect, it seems desirable to analyse individual minerals rather than total rock. Several workers in the past have, with success, undertaken studies on individual or suites of minerals, e.g. Slawson and Nackowski (1959), worked on lead in K-feldspar; Bush and Cook (1960) analyzed jasperoid for heavy metals; Putman and Burnham (1963) determined copper in biotite; Jedwab (1955) investigated the tin content of several minerals; Fullgar et al (1967) determined the iron and copper content of biotites.

The majority of workers, especially those involved in the earlier investigations, have used total rock surveys, and the need for more analyses of individual minerals is apparent. It would appear from work already published that there has been a greater degree of success in detecting trace element aureoles around mineral deposits utilizing mineral surveys than utilizing whole rock surveys.

ROCK WEATHERING

Another effect which may mask the true primary dispersion pattern is the alteration of the trace element content by weathering. While the exact magnitude of this effect has not been reported in the literature, it seems possible that the movement of surface and near surface waters, particularly in the neighbourhood of oxidizing sulfides, might partially or completely distort or conceal the original pattern. In order to reduce the number of variables and to gain maximum control, it is desirable to analyze unweathered samples.

CONCLUSIONS

It appears from the literature that while a certain number of studies of primary dispersion patterns have been undertaken in a large variety of different areas, the number of investigations into the dispersion patterns of sulfide deposits in greenschist volcanic rocks is extremely limited.

A method for extending the detectability of a mineralized zone for several tens or hundreds of feet would prove a considerable asset to exploration in the metasomatized, folded, complex and rarely correlatable volcanic rocks of the Springdale Peninsula. The present study was designed as a "reconnaisance" type of investigation with the purpose of determining the general nature of primary wall rock dispersion patterns of the deposits in the area, therefore, the writer has not attempted an exhaustive treatment of the trace element dispersion patterns of the sulfide deposits studied.

CHAPTER II. COLLECTION, PREPARATION AND ANALYSIS OF SAMPLES

General Considerations and Problems of Sampling

Ideally, geochemical studies should be a follow up to petrographic and structural studies, however, although a number of studies have been undertaken to date in the area studied very few have yielded any worthwhile results mainly due to the complexity of the geology, very fine grained nature of the rocks which are similar in hand specimen and the scarcity of outcrops in many areas. The geochemical data obtained in the present study has not been correlated with petrological and structural studies of the area because only limited geological information was available.

Almost all of the ore deposits of the Springdale Peninsula are found in chlorite schist zones which are considered to be shear zones within volcanic rocks (Peters, 1967). Post ore dikes cutting the ore zones and chlorite schist display a slight foliation, thus the ore zones have been subjected to some degree of deformation. However, the occurrence of pyrite and chalcopyrite in ramifying veinlets and massive sulfide veins cutting across the schistosity and lithologies suggests that the emplacement of the mineralization is certainly later than the emplacement of the volcanic rocks and probably later than the main deformation associated with the formation of the chlorite schist zones. This led the writer to the working hypothesis that the deposits are "epigenetic hydrothermal". Peters (1967) suggests that the genetic relationships may go back to original volcanism and that the deposits formed or accumulated in physical and chemical traps within the volcanic pile.

In the initial stages of the project the writer attempted to make chlorite separates from the chlorite schist zones and the country rocks.

It was found that although a chlorite separate could be obtained it involved a considerable expenditure of time and it was rarely possible to attain a separate of 98% purity because the majority of the chlorite grains contained finely intergrown quartz.

Since one of the aims of the present study was to establish whether primary dispersion halos suitable for exploration purposes existed around the mineral deposits, the writer considered the time needed to prepare suitable mineral separates would render the results of the study impractical for exploration purposes. Since there are recorded instances of reasonable success in detecting trace element aureoles by means of whole rock studies the writer decided to investigate the presence of primary dispersion patterns by means of whole rock analyses.

Although the deposits have been subjected to metamorphism and the initial dispersion patterns may have been altered, the present primary dispersion patterns are still of interest from the scientific and exploration point of view.

COLLECTION OF SAMPLES

Areas Sampled

The present study was confined to three sulfide deposits on the Springdale Peninsula, Notre Dame Bay, Newfoundland. It was impossible to sample adequately all the sulfide occurrences on the Springdale Peninsula in the time available for the present research. The deposits chosen are representative of the area and yet provide some variation in the type of deposit. Samples were taken from: 1) the Little Bay Mine, which occurs in a chlorite schist zone in basic volcanic rocks; 2) the Little Deer Mine,

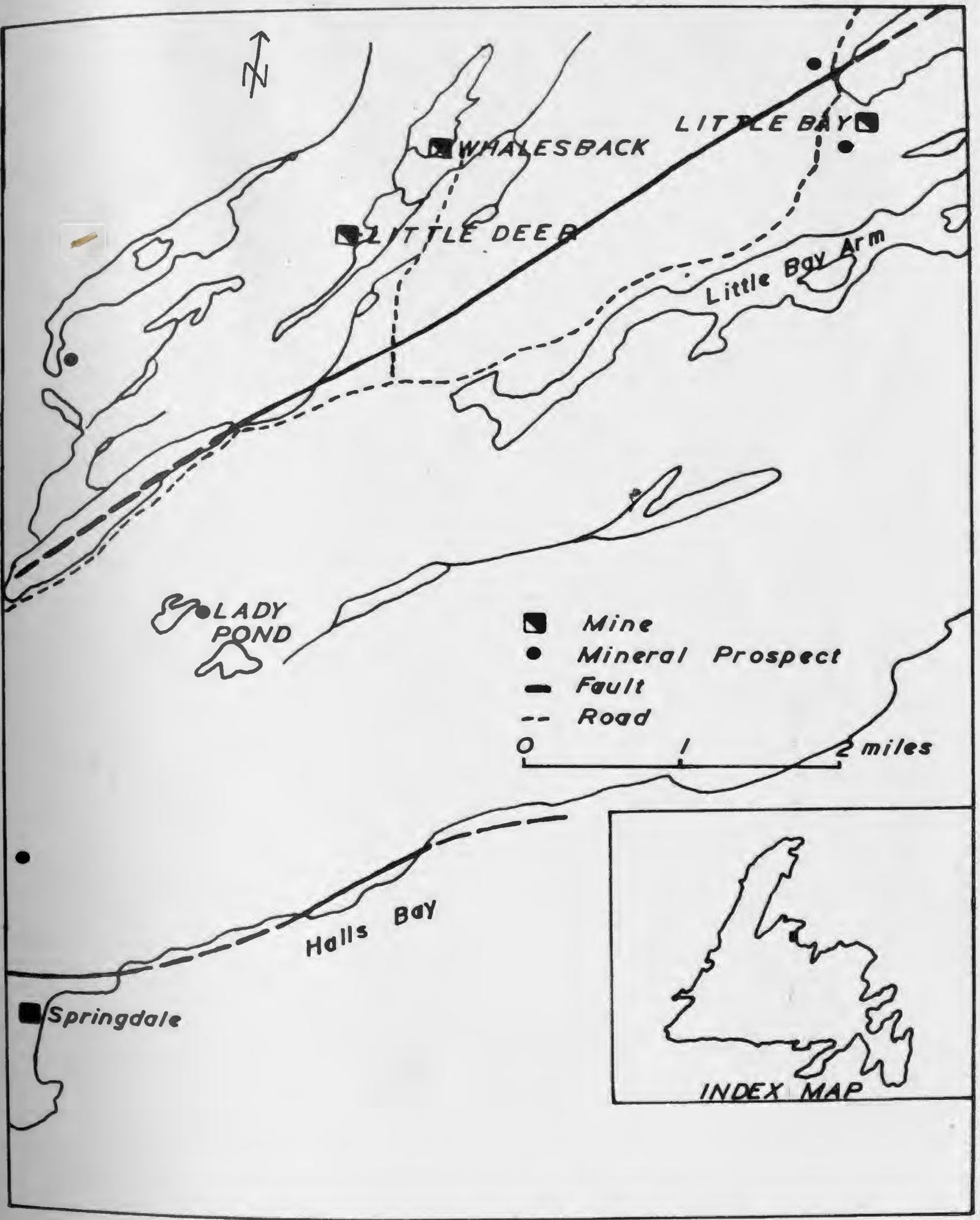


Figure 2-1 Outline map of part of the Springdale Peninsula showing the location of the properties sampled.

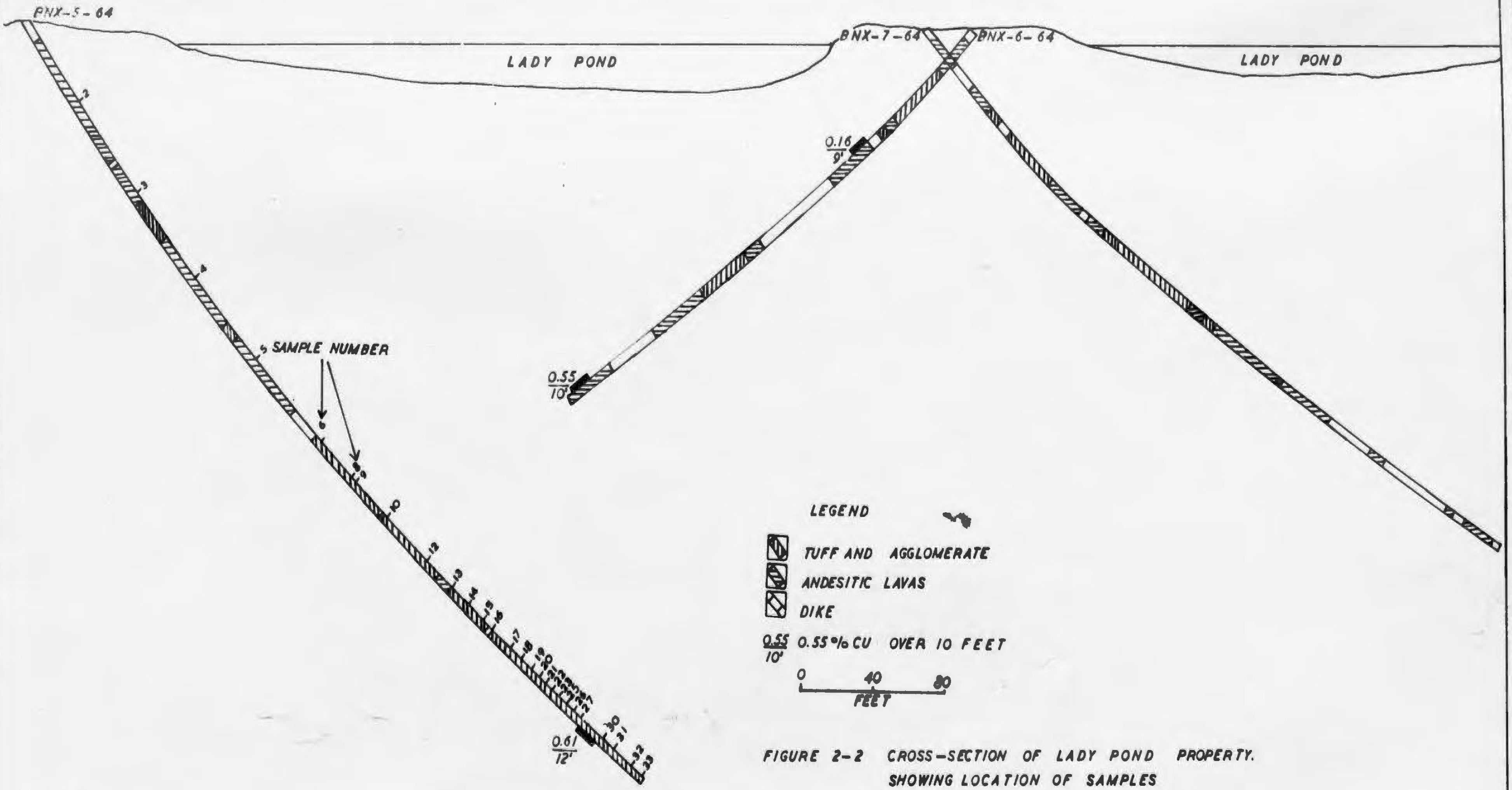


FIGURE 2-2 CROSS-SECTION OF LADY POND PROPERTY. SHOWING LOCATION OF SAMPLES

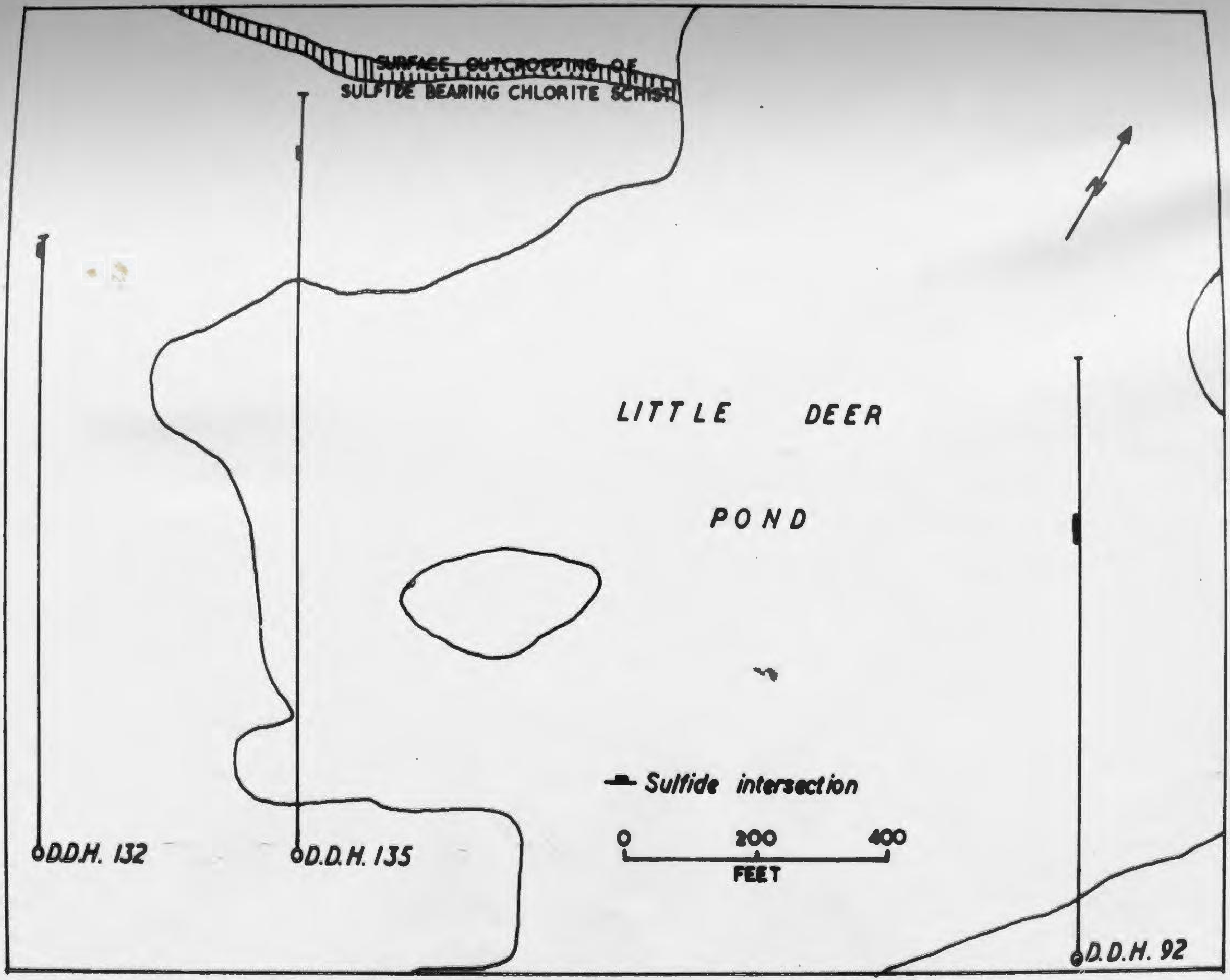


FIGURE 2—3 Surface plan of diamond drill holes sampled, Little Deer Mine.

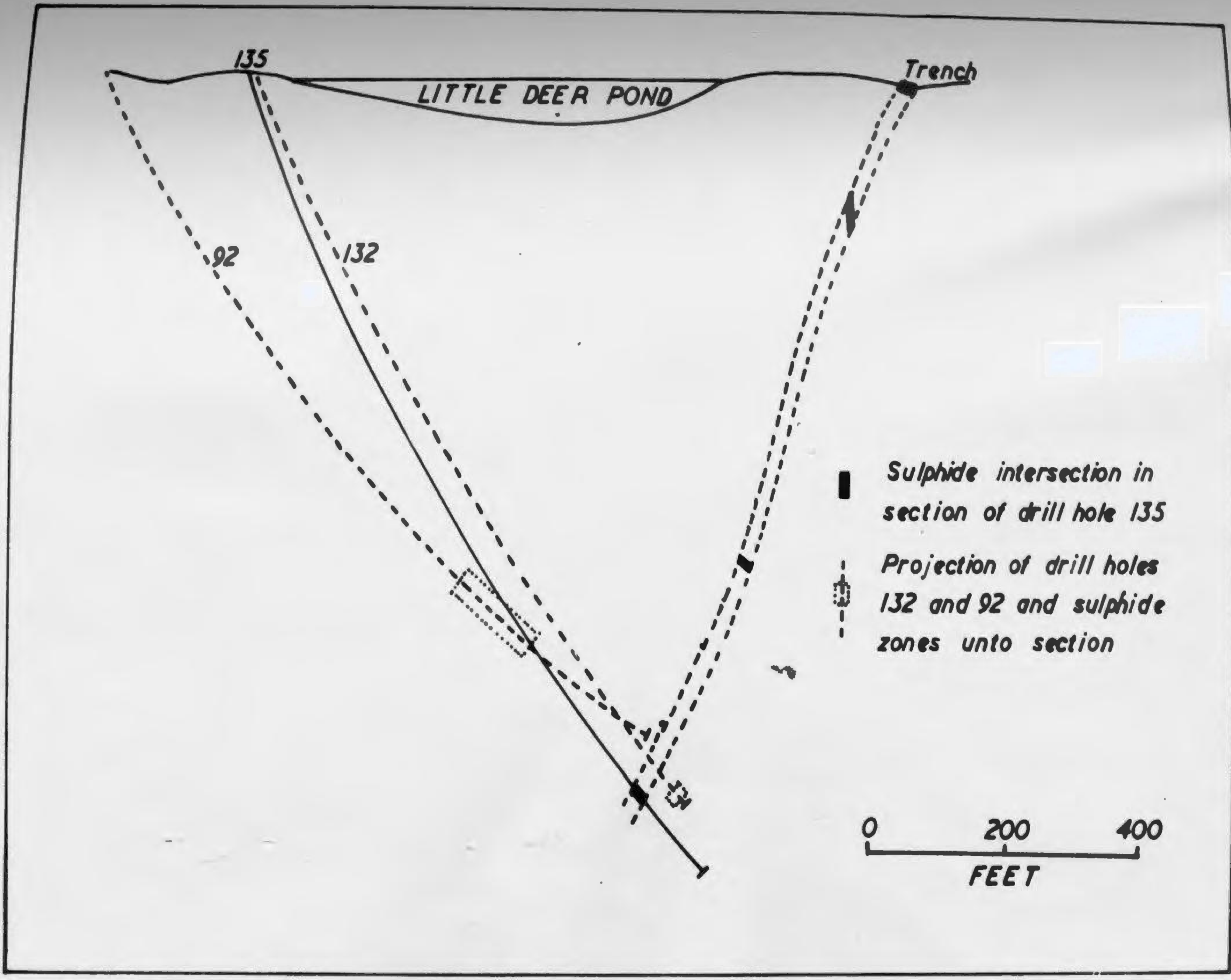


FIGURE 2-4 Diagrammatic section through Little Deer Mine illustrating drill holes sampled.

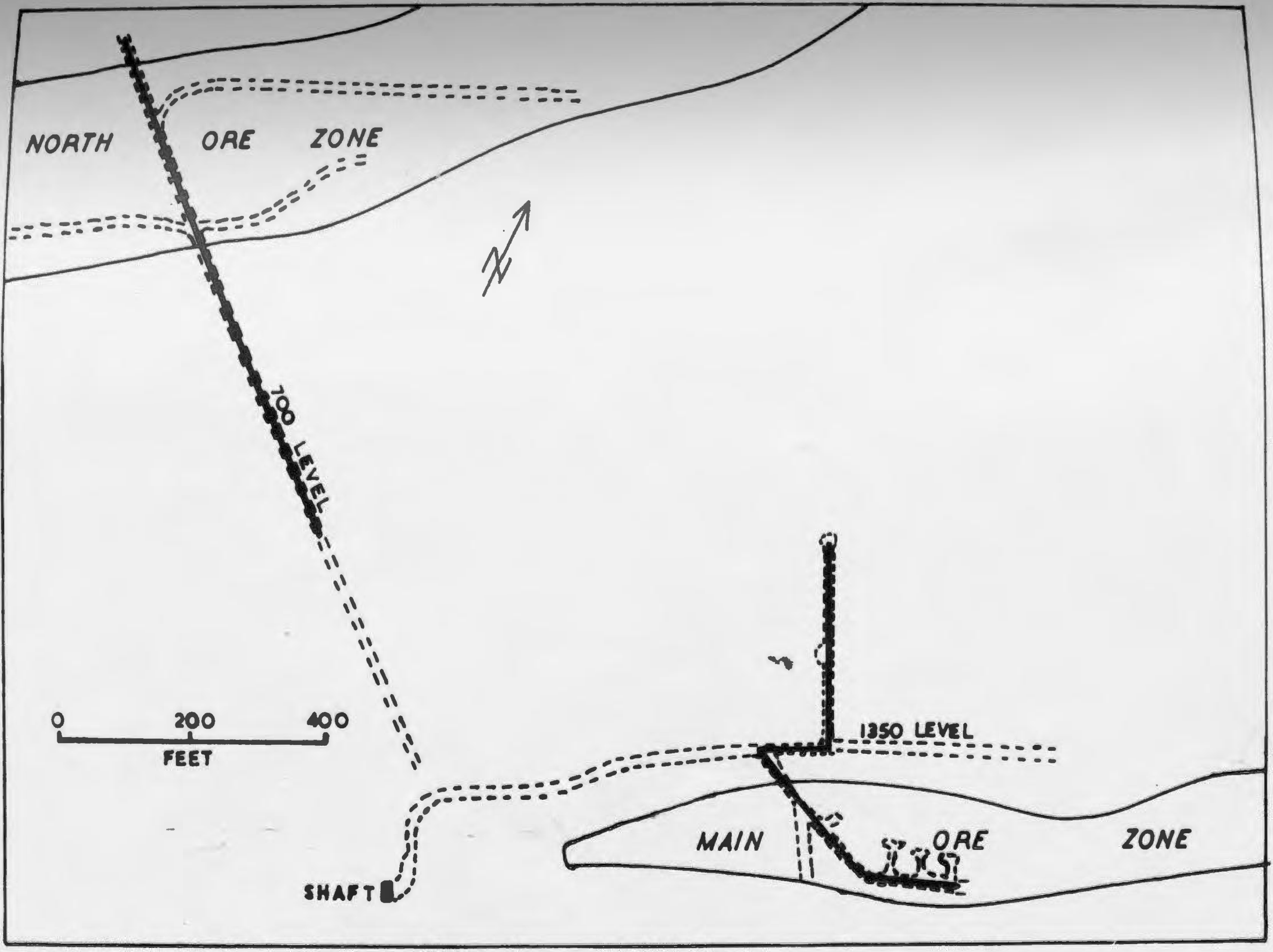


FIGURE 2-5 Outline map of Little Bay Mine with sample traverses (▬).

which is found in a chlorite schist zone that formed in predominantly andesitic volcanic rocks, and which contains dispersed vein-like mineralization; and 3) the Lady Pond prospect, a chlorite schist zone derived mainly from tuffaceous rocks containing traces of chalcopyrite and pyrite. Diagram 2-1 is an outline map of part of the Springdale Peninsula showing the location of the properties investigated.

Sample Traverses

The desirability of avoiding a variable error due to surface weathering was pointed out in the introduction. In order to do this, samples were collected only from diamond drill core and underground workings.

Samples were collected as follows:

Lady Pond prospect - AXT core from diamond drill hole BNX-5-64 was sampled. Figure 2-2 shows diagramatically the relationship of the Lady Pond drill hole samples and the sulfide zones intersected in other drill holes in the immediate vicinity.

Little Deer Mine - BXT core from Diamond drill holes No. 92, 132, and 135 were sampled. Figures 2-3 and 2-4 show the location of the Little Deer drill holes and a diagramatic section of the ore zone as determined by diamond drilling. Little Bay Mine - The North crosscut on the 700 level, and a crosscut and a drift on the 1350 level were sampled. Figure 2-5 shows the locations of the Little Bay sampling traverses.

Methods of Sampling

Samples collected from drill cores consisted of several six inch lengths of core selected over two to three foot intervals. Samples taken from the walls of the drifts were, whenever possible, channel or chip samples over a five or ten foot interval. Channel samples were obtained in the friable chlorite schist zones. Chip samples, consisting of one inch to two inch diameter chips spaced six inches apart, were collected from the massive and pillowed basaltic lavas.

All samples were collected using a geological hammer. The outer dirty parts of the rock were broken off and discarded. The samples, consisting of three to five pounds of rock, were placed in labelled paper bags.

In chip sampling the basaltic pillow lava two samples were taken within a circular area approximately five feet in diameter. One sample was taken from the schistose chloritic rims of the pillows and a second sample was taken from the epidotized pillow centers. In some cases a portion of the pillow located between the rim and center was only lightly epidotized, and resembled the massive lavas in hand specimen. A grab sample was taken of this "intermediate" pillow material whenever possible.

In places samples of chlorite schist were collected from inside zones of economic mineralization. Such samples would not, of course, be part of a primary dispersion aureole. They were collected not with the purpose of determining the extent of enrichment or impoverishment of elements within the ore zones as a whole, but with the purpose of comparing wall rock chlorite schist and similar (in so far as sampling would permit) chlorite schist within the ore zones. To this end samples collected within the ore zones were of material which did not appear to contain any chalcopyrite when viewed with a 10X hand lens. It was fully realized that in all probability such samples nevertheless contained minute grains of chalcopyrite. Specimens collected outside the ore zones were not selectively chosen with regard to sulfide content, and in fact, some did contain visible chalcopyrite.

Sampling Interval

During the initial stages of the programme an attempt was made to collect samples according to the scheme of logarithmically increasing distances between samples as described by Stonehouse (1964). The decision to do this was based upon the assumptions that the deposits are "epigenetic hydrothermal" in origin and that consequently the rate of decay in intensity of primary dispersion aureoles might be logarithmic which has been found to be the case for certain other epigenetic hydrothermal deposits (James, 1957; Morris and Lovering, 1952; and others). It was found that the complex geology in addition to the presence of numerous dikes made this method impractical and the writer adopted an alternative system of collecting. Samples taken within fifty feet of the ore zone were spaced five feet apart. Samples collected between fifty feet and one hundred feet away from the ore zone were spaced twenty feet apart. Samples collected more than one hundred feet away from the ore zone were taken at approximately one hundred foot intervals.

There was insufficient time available during the present research to allow an investigation of the effects of dike intrusion on the trace elements distribution. Samples of country rocks collected adjacent to dikes and samples of dike rocks were not analyzed. This omission of samples has resulted in the distribution patterns of the analyzed samples being less regular than implied by the above description of the sampling intervals. Nevertheless, the sampling intervals are less closer to the ore zones than they are several hundred feet away from the mineralization.

Sampling Precision

Several samples were taken from the same location at a number of places along the 1350 level traverse of the Little Bay Mine in order to determine the effects of sampling variables on the trace element content. The trace element contents of these samples are presented in Tables 2-1, 2-2 and 2-3.

Table 2-1 shows the difference in composition obtained for chip and grab samples of the same material. Sample 3AA consists of several pieces from the schistose chloritic rim of a pillow and sample 3AB, a chip sample, consists of numerous one-half inch pieces from the same pillow rim. The only significant difference in the analyses is in the content of sodium which is higher in the grab sample. If the mean values for duplicate chip samples of a basaltic lava, 8A and 8B, are compared with the values obtained for 8C, a four inch grab sample of the same material, the copper and sodium values can be seen to differ considerably.

Table 2-1 Compositional difference between chip and grab samples of the same material. Cu, Zn, Ni, and Co in ppm; Mn and Na in per cent.

Sample No.	Description	Cu	Zn	Ni	Co	Mn	Na
3AA	Grab	13	110	135	96	0.131	3.46
3AB	Chip	15	117	140	93	0.142	2.64
	Mean	14	113	137	94	0.136	3.05
Mean of 8A and 8B	Duplicate chip	112	79	113	60	0.092	1.18
8C	Grab	35	80	108	65	0.091	1.46
	Mean	73	79	110	62	0.091	1.32

Several samples were taken in order to determine the compositional differences, if any, between parts of pillows from the same locality. Samples taken at sample stations 3, 5 and 6 of the Little Bay 1350 level traverse are presented in Table 2-2. In general, lower concentrations of the elements analyzed were found in the epidotized cores than in the schistose chloritic rims of the pillows. The nickel value for 5b and the copper value for 6C are anomalous. Samples 3Bb and 6D represent non-schistose portions of the pillows that have been only lightly epidotized and are probably near the composition of the pillows prior to extensive epidotization. The analyses obtained for these lightly epidotized samples are, with the exception of copper in sample 6C, intermediate in concentration between the epidotized cores and the chloritic rims.

Table 2-2 Compositional differences between different portions of pillowed basalt from the same location sampled by identical methods. Cu, Zn, Ni and Co in ppm; Mn and Na as per cent.

Sample No.	Description	Cu	Zn	Ni	Co	Mn	Na
Mean of 5a and 5c	Chloritic rims	108	68	127	66	0.110	2.47
5b	Epidotized cores	30	32	150	42	0.083	0.09
3AB	Chloritic rims	15	117	140	93	0.142	2.64
3Bb	Partly epidotized cores	8	41	107	58	0.113	0.20
3Ba	Epidotized cores	8	--	92	50	---	0.11
6A	Massive lava	113	81	110	69	0.104	2.59
6B	Chloritic rims	119	108	153	97	0.125	2.92
6D	Partly epidotized interiors	40	60	110	57	0.089	0.80
6C	Epidotized cores	158	38	70	45	0.067	0.12

-- Not determined

Sample 6A was taken from a band of massive lava six feet away from samples 6B, 6C and 6D. This analysis is presented in order that a comparison may be made with the pillowed lavas. The values obtained for the pillow rims are slightly lower than, but of the same order of magnitude as, those obtained for the massive lavas whereas the values obtained for the epidotized cores of the pillows generally differ considerably from those of the massive lava.

Table 2-3 Compositional differences between duplicate chip samples of the same material. Cu, Zn, Ni and Co in ppm; Mn and Na in per cent.

Sample No.	Description	Cu	Zn	Ni	Co	Mn	Na
5a	Pillow	116	71	130	65	0.113	2.24
5c	rim	100	65	123	66	0.107	2.69
Mean		108	68	126	65.5	0.110	2.46
8A	massive	105	81	113	59	0.103	1.01
8B	lava	120	78	---	61	0.082	1.36
Mean		112	79	113	60	0.092	1.18
15a	massive	95	79	125	62	0.090	1.59
15c	lava	73	71	124	63	0.084	2.19
Mean		84	75	124	62	0.087	1.89
20b	Dioritic	73	89	112	77	0.165	2.29
20c	dike	82	76	114	74	0.141	2.67
Mean		77	82	113	75	0.153	2.48

-- Not determined.

The analyses of duplicate samples presented in Table 2-3 indicate that while copper and sodium tend to show a slight variation in concentration the other elements have nearly identical concentrations.

The precision of the analytical procedure (Table 2-6) is approximately the same as the apparent precision of the sampling procedure, provided identical material is considered. The variations shown in Tables 2-1 and 2-3 could therefore be largely due to analytical scatter rather than sampling inconsistencies. However, insufficient data were obtained to properly evaluate the precision of the sampling method, but the results shown in 2-3 indicate that it is within reasonable limits. On the other hand the data reported in Table 2-2 show variations between samples from different parts of the same basaltic pillows that are distinctly beyond the limits of precision of the analytical and sampling methods.

PREPARATION OF SAMPLES FOR ANALYSIS

Preparation of Mineral Separates

Early in the study the writer attempted to make mineral separates of chlorite, pyrite and chalcopyrite. Chlorite is abundant throughout the chlorite schist zones in which the mineralization occurs as well as in some of the country rocks beyond the schist zones. It seems reasonable to expect that chlorite in and near the mineralized zones would differ in trace element content from chlorites away from the mineralized zones because they either formed (in part at least) during and in response to the mineralizing process or else they formed during post mineralization metamorphism. The motivation for planning analysis of sulfide separates was mainly curiosity to establish the abundances of trace elements present and to determine whether sulfides from the three deposits investigated contained similar trace element values.

Some twenty samples of chlorite schists from the ore zone and the surrounding rocks were processed by the method outlined in Appendix III, however, the writer found that the average concentration obtained was 90% chlorite, due to the presence of very finely intergrown quartz (less than 0.001 mm) in the majority of the chlorite grains separated. These chlorite separates were not analyzed. (It may be possible to digest only the chlorite by dissolving the separates in an appropriate acid, such as perchloric. It may also be possible to obtain a better chlorite concentration by making a visual separation of the more chloritic rock fragments prior to grinding and separation).

The pyrite and chalcopyrite separations were quite successful in that mineral separates of 99%+ purity were obtained. The samples were not analyzed because there was not sufficient time available during the present study for the writer to establish a suitable analytical procedure and to determine the trace element content of the separates. This work is currently being continued by Dr. W. G. Smitheringale at Memorial University.

Preparation of Whole Rock Powders

Whole rock powders were prepared using the method outlined by Hounslow and Moore (1966). A detailed description of the method used is presented in Appendix III.

The specimen was thoroughly cleaned of any adhering foreign matter and broken to less than two inch diameters. The sample was coarse crushed in a Bico jaw crusher to give fragments less than one half inch in diameter. Any pieces of steel derived from the steel jaws of the crusher during crushing were removed from the sample by a strong hand magnet. The crushed sample was passed through a Bico pulverizer first with the ceramic disks set 1 mm apart and then a second time with the disks set at their minimum separation. A fifty gram portion of the sample, obtained by repeatedly splitting the powder from the pulverizer, was sieved through a plexiglass sieve fitted with 97 mesh nylon bolting cloth. The plus 97 mesh fraction was reduced to less than 97 mesh in ceramic grinding mills fitted onto a paint shaker. The powder was mixed by first resieving and then coneing at least five times. The mixed powder was stored in a labelled snapcap plastic vial.

ANALYSIS OF SAMPLES

Elements Analyzed

Copper and zinc were obvious choices because they are the principal elements of economic interest contained in the ore zones. Nickel and cobalt were chosen because they are among the trace elements most commonly associated with pyritic copper sulfide deposits.

Thin section studies showed that there was considerably less feldspar in the chlorite schists of the shear zones than in the surrounding country rocks. The feldspar was identified as sodic plagioclase and since its decrease in the shear zones was a result of alteration of the country rocks during development of the shear zone or leaching during the mineralizing processes or a combination of both events, sodium was determined in order to obtain a chemical index of the extent of alteration and/or hydrothermal leaching.

Manganese determinations were performed on the samples to determine how the development of the shear zones and emplacement of the ores affected the behaviour of this element.

Instrumentation

Since one of the objects of the present study was to become familiar with the method of analysis by atomic absorption spectrophotometry, all analyses were performed by this technique.

The rock powders were analyzed for copper, zinc, nickel, cobalt and manganese on a Perkin Elmer Model 303 with the recorder readout coupled to a Texas Instruments Incorporated Servoriter II chart recorder. The sodium analyses were determined on a Techtron Type AA4 using the built in absorption scale galvanometer.

Chemical Preparation

Approximately one gram of rock powder was weighed accurately into a Teflon beaker. The powder was moistened with distilled water and 10 mls of nitric acid, 20 mls of hydrofluoric acid and 2 mls of perchloric acid were added in turn. The mixture was heated on a sand bath until the hydrofluoric acid had been driven off and dense white perchloric fumes were being evolved. The beaker walls were then rinsed down inside with several mls of distilled water and left on the hot plate until perchloric fumes ceased to be evolved. The perchlorates were dissolved by boiling after adding 5 mls of hydrochloric acid, and 10 to 20 mls of distilled water. The solution was made up to 100 mls in a volumetric flask. All reagents used were Analytical grade and twice distilled water was used in all preparations and for washing glassware. The method of chemical preparation is described in detail in Appendix IV.

Standards

Standards were prepared by diluting specially prepared solutions obtained from the Fisher Scientific supply house. Details of the preparation of the working standards are described in Appendix IV.

Contamination

Contamination checks were run by preparing an acid blank solution with each batch of samples and by analyzing one powder from each batch several times during the course of the analyses.

Operating Conditions

It was found that the operating conditions specified by the Perkin Elmer Corporation (1967) were suitable for most analysis. However, slight adjustments were necessary in order to work within the concentration ranges of the sample solutions for certain elements. Table 2-4 lists the instrumental settings used and the concentration of solutions for which these settings were found to be most suitable.

The instrumental settings used on the Techtron instrument for the analysis of sodium were: wavelength, 3302 A; slit, 100u; burner set at 45° to the optical path; meter response, 1x and 5x; range of sample solution 0 to 600 ppm.

Table 2-5 gives the sensitivity (parts per million represented by 1% absorption), detection limit in the sample solution, and detection limit in the rock for the elements analyzed.

Table 2-4 Operating parameters for the Perkin Elmer Model 303 fitted with a Boling burner head.

Element	Wavelength A°	Slit	Burner angle	Scale response	Range of sol. in ppm.
Cu	3247	3	0	3x	0 - 4
	3247	3	0	1x	2 - 20
Co	2407	3	0	3x	0 - 2
Ni	2320	3	0	3x	0 - 2
Zn	2138	5	0	1x	0 - 2
Mn	2795	4	90°	1x	0 - 80

Burner angle = angle between axis of burner slits and optical path.

Table 2-5 Sensitivity and detection limits for the elements analyzed.

Element	Sensitivity (ppm/1% Abs.)	Detection limit, sample sol., ppm.	Detection limit in rock, ppm.
Cu	0.01	0.004	0.4
Co	0.06	0.02	2.0
Ni	0.06	0.02	2.0
Zn	0.015	0.005	0.5
Mn	1.0	0.2	20.
Na	2.0	0.2	20.

Precision and Accuracy

During the course of the analyses, several analyses were performed on the same rock samples. A group of seven samples were analyzed a number of times over a period of six weeks and should represent the overall variation in analytical procedure since some of the analyses were performed at the beginning of the analytical study and others near the end. These analyses therefore represent the sum of errors from weighings, chemical preparation, instrumental errors, and operator errors. Table 2-6 shows the individual values obtained for each run of the samples. Table 2-7 expresses these data statistically.

Table 2-6 Concentration of replicate analysis of samples 4, 15a, 15c of Little Bay 1350 level traverse, sample 22 from Little Deer drill hole 92, sample 26 from Little Deer drill hole 132 and samples 18 and 48 from Little Deer drill hole 135. Cu, Zn, Co and Ni in ppm; Mn and Na in per cent.

Sample	Cu	Zn	Co	Ni	Mn	Na
4a	163	60	60	98	0.087	3.33
	112	56	59	79	0.087	3.29
	--	66	--	--	0.088	3.38
	--	59	--	--	--	--
15a	87	80	60	130	0.089	1.65
	102	76	63	119	0.090	1.52
	--	81	63	--	--	1.61
15c	75	71	60	127	0.074	2.27
	78	73	62	121	0.084	2.10
	67	69	66	--	0.088	--
22	74	94	67	79	0.118	2.72
	72	95	73	88	0.120	2.72
	64	98	76	81	0.123	2.66
	74	100	79	80	0.119	2.70
26	90	100	78	80	0.127	2.26
	80	104	82	71	0.127	2.29
	90	107	81	79	0.126	2.21
	83	112	82	--	0.127	2.30
18	74	80	78	74	0.126	2.72
	71	83	74	72	0.136	2.80
	68	82	76	78	0.128	3.01
	75	89	76	--	0.129	--
48	80	94	75	61	0.143	0.35
	79	95	75	63	0.139	0.35
	78	99	--	62	0.136	0.35
	84	104	--	--	0.137	0.33

-- not determined.

Table 2-7 Standard and Relative Deviation of Atomic Absorption Analysis for replicate determinations of the samples given in Table 2-6.

Sample 4

Element	Mean ($\bar{x}$)	Standard Deviation	Relative Deviation	No. of determinations
Cu	137 ppm	± 30.0 ppm	21.1 %	2
Zn	60 ppm	± 4.2 ppm	7.0 %	4
Co	60 ppm	± 1.0 ppm	1.6 %	2
Ni	88 ppm	± 13.4 ppm	15.0 %	2
Mn	0.087 %	± 0.001 %	0.1 %	3
Na	3.33 %	± 0.004 %	0.1 %	3

Sample 15a

Cu	94 ppm	± 10.6 ppm	11.3 %	2
Zn	79 ppm	± 2.6 ppm	3.3 %	3
Co	62 ppm	± 1.7 ppm	2.7 %	3
Ni	125 ppm	± 7.1 ppm	5.7 %	2
Mn	0.089 %	± 0.001 %	0.01 %	2
Na	1.59 %	± 0.07 %	4.4 %	3

Sample 15c

Cu	73 ppm	± 5.6 ppm	7.7 %	3
Zn	71 ppm	± 2.0 ppm	2.8 %	3
Co	64 ppm	± 2.0 ppm	3.1 %	3
Ni	124 ppm	± 3.8 ppm	3.2 %	2
Mn	0.082 %	± 0.007 %	0.1 %	3
Na	2.14 %	± 0.02 %	1.0 %	2

Sample 22

Cu	71 ppm	± 4.8 ppm	6.7 %	4
Zn	96 ppm	± 2.8 ppm	2.9 %	4
Co	69 ppm	± 7.9 ppm	11.1 %	4
Ni	82 ppm	± 1.3 ppm	1.6 %	4
Mn	0.120 %	± 0.002 %	1.6 %	4
Na	2.70 %	± 0.028 %	1.0 %	4

Sample 26

Cu	86 ppm	± 5.1 ppm	5.9 %	4
Zn	105 ppm	± 4.1 ppm	3.9 %	4
Co	81 ppm	± 2.0 ppm	2.5 %	4
Ni	77 ppm	± 5.0 ppm	6.5 %	3
Mn	0.127 %	± 0.001 %	0.4 %	4
Na	2.26 %	± 0.04 %	1.8 %	4

Table 2-7 (continued)

Element	Mean ($\bar{x}$)	Standard Deviation	Relative Deviation	No. of determinations
		Sample 18		
Cu	72 ppm	3.2 ppm	4.5 %	4
Zn	83 ppm	3.9 ppm	4.7 %	4
Co	76 ppm	1.6 ppm	2.1 %	4
Ni	75 ppm	2.4 ppm	3.2 %	3
Mn	0.129 %	0.004 %	3.1 %	4
Na	2.84 %	0.14 %	4.9 %	3
		Sample 48		
Cu	80 ppm	2.6 ppm	3.3 %	4
Zn	98 ppm	4.6 ppm	4.7 %	4
Co	75 ppm	0.0 ppm	0.0 %	2
Ni	62 ppm	1.0 ppm	1.6 %	3
Mn	0.139 %	0.003 %	2.2 %	4
Na	0.35 %	0.01 %	0.3 %	4

$$\text{True Standard Deviation} = \sqrt{\pm\frac{(x-\bar{x})^2}{N-1}}$$

$$\text{Relative Deviation} = \frac{\text{Standard Deviation}}{\bar{x}} \times 100$$

where x = Value in ppm or percent
$\bar{x}$ = Mean concentration
N = Number of times sample was run.

Interferences

The sharp-line light source of the atomic absorption spectrophotometer removes most spectral interferences. A number of the earlier papers on atomic absorption spectrophotometry (Elwell and Gidley (1962), Slavin (1964) and others) reported that the technique was free from interferences. It has since been recognized that while the method is relatively free of interferences for aqueous solutions it is not necessarily true for geochemical and other solutions which often have a high concentration of other elements in comparison to the low concentration of the element being determined. Trace element studies of rocks are extremely susceptible to interferences since there is a low concentration of the trace element in comparison to the high content of the major rock forming elements. Several interferences were readily recognized by geochemists utilizing the atomic absorption method. Among these interferences are Al masking Mg and Ca and silicon interfering with the determination of base metals (a complete listing is given in Angino and Billings, 1967, p.58).

Billings (1965) discovered that high salt contents in geochemical solutions produced an interference which seemed to enhance absorption. He called this interference 'light scattering'. This 'light scattering' of Billings was investigated by Capacho-Delago and Sprague (1965) who attributed the enhanced absorption to absorption by a molecularly bonded species, especially CaOH, and the inability of the low temperature flame used by Billings, to break the molecular bonds to produce atoms.

The writer ran a number of experiments to determine whether such interferences were present in the sample solution concentrations expected in the present study. Potential silicon interference was obliterated by removing the silicon with hydrofluoric acid during decomposition of the sample. A batch of twenty samples were analyzed by the method of additions described by Abbey (1967) to ascertain any enhancements or depressions of the trace elements being investigated arising out of the differences in matrix of the samples. The writer found that there was a slight increase in absorption of samples diluted 50 fold, that is, one gram of sample diluted to a final volume of 50 mls. This enhancement disappeared when the samples were diluted 100 fold. Two hundred fold dilutions gave exactly the same results as those obtained for the 100 fold dilutions. The 100 fold or greater dilutions were used throughout this study.

The method of measuring the absorption on a non-absorbing wave-length as proposed by Billings (1965) to correct for light scattering was carried out for copper and zinc. The copper non-absorbing line gave 1% to 2%

absorption for the 50 fold dilutions but did not give any absorptions for the 100 and 200 fold dilutions. The zinc non-absorbing line gave erratic values for the 50 fold dilutions and reduced erratic values for 100 and 200 fold dilutions of the same samples. This was not surprising since the line used is an absorbing line for cadmium which may be present in the sample.

Similar tests were attempted for nickel and cobalt without success since there was some doubt concerning the instrumental settings required and the writer found difficulty in discriminating between the absorbing and non-absorbing lines with the wavelength selector.

Further attempts to determine the effects of the major elements upon the trace element determinations were carried out by mixing high purity (not Specpure) solutions together to approximate the chemical compositions of rock solutions and measuring the trace element contents of these solutions. In all cases the trace element content obtained was equivalent to the supplier's analyses. Furthermore, portions of these synthetic solutions were spiked with the trace elements being investigated. The spiked samples were analyzed using standards in aqueous solutions that had been acidified with the same concentrations of acids as had been used in the mixed synthetic solutions. The trace element content obtained was equal to that of the spike plus the concentration in the unspiked synthetic solution.

It was concluded from the negative results obtained from the foregoing tests and from a detailed perusal of the literature that there were no interferences to be contended with in the analysis for the trace elements in question if the dilutions were 100 fold or more.

A study of the acid content of the sample solutions gave differing results for differing quantities of hydrochloric acid in the standards and the samples. This was found not to be a spectral interference but to be the result of changes in viscosity due to the different concentrations of acid present. This was overcome by maintaining the equivalent of 5 mls of concentrated hydrochloric acid in every 100 mls of both sample and standard solutions.

Calculation of Sample Concentration

During the initial stages of the investigation the calculations were performed on an electric desk calculator. The per cent transmission obtained for the standard solutions was plotted against concentration on single cycle logarithmic-linear graph paper (see Appendix IV). The per cent transmission for the sample solution was used to determine the concentration in parts per million from the standard curve. The concentration of the element in the rock sample was determined using the formula

$$\frac{\text{Volume of Sample Sol.}}{\text{Weight of Sample}} \times \text{PPM in Sample Sol.} = \text{PPM in Rock}$$

A Fortran II computer programme used to compute the concentration of the elements in the majority of the sample analyses is described briefly in Appendix IV.

CHAPTER III. GEOLOGY AND DESCRIPTION OF THE SULFIDE DEPOSITS

Regional Geology

The geology of the Springdale Peninsula was described by MacLean (1947), Williams (1962), and Neale and Nash (1963). Detailed studies of the geology of part of the area of the Springdale Peninsula have been carried out by Papezik and Fleming (1967), Fleming (in preparation) and by mining and mineral exploration companies. Peters (1967) has described some of the sulfide deposits found in the area. Kanehira and Backinski (1968) describe in detail the geology and mineralogy of the Whalesback Mine.

The mineral deposits investigated are found within the assemblage of Ordovician and Silurian volcanic and sedimentary rocks known as the Central Mobile Belt of Newfoundland which extends for nearly 150 miles from Red Indian Lake in the southwest to Notre Dame Bay in the northeast. Fenwick, et al (1968) and Sheridan and Drake (1968) present geophysical evidence which suggests that the Central Mobile Belt may extend for a considerable distance out into the Atlantic Ocean as part of the continental shelf.

The volcanic assemblage of the Central Mobile Belt is represented on the Springdale Peninsula by the Ordovician volcanic rocks known as the Lush's Bight Group (MacLean, 1947) which occur as a northeast-trending, folded belt consisting of a thick accumulation of mainly basic pillow lavas and pyroclastic rocks with associated greywackes, cherts, rhyolitic lavas and minor limestones. Numerous sills and dikes of different types have been intruded into these rocks

Papezik and Fleming (1967) have made a detailed study of the Lush's Bight Group in the immediate vicinity of the Whalesback Mine. They have described the altered and sheared, pillowed basic rocks as:

> "The rocks between Whalesback Pond and Little Bay are mainly Ordovician basic lavas, both pillowed and massive, associated with minor amounts of pyroclastic rocks. Basic lavas predominate but some acid flows and/or pyroclastics are present, particularly in the southern part of the area. Chert appears commonly as fillings between pillows, as minor lenses in the volcanic rocks and, towards the north, as beds of ribbon chert of significant aggregate thickness. Recent work has shown in addition the presence of many thin lenses of magnetic "iron formation", probably lenses of iron-rich tuffaceous sediments. The volcanic assemblage is intruded by fine-grained gabbroic rocks in the form of dikes, sills, and small stocks, and a later set of porphyritic dikes characterized by coarse phenocrysts of feldspar, amphibole and pyroxene. A few thin dikes of relatively fresh hornblende and biotite lamprophyre and olivine diabase complete the assemblage (most of the younger dikes range from only a few inches to a few feet in thickness....
>
> ....All rocks in the area, with the exception on the younger dikes, have been subjected to a low-grade metamorphism and are partly or completely re-crystallized to a rather monotonous mineral assemblage (mainly albite, chlorite, epidote and leucoxene) characteristic of the greenschist facies. Many parts of the area have been affected by a local metasomatism involving mainly the addition of iron and water to, and a transfer of silica and calcium from, massive chloritic zones, which are the main host-rocks of the copper mineralization in the area ...." page 182.

Papezik and Fleming (1967) have defined two rock types within the Lush's Bight Group mainly on the basis of chemical composition,: the Whalesback type", resembling calc-alkaline (tholeiitic) basalts, appears to be the dominant rock type on the Springdale Peninsula, and the "St.Patrick type", which they classify as metamorphosed spilites. They have found difficulty in distinguishing the relationships of the basalts and spillites.

Geology of the Lady Pond Property

The Lady Pond property is located on the eastern side and the south-east corner of Lady Pond. Seven shafts were sunk to a depth of around

100 feet and mining operations were carried out in the 1890's (MacLean, 1947).

The geology of the area surrounding the sulfide zone has been mapped by the staff of the British Newfoundland Exploration Company (Figure 3-1). The writer's study of the geology of the area was restricted to an examination of drill core from the three drill holes shown in figure 3-1.

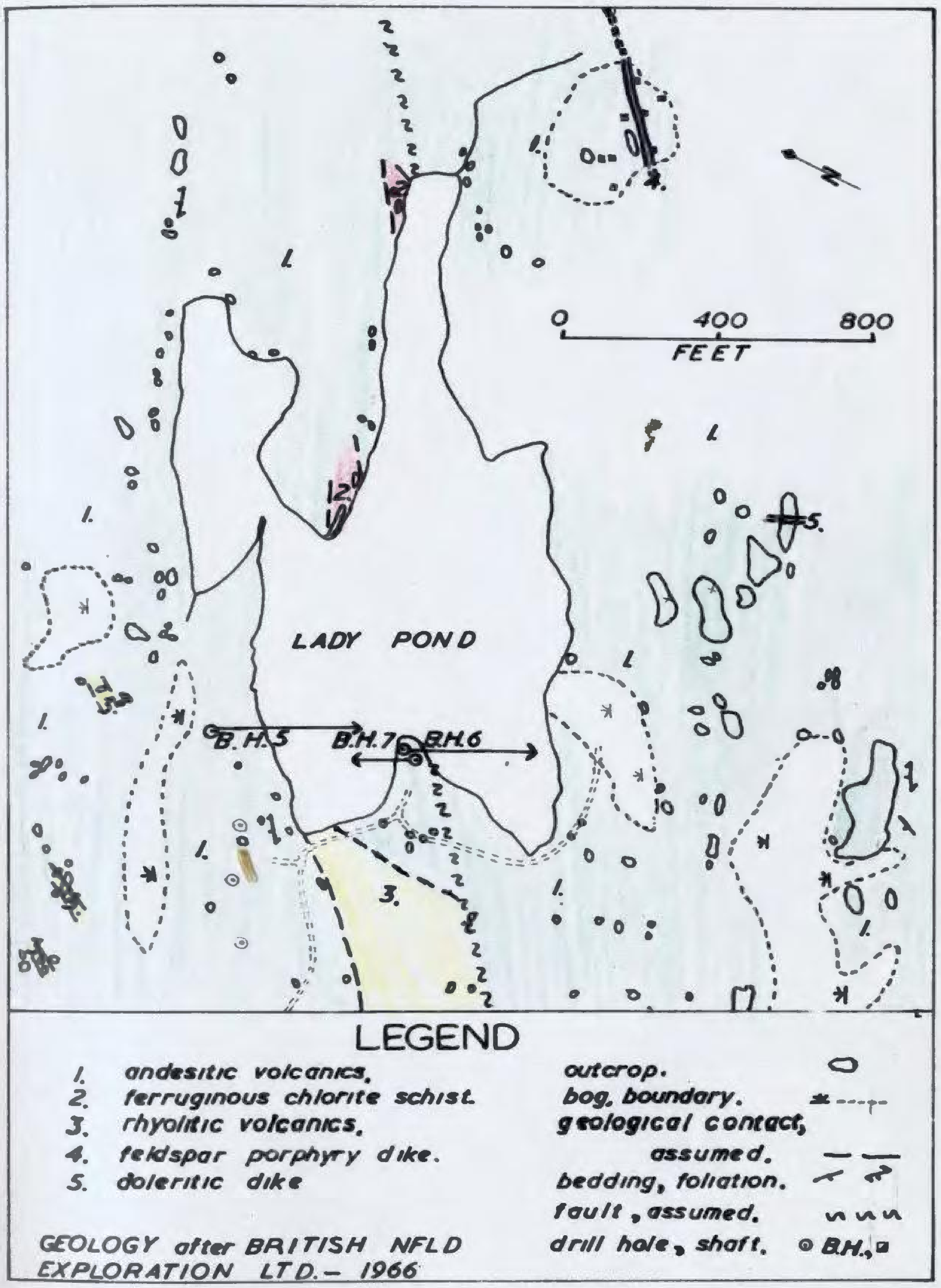
The drill cores consist predominantly of dark green, fine grained tuffaceous and fragmental rocks that are banded in part. Several thinly banded argillaceous and ash beds up to 1 foot wide, and fine - to medium - grained amygdaloidal andesitic lavas, both massive and pillowed, are present.

The andesitic lavas have been foliated, lightly chloritized, and epidotized while the schistose tuffaceous and fragmental rocks have been moderately to strongly chloritized, lightly epidotized and in places moderately pyritized (5-7 per cent pyrite).

Medium grained, lightly chloritized dioritic dikes and relatively fresh porphyritic feldspar and amphibole dikes intrude the country rocks.

The chalcopyrite mineralization examined is located in chlorite schist zones that vary from several feet to less than twenty feet wide and consist predominantly of chlorite with variable amounts, generally 30 per cent, of microscopic to fine grained quartz, epidote and calcite.

The mineralization consists of chalcopyrite and pyrrhotite veinlets up to one inch in width and massive pyrite bands up to six inches wide containing tiny irregular chalcopyrite veinlets. Minor amounts of bornite, wurtzite and magnetite are present in the ore zones. Quartz and chlorite are the principal non-metallic gangue minerals. Pyrite veins up to one inch wide are found scattered throughout the country rocks. Narrow white quartz veins, less than one-half inch wide are commonly found within a few feet of the ore zones.



GEOLOGY after BRITISH NFLD EXPLORATION LTD.- 1966

Fig. 3-1 Geology of Lady Pond property.

Geology of the Little Deer Mine

The Little Deer Mine is owned and operated by the British Newfoundland Exploration Company and is currently undergoing development in preparation for mining operations.

The Little Deer shear zone has been traced for several thousand feet on the surface by trenching, and a mineralized section has been traced for more than two thousand feet by diamond drilling. The main ore body is located beneath Little Deer Pond, but its delineation has not been completed and the dimensions of the ore zone will not be known until the current development work and further diamond drilling have been completed.

Figure 3-2, after Papezik and Fleming (1967), shows in detail the geology of the area around the Little Deer Mine. The chlorite schist zone containing the Little Deer Mine occurs within the "Whalesback Volcanics" division of Papezik and Fleming (1967) and is roughly parallel to the chlorite schist zone of the nearby Whalesback Mine.

The country rocks of the Little Deer Mine are included in a detailed petrographic study of the Whalesback - Little Deer area by Fleming (in preparation).

The following description is based upon an examination by the writer of drill cores from the hanging wall of the Little Deer Mine.

The country rocks consist predominantly of basic pillow lava interbanded with minor massive lava and pyroclastic rocks probably derived from the same source as the lavas. The rocks are generally fine grained and although the colour varies locally the rocks are generally greyish green. The pillowed lavas have dark green rims and creamy yellow epidotized centers, and the massive lavas have a light green mottled appearance due to epidote metacrysts. The pyroclastic rocks are generally banded and, like the chlorite schists, have a dark green to greenish black colour.

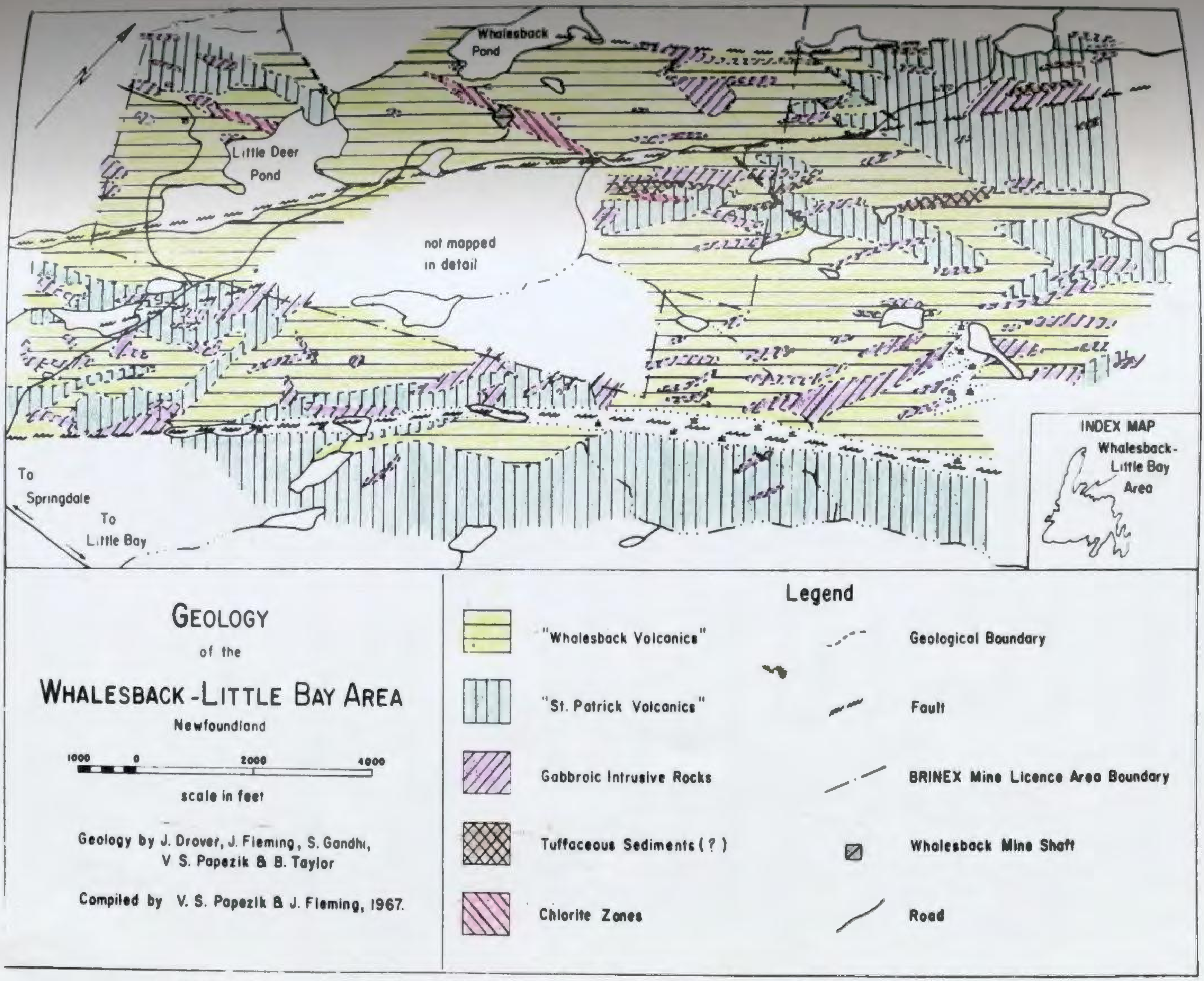


Fig. 3-2 Geology of the Whalesback — Little Bay Area, Newfoundland.

In thin section the lavas have microporphyritic hiatal to seriate textures. The phenocrysts, less than 1 mm in diameter, of albite and occasionally pyroxene, are found in a matrix of plagioclase microlites, cloudy granular epidote, pale green fibrous amphibole (actinolite), chlorite, quartz and leucoxene. Pyrite crystals, up to 1 mm in diameter, are scattered throughout the rocks and hematite coatings are commonly found on fractures. Calcite may occur as individual grains, 0.2 to 0.5 mm in diameter, in the groundmass and as quartz-calcite veinlets several millimeters wide that may parallel or cut across the schistosity planes. The pillowed lavas have been altered to a greater extent than the massive lavas and have distinct schistose and chloritic ferromagnesian rims surrounding massive centers consisting of more than 50 per cent epidote. The pyroclastic rocks do not contain appreciable quantities of epidote but they have been strongly chloritized and often contain more than 30 per cent chlorite. Feldspar phenocrysts in the pillow lavas are generally restricted to the lightly chloritized sections of the pillow rims.

Feldspar phenocrysts in the massive lavas are generally lath shaped and twinned on the Carlsbad twin law. The composition of these phenocrysts, as determined by means of a four axis universal stage, varies from An_0 to An_8. In the pillowed lavas the feldspar has been partly or completely altered to epidote and some partly altered grains contain microscopic chlorite, calcite, quartz and epidote.

Epidote occurs as cloudy irregular grains in the groundmass and as subhedral to euhedral crystals, as sperulites, veinlets, and massive lenses in the lavas.

Chlorite occurs intergrown with quartz along schistosity planes and is commonly found as submicroscopic grains formed by the alteration of minerals in the groundmass. The pyroclastic rocks often contain lenses and patches of chlorite several millimeters wide by several centimeters long. The chlorite found in the chlorite schist is generally darker coloured than that found in the nearby country rocks.

Quartz occurs as tiny microscopic grains in the groundmass of massive and pillowed lavas and as an aggregate of quartz crystals parallel to the schistosity planes in the rims of pillows.

Pyroxene (augite) phenocrysts are found in both the massive and pillowed lavas. The phenocrysts are generally euhedral and may be altered to chlorite along fractures.

Acicular amphibole is found as microscopic crystals in the groundmass of massive lavas, in the epidotized centers of pillows and in chlorite schists.

Calcite occurs commonly in the country rocks as isolated crystals, as calcite veinlets parallel to schistosity and as quartz-calcite veinlets cutting across the schistosity.

Intrusive rocks of the Little Deer property are similar to those found throughout the Springdale Peninsula. Dikes of amphibole-feldspar porphyry, andesite, fine - to medium - grained and porphyritic diorites, felsites, and black, aphanitic lamprophyric rocks are found within the immediate vicinity of the mine. These dikes vary from several inches to tens of feet in width and constitute an estimated 15 per cent by volume of the rocks in the area.

The andesitic and dioritic dikes have undergone an alteration similar to that of the lavas that they intrude. In places the andesitic dikes appear to grade into the medium-grained andesitic lavas and are only distinguishable on the basis of their chilled margins. These andesitic rocks may be sills related to the same period of volcanic activity as the lavas or they may be feeder dikes to overlying lavas that have been eroded. Some of the dioritic dikes cut across the ore zones and are post mineralization in age.

The Little Deer ore zone occurs in a shear zone consisting essentially of chlorite and quartz-sericite-chlorite schists. Variations in composition throughout the shear zone are common and many sections consist almost entirely of chlorite schist. Peters (1967) states that the main ore zone beneath Little Deer Pond occurs in a highly contorted and crenulated sericite schist. The change from chlorite to quartz-sericite-chlorite schist may represent variations in the original composition of the rocks from which the shear zone was derived. The intensity of alteration varies considerably along the length of the shear zone as well as across the shear zone. Narrow zones, several feet wide, of a bleached, massive and siliceous rock (rhyolitic-looking) occur in association with quartz-sericite-chlorite schists. Sericitization is usually more intense near the center of the mineralized zones, and within these rhyolitic-looking rocks. An agglomerate intersected in the hanging wall of the ore zone and the presence of tuffaceous-like rocks in other parts of the ore zone suggest that the ore may closely follow a stratigraphic horizon along part of its length.

Pyrite, pyrrhotite, chalcopyrite and sphalerite are the main sulfide minerals and quartz, calcite, sericite and chlorite are the main gangue minerals in the ore zone. The ore zone consists of several disconnected, high grade lenses containing 5 to 10 per cent copper and/or disseminated chalcopyrite impregnations of the chloritic and sericitic schists. Sphalerite generally occurs as narrow veinlets and threads in the footwall of the ore zone. Pyrite occurs as massive veins and as disseminations in the chloritic and sericitic schists throughout the ore zone. There is generally more pyrite stratigraphically below than above the chalcopyrite mineralization. The chalcopyrite-pyrrhotite mineralization occurs either as massive veins, generally less than one inch wide, associated with quartz, or as chalcopyrite-pyrrhotite veins have been observed to cut pyrite and sphalerite veins. Sphalerite veinlets often cut pyrite veins. The size of sphalerite veinlets decreases away from the ore zones.

Geology of the Little Bay Mine

The Little Bay Mine is owned and operated by the Atlantic Coast Copper Corporation and is situated at the head of Indian Bight, Little Bay. The mine, the oldest in the area, started production in 1878, and has produced approximately 1,900,000 tons of 2 per cent copper to date.

The mine consists of two "en-echelon" shear zones approximately 1000 feet apart. The main ore zone has been the principal producer ever since the mine began production and the North zone has undergone development during only the last few years, although its existence has been known for a number of years. Both ore zones occur in chlorite schist zones which are considered to be subsidiary to a nearby major fault.

The main ore zone strikes north 50 degrees east and dips 80 degrees to the south. The economic mineralization has a strike length of over 1000 feet, attains a maximum width of 80 feet and has been traced by diamond drilling to a depth of about 2000 feet. On the 700 level the chlorite schists of the north zone are mineralized for a distance of approximately 1200 feet along strike and through an average width of less than 100 feet. Mineralization has not been encountered to date by diamond drilling from the 1800 level of the main zone, and the depth of the ore zone has yet to be determined.

The Little Bay mine occurs in schistose and altered andesitic to basaltic pillow lavas which contain minor amounts of massive lavas and pyroclastic rocks. The rocks in the vicinity of the mine strike north 60 degrees east and dip at 75 to 85 degrees to the southeast.

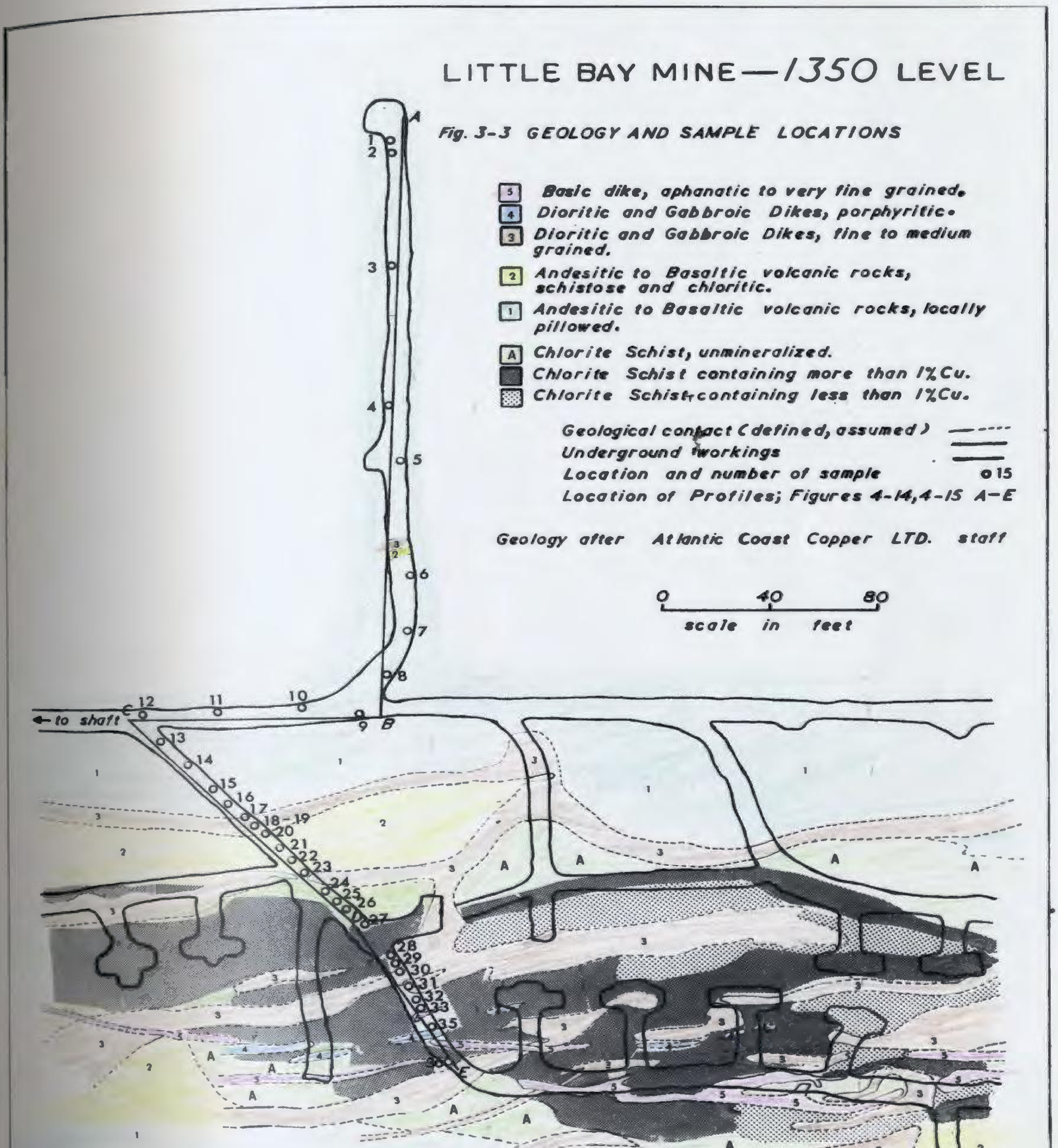
In the pillowed lavas the pillows have an average diameter of two feet, but they range up to more than four feet in diameter. They have dark green chloritic rims and light creamy to greenish yellow centers consisting predominantly of epidote and containing only minor amounts of quartz, amphibole and calcite.

In thin section the massive lavas resemble those found at Little Deer Pond both texturally and mineralogically.

Bands of chert interbedded with pyroclastic rocks are found in several places along the 700 level north crosscut. These chert bands are very fine grained and consist predominantly of epidote and quartz.

There is a decrease in the number and size of pillow structures as the chlorite schist zones are approached and with the exception of small epidotized knots less than one foot in diameter there is no indication of any pillow structures within fifty feet of the chlorite schist zones. The south contact of the chlorite schist in the north zone is in faulted contact with schistose andesitic (?) rocks, and the north contact is separated from the country rocks by a composite dike. On the 1350 level of the main zone the schistosity and the quartz content of the country rocks increase as the chlorite schist zone is approached. The increase in quartz becomes noticeable in hand specimen approximately 25 feet from the chlorite schist zone. The rocks become light green and take on a slaty appearance due to the increasing quartz content and the closely spaced schistosity planes. The siliceous rocks in this zone have 5 to 10 per cent disseminated pyrite which increases slightly to within five feet of the chlorite schist zone. The chlorite schist adjacent to this siliceous zone is dark green, friable and contains less than 2 per cent disseminated pyrite.

The mineralized zones and the country rocks have been cut by a swarm of north trending dikes which may vary in strike by 30 degrees east and west of north (Figure 3-3). They vary in composition and abundance. The most abundant dikes in frequency of occurence and in volume are andesitic and



LITTLE BAY MINE—1350 LEVEL

Fig. 3-3 GEOLOGY AND SAMPLE LOCATIONS

dioritic types. The andesitic dikes are fine to medium grained, dark green rocks that are similar in appearance to the andesitic lavas. These dikes are foliated, epidotized and appear to be the oldest dikes in the area. Their margins are only faintly chilled and it is often difficult to distinguish them from the surrounding rocks when they intrude massive andesitic (?) lava. The dioritic dikes consist of two types: an older fine-to medium-grained dioritic variety and a younger porphyritic variety. These dikes are dark greenish to greenish black and faintly foliated. They are either older than the mineralization or else they have remobilized the chalcopyrite during their intrusion since there are instances of chalcopyrite and quartz apophyses from massive pyrite and chalcopyrite veins penetrating the dike for a short distance, however, the writer is not aware of any occurence of a sulfide vein cutting through the dioritic dikes. These dioritic dikes pinch and swell and have very irregular shapes. They contain altered feldspar, epidote, chlorite, amphibole (actinolite) and scattered pyrite grains.

Felsite, feldspar porphyry and amphibole-feldspar porphry dikes have been found in the mine. A post-ore, aphanitic black dike considered to be a lamprophyre is probably the youngest rock in the area.

The main ore zone consists of several lenses of varying lengths with an average width of 25 feet. These lenses pinch and swell and plunge steeply. Within them the ore occurs as massive to semi-massive sulfide pods of 10 to 12 per cent copper and as narrow ramifying veinlets and impregnations of the chlorite schist by pyrite and chalcopyrite which average 1 per cent copper (see Figure 3-3). The chalcopyrite may occur as veinlets up to an inch wide with only traces of pyrite and quartz or as an uneven mixture of massive sulfides with pyrite predominating.

The north ore zone contains a number of massive pyrite-chalcopyrite veins with an average width of 12 inches and several small zones of disseminated chalcopyrite and pyrite in chlorite schists. Only a small portion of this zone is of economic interest.

The main sulfide minerals are pyrite and chalcopyrite. Wurtzite, magnetite, marcasite, sphalerite, and pyrrhotite are present in minor amounts. Small amounts of covellite and a narrow vein of native arsenic have been identified. Quartz, chlorite, epidote and calcite are the main gangue minerals.

Papezik (1967) has described native arsenic occurences in the Whalesback and Little Bay mines.

CHAPTER IV. TRACE ELEMENT DISPERSION PATTERNS

The mineralogical variations and the wall rock alterations adjacent to the sulfide deposits on the Springdale Peninsula have been investigated in connection with mineral exploration programs by H. R. Peters, M. J. Fleming and others (personal communications). The present study has been directed toward a study of the minor element variations in the wall rocks of the orebodies and the rocks within the ore zones. Insufficient attention has been given to the investigation of the mineralogical and textural aspects of the ore zones and their wall rocks to provide a comprehensive account of these features. The data gathered from thin section studies and from other workers in the area will be incorporated into the following discussions where possible.

Boyle (1961) found that there was a definite decrease in the Na_2O content of chlorite schist zones derived by the alteration of greenstone rocks in the Yellowknife district of the North West Territories. Also, Papezik and Fleming (1967) found that the sodium content of chlorite rock in the ore zone of the Whalesback Mine is less than that of the surrounding "Whalesback" type volcanics from which the chlorite rock was presumably derived. Since the ore zones of the three properties investigated are found in chlorite schist zones, the sodium content of the samples analyzed for trace elements gives a rough index of the extent, if not the exact nature, of the alteration in the chlorite schist zones. The writer considers that the data obtained on the sodium content of the rocks, in addition to the mineralogical and textural information obtained from thin section studies, are sufficient to interpret the trace element data.

Background

A prerequisite assumption in the investigation of dispersion patterns adjacent to orebodies, is that the abundance of an element is relatively constant in an area which has not been affected by the presence of a mineral deposit. That is, it is assumed that background concentrations are reasonably uniform. The initial sampling program was designed to obtain samples as far as possible from known mineralization on each traverse, in order to ensure that dispersion patterns of several hundred feet, if present, would be included, and to ascertain the background concentrations of the elements under investigation.

Table 4-1 gives the mean and the range for those samples in each traverse considered by the writer to be outside the influence of mineralizing fluids. All the samples used in compiling Table 4-1 are more than one hundred feet away from the nearest chalcopyrite mineralization or chlorite schist zone. Samples containing less than one per cent sodium and more than three times the mean copper values were omitted from these calculations to avoid including samples which had possibly been subjected to some hydrothermal activity. It is possible that some of the samples discarded may represent original syngenetic variations in the rocks, however, very few samples were omitted from the calculations and the indiscriminate inclusion of all analyses more than 100 feet away from the economic mineralization would produce results that are similar to those shown. During the interpretation of sample traverses background was considered to have been attained if, after a zone of erratic values adjacent to a mineralized or chlorite schist zone, a reasonably constant level of trace element content was obtained. For example in Figures 4-4 and 4-5 samples 30 to 39 are considered to represent the background values of the wall rocks.

The values obtained are local background values, and although they possibly do indicate the approximate values for similar rocks in other parts of the Springdale Peninsula the sampling was not extensive enough

Table 4-1 Background concentrations of elements. Cu, Zn, Ni and Co in ppm; Mn and Na as per cent.

LADY POND

Drill Hole 5

Element	Arithmetic Mean	Standard Deviation	Range	Number of Samples
Cu	32	± 15.2	13 - 59	3
Zn	102	± 9.1	91 - 116	3
Co	43	± 2.6	40 - 48	3
Ni	29	± 1.0	28 - 30	3
Mn	0.16%	± 0.022%	0.12 - 0.19%	3
Na	4.12%	± 0.191%	3.92 - 4.34%	3

LITTLE DEER

Drill Hole 92

Element	Arithmetic Mean	Standard Deviation	Range	Number of Samples
Cu	80	± 32.0	52 - 182	13
Zn	86	± 15.1	62 - 105	13
Co	66	± 6.9	50 - 73	13
Ni	61	± 13.9	40 - 82	13
Mn	0.14%	± 0.017%	0.12 - 0.17%	13
Na	2.25%	± 0.689%	1.30 - 3.45%	13

Drill Hole 132

Element	Arithmetic Mean	Standard Deviation	Range	Number of Samples
Cu	76	± 31.4	44 - 101	12
Zn	83	± 8.5	60 - 108	12
Co	71	± 7.1	64 - 85	12
Ni	73	± 4.3	46 - 87	10
Mn	0.12%	± 0.013%	0.10 - 0.15%	11
Na	2.36%	± 0.621%	1.27 - 3.27%	12

Drill Hole 135

Element	Arithmetic Mean	Standard Deviation	Range	Number of Samples
Cu	87	± 31.4	54 - 170	11
Zn	77	± 8.5	56 - 86	11
Co	71	± 7.1	63 - 87	11
Ni	69	± 4.3	63 - 74	9
Mn	0.11%	± 0.013%	0.10 - 0.13%	11
Na	2.72%	± 0.621%	1.50 - 3.55%	11

Table 4-1 (Continued)

Total for Little Deer Property (Sum of three traverses)

Element	Arithmetic Mean	Standard Deviation	Range	Number of Samples
Cu	81	± 23.9	44 - 182	36
Zn	82	± 14.3	56 - 108	36
Co	69	± 7.3	50 - 87	36
Ni	68	± 12.4	40 - 102	34
Mn	0.12%	± 0.017%	0.10 - 0.17%	35
Na	2.55%	± 0.618%	1.27 - 3.55%	36

LITTLE BAY

700 Level North Zone

Element	Arithmetic Mean	Standard Deviation	Range	Number of Samples
Cu	61	± 34.5	31 - 136	8
Zn	95	± 29.4	55 - 131	8
Co	70	± 54.1	50 - 92	8
Ni	148	± 37.6	100 - 240	7
Mn	0.11%	± 0.025%	0.06 - 0.13%	8
Na	1.97%	± 0.712%	1.06 - 3.53%	8

1350 Level

Element	Arithmetic Mean	Standard Deviation	Range	Number of Samples
Cu	91	± 44.4	13 - 169	22
Zn	71	± 16.9	57 - 117	22
Co	69	± 12.7	58 - 97	22
Ni	111	± 24.9	71 - 140	22
Mn	0.10%	± 0.019%	0.06 - 0.14%	21
Na	2.25%	± 0.632%	1.01 - 3.46%	21

Total for Little Bay (Sum of two traverses)

Element	Arithmetic Mean	Standard Deviation	Range	Number of Samples
Cu	83	± 43.7	13 - 169	30
Zn	80	± 23.6	55 - 131	30
Co	69	± 13.2	50 - 97	30
Ni	120	± 36.3	67 - 240	29
Mn	0.10%	± 0.021%	0.06 - 0.14%	29
Na	2.18%	± 0.645%	1.01 - 3.53%	29

to provide reliable regional background values. Local variations in the intensity of low grade regional metamorphism in the Springdale Peninsula volcanics (Papezik and Fleming, 1967) is one factor that might produce local variations in background values. The date presented are from samples of different rock types, although most profiles taken individually represent a single rock type, or at least very similar rock types. The trace element and sodium contents of the chloritic rims are similar to the values obtained for the massive basalts and thus are used instead of the values obtained on the epidotized pillow centers in preparing Table 4-1 and Figures 4-1 to 4-18. The relationships between the trace element and sodium contents of the pillow rims and centers are shown in Figures 4-14 and 4-15.

DISPERSION PATTERNS IN THE WALL ROCKS OF THE LADY POND PROPERTY.

One sampling traverse was obtained from diamond drill hole No. 5 in what is considered to be the hanging wall of the Lady Pond property (Fig. 2-2). The copper, zinc, manganese and sodium profiles obtained from this drill hole are shown in Figure 4-1. The nickel and cobalt values for the same samples show little deviation from a straight line and were omitted from the diagram, however, the values obtained are discussed below and are presented in full in Table I of Appendix I. This drill hole was investigated to determine whether the tuffaceous rocks of the Lady Pond property would produce different dispersion patterns from those obtained in the predominantly massive and pillowed lavas of the Little Deer and Little Bay Mines.

The drill hole intersected traces of chalcopyrite between 275 and 295 feet. A sulfide intersection at 440-452 feet averaged 0.61 per cent copper. The mineralization consists of bands of massive chalcopyrite and pyrite less than one inch wide. A number of quartz veinlets, less than one half inch wide, occur over a six foot zone (425-431 feet) in the hanging wall within

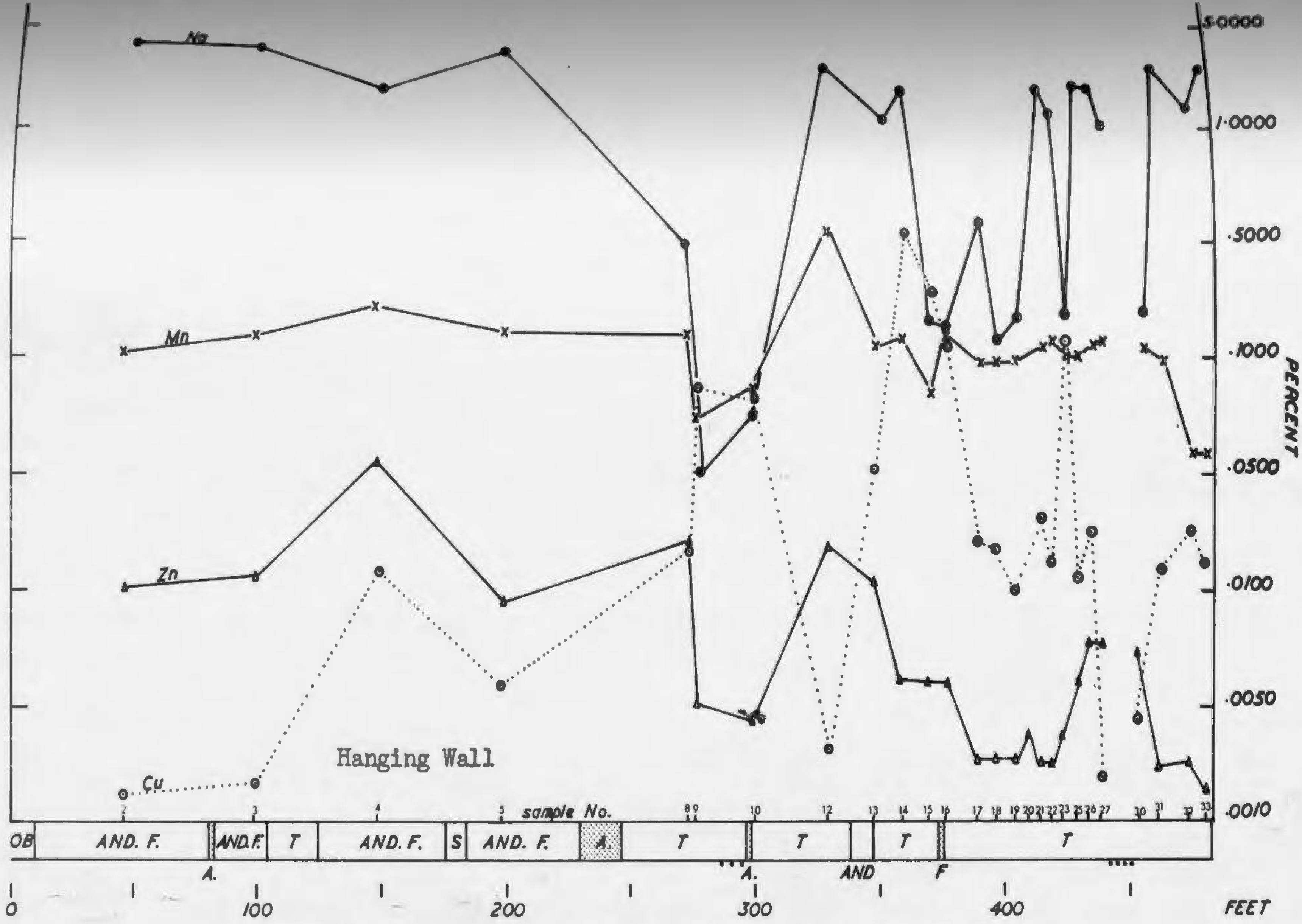


FIGURE 4-1 Variation in Na, Mn, Zn and Cu content in Lady Pond Drill Hole 5. Drill Log:– F= Feldspar Porphyry Dike, A.= Andesitic Dike, AND = Amygdaloidal Andesitic lavas, AND. F. = Fragmental Andesitic rocks, T= Chloritic Andesitic tuffaceous rocks, S= Siltstone, OB= Overburden, ▪▪▪ less than 1% Cu

ten feet of the sulfide zone. This drill hole contains considerably more disseminated pyrite cubes than any of the Little Deer or Little Bay traverses and the strongly foliated tuffaceous bands often contain as much as five per cent pyrite visible in a hand specimen. It was possible to collect samples on both sides of the main intersection of sulfide mineralization, however, it is not known if this drill hole intersected all of the sulfide zones in the immediate vicinity.

The Lady Pond profiles are the most irregular obtained during the present study. There are considerable variations in the content of all elements shown in Figure 4-1 for over 175 feet away from the major sulfide zone. It is not known whether this is due to the action of mineralizing fluids or to the original composition of the sedimentary and tuffaceous rocks or a combination of both factors.

The sodium content of the wall rocks appears to have two distinct ranges, one with concentrations of approximately 1.0 to 4.3 per cent and the other with concentrations of 0.07 to 0.14 per cent. Thin section studies and examination of core reveal that specimens falling within the lower range were collected from zones of chloritization and silicification and that the sodium content of the rock varies inversely as the degree of chloritization. The concentration of copper in some samples is inversely related to the sodium content, for example, in samples 2 to 5 outside the tuffaceous zone and in samples 8, 9, 10, 15, 16, 23 and 27 within the tuffaceous rocks. This suggests a possible relationship between copper content and degree of chloritization, which might be expected on the basis of the general geochemical affinities of copper. On the other hand, not all samples with a low sodium and high chlorite content have a high copper content, for example, samples 17, 18 and 19. There is insufficient data to suggest with any certainity that the copper in the chloritized rocks was introduced by hydrothermal fluids during their chloritization since the copper distribution may simply reflect syngenetic variations.

The high copper content of samples 13 and 14, which are high in sodium but low in chlorite, is due to tiny chalcopyrite grains in pyrite veinlets (approximately 1 mm wide) in the samples.

The low copper concentrations found in samples 27 and 30, which occur on either side of a sulfide zone, could be interpreted as evidence of pre-mineralizing fluids leaching the wall rocks and failure of the copper bearing solutions to permeate the wall rocks to any extent, or migration of the copper from the wall rocks into the ore zone, or of pre-alteration-mineralization variations in the wall rocks. The samples analyzed are spaced too far apart to provide sufficient information to determine exactly the behaviour of the elements in the vicinity of this sulfide zone.

Before an intelligent discussion of abnormalities in the profile can be undertaken it will be necessary to obtain trace element data on more samples and also to determine the variations in the major elements, iron, magnesium and others with which the minor elements are associated.

The manganese profile of the Lady Pond traverse is relatively smooth in comparison to the erratic copper and sodium profiles. The anomalously high manganese content of sample 12 may be due to the presence of manganese minerals in some of the quartz veinlets in the sample.

The zinc profile is similar in shape to the manganese profile for samples 2 to 16. Samples 17 to 22 and 31 to 33 have background values much lower than the rest of the profile and consequently there appears to be a zinc aureole around the sulfide zone between samples 27 and 30, that is about 25 feet wide in the hanging wall. The maximum values obtained on the samples adjacent to the sulfide deposit are less than the background values found in other parts of the traverse, and thus do not represent a zinc aureole.

The nickel values obtained on the Lady Pond samples show little variation with mineralization and range between 21 and 38 parts per million. The cobalt content of the samples have a range of 21 to 56 parts per million, however, samples 9 and 10 which have high copper values have 75 ppm cobalt. The nickel content of these two samples was not determined. The samples on which nickel and cobalt were both determined have nickel/cobalt ratios equal to or less than 1.

DISPERSION PATTERNS IN THE LITTLE DEER MINE.

Three diamond drill holes which intersected the Little Deer sulfide deposit at approximately 800 feet below the surface were sampled along their entire length. The holes were drilled in the hanging wall of the deposit and consequently penetration of the foot wall was seldom more than several tens of feet (Fig. 2-4). The widths of the sulfide mineralization intersected varied from less than fifty feet in drill hole 135 to almost 200 feet in drill hole 92.

Figures 4-2 to 4-9 show the dispersion patterns found in each drill hole. The figures are described separately below.

Drill Hole 92

Figures 4-2 and 4-3 show the dispersion patterns for drill hole 92. Thin sections again show that the sodium content of the samples is a good index of their chlorite content. All of the samples which contain less than one per cent sodium have undergone considerable chloritization. The more extensively chloritized samples such as samples 26 and 36 contain 20 per cent and 30 per cent chlorite and 0.76 per cent and 0.72 per cent sodium respectively. Samples 50, 51 and 70 are chlorite schists containing 50 to 60 per cent chlorite and less than 0.10 per cent sodium. Furthermore, samples 50, 51 and 53 and the three samples 70, 71 and 72 show a definite increase

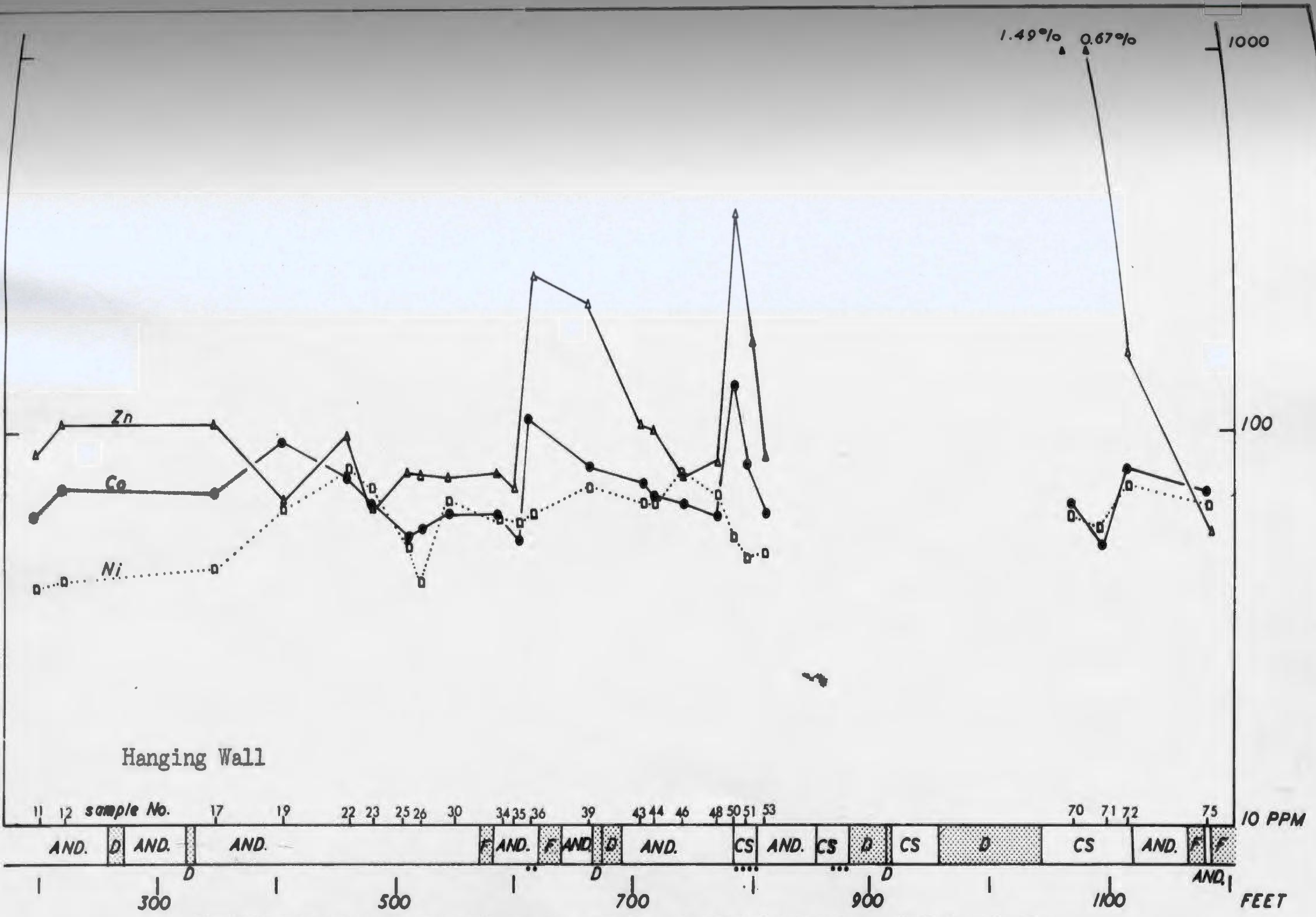


FIGURE 4-2 Variation in Zn, Co, and Ni content in Little Deer Drill Hole 92. Drill Log:- F=Feldspar Porphyry Dike, D=Dioritic Dike, AND. = Andesitic lavas and tuffs, CS=Chlorite Schist, ▬ greater than 1% Cu, ··· Less than 1% Cu.

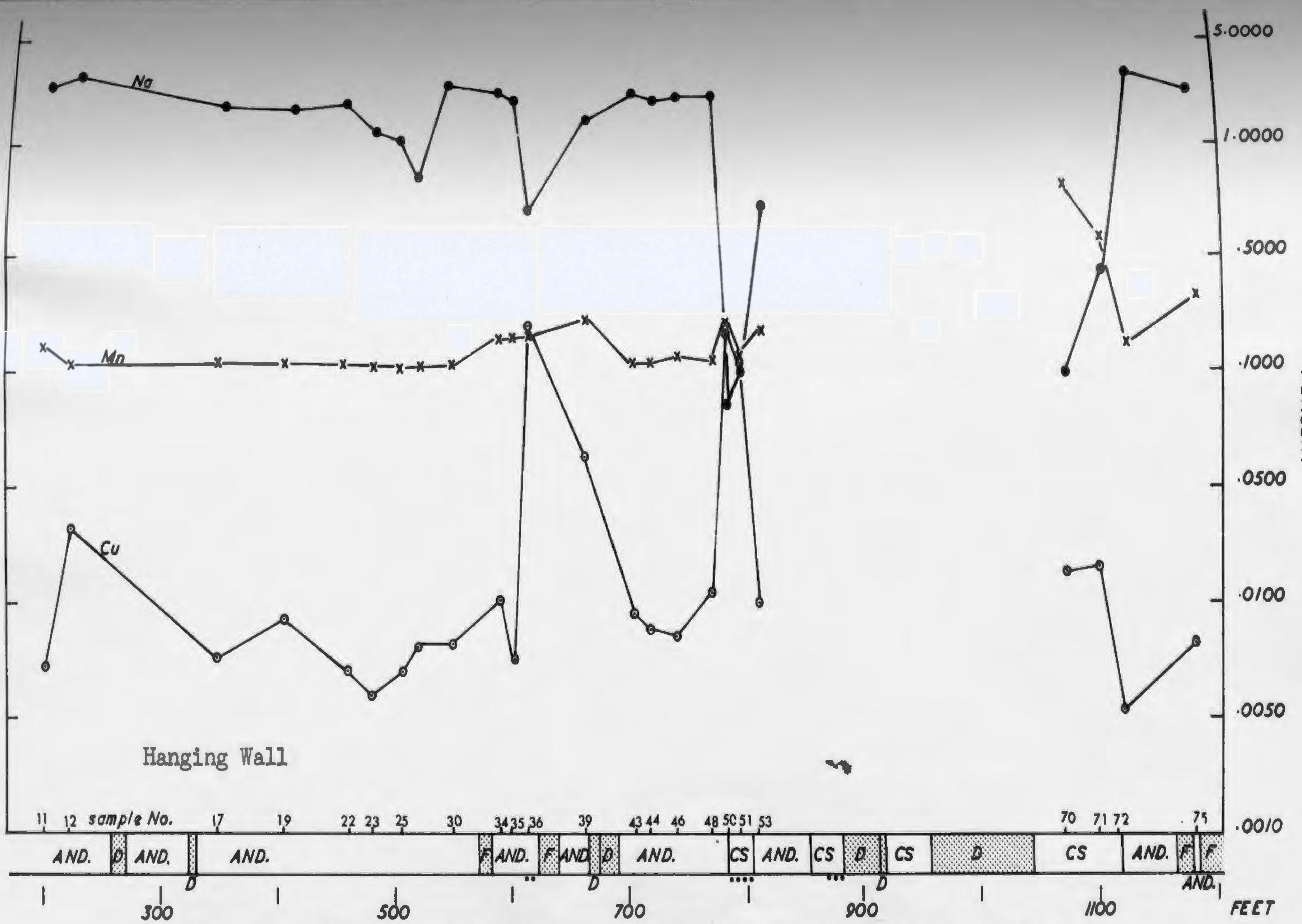


FIGURE 4-3 Variation in Na, Mn and Cu content in Little Deer Drill Hole 92. Drill Log:- F=Feldspar Porphyry Dike, D=Dioritic Dike, AND. = Andesitic lavas and tuffs, CS=Chlorite Schist, ▬ greater than 1% Cu, ⋯ Less than 1% Cu.

in sodium with a corresponding decrease in chlorite.

The manganese profile is fairly uniform and shows little correlation with the sodium content of the rocks. The anomalous manganese values in samples 50, 53, 70 and 71 are associated with silicification and sericitization, however, a quartz-sericite schist adjacent to sample 75 contains only 0.12 per cent manganese. Samples 34 to 39 contain more manganese, 0.22 to 0.30 per cent, than the surrounding rocks which contain an average of 0.13 per cent manganese. Many of the samples in this profile containing manganese values greater than the mean are associated with alteration and mineralization.

Copper tends to show increases in the chlorite schist zones. However the samples from this hole are spaced too far apart to reveal whether or not there are narrow copper aureoles surrounding individual zones of economic mineralization. The chlorite schist zone containing samples 70 and 71 has relatively low copper values. No visible chalcopyrite was found in this chlorite schist zone, but massive pyrite and sphalerite veinlets are scattered throughout the zone. It is possible that the hydrothermal activity preceeding the mineralization was active in this zone but the later copper bearing solutions did not pass through this chlorite schist zone.

The nickel and cobalt dispersion patterns of the wall rocks and the ore zone, are erratic. There is a weak expression of an aureole in the chalcopyrite zone at samples 50 and 51, however, the high cobalt contents correspond to high copper values and it is thought that the cobalt is present in the disseminated sulfides as a trace constituent.

The zinc profile of drill hole 92 has aureoles in the foot wall of two of the chlorite schist zones. The most pronounced of these aureoles is found adjacent to the chlorite schist zone that does not appear to contain visible chalcopyrite. It could be seen from the drill core that the size and quantity of the sphalerite threads and pyrite veinlets diminished away from the more chloritic parts of the schist zone and that the sphalerite threads penetrated the wall rocks for only a few feet. Only samples with visible sphalerite and pyrite mineralization and samples collected adjacent to visible sphalerite mineralization exhibit zinc values above the background.

Since sample 39 is a massive volcanic rock with several pyrite veinlets, the high copper, cobalt and zinc values are considered to reflect leakage from the nearby chalcopyrite zone via the pyrite veinlets. The sample does not show extensive chloritization, sericitization or other evidence of alteration.

Drill Hole 132

The alteration zone itself was probably a tuffaceous horizon. It is bounded in the hanging wall by a fifty foot section of agglomeratic andesite, and the foot wall border consists of chloritic andesitic lava. The alteration consists of silicification, sericitization and chloritization which varies slightly throughout the section in that some sections are friable and consist predominantly of chlorite and quartz while others are only lightly chloritized or consist of a foliated siliceous-sericite-chlorite schist with a slaty appearance. The contacts with the hanging wall and foot wall are sharp. Immediately beyond the foot wall contact the andesitic lava has been cut by several massive pyrite veinlets, less than one inch wide, quartz bands up to one half inch wide and a one foot wide quartz-sericite section. The drill hole was stopped at a dioritic dike and it is not known how far the alteration penetrated the foot wall, however, it is assumed from the restriction of the alteration in the ore zone to several narrow sections with sharp contacts, that the alteration here will not extend for any great distance away from

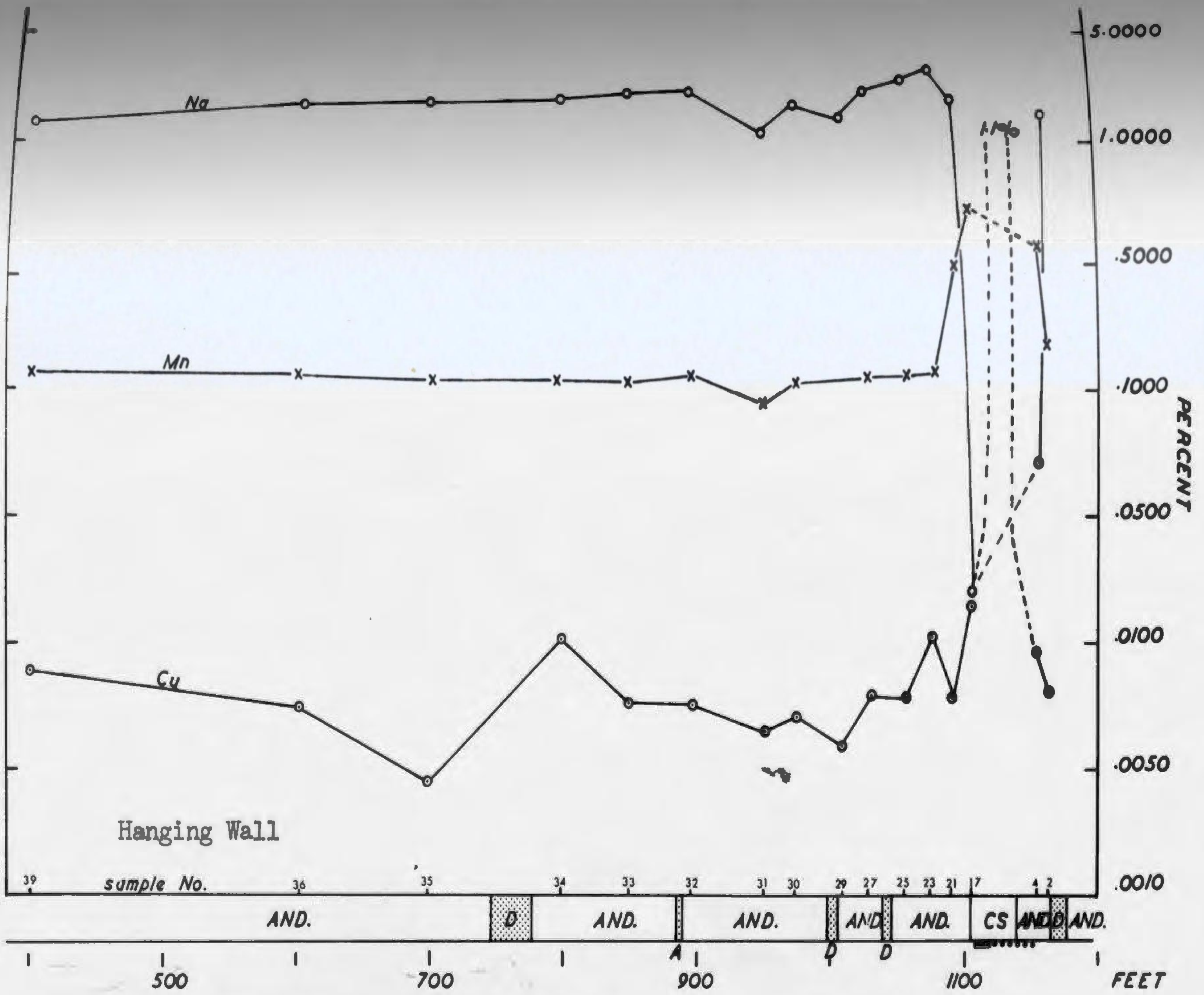


FIGURE4-4 Variation in Na, Mn and Cu content in Little Deer Drill Hole 132. Drill Log:— A = Amphibolite Feldspar Porphyry Dike, D = Diorite Dike, AND. = Andesitic lavas and tuffs, CS = Chlorite Schist, ▬ greater than 1% Cu, ┳┳┳ less than 1% Cu.

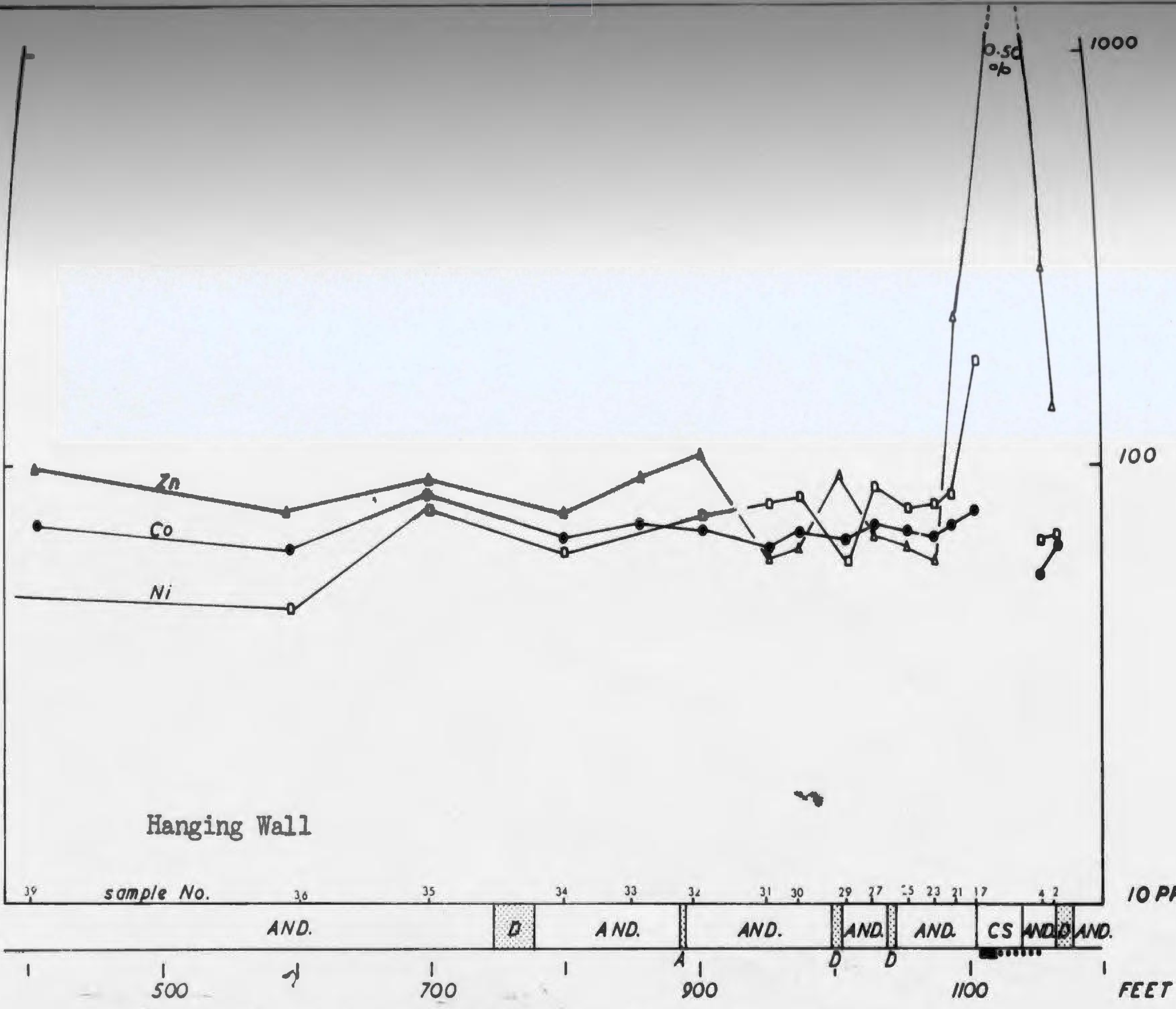


FIGURE 4-5 Variation in Zn, Co and Ni content in Little Deer Drill Hole 132. Drill Log:— A = Amphibolite Feldspar Porphyry Dike, D = Diorite Dike, AND. = Andesitic lavas and tuffs, CS = Chlorite Schist, ▬ greater than 1% Cu, ┳┳┳ less than 1% Cu.

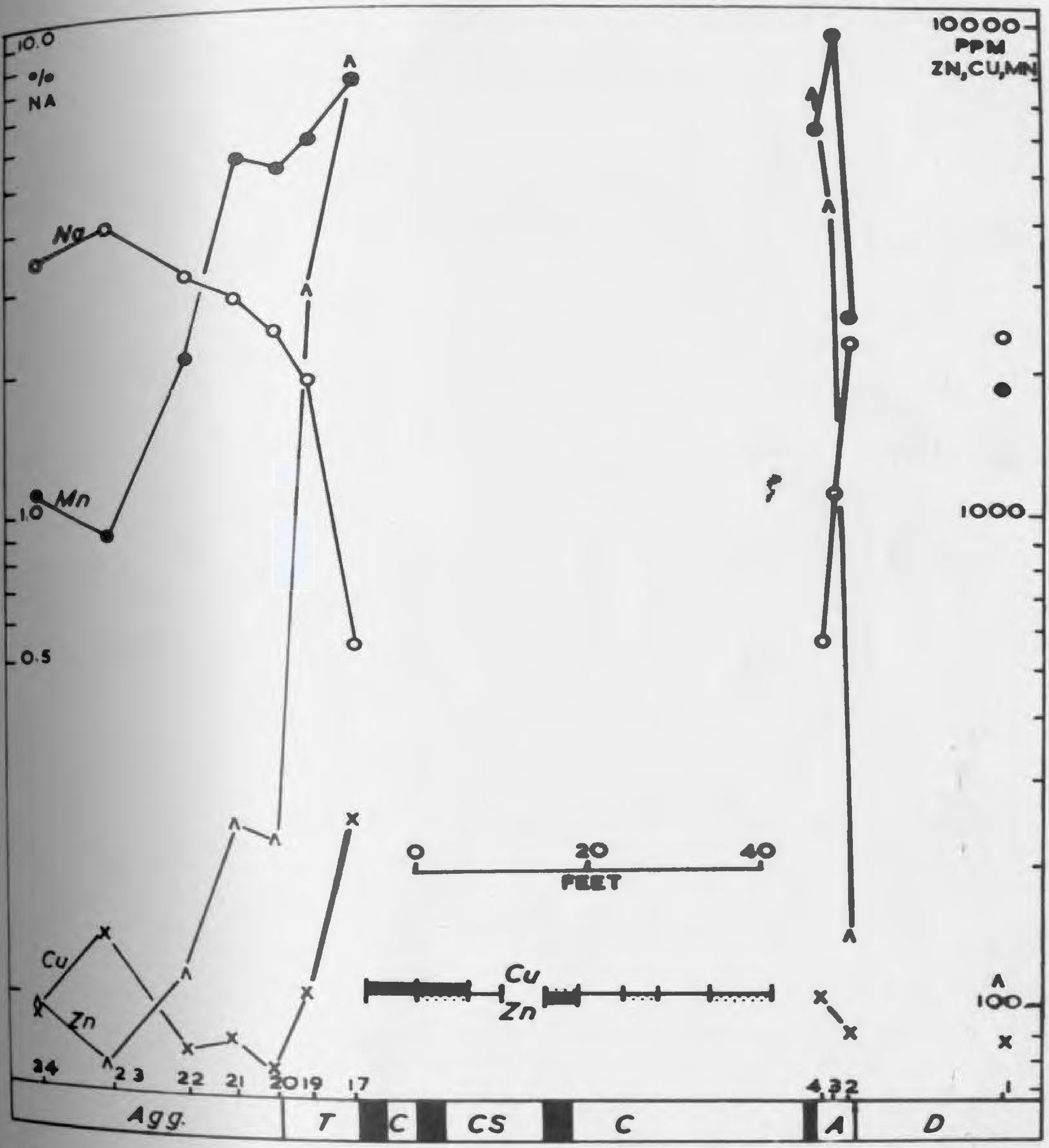


Figure 4 — 6 Na, Mn, Cu, and Zn dispersion patterns around the ore intersection of Drill Hole 132. Drill Log:- A — Andesitic lava; Agg.- Agglomerate with minor tuff; T — Banded tuff; C — Chlorite schist; CS-Quartz sericite chlorite schist; D — Diorite dike; ▬ greater than 1% Cu, less than 0.25% Zn; ├─┤ greater than 0.25% and less than 1% Cu and Zn; ▮ more than 50% sulphides.

the main sulfide zone.

The sodium content of the samples corresponds to the extent of alteration and although the sodium profile does show some variations within 200 feet of the ore zone the profile is relatively smooth outside the sulfide zone (Figure 4-4). Copper has a relatively smooth background profile in comparison to that found in drill hole 92 (Figure 4-3) and increases only immediately adjacent to the chlorite schist zone.

The manganese content of samples adjacent to the ore zone decreases sharply and approaches background values quickly outside the ore zone (Figure 4-4) and maintains a uniform concentration for at least 600 feet away from the ore zone. Similarly the zinc, nickel and cobalt profiles in Figure 4-5 attain uniform background values a short distance from the ore zone and show little variation over the 600 feet of wall rock sampled. None of the elements appear to show, at the scale of Figure 4-4, dispersion aureoles, although samples 21 and 4, on either side of the mineralized schist zone do show values different from those of the background.

The nickel and cobalt profiles show little variation along the drill hole (Figure 4-5). The exception is sample 17 with more than 2 per cent sulfide which has a nickel content of 117 parts per million in comparison to a mean background value of 73 parts per million.

Figure 4-6 shows in detail the dispersion patterns of copper, manganese, zinc and sodium adjacent to the ore zone. The assay values obtained by the British Newfoundland Exploration Company on samples across the mineralized zone are presented to show the distribution of copper and zinc within the ore zone.

Sodium maintains background values to within 25 feet of the hanging wall of the mineralization and then shows an approximate logarithmic decrease as the ore zone is approached. The manganese profile exhibits a steady rise toward the ore zone from the background value of sample 23 through to sample 17 which has a manganese content seven times the background value. Samples 4 and 2 from the foot wall also have manganese values higher than those of the background.

Zinc has higher than background values in the hanging wall rocks for approximately 25 feet from the ore zone. The profile rises sharply as the zinc content increases from a local background value of less than 100 parts per million to about 200 parts per million for samples 21 and 20 and then rises quickly to almost 8000 parts per million. Sample 17 was collected one foot away from visible copper mineralization but it contains threads of sphalerite and some pyrite. The foot wall samples show a decrease from 7000 parts per million in sample 4 to 130 parts per million in sample 2 only three feet away. The British Newfoundland Company reports that zinc values in the ore zone range from trace amounts to 4.14 per cent.

Sample 17 with 224 parts per million copper has a value higher than background while sample 19 has a copper content well within the background range. It is concluded from this that the copper bearing solutions did not penetrate six feet into the hanging wall in this part of the ore zone.

The sodium and manganese contents of the hanging wall rocks have been affected for a distance of at least 25 feet outward from the visible mineralization. Zinc too has been increased for a distance of at least 25 feet beyond the copper mineralization and for approximately 10 feet beyond the visible sphalerite mineralization, although copper has not reached six feet. This could be a reflection of the permeability of the wall rocks since the agglomeratic andesite becomes finer grained and more tuffaceous as the ore zone is approached and there is an increase in banding towards the ore zone.

The samples in the foot wall provide only limited information on the dispersion patterns since they are restricted to a three foot interval of andesites. The foot wall portion of the zinc profile exhibits a narrow aureole which can be attributed to the presence of disseminated sulfides. Samples 4, 3 and 2 contain 5, 2 and 1 per cent sulfides respectively and samples 4 and 3 contain both pyrite and sphalerite whereas sample 2 contains only pyrite.

The copper, zinc and manganese values for the dioritic dike at the end of the drill hole (Figure 4-6) are within the background range for these elements in the andesitic rocks. The sodium content of the dioritic dike is below that of the andesitic rocks.

Drill Hole 135

The dispersion patterns for drill hole 135, Figures 4-7 and 4-8, are similar to the patterns obtained for drill hole 132 in that the elements attain background values within a short distance of the ore zone and have a relatively uniform distribution along the traverse away from the ore zone.

The copper profile is very erratic for samples taken from the predominantly pillowed lavas. The explanations of the two anomalously high values, samples 4 and 19, are not apparent. Sample 19 is peculiar in that it consisted of over 80% epidote yet its content of sodium, manganese, zinc, cobalt and nickel is close to background values. Sample 4 contained a number of quartz and carbonate veinlets, and this is reflected by its abnormally low values for all the elements except copper. It is possible that the high copper content of both samples is due to the unnoticed presence of chalcopyrite.

Figures 4-7 and 4-9 indicate a zinc aureole extending some 75 feet into the foot wall. The aureole is odd in that two samples immediately adjacent to the foot wall (Nos. 48 and 49) and one sample in the middle of the aureole (No. 53) have background values. Furthermore, two of the samples

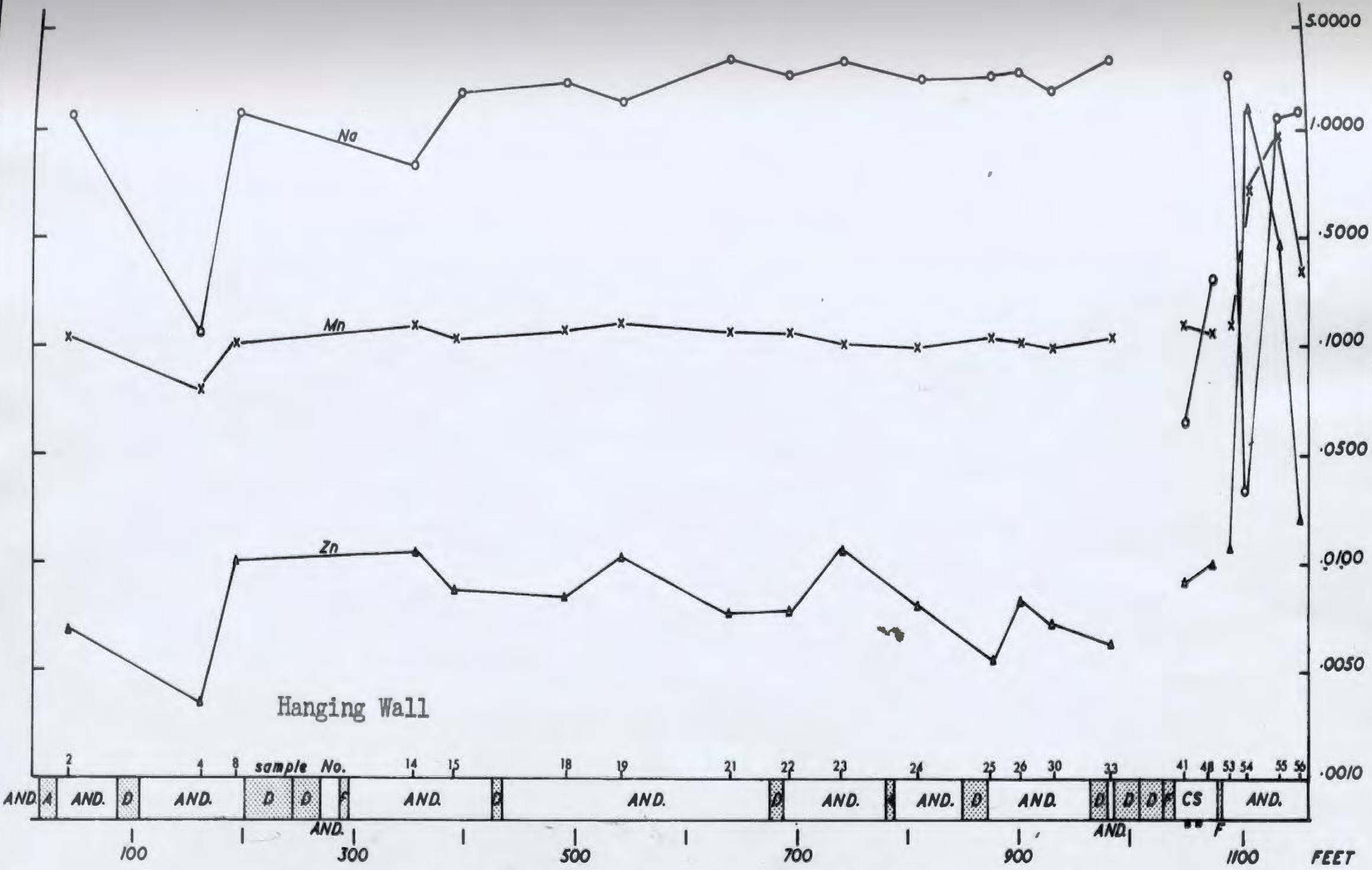


FIGURE 4-7 Variation in Na, Mn and Zn content in Little Deer Drill Hole 135. Drill Log:— A= Amphibolite Feldspar Porphyry, D = Diorite Dike, F = Feldspar Porphyr Dike, AND.= Andesitic lavas and tuffs, CS = Chlorite Schist, ▬ greater than 1% Cu, ╥ less than 1% Cu.

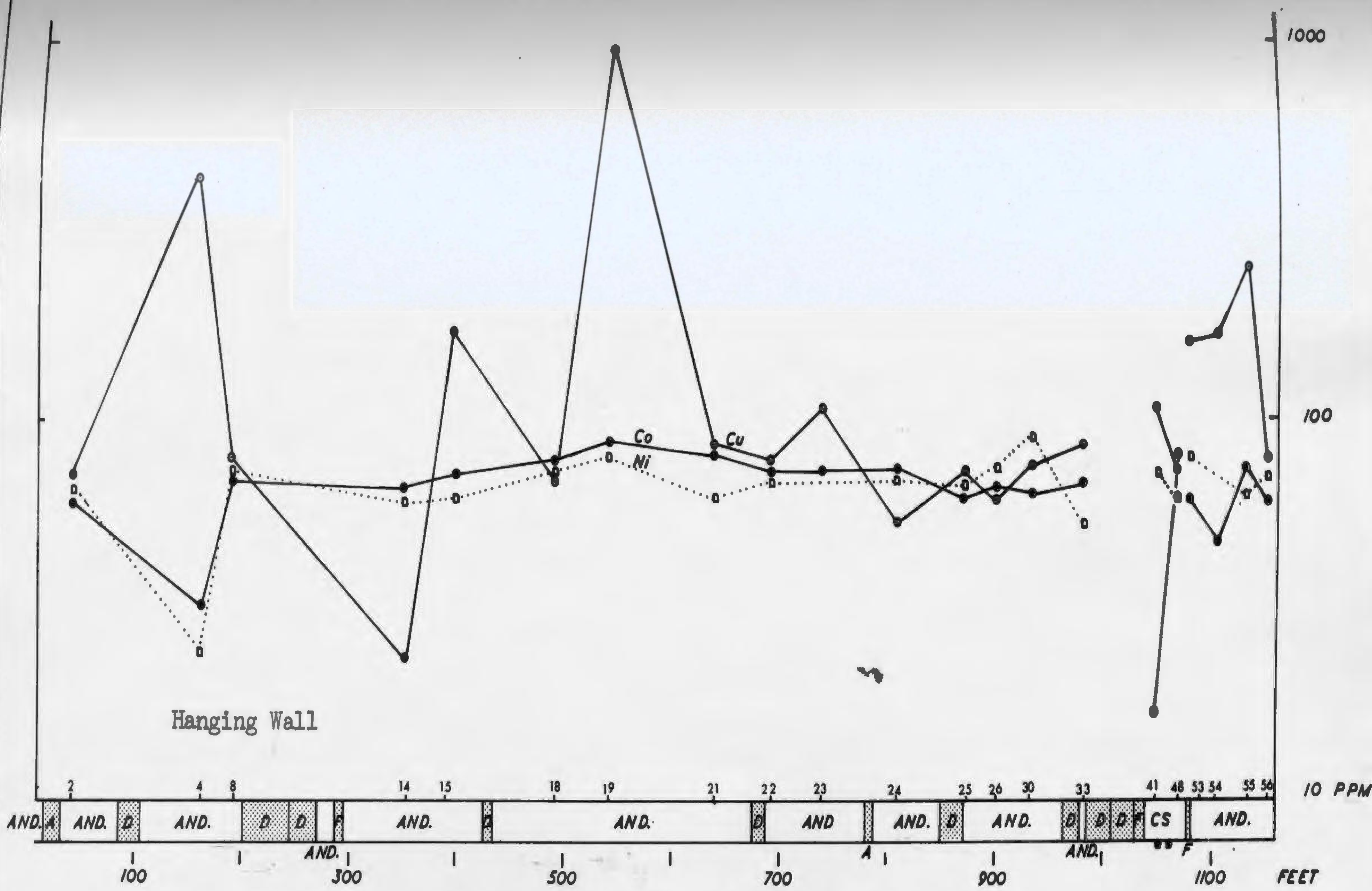


FIGURE 4-8 Variation in Cu, Co and Zn content in Little Deer Drill Hole 135. Drill Log:— A= Amphibolite Feldspar Porphyry Dike, D=Diorite Dike, F=Feldspar Porphyry Dike, AND.=Andesitic lavas and tuffs, CS=Chlorite Schist, ▬ greater than 1% Cu, ╥ less than 1% Cu.

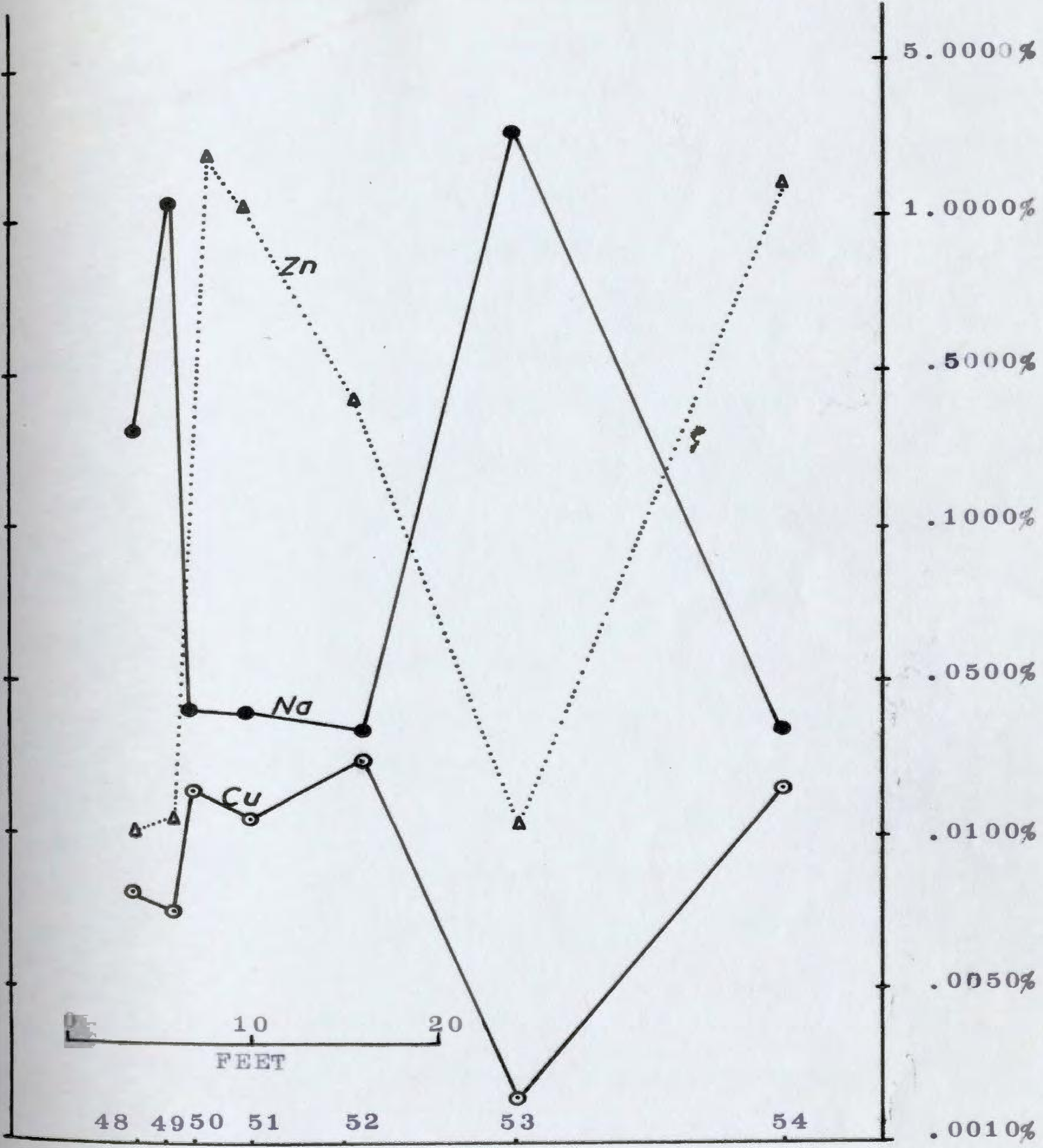


Figure 4-9 The Dispersion Patterns of Zn, Cu and Na in the Ore Zone intersection of Little Deer Drill Hole 135.

having high zinc values (Nos. 54 and 55) and which have been hydrothermally altered, are separated by massive unaltered andesite. These features suggest that the aureole may be composite in nature, consisting of several aureoles related to different channels of hydrothermal activity. Samples 50, 51 and 54 contain threads of sphalerite visible with a hand lens. Sample 55 is silicified and contains visible pyrite.

The sodium and copper values for the foot wall samples show that while there has been a considerable removal of sodium in some samples, there has not been any appreciable addition of copper.

The nickel and cobalt contents of the samples remain relatively constant in the ore zone and the host rocks. It is possible that the pyrite contents of the samples collected was too low to appreciably affect the nickel and cobalt.

DISPERSION PATTERNS IN THE LITTLE BAY MINE

Samples were obtained from two traverses across the ore zones of the Little Bay Mine (Figure 2-5). The North Zone was sampled along the 700 level crosscut from the Main Ore Zone to the North Zone. The 1350 level was sampled along a diamond drill drift and a crosscut to give a traverse that was approximately at right angles to the Main Ore Zone, see Figures 2-5, 3-3 and 3-5.

The samples from this property are mainly chip samples taken over several feet of a drift wall. In the initial sampling program the writer collected a number of samples to study the distribution of trace elements not only in relation to the ore zone but also in relation to various rock types and the effect of dike intrusions. Only a limited number of the samples collected could be analyzed in the available time.

700 Level

Figures 4-10 and 4-11 show the dispersion patterns found in the traverse across the North Zone. Further detail of parts of this traverse are shown in Figures 4-12 to 4-15.

In the case of samples obtained from wall rocks consisting of basic pillow lava, only the values for the rims of the pillows are presented in Figures 4-10 and 4-11. The data obtained on the intermediate portions and centers of the same pillows are presented in Figures 4-14 and 4-15.

The dispersion patterns of the elements, with the exception of copper and sodium, show little variation in either the ore body or the wall rocks.

The sodium profile is rather uniform over the wall rocks, in which it varies between 1.06 and 3.18 per cent. In the chloritic schists of the ore zone, however, its distribution becomes less regular and drops to less than 0.10 per cent, except for sample 31 with 0.38 per cent sodium.

The manganese profile is fairly uniform over most of its length. Although the majority of samples in the ore zone have values similar to those obtained on the wall rocks local highs are found (Figure 4-13).

The zinc, nickel and cobalt profiles (Figures 4-11 and 4-13) are quite flat within the wall rocks, and although values vary erratically within the mineralized zone (Figure 4-13) the general levels of concentration do not differ much from the wall rocks.

Figures 4-10 and 4-13 show copper values within the mineralized chlorite schists to be an order of magnitude higher, and much more erratic, than copper values in the wall rocks. In an attempt to obtain samples from the ore zone with a mineralogy as similar as possible to the chlorite schist wall rocks highly mineralized portions of the ore zone were avoided when sampling there. Nevertheless ore zone samples did contain small grains or threads of sulfides and these are of course the reason for the high and erratic copper values

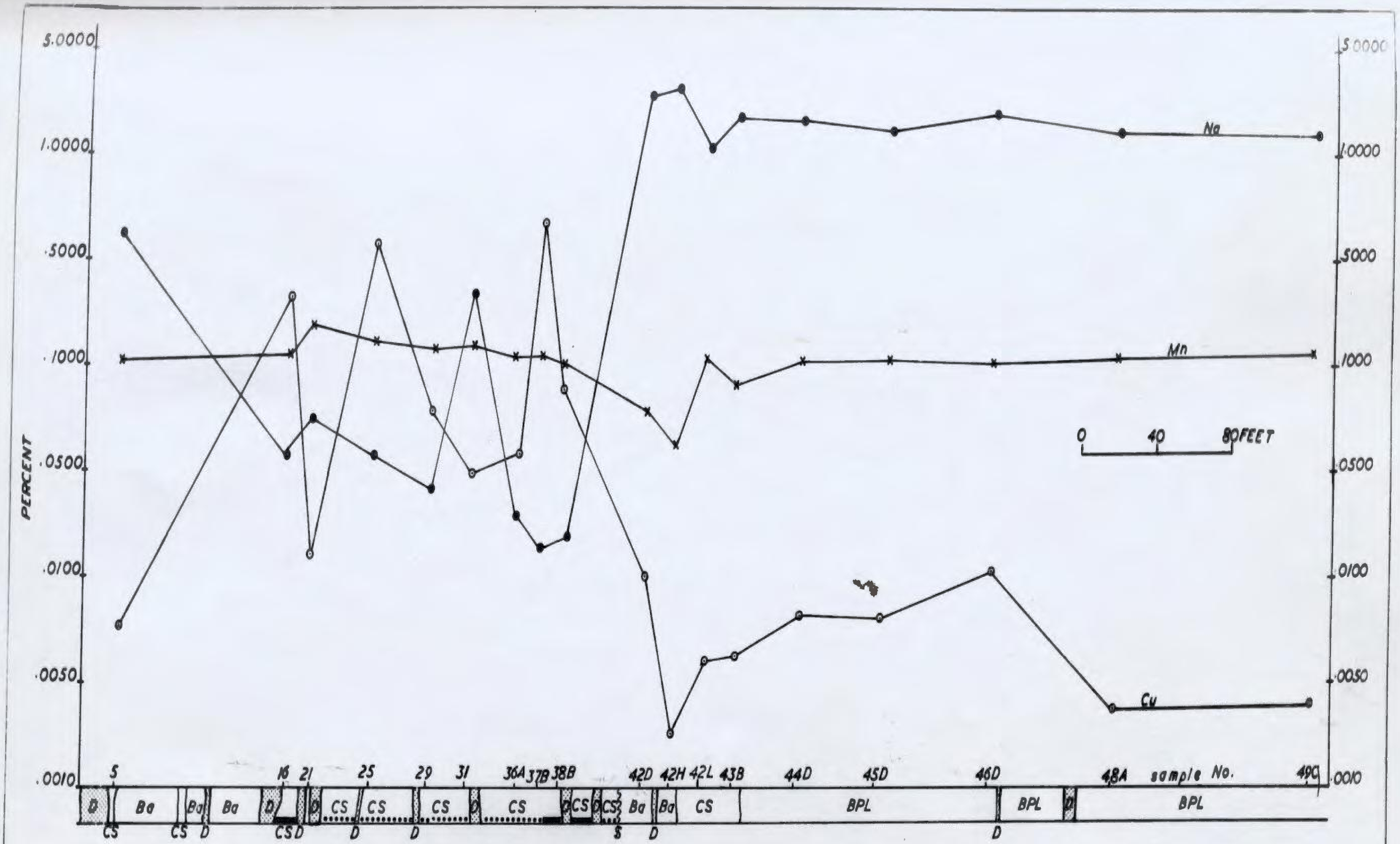


FIGURE 4-10 VARIATION IN Na, Mn AND Cu CONTENT IN LITTLE BAY 700 LEVEL NORTH ZONE.
DRIFT LOG:— D=DIORITIC DIKE, Ba=BASIC VOLCANIC ROCKS, BPL=BASIC PILLOW LAVAS, CS=CHLORITE SCHIST, S=SHEAR ZONE, ▬ GREATER THAN 1% Cu, ⋯ LESS THAN 1% Cu.

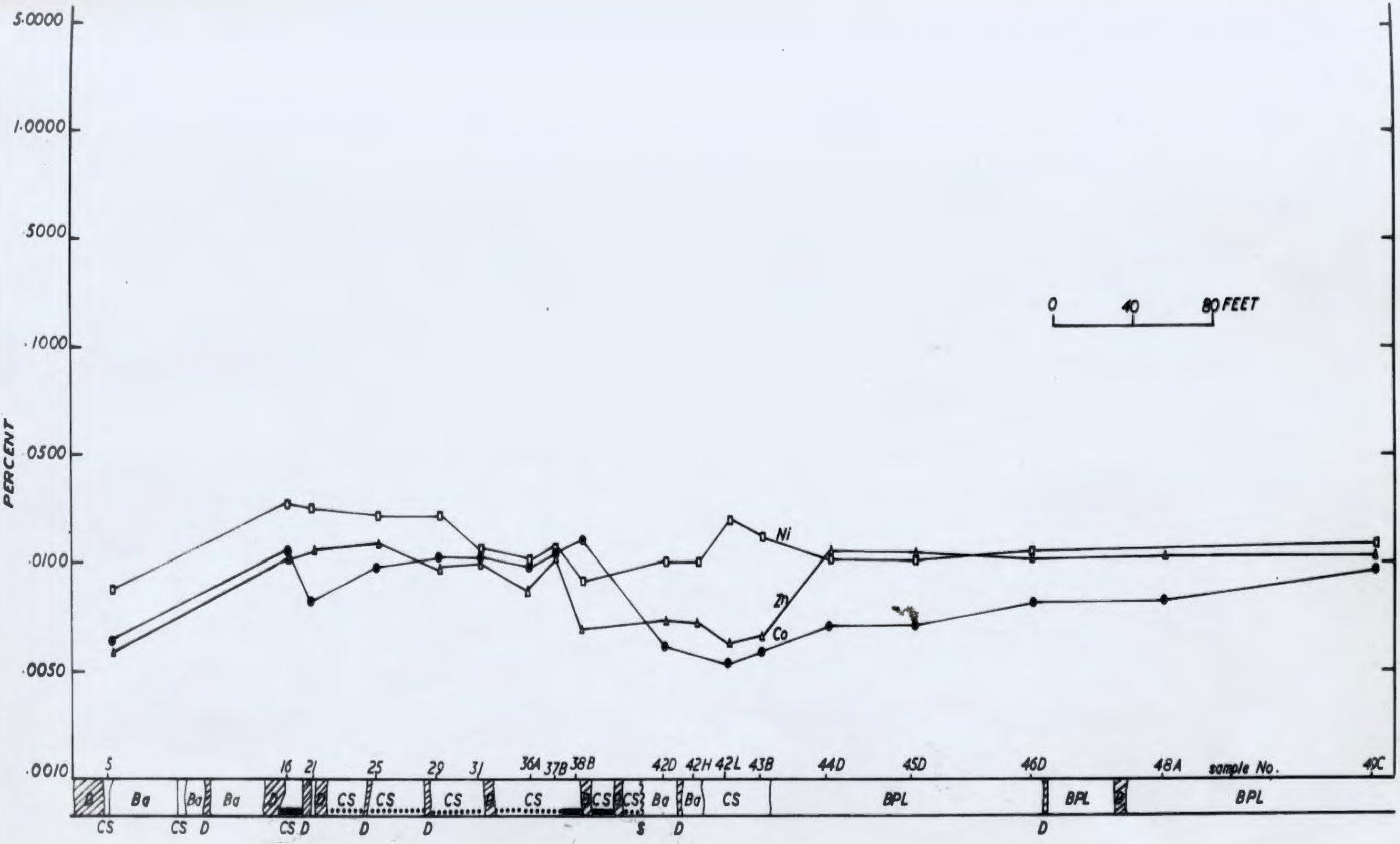


FIGURE 4-11 VARIATION IN Ni, Zn AND Co CONTENT IN LITTLE BAY 700 LEVEL NORTH ZONE.
DRIFT LOG:— D=DIORITIC DIKE, Ba=BASIC VOLCANIC ROCKS, BPL=BASIC PILLOW LAVAS,
CS=CHLORITE SCHIST, S=SHEAR ZONE, ▬ GREATER THAN 1% Cu, ┅ LESS THAN 1% Cu.

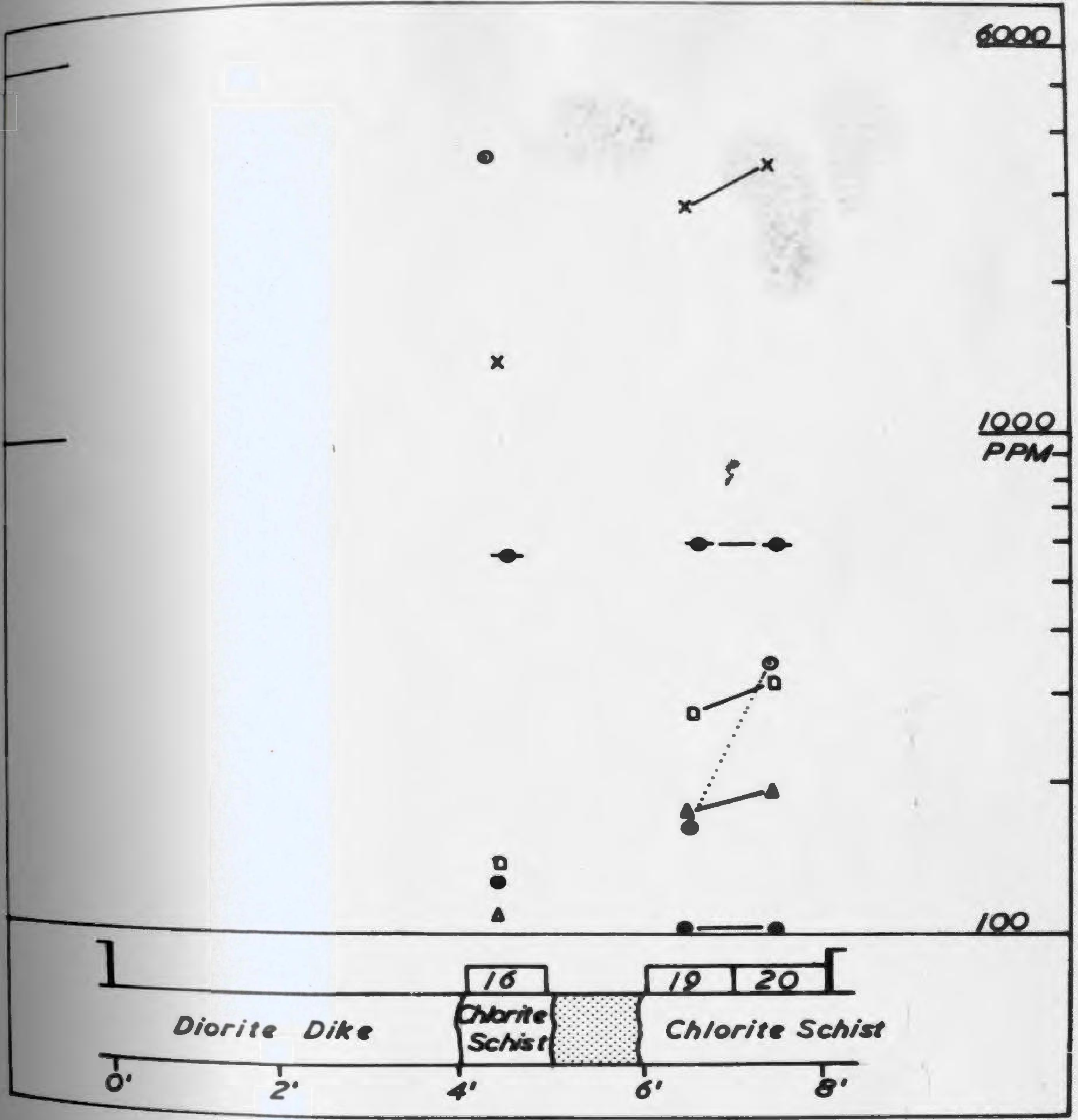


Figure 4-12: Concentration of Cu, Zn, Ni, Co, Mn and Na adjacent to a massive sulfide vein.
⊙=Cu, x=Mn, -●-=Na, ▲=Zn, □=Ni, ●=Co, [19] = Sample Interval and Number, ▨ = Massive Sulfides,] = Drift Wall.

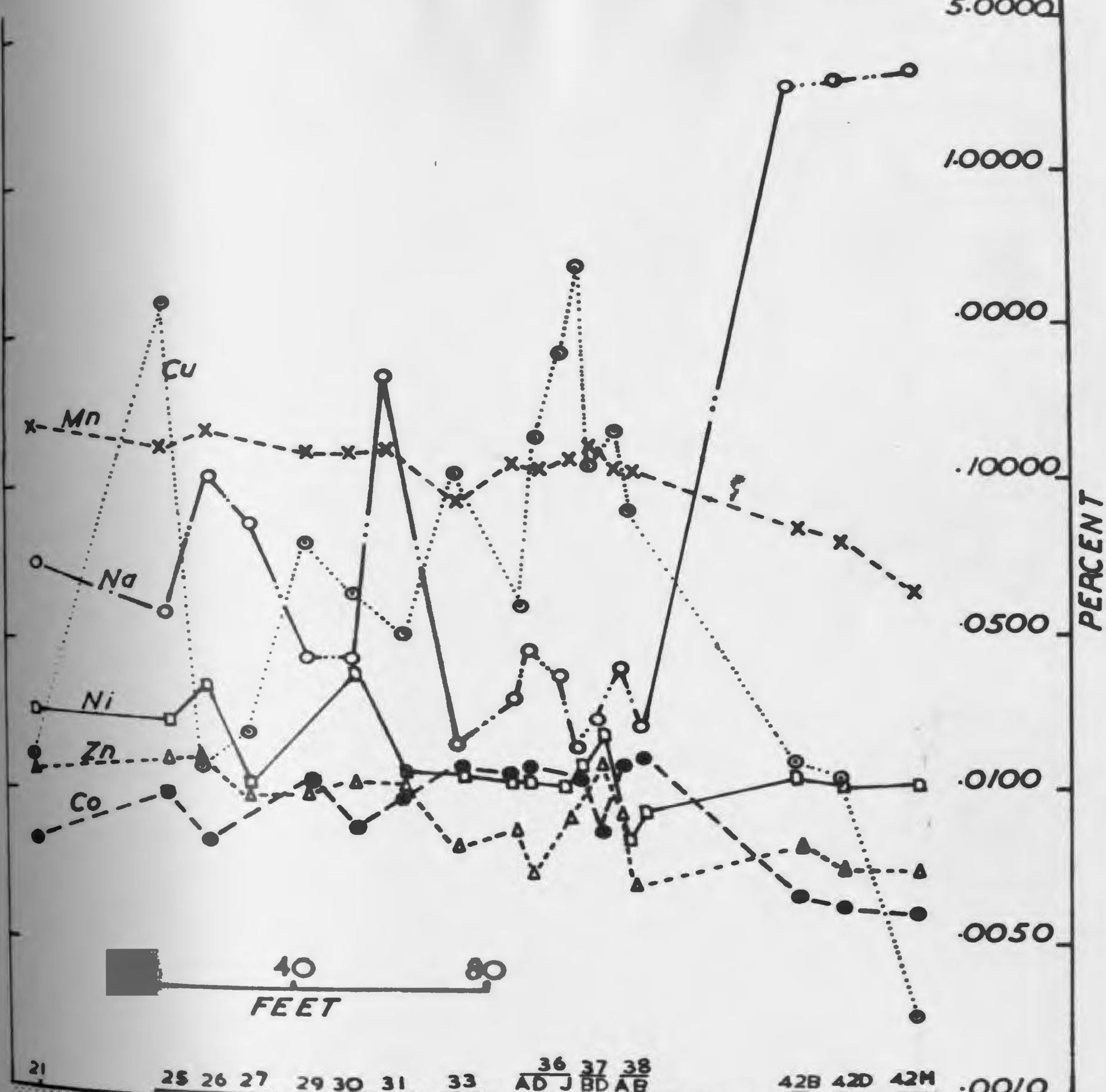


Figure 4-13 Dispersion Patterns of Cu, Zn, Ni, Co, Mn and Na in North Zone Orebody, Little Bay Mine.
Ba — Basaltic lavas; ▨ Dioritic dikes; ░ Chlorite Schist with sulphides; ▮ — massive sulfide vein.

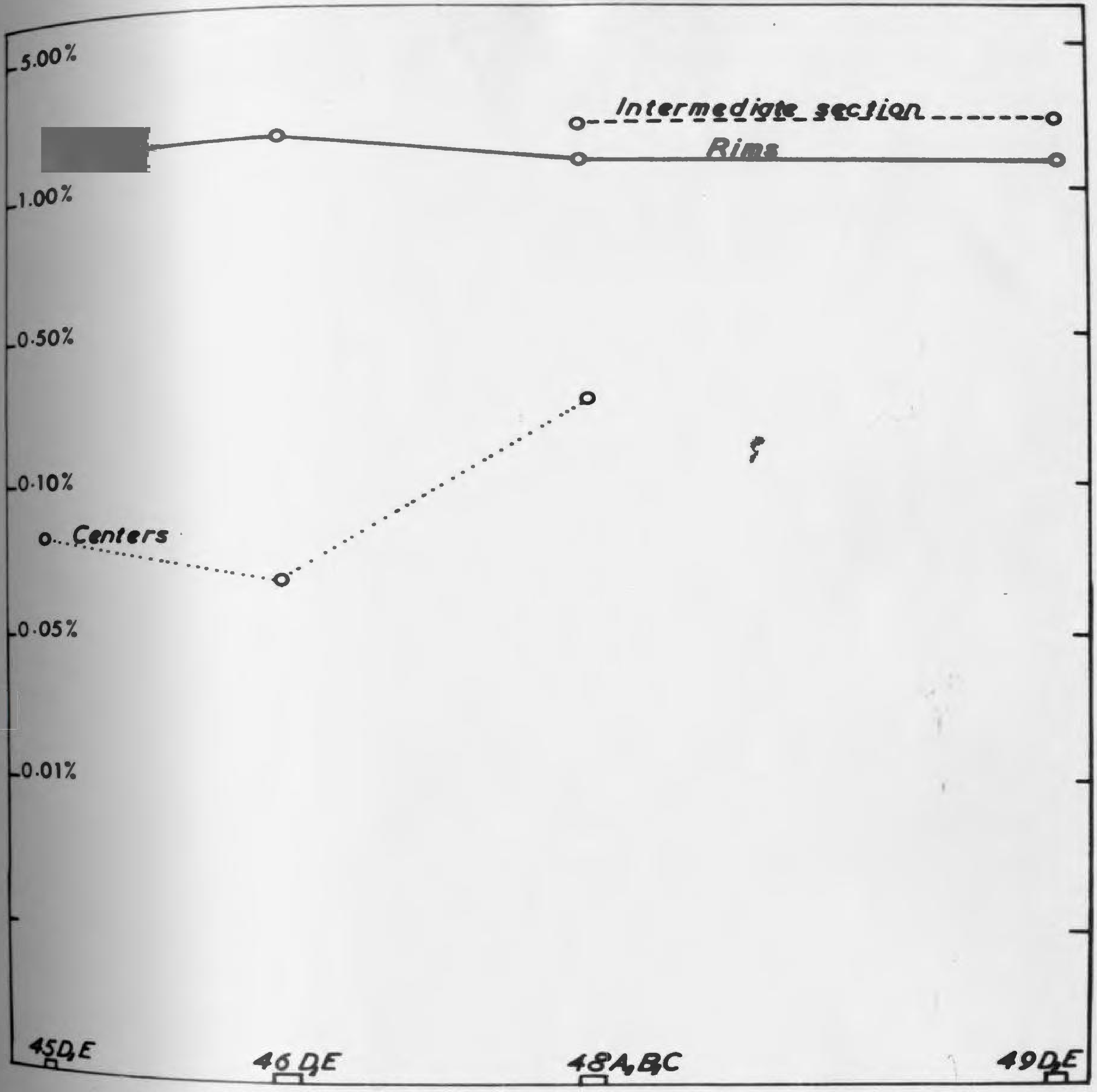


Figure 4-14 Distribution of Sodium in Rims, Intermediate sections, and Centers of Pillows in Basic Pillow Lava, Little Bay Mine.

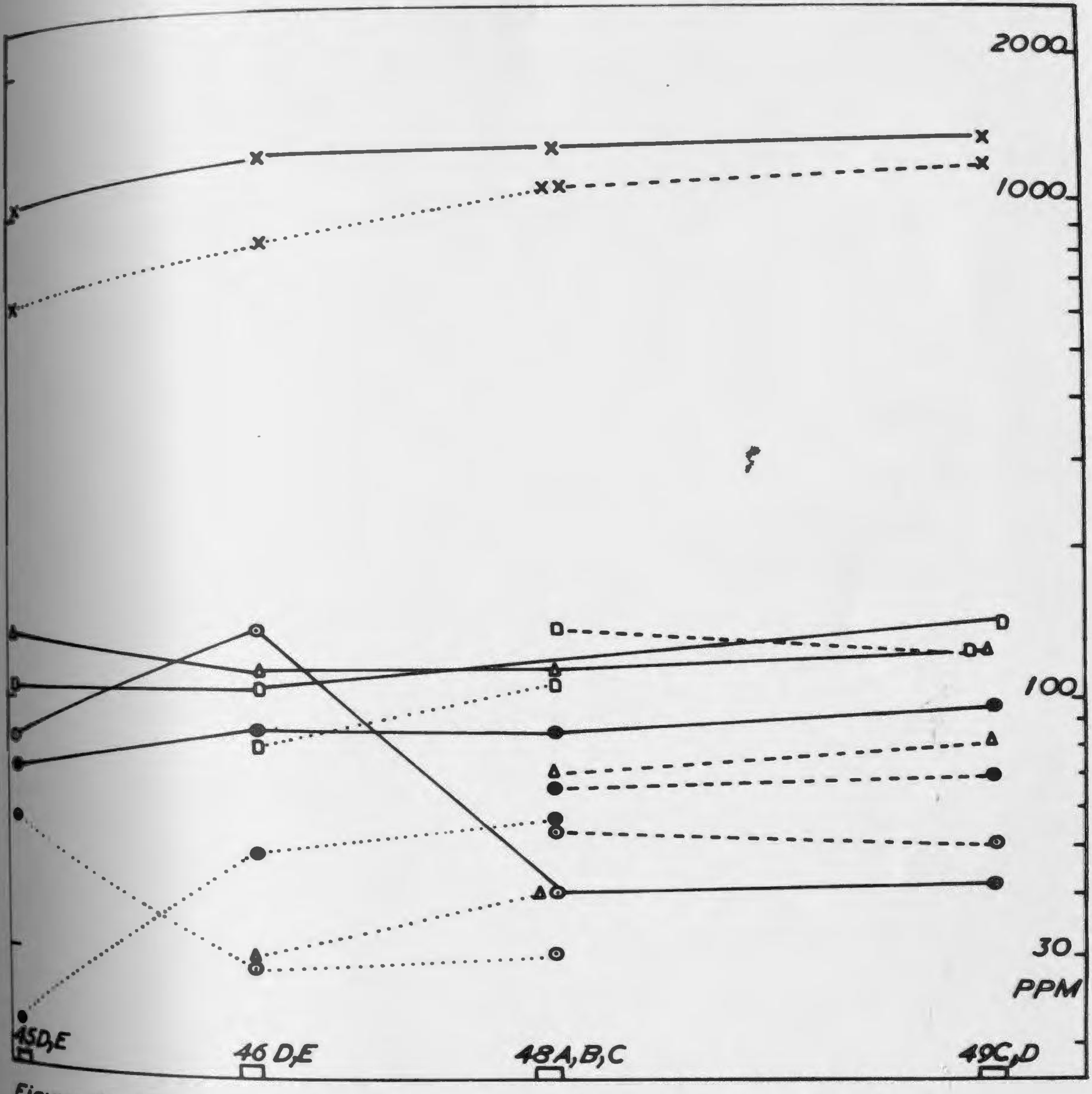


Figure 4- 15 Distribution of Cu, Zn, Ni, Co and Mn in the Rims, Intermediate sections, and Centers of Pillows in Basic Pillow Lavas, Little Bay Mine. ——— Rims, ------Intermediate sections, ········Centers. ⊙=Cu, △=Zn, □=Ni, ●=Co, x=Mn.

for these samples.

Figure 4-12 shows the concentration of the elements adjacent to a massive pyrite-chalcopyrite vein. The three samples represented here were each collected over a one foot interval with the purpose of testing for lateral dispersion originating from an obviously localized source of metal (the massive sulfide vein). The purpose was not fulfilled, for not enough samples were taken and the effect of the dike, which may be post-ore is unknown. Nevertheless two points are worth noting. Firstly, the concentration ranges for the rest of the mineralized zone, and secondly, the sample collected 12 to 24 inches from the vein contained more copper, zinc, nickel and manganese than the sample on the same side of the vein collected 0 to 12 inches from the vein. One would expect the reverse relation if elements diffused out from the vein. Although the detail is scanty, it does seem to rule out any significant migration of material outwards from the vein into the immediately surrounding rocks.

Figures 4-14 and 4-15 show the distribution of the elements between three recognizable petrographic units of the basic pillow lavas: the chloritic and schistose rims, the massive relatively unaltered intermediate section, and the yellowish, predominantly epidote centers.

It can be seen that there is a definite fractionation of sodium between the three units. The intermediate section of the pillow contains approximately twice as much sodium as the chloritic and schistose rims, and the rims in turn have more than twice as much as the epidotized portions of the pillows. The sodium values obtained for the Little Bay pillows are quite different from the values obtained by Hopgood (1962) on an unaltered spilitic pillow from the Franciscan Formation, California. Hopgood found that the sodium values for the selvedges of his pillow were 2.51 to 3.73 per cent Na_2O, the intermediate portion of his pillow contained 5.24 to 7.06

Table 4-2 Concentration of elements in the sheared chloritic rims, massive and relatively unaltered intermediate portions and the epidote centers of pillows from the same locations on the Little Bay 700 level. Cu, Zn, Ni and Co in ppm; Mn and Na as per cent.

Copper

Sample No.	45	46	48	49
Chloritic Rim	81	136	40	43
Intermediate	--	--	54	51
Epidote Center	56	28	30	--

Zinc

Sample No.	45	46	48	49
Chloritic Rim	131	111	112	127
Intermediate	--	--	70	81
Epidote Center	--	29	42	--

Nickel

Sample No.	45	46	48	49
Chloritic Rim	105	104	--	141
Intermediate	--	--	136	127
Epidote Center	--	79	108	--

Cobalt

Sample No.	45	46	48	49
Chloritic Rim	72	84	83	92
Intermediate	--	--	66	70
Epidote Center	22	48	55	--

Table 4-2 (continued)

Manganese

Sample No.	45	46	48	49
Chloritic Rim	0.107%	0.121%	0.129%	0.139%
Intermediate	-----	-----	0.104%	0.121%
Epidote Center	0.065%	0.083%	0.104%	-----

Sodium

Sample No.	45	46	48	49
Chloritic Rim	1.99%	2.40%	1.79%	1.81%
Intermediate	----	----	2.53%	2.91%
Epidote Center	0.08%	0.07%	0.34%	----

per cent Na_2O, and the central portions of the pillow contained 5.62 per cent Na_2O.

The distributions of copper, zinc, nickel, cobalt, and manganese within pillows are shown in Figure 4-15. All three portions of a pillow were sampled in only one case, sample 48. In other cases the rim was sampled but either the intermediate portion or the center of the pillow was omitted. Nevertheless the trends shown in Figure 4-15 are distinct. The rims are richer than the inner portions in all elements except copper. Copper is most abundant in the intermediate parts of the pillows and least abundant in the centers. All elements are least abundant in the center of pillow 48.

Table 4-2 gives the numerical values obtained for the data shown in Figures 4-14 and 4-15.

1350 Level

Chip samples were collected in the hanging wall of the Main Zone of the Little Bay Mine on the 1350 level to give a traverse at approximately right angles to the ore zone. The dispersion patterns, Figures 4-16 and 4-17, are quite similar to those found in the other traverses described previously in this chapter.

In the wall rocks each element shows a greater range of values than in the other Little Bay profiles, although like the other profiles the mean is uniform throughout the wall rocks. Copper especially shows several exceptionally low values, two of which (numbers 3 and 13) are samples of chloritic rims of pillows.

The sodium profile is quite similar to that of the other traverses in that it shows an abrupt drop as the chloritic zone is entered and it maintains low concentrations throughout the ore zone. Copper is extremely variable throughout the ore zone, possibly reflecting varying quantities of finely disseminated chalcopyrite in the samples, even though none was visible in

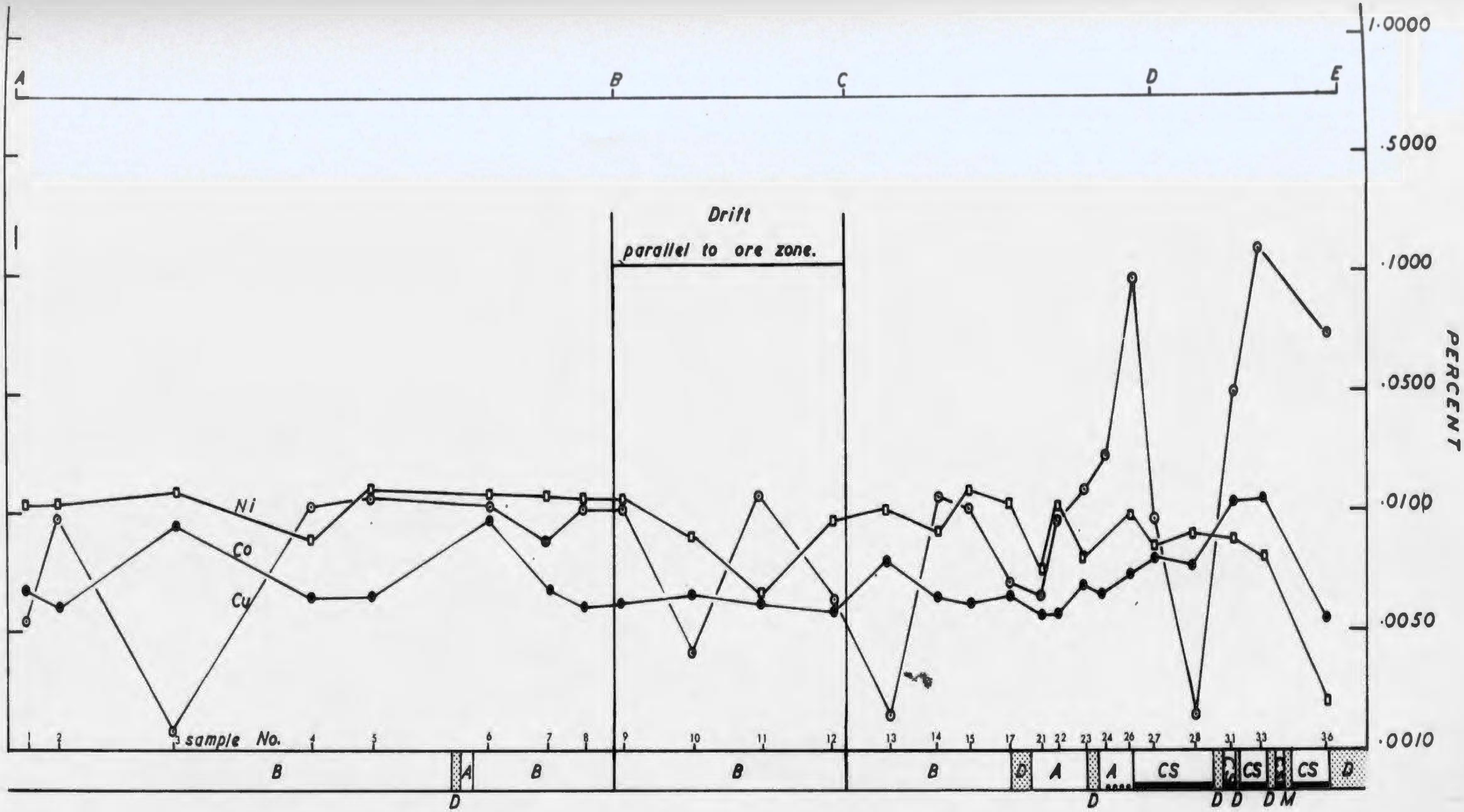


FIGURE 4-16 Variation in Ni, Co and Cu content in Little Bay 1350 Level Diamond Drill Crosscut. DRIFT LOG:—M=Mafic Dike, D=Dioritic Dike, A=Schistose Andesitic to Basaltic rocks, B=Andesitic to Basaltic lavas and pyroclastics, CS=Chlorite Schist, ▬ greater than 1% Cu, ...less than 1% Cu. A-B-C-D-E:—Traverse trace Figure 3-3.

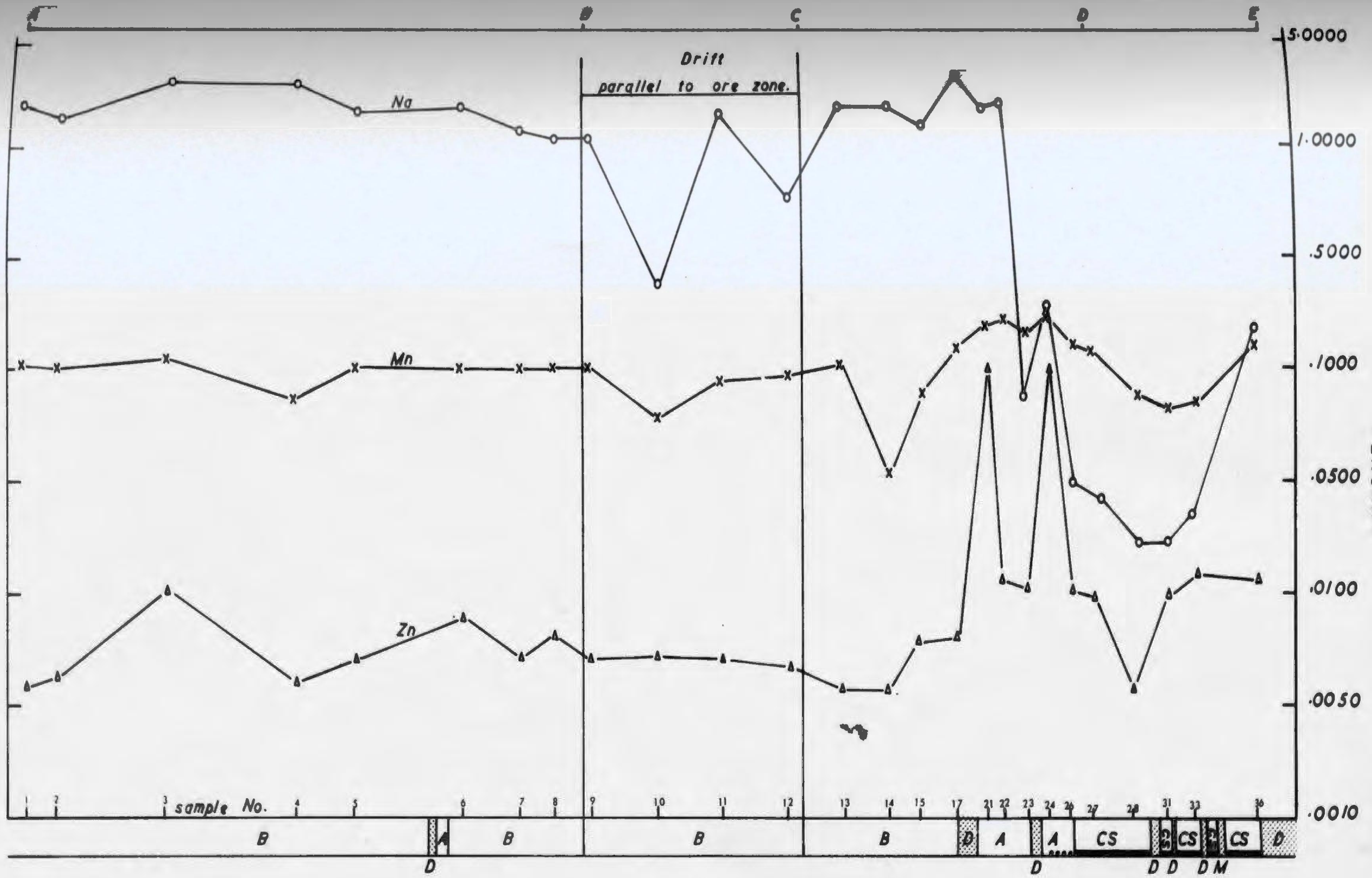


FIGURE 4-17 Variation in Na, Mn and Zn content in Little Bay 1350 Level Diamond Drill Crosscut. DRIFT LOG:—M= Mafic Dike, D= Dioritic Dike, A= Schistose Andesitic to Basaltic rocks, B= Andesitic to Basaltic lavas and pyroclastics, CS= Chlorite Schist, ▬ greater than 1% Cu, ...less than ·1% Cu. A-B-C-D-E:—Traverse trace Figure 3-3

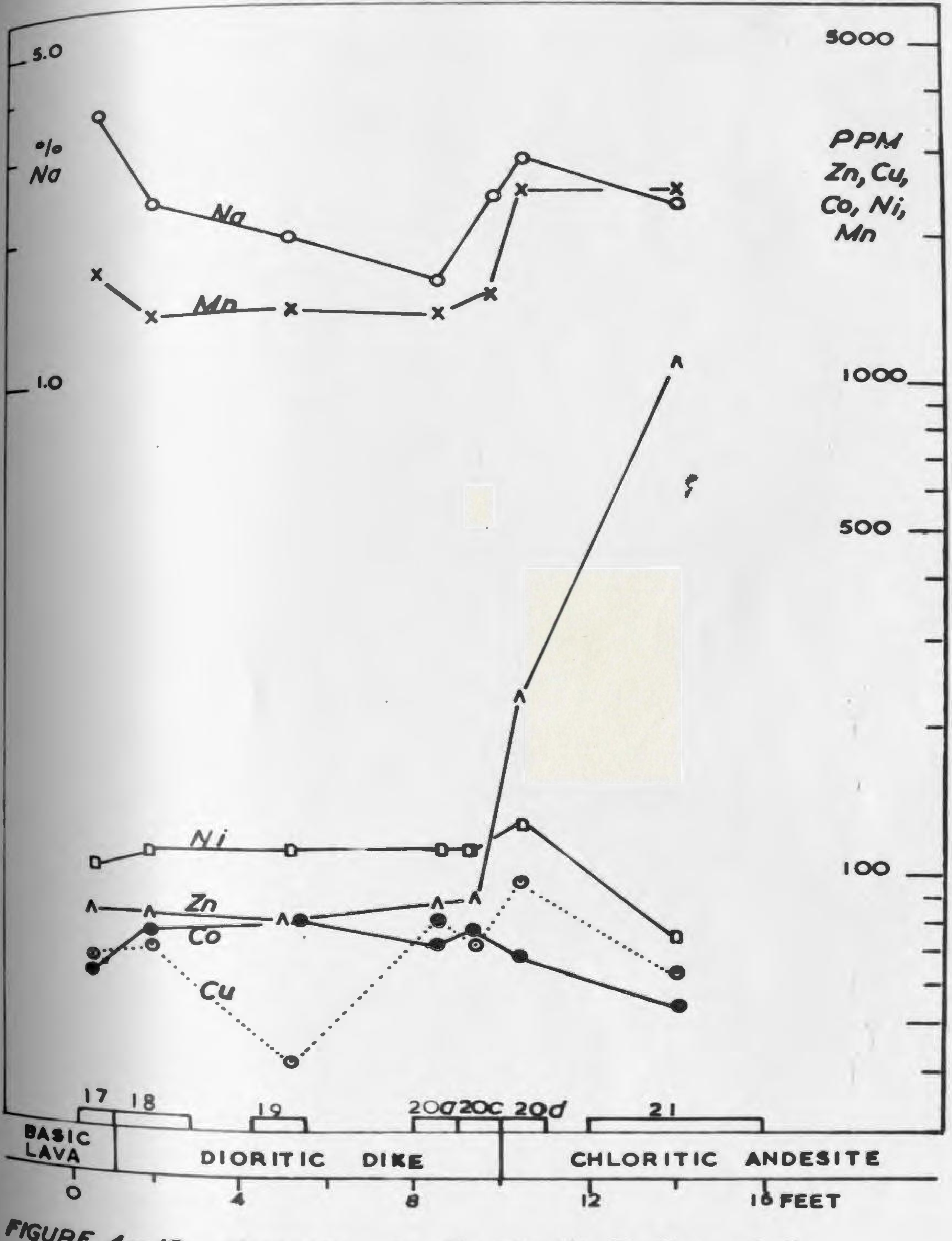


FIGURE 4–18 Variation in Na, Mn, Ni, Zn, Co and Cu across a dioritic dike.

the hand specimens. Nickel and cobalt are fairly constant throughout the ore zone at approximately the same levels as the wall rocks. It should be noted that the nickel and cobalt contents of samples 17 to 26 which contain visible pyrite are similar to those samples without visible pyrite.

The zinc profile has two high values outside of, but adjacent to, the ore zone. Both of the samples, 21 and 24, contain visible pyrite, which is abnormal for wall rock samples. It is possible that the pyrite contained very fine grained disseminated sphalerite.

Samples 36 and 28 of this traverse are of special interest. Sample 36 was obtained from a six inch post-mineralization, but unmineralized, shear zone that cuts obliquely across the ore zone. Sample 28 was obtained two inches from a two inch wide vein of massive chalcopyrite.

Figure 4-18 illustrates the dispersion of elements in and adjacent to a post-ore dioritic dike. In general, the concentrations of the elements in and adjacent to the dike are similar to the background values of the wall rocks.

Samples of rims and centers of epidotized pillow lavas show a distribution of elements similar to that obtained for the 700 level. The values obtained for the chloritic rims and the epidotized centers of pillows are shown in Table 4-3. Except for the erratic values of copper there is a general tendency for the elements to be lower in the epidotized centers than in the schistose and ferromagnesian rich chloritic rims of the pillow structures. The high nickel content of 5b is an exception. This value may be spurious; it was not duplicated.

Table 4-3 Concentration of elements in the chloritic rims and epidote centers of pillows from the Little Bay 1350 level. Cu, Zn, Ni and Co in ppm; Mn and Na as per cent.

Sample	Rock Type	Cu	Zn	Ni	Co	Mn	Na
3AA	Chloritic Rims	13	110	135	96	0.131%	3.46%
3Bb	Epidote Center	8	41	107	58	0.113%	0.20%
5a	Chloritic Rims	116	71	130	65	0.113%	2.24%
5b	Epidote Centers	30	32	150	42	0.083%	0.09%
6B	Chloritic Rims	119	108	153	97	0.125%	2.92%
6C	Epidote Centers	158	38	70	45	0.067%	0.12%
13a	Chloritic Rims	23	57	105	79	0.103%	2.41%
13c	Epidote Centers	27	26	72	38	0.070%	0.09%

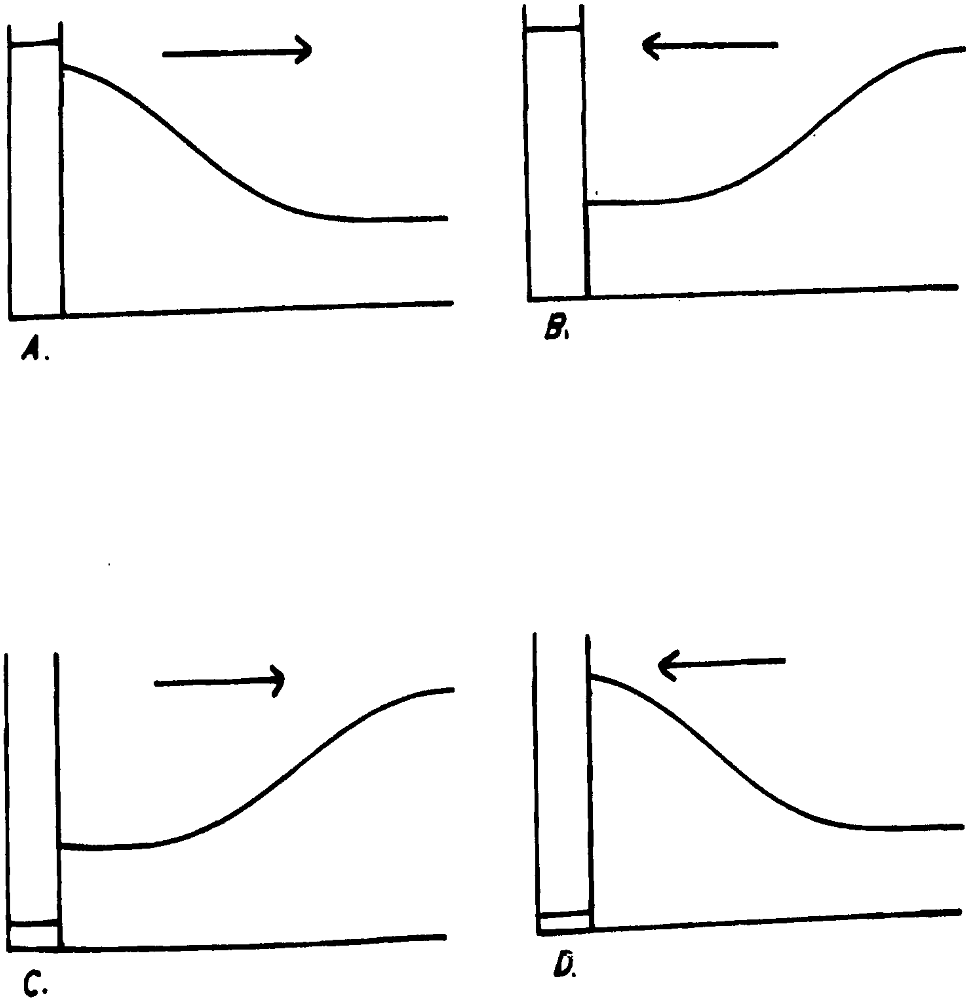
CHAPTER V. SUMMARY AND CONCLUSIONS

The origin of certain economic mineral deposits has always been very much in dispute. Ideally the shape of the dispersion pattern found can help in deciding this point. Assuming the dispersion pattern is primary and epigenetic it is generally possible to tell the direction of movement during mineralization of material across the contacts of the ore body; that is, whether ore constituents moved into or out of the wall rocks. This question of the direction of movement of components in relation to the wall rocks has been discussed by Reitan (1959) whose diagrams, with explanatory notes, are reproduced here (Figure 5-1). Reitan's models assume movement into the wall rocks by diffusion. However, permeation of permeable wall rocks by physical flow of ore fluids would not produce the same patterns as those suggested by Reitan.

Most of the examples quoted in the literature appear to be the type of dispersion pattern which would be expected from deposits with a hydrothermal origin, or by any other origin, involving epigenetic emplacement (e.g. Morris and Lovering, 1952, and many others). They would correspond to model A of Figure 5-1. Boyle (1961, 1968) argues for the diffusion of metals from the country rocks into the vein to form an ore deposit as in model B of Figure 5-1.

Models C and D of Figure 5-1 cannot produce ore deposits but they may often represent the behaviour of the major rock forming elements during the formation of an ore deposit.

Most of the sodium profiles presented in Chapter IV show an abrupt change from high and uniform sodium values in the country rocks to low and non-uniform values in the chlorite schists. Except for Little Deer drill hole 132 the sampling interval is too great to show whether this is in fact an abrupt change or whether it is a gradual change over distances



A. Diffusion from concentration in vein into country rocks.

B. Movement of component from surrounding rocks into vein.

C. Movement of another(other) component(s) from vein into surrounding rocks.

D. Movement of another(other) component from surrounding rock into vein.

FIGURE 5-1 Wall Rock Dispersion Patterns after Reitan (1959).

less than the sampling interval. When the author obtained this data there was, unfortunately, insufficient time available to resample the critical areas on a closer spacing. However, in the Little Deer drill hole 132, where the samples are closely spaced the sodium values decrease gradually over a 25 foot interval as the ore bearing chlorite schist zone is approached. In terms of the working hypothesis that these are epigenetic hydrothermal deposits this gradual change in sodium content adjacent to an ore zone suggests that sodium was removed from the country rock, as well as from the ore bearing chlorite schists, by pre-ore and/or ore forming fluids. The sodium distribution resembles a modified form of Reitan's model b, in which the sodium removed from the country rock did not accumulate in the "vein" but was carried out of the system by the hydrothermal fluids.

On the other hand, if the epigenetic hydrothermal hypothesis is not adhered to, it is possible that the low sodium content in those ore zones occuring in chlorite schists which are developed in pyroclastic rocks could be attributed to an initially low sodium content, relative to the country rock lavas, of the pyroclastics. This could be the case for the Little Deer and Lady Pond chlorite schist zones. In opposition to this interpretation it should be noted that the pyroclastic rocks which have not been altered to chlorite schists contain as much sodium as the lavas. Furthermore, a syngenetic distribution cannot be invoked to describe the Little Bay traverses since part of the chlorite schist zones there appear to have been derived from lavas. Thus the low sodium content of the chlorite schist zones is considered to be the result of sodium removal by hydrothermal activity.

Manganese values in the wall rocks are remarkably uniform and generally approximate a straight line outside the immediate ore zones. The erratic manganese values found in the Lady Pond drill hole have been explained earlier as being due to variations in lithology. The distribution of manganese in the ore zones, chloritic schist zones and adjacent to pyroclastics is much more variable than in the normal country rocks. Manganese profiles obtained across the two Little Bay ore zones exhibit different patterns. The Little Bay North ore zone has manganese values nearly identical to the surrounding country rocks while the Main ore zone values increase as the ore zone is approached, attain a maximum of three times that of the background at the edge of the chlorite schist zone, and gradually decrease to background values within the ore zone. The Little Deer drill hole 132 shows a narrow but distinct manganese aureole around the ore zone up to 25 feet wide. However, the remaining Little Deer profiles and the Lady Pond profile do not exhibit anomalous manganese values adjacent to the ore zones.

Nickel and cobalt analyses fall within the same range in country rock, chlorite schist zones and ore zones for each profile. There appears to be a tendency for nickel and cobalt to have a more uniform distribution in the country rocks, however the Little Deer diamond drill hole 92 and Little Bay 1350 level profiles are exceptions. Several high cobalt and nickel values in the ore zones can be directly correlated with sulfides visible in hand specimens with the naked eye. The nickel:cobalt ratio in the wall rocks of the Little Bay mine are greater than one while in Little Deer the ratio is usually less than one away from the mineralization but greater than one near the mineralized zone. The Lady Pond nickel:cobalt ratio is less than one in most cases, unfortunately not all of the samples from this traverse were analyzed for both elements.

The zinc profile of Lady Pond diamond drill hole 5 is quite irregular. In the other deposits zinc profiles tend to be uniform in the country rocks although the range of concentration is greater than for sodium, manganese, nickel and cobalt. Within the chlorite schist and mineralized zones the zinc profiles are much less regular than in the country rocks and although some of the lower values are within the range of the country rocks many values are several times higher than the highest country rock values. Some, although not all, of the high values were obtained from specimens containing disseminated threads and tiny grains of sphalerite visible in hand specimens with a 10x hand lens. Zinc enrichment relative to country rocks seems to be at least as wide spread as copper enrichment. In places zinc forms aureoles around zones of copper mineralization even though the ore zones are barely enriched in zinc (e.g. Little Bay profiles). The Little Deer zinc profiles show pronounced aureoles around the ore zones as well as around chlorite schist zones which contain only traces of chalcopyrite. However, the aureoles are narrow and extend for less than several tens of feet beyond the sphalerite mineralization visible in hand specimen with a 10x hand lens (e.g. Figure 4-6). The zinc aureole in the foot wall of the Little Deer deposit is revealed by finely disseminated sphalerite in the drill core. The Little Bay 700 level profile does not show any marked difference in zinc content between the wall rocks and the ore zone. The Little Bay 1350 level profile shows an erratic and weakly defined zinc aureole extending for some twenty five feet into the hanging wall (specimens 17 and 23), however, ore zone values are only slightly higher than those found in the wall rocks.

Copper profiles are irregular throughout, although in the chlorite schist and mineralized zones the profiles are characteristically more irregular and contain values at least an order of magnitude greater than the values obtained in the country rocks. Copper aureoles exist around all zones of copper mineralization. The aureoles are commonly irregular, and in some, although not all, cases they are characterized by disseminated chalcopyrite visible in hand specimens with the naked eye. In most cases the dispersion of copper has not extended beyond the limits of the chloritic schist zone and where primary dispersion halos of copper exist in the wall rocks, Figure 4-6, the dispersion has been restricted to within a few feet of mineralization visible to the naked eye.

The manganese, cobalt and nickel dispersion patterns obviously do not fit any of Reitan's models. The generally similar values throughout the profiles of these elements suggests that the main component of the present dispersion is a primary dispersion syngenetic to the volcanic rocks. This is not surprising since the composition of the pyroclastic rocks (in which most of the chlorite schist zones appear to have formed) is similar to that of the flow rocks from which they presumably were derived and because cobalt and nickel, and to a lesser extent manganese, are not elements that one would expect to be contributed to marine pyroclastic rocks by sea water. The tendency for a greater spread, or range, of values in the chloritic schist and mineralized zones can be attributed to modification of the syngenetic pattern by hydrothermal activity. If the profiles do represent primary syngenetic dispersion, the first thought that springs to mind is that there has been no hydrothermal or epigenetic introduction of manganese, cobalt and nickel. However, it is not possible to make this conclusion because it must be remembered that the samples in the chlorite schist and mineralized zones were chosen so as to avoid as much as possible concentrations of sulfides. In other words, the samples are not representative of the whole ore zone. It would be interesting, however, to sample in a representative manner the chlorite schist and mineralized zones with the aim of determining the average manganese, cobalt and nickel contents of these zones.

The zinc and copper dispersion patterns are compatible with the hypothesis that the zinc and copper mineralization is epigenetic, that movement of zinc and copper (but not manganese, cobalt, or nickel) took place from the sites of mineralization into the wall rocks for short distances, and that the ideal dispersion pattern that would be expected from such a process was modified by a directional fabric, a foliation, that already existed at the time of mineralization or by post mineralization shearing and/or metamorphism.

The sampling of pillow lavas at the Little Bay Mine illustrates the need for detailed petrological studies to be carried out in conjunction with geochemical investigations. A limited amount of data on the distribution of the elements between the rims, centers and intermediate sections of pillows found in pillow lavas is presented in Tables 4-2 and 4-3.

One purpose of this study was to simply collect geochemical data characterizing the mineral deposits of the Springdale Peninsula, of which the three deposits studied are representative. A good indication of local background values and more important, their range of variations, has been obtained for sodium, manganese, cobalt, nickel, zinc and copper in the country rocks and chloritic shear zones in which the three representative deposits occur.

Another purpose of the study was to determine whether or not trace element dispersion aureoles that could be used as an aid to exploration exist around the ore bodies. Of the elements studied none has a distinct and broad aureole around the economic mineralization and where local aureoles do exist they are seldom wider than the chlorite schist zone itself and therefore of little or no practical use in exploration.

Since the present study has been of a reconnaisance type, several facets of the investigation have been given only limited attention and should be pursued further.

Ideally, provided a suitable method of separation can be devised, analyses of sulfide phases and chlorite should be performed on the samples included in this study to determine what portion of the trace element content can be attributed to the sulfide phases and chlorites of the rock. Mechanical methods of separation have proven unsuccessful and hot nitric acid digests dissolve some of the chlorites. It may be possible to separate the sulfides by means of the hydrofluoric acid digestion method of Neuerburg (1961).

If further work similar to the present study is planned, quantitative mineralogical studies should be incorporated as an aid in interpreting the partition of elements between minerals. Such work would be difficult, however, due to the very fine grained nature of many of the rocks. Since modal analysis of thin sections is next to impossible in these rocks, quantitative X-ray diffraction analysis would have to be adopted.

Major element analyses of the chlorite schists and host rocks are needed to determine the nature of the metasomatism of the chlorite schists and host rocks. These analyses would also permit correlation of trace element and major element data.

Detailed sampling and major and trace element analyses of pillowed and massive lavas should be undertaken in order to determine what constitutes a representative sample in these rocks. A determination of major and trace element geochemistry of the metasomatized pillowed lavas could have a direct bearing on the problem of the origin of spilites.

Since the present investigation has shown that aureoles for copper and zinc extend for less than 25 feet beyond the zones of economic mineralization, it is advisable that any further investigation of aureoles around these deposits be based on shorter sampling intervals.

A study should be made of the **normal** distribution of elements in sulfide free chlorite schist zones in order to provide background information for assessing alterations produced by the mineralizing processes.

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APPENDIX I

CONCENTRATION OF ELEMENTS IN SAMPLES ANALYZED

Table I Concentration of Elements in Lady Pond Samples.

Sample	Cu	Zn	Ni	Co	Mn	Na
2	13*	101*	28*	40*	0.12%	4.34%
3	24	116	29	48	0.19	4.00
4	167	552	38	55	0.28	2.54
5	59	91	30	42	0.17	3.92
8	239	270	--	48	0.18	0.41
9	872	51	--	75	0.07	0.04
10	844	45	--	75	0.08	0.08
12	35	266	21	50	0.53	3.19
13	517	130	--	28	0.13	1.12
14	--	63	30	30	0.16	2.15
15	3260	59	29	38	0.08	0.21
16	1380	59	--	35	0.13	0.14
17	260	35	25	28	0.10	0.56
18	248	33	--	52	0.10	0.16
19	92	34	--	37	0.10	0.23
20	--	42	30	44	0.15	0.18
21	362	32	26	30	0.12	2.13
22	201	28	24	33	0.15	1.67
23	1530	41	31	40	0.11	0.24
25	146	60	26	36	0.11	2.54
26	300	73	27	34	0.14	2.28
27	--	76	28	29	0.15	1.00
30	45	76	26	31	0.13	0.26
31	168	29	24	42	0.10	3.07
32	298	30	25	35	0.06	1.78
33	203	23	21	26	0.06	3.11

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* parts per million

-- not determined

Table II Concentration of Elements in Little Deer Drill

Hole 92.

Sample	Cu	Zn	Ni	Co	Mn	Na
11	71*	89*	40*	62*	0.17%	3.12%
12	182	105	43	73	0.12	3.45
17	76	101	46	70	0.14	2.53
19	93	67	65	91	0.12	2.27
22	71	97	82	74	0.12	2.70
23	59	62	73	63	0.12	1.34
25	70	79	52	50	0.12	1.30
26	83	76	36	56	0.12	0.76
30	86	76	68	61	0.13	3.03
34	102	79	60	60	0.22	2.93
35	75	72	58	53	0.22	2.86
36	2350	255	63	109	0.25	0.72
39	656	209	71	80	0.30	2.07
43	95	101	65	73	0.13	2.93
44	88	100	67	66	0.13	2.64
46	85	76	77	64	0.16	2.89
48	117	83	68	62	0.13	2.87
50	2290	350	52	126	0.27	0.09
51	1320	168	47	81	0.15	0.10
53	102	86	48	61	0.24	0.69
70	215	14900	68	65	0.77	0.10
71	244	6680	61	56	0.57	0.46
72	56	154	71	78	0.18	3.95
75	83	56	67	70	0.36	3.06

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* parts per million

Table III Concentration of Elements in Little Deer Drill Hole

132 Samples.

Sample	Cu	Zn	Ni	Co	Mn	Na
1	79*	97*	34*	72*	0.17%	2.08%
2	82	132	68	69	0.23	2.05
3	28	4000	73	73	----	1.06
4	95	6900	65	55	0.57	0.07
17	224	7910	177	78	0.72	0.02
19	99	2850	58	66	0.54	1.76
20	66	205	--	62	0.47	2.22
21	79	222	85	71	0.50	2.57
22	74	106	--	64	0.20	2.93
23	127	59	80	67	0.09	2.66
24	86	85	90	78	0.10	3.23
25	79	65	80	68	0.13	3.27
26	88	106	77	81	0.13	2.27
27	80	68	87	69	0.13	2.87
29	59	93	57	65	——	1.97
30	72	64	84	70	0.12	2.27
31	66	60	81	64	0.10	1.27
32	76	108	75	76	0.15	2.88
33	76	91	—	74	0.12	2.83
34	101	76	61	67	0.13	2.48
35	44	90	78	85	0.13	2.34
36	74	77	46	64	0.15	2.26
39	88	99	—	74	0.15	1.85

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* parts per million

-- not determined

Table IV Concentration of Elements in Little Deer Drill Hole

135 Samples

Sample	Cu	Zn	Ni	Co	Mn	Na
2	73 *	68*	66*	63*	0.11	1.50
4	430	39	25	43	0.08	0.12
8	78	79	74	70	0.11	1.89
14	25	131	60	66	0.18	0.84
15	170	86	63	72	0.12	2.60
18	72	84	74	76	0.13	2.85
19	2340	101	82	86	0.16	2.01
21	86	76	63	87	0.14	3.42
22	76	77	71	71	0.12	3.09
23	105	81	—	71	0.10	3.55
24	54	79	70	73	0.10	2.95
25	72	56	66	64	0.12	2.96
26	60	83	72	63	0.10	3.05
30	76	73	—	64	0.10	2.36
33	86	63	53	68	0.12	3.50
41	17	91	71	105	0.16	0.06
48	80	98	62	75	0.14	0.34
49	74	107	65	—	0.14	1.17
50	215	20600	73	59	0.32	0.04
51	160	10200	77	61	0.52	0.05
52	276	4100	64	56	0.73	0.03
53	15	125	37	62	0.19	3.02
54	162	17700	—	46	0.71	0.04
55	242	4750	62	70	0.98	1.45
56	78	267	72	60	0.35	1.85

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* parts per million

— not determined

Table V Concentration of Elements in Samples from Little Bay 700 Level North Zone.

Sample	Cu	Zn	Ni	Co	Mn	Na
5	77*	58*	88*	64*	0.13%	0.63%
16	3500	111	142	130	0.14	0.06
19	165	175	284	68	0.29	0.05
20	355	197	321	69	0.36	0.06
21	192	184	306	84	0.25	0.08
25	5870	189	273	98	0.18	0.06
26	167	172	364	87	0.22	0.10
27	245	97	129	120	—	0.09
29	794	98	—	119	0.15	0.04
30	621	114	399	88	0.15	0.04
31	497	112	121	99	0.17	0.38
33	1060	82	119	122	0.09	0.02
36A	565	87	105	101	0.12	0.03
36D	1910	71	120	153	0.11	0.05
36J	4180	92	111	100	0.13	0.04
37B	6630	123	176	134	0.132	0.02
37D	1050	155	231	85	0.17	0.03
38A	2180	93	81	147	0.11	0.04
38B	895	69	92	160	0.10	0.03
42B	156	81	106	66	0.08	3.02
42D	124	72	104	60	0.08	3.18
42H	31	72	100	57	0.06	3.53

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* parts per million

-- not determined

Table V (continued)

Sample	Cu	Zn	Ni	Co	Mn	Na
42L	62*	55*	240*	50 *	0.12%	1.06%
43B	64	67	199	60	0.09	1.79
44D	35	78	126	62	0.12	2.32
45D	81	131	105	72	0.11	1.99
45E	56	--	--	22	0.07	0.08
46D	136	111	104	84	0.12	2.40
46E	28	29	79	48	0.08	0.07
48A	40	112	--	83	0.13	1.79
48B	54	70	136	66	0.10	2.53
48C	30	42	108	55	0.10	0.34
49C	43	127	141	92	0.14	1.81
49D	51	81	127	70	0.12	2.91

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* parts per million

-- not determined

Table VI Concentration of Elements in Samples from Little Bay 1350 Level, Main Ore Zone.

Sample	Cu	Zn	Ni	Co	Mn	Na
1	55*	59*	115*	67*	0.12%	2.80%
2	95	66	108	60	0.11	2.06
3AA	13	110	135	96	0.13	3.46
3AB	15	117	140	93	0.14	2.64
3Ba	8	--	92	50	--	0.11
3Bb	8	41	107	58	0.11	0.20
4	137	60	88	60	0.09	3.33
5a	116	71	130	65	0.11	2.24
5b	30	32	150	42	0.08	0.09
5c	100	65	123	66	0.11	2.69
6A	113	81	110	69	0.10	2.59
6B	119	108	153	97	0.13	2.92
6C	158	38	70	45	0.07	0.12
6D	40	60	110	57	0.09	0.80
7a	89	74	113	63	0.11	1.92
8A	105	81	113	59	0.10	1.01
8B	120	78	--	61	0.08	1.36
8C	35	80	108	65	0.09	1.46
9	117	71	103	60	0.10	1.44
10	42	76	89	65	0.08	0.41
11	142	73	71	61	0.09	2.36
12	64	69	94	66	0.10	0.77
13a	23	57	105	79	0.10	2.41
13c	27	26	72	38	0.07	0.09

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* parts per million

-- not determined

Table VI (continued)

Sample	Cu	Zn	Ni	Co	Mn	Na
14	150*	57*	90*	63*	0.06%	2.50%
15a	95	79	125	62	0.09	1.59
15c	73	71	124	63	0.08	2.19
16a	169	66	108	58	0.11	2.40
17	69	83	107	65	0.17	3.70
18	72	83	112	76	0.14	2.26
19	44	82	110	82	0.14	1.91
20a	82	82	110	72	0.14	1.56
20b	73	89	112	77	0.17	2.29
20c	82	76	114	74	0.14	2.67
20d	99	231	129	69	0.24	2.96
21	64	1100	75	56	0.25	2.39
22	96	154	114	56	0.27	2.54
23Bb	149	177	80	69	0.24	0.09
24	294	1120	--	66	0.29	0.31
26b	997	68	73	95	0.15	0.04
27	92	95	86	79	0.15	0.05
28	10	58	89	77	0.09	0.03
31	509	103	87	109	0.08	0.03
32a	180	45	106	121	0.09	0.03
32b	43	48	98	91	0.09	0.04
33	1910	190	83	136	0.09	0.04
35a	2655	63	62	144	0.09	0.04
35c	83	68	105	60	0.09	0.92
36	750	169	30	56	0.18	0.24

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* parts per million

-- not determined

APPENDIX II

DESCRIPTION OF SAMPLES ANALYZED

Table I Lady Pond Drill Hole

Sample	Footage *	Description
2	51	Andesitic lava; banded amygdaloidal sections; fine grained, grey green rock with quartz filled amygdules; several quartz and epidote veinlets less than $\frac{1}{4}$ inch wide.
3	99	Andesitic: fragmental; dark green, fine grained, foliated rock; banded; weakly chloritic; scattered quartz metacrysts.
4	150	Andesitic: dark green, fine grained rock with several purple-grey bands which may be tuffaceous.
5	199	Andesitic: fragmental; fine grained, greyish green, siliceous rock; chloritic in part; several carbonate veinlets.
8	274	Andesitic tuff: grey green, fine grained, schistose rock; laminated in part; several eye-like quartz metacrysts.
9	275	Andesitic tuff: same as sample 8, but poor core recovery.
10	300	Andesitic tuff: dark green, chloritic schist; eye-like quartz metacrysts; disseminated chalcopyrite and pyrite.
12	330	Andesitic tuff: dark green, banded rock with several quartz veinlets.
13	349	Andesitic tuff: chloritic, banded rock with several 1 mm pyrite veinlets.
14	360	Andesitic tuff: chloritic, banded rock with several pyrite veinlets.
15	370	Andesitic tuff: dark green, chloritic, and schistose rock with numerous eye-like quartz metacrysts.
16	377	Andesitic tuff: dark green, fine grained, banded rock; chloritic; scattered pyrite crystals.
17	390	Andesitic tuff: chloritic, dark green, schistose rock with disseminated pyrite grains.
18	399	Andesitic tuff: same as 17.
19	405	Andesitic tuff: same as 17.
20	410	Andesitic tuff: same as 17.

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* measured from collar of drill hole.

21	415	Andesitic tuff: chloritic, dark green, banded rock with disseminated pyrite.
22	420	Andesitic tuff: chloritic, dark green, banded rock with disseminated pyrite.
23	425	Andesitic tuff: dark green, chloritic, schistose rock with several quartz veinlets.
25	430	Andesitic tuff: in part fragmental; dark green, chloritic, banded rock with several quartz veinlets.
26	435	Andesitic tuff: dark green, chloritic, banded rock with disseminated pyrite.
27	440	Andesitic tuff: 0" to 6" away from mineralized section; dark green, chloritic, schistose rock.
30	455	Andesitic tuff: light green, chloritic rock with alternating light and dark bands; slightly siliceous.
31	463	Andesitic tuff: light green, chloritic, fine grained, foliated rock; siliceous in part.
32	475	Andesitic tuff: dark green, chloritic and schistose rock.
33	483	Andesitic tuff: light green, fine grained foliated rock; lightly chloritic.

Table II Little Deer Drill Hole 92

Sample	Footage*	Description
11	200	Andesitic lava: dark green schistose rock; partly altered feldspar phenocrysts in an aphanatic to very fine grained chloritic groundmass; scattered epidote, quartz and pyrite grains; hematite on fractures.
12	220	Andesitic lava: chloritic; fine to medium grained, foliated rock; approximately 50% epidote; several hematite coated fractures; scattered quartz veinlets.
17	343	Andesitic lava: brecciated, fine grained, foliated rock; chlorite, epidote, feldspar, amphibole and quartz.
19	402	Andesitic: fine grained, foliated rock; approximately 60% epidote, 10% chlorite, 10% quartz porphyroblasts, and 20% groundmass; many of the feldspars have been completely epidotized.
22	460	Andesitic lava: fine grained, foliated rock; epidotized in part; chlorite developed, mainly on foliation planes; occasional quartz and epidote segregations.
23	480	Andesitic lava: fine grained massive rock; light green with yellow epidote spots.
25	504	Andesitic: chloritic; fine grained foliated rock with approximately 10% white quartz veinlets.
26	514	Andesitic lava: very fine and fine grained schistose rock containing feldspar (30%), quartz (10%), carbonate veinlets and grains (20%), chlorite (20%), and scattered epidote and pyrite grains in a microscopic groundmass.
30	550	Andesitic: fine grained, schistose rock with fine grained feldspar phenocrysts in a very fine grained chloritic groundmass; approximately 15% carbonate, less than 5% epidote; tuffaceous?
34	590	Andesitic: chloritic, schistose rock with approximately 5% pyrite as quartz-pyrite veinlets and disseminated crystals.
35	600	Andesitic: chloritic, very fine grained schistose rock with about 4% pyrite in quartz-pyrite veinlets; tuffaceous?
36	646	Chlorite schist: friable; approximately 40% chlorite; scattered pyrite grains and chalcopyrite blebs.

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* from collar of drill hole.

39	660	Andesitic lava: very fine grained with fine grained feldspar phenocrysts; several quartz-pyrite veinlets.
43	703	Andesitic lava: very fine to fine grained chloritic rock with traces of epidote.
44	720	Andesitic lava: fine grained foliated rock containing feldspar phenocrysts (20%), epidote (10%), carbonate (5-10%), Chlorite (10-20%) and a very fine grained quartz and feldspar groundmass (40-50%).
46	742	Andesitic: fine grained foliated rock with traces of chlorite and epidote.
48	770	Andesitic: tuffaceous looking fine grained schistose rock with feldspar phenocrysts (20%), epidote (20%), chlorite (15%), carbonate (5%), quartz (10%), and groundmass (30%).
50	784	Chlorite schist: very fine grained, dark green to black schist; no sulfides visible in hand specimen.
51	795	Chlorite schist: friable; approximately 2% pyrite.
53	810	Chloritic schist: tuffaceous looking; very fine grained rock with quartz metacrysts (20%), carbonate (30%) and chlorite (50%).
70	1067	Chlorite schist: dark green schist with sphalerite, and quartz-pyrite veinlets.
71	1100	Chlorite schist: tuffaceous looking; very fine grained schist with a 1 mm pyrite veinlet and several 1 mm wide quartz-carbonate veinlets.
72	1120	Andesitic: chloritic, schistose rock with feldspar phenocrysts, quartz, epidote and calcite, in a very fine grained chloritic groundmass.
75	1176	Andesitic lava: fine grained, light green, foliated rock; several epidote veinlets; a pillow selvedge in part.

Table III Little Deer Drill Hole. 132 Samples.

Sample	Footage *	Description
1	1180	Dioritic dike: fine to medium grained greenish black; epidote, feldspar (partly epidotized), amphibole, minor amounts of quartz and chlorite.
2	1162	Andesitic: aphanitic to very fine grained greenish black; foliated but not schistose; several 1 mm epidote veinlets.
3	1160	Andesitic: fine grained, black, massive rock with several fractures.
4	1159	Chloritic schist: very fine grained, dark green, schistose rock with scattered 1 mm pyrite crystals; porphyroblastic quartz knots on schistosity planes; microscopic quartz grains intergrown with chlorite; several streaks of sphalerite in 0.1 mm veinlets.
17	1105	Andesitic (tuffaceous): very fine grained, banded rock; sericitic, chloritic and moderately schistose; several 0.5 mm pyrite veinlets and one veinlet of sphalerite 0.2 mm wide.
19	1099	Andesitic tuff: fine grained, foliated; scattered quartz metacrysts; chlorite and sericite on foliation planes; pyrite crystals 1 mm in diameter are common.
20	1096	Andesitic agglomerate: microscopic to fine grained quartz and chlorite in bands 1 mm wide alternate with fine grained feldspar and quartz bands approximately 1-2 mm wide; occasionally the bands consist of partly chloritized submicroscopic material.
21	1091	Andesitic tuff: fine to medium grained; light green, chloritic and foliated.
22	1085	Andesitic agglomerate: aphanatic with fine grained, 0.5 mm diameter, feldspar phenocrysts; scattered epidote crystals make up 30% of the specimen; scattered pyrite crystals; traces of quartz metacrysts.
23	1075	Andesitic agglomerate: tuffaceous in part; fine grained chloritic, schistose rock; mottled appearance due to eye-like quartz and epidote metacrysts and chlorite clusters.
24	1065	Andesitic agglomerate: aphanitic to very fine grained, chloritic schistose rock.

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* from collar of drill hole.

Sample	Footage	Description
25	1054	Andesitic agglomerate: light green, foliated rock; devitrified groundmass with feldspar and pyroxene phenocrysts; scattered epidote grains.
27	1030	Andesitic pillow lava: light green, foliated rock, porphyroblastic quartz; quartz and epidote filled amygdules (?).
29	1008	Andesitic agglomerate: fine grained, faintly foliated rock; quartz and carbonate veinlets less than $\frac{1}{4}$ inch in width; chlorite found only on foliation planes.
30	974	Andesitic lava: pillowed in part; fine grained, granular, epidotized rock; several hematite coated fractures.
31	951	Andesitic lava: pillowed; fine grained, epidotized, granular rock; several threads of epidote and quartz.
32	895	Andesitic lava: pillowed in part; light green, fine grained, massive rock with several quartz and carbonate veinlets.
33	851	Andesitic lava: pillowed; light green, fine grained massive rock; epidotized and cut by 1 mm epidote veinlets; traces of chlorite on fractures; quartz carbonate veinlets less than $\frac{1}{4}$ inch wide; may be a pillow selvedge in part.
34	800	Andesitic lava: fine grained, epidotized, granular rock with several 1 mm quartz veinlets.
35	701	Andesitic lava: pillowed in part; very fine grained, epidotized rock with fine grained feldspar and pyroxene phenocrysts; groundmass consists mainly of microscopic feldspar, epidote and chlorite.
36	605	Andesitic lava: pillowed; very fine grained quartz-feldspar-epidote groundmass containing feldspar phenocrysts; chlorite patches on foliation planes.
39	400	Andesitic lava: pillowed; fine grained feldspar phenocrysts in a very fine grained chloritic and epidotized groundmass; approximately 20% carbonate.
42	200	Andesitic lava: pale green, very fine grained epidotized rock; scattered quartz metacrysts; several quartz veinlets 1 mm wide; chlorite flecks found on foliation planes.

Table IV Little Deer Drill Hole 135 Samples.

Sample	Footage *	Description
2	52	Andesitic lava: fine grained, light green vesicular rock with epidote metacrysts.
4	145	Epidote: massive, fine grained epidote with scattered 1 mm quartz veinlets; approximately 85% epidote, 5% quartz, and 10% ascicular amphibole; several 0.5 mm chalcopyrite grains visible in hand specimen; specimen taken adjacent to an aphanatic black basic dike.
8	200	Andesitic lava: fine grained, light green, and foliated; mottled appearance due to epidote metacrysts; traces of chlorite on foliation planes.
14	362	Andesitic: chloritic and moderately schistose; scattered quartz and epidote metacrysts.
15	396	Andesitic lava: fine grained, light green, foliated rock with euthedral feldspar phenocrysts, scattered quartz and epidote grains in a very fine grained, chloritic groundmass of feldspar and quartz; epidote and calcite veinlets are parallel to foliation.
18	500	Andesitic lava: pillowed and vesicular; specimen taken from pillow selvedge; extremely fine grained cloudy groundmass of devitrified glass and feldspar microlites enclosing 0.5 mm feldspar phenocrysts and scattered fine grained epidote grains.
19	551	Andesitic lava: pillowed and vesicular; fine grained, chloritic and foliated; mottled appearance due to scattered epidote metacrysts up to 1 mm in diameter; several tiny chalcopyrite and pyrite grains.
21	650	Andesitic lava: pillowed and vesicular; fine grained, light green and massive; feldspar and pyroxene phenocrysts; epidotized and chloritized feldspar and quartz groundmass.
22	703	Andesitic lava: pillowed; fine grained, light green and foliated; mottled appearance due to light, creamy yellow, epidote metacrysts.
23	749	Andesitic lava: pillowed, fine grained, light green and foliated; weakly chloritized and epidotized.
24	820	Andesitic lava: probably agglomeratic; fine grained feldspar phenocrysts in a groundmass of feldspar, amphibole epidote and chlorite.

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* from collar of drill hole

25	882	Andesitic: tuffaceous; very fine grained, banded and schistose; fine grained feldspar phenocrysts and epidote metacrysts in a feldspar rich groundmass with approximately 20% chlorite, 20% calcite and about 10% extremely fine grained dusty epidote.
26	910	Andesitic: tuffaceous; fine grained, chloritic and foliated; scattered epidote metacrysts and pyrite grains.
30	941	Andesitic lava: blocky with quartz filled fractures; fine grained, dark green and massive; hematite films on open fractures.
33	983	Andesitic lava: pillowed selvedge; aphanatic to fine grained, dark green, and weakly epidotized; several narrow quartz veinlets.
41	1051	Andesitic tuff: dark green, fine grained, dark green and schistose; approximately 75% very fine grained chloritic quartz and feldspar groundmass.
41	1051	Andesitic tuff: dark green chlorite schist with approximately 75% chlorite, 15% quartz, 10% feldspar and traces of sericite and pyrite.
48	1081	Tuff/argillaceous sediment: very fine grained dark brown argillaceous rock with several carbonate veinlets less than $\frac{1}{4}$ inch in width.
49	1083	Felsitic Dike: aphanitic; numerous carbonate and quartz veinlets.
50	1084	Chloritized fragmental: very fine grained and schistose with numerous sphalerite threads.
51	1087	Chloritized tuffaceous schist: fine grained with scattered sphalerite threads.
52	1092	Andesitic tuff: chloritic and schistose; traces of sericite; scattered pyrite grains.
53	1101	Andesitic (?): fine grained, siliceous and sericitic.
54	1115	Andesitic: fine grained, siliceous and foliated; traces of sericite; pyrite vein 1 inch wide contains considerable sphalerite.
55	1142	Andesitic: tuffaceous, schistose and siliceous; approximately 10% pyrite and several sphalerite threads.
56	1160	Andesitic: tuffaceous and schistose; fine grained groundmass of quartz, feldspar and chlorite with feldspar phenocrysts and quartz porphyroblasts.

Table V Little Bay 700 Level Samples. Sample locations are shown on Figures 4-10, 4-11, 4-12, 4-13, 4-14, and 4-15.

Sample	Description
5	Basaltic lava: dark green, chloritic and schistose.
16	Chlorite Schist: disseminated pyrite; taken from 12 inch chlorite schist band located between a diorite dike and a 12 inch wide massive pyrite and chalcopyrite vein.
19	Chlorite Schist: dark green; scattered white quartz veinlets and disseminated pyrite crystals; chip sample taken 0-12 inches away from massive sulfide vein.
20	Chlorite Schist: chip sample 12 to 24 inches away from massive sulfide vein.
21	Chlorite Schist: very dark green to black; disseminated pyrite; located between two dioritic dikes.
25	Chlorite Schist: black, friable; scattered white quartz veinlets; dissmeinated pyrite and chalcopyrite.
26	Chlorite Schist: black; friable; scattered white quartz veinlets and disseminated pyrite.
27	Chlorite Schist: dark green, friable, scattered white quartz, calcite and epidote veinlets; approximately 40% porphyroblastic white quartz in eye-like metacrysts; disseminated pyrite and chalcopyrite.
29	Chlorite Schist: dark green; friable; disseminated pyrite and chalcopyrite.
30	Chlorite Schist: dark green; friable; disseminated pyrite and chalcopyrite.
31	Chlorite Schist: dark green; friable; disseminated pyrite and chalcopyrite.
33	Chlorite Schist: dark green; silicified in part producing a slaty appearance; disseminated pyrite and chalcopyrite.
36A	Chlorite Schist: dark green to black; friable; disseminated pyrite and chalcopyrite.
36D	Chlorite Schist: dark green to black; friable; disseminated pyrite and chalcopyrite.
36J	Chlorite Schist: green; slaty appearance; scattered white quartz veinlets; ramifying chalcopyrite veinlets; disseminated pyrite.
37B	Chlorite Schist: dark green; friable; ramifying veinlets of quartz and chalcopyrite; approximately 1% disseminated pyrite.

37D	Chlorite Schist: dark green; friable; ramifying chalcopyrite veinlets; disseminated pyrite.
38A	Chlorite Schist: dark green to black; friable; ramifying chalcopyrite veinlets; scattered veinlets and disseminate pyrite.
38B	Chlorite Schist: dark green; friable; widely scattered chalcopyrite veinlets; disseminated pyrite grains.
42B	Basaltic lava: light green; fine grained; chloritic and schistose in part; eye-like quartz metacrysts; disseminated pyrite and epidote.
42D	Basaltic lava: chloritic and schistose; very fine grained with fine grained feldspar phenocrysts; approximately 30% porphyroblastic quartz, 10% carbonate, 40% chlorite, and 20% epidotized groundmass consisting predominantly of feldspar and epidote.
42H	Basaltic lava: chloritic and schistose; scattered feldspar phenocrysts; approximately 30% chlorite; quartz and epidote metacrysts are visible in hand specimen and make up about 40% of the rock; scattered tiny calcite veinlets; hematite films are present on many of the fractures.
42L	Chloritic Schist: slaty appearance; epidote veinlets and metacrysts are common; quartz porphyroblasts are present along schistosity planes and are generally wrapped in chlorite.
43B	Chloritic Schist: slaty appearance; weakly epidotized; several quartz-carbonate veinlets; occasional scattered quartz-epidote metacrysts.
44D	Basaltic lava: fine grained, dark green and schistose; feldspar occurs as phenocrysts and as microscopic grains in the groundmass; quartz porphyroblasts occur along schistosity planes; banded chlorite constitutes 40% of the rock; epidote occurs as cloudy microscopic crystals in the groundmass, as 1 mm epidote and quartz veinlets and as epidote and quartz metacrysts; carbonate veinlets and crystals make up approximately 10% of the rock.
45D	Basaltic pillow rims: very fine grained to fine grained, chloritic and schistose.
45E	Epidote pillow centers: fine grained, creamy yellow, and massive; approximately 70% epidote, 20% quartz and 10% chlorite and amphibole.
46D	Basaltic pillow rims: very fine to fine grained, dark green, chloritic and schistose.
46E	Epidote pillow centers: fine grained, greenish yellow and massive; consists predominantly of epidote and less than 20% quartz, amphibole and calcite.

48A	Basaltic pillow rims: fine grained, dark green, schistose rock containing feldspar, quartz, chlorite, ascicular amphibole and traces of epidote.
48B	Basaltic pillow lava: intermediate between chloritic rim and epidote center; fine grained, light greenish grey, and massive.
48C	Epidote pillow centers: fine grained, creamy yellow and massive; consists mainly of epidote, minor amounts of quartz and a fibrous amphibole are usually present; there are no feldspars or pseudomorphs recognizable in thin sections.
49C	Basaltic pillow rims: fine grained, dark green, chloritic and schistose.
49D	Basaltic pillow lava: intermediate part of pillow found between chloritic rims and epidote centers; greenish grey and massive; fine grained and granular; consists of feldspar (30%) fibrous amphibole (15-20%), quartz (10%), chlorite and calcite (10%), less than 5% epidote, and approximately 30% submicroscopic groundmass.

Table VI Little Bay 1350 Level Samples. Sample locations are shown on Figures 3-3, 4-16, 4-17 and 4-18.

Sample	Description.
1	Basaltic lava: very fine grained, light green, chloritic and schistose; consists of fine grained feldspar phenocrysts in a very fine grained groundmass of quartz, epidote, ascicular amphibole, feldspar, chlorite and calcite.
2	Basaltic lava: very fine grained, dark green, foliated; scattered quartz porphyroblasts.
3AA	Chloritic rims of pillow lava: very fine grained, dark green, and schistose; scattered quartz and epidote porphyroblasts; traces of calcite and tremolite.
3AB	Chloritic rims of pillow lavas: hand picked pieces less than one half inch in diameter.
3Ba	Epidote center of pillow: very fine grained, greenish yellow and massive; consists predominantly of epidote; less than 10 per cent quartz, ascicular amphibole and calcite.
3Bb	Epidote center and partly epidotized section from the central portion of a pillow.
4	Basaltic lava: very fine grained, dark greenish, and schistose; approximately 50% epidote.
5a	Basaltic lava: very fine grained, dark green, and schistose; contains quartz, epidote, chlorite, amphibole, and calcite.
5b	Epidote center of pillow.
5c	Basaltic lava: same as 5a; dust from mining operations not thoroughly removed.
6A	Basaltic lava: very fine grained, dark green and schistose; contains several 0.5 mm wide quartz and epidote veinlets.
6B	Chloritic rims of pillows.
6C	Epidote center of pillow: contains several 1 mm quartz veinlets.
6D	Basaltic lava: Intermediate section of pillow located between chloritic rim and epidote center.
7a	Basaltic lava: fine grained, dark green, massive; approximately 20% epidote.

8A	Basaltic lava: fine grained, dark green, and massive; scattered epidote clusters up to 1 mm in diameter; several 1 mm tiny quartz veinlets; hematite coatings on fractures.
8B	Basaltic lava: sample taken over same area as 8A.
8C	Basaltic lava: grab sample from same area as 8A.
9	Basaltic lava: very fine grained, chloritic and schistose.
10	Basaltic lava: very fine grained, dark green, schistose; contains feldspar, ascicular amphibole, quartz, chlorite and up to 30% carbonate.
11	Basaltic lava: fine grained, dark green, and foliated.
12	Basaltic lava: fine grained, dark green, foliated; lightly epidotized.
13a	Basaltic lava: fine grained, greyish green, moderately schistose; scattered quartz and epidote eye-like metacrysts; several quartz, epidote and carbonate veinlets.
13c	Basaltic lava: fine grained, light green, and foliated; quartz and epidote filled vesicules.
14	Basaltic lava: fine grained, dark green, and foliated; approximately 30% epidote; feldspar phenocrysts are found in the unepidotized parts of the section; the groundmass consists of very fine grained feldspar, quartz, ascicular amphibole and chlorite.
15a	Volcanic: dark green, fine grained, chloritic and schistose.
15c	Basaltic lava: duplicate sample of 15a.
16a	Basaltic lava: fine grained, dark green, and schistose; feldspar phenocrysts and quartz metacrysts in a groundmass containing feldspar, quartz, ascicular amphibole, calcite and chlorite.
17	Basaltic lava: dark green, schistose; scattered quartz grains and veinlets; disseminated pyrite grains; sample taken 0" to 12" away from contact of dioritic dike.
18	Dioritic dike: fine grained, granular and foliated; lightly epidotized; consists essentially of feldspar, amphibole, and traces of quartz, and chlorite. Sample taken 0" to 12" from contact.
19	Dioritic dike: center of dike, approximately 5' from contact.

20a	Dioritic dike: 1' from contact.
20b	Dioritic dike: 0" to 6" from contact.
20c	Dioritic dike: chilled margin.
20d	Basaltic lava: 0" to 12" from dike contact.
21	Basaltic lava: schistose and chloritic; slaty appearance; approximately 5% pyrite; scattered eye-like quartz metacrysts.
22	Chloritic schist: slaty appearance; chlorite aggregations on schistosity planes give the rock a mottled appearance; approximately 2% disseminated pyrite.
23Bb	Chloritic schist: dark green and friable; disseminated pyrite and several tiny pyrite veinlets.
24	Chloritic schist: greenish black and friable; approximately 2% disseminated pyrite.
26b	Chloritic schist: slate-like appearance; no visible chalcopyrite or pyrite.
27	Chloritic schist: silicic; slate-like appearance; no sulfides visible in hand specimen.
28	Chloritic schist: dark green, slate-like appearance; scattered pyrite grains; sample taken 2" to 6" away from a 2" massive chalcopyrite vein.
31	Chlorite schist: dark green, brittle.
35a	Chloritic schist: dark green, friable.
35c	Chloritic schist: light green, brittle. Same location as 35a.
36	Chloritic schist: post mineralization shear 6" wide; dark green, friable; no visible sulfides.

APPENDIX III

PREPARATION OF ROCK SAMPLES FOR ANALYSIS BY ATOMIC ABSORPTION SPECTROPHOTOMETRY

PREPARATION OF ROCK SAMPLES FOR ANALYSIS BY ATOMIC ABSORPTION SPECTROPHOTOMETRY.

The methods described here have been adopted with modifications from the techniques published by Laverque (1965) and Hounslow and Moore (1966) for the preparation of rock samples for chemical and instrumental methods of analysis.

The techniques used in the preparation of rock samples for Atomic Absorption Spectrophotometry are similar to those utilized in the preparation of rock samples for analysis by chemical and spectrographic techniques.

The techniques employed in the preparation of mineral separates are described to provide future workers in this department with a reference to the techniques used and equipment employed.

Preparation of Whole Rock Powders

Samples selected for analysis were cleaned of any adhering foreign matter that may have been a possible source of contamination. Specimens collected from underground drifts were brushed clean with a stainless steel brush and washed in distilled water. Samples of diamond drill core were washed in hot soapy water followed by rinsing in distilled water. This effectively removed dust and any drilling grease present. Core samples were discarded if they contained a thin film of metal derived from the walls of the core barrel.

The crusher, pulverizer, ball mill and all equipment to be used in the preparation of the samples were thoroughly cleaned of any adhering rock fragments or dust prior to starting a group of samples. The crusher, pulverizer and ball mills were cleaned of residue from previous samples by first passing high purity quartz through them as a sample and then thoroughly cleaning them with paper towels, a stiff brush and a vacuum cleaner.

The samples were arranged in numerical order in batches of ten to reduce the possibility of errors in labelling since several samples were usually processed at the same time. Sulfide-bearing samples and rock samples were processed separately.

The samples, if larger than 2 inches in diameter, were first broken on a hydraulic rock splitter to less than two inches in diameter. Lenticular shaped samples were broken on a stainless steel plate with a steel geological hammer. It was found that the steel hammer and plate method resulted in considerable loss and some contamination when the samples were hard and equidimensional.

The samples were crushed in a Bico jaw crusher with the steel plates set approximately one inch apart. The jaws of the crusher were then closed as tightly as possible and the sample was passed through the crusher again, resulting in rock fragments less than one half inch in diameter.

A hand magnet was passed over the sample as it was gently shaken to remove any bits of steel from the grinding jaws which not only produced contamination of the sample but also caused damage to the ceramic disks of the pulverizer.

The crushed sample was ground in a Bico pulverizer fitted with ceramic grinding plates reinforced with an annular steel ring. The crushed sample was first ground with the grinding plates set approximately 1 mm apart. The ground sample was then split repeatedly in an aluminium sample splitter to give a sample of approximately 200 grams weight. The remainder of the sample was stored for reference or used for mineral separations. The 200 gram portion of the sample was again passed through the pulverizer with the disks set at their closest setting. The resulting powder was split several times in the sample splitter to give approximately 50 grams of powder. The remainder of the powder was stored with the coarser fraction in the event the 50 gram sample should be lost or contaminated during further processing.

The 50 gram portion of the sample was reduced to minus 97 mesh size by sieving through plexiglass sieves fitted with 97 mesh nylon bolting cloth. The plus 97 fraction was reduced in ceramic grinding mills fitted onto a paint shaker. The two fractions were mixed by resieving together and by coneing at least five times. The final minus 97 mesh powder was stored in snapcap plastic vials.

All equipment and working spaces used were thoroughly cleaned after each sample. The jaw crusher was cleaned with a wire brush and a vacuum cleaner. The pulverizer was cleaned by pulverizing a handful of high purity quartz followed by a thorough cleaning with a vacuum cleaner and paper towels. The sample splitter and the sieves were cleaned by means of a stiff brush and an air blast outside the working area. The ceramic ball mills were run for five minutes with a charge of high purity quartz and then cleaned with the air blast. When the ceramic ball mills and grinding balls became discoloured they were boiled in strong hydrochloric acid for several hours. After every batch of ten samples several pounds of high purity quartz were passed through the crusher and pulverized to remove any rock fragments or particles stuck into the grinding faces.

When sulfide-rich samples were being processed a separate set of sieves and ceramic ball mills were employed. After the processing of any samples with a high sulfide content all of the equipment used was cleaned by passing a considerable amount of quartz through it before attempting to process any sulfide free rock samples.

Preparation of Mineral Separates

Samples from which mineral separates were to be made were prepared in a similar manner as samples from which whole rock powders were prepared. However, after the first grinding in the pulverizer it was generally necessary to take five hundred grams or more of the coarsely ground material for further grinding in order to prepare mineral separates. The five hundred grams of sample were passed through the pulverizer with the ceramic plates set at their finest setting. The finely ground sample was sieved on a mechanical shaker in plexiglass sieves fitted with 97 and 200 meshes per inch nylon bolting cloth. The minus 97 plus 200 mesh fraction was retained for further processing. The outsize fractions were stored. It was sometimes possible to hand pick coarse fragments of the mineral to be separated and reduce them in the ball mills before sieving.

The minus 97 plus 200 size fraction was then washed in distilled water several times by stirring with a stirring rod and decanting the fine dust particles to avoid blocking the Franz Isodynamic Separator and to prevent contamination of the heavy liquid media. The washed sample was dried at approximately 120° Celsius in a drying oven.

The magnetic minerals such as magnetite and pyrrhotite which tended to clogg the magnetic separator were removed by means of a strong hand magnet. The Franz Isodynamic Separator was set at a 15° side tilt and a 25° forward tilt, the vibrator was usually set at 4 and the current was set either to allow for unimpeded flow of the mineral grains or to allow the magnetically susceptible minerals being concentrated to be barely taken down the magnetic chute. Then the amperage was set to separate the majority of the mineral sought on the magnetic side of the instrument. The sample was run through the instrument several times at a current slightly above that at which the mineral first came off and then slightly below that at which all of the mineral sought was attracted to the magnetic side of the instrument. No absolute settings are given here since the settings varied slightly with each individual sample. The values given by Rosenblum (1958) serve as an excellent guide for getting within the range of magnetic susceptibilities quickly.

For non-magnetic minerals the current was gradually increased by steps to prevent clogging of the instrument until a maximum current was obtained and the non-magnetic minerals were left as a residue in the non-magnetic channel.

The magnetic fractions obtained were treated separately in heavy liquids to effect further concentration of the desired minerals.

The chlorite bearing magnetic fraction was first treated with Bromoform, Specific Gravity 2.85, to remove the lighter than chlorite minerals and secondly with Methyl Iodide, Specific Gravity 3.3, to remove the sulfide and other heavy minerals. The float from the Methyl Iodide treatment then contained the chlorite fraction.

The non-magnetic chalcopyrite and pyrite fractions obtained from the magnetic separator were treated with Methyl Iodide to remove any non-magnetic silicate minerals present.

The heavy liquid used in the separation process was filtered through Whatman No. 1 filter paper and the filtrate collected for reuse. The mineral grains of both sink and float and the filter papers on which they were collected were treated with technical grade acetone to recover adhering heavy liquid. The Bromoform was recovered from the acetone-Bromoform washings by stirring with water, allowing the acetone to dissolve in the water and then collecting the purified Bromoform from the bottom of the container. The acetone-Methyl Iodide washings were filtered into amber storage bottles until a gallon or more had been obtained and then the Methyl Iodide was recovered by evaporating off the acetone.

The mineral fractions obtained from the heavy media treatment were passed through the Franz separator until the optimum separation had been achieved.

All separation processes were monitored by means of a binocular microscope. The final process of the chlorite separation was monitored by means of a polarizing microscope.

Since the preparation of mineral separates was not carried to completion, the writer did not attempt to complete the separation process by hand picking impurities remaining in the mineral fractions obtained.

APPENDIX IV

ANALYTICAL PROCEDURE USED IN ATOMIC ABSORPTION SPECTROPHOTOMETRY

ANALYTICAL PROCEDURE USED IN ATOMIC ABSORPTION SPECTROPHOTOMETRY

The theory of atomic absorption spectrophotometry is well presented in Elwell and Gidley (1962) and Angino and Billings (1967). Most of the published literature on atomic absorption spectrophotometry related to geology has been orientated toward the preparation of rock, mineral and soil samples for analysis and the detection limits of the elements determined by a particular technique.

A number of papers have been written expounding the attributes of atomic absorption methods applied to geological problems. One of the first workers to apply the technique of atomic absorption to geology was Belt (1964) who determined Zn and Cu in rock samples. Since Belt's pioneer work, the equipment available has achieved a remarkable degree of sophistication and it is now possible to determine more than 45 elements by atomic absorption techniques with accuracies comparable to, or better than those produced by other methods. Angino and Billings (1967) have presented a detailed and comprehensive survey of the literature pertaining to the application of atomic absorption techniques to geological problems. They have described briefly the methods of sample preparation for many geological samples and where their descriptions are too sparse for direct application the analytical geochemist can obtain references to the original papers from their extensive bibliography.

The method used by the writer, outlined in detail below, is a modification of the methods described by Belt (1966) and Abbey (1967).

Chemical Treatment of the Sample

The rock powder in a 50 gram storage vial was thoroughly mixed by repeatedly coneing and rolling. The powder was then spread into a three to four inch diameter circle and tiny systematic grab samples were taken and placed in an aluminium weighing pan to give approximately one gram of rock powder. The aluminium weighing pans were transferred in batches of 20, to a clean drying oven set at 120° Celsius and allowed to dry for a period of 2 to 3 hours. The dried samples were stored in a sealed dessicator until cool, weighed on an analytical balance to the nearest 0.0002 gram and then transferred to 100 ml Teflon beakers. Care was taken to avoid loss of the fine fraction into the atmosphere during the transfer from the aluminium weighing pans to the Teflon beakers.

After each sample had been moistened with approximately 5 mls of water, 10 mls of concentrated nitric acid were added slowly by measuring cylinder. The beakers were covered to avoid loss of material during any vigorous reactions that often occured and to avoid contamination from atmospheric dust. After the initial reaction had subsided, 20 mls of 50 per cent hydrofluoric acid was added slowly from a Teflon measuring cylinder.

The beakers were covered and left to stand at room temperature for several hours in a fume cabinet. Two mls of 70 per cent perchloric acid were added to the mixture and the beakers were placed on a sand bath maintained as closely as possible to 180° Celsius. After 6 to 8 hours dense white perchlorate fumes began to be evolved. The mixture was allowed to fume vigorously for 15-20 minutes and then the walls of the beaker were rinsed down with distilled water to remove any hydrofluoric acid adhering to the sides of the beaker. The beakers remained on the hot plate until perchlorate fumes ceased to be expelled. If the samples were unattended for a period of time and the perchloric acid was completely expelled before the beaker walls were rinsed down, a further 0.5 ml of perchloric acid was added to the dry salts, the walls were washed down with distilled water and the beaker again heated on the sand bath until perchlorate fumes ceased to be evolved.

Five mls of concentrated hydrochloric acid were added to the dry sample cake and the beaker was heated at approximately 100° Celsius to dissolve the salts. Ten mls of water were added slowly a few minutes after the acid had been added and the solution boiled until clear.

The solution was filtered into 100 ml volumetric flasks and allowed to cool to room temperature. The solution was brought to volume, shaken well and transferred to 125 ml polyethylene screw cap bottles for storage until the analyses could be performed on the atomic absorption spectrophotometer.

Calibration

The instrumental settings given in Chapter II were set for the element being determined and the hollow cathode lamp was allowed to warm up for 20 minutes.

Working standards were made up from 10, 100 and 1000 parts per million stock solutions prepared from high purity standard solutions obtained from Fisher Scientific Limited by first mixing an appropriate amount of the Cu, Zn, Ni, Co and Mn solutions together to give stock solutions containing all of these elements in the same concentration. The stock solutions were prepared by evaporating aliquots of the Fisher Solutions to dryness and treating in the same manner as the rock samples. A 1000 ppm stock solution of Na was prepared by diluting a 10,000 ppm standard solution obtained from Fisher Scientific Limited.

Working standards were then prepared by taking suitable aliquots of one of the stock solutions, adding 5 mls of concentrated hydrochloric acid and diluting to 100 mls. For example, the Zn, Cu, Ni and Co working standards were prepared by pipetting 0, 5, 10 and 15 mls of the 10 ppm stock solution and 2, 3, 4 and 5 mls of the 100 ppm stock solution into 100 ml volumetric flasks. Five mls of concentrated hydrochloric acid were added to each flask and the mixture was brought to volume with distilled water to give working standards of 0.0, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0 and 5.0 ppm of Cu, Zn, Ni, Co and Mn with the same acid content as each sample solution.

The standards were aspirated in order of increasing concentration for approximately 30 seconds each. Distilled water was aspirated before and after each standard solution to ensure that the instrument was reset to a common base line. A calibration graph was plotted from the absorption readings obtained on the chart recorder by plotting the per cent transmission, 100 per cent minus the per cent absorption, on single cycle logarithmetic-linear graph paper (Figures 1 and 2). If the calibration graph was a straight line over most of its length, the standards were accepted as being correctly prepared, otherwise, the instrumental parameters were reset and if no improvement could be obtained another set of standards was prepared.

When a satisfactory calibration curve had been established the sample solutions were run in batches of ten by aspirating in the order: standards, samples, standards, samples and standards. Thus for each batch of ten samples the standards were determined three times and the unknown sample solutions were each aspirated twice. Distilled water was aspirated before and after each standard and sample solution.

If the sample solution gave a lower transmission value than the highest standard solution used, the sample solution was diluted until it gave a transmission value within the range of the standard solutions in use.

Calculation

The concentration of the sample solutions was determined by comparing the transmission value of the sample solution to the calibration curve

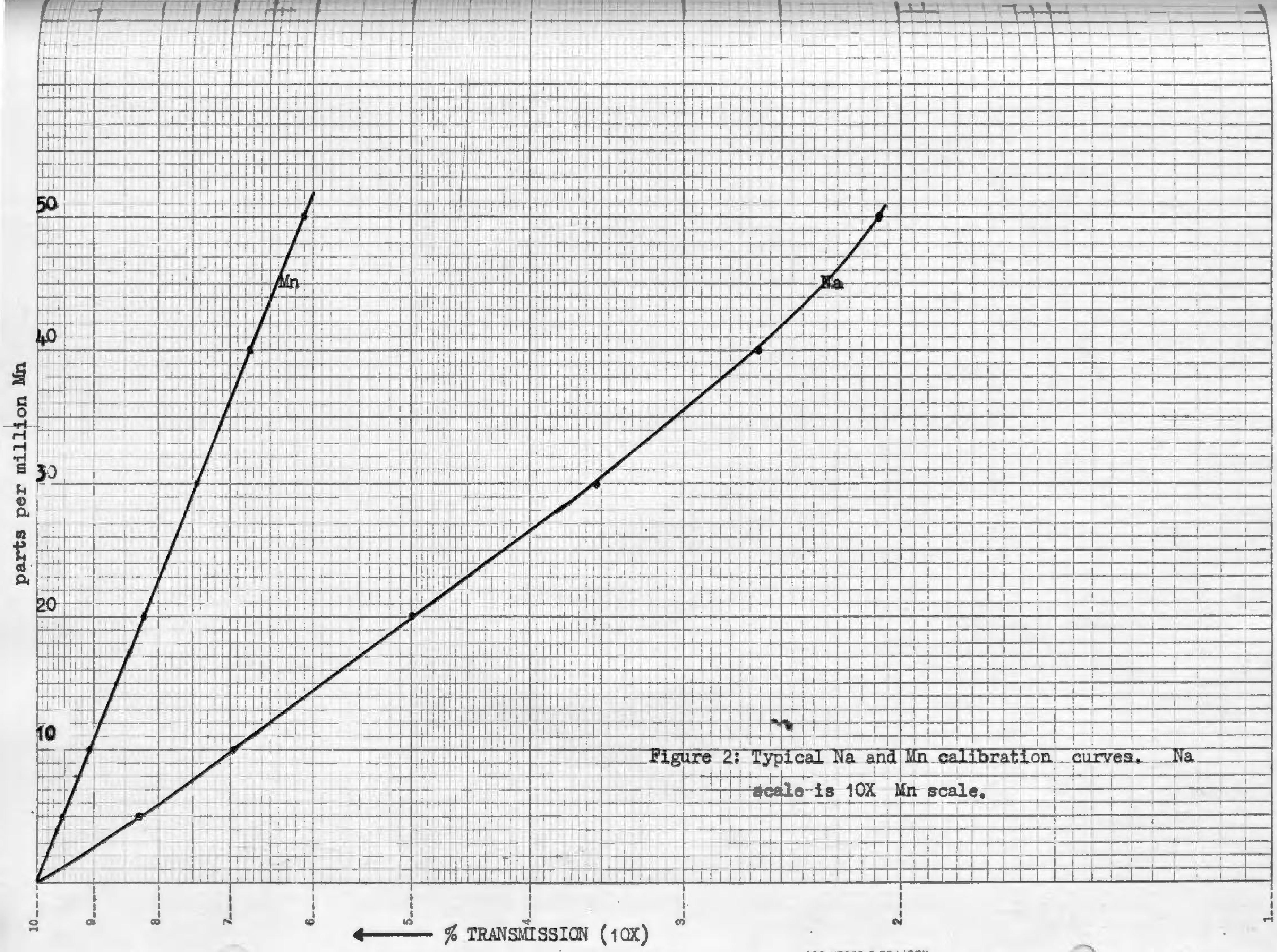

Figure 2: Typical Na and Mn calibration curves. Na scale is 10X Mn scale.

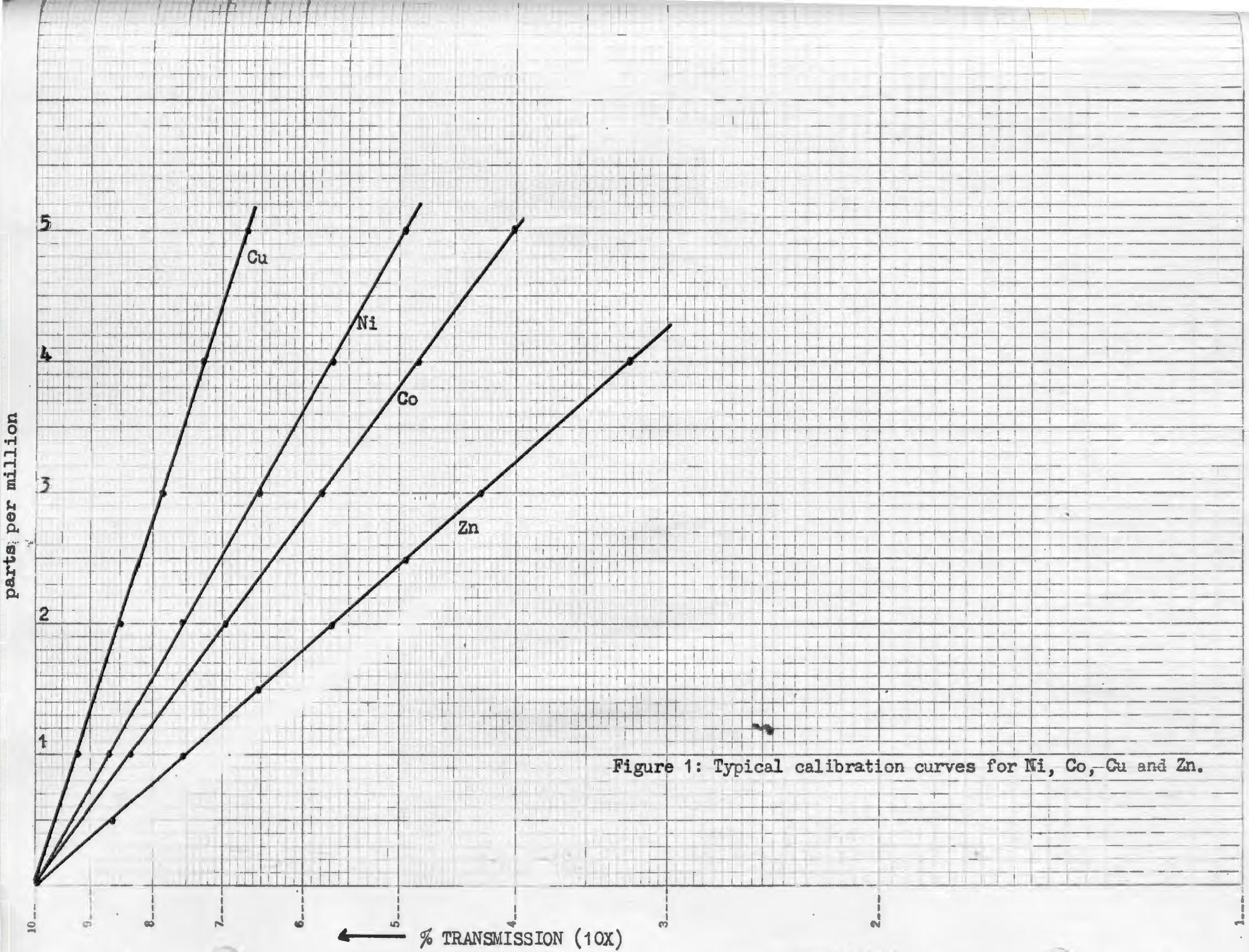

Figure 1: Typical calibration curves for Ni, Co, Cu and Zn.

derived from the standard solutions and reading off the concentration in parts per million on the linear scale of the graph sheet. The value obtained for the blank sample solution was subtracted from the concentration obtained for each sample solution, excepting those requiring further dilution, to give the true concentration of the element in the solution. The concentration of the element in the original rock sample was obtained by conversion in the formula:

$$\frac{\text{Volume of Sample Sol.}}{\text{Weight of sample}} \times \text{ppm in Sample Sol.} = \text{PPM in Rock.}$$

In the latter part of the project the computation of the concentration of the elements in the sample solutions and in the rock samples was performed on an IBM 1620 computer utilizing a Fortran II version of a Fortran IV computer program obtained from R. H. Wendt (1968). The computer prepared a calibration curve and calculated the parts per million of the element in the sample solution and the parts per million or percentage of the element in the rock sample.

Manganese and sodium were determined on the same solutions as those used for the trace elements. However, the standard solutions used ranged from 0 to 50 parts per million for manganese and 0 to 600 parts per million for sodium. The absorption values for sodium were read directly from the instrument galvanometer since the Techtron instrument used for the sodium determinations did not have a chart recorder.