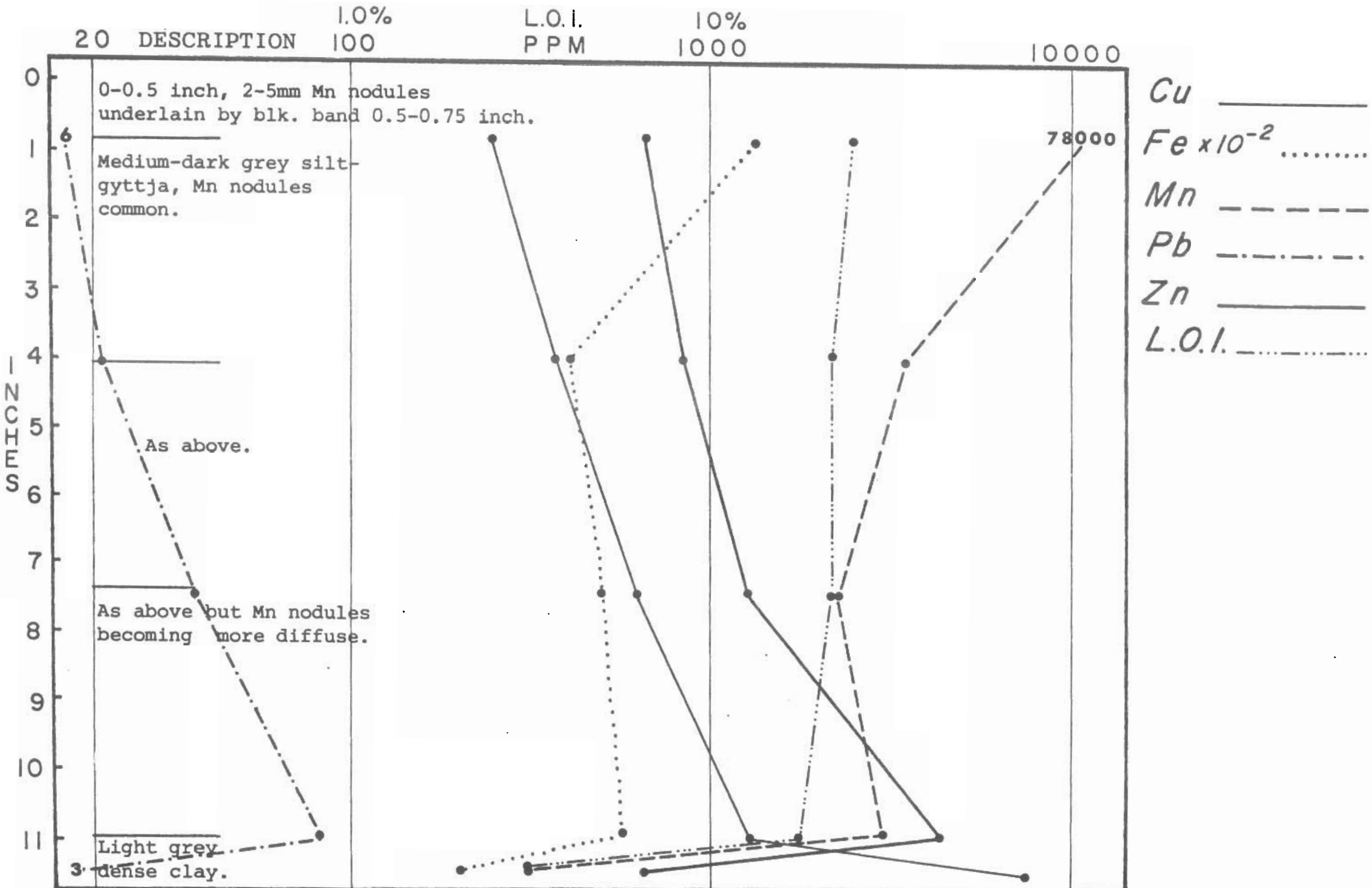

Figure 123. Banana Lake: core 1645, stratigraphy, metal content and L.O.I. with depth.

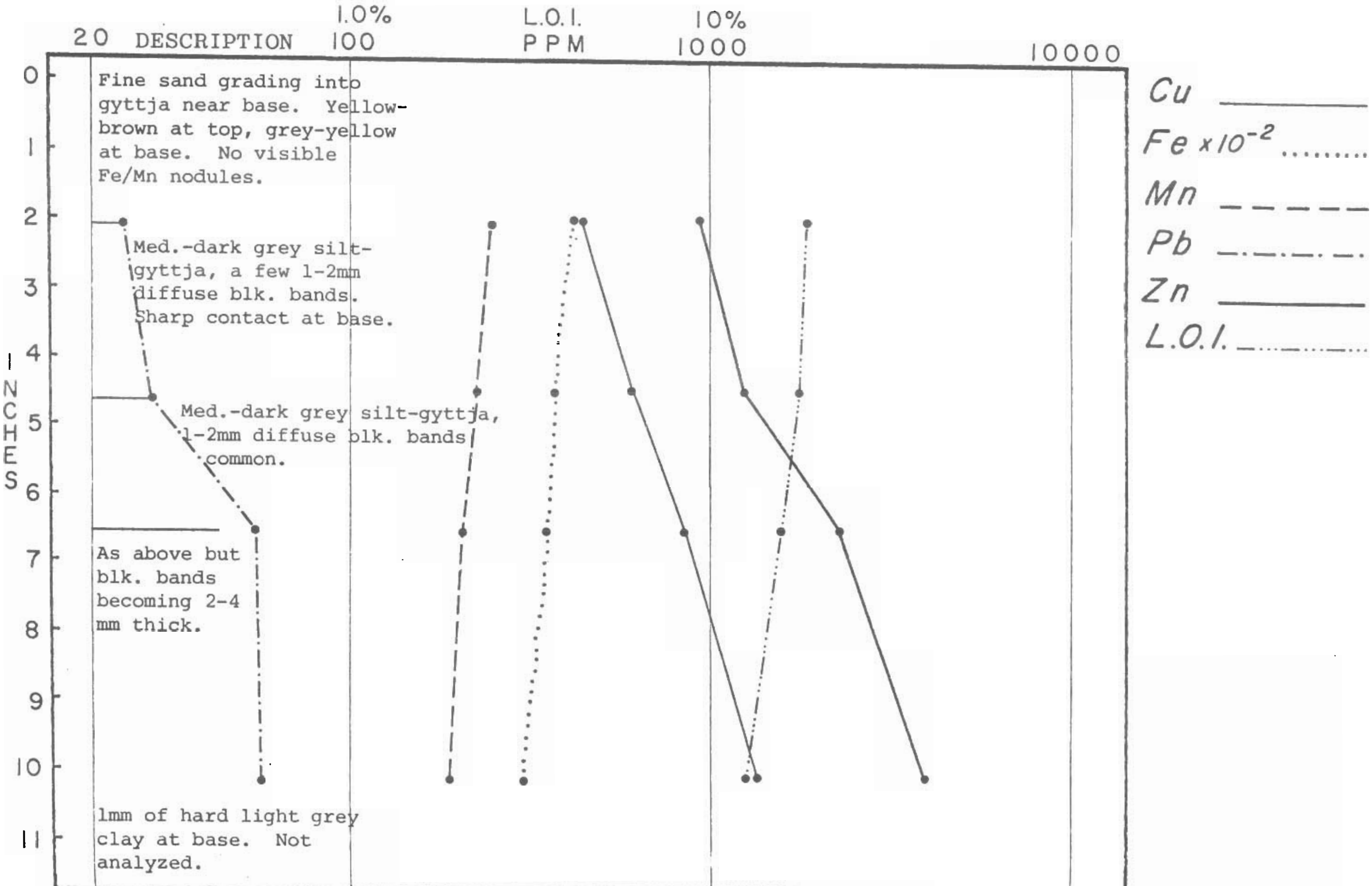

Figure 124. Banana Lake: core 1646, stratigraphy, metal content and L.O.I. with depth.

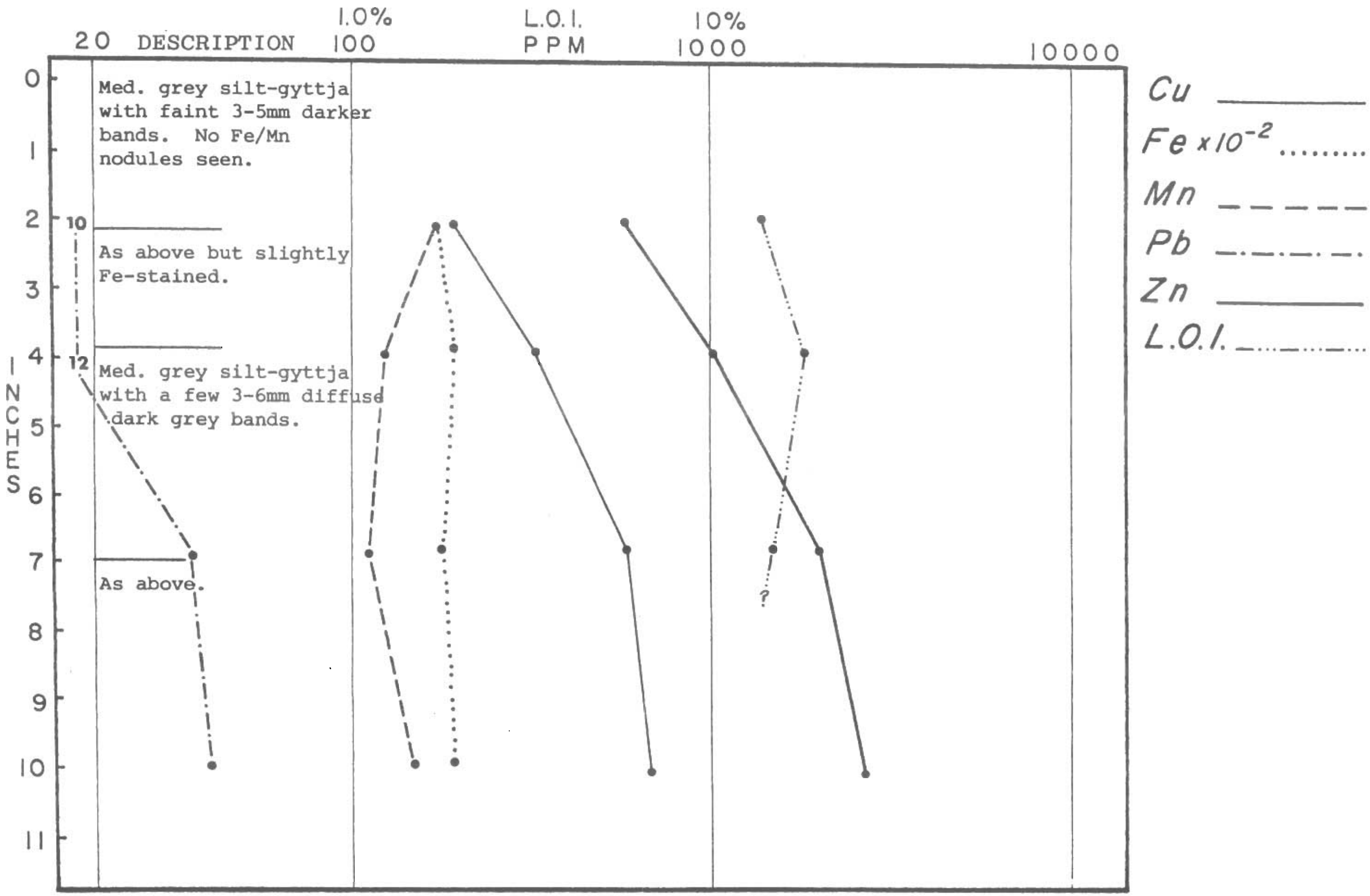

Figure 125. Banana Lake: core 1647, stratigraphy, metal content and L.O.I. with depth.

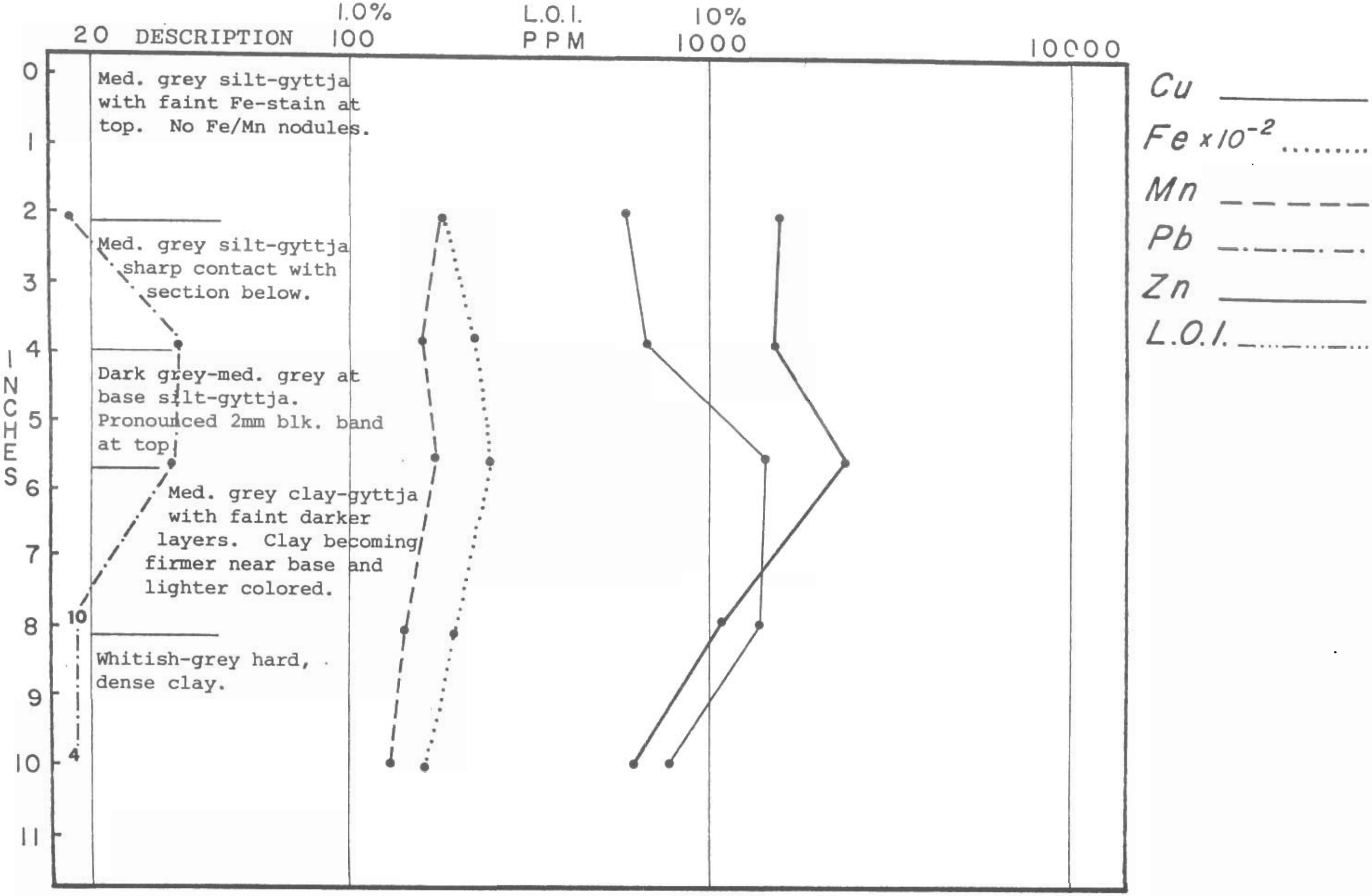

Figure 126. Banana Lake: core 1648, stratigraphy and metal content with depth.

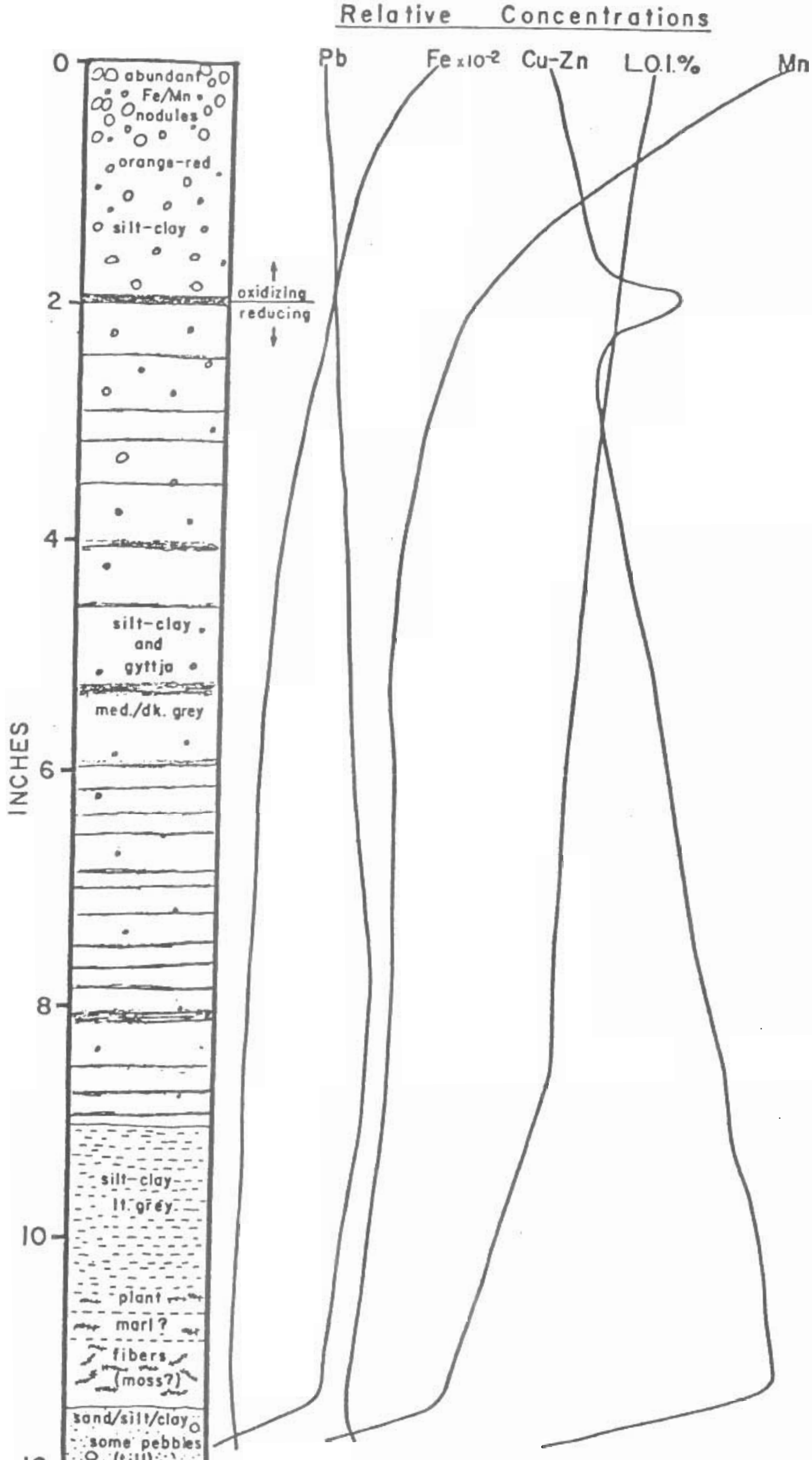

Figure 127. Idealized stratigraphic and geochemical model of center-lake sediments at Bathurst Norsemines.

CHAPTER 5

GENERAL DISCUSSION AND SUMMARY OF GEOCHEMICAL DISPERSION AT BATHURST NORSEMINES

I SOILS

A. Glacial Dispersion Model

Skinner (1972) at the Jameland Mine, Ontario, found that the dispersive mode of glaciers, especially within a mile or two of an anomaly source, is often as thin imbricated sheet-like zones or wedges which rise from bedrock to the till sheet surface (Fig. 128). The attitude and thickness of these zones vary in complex ways, but they often appear to correspond to relic shear (thrust) planes within the till.

At the Louvem Deposit, Quebec, Garrett (1971) found, through overburden drilling to bedrock and sampling at regularly spaced intervals, that..."there is also evidence that the anomalous zone escalades within the till. Close to the ore, the anomalous Cu and Zn are found at the base of the till; however, as one proceeds down ice, the anomaly appears to rise at a gradient of 1 to 100 within the till. This feature is known as overriding and is well known in Quaternary geology".

Recent studies by this author in the Republic of Ireland on disseminated galena occurrences in sandstone have also revealed extensive down ice dispersion of Pb as low angle, thin sheets or zones (Fig. 129). In more general terms, Moran (1971) and White (1971) also noted the rather ubiquitous

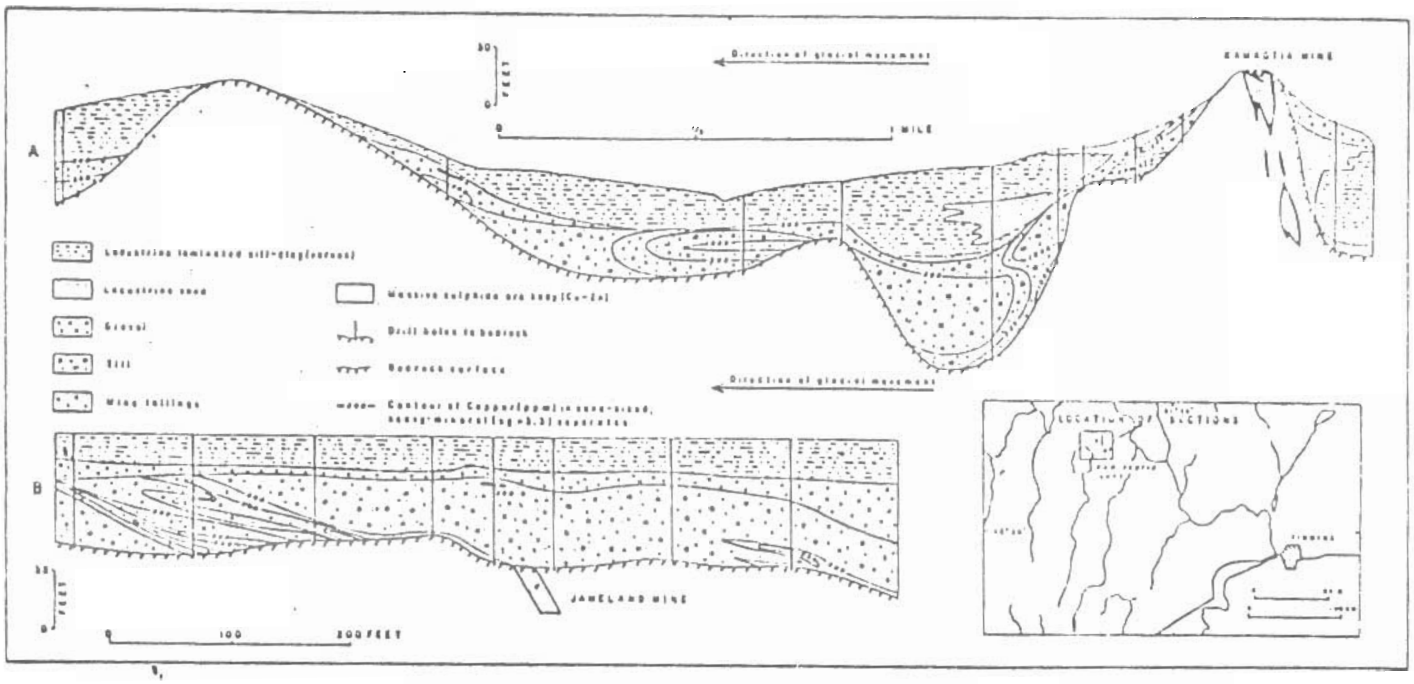

Figure 128. Cross section of glacial deposits showing sheet-like zones of high copper concentrations extending in a down-ice direction from the Jameland and Kamkotia mines (taken from Skinner, GSC Open File Report 116).

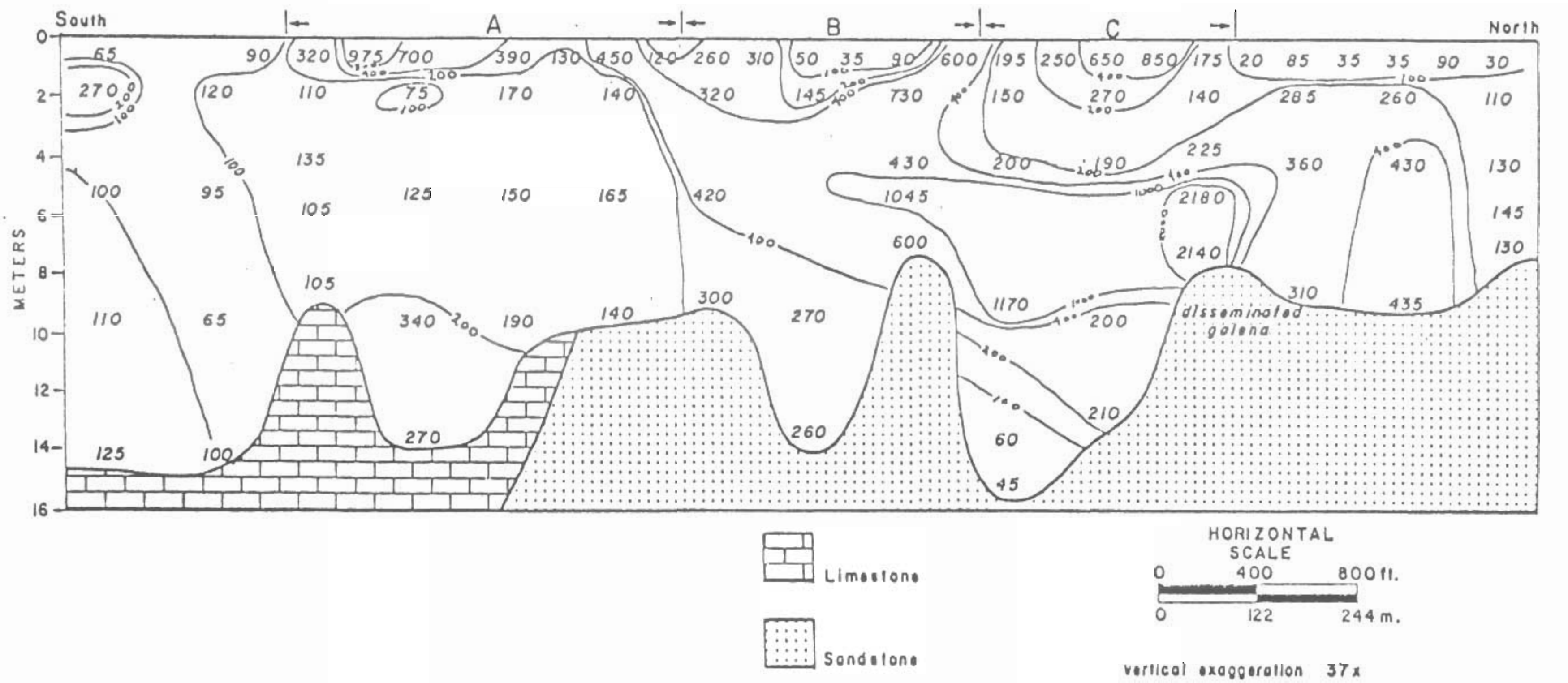

Figure 129. Cross section of deep soil Pb (ppm) geochemistry, over a disseminated galena occurrence in the Republic of Ireland. Glaciation was from north to south. A and C = near-surface zones of decreasing Pb values with depth; B = zone of increasing values with depth. Data courtesy of Dresser Minerals International Inc. Compare with Figures 130 and 131.

occurrence of "transportational stacking" within single till sheets and have extensively elaborated on such glacio-tectonic structures in drift.

A similar mechanism appears to have been operative at Camp Lake. Thus, considering dispersion of Pb (which has been least affected by post-glacial weathering from mineralized outcrops near B-C stream) it is apparent that: 1) the highest near-surface values (outside of those adjacent to the outcrops and related to present-day weathering) occur at $\geq$1500 feet down ice; and 2) comparing Layers 1 and 2 the 100 ppm contour plunges up ice towards the source. In contrast, if simple glacial corrosion and transport were the dominant mode of anomaly formation, then one might expect Pb values in the near-surface till to increase towards the source but, in this case they decrease! It is only in areas directly adjacent to mineralized outcrops that Pb values again increase and this is solely a result of post-glacial weathering (Chapter 4, Section IIIB).

Based on the soil grid and pit data, particularly for Pb, and the variation of Pb between soil layers (Fig. 130) the overall geochemical patterns at Camp Lake are thought to reflect a dispersive mode consistent with glacio-tectonic processes. That is, geochemical dispersion at Camp Lake originated primarily from the two closely spaced mineralized outcrops west of B-C stream and, to a lesser extent, the mineralized outcrop just east of B-C stream near site 198.

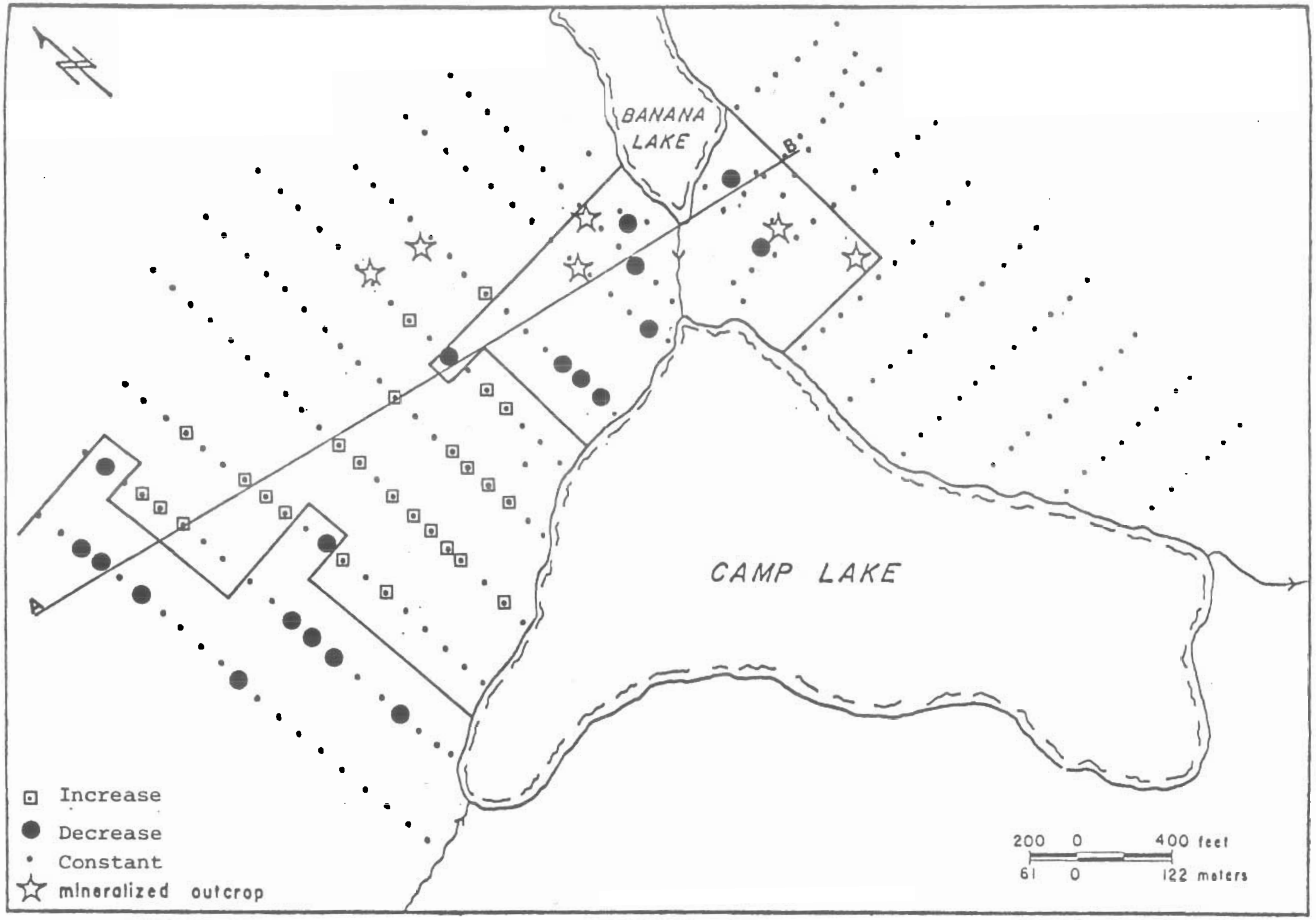

Figure 130. Variation (>10%) of Pb content between Layers 1 and 2. Note grouping of data. Line A-B denotes cross section shown in Figure 131.

Dispersion was down ice in rather narrow ribbon-like or fan-type trains which gradually rose at low to very low angles (1 : 100) from the bedrock surface resulting in relatively thin (1 to 3 feet), narrow zones of highly anomalous till surrounded by an envelope of less anomalous till. However, because of possible bedrock irregularities, which may result in transposing anomalous till to higher levels within the same till sheet (cf. Garrett, 1971), the ability to recognize glacial thrusting as such, as opposed to gradual mechanical mixing and assimilation is difficult at best. Nevertheless, this probably has occurred as evidenced by distinct geochemical layering (Figs. 71, 72, 77 and 78) and possible repetition of highly anomalous ($\geq$1000 ppm) patches (Fig. 40).

Variation of Pb content between soil layers may be related, ideally, to the glacial dispersion model for Camp Lake (Fig. 131). However, in areas immediately adjacent to mineralized outcrops, there is a general decrease in Pb values with respect to depth, especially down slope, because of post glacial weathering processes which have enriched the surface soil. Down ice, there is an area of low to moderate Pb values which are generally constant with depth. This is followed further down ice by a zone of moderate to high Pb values, which often increases substantially with depth, as the anomalous to highly anomalous portions of the indicator train are intercepted. Pb values continue to display increasing values with respect to depth until the most intense

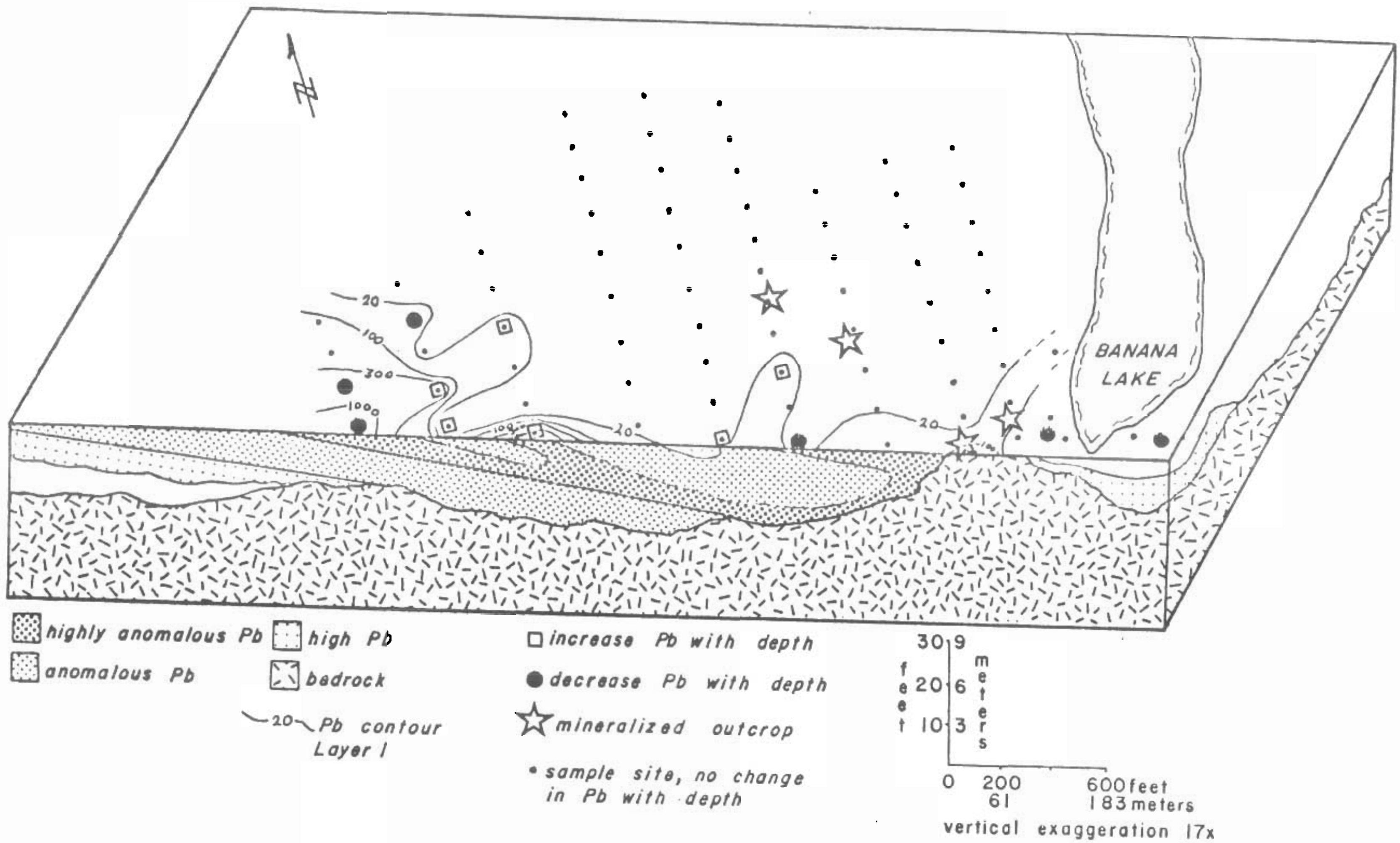

Figure 131. Idealized glacial dispersion model for Pb (and other elements) at Camp Lake. Glaciation was from right to left. Pb values in ppm. Compare with Figures 40, 128 and 129.

portion of the anomaly is reached, beyond which an abrupt transition to decreasing values occurs. This abrupt transition is a reflection of the relatively thin zone or layer of highly anomalous till, as seen at depth in soil pits 17 and 20 (Figs. 74 and 77 respectively), and in similar situations at the Jameland Mine, Ontario and the Louvem Deposit, Quebec. Enveloping the highly anomalous zone is a slightly thicker zone of less anomalous till which grades laterally over tens of feet to perhaps a few hundred feet into till containing background concentrations of Pb. Consequently, only a relatively short lateral distance of a few hundred feet is required to proceed from increasing to decreasing Pb values with respect to depth as shown in Figure 130. For shallower thicknesses of till the above sequence may be laterally shortened and/or various trends absent (e.g. the southern Pb anomaly, Figs. 40, 41 and 129). Conversely, for greater thicknesses of till there may be little near-surface expression of concealed mineralization (cf. Garrett, 1971).

Due to the high secondary geochemical mobility of Cu and, in particular, Zn it is more difficult to relate patterns for these elements to a clastic glacial dispersion model. Nevertheless, as discussed later, it can reasonably be assumed that these two elements were dispersed in a manner similar, if not identical, to Pb but have undergone subsequent substantial hydromorphic redistribution due to high solubilities of secondary weathering products (Table 29).

B. Post-glacial Dispersion

Geochemical results for Camp Lake were first statistically analyzed by means of histograms and probability plots, as presented and discussed in Chapter 4, Section IIA. The bimodal distributions, characteristic of most elements, have been partitioned into two groups with population A relatable to sulphide mineralization and population B generally consistent with local background concentrations. The degree of bimodality and the ease with which these two populations (A and B) can be distinguished is related to metal mobility, that is, for immobile elements (Ag, Pb and, to a lesser extent, Fe) there is a greater difference between population parameters of A and B than there is for mobile elements (Cu, Mn and Zn).

The lack of relatively large parameter differences between populations A and B for mobile elements versus immobile elements is probably a result of intensive post-glacial weathering. Extensive leaching and redistribution of the more mobile elements has tended to smooth out or homogenize the differences between populations. The mobile element patterns may be said to be analogous to a photograph which was initially well developed with high contrast (initial post-glacial pattern) but which, after continued exposure to developing (post-glacial weathering) has faded and lost much

Table 29. Solubilities of Cu, Pb and Zn sulphates.

Sulphate	Solubility g/100ml H_2O, 0^oC
$ZnSO_4$	≈90
$CuSO_4$	14-32
$PbSO_4$	<0.005

Data from Weast, R.C., 1976.

of its sharpness and contrast.

Based on geology (Figs. 17 and 18) and glacial direction(s) (Fig. 14), as discussed in preceding sections, geochemical patterns for Ag, Fe and Pb are considered the result of glacial corrosion and down-ice dispersion from the vicinity of the three mineralized outcrops lying closest to B-C stream. The patterns display two distinct pencil to fan-shaped anomalies extending west to northwest from these sources. The northernmost anomaly extends over 2500 feet from just west of B-C stream to well beyond the western grid limit; however, the limit of dispersion may be on the order of 4500 to 5500 feet based on the distribution of gossan (Plate 15). Lateral mechanical dispersion is generally moderate with only a 3x to 6x increase at the western end of the grid over the estimated width (≈150 feet) at the source. This is consistent with evidence from air photos (Plates 15 and 16) and field observations of circles (Plate 2) that movement of soils by solifluction, soil creep, etc. is relatively minor and generally does not exceed a few tens of feet.

In general, the northern anomaly is characterized by high metal values within surficial soil in close proximity to mineralized outcrops. This reflects post-glacial weathering and transport of mineralized fragments from these outcrops by sheet wash and solifluction. Down ice, metal values in Layer 1 decrease away from these outcrops followed by a substantial increase still further down ice before gradually diminishing to background levels with isolated nebulous patches of high values. Partly as a result of more limited post-glacial modification, anomalous trends and contrast are better preserved in Layer 2 and it is apparent that, as described in the glacial model, the anomaly plunges up ice towards its source.

A similar situation exists for the southern Ag, Fe and Pb anomaly; however, this anomaly is shorter (1500 to 1800 feet) not as strongly anomalous nor as well developed as the more northerly anomaly. Nevertheless, in some instances (e.g. Pb in the L-F-H horizon) anomalous values ($\geq$80 ppm) extend beyond the western grid limit, a distance exceeding 2800 feet (Fig. 39).

The overall lack of development of the southern anomaly, relative to the northern anomaly, is thought to be a result of less extensive corrosion and down-ice dispersion of mineralized rock brought about by the relative positions of the two principal point sources. The sulphide-bearing outcrops east of B-C stream lie on a gently westward facing slope and are not as prominent as the outcrops just west of B-C stream which lie on a south to east facing slope. Consequently, because the former outcrops are topographically less prominent and lie on a slope which slopes in the principal direction of glacial flow, they were somewhat protected from glacial corrosion.

Although Ag, Cu, Fe, Pb and Zn were all presumably dispersed in the same manner by glaciation, subsequent intensive post-glacial weathering has resulted in Zn, and to a lesser extent, Cu patterns becoming irregular and nebulous due to hydromorphic dispersion. Both Cu and Zn are depleted in soils relative to the grade of sulphide mineralization (0.4% Cu; 7.5% Zn) and unlike the immobile elements their contrast decreases with depth. Although mobile element patterns are less well developed relative to immobile element patterns, they are best defined and related to mineralization in the L-F-H horizon. This tendency suggests that scavenging associated with organic matter has occurred, especially for Cu. The significance of the capillary-action mechanism (Fig. 7) is unknown but most likely contributes mobile metals in some degree to the L-F-H horizon and plays some role in establishing decreasing contrast levels with respect to depth (Table 10).

In the case of Zn, geochemical patterns are very poorly developed. Contrast is low (Table 10) and in some areas of low pH values (and high Pb contents) very low Zn levels ($\leq$ 50 ppm) form negative anomalies as a result of intense leaching. Higher Zn concentrations ($\geq$ 200 ppm) occur in the western portion of the grid where pH is less acidic; no where, however, does Zn show evidence of significant near-surface hydromorphic accumulation.

A similar situation exists for Cu. However, unlike Zn, the slightly lower mobility of Cu and its greater affinity for organic matter has resulted in Cu being scavenged by the

L-F-H horizon of swampy or gleyed soils (compare Figs. 16 and 39). The underlying mineral soil contains relatively lower values (compare Figs. 31 and 32 with 30) due to lower pH and Eh. In addition, some zones of low Cu concentrations near B-C stream, like those of Zn, are associated with areas of low pH resulting in negative anomalies (compare Figs. 31 and 32 with 48). Comparison of Cu (particularly in the L-F-H horizon) and Pb patterns shows that sporadic high Cu concentrations ($\geq$200 ppm) often coincide with areas of high Pb values and that these patches of high Cu may have once been connected some time after deglaciation but before redistribution by chemical weathering. Furthermore, there is some evidence, from a comparison of Cu_H and Pb_H patterns, that high Cu concentrations generally lie to the north of high Pb values and are associated with footwall rocks while Pb values are spatially related to the "mineral horizon" (Fig. 18). This suggests that the lower part of the footwall is relatively depleted in Pb in relation to Cu as documented in numerous studies of volcanogenic massive sulphides (Sangster, 1972; Lambert and Sato, 1974).

The large north-south zone of high ($\geq$200 ppm) Cu in the mineral soil may be explained as a case of hydromorphic transport and precipitation. Examination of air photos suggests that Cu is transported in solution along a slight depression from an area of low ($\leq$4.5) pH and high ($\geq$1000 ppm) Pb values towards Camp Lake (compare Fig. 32 with 41 and 48). Unfortunately, pH and partial extraction data are not available for this area. Nevertheless, extrapolation of pH data suggests that pH increases towards the lake and precipitation of Cu could therefore be expected. This would explain the narrowness, intensity, orientation and partial Pb/Cu overlap (with the higher Cu values displaced down slope) of this zone. In addition, the highest Cu values in Camp Lake sediments are found adjacent to this zone (Fig. 102).

It is generally thought (Hawkes and Webb, 1963; pp. 150-151) that the degree of secondary mobility is reflected by partial attacks with the more mobile elements generally being the easiest to extract. Consequently mobile elements generally have the highest partial to total ratios, while relatively immobile elements are characterized by lower percentages of readily extractable metal. At Bathurst Norsemines the opposite trend is found (Tables 10 and 12).

Examination of the partial extraction data (Chapter 4, Section IIC) readily reveals that the percentage of trace metal extracted by 1.0M HCl and, to a lesser extent, 0.05M EDTA, is directly relatable to the degree of secondary mobility/solubility (Table 29) and hence contrast (Table 10). Consequently the mobility order (Zn>Cu>Ag>Pb) is inversely related to contrast and the percentage of 1.0M HCl and 0.05M EDTA extractable metal. Although Pb is the most immobile element with the highest contrast, it is also the most easily and readily extractable element; whereas Zn, the most mobile element has the lowest contrast, and relative to total values, is most difficult to extract.

Total and partial extraction data for different size fractions are usually characterized by a general decrease in metal values from the fine to coarse size fractions with a slight peak in the coarser fractions (-10+40 or -40+80 mesh) and lowest values in the fine sand fractions (-80+270 mesh). The secondary peak in the coarse fractions is largely confined to total data plots, increases with grinding and is only occasionally present in the partial extraction data. It is therefore suggested that this peak is largely related to sulphide inclusions and/or lattice bound metal and that Fe/Mn oxide coatings are of relatively minor importance in terms of scavenging Cu, Pb or Zn. Cameron (1977a) has described a similar situation.

It would therefore appear that under the extremely acidic soil conditions characteristic of the anomalous zone, retention of Cu and Zn in soils by secondary Fe and Mn minerals is not important. Both Cu and Zn are extensively leached from the soil, leaching being most effective close to mineralized outcrop where pH values are lowest. This results in negative Zn anomalies. Any remaining Zn at these soil sites is held in non-labile lattice positions which are least likely to reflect the presence of sulphides and which are not solubilized by partial extractions. In contrast, Pb which probably remains in the soils as an insoluble secondary Pb mineral (anglesite/plumbojarosite?) can be brought into solution by relatively mild extractions (1.0M cold HCl or 0.05M EDTA).

II WATERS AND SEDIMENTS

A. Surface-seepage, Pit and Snow-melt Runoff

Analysis of surface-seepage, pit and snow-melt waters reveals the quantity and relative proportions (mobility) of metals being leached from soils; thereby providing a link between metal values in soils with those in lake waters and sediments. This facilitates a better understanding of chemical weathering and the manner in which lake water and sediment anomalies are generated and clastic soil anomalies destroyed.

Water data for surface-seepage, pit and snow-melt runoff readily reveal high levels of Zn with lesser concentrations of Cu. Pb was not detected in any sample. Values range from less than 10 ppb to over 70 ppm (Zn) with the higher values generally confined to areas of high soil values. However, the highest Cu and Zn values occur where soil values and soil and water pH's are lowest (e.g. near B-C stream, Fig. 98). For example, down slope of mineralized outcrops near B-C stream low Zn and Cu ($\leq$50 ppm and $\leq$20 ppm respectively) are present in gossanous soils. These low values are associated with high levels of Cu and Zn in seepage/pit water and snow-melt runoff. This suggests that leaching of Cu and Zn from these areas is well advanced and that flushing of Cu and Zn from soils under extremely acidic conditions is responsible for negative soil geochemical anomalies.

The apparent Zn enrichment in surface-seepage waters over pit waters (Table 20) may be the result of evaporative concentration. Although Cu is also concentrated by this process, its lower mobility and higher degree of susceptibility to scavenging generally negates the effects of evaporative concentration.

Examination of Zn/Cu ratios for soil, sediment, seepage/pit, snow-melt and lake waters reveals similar ratios for all media except Camp Lake water (Table 30). The Zn/Cu ratio for combined seepage/pit and snow-melt waters is approximately 1.5 to 1.6 which compares with a ratio of 1.12 in soils, 8.0 in lake waters and 1.3 in sediments. This suggests that, relative to Cu, Zn is being removed from soils at a slightly higher rate and in greater quantities. Upon entering Camp Lake, Cu is precipitated or scavenged faster than Zn resulting in an increase of the Zn/Cu ratio to 8.0. The present lake sediment Zn/Cu ratio of 1.3 can be explained as follows: Cu and Zn input from groundwater and snow-melt runoff roughly averages 230 ppb and 350 ppb respectively. Dilution

Table 30. Comparison of Cu and Zn concentrations and Zn/Cu ratios in sampling media at Camp Lake.

Sample Type	mean concentration(ppm) Cu	Zn	Zn/Cu
Soil[1]	60	67	1.12
Seepage/pit water	0.265	0.460	1.73
Snow-melt water	0.207	0.296	1.42
Lake water	0.009	0.072	8.00
Lake sediment	794	1064	1.34

1: Combined averages for the L-F-H horizon, Layers 1 and 2.