REPORT OF INVESTIGATION No. 11

THE Cu, Pb, Zn, Mn and Mo CONTENT OF STREAM AND SPRING SEDIMENTS, SOUTHWESTERN NEW BRUNSWICK N.T.S. 21-G/6, 7, 8W, 10, 11

by

V. B. AUSTRIA, JR.

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DEPARTMENT OF NATURAL RESOURCES
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ILLUSTRATIONS

COPPER, LEAD, ZINC, MOLYBDENUM AND MANGANESE CONTENT OF STREAM AND SPRING SEDIMENTS, SOUTHWESTERN NEW BRUNSWICK

INTRODUCTION

This report presents the results of a reconnaissance geochemical survey carried out in southwestern New Brunswick during the summers of 1968 and 1969. The sampling program was started in 1966 (Wolfe and Mazerolle, 1967) and continued in 1967 (Wolfe and Szabo, 1968).

This geochemical survey is part of a five-year project sponsored jointly by the Province of New Brunswick and the Atlantic Development Board. It is intended to provide basic information on the distribution of trace elements in drainage sediments from which potentially mineralized areas can be broadly outlined.

GENERAL GEOLOGY

The area has been mapped on a regional basis by Tupper (1959), MacKenzie and Alcock (1960b), R. K. Clark (1961), G. S. Clark (1962) and MacKenzie (1964a). Some parts of the area have been re-mapped on a more detailed scale by van de Poll (1967), Hay (1967), and Ruitenberg, (1967, 1968), and as a result, numerous revisions have been made on the stratigraphy and structures in the area. The geological map (Map 1) that accompanies this report is a compilation of the work published by these workers.

The area is underlain mostly by highly deformed metasedimentary and metavolcanic rocks that range in age from Early Ordovician to Early Devonian. They have been intruded by granitic and gabbroic rocks in southeastern and northwestern parts of the area.

The northern and northeastern part of the area is underlain mainly by Carboniferous sedimentary and volcanic rocks. They are relatively undeformed and unconformably overlie all older strata.

ORDOVICIAN

Ordovician rocks (1) in the southwestern part of the area consist of black slate, phyllite and biotite - muscovite schist. These rocks comprise the Cookson Formation of Ruitenberg (1967), and occupy the core of a major northeast trending antiform.

SILURIAN

Silurian volcanic and sedimentary rocks outcrop mainly in the south-eastern part of the map-area between Nerepis and New River. Included here are:

a basalt, andesite and rhyolitic tuff sequence (2a); and a dark argillite - phyllite sequence (2b) (Hay, 1967; Ruitenberg, 1968). Similar rock types north and northeast of Nerepis have not been differentiated (MacKenzie, 1964a).

Calcareous slate and hornfels with intercalated metamorphosed tuff and breccia (2c) occur south of Nerepis and have been tentatively dated as Pre-Silurian (Ruitenberg, 1968).

Silurian strata of the Oak Bay Formation (2c) unconformably overlie the Ordovician rocks (1) in the southwestern part of the map-area (Ruitenberg, 1967). They are mainly polymictic conglomerate and greywacke.

SILURIAN AND DEVONIAN

Strata of Silurian and Devonian age in the southwestern part of the area include: green-grey feldspathic greywacke, quartz-wacke and slate that commonly grade into hornfels, schist and phyllite near the granite contact. Three major units have been recognized: Flume Ridge Formation (3a), Digdeguash Formation (3b) and Waweig Formation (3c).

The undivided sedimentary rocks (3d) with minor volcanic rocks in the western and northeastern parts of the area have been dated as Ordovician by MacKenzie and Alcock (1960b) and Tupper (1959), or Ordovician to Silurian by R.K. Clark (1961). Ruitenberg (oral communication) believes these rocks to be of Silurian and Devonian age.

DEVONIAN

The St. George batholith intruded all older volcanic and sedimentary rocks during the Middle Devonian. It underlies most of the southeastern part of the map-area. A similar intrusive mass, the McAdam batholith, underlies the extreme northwestern part of the area.

The St. George batholith (6) consists mainly of biotite granite and quartz-monzonite, but syenitic and rapakivi facies have been recognized locally. Mafic and intermediate rocks near and within this batholith are believed to be part of the same intrusive event.

Satellitic stocks of adamellite (6a) which post-date the intrusion of the main granitic mass have been mapped in the Piskahegan - Rolling Dam area (Ruitenberg, 1967). To the east, sill-like masses of adamellite, syenite, and gabbro have been interpreted to represent various stages of magmatic differentiation associated with Devonian granitic intrusions (MacKenzie, 1964a).

Cataclastic and migmatitic granodiorite, gabbro, diorite, gneiss and metamorphosed volcanic and sedimentary rocks (4) occur extensively along the southeast margin of the St. George batholith. Potter, et al (1968) assigned these rocks to the Devonian.

MISSISSIPPIAN

Mississippian volcanic and sedimentary rocks unconformably overlie older rocks in the northeast and central parts of the map-area. They have been included in the Piskahegan Group by van de Poll (1967). The stratigraphic section comprises a basal porphyritic and amygdaloidal basalt (7), two volcanic sequences (Seely's and Rothea porphyries, 8), and an assemblage of redbeds, arkoses and greywackes with intercalated basalt, andesite, volcanic breccia and limestone (Carrow Formation (9) and Kleef Formation (11a)). These two volcanic sequences are lithologically similar but represent two periods of vulcanism. The volcanic rocks are mainly quartz-latite porphyry, lithic and porphyritic ash-flow tuff and granophyre (van de Poll, 1967).

Undivided redbeds (11) west of McAdam (Clark, R. K., 1961) are probably correlatives of the Kleef Formation (11a).

MISSISSIPPIAN AND/OR PENNSYLVANIAN

The Shin redbeds (12a), probably represent the uppermost part of the Mississippian succession and are composed of red conglomerate, sub-greywacke and pebbly to silty sandstone (van de Poll, 1967). Similar strata occur south and west of Oromocto Lake (Clark, R. K., 1961).

PENNSYLVANIAN

Pennsylvanian sedimentary rocks in the northern part of the area have been subdivided into: predominantly grey-green to grey conglomerate and sandstone (13), and predominantly red conglomerate, sandstone and shale (14) (Clark, G. S., 1962). Red manganiferous and carbonaceous beds (13a) are locally associated with the grey beds.

Erosional remnants of the Pennsylvanian green-grey and grey sandstones have been mapped south of McAdam.

GEOCHEMICAL SURVEY

FIELD AND ANALYTICAL PROCEDURES

Sediment samples were collected from active stream channels and from rivulets fed by springs and seeps. Streams were traversed on foot and samples collected every 1500 to 2000 feet. A uniform spacing between samples could not be maintained because of: variations in the drainage condition, irregular distribution of streams, springs and seeps, and the absence of silt-size sediments in some stream beds.

Sampling procedures followed were designed to reduce inhomogeneties in size and composition of samples and nature of the drainage environment. Only sediments below water level were taken, and where possible, from the center of the channel. Swamps, marshes and muddy parts of streams were not sampled.

Pertinent data on the nature of sediment samples and drainage environment were recorded and coded on field cards. No attempt was made to obtain detailed variations in the pH of surface waters as tests made on some streams and springs consistently showed neutral or nearly neutral pH.

Sediment samples were dried and later seived. The minus 80-mesh fractions were submitted to the New Brunswick Research and Productivity Council for analysis.

Copper, lead, zinc, and manganese were determined by the atomic absorption analysis after initial extraction with nitric acid. Molybdenum was determined colorimentrically by the dithiol method after initial extraction by fusion with sodium nitrate, sodium chloride and potassium nitrate.

All analytical data obtained and presented in this report are expressed in parts per million (ppm).

RESULTS OF INVESTIGATION

The regional distribution of copper, lead, zinc, molybdenum and manganese are shown on maps 2, 3, 4, 5 and 6 in that order. The nature of the distribution patterns of the elements were analyzed statistically in an attempt to estimate threshold values. The possible significance of dispersion patterns and behavior of the elements in the secondary environment, are discussed. Relationships between manganese and other elements are summarized.

Numerical results of trace analyses were not plotted due to space limitations. Variations in the metal content of sediments are indicated by colored circles, each color representing a grouped value or concentration range. Black circles can be considered to represent anomalous concentrations of the elements, with the possible exception of manganese. The blue and green circles represent the critical concentration range for copper, lead, zinc, and molybdenum. These multi-colored maps are convenient for showing gross regional variations in metal distribution, and are most effective in revealing areas of anomalous metal concentration. They do not, however, show variations in the anomalous concentration ranges. This may be a possible disadvantage when the significance of the anomalies is measured on the basis of the magnitude of the contrast between background and anomalous concentrations.

All published geochemical data will be plotted on a new series of 1:50, 000 scale maps, based on the National Topographic System. It is hoped they will be available in the near future.

STATISTICAL ANALYSIS

ESTIMATION OF THRESHOLD VALUE

The estimation of threshold value can be a critical factor when dealing with large amount of geochemical data over diverse rock types and varies surficial environments. Under such conditions, the use of fixed threshold value for a particular metal can be disrupted. Where the principal factors that influence the distribution of an element are recognizable and can be segregated, the use of more than one threshold would be more logical.

The area surveyed includes varied rock types, soil types topography and drainage - the factors that would significantly affect the regional distribution of the elements. Unfortunately, the scope of the present study is too limited to include detailed investigation of nature of dispersion patterns and fixation of the metals in drainage sediments in relation to the bedrock and surface environments. The applicability of multi-threshold values is conceivable here, but under the present circumstances, cannot be pursued. For this matter, the possibility of using fixed threshold values derived from graphic statistical method has been investigated.

The graphic statistical method is based on the assumption that the distribution of elements follows a natural pattern, more commonly, a lognormal pattern (Ahrens, 1956). A particular pattern would therefore be indicated by a straight line when the cumulative frequency distribution is plotted on probability paper (Tenant and White, 1956). Two distributions, one normal and the other anomalous, would be indicated by two intersecting lines. The concentration of a particular element corresponding to the point of intersection of these two lines is conventionally taken as the threshold value. In the case of a single lognormal distribution, the concentration of the element corresponding to 97. 5 percent of the total distribution is considered as the threshold value (Lepeltier, 1969). Cumulative frequency distribution plots and threshold values, as well as the average (geometric) values derived from these plots are shown and discussed under the heading for each element investigated.

It is suffice to mention here that threshold values derived by the methods discussed above seem inapplicable for the entire map-area and that more flexibility is required in dealing with the geochemical data.

EFFECT OF MANGANESE ON THE DISPERSION OF MINOR METALS

Manganese oxides and hydroxides are known to be effective scavenging agents for minor metals. Variations in copper, lead, zinc, and molybdenum content with respect to manganese content in drainage sediments have been described in reports from other parts of New Brunswick (Boyle, et al, 1965; Wolfe, 1968). Correlation tests for manganese and zinc have shown the relationship is exponential (Canney, 1966). This can be illustrated graphically with the use of logarithmic paper.

In the present study, correlation tests were made on groups of samples; each group representing a particular environment based on bedrock type. The three environments considered in this report include: granitic bedrock, non-granitic bedrock and mineralized bedrock of various types. The sample data were picked from streams that do not cross geological boundaries. The correlation diagrams are shown and the relationships between manganese and other elements are summarized in the later part of the report.

DISPERSION OF COPPER

The copper content of stream and spring sediments ranges from less than 1 ppm (below detection limit) to 250 ppm. About 55 percent of the total number of samples contain 4 ppm or less copper, and not more than 12 percent yielded concentration greater than 8 ppm. The regional background may range from 3 to 4 ppm.

The cumulative frequency diagram for copper (Fig. 1) suggests a single lognormal distribution of the element. By definition, the threshold value derived from the graph is about 22 ppm, whereas the average background is about 3 ppm.

The applicability of this value can be questioned for the reason that most, if not all possible significant values of copper are below 22 ppm. In some places, such as the Jake Lee Mt. area or the area southwest of Nerepis, values less than 22 ppm are associated with known base metal occurrences described previously by Ruitenberg (1968). Similar mineral occurrences are likely to be missed if the 22 ppm threshold value is applied rigidly in all parts of the map-area. On factual observations, it would seem reasonable to assume a 11-16 ppm range as threshold.

The distribution map for copper (Map 1) shows an unusual distribution of copper highs in the Mount Pleasant - Rolling Dam area. Equally notable are the anomalies southwest of Nerepis. Elsewhere, anomalies are either isolated or randomly distributed.

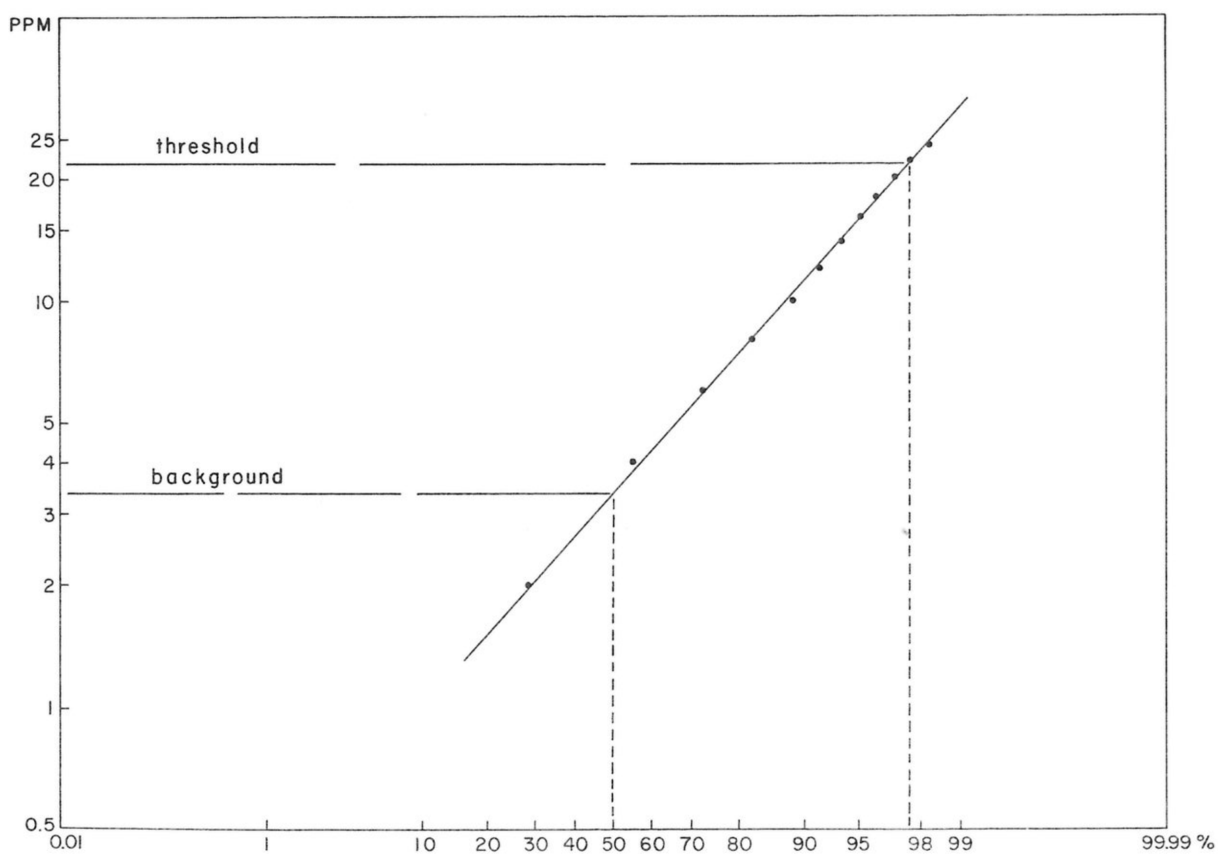

FIGURE 1: Cumulative frequency distribution of copper

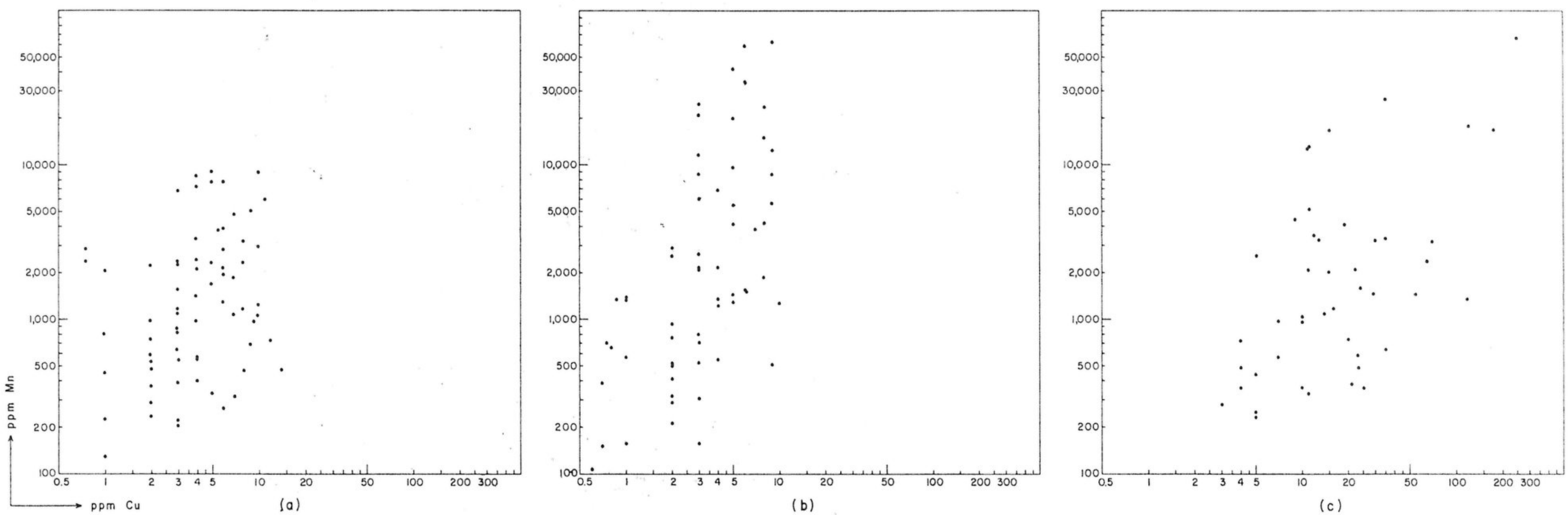

FIGURE 2 : Correlation diagrams, copper - manganese : (a) non-granitic areas; (b) granitic areas; (c) mineralized areas

Unlike other elements, copper is distributed more evenly in most dispersion trains, particularly those that represent unmineralized bedrock. In some anomalous dispersion trains however, fluctuations or abrupt decreases of copper values have been recorded.

The dispersion of copper in the secondary environment is greatly affected by the changes in pH. This element is mobile in an acidic environment but it is relatively immobile in a neutral or basic environment. In places, copper can be immobilized by adsorption or co-precipitation with iron and manganese oxides or with organic compounds. The consistently neutral or nearly neutral pH of the stream and spring waters in the region would probably explain the relatively uniform distribution of copper in most dispersion trains. The fluctuations in some anomalous trains are probably due to concentration by adsorption, or by precipitation of secondary copper minerals in favorable environments.

The possible enrichment of copper in manganiferous sediments has been described elsewhere (Boyle, et al, 1956; Wolfe, 1968). Results of correlation tests shown diagrammatically in Figure 2 a, b, c, suggest copper is not sensitive to variations in manganese content of sediments in the three environments specified. The behavior of copper in the granitic environment is most revealing. Here the copper concentration is fixed at 10 ppm or less despite considerable increases in manganese content of the sediments.

DISPERSION OF LEAD

The lead content of stream and spring sediments ranges from less than 4 ppm to 2,200 ppm. About 65 percent of the analyses do not exceed 30 ppm and less than 10 percent exceed 60 ppm. The regional background may range from 20 to 30 ppm.

Two straight lines on the cumulative frequency plot for lead (Fig. 3) indicates two sets of distributions. This plot also indicates a threshold value of 42 ppm and an average background of 20 ppm. About 20 percent of the total analyses for lead is represented in the set with values greater than 42 ppm.

A threshold of 42 ppm may seem too low to be applicable in the whole region considering the high normal abundance of lead and the normal range of fluctuation expected under normal surface conditions. Values within the 31-50 ppm range or higher have been observed in both unmineralized and mineralized areas, but in the latter, low lead values are associated with anomalously high values. It is therefore possible that the distribution pattern with the higher average is not entirely an anomalous distribution related to mineralization and that the distribution could have been formed as a result of the fluctuations of both the normal and anomalous lead dispersion. Choice of threshold value should depend more on the nature of the dispersion patterns and variations of lead values in a particular locality.

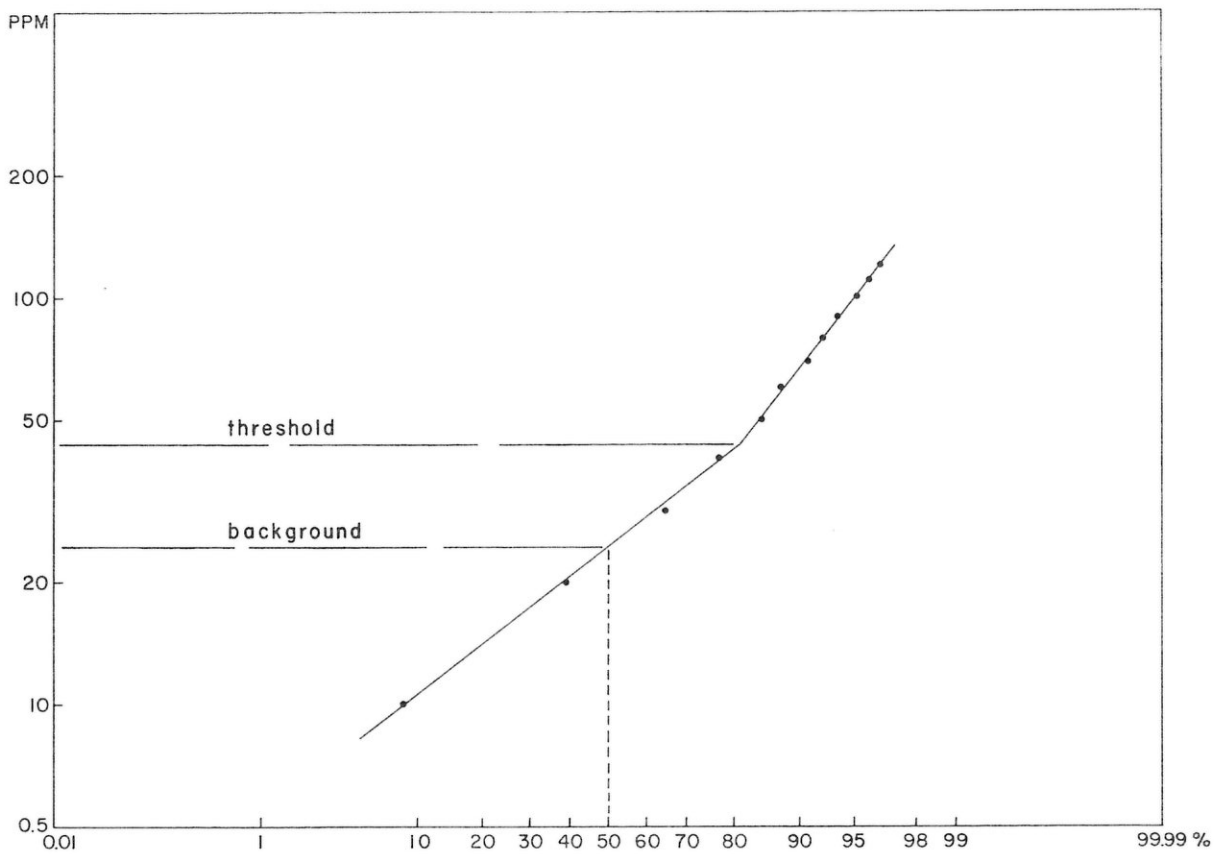

FIGURE 3 : Cumulative frequency distribution of lead

A great abundance of lead is indicated in the southern half of the map-area (Map 2). Anomalous dispersion trains and clusters of lead highs occur in the Mt. Pleasant - Rolling Dam area, near New River, southeast of South Oromocto Lake and southwest of Nerepis. High values were found near lead-bearing mineralization.

The dispersion trains of anomalous lead values are relatively short, and in most places terminate abruptly in lakes and swamps. Lead values not only dissipate readily downstream but also fluctuate considerably. High contrast between adjacent values in the same stream is not uncommon. In background areas however, the dispersion of lead is comparatively uniform. The observed dispersion patterns of lead can be attributed to the low mobility of this element under ordinary surface conditions and to its susceptibility to adsorption and to co-precipitation with organic matter, iron and manganese oxides.

Manganese-lead correlation studies (Figure 4 a, b, c) indicates that lead concentration in drainage sediments varies proportionately with the concentration of manganese. Lead can also be enriched preferentially in manganiferous sediments. It tends to behave independently in mineralized areas or where the lead to manganese ratio tends to increase.

DISPERSION OF ZINC

The zinc content of stream and spring sediments ranges from less than 2 ppm to 4, 300 ppm. About 65 percent of the analyses do not exceed 60 ppm. The background for the region is about 50 ppm.

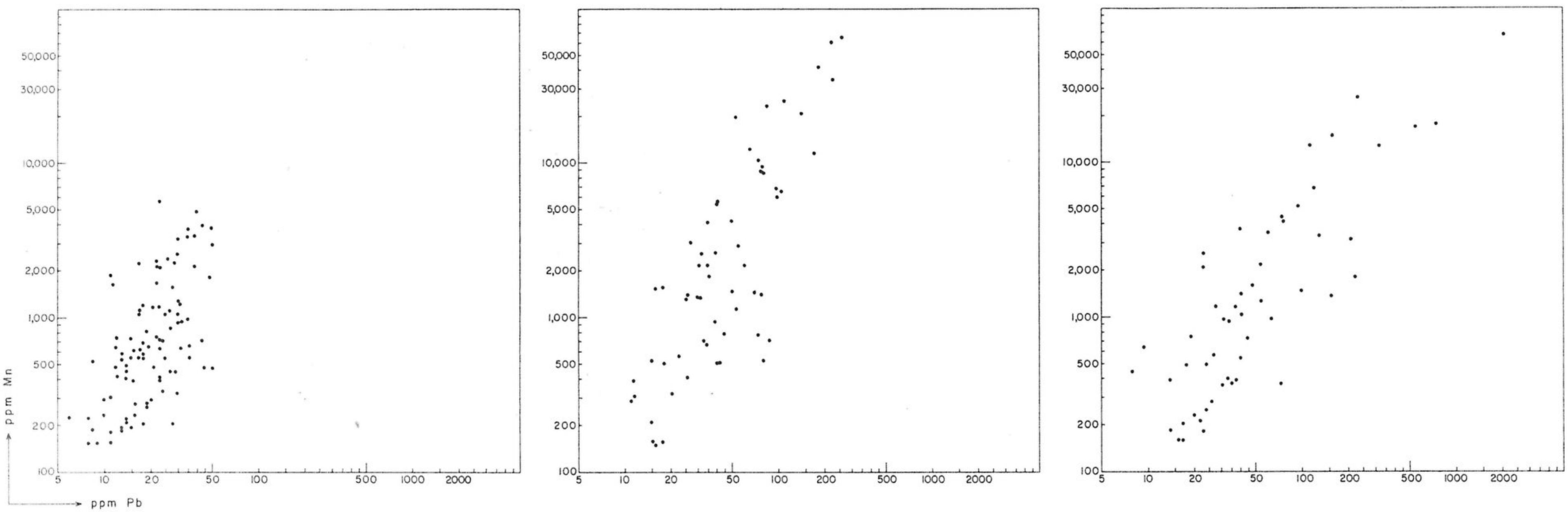

FIGURE 4 : Correlation diagrams, lead-manganese : (a) non-granitic areas; (b) granitic areas; (c) mineralized areas

The cumulative frequency plot for zinc is similar to that of lead, but the normal abundance of zinc is about twice that of lead (Fig. 5). The threshold value derived from the diagram is about 90 ppm as compared to an average background of about 50 ppm.

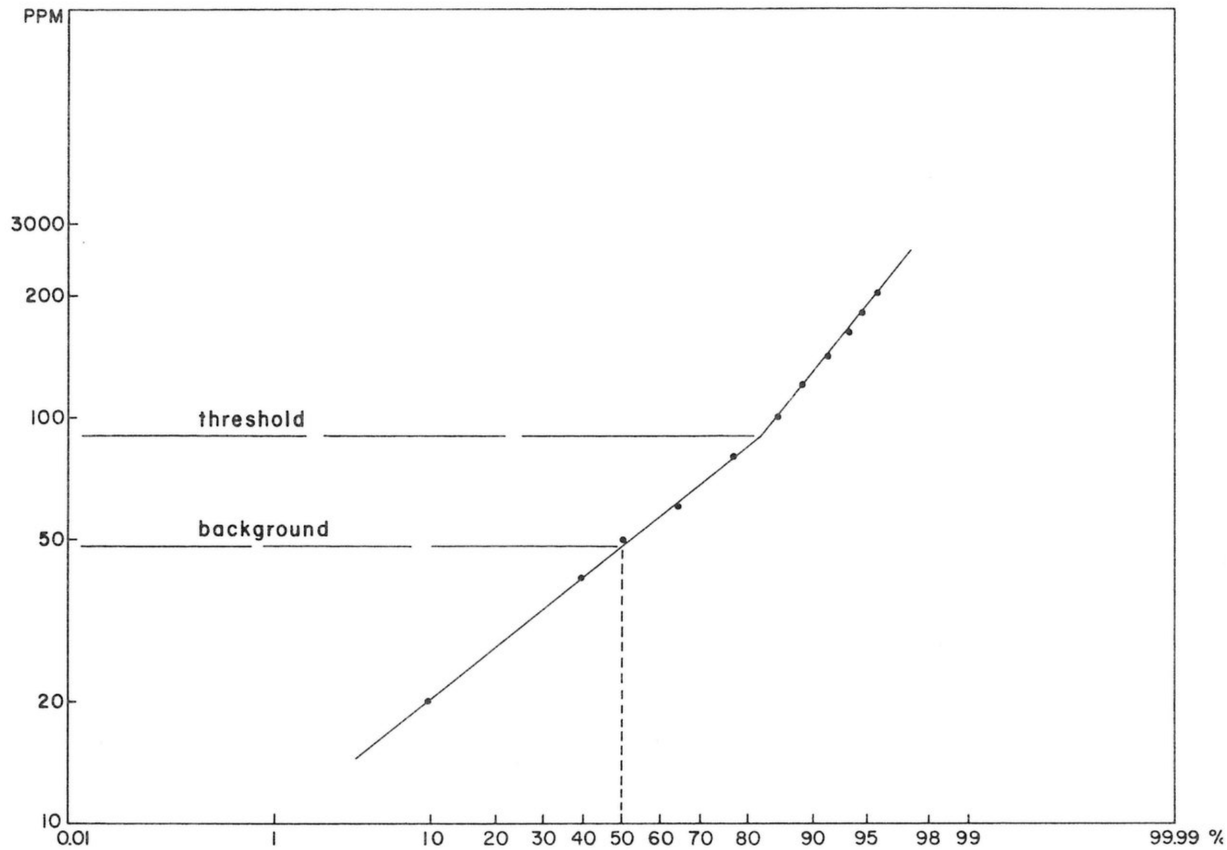

FIGURE 5 : Cumulative frequency distribution of zinc

Like lead, threshold values for zinc seem too low considering the high normal abundance of this element in most parts of the region. Similarly, the distribution with the higher average may not represent an entirely anomalous distribution related to mineralization. The threshold value for zinc may vary considerably and is probably dependent upon the nature of dispersion of the element in a particular area.

Areas of anomalous zinc generally conform to those of the other elements. Discrepancies are mainly in the intensity of anomalies and characteristics of the dispersion trains. Unlike lead, molybdenum and manganese, zinc anomalies are somewhat subdued in the Nerepis area. On the other hand, zinc forms the most persistent dispersion trains in the vicinity of Mount Pleasant.

The mobility of zinc under most conditions is generally greater than that of lead or copper. It is highly mobile in acid waters but tends to be adsorped readily by organic matter, clay minerals, iron and manganese oxides upon neutralization of the dispersing medium.

Manganiferous sediments are generally rich in zinc and previous work in adjacent areas have shown positive correlation between these elements (Wolfe, 1968). Results of correlation tests in the area covered by this report showed similar manganese-zinc relationships (Figure 6a, b). In mineralized areas however, the ratio of zinc to manganese tends to increase (Figure 6c). The manganese content of sediments should be considered in assessing the significance of some zinc anomalies.

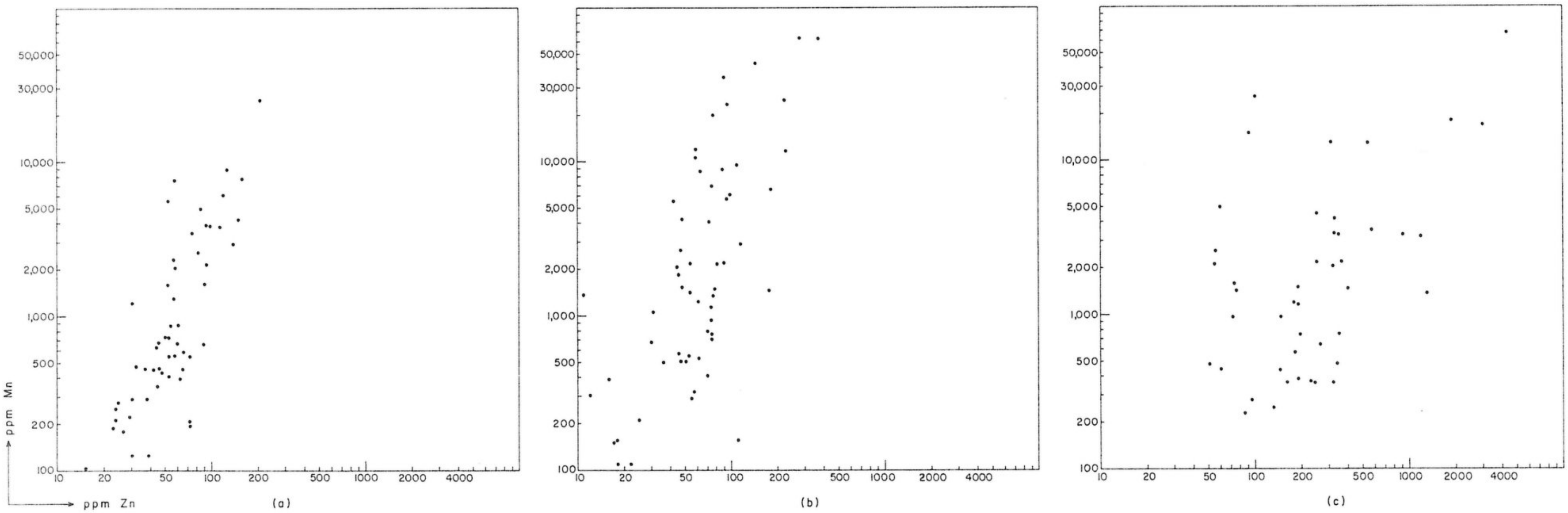

FIGURE 6 : Correlation diagrams, zinc-manganese : (a) non-granitic areas; (b) granitic areas; (c) mineralized areas

DISPERSION OF MOLYBDENUM

The molybdenum content of stream and spring sediments ranges from less than 1 ppm to 300 ppm. Approximately 70 percent of the total number of samples contain 2 ppm or less. The regional background is about 2 ppm, but may be less than 1 ppm in areas underlain by Carboniferous rocks or greater than 2 ppm in granitic areas.

The cumulative frequency plot for molybdenum (Fig. 7) suggests the presence of three sets of distributions. This type of curve is more commonly interpreted to represent two principal sets of population and one mixed population, corresponding to the two extreme lines and the middle line respectively (Tenant and White, 1956). The curve would indicate a threshold value of 12 ppm and an average background of less than 1 ppm.

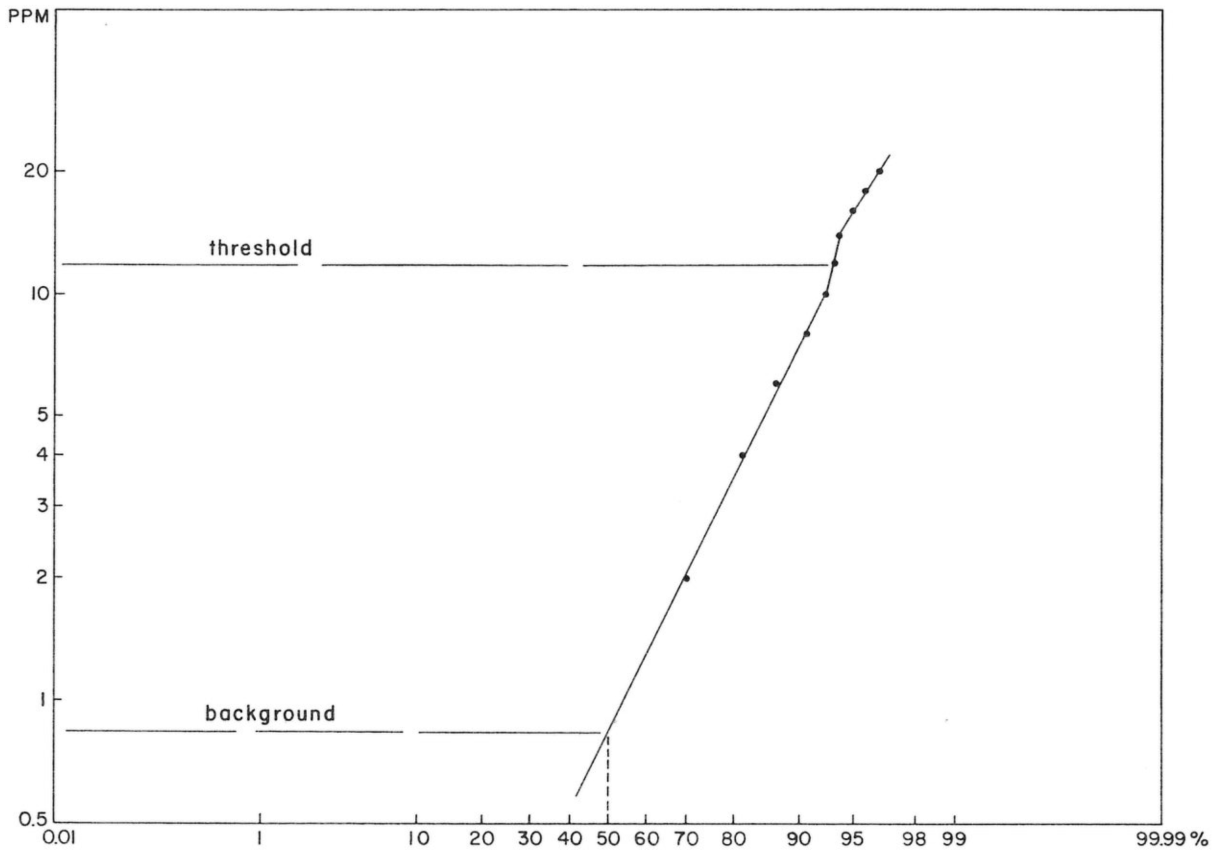

FIGURE 7 : Cumulative frequency distribution of molybdenum

The threshold value derived above is generally higher than most of the significant values associated with known molybdenite occurrences. The use of a fixed 12 ppm threshold would disregard the lower but significant fluctuation level of some anomalous dispersions. In some places, a concentration range of 7-10 ppm may be significant.

Molybdenum values are generally high near known molybdenite occurrences. The Sn, Cu, Zn, Mo deposit in Mount Pleasant is outlined by the exceptionally high values of molybdenum in drainage sediments. Anomalous patterns in the area west of Welsford can also be associated with the known molybdenite occurrences.

Regional variations of molybdenum concentration are generally related to the bedrock type. The highest average concentration is over granitic terrain and the lowest average is over Carboniferous strata. Higher than normal values are distributed mainly in the southern half of the map-area and the anomalous distribution patterns here generally correspond to those of the other elements.

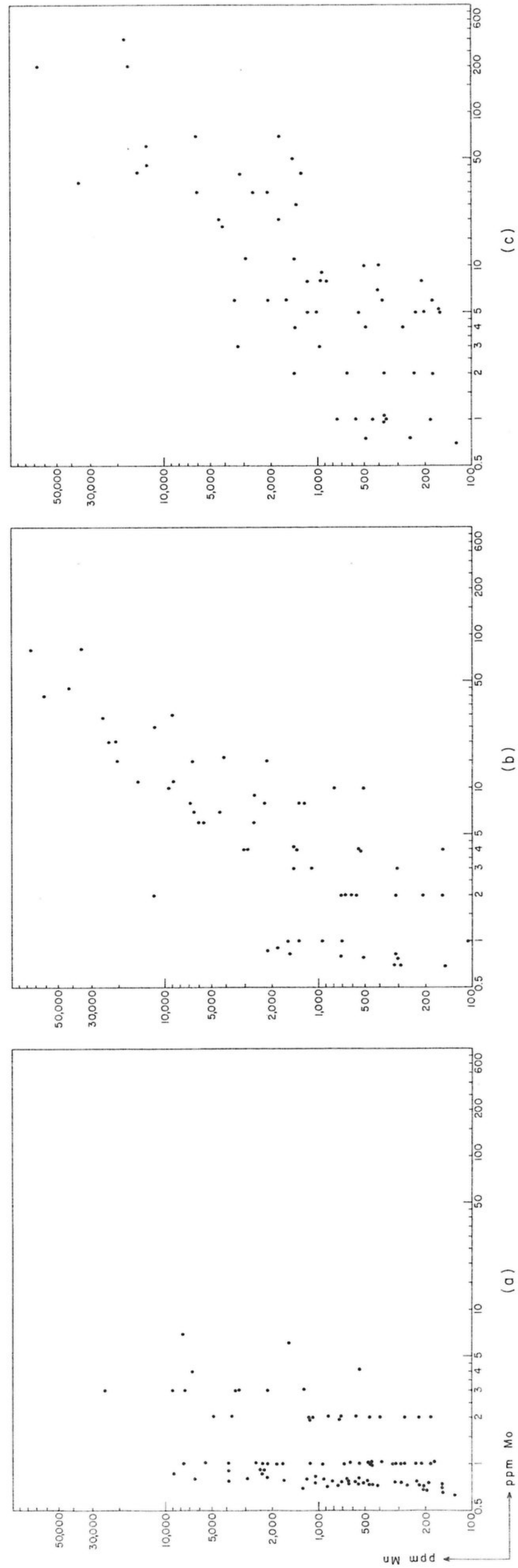

FIGURE 8 : Correlation diagrams, molybdenum-manganese : (a) non-granitic areas ; (b) granitic areas ; (c) mineralized areas

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Anomalous dispersion trains of molybdenum, unlike those of zinc, do not persist for several miles downstream. Like lead, trains terminate or fade out on the downstream side of swampy areas. Extreme fluctuations are notable in most dispersion trains and values from 8 ppm to 45 ppm have been recorded in adjacent samples from mineralized areas as well as from areas with no known molybdenite.

Molybdenum is mobile under ordinary surface conditions but its mobility can be suppressed effectively by adsorption and co-precipitation with organic compounds, iron or manganese oxides.

Like lead and zinc, molybdenum is preferentially enriched in manganiferous sediments, but manganese-dependent anomalies may be shown by use of a fixed threshold value. Manganese-molybdenum correlation tests however indicated that concentrations of molybdenum in manganiferous sediments may be possible only where molybdenum is present in detectible amounts and is available for concentration. This can be deduced from the scatter diagrams for non-granitic and granitic environments (Figure 8 a, b) where the average concentration of molybdenum is low in the former and high in the latter. Molybdenum tends to become less dependent of manganese in mineralized areas as indicated by the increase in the ratio of molybdenum to manganese (Figure 8c). The enrichment of molybdenum, like that of lead or zinc in manganiferous sediments might lead to the formation of manganese-dependent anomalies. These type of anomalies should therefore be assessed with care.

DISPERSION OF MANGANESE

The manganese content of stream and spring sediments ranges from 70 ppm to greater than 100, 000 ppm, with a regional background of about 500 ppm. About 15 percent of the analyses exceed 3, 000 ppm.

The manganese distribution in the 0 to 3, 000 ppm range (excluding about 15 percent of the total analyses) is possibly made up of two sets (Fig. 9). This curve is very similar to those obtained for lead and zinc; but with a threshold value of 1, 800 ppm and an average background of about 500 ppm.

The significance of the 1, 800 ppm level in the regional distribution of manganese is questionable as fluctuations in background concentration can be expected to exceed 1, 800 ppm under ordinary surface conditions. It is most likely that the distribution with the higher average background represents dispersion of manganese in a specific environment related to bedrock type and/or surface conditions.

Regional variations in the manganese content of sediments may be related to bedrock type as the average concentration of this element is generally higher in granitic terrain than in the non-granitic terrain. Sediments derived from Carboniferous rocks have the lowest average Mn content. Reasons for these variations can only be speculated; ie. in the manganese content of the different rock types, or gross variations in the nature of the environment. No data is available on manganese content of the major rock types in this area. Manganese is relatively immobile under ordinary surface conditions and its mobility is fundamentally a function of pH and Eh. Precipitation of manganese oxides and hydroxides is favored in an environment with high pH and Eh.

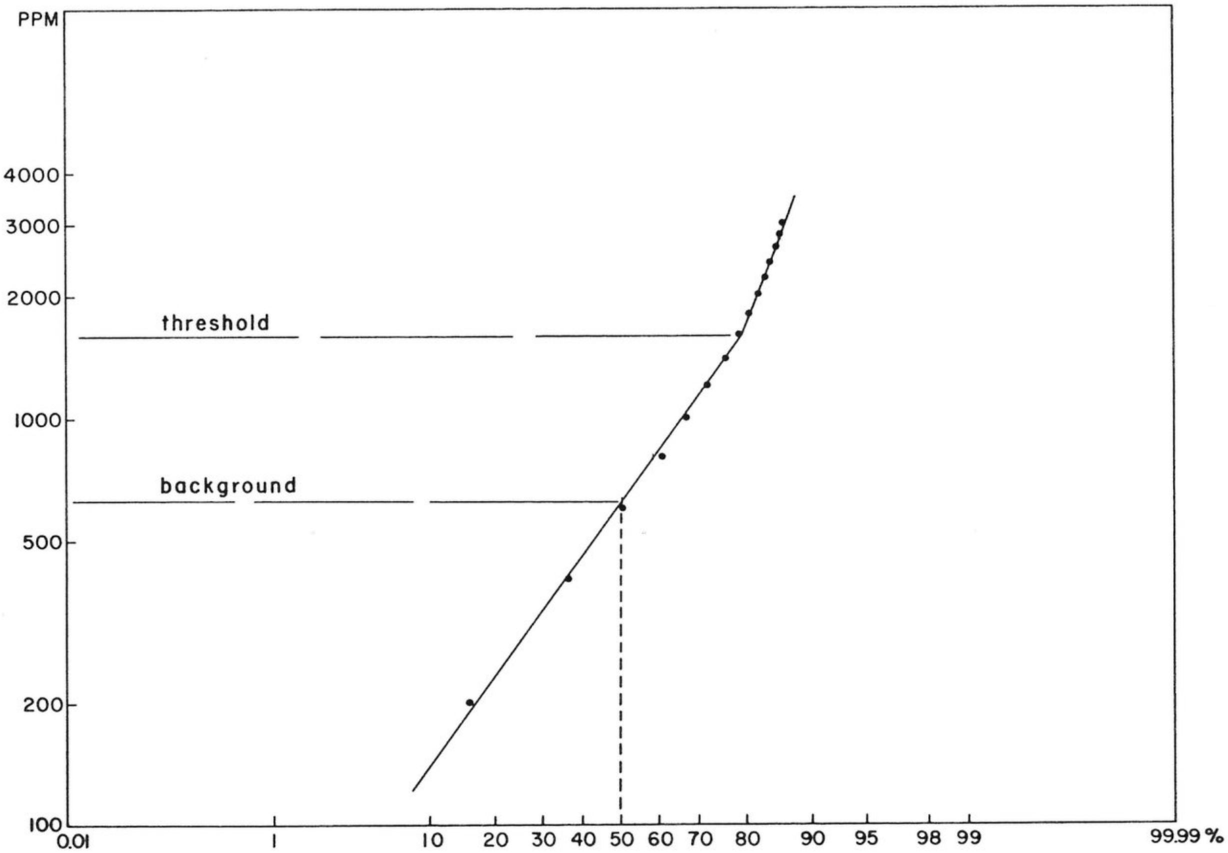

FIGURE 9 : Cumulative frequency distribution of manganese

Dissolved manganese in surface waters draining acidic soil would be precipitated as oxides upon reaching bodies of water with higher pH and Eh. Similarly, precipitation of soluble manganese from groundwater solutions would be favored in springs and seeps because of the increased oxidation potential. Aside from the pH and Eh factors, it has been suggested that feldspar grains, probably acting as catalyzers, could induce a faster rate of precipitation of manganese oxides from neutral solutions (Hem, 1963).

The behavior of manganese in the surficial environment would probably explain the high concentration of this element in sediments derived from granitic rocks. Soils over granitic terrain are generally acidic and would be impoverisheed in manganese as compared to sediments where the environment is more conductive for the precipitation of this element. Moreover, the presence of abundant feldspathic sediments in stream beds in granitic areas might have a significant effect on the oxidation of manganese ions, Hem (1963). Regional variations in the dispersion of manganese may therefore reflect the type of surface environment related to specific rock types, rather than the reflect of the manganese content of the rocks.

Manganiferous sediments, particularly those in the granitic terrain, generally contain unusual abundance of lead, zinc and molybdenum. Results of correlation tests presented earlier have shown positive relationships between manganese and the above three elements. These relationships may be explained by the strong capacity of manganese oxides to adsorb minor metals. The manganese content of sediments should therefore be considered when dealing with higher than normal values of lead, zinc, and molybdenum.

The occurrence of unusually high concentrations of manganese in known mineralized areas, such as Mount Pleasant and Nerepis suggests that this element might be related to some base metal mineralization. This possibility should not be ignored in assessing the significance of high concentrations of manganese, particularly values in the order of 10, 000 ppm.

CONCLUSIONS AND SUGGESTIONS

The survey has been effective in showing the presence and distribution of copper, lead, zinc, molybdenum and manganese in the streams of southwestern New Brunswick. Regional and local variations in the distribution of the metallic elements have been indicated and areas containing unusual abundance of the metals (the potentially mineralized areas) have been broadly outlined. More detailed exploration in the region is warranted.

Higher than normal values of the five elements were found in the southern half of the area, mainly between Mount Pleasant and Rolling Dam and between Jake Lee Mt., New River, Nerepis and Welsford. The high potential of these areas can be gauged, not only on the basis of encouraging geochemical results but also on the geological environment that is favorable for base metals, Mo, Sn, W, Au, and Ag mineralization (Potter, Ruitenberg and Davies; 1968).

Additional work in the region should be programmed initially to establish the significance of the geochemical anomalies, particularly those not directly associated with known mineral occurrences. Despite all attempts to reduce inhomogeneties, significant variations in the dispersion of metals in the secondary environment can be expected. In an area of diverse rock types and varied surface conditions, these inhomogeneties can only be reduced, not eliminated.

Sediments with high content of iron and manganese oxides, organic matter and clay minerals are commonly enriched in copper, zinc, lead or molybdenum. The various aspects of the nature and extent of enrichment of these elements have not been investigated in detail. Nevertheless, quantitative data available for manganese have been used advantageously in measuring the possible effect of manganese compounds in the dispersion of the other elements.

Positive relationships exist between manganese and zinc, lead and molybdenum. It is therefore probable that some zinc, lead and molybdenum anomalies are formed mainly through enrichment of the metals in manganese-rich sediments. This does not, however, constitute a valid reason to disregard the possible significance of the manganiferous sediments that contain anomalous concentration of the other metals. The nature of dispersion of manganese in the sediments is not known, and it is probable that some high concentrations of manganese are related to base metal mineralization. All anomalies should therefore be considered significant until proven otherwise.

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