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# Pedogeochemical and biogeochemical trends at the Heddleston porphyry copper-molybdenum deposit Lewis and Clark County Montana

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# PEDOGEOCHEMICAL AND BIOGEOCHEMICAL TRENDS AT THE HEDDLESTON PORPHYRY COPPER-MOLYBDENUM DEPOSIT, LEWIS AND CLARK COUNTY, MONTANA

by

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Approved by:

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Chairman, Board of Examiners

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Date

# ABSTRACT

Castle, Bruce, M.S., Summer, 1980 Geology

Pedogeochemical and Biogeochemical Trends at the Heddleston Porphyry Copper-Molybdenum Deposit, Lewis and Clark County, Montana

Director: Ian M. Lange Ian Lange DMF

Soil samples and Lodgepole pine twig samples were collected over unexposed copper-molybdenum mineralization at the Heddleston deposit in Montana. These samples were analyzed for a suite of eleven base and precious metals to determine whether surficial geochemical methods could define all or part of the system. Correlation analysis, simple graphical techniques and trend surface analysis were utilized to evaluate the resultant data.

Soil geochemistry was able to outline the zone of strong wall rock alteration with trends of low "total" lead, zinc, manganese and iron. Weak acid extractable manganese and oxidizable manganese showed similar trends. Only weak acid extractable iron yielded a "high" which may reflect a pyritic halo above an area of deep molybdenum potential.

Biogeochemical trends proved to be largely ineffective guides to the mineralized system. Iron was the only exception. A high iron "bullseye" occurred over deeply buried molybdenum mineralization at the northwest end of the deposit.

Although cadmium and zinc trends in Lodgepole pines were not effective in delineating the Heddleston deposit, the strong direct relationship between soil and plant abundance levels indicates a potential for utilizing them in biogeochemical exploration for zinc deposits.

# ACKNOWLEDGMENTS

I owe thanks to numerous people directly and indirectly involved in this study. Bruce Johnson, Rich Harris, Scott Bryant and Ian Lange all labored mightily with the sample collecting and preparation. Bruce Johnson is directly responsible for a working trend surface program. Lynn Miller and Susan Guthrie spent hours at the keypunch transferring the raw data to computer cards. Finally, the encouragement and patience of my advisor, Dr. Ian Lange, is acknowledged. Without his support this project would not have been completed.

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# CHAPTER I

# INTRODUCTION

Porphyry copper-molybdenum deposits consist of disseminated and stock work sulfide veinlet mineralization emplaced in various hydrothermally altered host rocks, showing concentric zoning patterns and associated with a stock of intermediate (typically quartz monzonite porphyry) composition (Lowell and Gilbert, 1970). Usually they are large tonnage (averaging 140 million tons of ore), low grade (averaging 0.8% Cu and 0.015% Mo), and are mined with large scale, low cost mining methods (Lowell and Gilbert, 1970). Such deposits are widespread in the Western Cordillera, and for decades have been the major source of domestic copper ore. Worldwide, porphyry copper-molybdenum deposits provide 43% of the new copper, 95% of the molybdenum, 100% of the rhenium, along with significant quantities of gold and silver (Sutulov, 1974).

For several reasons, porphyry deposits are almost ideal "targets" for geochemical prospecting techniques. First, the targets are of large dimensions. A typical porphyry copper-molybdenum deposits is an oval or pipe shaped body roughly 1,000 meters by 1,800 meters in plan and up to 3,000 meters in depth (Lowell and Gilbert, 1970). Second, the host rocks are commonly highly fractured and altered allowing easy access of oxygen and water and release of weathering products. Finally, the dispersed and disseminated sulfides present large surface areas for oxidation processes. This results in an acid weathering environment which favors the mobilization of copper and other metals.

Geochemical prospecting techniques have been highly successful in locating previously undiscovered porphyry deposits, e.g., Casino in the Yokon Territory, Canada (Archer and Main, 1970), as well as more extensive mineralization near known showings, e.g., Bouganville in the South Pacific (Coope, 1973). However, there are important deposits, even entire districts, where geochemical prospecting has not contributed significantly to the discovery of porphyry mineralization. Some districts in the southwestern United States and the Highland Valley District of British Columbia illustrate this point (Coope, 1973). The reasons for the failure of geochemical techniques in these instances include complex overburden as well as the current state of geochemical expertise.

## Statement of the Problem

The Heddleston porphyry copper-molybdenum deposit, currently owned by Anaconda Mining Company, represents a failure of exploration geochemistry (Miller et al., 1973). Kennecott Copper Company geologists walked over the deposit without detecting it. Anaconda geologists located it and defined its extent by drilling and induced polarization methods. Soil geochemistry was of little value in this effort (Miller et al., 1973).

The Heddleston deposit is not a truly "blind" deposit. Base and precious metal vein deposits which occur peripherally represent "leakage" from the unexposed copper-molybdenum mineralization.

Since this mineralization now known to occur at Heddleston is found at some depth, the question arises whether <u>any</u> surficial geochemical technique could have indicated its presence below. Specifically, could biogeochemical prospecting work? Malyuga (1964) concludes his excellent text on this subject by saying:

> The experience of our studies has revealed that <u>without</u> <u>exception</u> all plants growing over ore deposits have an increased metal content.

If this constitutes more than Soviet rhetoric, then it seems possible that the buried mineralization at Heddleston is expressed in metal content of the overlying plants.

The purpose of this study is to apply biogeochemical methods to the Heddleston deposit. In detail, the trace element content of twigs from Lodgepole pine trees growing over mineralized and unmineralized ground was determined. The emphasis was on eliminating effects attributable to environmental parameters and defining subtle relationships via statistical analysis. From sampling through statistics, most of the methods utilized were in isde use by the mineral industry at the time of the study.

# CHAPTER II

# GEOLOGY OF THE HEDDLESTON COPPER-MOLYBDENUM DEPOSIT

## Location

The Heddleston deposit is located in the Heddleston Mining District (Figure 1), about 53 air kilometers northwest of Helena, Montana, at the head of the Blackfoot River. It lies in Sections 20, 21, 28 and 29, T15N, R6W, Lewis and Clark County. Montana Highway 200 cuts across the NW corner of the deposit, about one mile west of Rogers Pass on the Continental Divide.

## History and Production

The Heddleston District was named for William Heddleston, who, along with George Padbury, discovered lode gold there in 1889. Additional discoveries of base and precious metal mineralization in shear zones and veins were made shortly thereafter, though poor accessibility hampered development. Construction of a small concentrating mill at the Mike Horse Mine in 1919 spurred road building and led to lode mining at the Carbonate, Anaconda, Paymaster and Midnight mines. By 1930, ores of lead, gold and silver, along with some copper and zinc, worth an estimated $2,000,000, had been produced.

Between 1930 and 1958, the Mike Horse Mine was the principal producer in the district. Three major veins contributed most of

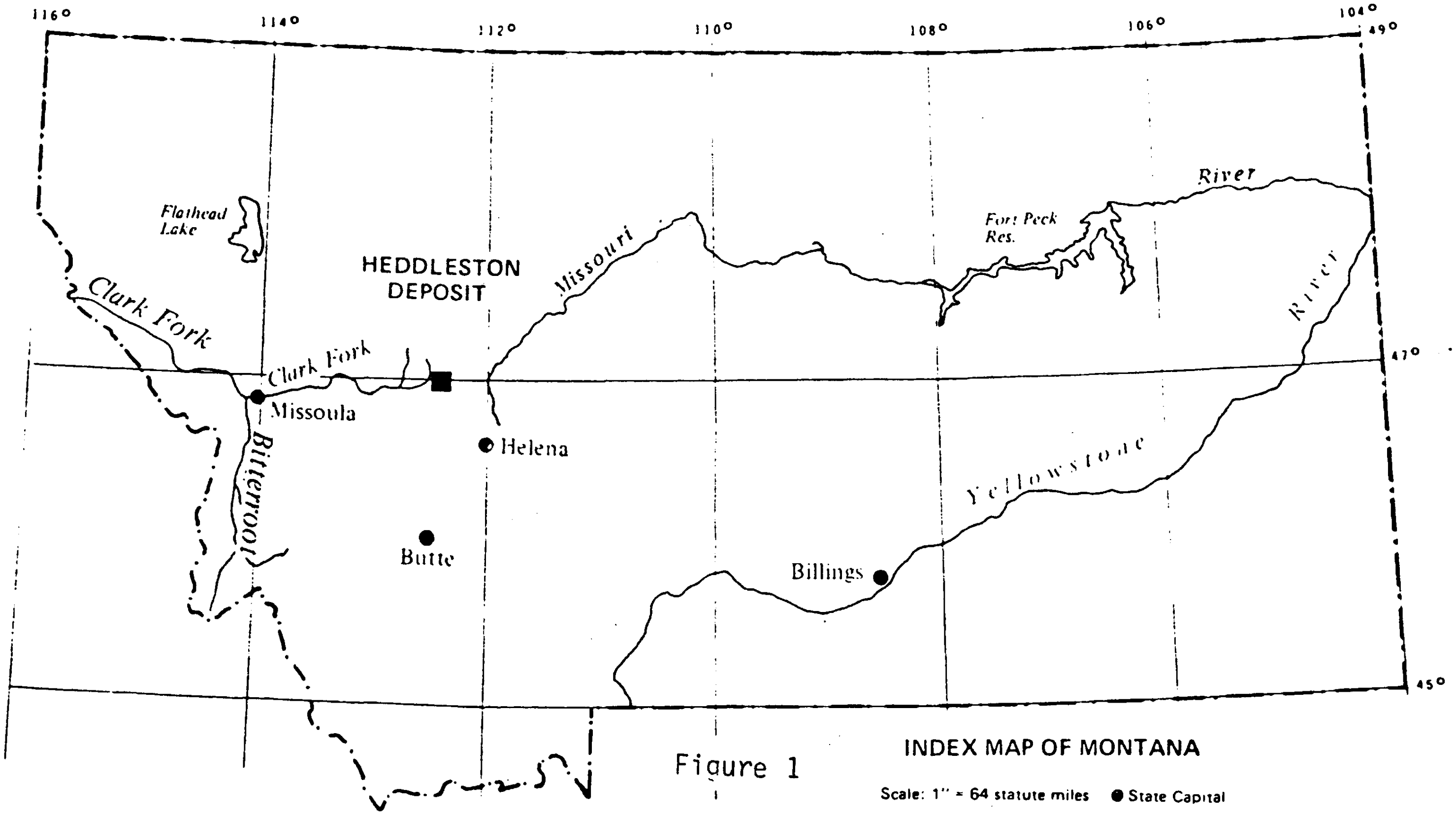


Figure 1

INDEX MAP OF MONTANA

Scale: 1" = 64 statute miles ● State Capital the ore. The Mike Horse vein alone was worked on six levels over a lateral distance of 600 meters and to a depth of 300 meters below the surface. Although declining metal prices forced production to cease in 1958, the estimated total value of ores and concentrates shipped from the district was $25,000,000 (Miller, et al., 1973).

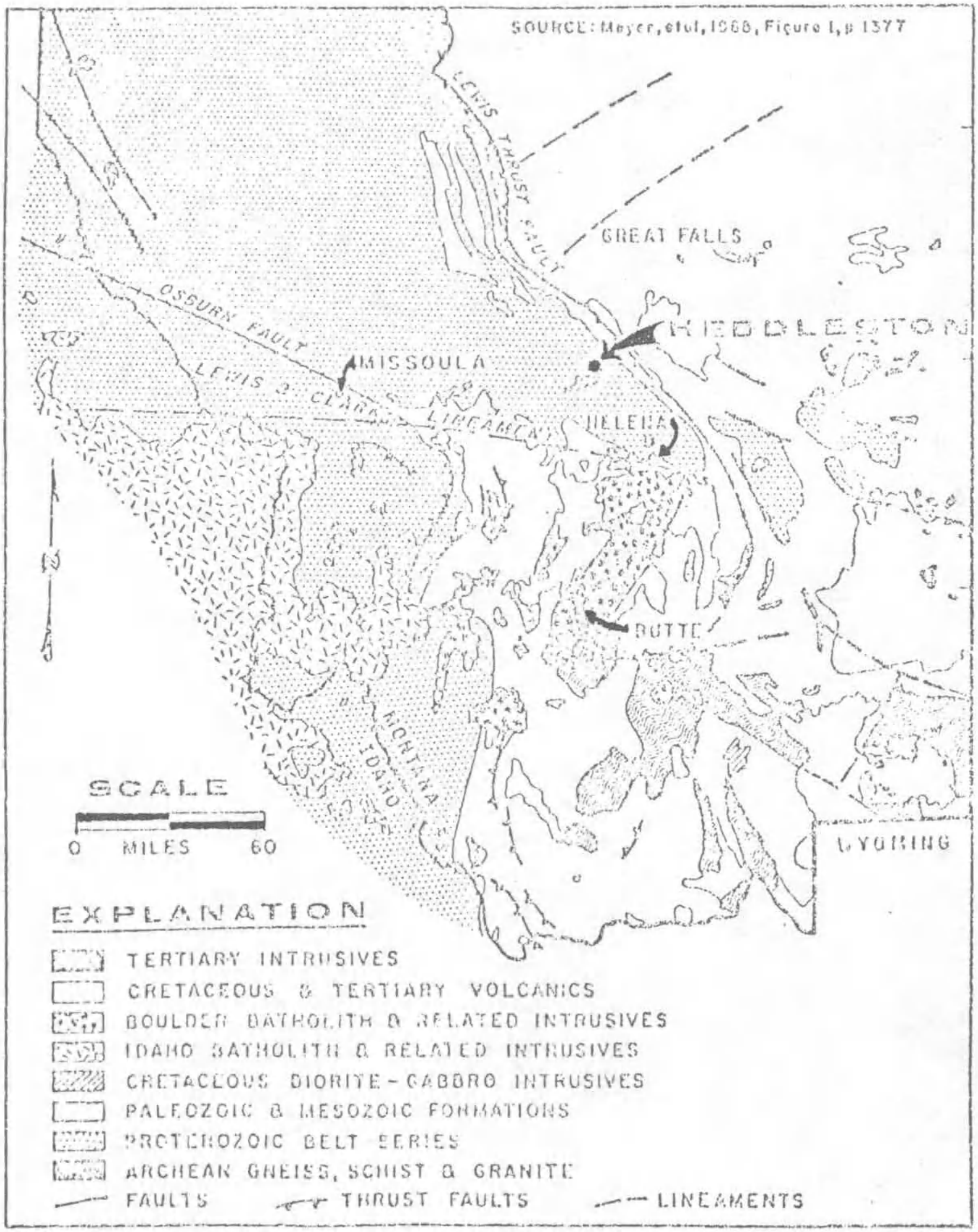
In 1962 Anaconda Mining Company commenced a full-scale exploration program in the district. Over an eight year period AMC did almost a quarter of a million feet of diamond and churn drilling, drove several exploratory crosscuts, and constructed twenty-seven miles of road. This work was suspended in 1970, though annual assessment work on unpatented claims and environmental restoration projects are continuing.

## Previous Work

The most complete geologic study of the district was done by the Anaconda Mining Company and summarized by Miller, et al. (1973). This paper is the first detailed synthesis of the results of Anaconda's eight year exploration program, and the reader is referred to this source for detailed information on the district. Pardee and Schrader (1933) give an excellent account of early history and a more detailed description of the first lode mines.

## Regional Geology

Western Montana is broken into three large tectonic blocks by the Osburn Fault and the Lewis and Clark Lineament (Figure 2). These two lineaments seem to be deep seated features involving the underlying



SOURCE: Meyer, et al, 1968, Figure 1, p 1377

Figure 2.- Tectonic Elements of Western Montana, showing the position of the Heddleston District in the Upper Plate of the Lewis Overthrust.

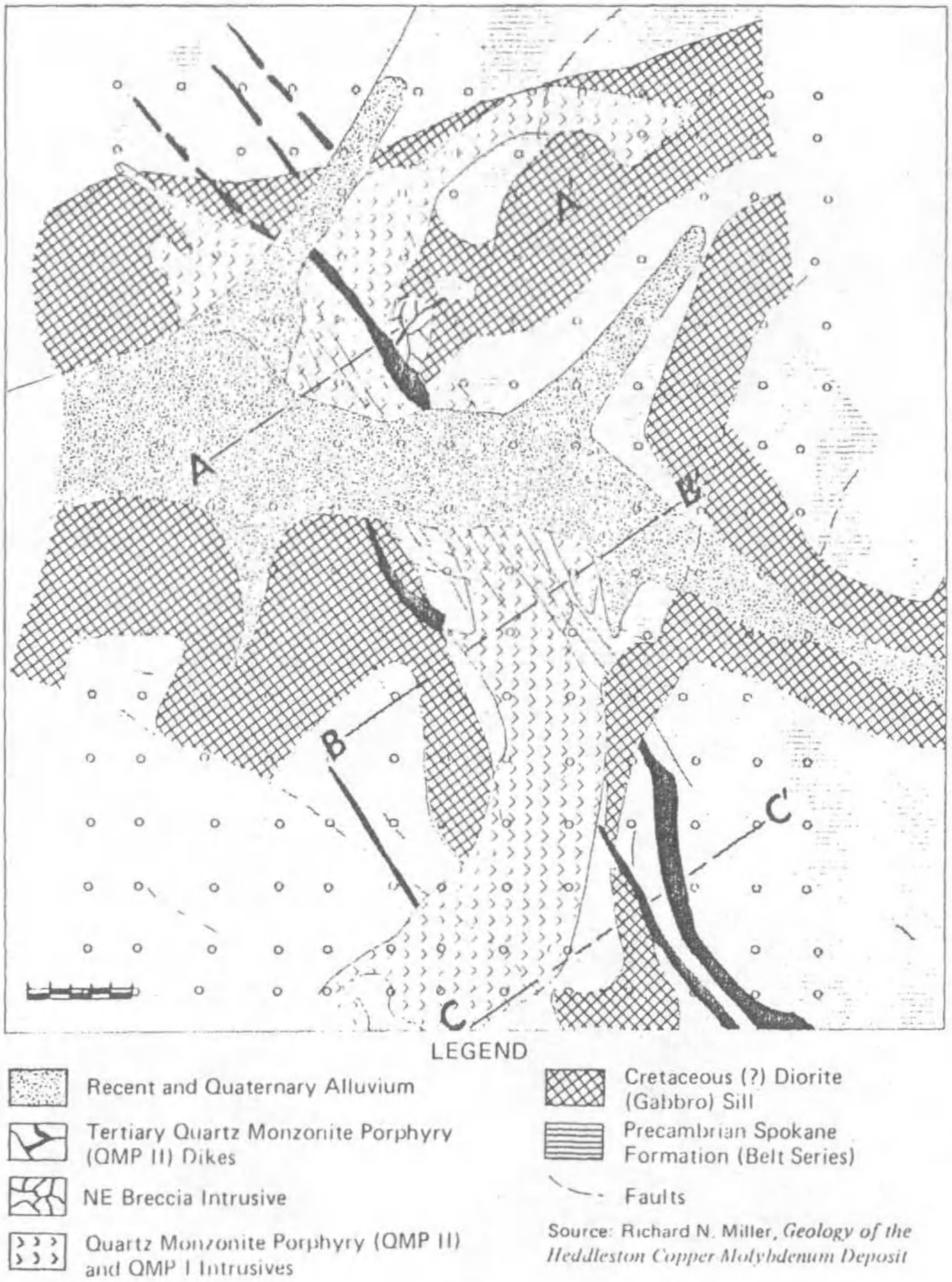
Archean(?) basement. The Heddleston deposit is located north of the Lewis and Clark Lineament.

Bedrock in the region is composed of a thick sequence of late Precambrian (Belt Series), Paleozoic and Mesozoic sediments which were deformed into broad open folds in the late Mesozoic. Major thrust faulting was widespread subsequent to the emplacement of the Boulder Batholith to the south in late Cretaceous time. A thick sheet of Precambrian Belt rocks and overlying Paleozoic and Mesozoic rocks were thrust eastward as the Lewis overthrust.

Igneous activity accompanied the late Cretaceous-early Tertiary folding and thrust faulting. Numerous dikes, sills, and plutons of diorite, quartz diorite and granodiorite were intruded, along with a thick flat-lying diorite-gabbro sill in the region surrounding the Heddleston deposit. Andesitic and latitic flows overlain by a series of rhyolite welded ash flows were extruded in Eocene time in areas to the south and southwest of Heddleston. Regional block faulting along older normal faults in Oligocene-Pliocene time and block uplift resulted in erosional removal of much of the volcanic cover.

## Geology of the Heddleston Deposit

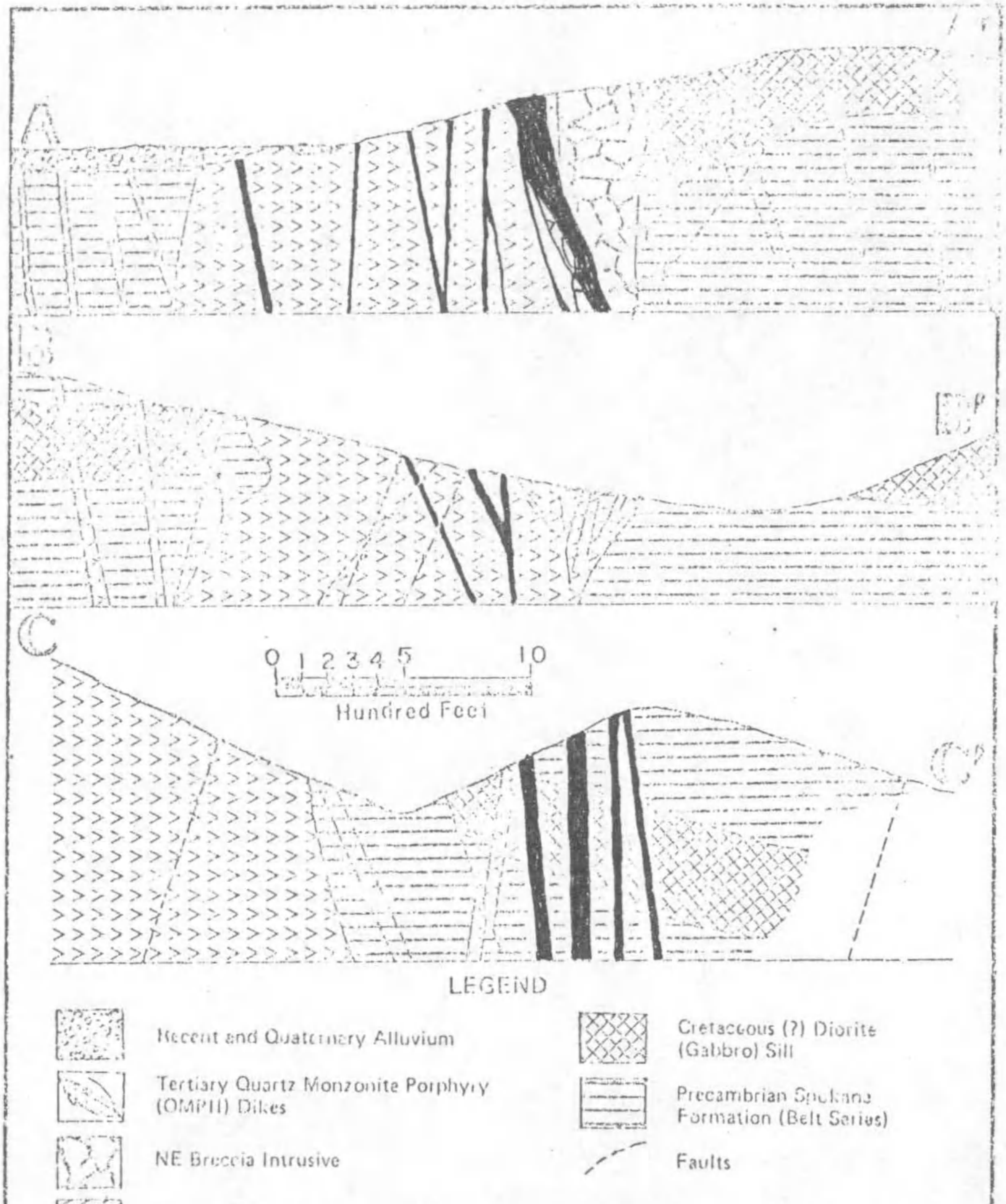
A geologic map and serial cross sections of the Heddleston deposit are shown on Figures 3 and 4. Both are modified after Miller, et al. (1973).



Source: Richard N. Miller, *Geology of the Heddleston Copper Molybdenum Deposit*

Bruce Castle, D.K. March 29, 1975

Figure 3 Geology of the Heddleston Deposit



Source: Richard N. Miller, *Geology of the Heddleston Copper-Molybdenum Deposit*

Figure 4 Geologic Cross-Sections of the Heddleston Deposit

Country rocks. Sedimentary rocks of the Precambrian (Belt Series) Spokane formation are the only non-igneous rocks in the vicinity of the Heddleston deposit. They include massive, light to dark gray quartzites and argillites which grade upward into medium-bedded red to green argillites. The beds are folded into a broad, closed anticlinal structure plunging to the north. Striked vary from N65°E to N50°E while dips vary 5° to 30° to the north.

A large, flat-laying, Cretaceous diorite (gabbro) sill outcrops in the central portion of the district. Its thickness ranges from 60 to 150 meters and its upper contact dips gently to the north, striking approximately northeast-southwest. Petrologically, the bulk of the unit is a hornblende diorite which locally grades into quartz diorite, augite diorite, and gabbro. A late crystallizing granophyric assemblage of quartz and potash feldspar is also present.

Structure. There are two major fault systems in the district, a northwesterly set, striking N50-70°W., and a northeasterly set, striking N20-40°E. Vertical displacement along two major faults in the northwest system exceed 120 meters in one case and 360 meters in another. Faults of both systems seem to have been active before, during and after mineralization. They also seem to have controlled the intrusion of porphyry dikes.

Porphyry Intrusions and Breccia Pipes. Three Tertiary porphyritic intrusions and two breccia pipes are found in the central part of the Heddleston district. They are collectively responsible for the primary copper-molybdenum mineralization and extensive hydrothermal alteration.

The main intrusive is a quartz monzonite porphyry with large phenocrysts of potash feldspar, plagioclase, biotite and quartz in an aplitic, quartzofeldspathic groundmass. In the area of the Midnight mine, a similar porphyry which lacks biotite is found in contact with the quartz monzonite porphyry. It may be a separate intrusion, though it is mapped as part of the quartz monzonite porphyry. Late stage quartz monzonite porphyry dikes with a strong northwesterly trend represent the final intrusive event in the district. Two breccia pipes containing fragments of sedimentary country rock as well as quartz monzonite are found near the margins of the main porphyry. They appear to have been associated with the intrusion of the main quartz monzonite porphyry.

Mineralization-alteration. The emplacement of porphyry intrusives and breccia pipes, copper-molybdenum mineralization, faulting and late-stage base and precious metal vein mineralization are all related in a very complex manner. Table 1 summarizes the mineralization history as deduced from field relationships.

Broadly speaking, there were several early mineralizing events characterized by quartz-molybdenite veins. These were followed by three or four additional veining events in which pyrite, chalcopyrite and molybdenite were deposited. Late stage mineralization then

Table 1. Tabulation of indicated intrusive-vein-alteration sequence in the Heddleston copper-molybdenum deposit, Lewis and Clark County, Montana. Scale of decreasing mineral abundance is $^{++}$, $^{+}$, no symbol, $^{-}$, and $^{=}$ for trace amounts only.

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Erosion and Supergene Enrichment

Latest fractures re-cemented by carbonate ++ -chalcopyrite-; local rhodochrosite ++.

Earlier veins re-fractured, re-opened; main inactive producing veins re-mineralized; late assemblage of chalcopyrite, sphalerite, sphalerite (chalcopyrite), galena, marcasite, arsenopyrite, comb quartz, carbonate and bornite-tennantite (only in large peripheral veins) introduced.

Later, tight quartz+-pyrite+ veinlets without alteration.

Intermediate-age quartz++-chalcopyrite$^{-}$-molybdenite$^{=}$ veinlets without strong sericitic alteration.

QMP II Dike Swarm; mostly unaltered, but very locally with weakly developed early 'hydrothermal' veins as below.

Main 'hydrothermal' stage; early quartz$^{++}$-pyrite$^{+}$-chalcopyrite$^{-}$ veinlets with strong, conspicuous sericitic-silicic-pyritic selvages; probably early vein 'frame work' in now inactive vein miners.

Quartz Porphyry and Breccia Pipe(s)

?'Background' Disseminated Chalcopyrite (molybdenite ?), and pyrite-chalcopyrite-alkali feldspar veinlets.

Late QMP I Dikes, Autointrusion, and Breccia intrusives

Later quartz$^{+}$ -pyrite-molybdenite-chalcopyrite-veinlets with weak sericitic alteration.

Early quartz$^{++}$-molybdenite$^{+}$ veinlets without alteration.

Early 'magmatic stage' barren quartz veins without alteration.

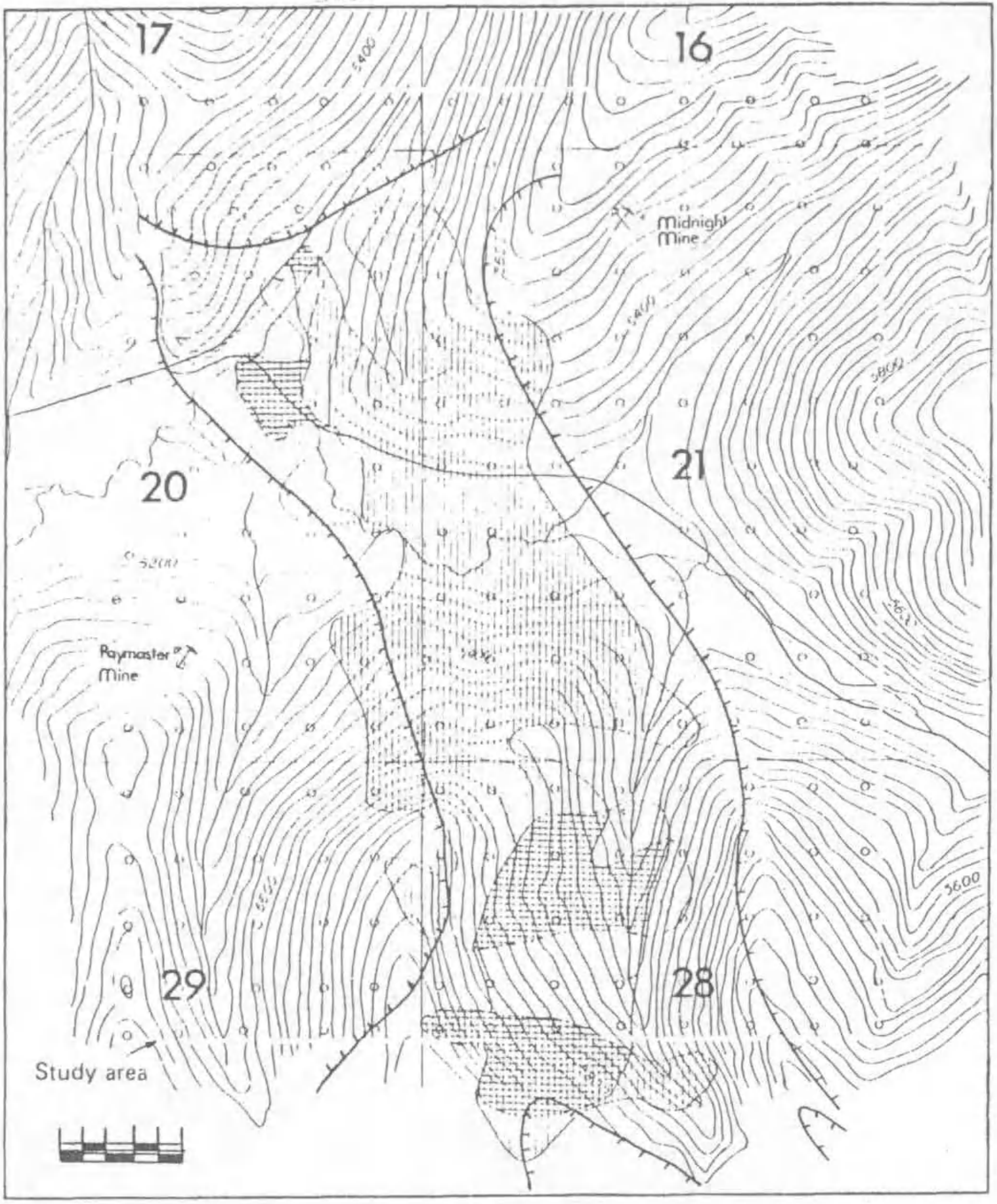
Main QMP I Intrusion (45-48 m.y.?)

Source: Miller et. al., 1973

followed depositing chalcopyrite, sphalerite, aglena, arsenopyrite, bornite, tennantite, pyrite, quartz and carbonate in refractured, earlier veins. The latest fractures contain carbonate, rhodochrosite, and chalcopyrite.

Hydrothermal alteration accompanying the different mineralizing events varied greatly in intensity. Argillic and sericitic alteration enveloped many of the veins. The aggregate effect of many periods of mineralization/alteration was to produce an extensive northwest-trending, hydrothermally altered zone superimposed on the main porphyry trend and adjacent contact areas (Figure 5).

Supergene enrichment, which often produces thick, high grade ore sections at other porphyry copper deposits, occurs in varying degrees in Heddleston. A uniform enrichment blanket is not present. Rather, such zones are localized along steeply dipping vein systems, in broad areas of quartz monzonite porphyry containing a strong primary chalcopyrite-pyrite component, and along extensively fractured contact zones.



Source: Richard N. Miller, *Geology of the Heddleston Copper-Molybdenum Deposit*

Figure 5

Mineralization and Wallrock Alteration at the Heddleston Deposit

# CHAPTER III

# SAMPLING AND ANALYTICAL METHODS

## Sampling

Samples of twigs two or three years old were systematically collected from mature Lodgepole pine trees (Pinus contorta) growing over mineralized and barren ground at Heddleston. Lodgepole pine was selected because it is the only plant species with a continuous distribution over the area of interest. Second and third year twig growth was sampled in preference to needles or bark, etc., on the basis of biogeochemical studies conducted in British Columbia. These studies indicated that this particular organ most accurately reflected substrata geochemistry (Warren, et al., 1955). Concomitant soil samples were also collected at each location. Sample sites were located at 500 foot intervals within a rectangular area measuring 7,300 feet N-S and 6,000 feet E-W. The area encompassed most of the deposit as it was known in 1973.

A five man team was required to efficiently sample the grid. Two men established sample stations using a brunton compass and 100 foot steel tape. Three samplers followed behind, one collecting soils, the other two collecting twig samples.

The brunton and tape crew ran the traverses primarily in a E-W direction, with some N-S traverses where topography dictated. Work began on the north edge of the area and proceeded south. End points of traverses were determined by measurement from drill collars, road intersections, etc., which were close to sample points. All traverses were either closed or run from one known point to another. Elevations were taken at each station to enable slope distances measured to be converted to actual map distances later. Most traverses crossed over enough known points that distances measured between known points were small, i.e. less than 1,500 feet. In these cases corrections were made in the field.

Obtaining a sufficient quantity of fine-grained soil was a problem due to its coarseness. Often there was only a thin veneer of humus overlying mixed soil and rock fragments, usually termed the "C" horizon. Composite samples were collected from shallow holes dug beneath the tree being sampled. They were stored in Kraft paper sample bags.

Lodgepole pine twigs were more difficult to collect. It was occasionally necessary to deviate as much as 100 feet from the ideal sample site in order to find a Lodgepole pine. Extendable pruners capable of reaching over 30 feet were used to clip actively growing branches from four or five locations around the circumference of the tree. The current year's growth was removed with stainless steel rose clippers and discarded, as was all growth older than three years. The second and third year growth was placed in a plastic bag. No attempt was made to remove the needles from the twigs in the field because this would have required too much time.

Two types of observational data were recorded in the field:

1. information related to sample stations location and,
2. observations which might be valuable in interpreting the plant and soil data.

The former includes the position of a sample point relative to main roads, drill roads, ponds, numbered drill collars, mine portals, streams and other land marks. The latter includes slope orientation, tree density, tree growth (vigorous versus stagnant), tree size, soil thickness, soil parent material, presence of slope wash contaminants (drill cuttings, mine drainage, dump material) and proximity to swampy or saturated ground. All the field observations are tabulated in Appendix I.

Paired soil and twig samples were collected at 198 sample sites in seven days. Ideally, there were 208 sites within the 6,000' x 7,500' sample grid, but 10 sample sites fell in inaccessible bogs.

At the close of the field work, the actual location of the sites sampled was determined by a combination of three steps:

1. When it was necessary to collect a sample away from the ideal grid station, the offset was measured and recorded. These offsets were then applied to the original sample grid.
2. Slope distances versus map distance calculations were made for each segment of traverses which did not end at a known map location. THese corrections were then made to the site locations.
3. The total error on closed traverses was noted in the field. This error was evenly distributed between all sites along the traverses.

The final estimates of sample site locations were then put on computer cards for use in subsequent trend surface analysis and plotted on the geologic and alteration maps (Figs. 3 and 5).

## Sample Preparation

Soil samples were dried, sieved and then dried to a constant weight. Once the samples were air dried in their Kraft envelopes, they were broken up in a porcelain mortar and sieved to -110 mesh with a silk screen sieve. The minus 110 mesh material was placed in jars, dried for 24 hours at 80°C, cooled in a desicator and then sealed.

Twig samples were stripped of their needles, rinsed in distilled water, air dried, ground to -40 mesh, and dried to constant weight.

Following collection, twig samples were allowed to air dry while the needles were hand picked. The twigs were rinsed three times in distilled water to remove surface contamination. They were then ground to -20 mesh. This ground material was placed in small wide mouth jars, dried for three days at 80°C, cooled in a desicator, and sealed.

## Analytical Procedures

Soil samples collected at Heddleston were analyzed for a variety of chemical parameters. PH, the only parameter measured in the field, was determined with a portable Orion pH meter utilizing unsieved material. All additional analyses were made in the laboratory subsequent to sieving and drying. Cold extractable copper and cold extractable heavy metals were analyzed using dithizone tests (Hawkes, 1968; Smith, 1964; and Holman, 1962). Organic carbon was determined by the Walkley-Black method (Black, 1968). Hot acid extractable Cu, Pb, Zn, Mo, Co, Ni, Ag, Bi, Cd, Fe and Mn determinations were made with a Techtron AA-6 atomic absorption spectrophotometer utilizng a method similar to that of the U.S.G.S. (Ward, et al., 1969). An atomic absorption procedure formeasuring "available" cations developed by Dr. Nellie Stark (University of Montana Forestry School) was also used. Details of all the soil analytical procedures are given in Appendix II.

Plant samples were wet ashed and analyzed by atomic absorption for the same suite of cations mentioned above. A detailed discussion of the methods used is given in Appendix II.

# CHAPTER IV

# RESULTS

## Introduction

Over 7,000 analytical determinations were made on the plant and soil samples collected at Heddleston. Many of the elements sought were not present in amounts above their detection limits on the atomic absorption spectrophotometer, e.g., molybdenum. Data sets with few or no detectable results were not considered for subsequent interpretation. The results are summarized in Table 2. Complete listings of all of the raw data are incorporated in Appendices III, IV and V.

Due to the volume of data generated by the geochemical survey, computerized statistical analysis and simple graphical analyses were deemed the most efficient means of extracting the data's information content. This involved correlation analysis, log-log plots of plant versus soil parameters, and trend surface analysis. The first two methods were selected to evaluate interrelationships among the many plant and soil parameters measured. The trend surface methodology was selected to depict the "geochemical landscape" without the potential bias or tremendous investment in time involved in hand contouring. All the statistical work was completed on the University of Montana's DEC-10 computer.

Table 2. Statistical Summary, Soil and Plant Sample Analyses

| Sample Type and Element | Mean (ppm) | Std. Dev. | Range (ppm) |
|---|---|---|---|
| Soil Cu | 72 | 206 | 5 - 2725 |
| Soil Pb | 167 | 744 | 20 - 10,000 |
| Soil Zn | 119 | 442 | 7 - 500 |
| Soil Mn | 198 | 235 | 8 - 1775 |
| Soil Fe | 13,536 | 9,300 | 5000 - 83,750 |
| Avail. Zn | 6.6 | 30.4 | 0.2 - 332 |
| Avail. Mn | 25.0 | 30.3 | 1 - 236 |
| Avail. Fe | 11.0 | 18.2 | 2 - 244 |
| Cold Ext. Cu | 3.9 | 14.0 | 1 - 100 |
| Cold Ext. T.H.M. | 17.4 | 21.3 | 1 - 105 |
| pH | 5.1 (pH units) | 0.7 | 3.5 - 6.8 |
| Organic Carbon | 2.1% | 1.4 | 0.3 - 9.4 |
| Plant Cu | 12.9 | 3.8 | 7 - 29 |
| Plant Pb | 24.5 | 8.1 | 12 - 70 |
| Plant Zn | 67.2 | 38.0 | 37 - 298 |
| Plant Mn | 21.1 | 11.0 | 39 - 66 |
| Plant Fe | 306 | 88 | 156 - 668 |
| Plant Cd | 7.4 | 3.4 | 4 - 26 |
| Plant Ni | 6.3 | 6.1 | 2 - 52 |

## Correlation Analysis

Estimates of the degree of interrelation between two variables in a manner not influenced by their units of measurement can be obtained in two ways. Most commonly the Pearson product moment or so-called "linear" correlation coefficient is calculated. As the name implies, this statistic is an expression of the linear relationship between two variables. An underlying assumption is that both sample populations must be normally distributed. A second approach is calculation of the Spearman rank correlation coefficient. This method also quantifies the strength of the linear relationship between variables; however, since it is "non-parametric" there is no underlying assumption concerning the population distribution.

In order to evaluate the potential efficacy of utilizing Pearson's coefficient, histograms were drawn for all the Heddleston data sets (Appendix VI). Examination of these histograms indicated that both normal and log-normal distributions were present, and that virtually all were multimodal. As a result, the non-parametric Spearman test statistic was selected for correlation analysis.

Spearman rank correlation coefficients for all plant and soil parameters are presented in Figure 6. A detailed discussion of their significance follows in Chapter V.

|  | Plant Copper | Plant Lead | Plant Zinc | Plant Cadmium | Plant Nickel | Plant Manganese | Plant Iron | Soil Copper | Soil Lead | Soil Zinc | Soil Manganese | Soil Iron | Available Zinc | Available Manganese | Available Iron | Cold Extract. Heavy Metals | Cold Extract. Copper | pH | Organic Carbon |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant Copper |  | 0.36 | 0.17 | 0.29 | 0.46 | -.18 | 0.38 | 0.09 | 0.13 | 0.18 | 0.11 | -.01 | -.01 | 0.00 | -.06 | 0.11 | 0.20 | 0.00 | 0.19 |
| Plant Lead | S** |  | -.16 | 0.11 | 0.32 | -.07 | 0.56 | -.20 | 0.00 | - 01 | 0.10 | -.11 | 0.07 | 0.22 | 0.03 | -.03 | -.04 | -.12 | 0.07 |
| Plant Zinc | S | S |  | 0.48 | 0.16 | 0.08 | -.05 | 0.28 | 0.27 | 0 46 | 0.23 | 0.05 | 0.16 | -.09 | -.07 | 0.35 | 0.30 | 0.30 | 0.12 |
| Plant Cadmium | S** | NS | S** |  | 0.13 | 0.00 | 0.15 | 0.14 | 0.34 | 0.53 | 0.31 | -.08 | 0.22 | 0.11 | -.07 | 0.31 | 0.27 | 0.15 | 0.16 |
| Plant Nickel | S** | S** | S | PS |  | -.05 | 0.22 | 0.11 | 0.08 | 0.12 | 0.06 | 0.03 | 0.04 | 0.04 | -.06 | 0.08 | 0.14 | -.03 | 0.11 |
| Plant Manganese | S | NS | NS | NS | NS |  | 0.08 | -.25 | -.02 | -.14 | -.14 | -.17 | 0.15 | 0.21 | -.17 | -.23 | -.38 | -.15 | -.14 |
| Plant Iron | S** | S** | NS | S | S* | NS |  | 0.14 | 0.06 | -.12 | -.15 | 0.13 | 0.19 | 0.00 | -.02 | -.06 | -.03 | -.13 | -.09 |
| Soil Copper | NS | S* | S** | PS | NS | S** | S |  | 0.28 | -.02 | -.16 | 0.69 | 0.15 | -.41 | 0.09 | 0.30 | 0.50 | 0.24 | -.05 |
| Soil Lead | PS | NS | S** | S** | NS | NS | NS | S** |  | 0.33 | 0.21 | 0.15 | 0.20 | 0.10 | 0.03 | 0.30 | 0.28 | 0.06 | 0.06 |
| Soil Zinc | S | NS | S** | S** | NS | PS | PS | NS | S** |  | 0.78 | -.21 | 0.00 | 0.39 | -.16 | 0.60 | 0.36 | 0.24 | 0.57 |
| Soil Manganese | NS | NS | S* | S** | NS | S | S | S | S* | S** |  | -.18 | -.16 | 0.60 | -.13 | 0.41 | 0.27 | 0.23 | 0.58 |
| Soil Iron | NS | NS | NS | NS | NS | S | PS | S** | S | S* | S* |  | -.03 | -.28 | 0.16 | 0.08 | 0.27 | 0.12 | -.15 |
| Available Zinc | NS | NS | S | S* | NS | S | S* | S | S* | NS | S | NS |  | 0.14 | 0.05 | 0.26 | 0.06 | -.11 | -.15 |
| Available Manganese | NS | S* | NS | NS | NS | S* | NS | S** | NS | S** | S** | S** | PS |  | -.11 | 0.14 | -.01 | -.13 | 0.25 |
| Available Iron | NS | NS | NS | NS | NS | S | NS | NS | NS | S | PS | S | NS | NS |  | -.05 | 0.18 | -.07 | 0.07 |
| Cold Extractable Heavy Metals | NS | NS | S** | S** | NS | S* | NS | S** | S** | S** | S** | NS | S** | PS | NS |  | 0.51 | 0.23 | 0.40 |
| Cold Extractable Copper | S* | NS | S** | S** | PS | S** | NS | S** | S** | S** | S** | S** | NS | NS | S | S** |  | 0.15 | 0.38 |
| pH | NS | NS | S** | S | NS | S | PS | S** | NS | S** | S* | PS | NS | PS | NS | S* | S |  | 0.16 |
| Organic Carbon | S | NS | NS | S | NS | PS | NS | NS | NS | S** | S** | S | S | S** | NS | S** | S** | S |  |

Figure 6 SPEARMAN RANK CORRELATION COEFFICIENTS FOR PLANT AND SOIL ANALYSES. STATISTICAL SIGNIFICANCE IS CLASSIFIED UTILIZING THE PROBABILITY, P, THAT NO RELATIONSHIP EXISTS, ACCORDING TO THE SCHEME PROPOSED BY BROOKS (1972).

NS = NOT SIGNIFICANT; P IS GREATER THAN 0.10
PS = POSSIBLY SIGNIFICANT; P IS BETWEEN 0.10 AND 0.05
S = SIGNIFICANT; P IS BETWEEN 0.05 AND 0.01
S* = HIGHLY SIGNIFICANT; P IS BETWEEN 0.01 AND 0.001
S** = VERY HIGHLY SIGNIFICANT; P IS LESS THAN 0.001

## Graphical Analysis

The nature of the plant-soil relationship at Heddleston was further investigated utilizing simple graphical techniques proposed by Brooks (1972) and Timperley, et al. (1970).

These authors found that for some elements a simple linear relationship exists between the metal content of the soil and the plants relative uptake of that element. Figure 7 illustrates such a relationship for copper at Heddleston. A detailed discussion of this plot and others follows in Chapter VI.

## Trend Surface Analysis

Trend surface analysis is a mathematical method for separating relatively large-scale systematic changes in mapped data (i.e. the trend) from essentially non-systematic small-scale variations due to local effects (i.e. the residuals). Utilizing geochemical data for illustrative purposes, the assumption is that the areal variation in the abundance of an element can be represented by a function $Z=f(x_1, x_2)$ where $x_1$ and $x_2$ are the geographic coordinates of a point and Z is the abundance of the element at that point. This trend function is further assumed to be a linear polynomial function.

Davis (1973) gives an operational definition of the trend as "a linear function of the geographic coordinates of a set of observations so constructed that the squared deviations from the trend are minimized." Hence trend surface analysis is merely an extension of

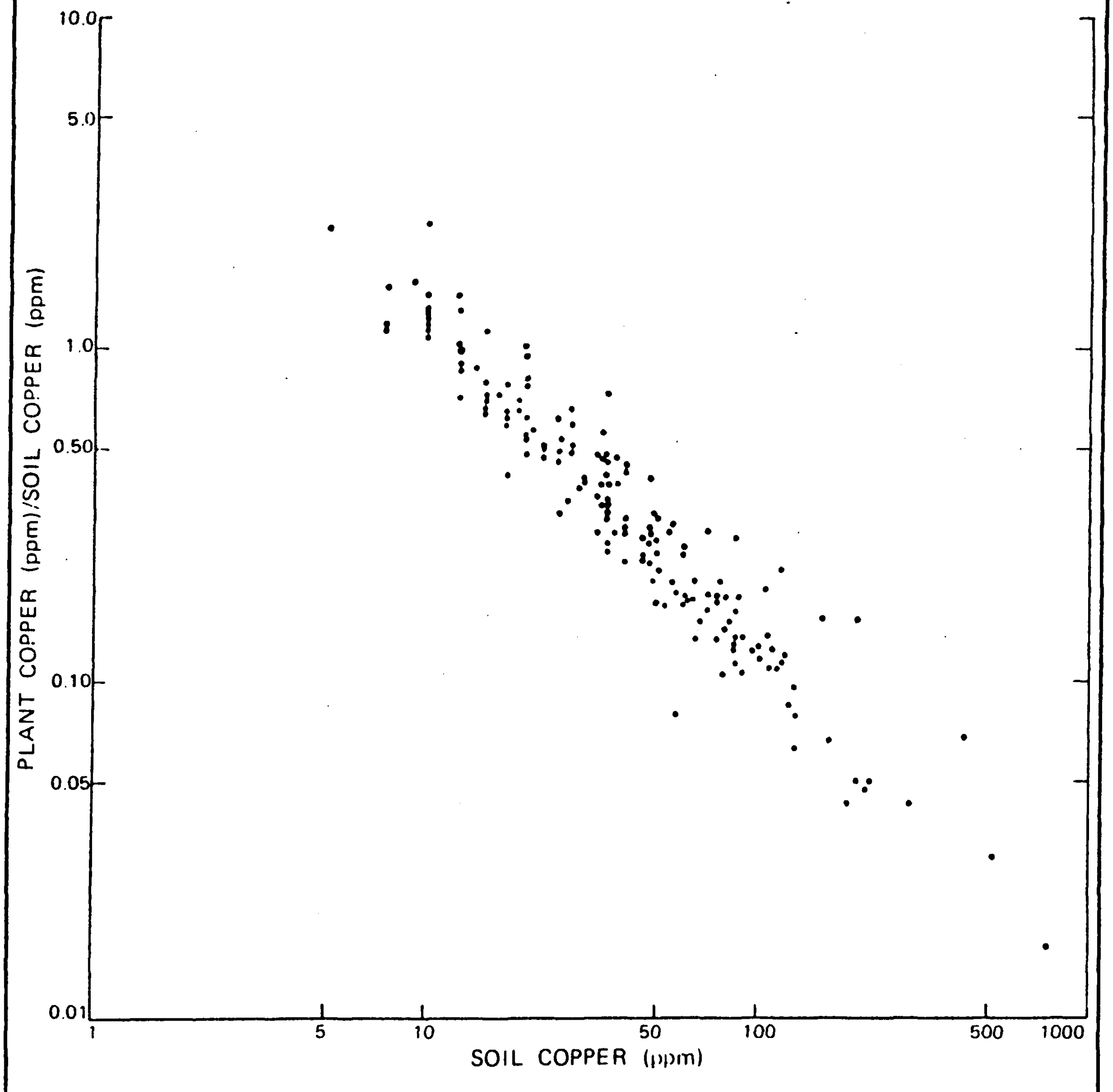


Figure 7 Relative Accumulation of Copper in Lodgepole Pine

simple regression analysis. For further information the reader is referred to Davis (1973) and Koch and Link (1971).

Trend surface methodology was utilized for evaluating Heddleston geochemical data for two pragmatic reasons. First, the technique has been successfully applied in mineral exploration studies. Several examples include Nordeng et al. (1964) and Connor and Miesch (1964). Second, it was the only contouring technique available on the University of Montana DEC-10 computer at the time the project was undertaken. Hand contouring was deemed too labor intensive to be practical and potentially could be influenced by personal bias.

Figure 8 is a 6th order trend surface for copper in Heddleston soil samples. A detailed discussion of this and other trend surfaces follows in Chapter VII.

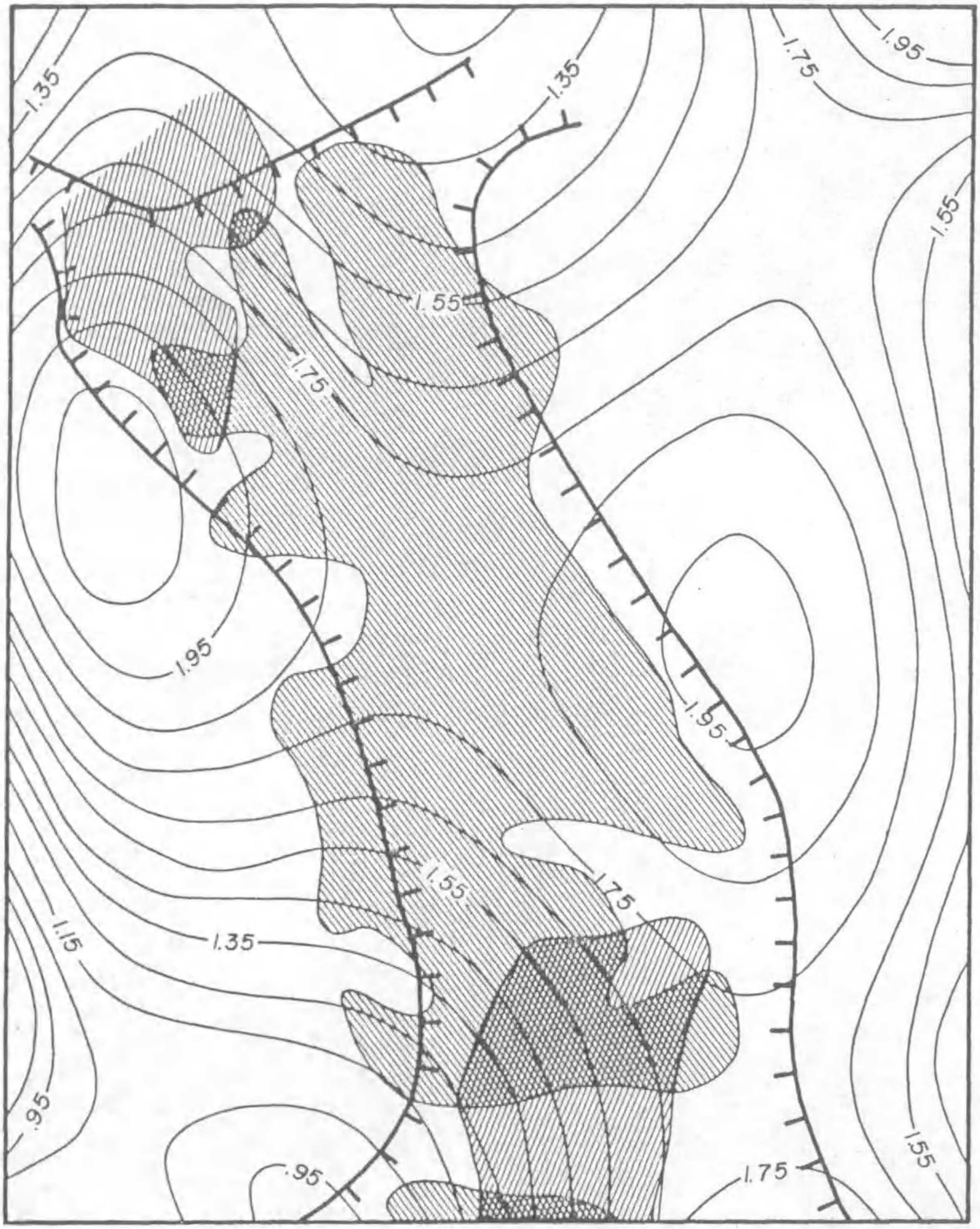


Figure 8 6th ORDER TREND SURFACE- SOIL COPPER ANALYSES ( $\mathrm{LOG}_{10}$ TRANSFORMED )

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.1 LG OF PPM

r = CORRELATION COEFFICIENT
r = 0.68

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.46

N

# CHAPTER V

# CORRELATION ANALYSES: DISCUSSION AND INTERPRETATION

In view of the large number of plant variables measured during the study, discussion of the correlation analysis is most conveniently approached in a sequential manner, starting with soil parameters and proceeding through plant parameters.

## Soil Parameters

Spearman rank correlation coefficients for hot acid extractable base metals in soils are arranged in matrix form in Figure 9. An evaluation of the statistical significance of the coefficients is also given, utilizing a scheme proposed by Brooks (1972).

Two fundamental base metal associations are suggested by the soil samples, copper-iron and zinc-manganese. These element pairs have the highest correlation coefficients in the entire matrix; a plot of soil zinc versus soil manganese (Figure 10) visually attests to the strength of this association. Highly significant negative correlations between copper-manganese, iron-manganese, and zinc-iron are further evidence that base metal partitioning is a fundamental characteristic of the Heddleston soil environment. Lead is the only metal which correlates positively with both groups, though its association with iron appears to be somewhat weaker than with the other base metals.

| | Soil Copper | Soil Lead | Soil Zinc | Soil Manganese | Soil Iron |
|---|---|---|---|---|---|
| Soil Copper | | 0.28 | - .02 | - .16 | 0.69 |
| Soil Lead | S** | | 0.33 | 0.21 | 0.15 |
| Soil Zinc | NS | S** | | 0.78 | - .21 |
| Soil Manganese | S | S* | S** | | - .18 |
| Soil Iron | S** | S | S* | S* | |

NS = Not Significant; P is greater than 0.10
PS = Possibly Significant; P is between 0.10 and 0.05
S = Significant; P is between 0.05 and 0.01
S* = Highly Significant; P is between 0.01 and 0.001
S** = Very Highly Significant; P is less than 0.001

Figure 9. Spearman rank correlation coefficients for soil analyses (hot acid extraction). Statistical significance is classified utilizing the probability, P, that no relationship exists, after the scheme proposed by Brooks (1972).

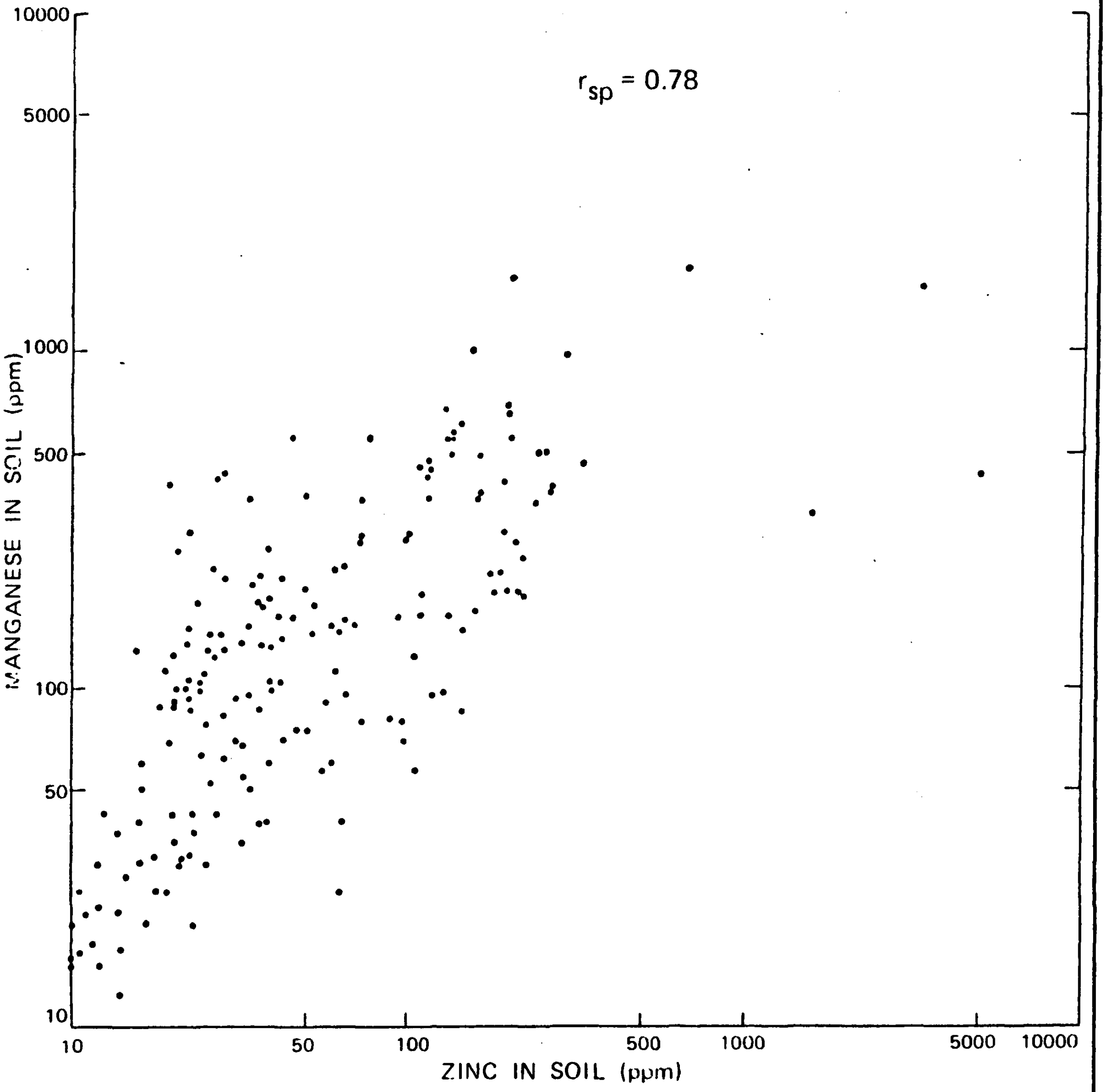


Figure 10 Soil Zinc plotted against Soil Manganese

These relationships can be interpreted in terms of primary differences in the spatial distribution of sulfide minerals. Base metal vein-type mineralization occurs in areas peripheral to the porphyry system and is dominated by lead and zinc minerals with subordinate copper and manganese (Table 1). This contrasts with later vein/disseminated pyrite and chalcopyrite which characterize the porphyry system. The study area encompasses both mineralized environments, and the correlation coefficients reflect this fact.

However, since zinc and lead sulfides occur together, the zinc-iron and zinc-manganese correlations should be similar to those of lead-iron and lead-manganese if primary relationships are the only causal influence. Their dissimilarity in magnitudes and/or signs of the correlation coefficients suggests that secondary effects are substantial. Indeed, Pardee and Schrader (1933) report that sulfides in the lead-zinc vein systems of the Heddleston District are heavily oxidized to depths of 15 to 30 meters. In these instances the original minerals have been converted to a spongy mass of iron oxides, manganese oxides, and cerrusite. This suggests that hydrous manganese oxides are the dominant control in scavenging zinc released by the oxidation of sulfides. On the other hand, iron oxides seem to be the dominant control for copper fixation. Lead fixation is influenced by both oxides, though to a lesser degree, reflecting its occurrence as cerrusite in the weathering environment. These observations are supported conceptually by a number of recent papers which document the selective scavenging effects of iron and manganese oxides (e.g., Chao and Anderson, 1974).

Expanding the correlation matrix to include weak acid extractable or "available" metals gives further insight into the soil geochemistry at Heddleston (Figure 11). These "availability" determinations measure only those weakly bonded base metal cations which can be extracted by 0.002 N $H_2SO_4$. Of all the metals analyzed, only zinc, manganese and iron occur in detectable concentrations.

The relationships between available zinc and many of the aforementioned soil analyses are unusual. A weak but significant positive correlation with soil copper emerges as does a weak but significant negative correlation with soil manganese. Even more intriguing is the lack of correlation with soil zinc. Available zinc shows a highly significant positive correlation with soil lead. Soil iron is uncorrelated. These results suggest that virtually none of the zinc sequestered by hydrous manganese oxides is exchangeable with low concentrations of $H^+$ ions. (In terms of analytical technique, it also implies that the weak acid extracting solution could not dissolve a significant proportion of the manganese oxides.) In view of this, the positive correlations with lead and copper must reflect zinc sited within another type of mineralogical matrix. Since both accessory cerrusite and malachite/azurite are reported in the weathered vein

|  | Soil Copper | Soil Lead | Soil Zinc | Soil Manganese | Soil Iron | Avail. Zinc | Avail. Manganese | Avail. Iron |
|---|---|---|---|---|---|---|---|---|
| Soil Copper |  | 0.28 | - .02 | - .16 | 0.69 | 0.15 | - .41 | 0.09 |
| Soil Lead | S** |  | 0.33 | 0.21 | 0.15 | 0.20 | 0.10 | 0.03 |
| Soil Zinc | NS | S** |  | 0.78 | - .21 | 0.00 | 0.39 | - .16 |
| Soil Manganese | S | S* | S** |  | - .18 | - .16 | 0.60 | - .13 |
| Soil Iron | S** | S | S* | S* |  | - .03 | - .28 | 0.16 |
| Avail. Zinc | S | S* | NS | S | NS |  | 0.14 | 0.05 |
| Avail. Manganese | S** | NS | S** | S** | S** | PS |  | - .11 |
| Avail. Iron | NS | NS | S | PS | S | NS | NS |  |

Figure 11. Spearman rank correlation coefficients for soil analyses (hot acid and weak acid extractions). Statistical significance is classified utilizing the probability, P, that no relationship exists, according to the scheme proposed by Brooks (1972).

NS = Not Significant; P is greater than 0.10
PS = Possibly Significant; P is between 0.10 and 0.05
S = Significant; P is between 0.05 and 0.01
S* = Highly Significant; P is between 0.01 and 0.001
S** = Very Highly Significant; P is less than 0.001

deposits of the Heddleston District (Pardee and Schrader, 1933), it seems reasonable to assume that hydrozincite and/or smithsonite are also present. Hence, the positive correlations between available zinc and both copper and lead may reflect an association of base metal carbonates.

Available manganese correlates with base metal soil analyses in a more predictable manner. The strong, very highly significant relationships to soil, copper, zinc, manganese and iron indicate that most of the available manganese is derived from hydrous manganese oxides. Previous results implied that weak acid does not dissolve manganese oxides; hence, the direct correlation between available manganese and soil manganese can only be explained by divalent manganese ions occupying exchange active sites on the manganese oxide surface. The very weak positive correlation with available zinc suggests that a minor component of available manganese could also be derived from manganiferous carbonate.

The relationships between available iron and base metal soil analyses are also not unusual. The weak positive correlation with soil iron indicates that increasing amounts of iron oxide in the soil hardly affect the amount of iron that can be extracted by weak acid solutions.

|  | Soil Copper | Soil Lead | Soil Zinc | Soil Manganese | Soil Iron | Avail. Zinc | Avail. Manganese | Avail. Iron | Cold Ext. H.M. | Cold. Ext. Copper |
|---|---|---|---|---|---|---|---|---|---|---|
| Soil Copper |  | 0.28 | -.02 | -.16 | 0.69 | 0.15 | -.41 | 0.09 | 0.30 | 0.50 |
| Soil Lead | S** |  | 0.33 | 0.21 | 0.15 | 0.20 | 0.10 | 0.03 | 0.30 | 0.28 |
| Soil Zinc | NS | S** |  | 0.78 | -.21 | 0.00 | 0.39 | -.16 | 0.50 | 0.36 |
| Soil Manganese | S | S* | S** |  | -.18 | -.16 | 0.60 | -.13 | 0.41 | 0.27 |
| Soil Iron | S** | S | S* | S* |  | -.03 | -.28 | 0.16 | 0.08 | 0.27 |
| Avail. Zinc | S | S* | NS | S | NS |  | 0.14 | 0.05 | 0.26 | 0.06 |
| Avail. Manganese | S** | NS | S** | S** | S** | PS |  | -.11 | 0.14 | -.01 |
| Avail. Iron | NS | NS | S | PS | S | NS | NS |  | -.05 | 0.18 |
| Cold Ext. HM | S** | S** | S** | S** | NS | S** | PS | NS |  | 0.51 |
| Cold Ext. Copper | S** | S** | S** | S** | S** | NS | NS | S | S** |  |

Figure 12. Spearman rank correlation coefficients for soil analyses (hot acid, weak acid and ammonium citrate extractions). Statistical significance is classified utilizing the probability, P, that no relationship exists, according to the scheme proposed by Brooks (1972).

NS = Not Significant; P is greater than 0.10
PS = Possibly Significant; P is between 0.10 and 0.05
S = Significant; P is between 0.05 and 0.01
S* = Highly Significant; P is between 0.01 and 0.001
S** = Very Highly Significant; P is less than 0.001

Figure 12 represents a further expansion of the correlation matrix to incorporate the results of a second partial extraction technique, the ammonium citrate or so-called "cold extractable" metals. Two types of determinations are represented: cold extractable "heavy metals" and cold extractable copper. In theory, the cold extractable "heavy metals" measures a combination of metals, i.e., copper, lead, zinc, cobalt, nickel, silver and tin, though in fact, zinc is the dominant cation determined (Smith, 1964). As the name suggests, cold extractable copper is specific for that element.

The results of both cold extractable techniques show very highly significant positive correlations with virtually all the hot acid soil results. Only soil iron and cold extractable heavy metals do not correlate. In addition, cold extractable heavy metals shows a strong positive relationship to available zinc, and cold extractable copper a weak but significant positive relationship to available iron.

These correlations are readily explicable. Since cold extractable heavy metals determinations include copper, lead and zinc, the positive correlations with these metals are reasonable. Similarly, since zinc is the metal which is dominantly being measured, the strong association with soil manganese is also reasonable, especially in light of the control of zinc by secondary manganese oxides.

Furthermore, if the relationships among soil zinc, soil manganese, available zinc, and cold extractable heavy metals are considered, it is obvious that ammonium citrate is more efficient or effective at extracting zinc from the hydrous manganese oxides than is a weak acid solution. This may mean that ammonium citrate is able to cause zinc desorption from exchange sites that $H^+$ ions cannot affect, and/or there is some dissolution of the manganese oxides by hydroxylamine hydrochloride which thereby releases both absorbed and occluded zinc. The cold extractable copper relationships with the base metal soil analyses reflect the presence of copper mineralization associated with both peripheral lead-zinc-manganese veins and porphyry hosted pyrite-chalcopyrite veinlets.

Two more quantifiable soil parameters are added to the correlation matrix in Figure 13. These are pH and organic carbon. Both variables are often cited as major controls of soil geochemistry (e.g., Mitchell, 1972).

Very highly significant positive correlations are evidence between soil pH and both soil copper and soil zinc. Weaker but still significant positive correlations also occur between pH and soil manganese, cold extractable heavy metals and cold extractable copper. These all seem reasonable in that most base metals become less mobile with increasing pH, thereby concentrating in the soil system rather than being leached out.

Organic carbon shows strong positive correlations with soil zinc, soil manganese, available manganese, cold extractable heavy metals and cold extractable copper. A weak positive correlation exists between

|  | Soil Copper | Soil Lead | Soil Zinc | Soil Manganese | Soil Iron | Avail. Zinc | Avail. Manganese | Avail. Iron | Cold Ext. H.M. | Cold Ext. Copper | pH | Organic Carbon |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil Copper |  | 0.28 | -.02 | -.16 | 0.69 | 0.15 | -.41 | 0.09 | 0.30 | 0.50 | 0.24 | -.05 |
| Soil Lead | S** |  | 0.33 | 0.21 | 0.15 | 0.20 | 0.10 | 0.03 | 0.30 | 0.28 | 0.06 | 0.06 |
| Soil Zinc | NS | S** |  | 0.78 | -.21 | 0.00 | 0.39 | -.16 | 0.50 | 0.36 | 0.24 | 0.57 |
| Soil Manganese | S | S* | S** |  | -.18 | -.16 | 0.60 | -.13 | 0.41 | 0.27 | 0.23 | 0.58 |
| Soil Iron | S** | S | S* | S* |  | -.03 | -.28 | 0.16 | 0.08 | 0.27 | 0.12 | -.15 |
| Avail. Zinc. | S | S* | NS | S | NS |  | 0.14 | 0.05 | 0.26 | 0.06 | -.11 | -.15 |
| Avail. Manganese | S** | NS | S** | S** | S** | PS |  | -.11 | 0.14 | -.01 | -.13 | 0.25 |
| Avail. Iron | NS | NS | S | PS | S | NS | NS |  | -.05 | 0.18 | -.07 | 0.07 |
| Cold Ext. HM | S** | S** | S** | S** | NS | S** | PS | NS |  | 0.51 | 0.23 | 0.40 |
| Cold Ext. Copper | S** | S** | S** | S** | S** | NS | NS | S | S** |  | 0.15 | 0.38 |
| pH | S** | NS | S** | S* | PS | NS | PS | NS | S* | S |  | 0.16 |
| Organic Carbon | NS | NS | S** | S** | S | S | S** | NS | S** | S** | S |  |

Figure 13. Spearman rank correlation coefficients for all soil analyses. Statistical significance is classified utilizing the probability, P, that no relationships exists, according to the scheme proposed by Brooks (1972).

NS = Not Significant; P is greater than 0.10
PS = Possibly Significant; P is between 0.10 and 0.05
S = Significant; P is between 0.05 and 0.01
S* = Highly Significant; P is between 0.01 and 0.001
S** = Very Highly Significant; P is less than 0.001

organic carbon and pH. Weak negative correlations occur between organic carbon and both soil iron and available zinc. At first glance these results could be interpreted to mean that zinc and manganese concentrations are strongly controlled by organic matter. This is reasonable because organic compounds have long been touted as potent controls in soil geochemistry via such mechanisms as chelation and adsorption (Mitchell, 1972).

However, this close association with manganese is disquieting in view of the method utilized to measure organic carbon. The Walkley-Black method utilizes a heated mixture of $H_2SO_4$ and $K_2CR_2O_7$ to indirectly determine oxidizable is calculated from the amount of $Cr_2O_7^{-2}$ reduced assuming this reduction to be solely the result of organic matter. It seems quite possible that $Mn^{++}$ released by the action of hot $H_2SO_4$ on manganiferous carbonates and oxides could also reduce $Cr_2O_7^{-2}$. Hence the organic carbon analyses measure <u>both</u> oxidizable organic matter and oxidizable $Mn^{++}$. Soil manganese and organic carbon yield an amazingly similar suite of correlations (Table 3) which further suggests that $Mn^{++}$ is the dominant constituent measured by the organic carbon analyses.

## Plant Parameters

The addition of plant elemental data completes the correlation matrix for the Heddleston samples (Figure 14). Included are cadmium and nickel, two elements which yielded consistently detectable results for plant samples, though not for soils.

Table 3. Comparative Spearman Rank Correlation Coefficients, Soil Manganese and Organic Carbon

| | Soil Manganese | | Organic Carbon | |
|---|---|---|---|---|
| Soil Zinc | 0.78 | S** | 0.57 | S** |
| Soil Manganese | -------- | | 0.58 | S** |
| Soil Iron | - .18 | S* | - .15 | S |
| Avail. Zinc | - .16 | S | - .15 | S |
| Avail. Manganese | 0.60 | S** | 0.25 | S** |
| Avail. Iron | - .13 | PS | 0.07 | NS |
| Cold Ext. H.M. | 0.41 | S** | 0.40 | S** |
| Cold Ext. Copper | 0.27 | S** | 0.38 | S** |
| pH | 0.23 | S* | 0.16 | S |

Note: Statistical significance classified utilizing the probability, P, that no relationship exists, according to the scheme proposed by Brooks (1972).

NS = Not Significant; P is greater than 0.10
PS = Possibly Significant; P is between 0.10 and 0.05
S = Significant; P is between 0.05 and 0.01
S* = Highly Significant; P is between 0.01 and 0.001
S** = Very Highly Significant; P is less than 0.001

|  | Plant Copper | Plant Lead | Plant Zinc | Plant Cadmium | Plant Nickel | Plant Manganese | Plant Iron | Soil Copper | Soil Lead | Soil Zinc | Soil Manganese | Soil Iron | Available Zinc | Available Manganese | Available Iron | Cold Extract. Heavy Metals | Cold Extract. Copper | pH | Organic Carbon |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant Copper |  | 0.36 | 0.17 | 0.29 | 0.46 | -.18 | 0.38 | 0.09 | 0.13 | 0.18 | 0.11 | -.01 | -.01 | 0.00 | -.06 | 0.11 | 0.20 | 0.00 | 0.19 |
| Plant Lead | S** |  | -.16 | 0.11 | 0.32 | -.07 | 0.56 | -.20 | 0.00 | - 01 | 0.10 | -.11 | 0.07 | 0.22 | 0.03 | -.03 | -.04 | -.12 | 0.07 |
| Plant Zinc | S | S |  | 0.48 | 0.16 | 0.08 | -.05 | 0.28 | 0.27 | 0 46 | 0.23 | 0.05 | 0.16 | -.09 | -.07 | 0.35 | 0.30 | 0.30 | 0.12 |
| Plant Cadmium | S** | NS | S** |  | 0.13 | 0.00 | 0.15 | 0.14 | 0.34 | 0.53 | 0.31 | -.08 | 0.22 | 0.11 | -.07 | 0.31 | 0.27 | 0.15 | 0.16 |
| Plant Nickel | S** | S** | S | PS |  | -.05 | 0.22 | 0.11 | 0.08 | 0.12 | 0.06 | 0.03 | 0.04 | 0.04 | -.06 | 0.08 | 0.14 | -.03 | 0.11 |
| Plant Manganese | S | NS | NS | NS | NS |  | 0.08 | -.25 | -.02 | -.14 | -.14 | -.17 | 0.15 | 0.21 | -.17 | -.23 | -.38 | -.15 | -.14 |
| Plant Iron | S** | S** | NS | S | S* | NS |  | 0.14 | 0.06 | -.12 | -.15 | 0.13 | 0.19 | 0.00 | -.02 | -.06 | -.03 | -.13 | -.09 |
| Soil Copper | NS | S* | S** | PS | NS | S** | S |  | 0.28 | -.02 | -.16 | 0.69 | 0.15 | -.41 | 0.09 | 0.30 | 0.50 | 0.24 | -.05 |
| Soil Lead | PS | NS | S** | S** | NS | NS | NS | S** |  | 0.33 | 0.21 | 0.15 | 0.20 | 0.10 | 0.03 | 0.30 | 0.28 | 0.06 | 0.06 |
| Soil Zinc | S | NS | S** | S** | NS | PS | PS | NS | S** |  | 0.78 | -.21 | 0.00 | 0.39 | -.16 | 0.50 | 0.36 | 0.24 | 0.57 |
| Soil Manganese | NS | NS | S* | S** | NS | S | S | S | S* | S** |  | -.18 | -.16 | 0.60 | -.13 | 0.41 | 0.27 | 0.23 | 0.58 |
| Soil Iron | NS | NS | NS | NS | NS | S | PS | S** | S | S* | S* |  | -.03 | -.28 | 0.16 | 0.08 | 0.27 | 0.12 | -.15 |
| Available Zinc | NS | NS | S | S* | NS | S | S* | S | S* | NS | S | NS |  | 0.14 | 0.05 | 0.26 | 0.06 | -.11 | -.15 |
| Available Manganese | NS | S* | NS | NS | NS | S* | NS | S** | NS | S** | S** | S** | PS |  | -.11 | 0.14 | -.01 | -.13 | 0.25 |
| Available Iron | NS | NS | NS | NS | NS | S | NS | NS | NS | S | PS | S | N8 | NS |  | -.05 | 0.18 | -.07 | 0.07 |
| Cold Extractable Heavy Metals | NS | NS | S** | S** | NS | S* | NS | S** | S** | S** | S** | NS | S** | PS | NS |  | 0.51 | 0.23 | 0.40 |
| Cold Extractable Copper | S* | NS | S** | S** | PS | S** | NS | S** | S** | S** | S** | S** | NS | NS | S | S** |  | 0.15 | 0.38 |
| pH | NS | NS | S** | S | NS | S | PS | S** | NS | S** | S* | PS | NS | PS | NS | S* | S |  | 0.16 |
| Organic Carbon | S | NS | NS | S | NS | PS | NS | NS | NS | S** | S** | S | S | S** | NS | S** | S** | S |  |

Figure 14 SPEARMAN RANK CORRELATION COEFFICIENTS FOR PLANT AND SOIL ANALYSES. STATISTICAL SIGNIFICANCE IS CLASSIFIED UTILIZING THE PROBABILITY, P, THAT NO RELATIONSHIP EXISTS, ACCORDING TO THE SCHEME PROPOSED BY BROOKS (1972).

NS = NOT SIGNIFICANT; P IS GREATER THAN 0.10
PS = POSSIBLY SIGNIFICANT; P IS BETWEEN 0.10 AND 0.05
S = SIGNIFICANT; P IS BETWEEN 0.05 AND 0.01
S* = HIGHLY SIGNIFICANT; P IS BETWEEN 0.01 AND 0.001
S** = VERY HIGHLY SIGNIFICANT; P IS LESS THAN 0.001

Before considering individual correlations in detail, it is useful to compare elemental relationships among groups of data. Table 4 does this for plant analyses, hot acid extractable soil analyses, and soil availability analyses.

Two observations can be made from Table 4. First, the relationship between element pairs in the soil samples is not usually repeated in the plant samples. Second, though the data is limited, the relationship between element pairs in plant samples corresponds more closely to the relationships shown by availability analyses.

Considering the relationships between elemental pairs in plant samples alone, several general observations can be made. First, copper, lead, nickel and iron show mutual, very highly significant positive correlations. Second, zinc shows weak positive relationships with copper and nickel, whereas cadmium is strongly positively correlated with copper and zinc and weakly correlated with iron. Finally, manganese is unrelated to the other elements except for a weak, antipathetic relationship with copper.

These relationships can be interpreted in terms of: (1) "active accumulation" processes, or (2) factors controlling the "availability" of metals in the soil. Lead, cadmium and nickel seemingly are concentrated within the plant as the indirect result of active accumulation of iron and copper. The zinc accumulation mechanism seems to be more specific, with cadmium the only "exotic" element capable of substituting for it on the active transport substrate. The weak

Table 4. A Comparison of Spearman Rank Correlation Coefficients Among Grouped Data Sets

| Element Pair | Plant Analyses | Soil Analyses | Availability Analyses |
|---|---|---|---|
| Cu-Pb | 0.36 S** | 0.28 S** | --- |
| Cu-Zn | 0.17 S | - .02 NS | 0.51 S** |
| Cu-Fe | 0.38 S** | 0.69 S** | --- |
| Cu-Mn | - .18 S | - .16 S | --- |
| Pb-Zn | - .16 S | 0.33 S** | --- |
| Pb-Fe | 0.56 S** | 0.15 S | --- |
| Pb-Mn | - .07 NS | 0.21 S* | --- |
| Zn-Fe | - .05 NS | - .21 S* | 0.05 NS |
| Zn-Mn | 0.08 NS | 0.78 S** | 0.14 PS |
| Fe-Mn | 0.08 NS | - .18 S* | - .11 NS |

Note: Statistical significance classified utilizing the probability, P, that no relationship exists, according to the scheme proposed by Brooks (1972).

NS = Not Significant; P is greater than 0.10
PS = Possibly Significant; P is between 0.10 and 0.05
S = Significant; P is between 0.05 and 0.01
S* = Highly significant with P between 0.001 and 0.001
S** = Very Highly Significant; P is less than 0.001

positive relationship between zinc and copper suggests that zinc itself is capable of transport by the less specific copper accumulation mechanism. Alternatively, it may reflect an availability control wherein loosely bonded copper and zinc are directly related. A weak negative correlation between zinc and lead suggests competition for the transport substrate. The absorption of one inhibits the absorption of the other. The active accumulation of manganese seems to be the most specific. The weak antipathetic relationship with copper is the only significant correlation observed. This relationship is identical to that observed in the soil; hence is probably the result of differences in the spatial distribution of copper and manganese.

Turning to the broader subject of plant-soil relationships, the correlation coefficients in Figure 14 show generally poor correspondence between base metal content of the plants and soils they grow on.

Plant copper is unrelated to the "total" or hot acid extractable content of the soil, but does show a highly significant positive correlation with cold extractable copper. Additional weaker positive relationships exist between plant copper and both soil zinc and soil organic carbon. These results suggest that an increase in loosely bonded copper in the soil can produce a concomitant increase in the copper content of Lodgepole pines. However, the positive correlations with organic carbon (now thought to reflect oxidizable organic matter and manganese) and soil zinc suggest this is true for the peripheral lead-zinc vein environment and not the main copper porphyry system.

Seemingly, the iron oxide-rich, manganese-poor surficial environment associated with the porphyry offers a few low-strength bonding sites which could make copper ions more available to the overlying flora.

Only two plant lead correlation coefficients are other than zero: soil copper and available manganese. These relationships are different to interpret. If a significant amount of what is termed "available" manganese represents manganese sited in one or more carbonate minerals, then perhaps the increased lead content in plants reflects increased availability of lead when the latter is sited in carbonates. Since the methodology used in this study to measure "available" elements depended upon a weak sulfuric acid extraction and was therefore unsuitable for lead determinations, there is no direct data to support this interpretation. The antipathetic relationship between soil copper and plant lead is explicable if the above interpretation is true. Most of the soil copper is associated with the chalcopyrite-pyrite veinlets of the main porphyry system, spatially dissociated from the peripheral manganese-bearing carbonate veins. Alternatively, an increase in soil copper in the peripheral vein environment may reflect an increase in copper-iron sulfides which when oxidized would yield acid solutions capable of dissolving carbonates. This would either leach the lead from the system or precipitate it in forms less available to plants.

Correlation analysis indicates that zinc is the only element determined whose abundance in Lodgepole pine is directly proportional to its abundance in the soil. Significant positive correlations between plant zinc and each of the following; soil copper, soil lead, soil zinc, soil manganese, available zinc, cold extractable heavy metals, and cold extractable copper are all reasonable. They probably reflect the influence of vein-hosted lead-zinc-copper-manganese mineralization peripheral to the Heddleston porphyry.

Plant cadmium, by virtue of its chemical similarity to zinc, mimics the latter's inter-element relationships. Plant nickel shows no significant correlation with any of the measured soil parameters. Since its level of concentration within the soils rarely exceeded the detection limit of the atomic absorption technique, there is no indication of how well soil nickel and plant nickel correspond.

Manganese abundance levels in Lodgepole pine correlate directly with only two parameters; available manganese and available zinc. A number of antipathetic relationships ranging from weak to strong are also evident, the most surprising of which is soil manganese. The most reasonable explanation for these relationships is that the manganese abundance level of Lodgepole pine will directly reflect the presence of vein-hosted manganiferous carbonate mineralization, but only if the latter are not accompanied by significant sulfides. When copper/iron sulfides are present, acid solutions are generated during oxidation which in turn dissolves the carbonates. Manganese liberated in this manner is either leached from the soil system and/or precipitated as hydrous oxides. In either case, the net effect is to render manganese less available to the plant.

Plant iron abundance levels show few significant correlations with soil parameters. Weak correlations with soil copper, soil manganese and soil iron probably reflect the weak influence of soil abundance levels. The highly significant positive correlation with weak acid extractable zinc is surprising. A possible explanation is that iron may be locally more available to plants when it is sited in carbonates, just as zinc seems to be and that this increased availability does reflect directly in the plant. The lack of significant correlation with weak acid extractable iron may be a function of the slowness with which weak acid attacks iron carbonates rather than the absence of a real relationship between iron availability and plant abundance level.

## Summation

Significant conclusions drawn from the correlation analysis of Heddleston data are:

(1) Base metals in soil samples are strongly partitioned between manganese and iron oxides.

(2) Partial extraction techniques utilized on soil samples indicate that the relationship between "loosely bonded" and "total" metals may be weak or non-existent.

(3) With the exception of zinc and possibly iron, the metal content of Lodgepole pines is not directly proportional to the total metal content of the soil in which they grow.

(4) pH strongly affects both copper and zinc in the soil. However, this effect lessens from "total" through "cold extractable" to "available" determinations. Hence pH has virtually no effect on the weakly bonded cation population.

(5) For copper, zinc, and manganese, the metal content of Lodgepole pines does show a direct relationship to the loosely bonded or available metal content of the underlying soil.

(6) The relationship between the two elements of a base metal pair in Lodgepole pine analyses is usually different from the relationship between the same two elements in hot acid soil analyses when either zinc or manganese is concerned. Partial extraction techniques seem to be much better at mimicing the interelement relationships in the plants.

(7) The relationship between the two elements of a base metal pair in Lodgepole pine analyses is similar to the relationship between the same two elements in hot acid soil analyses when copper is involved.

# CHAPTER VI

## GRAPHIC ANALYSES:
## DISCUSSION AND INTERPRETATION

Figure 15-19 are log-log plots of plant "enrichment factors" or relative uptake against soil metal content for copper, lead, zinc, manganese and iron respectively. These nearly perfect linear plots are similar to those obtained by Brooks (1972) and imply that a simple linear relationship exists between the relative uptake and soil content variables. Linearity implies that:

$$\log Y + n \log X + \log K$$

where Y is the relative uptake, X is the concentration of the element in the soil, and K is a constant. Since Figures 15-19 indicate that $n - -1$,

$$\log Y = -\log X + \log K$$

and $\log XY = \log K$

Finally, $XY = K$, or in other words, the relative uptake decreases as the metal content of soil increases in order to preserve the value of K. Brooks (1972) interpreted K as the plant's physiological requirement level for the element concerned.

A significant difference exists between the results obtained by Brooks (1972) and those obtained at Heddleston. Brooks (1972) observed this inverse linear relationship only for essential elements (see Table 5). Figure 16 on the other hand shows that within the samples

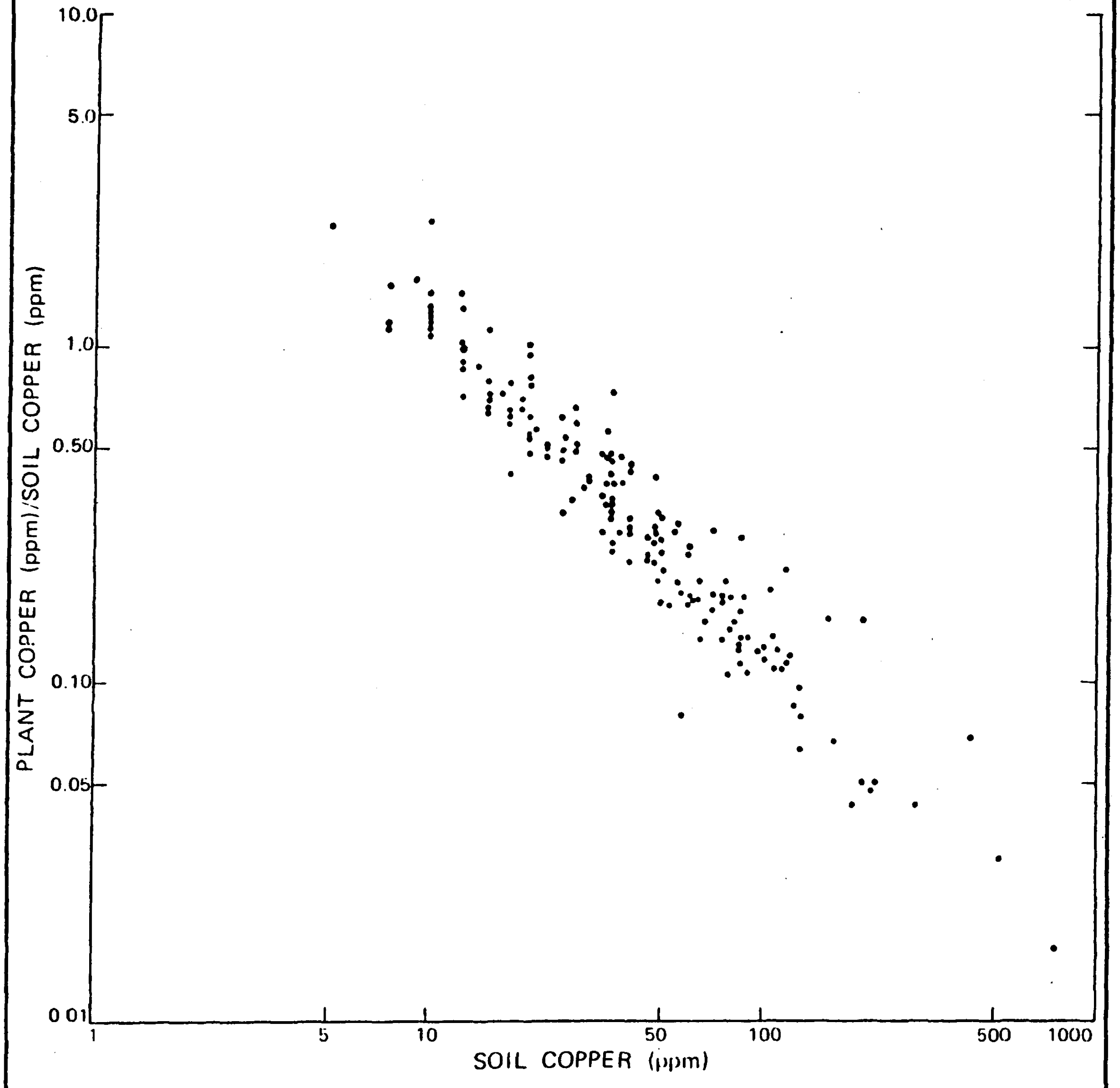


Figure 15 Relative Accumulation of Copper in Lodgepole Pine

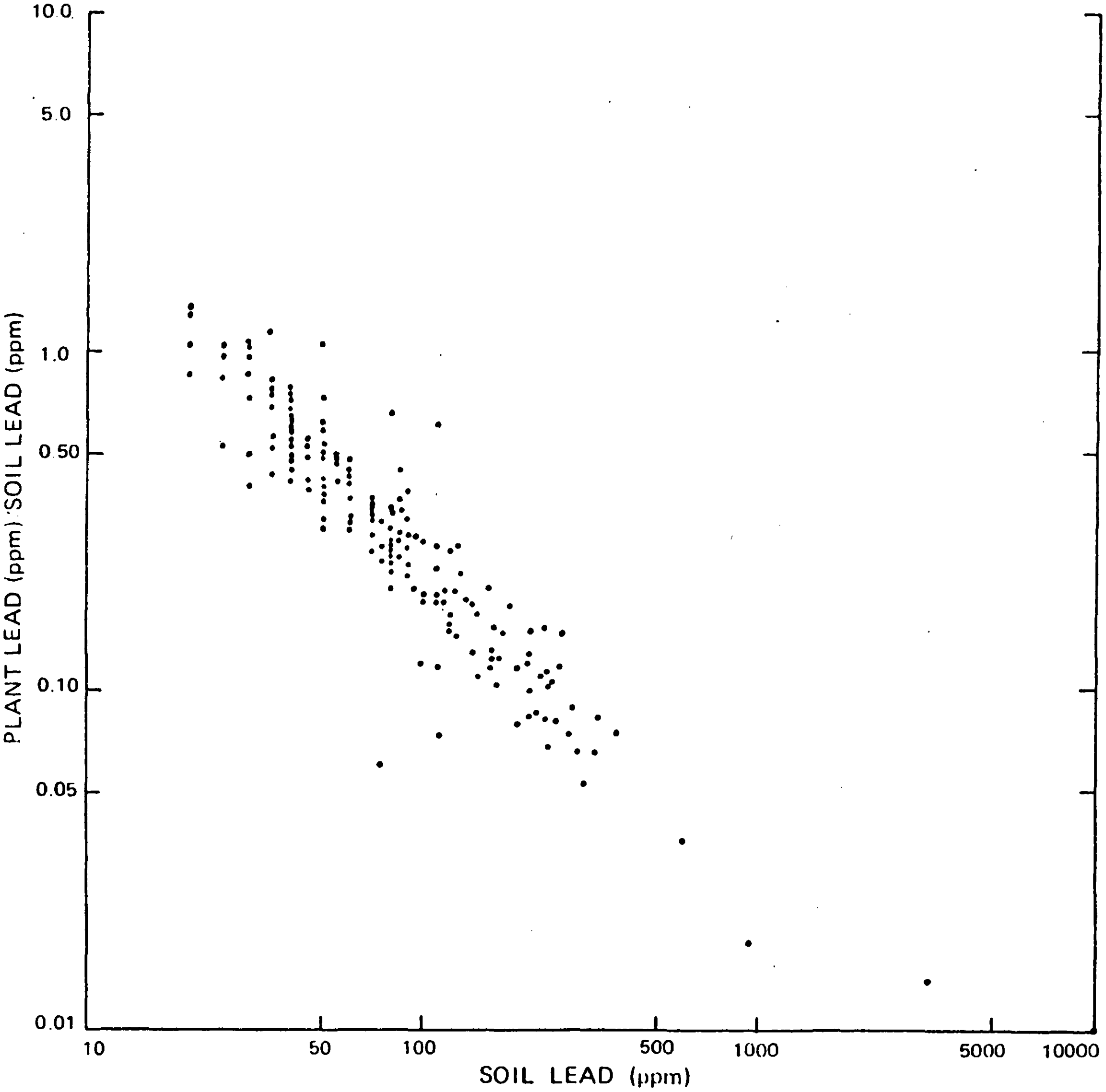


Figure 16 Relative Accumulation of Lead in Lodgepole Pine

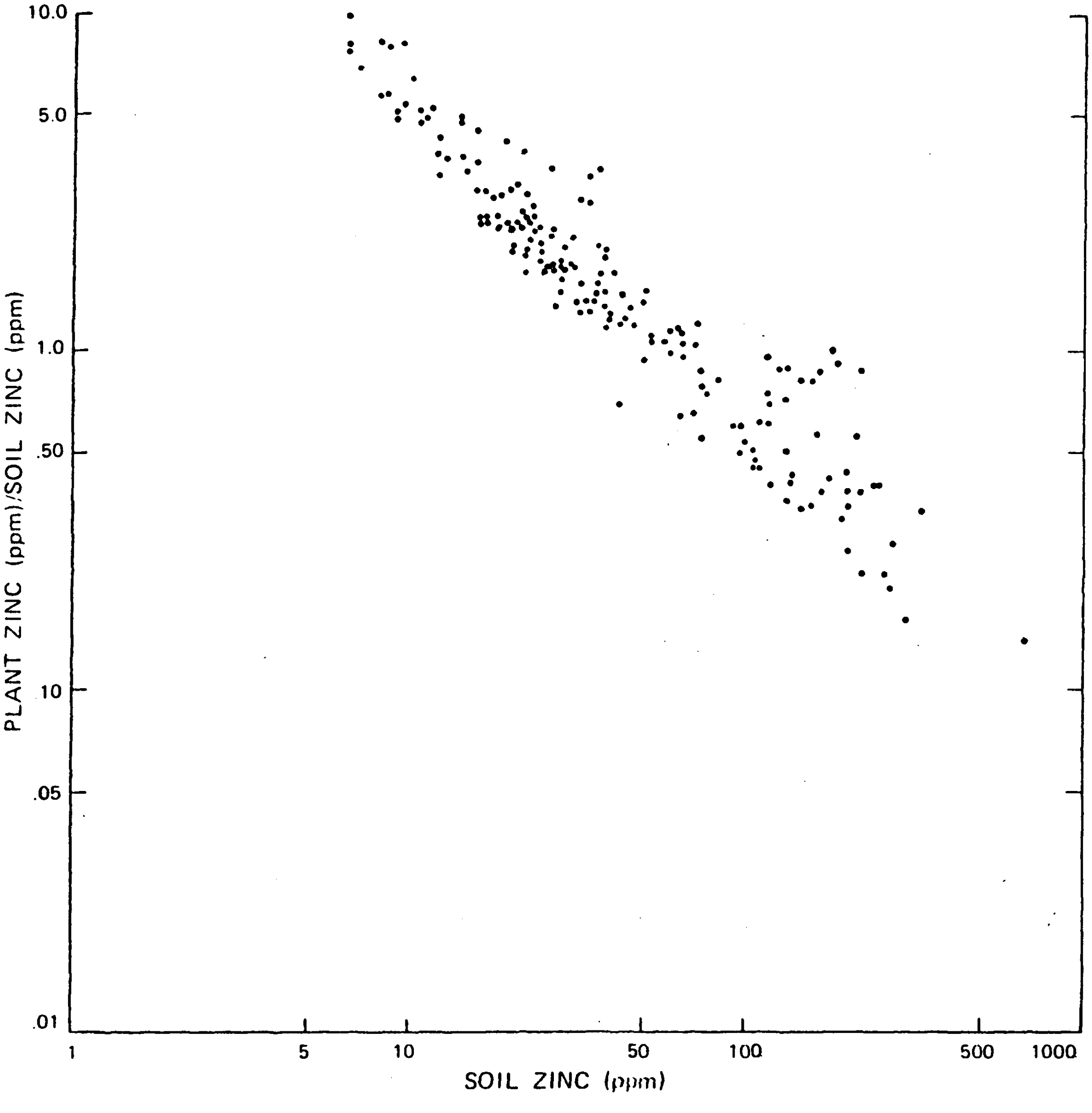


Figure 17 Relative Accumulation of Zinc in Lodgepole Pine

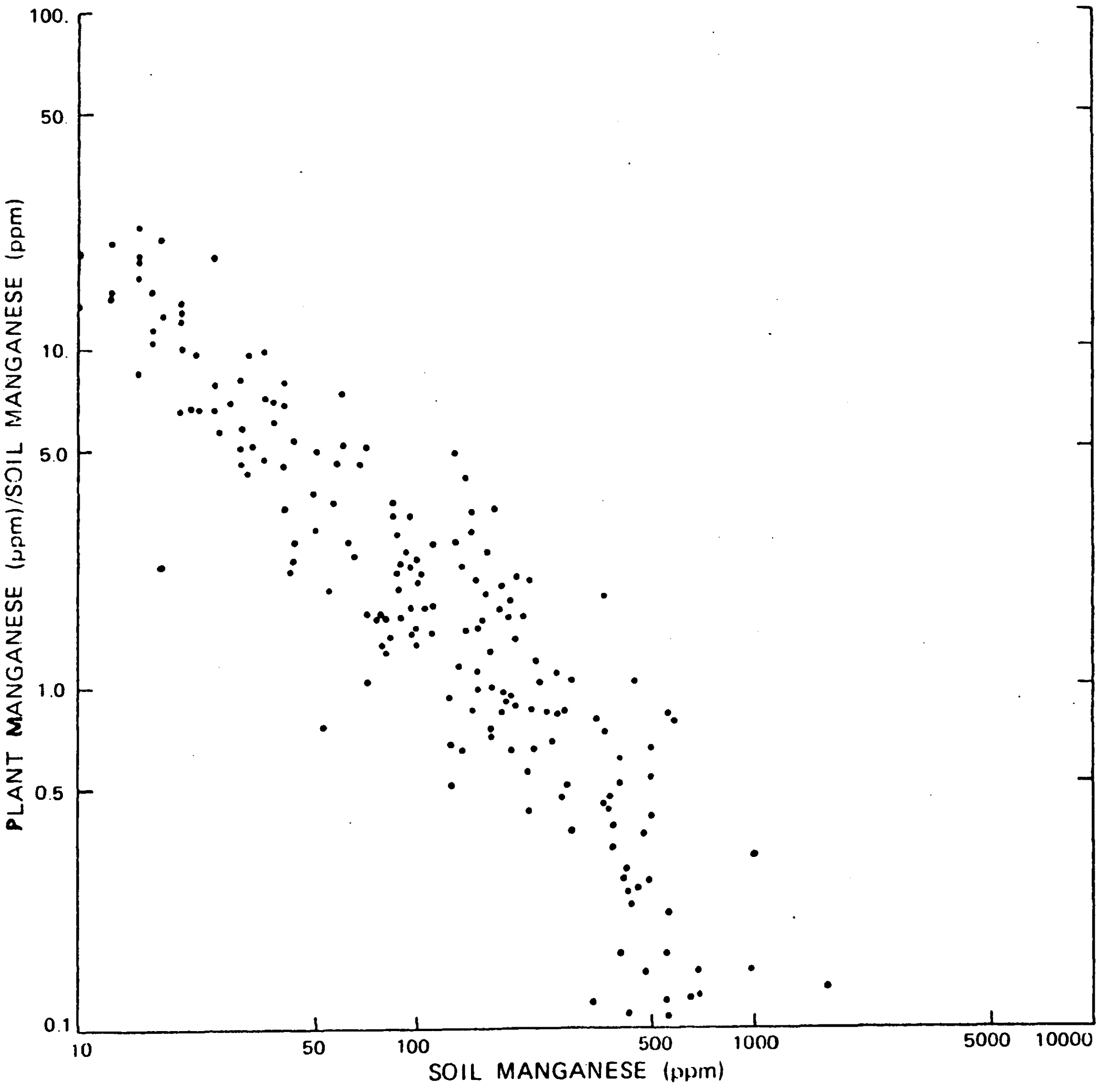


Figure 18 Relative Accumulation of Manganese in Lodgepole Pine

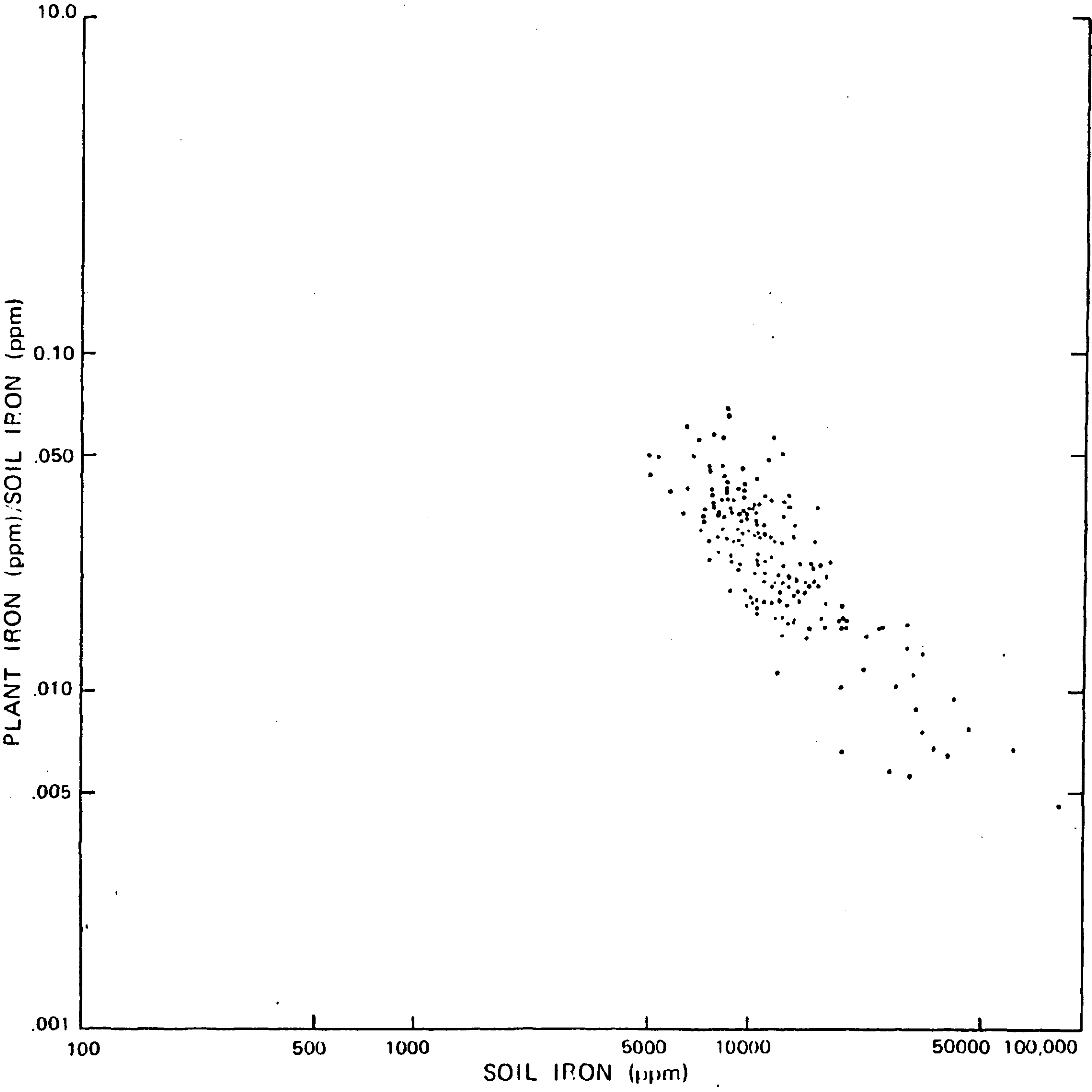


Figure 19 Relative Accumulation of Iron in Lodgepole Pine

Table 5. Concentrations of Major and Minor Essential Nutrient Elements in Plant Material Art at Levels Considered Adequate*

| Element | Chemical Symbol | Atomic Weight | Concentration in dry matter | | Relative number of atoms with respect to molybdenum | Crustal Abundance** ppm |
|---|---|---|---|---|---|---|
| | | | Mole/gm | ppm or % | | |
| | | | | ppm | | |
| Molybdenum | Mo | 95.95 | 0.001 | 0.1 | 1 | 1.5 |
| Copper | Cu | 63.54 | 0.10 | 6 | 100 | 55 |
| Zinc | Zn | 65.38 | 0.30 | 20 | 300 | 70 |
| Manganese | Mn | 54.95 | 1.0 | 50 | 1,000 | 950 |
| Iron | Fe | 55.85 | 2.0 | 100 | 2,000 | -- |
| Boron | B | 10.82 | 2.0 | 20 | 2,000 | 10 |
| Chlorine | Cl | 35.46 | 3.0 | 100 | 3,000 | 130 |
| | | | | % | | |
| Sulfur | S | 32.07 | 30 | 0.1 | 30,000 | |
| Phosphorus | P | 30.98 | 60 | 0.2 | 60,000 | |
| Manganesium | Mg | 24.32 | 80 | 0.2 | 80,000 | |
| Calcium | Ca | 40.08 | 125 | 0.5 | 125,000 | |
| Potassium | K | 39.10 | 250 | 1.0 | 250,000 | |
| Nitrogen | N | 14.01 | 1,000 | 1.5 | 1,000,000 | |
| Oxygen | O | 16.00 | 30,000 | 45 | 30,000,000 | |
| Carbon | C | 12.01 | 35,000 | 45 | 35,000,000 | |
| Hydrogen | H | 1.01 | 60,000 | 6 | 60,000,000 | |

*After Epstein (1965)
**After Levinson (1974)

collected at Heddleston, lead behaves in precisely the same manner though that element has never been considered essential to plant growth.

If the same variables are plotted utilizing arithmetic rather than logarithmic scales, good approximations of rectangular hyperbolae can be fit to them by eye (Figures 20-25). Brooks (1972) considered the hyperbolic plot to be a definitive characteristic of essential elements. Furthermore, he concluded that the portion of the hyperbola which approaches parallelism with the X-axis represents a breakdown of the plant's selective accumulation mechanisms due to overwhelming concentrations of metal. An implication of this is that the biogeochemical method could only be effective for essential elements when this occurred.

Figures 20-25 demonstrate that essential and nonessential elements in Lodgepole pine at Heddleston are not differentiable on the basis of such arithmetic plots.

The contradiction between Brooks (1972) results and the results obtained at Heddleston can be interpreted to two ways: (1) lead and nickel are essential trace nutrients in Lodgepole pine, or (2) the relationships represented by the distinctive plots do not reflect the tendency of plants to keep their trace element content constant regardless of the amounts in the soil. If the first interpretation is rejected, then the alternative demands a controlling mechanism in the soil system rather than in the plant system.

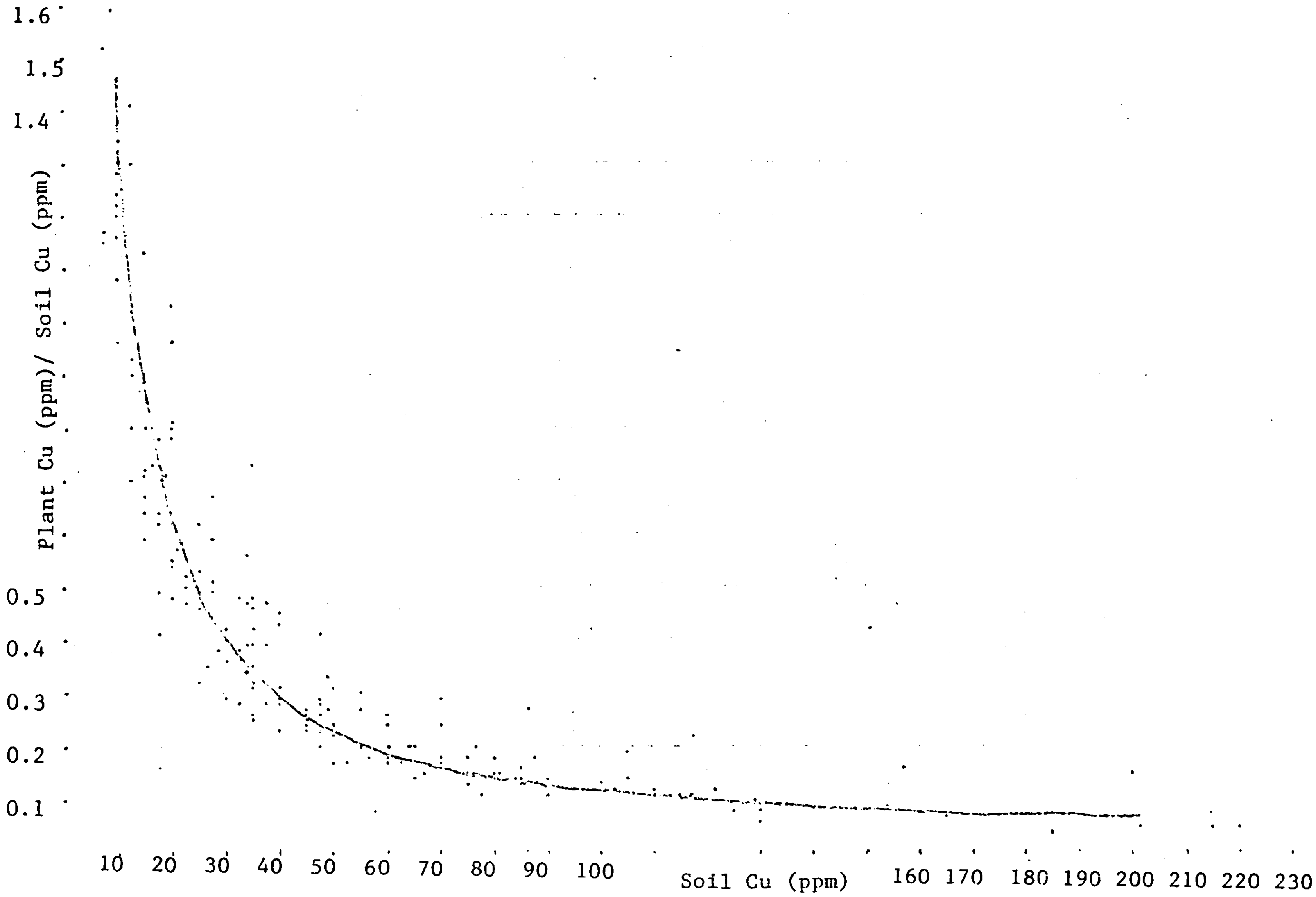


Figure 20 Relative Accumulation of Copper in Lodgepole Pine

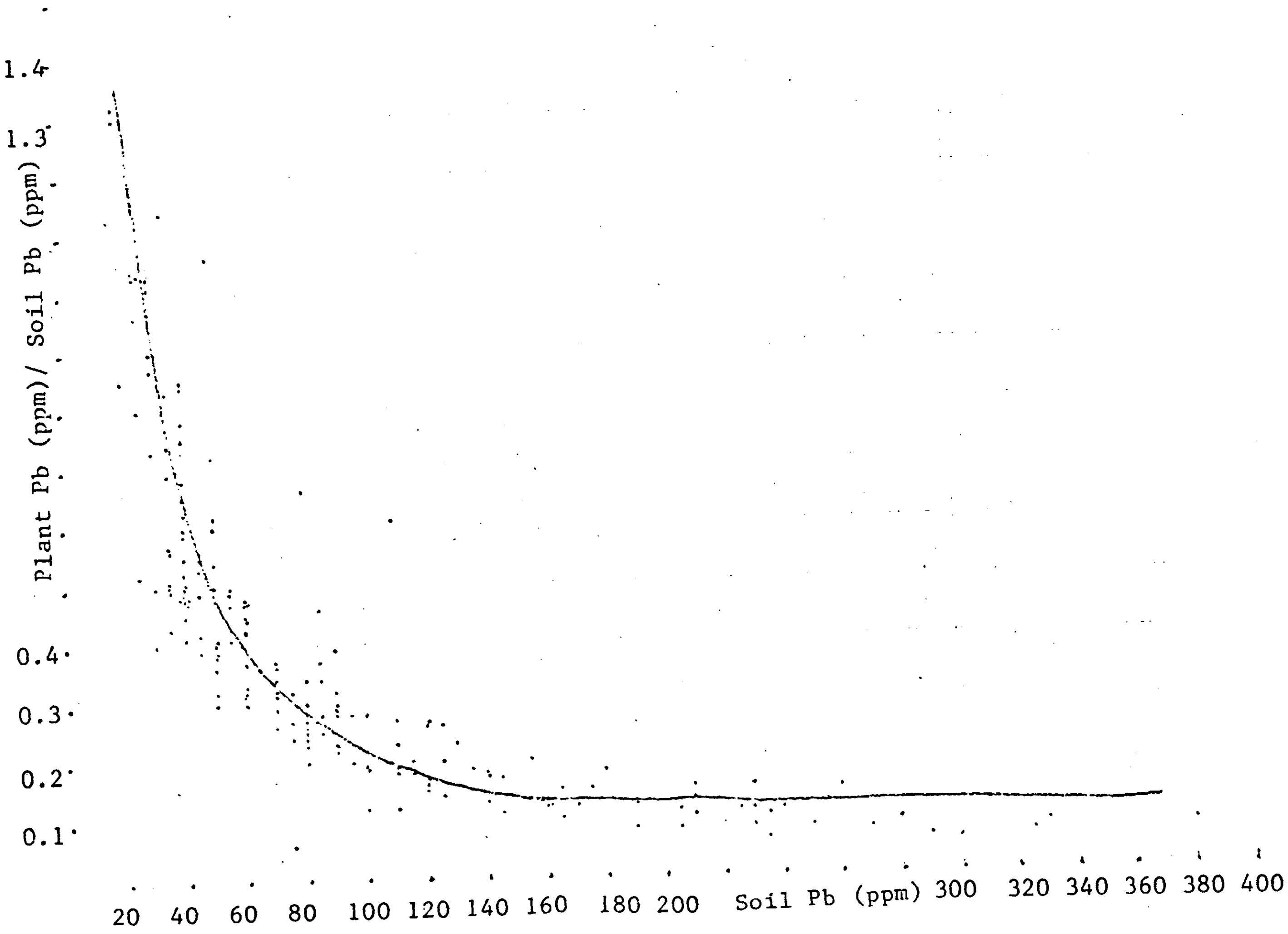


Figure 21 Relative Accumulation of Lead in Lodgepole Pine

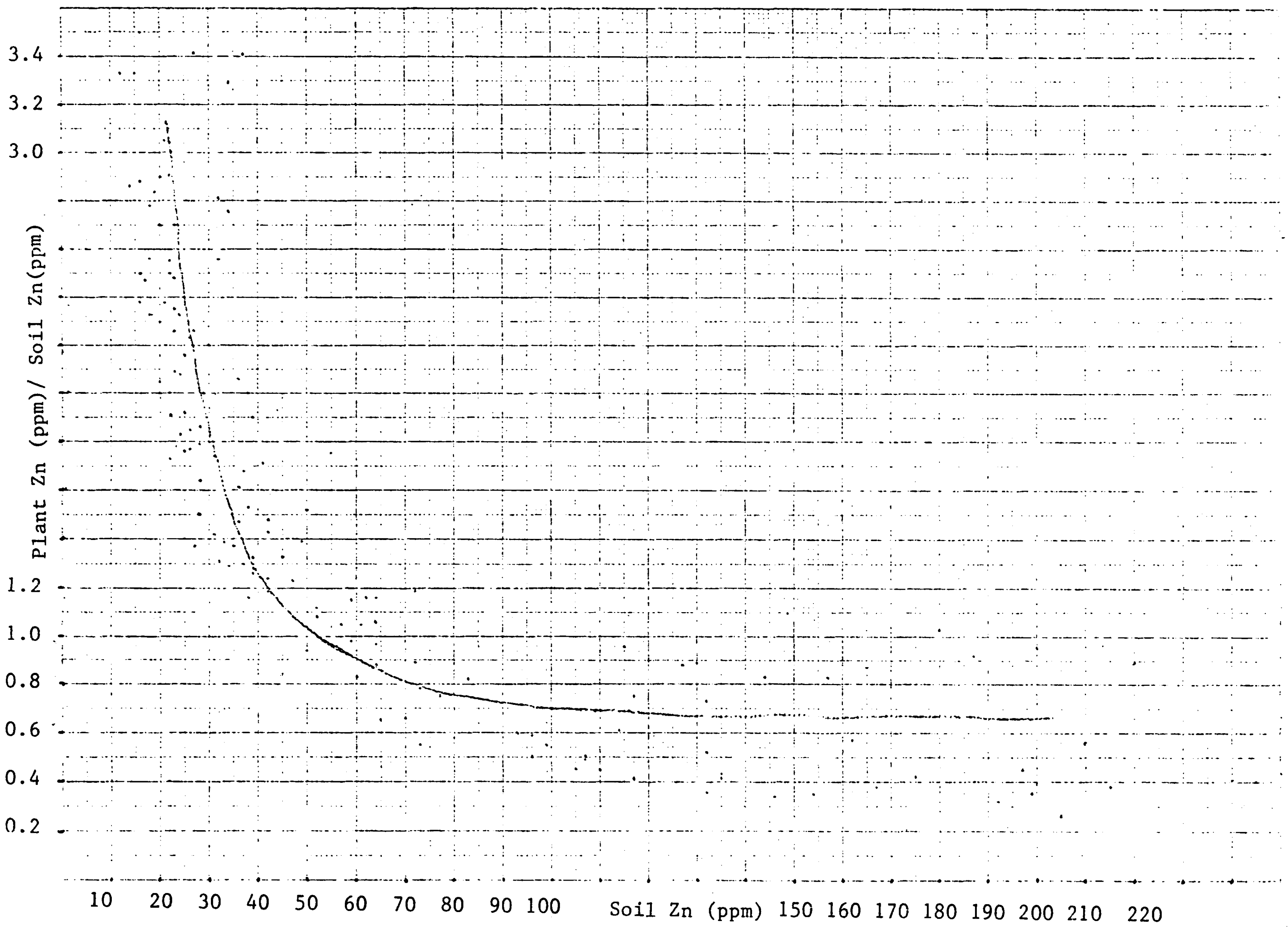


Figure 22 Relative Accumulation of Zinc in Lodgepole Pine

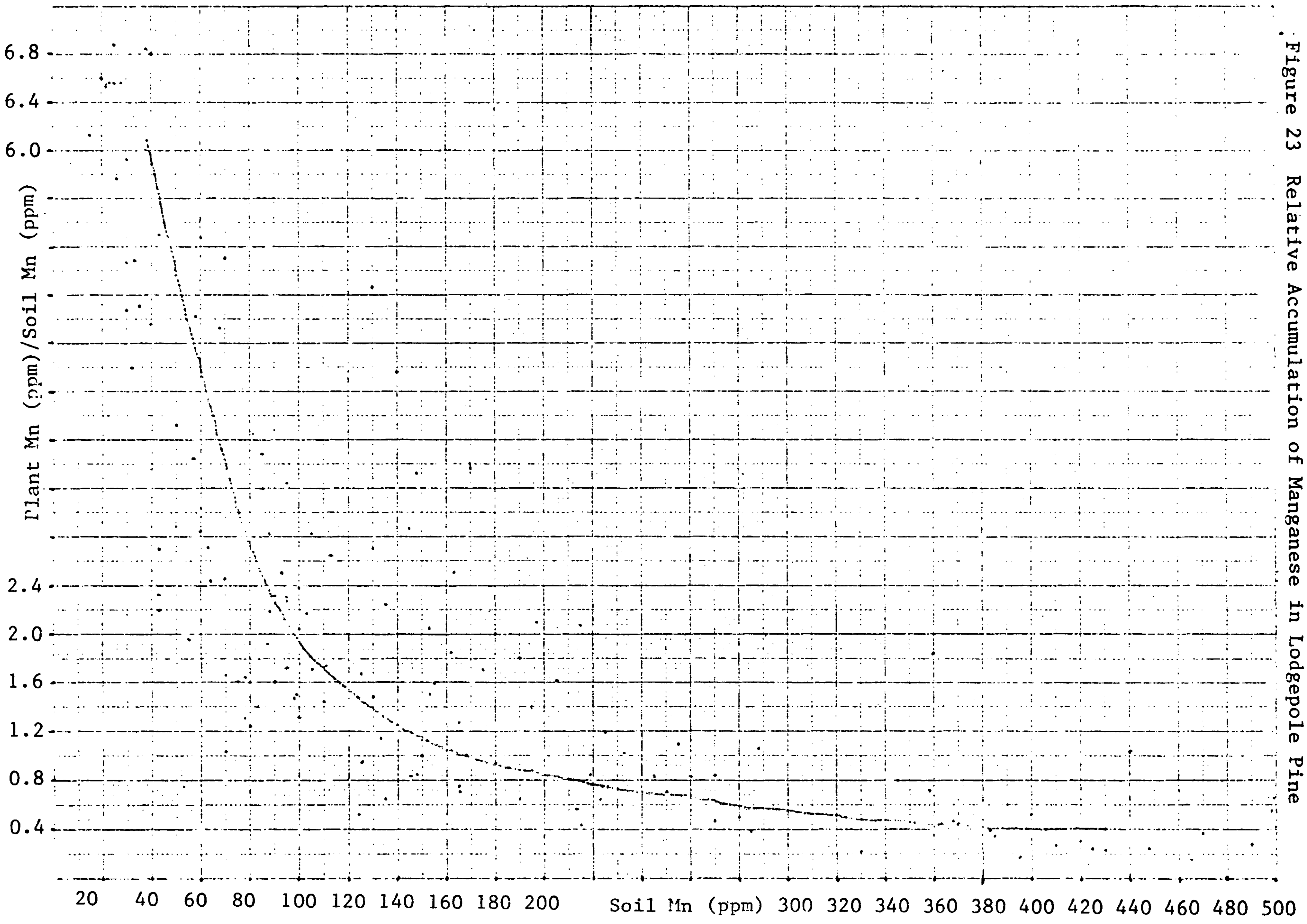


Figure 23 Relative Accumulation of Manganese in Lodgepole Pine

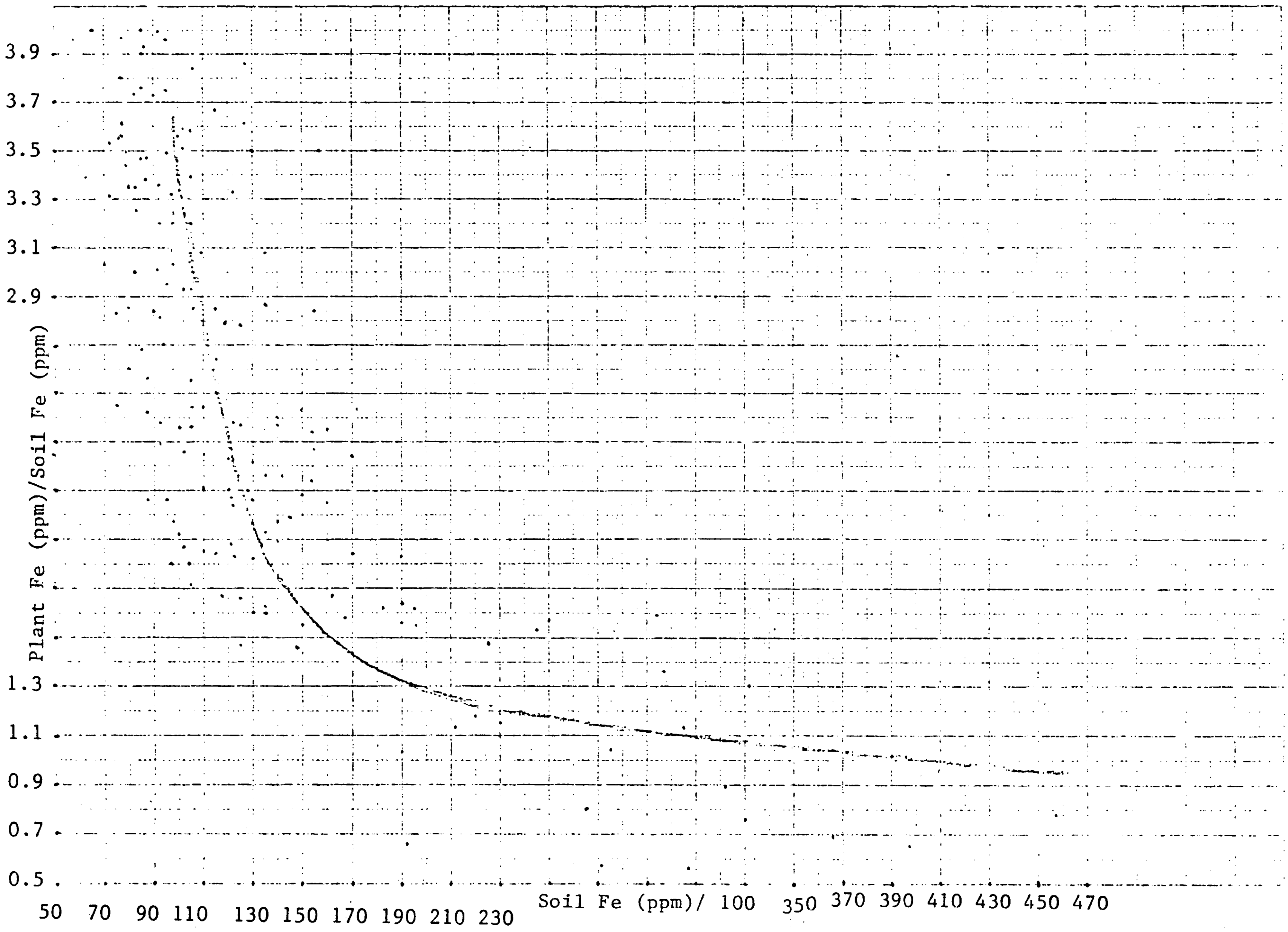


Figure 24 Relative Accumulation of Iron in Lodgepole Pine

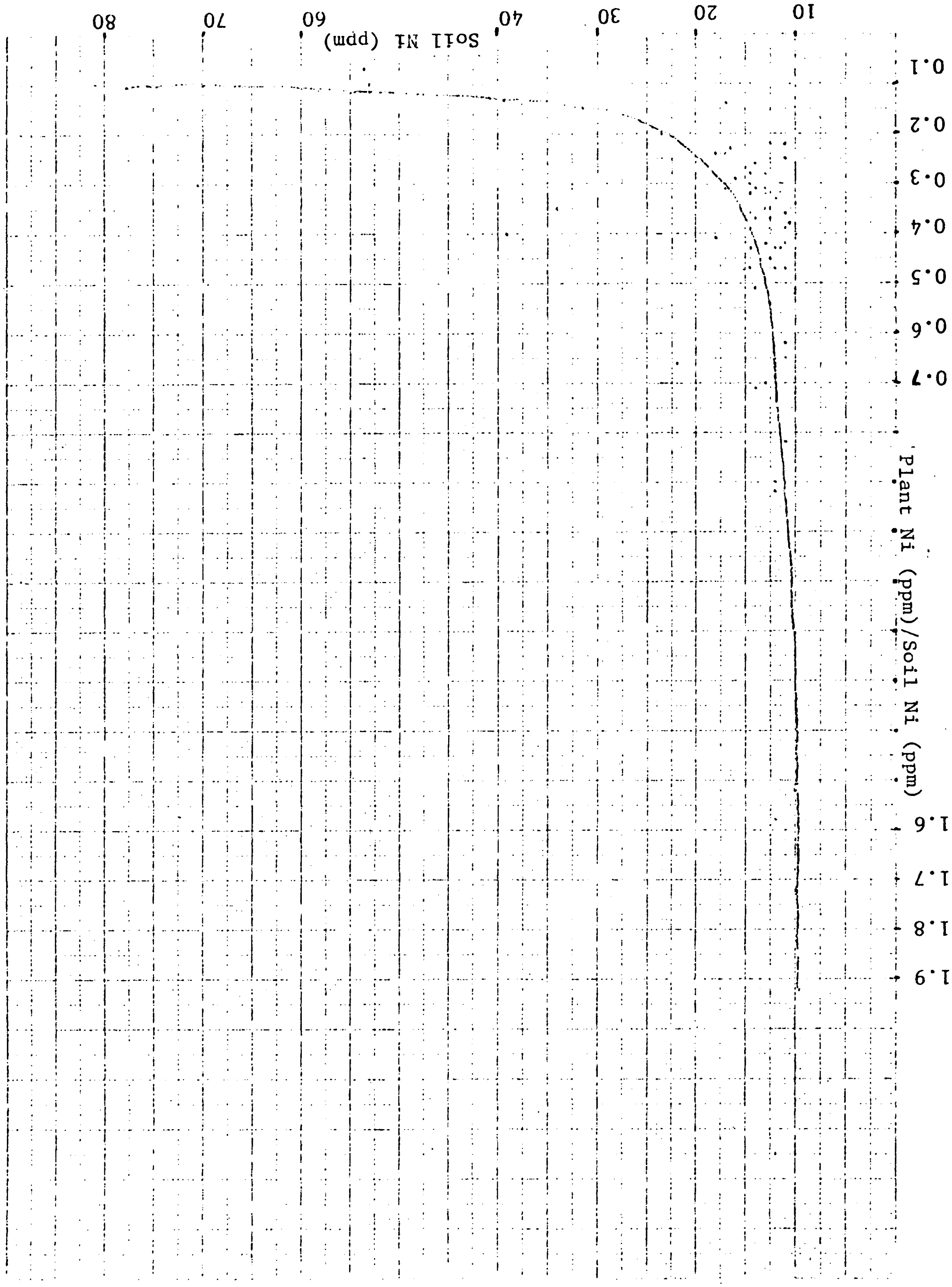


Figure 25 Relative Accumulation of Nickel in Lodgepole Pine

Figure 26 is a log-log plot of zinc "availability coefficients" against soil zinc. The similarity between this graph and those obtained previously with plant "enrichment coefficients" is obvious. This suggests that some mechanism or mechanisms operating within the soil system regulates the amount of loosely bonded or "available" zinc, the effect of which is to keep the level relatively constant regardless of zinc's total abundance in the soil.

The "available" zinc as it was measured in this study, is at best, a poor approximation of the zinc truly available to plant root systems. However, Figure 26 may be an indication of broader principles. Namely that true trace element availability in the soil system is a dominant, direct control on the trace element abundance levels found in plants growing therein. Further, the level of this availability is determined by a complex combination of elemental "sinks," e.g., hydrous manganese and iron oxides, clay minerals organic colloids, microbiota, etc., as well as the chemical nature of the trace element species concerned. Hence the degree to which the trace element content of plants follow the trace element content of their substrate will depend upon the amount of metal necessary to saturate the chemical "sinks" within the soil system.

The above scenario is of direct concern to the biogeochemical explorationist. Biogeochemical prospecting can only be effective when the metal or metals of interest are present in concentrations sufficient to overwhelm the availability controls. More practically, since this

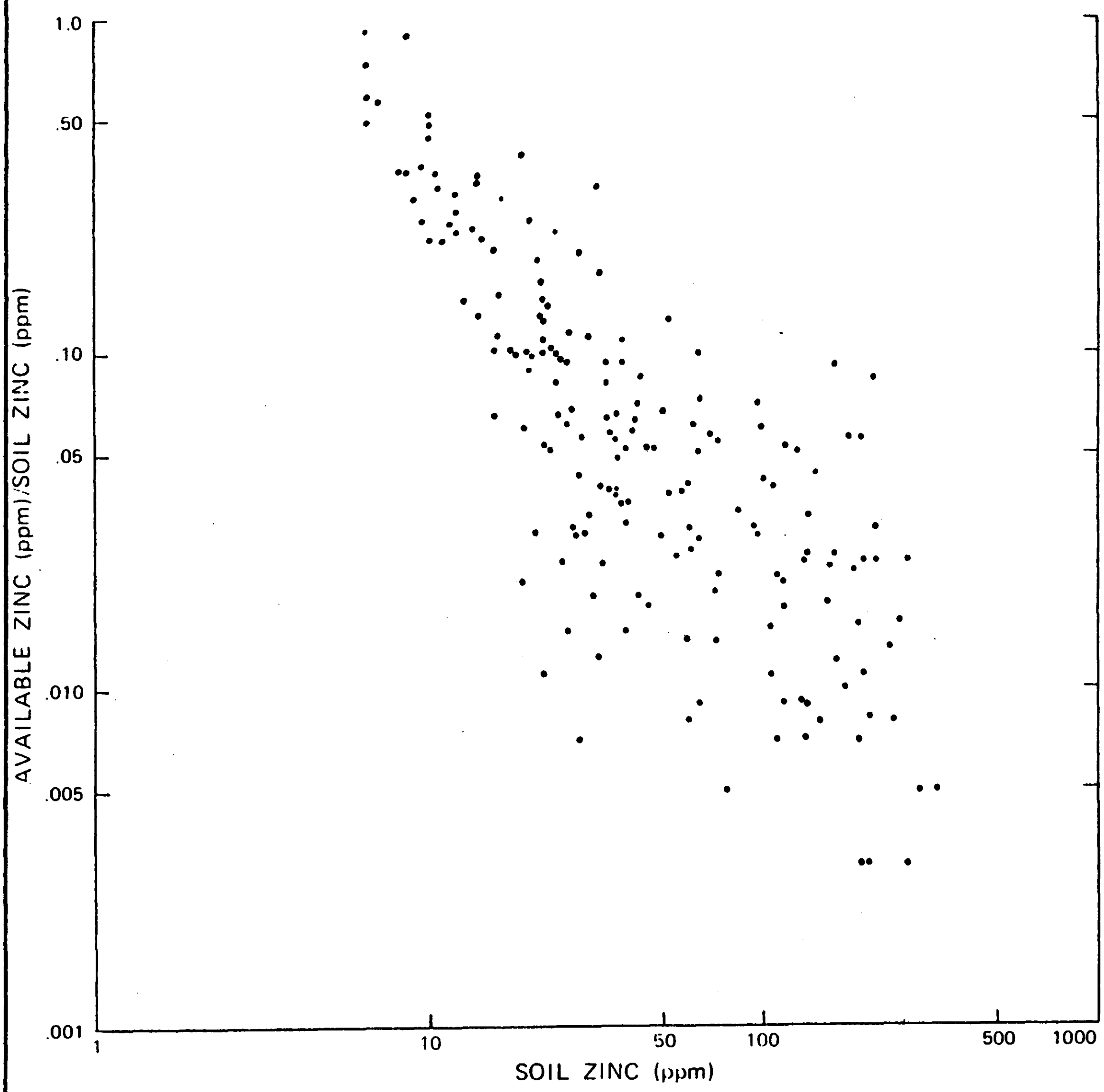


Figure 26 Relative Availability of Zinc

availability variation is directly reflected in the plants, it is possible to use the lower limb of hyperbolic plots like Figures 20-25 to define thresholds of efficacy for the biogeochemical method.

Applying this logic to Heddleston it is concluded that soils must contain at least the following approximate concentrations of metals for Lodgepole pine biogeochemistry to be effective: copper, 70 ppm; lead, 140 ppm; zinc, 90 ppm; manganese, 220 ppm; iron, 21000 ppm; and nickel, 20 ppm.

# CHAPTER VII

# TREND SURFACE ANALYSIS: DISCUSSION AND INTERPRETATION

The results of the trend surface analyses of Heddleston soil and plant sample data are summarized in Tables 6 and 7 respectively. Included are several common test statistics for evaluating "goodness of fit" such as correlation coefficient, coefficient of determination, and F-test. The statistical significance of the latter is classified according to the same scheme utilized previously for Spearman rank correlation coefficients. Only those trend surfaces that are significant at the 0.05 level or better according to the F-test are discussed further. For the sake of completeness the remaining trend surfaces are presented without comment in Appendix VI.

## Soils: Total Metal Analysis

A 6th order trend surface for logarithmically transformed hot acid extractable soil copper is shown in Figure 27. It is readily apparent that the pattern depicted bears no relationship to either the zone of strong wallrock alteration or the unexposed copper-molybdenum mineralization. Comparison to the geologic map (Fig. 3) indicates a general correspondence between high copper values and alluvium filled valley. This suggests a general tendency for copper dispersing from the surrounding slopes to concentrate in low-lying areas. In detail,

Table 6. Statistical Summary, Soil Sample Trend Surface Analyses

| Sample Type and Element | Mean (ppm) | Std. Dev. | Correlation Coefficient | Coefficient of Determination | F-Test | Significance of F-Test |
|---|---|---|---|---|---|---|
| Soil Cu | 71.8 | 206 | 0.35 | 0.12 | 0.83 | NS |
| Soil Cu ($Log_{10}$ Transformed) | 1.59 | 0.40 | 0.68 | 0.46 | 5.08 | S** |
| Soil Pb | 167 | 744 | 0.28 | 0.08 | 0.50 | NS |
| Soil Pb ($Log_{10}$ Transformed) | 1.9 | 0.36 | 0.57 | 0.33 | 2.93 | S** |
| Soil Zn | 119 | 442 | 0.35 | 0.13 | 0.86 | NS |
| Soil Zn ($Log_{10}$ Transformed) | 1.64 | 0.49 | 0.72 | 0.51 | 6.20 | S** |
| Soil Mn | 198 | 256 | 0.62 | 0.38 | 3.64 | S** |
| Soil Mn ($Log_{10}$ Transformed) | 2.02 | 0.51 | 0.69 | 0.48 | 5.48 | S** |
| Soil Fe | 13,586 | 9,300 | 0.45 | 0.21 | 1.55 | PS |
| Soil Fe ($Log_{10}$ Transformed) | 4.1 | 0.20 | 0.56 | 0.32 | 2.76 | S** |
| Avail. Cu | 0.67 | 2.54 | 0.26 | 0.07 | 0.58 | NS |
| Avail Zn | 6.57 | 30.4 | 0.31 | 0.10 | 0.65 | NS |
| Avail. Zn ($Log_{10}$ Transformed) | -0.91 | 0.41 | 0.38 | 0.15 | 1.40 | PS |

Table 6 (continued)

| Sample Type and Element | Mean (ppm) | Std. Dev. | Correlation Coefficient | Coefficient of Determination | F-Test | Significance of F-Test |
|---|---|---|---|---|---|---|
| Avail. Mn | 25.0 | 30.3 | 0.53 | 0.28 | 1.76 | S* |
| Avail. Mn (Log$_{10}$ Transformed) | - 0.11 | 0.48 | 0.54 | 0.30 | 2.31 | S** |
| Avail. Fe | 11.0 | 18.2 | 0.47 | 0.22 | 1.69 | S |
| Avail. Fe (Log$_{10}$ Transformed) | - 0.41 | 0.35 | 0.42 | 0.18 | 1.29 | NS |
| CxCu | 3.9 | 14.0 | 0.40 | 0.16 | 1.16 | NS |
| CxHM | 17.4 | 21.3 | 0.52 | 0.27 | 2.17 | S** |
| pH | 5.1 | 0.71 | 0.63 | 0.40 | 3.99 | S** |
| Org. Carb. | 2.05% | 1.38 | 0.43 | 0.18 | 1.30 | NS |
| Org. Carb. (Log$_{10}$ Transformed) | 0.21 | 0.33 | 0.50 | 0.25 | 2.06 | S* |

Statistical Significance is classified utilizing the probability, P, that the regression coefficients are zero, i.e., there is no regression.

NS = Not significant; P is greater than 0.10
PS = Possibly significant; P lies between 0.10 and 0.05
S = Significant; P lies between 0.05 and 0.01
S* = Highly significant; P lies between 0.01 and 0.001
S**= Very highly significant; P is less than 0.001

Table 7. Statistical Summary, Plant Sample Trend Surface Analyses

| Sample Type and Element | Mean (ppm) | Std. Dev. | Correlation Coefficient | Coefficient of Determination | F-Test | Significance of F-Test |
|---|---|---|---|---|---|---|
| Plant Cu | 12.9 | 3.8 | 0.38 | 0.14 | 0.96 | NS |
| Plant Cu ($Log_{10}$ Transformed) | 1.09 | 0.12 | 0.37 | 0.14 | 0.95 | NS |
| Plant Pb | 24.5 | 8.09 | 0.61 | 0.38 | 3.52 | S** |
| Plant Pb ($Log_{10}$ Transformed) | 1.37 | 0.12 | 0.59 | 0.39 | 3.14 | S** |
| Plant Zn | 67.2 | 38.0 | 0.51 | 0.26 | 2.05 | S* |
| Plant Zn ($Log_{10}$ Transformed) | 1.78 | 0.18 | 0.53 | 0.28 | 2.29 | S** |
| Plant Mn | 211 | 110 | 0.49 | 0.24 | 1.83 | S* |
| Plant Mn ($Log_{10}$ Transformed) | 2.27 | 0.22 | 0.52 | 0.27 | 1.61 | S |
| Plant Fe | 306 | 88 | 0.52 | 0.27 | 2.21 | S** |
| Plant Fe ($Log_{10}$ Transformed) | 2.47 | 0.12 | 0.52 | 0.27 | 2.13 | S** |
| Plant Cd | 7.4 | 3.4 | 0.68 | 0.46 | 5.01 | S** |
| Plant Cd ($Log_{10}$ Transformed) | 0.83 | 0.17 | 0.66 | 0.44 | 4.53 | S** |

Table 7 (Continued)

| Sample Type and Element | Mean (ppm) | Std. Dev. | Correlation Coefficient | Coefficient of Determination | F-Test | Significance of F-Test |
|---|---|---|---|---|---|---|
| Plant Ni | 6.29 | 6.1 | 0.36 | 0.13 | 0.87 | NS |
| Plant Ni ($\text{Log}_{10}$ Transformed) | 0.71 | 0.23 | 0.36 | 0.15 | 1.01 | NS |

Statistical Significance is classified utilizing the probability, P, that the regression coefficients are zero, i.e., there is no regression.

NS = Not significant; P is greater than 0.10
PS = Possibly significant; P lies between 0.10 and 0.05
S = Significant; P lies between 0.05 and 0.01
S* = Highly significant; P lies between 0.01 and 0.001
S** = Very highly significant; P is less than 0.001

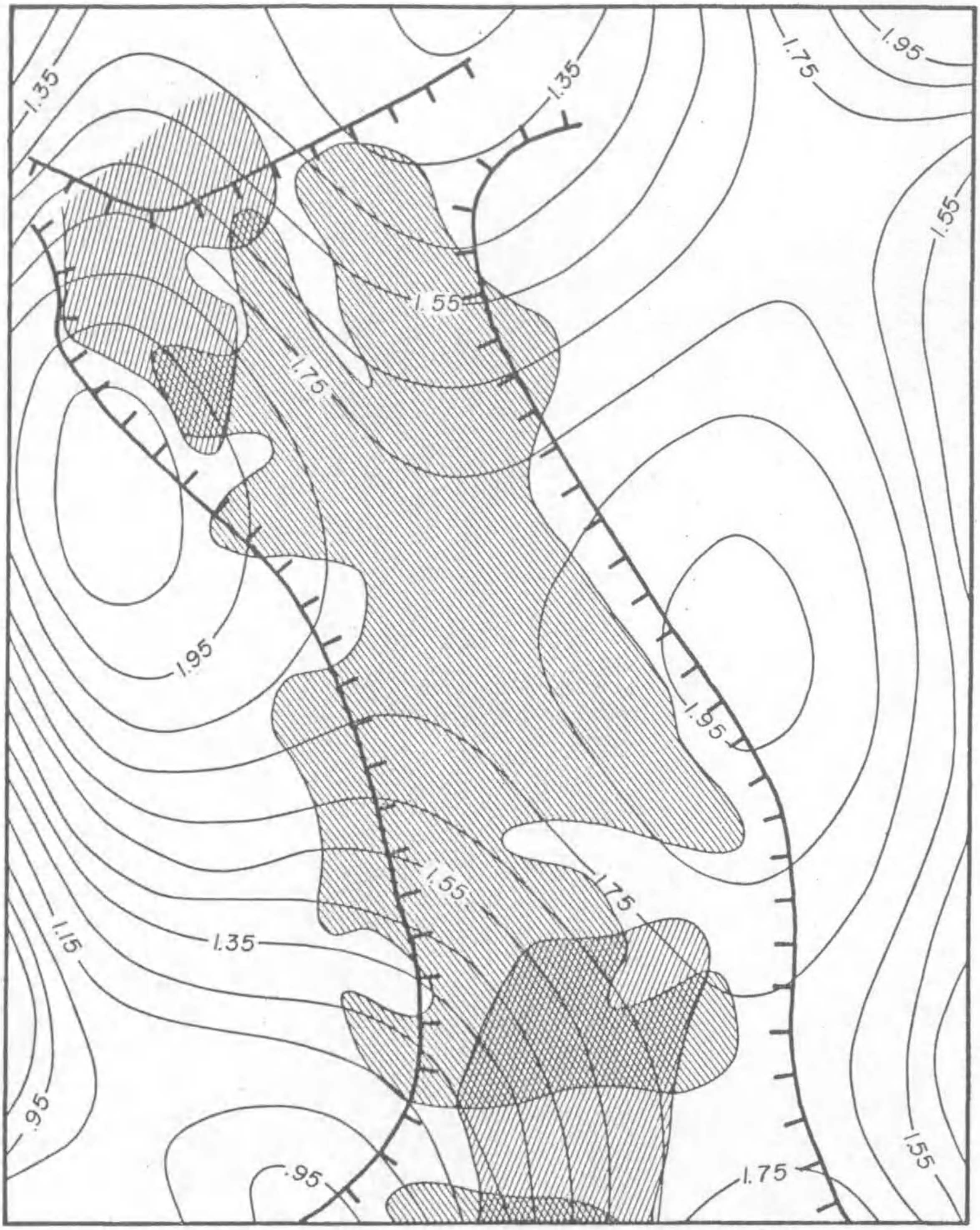


Figure 27 6th ORDER TREND SURFACE- SOIL COPPER ANALYSES (LOG$_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.1 LG OF PPM

r = CORRELATION COEFFICIENT
r = 0.68

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.46

N

both circular copper highs are centered over alluvium downstream from old mines. Hence the copper distribution trend may also reflect the effects of previous mining activity as well as normal hydromorphic dispersion.

Figure 28 shows a 6th order trend surface for hot acid extractable soil lead analyses, also logarithmically transformed. A sinuous "trough" of lower lead values cuts across the zone of strong wall rock alteration and the zones of mineralization known to occur at depth. A local "basin" within the low lead trough grossly coincides with a lobe of shallow to intermediate depth copper-molybdenum potential. However, this is the only such instance. A comparison with the geology map (Fig. 3) likewise fails to show any gross similarities between the lead trends and lithologic units.

The 6th order trend surface for hot acid extractable zinc analyses (logarithmically transformed) is shown in Figure 29. A circular zinc low occurs over an area to the south where shallow to intermediate depth copper-molybdenum potential overlaps deep molybdenum potential. To the north, a second more oblong zinc low partially overlaps a lobe of shallow to intermediate copper-molybdenum potential. In the terms of surficial geology, zinc shows a strong tendency to concentrate in the low-lying, alluvial environment.

Manganese is the only element for which very highly significant trend surfaces could be derived from both raw and logarithmically transformed soil data (Figs. 30 & 31). The trend patterns displayed

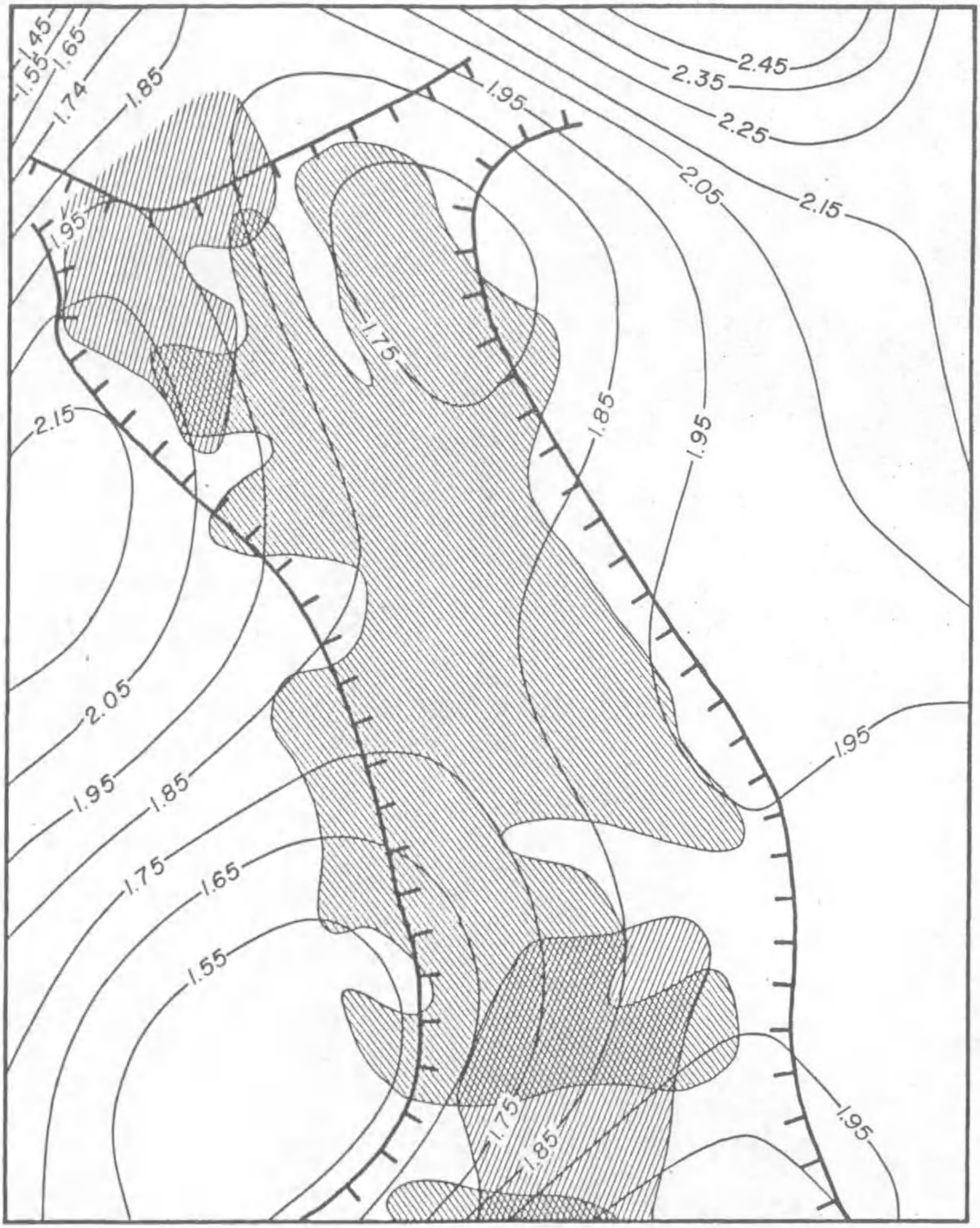


Figure 28 6th ORDER TREND SURFACE - SOIL LEAD ANALYSES ( LOG$_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10
HUNDRED FEET

CONTOUR INTERVAL = 0.1 LG OF PPM

r = CORRELATION COEFFICIENT
r = 0.57

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.33

N

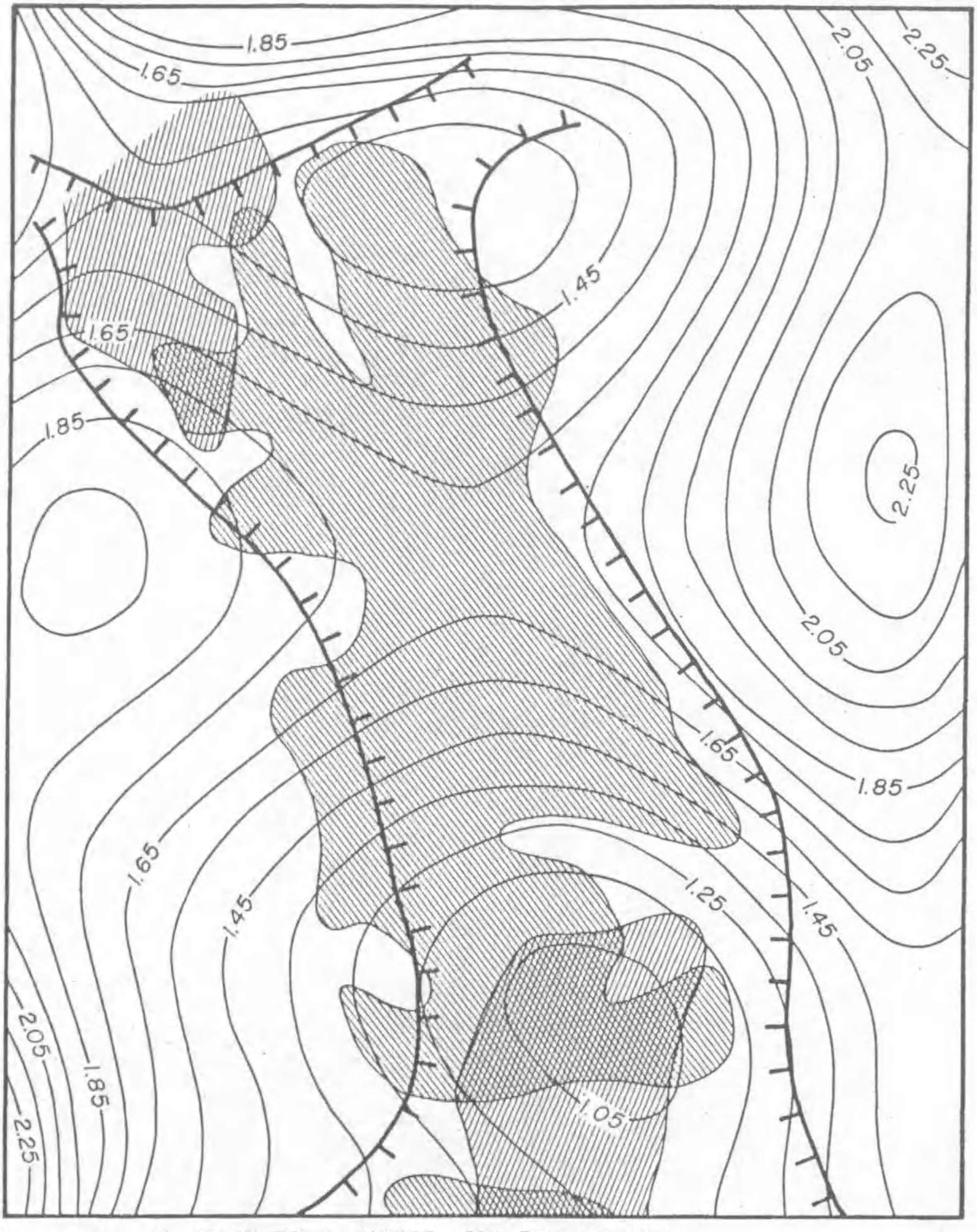


Figure 29 6th ORDER TREND SURFACE – SOIL ZINC ANALYSES (LOG$_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.1 LG OF PPM

$r$ = CORRELATION COEFFICIENT
$r$ = 0.72

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.51

N

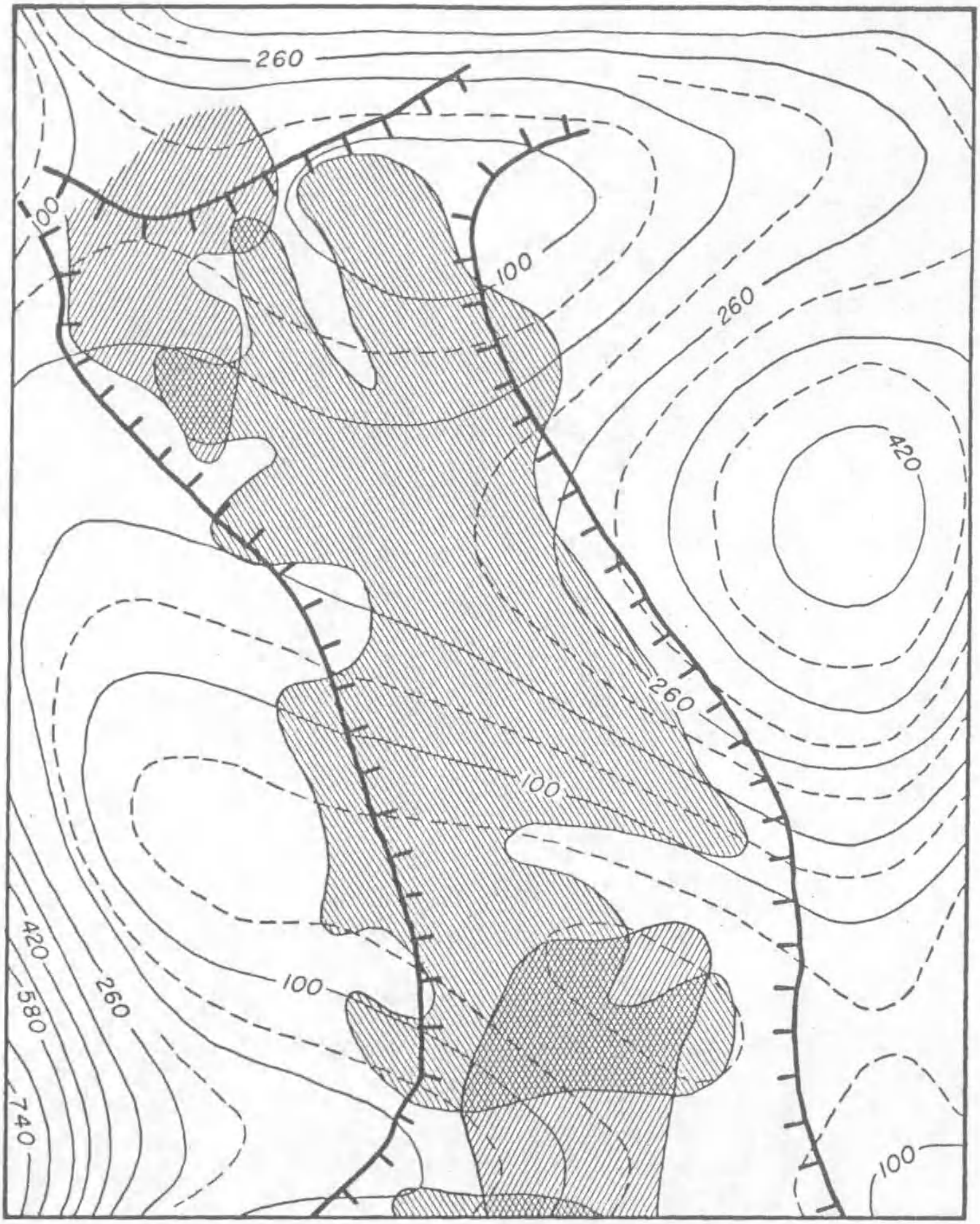


Figure 30 6th ORDER TREND SURFACE-SOIL MANGANESE ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 80 PPM
HALF-CONTOUR INTERVAL = - - - -

r = CORRELATION COEFFICIENT
r = 0.62

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.38

N

are quite similar: a circular manganese low in the south, an elongate low north of the Northeast Breccia Pipe, and a pronounced circular high to the east. Figure 31, a 6th order trend surface utilizing logarithmically transformed data, shows the closeset correspondence to the shape of the buried porphyry system. In this figure the manganese trend of interest consists of a sinuous "trough" with a deep "basin" in the south and a less pronounced "basin" in the north.

Hot acid extractable iron yields a statistically significant 6th order trend surface for logarithmically transformed soil analyses (Fig. 32). The only part of the pattern broadly coincident with the mineralization known to occur at depth is an elongate "saddle" of lower iron which extends from the Northeast Breccia Pipe across the alluvium filled valley almost to the southern lobe of deep molybdenum potential.

## Synthesis

Three conclusions can be drawn from the trend surface analyses of hot acid extractable base metals in soils from Heddleston:

(1) $\log_{10}$ transformations consistently yield statistically more significant surfaces;

(2) in spite of the fact that the target is chiefly a copper system, copper trends in no way reflect the presence of such a system;

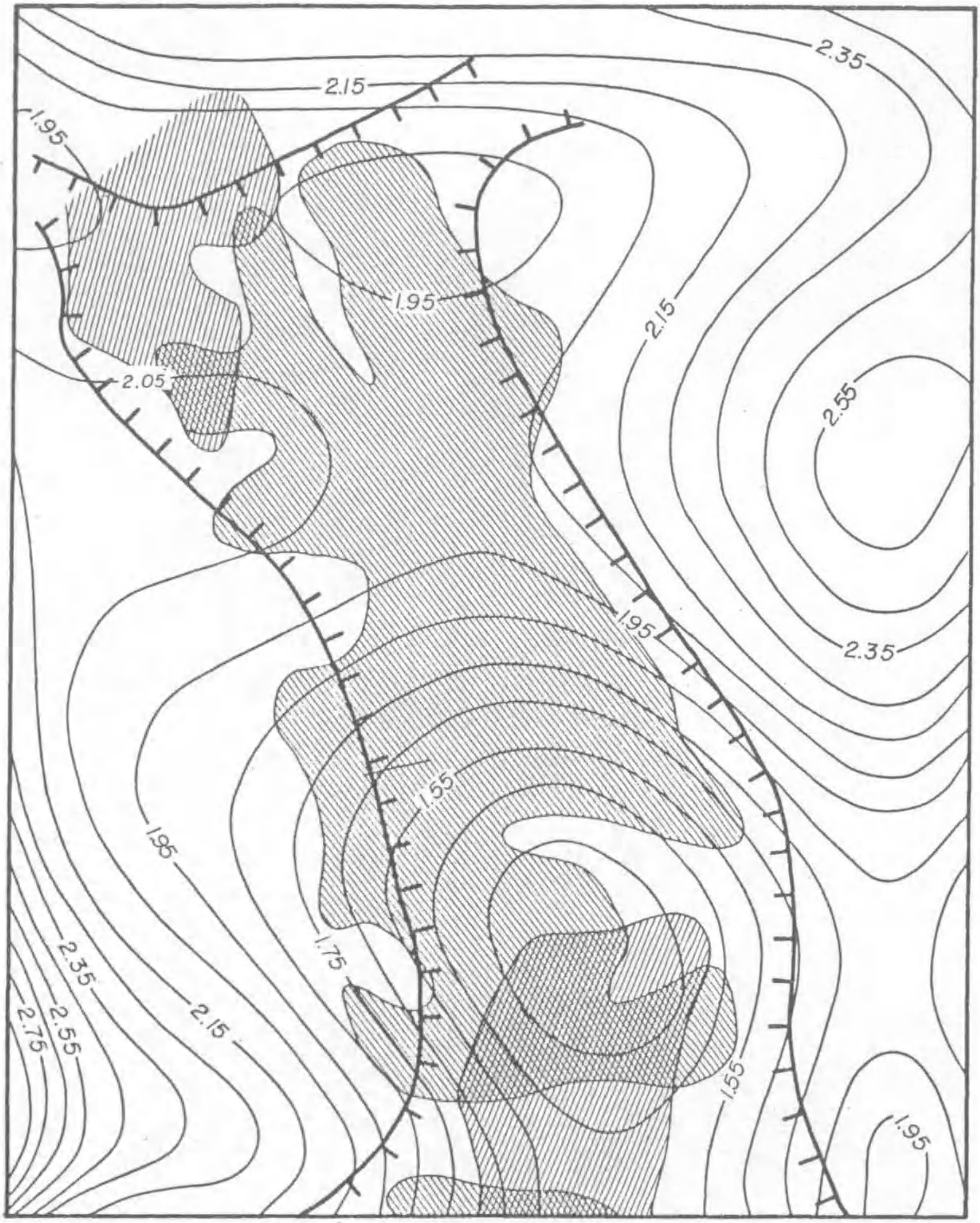


Figure 31 6th ORDER TREND SURFACE - SOIL MANGANESE ANALYSES ($LOG_{10}$ TRANSFORMED)

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.1 LG OF PPM

r = CORRELATION COEFFICIENT
r = 0.69

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.48

N

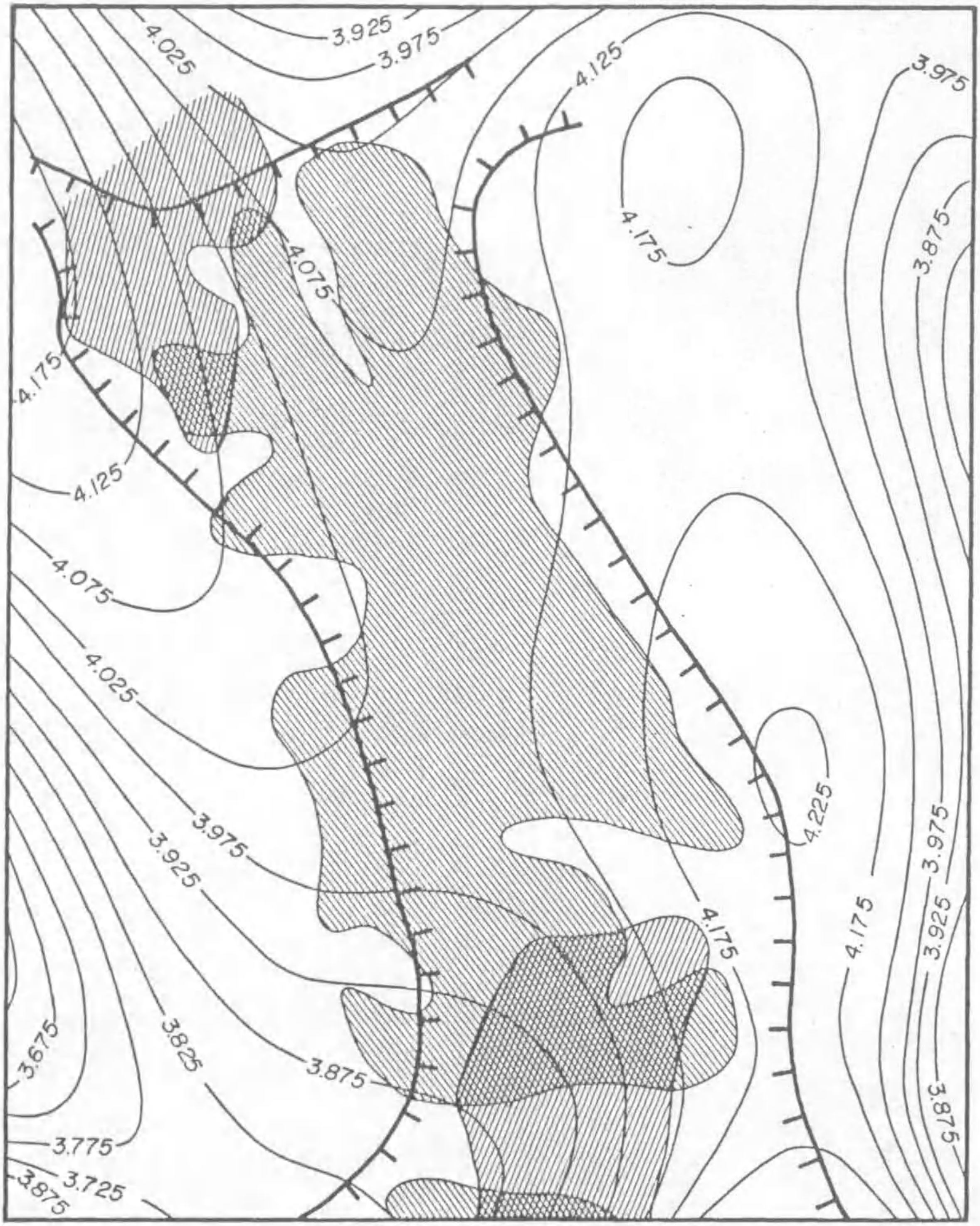


Figure 32 6th ORDER TREND SURFACE – SOIL IRON ANALYSES (LOG$_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.05 LG OF PPM

$r$ = CORRELATION COEFFICIENT
$r$ = 0.56

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.32

N

(3) lead, zinc manganese and iron grossly outline the mineralized system with sinuous "troughs" or trends of lower elemental abundance.

This latter observation is made more visually apparent in Figure 33. The axis of the geochemical "troughs" follow the axis of the altered/mineralized system. This may reflect a general depletion in base metals due to the strong wallrock alteration. Furthermore, geochemical "basins" occur within the lead zinc and manganese "troughs" in both north and south-central parts of the map. The lead, zinc, and manganese "basins" in the north closely coincide with each other. Those to the south are separated, particularly in the case of lead. In addition, for all three elements the "basins" in the south are much "deeper" than those to the north. Without further geological data this difference is difficult to interpret. However, if the trends of lower elemental abundance are the result of base metal depletion due to hydrothermal alteration, then the dissimilarities between the basins in the north and the south may reflect significant differences in the degree of alteration and/or depth of exposure.

## Miscellaneous Soil Analyses

Weak acid extractable (i.e. "available") manganese yields statistically significant trend surfaces for both raw and logarithmically transformed data (Figs. 34 & 35). Again a familiar pattern emerges, a broad "trough" of lower geochemical values trending north, northwest across the map. A local "basin" occurs in the southern quadrant of the map, centered over QMP I porphyry (Fig. 3).

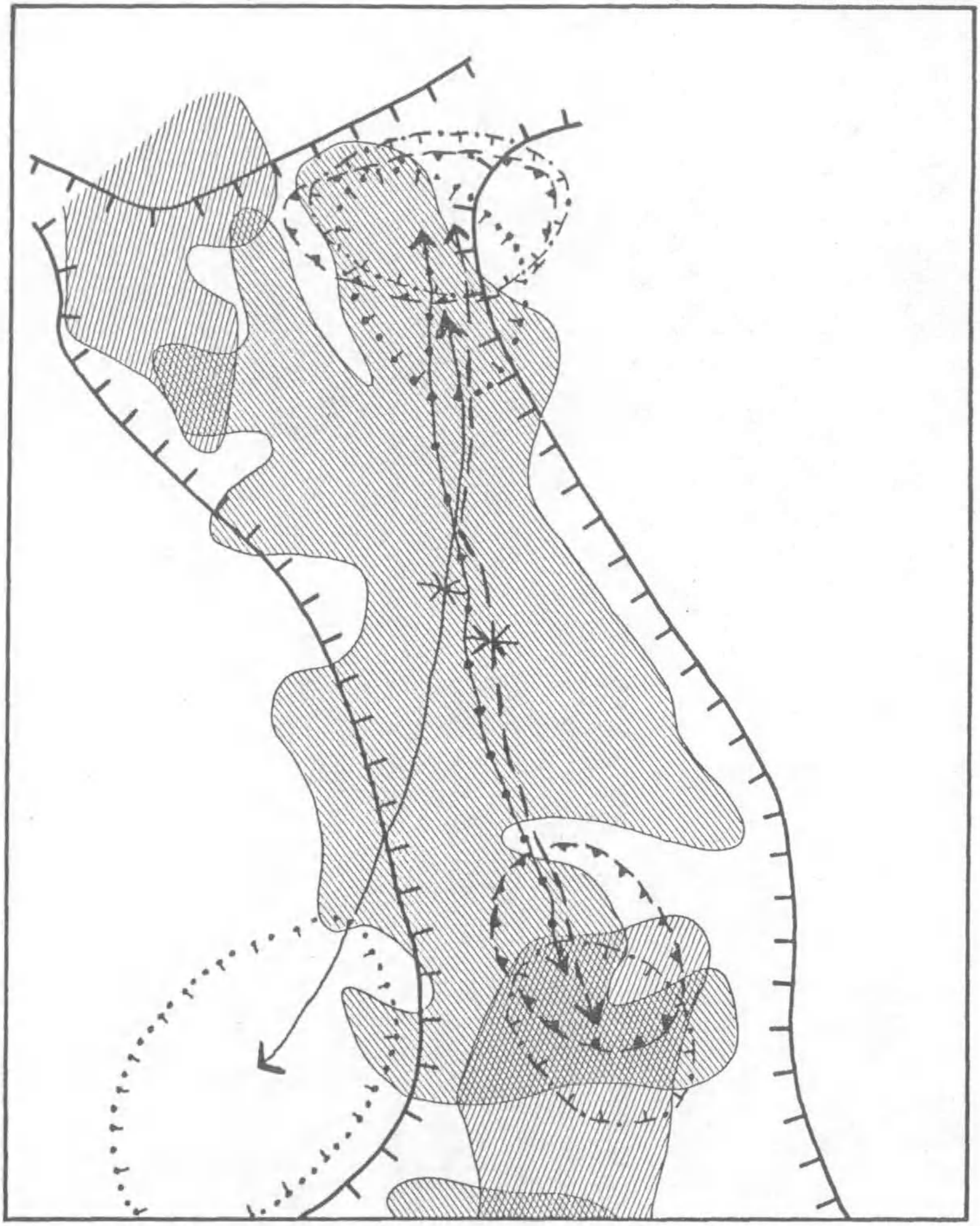


FIGURE 33 Geochemical "Troughs" and "Basins", Soil Sample Analyses.

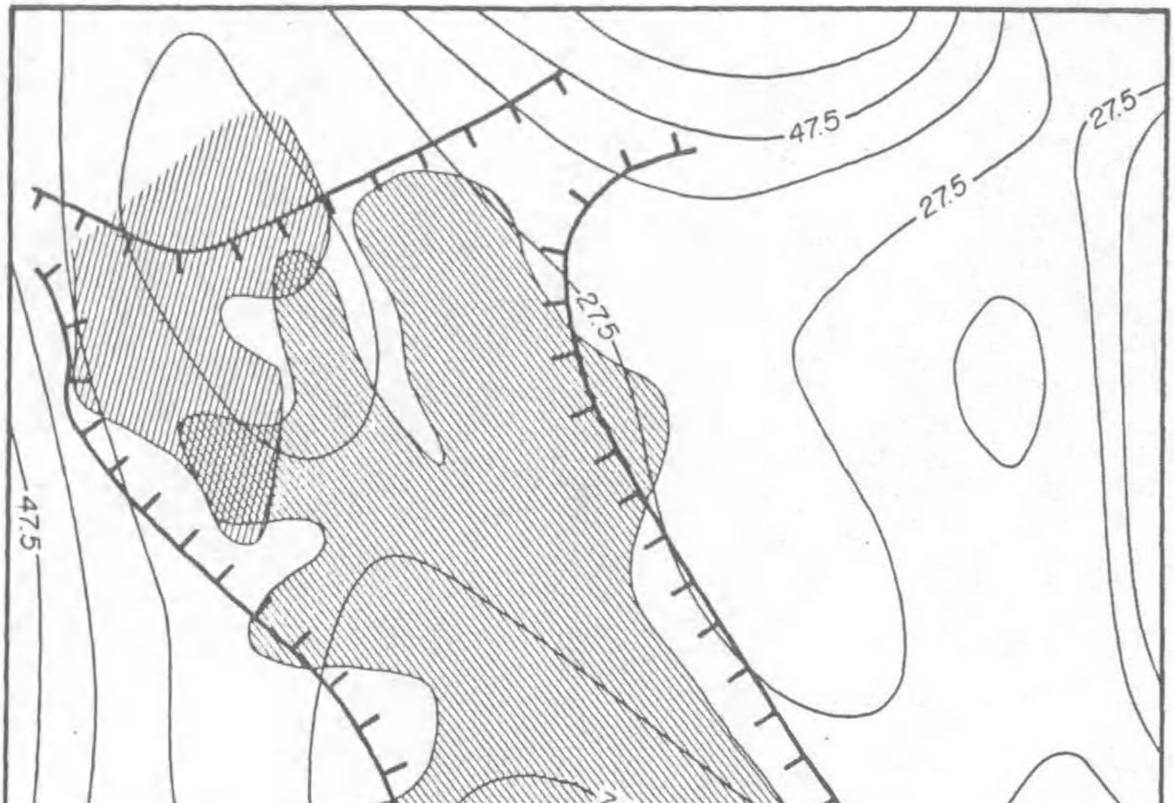


Figure 34 7th ORDER TREND SURFACE - AVAILABLE MANGANESE ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 10 PPM

r = CORRELATION COEFFICIENT
r = 0.53

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.28

N

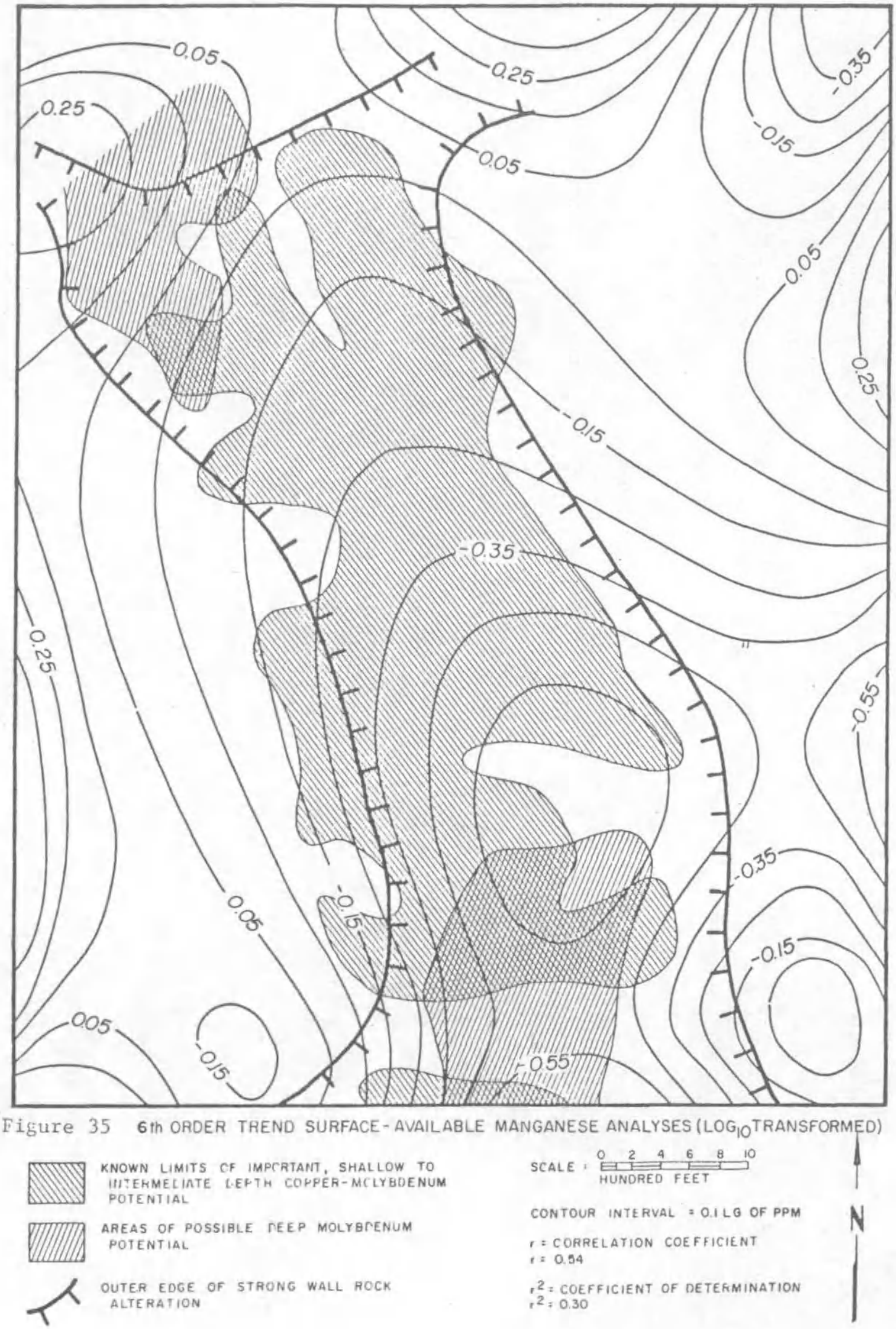


Figure 35 6th ORDER TREND SURFACE - AVAILABLE MANGANESE ANALYSES ($LOG_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.1 LG OF PPM

r = CORRELATION COEFFICIENT
r = 0.54

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.30

N

Cold extractable heavy metal data, untransformed, also yields a statistically significant 6th order trend surface (Fig. 36). The apparent trends seem to be wholly unrelated to either the zone of strong wallrock alteration or the porphyry system as outlined by drilling. Comparison with the geologic map (Fig. 3) does indicate a tendency for heavy metal values to increase in the alluvium filled valley.

The 6th order trend surface for soil pH analyses is shown in Figure 37. The patterns depicted indicate a strong environmental control. Values tend to rise towards the alluvium filled valley. The "grain" of the map is dominantly east-west, cross cutting the zone of strong wallrock alteration and buried porphyry potential.

Finally, organic carbon analyses ($\log_{10}$ transformed) yield a highly significant 6th order trend surface (Fig. 38). The surface shown is characterized by very little geochemical "relief", though two elongate "lows" are evident. Both show good spatial correlation with strong wallrock alteration and areas of subsurface copper-molybdenum potential. Referring back to the previous section on correlation analysis, it should be recalled that there is ample reason to believe that the "organic carbon" determinations really measured oxidizatable manganese (e.g. $Mn^{++}$). If this is true, then the trends shown on Figure 38 are more understandable because both hot acid and weak acid extractable manganese analyses show similar spatial relationships.

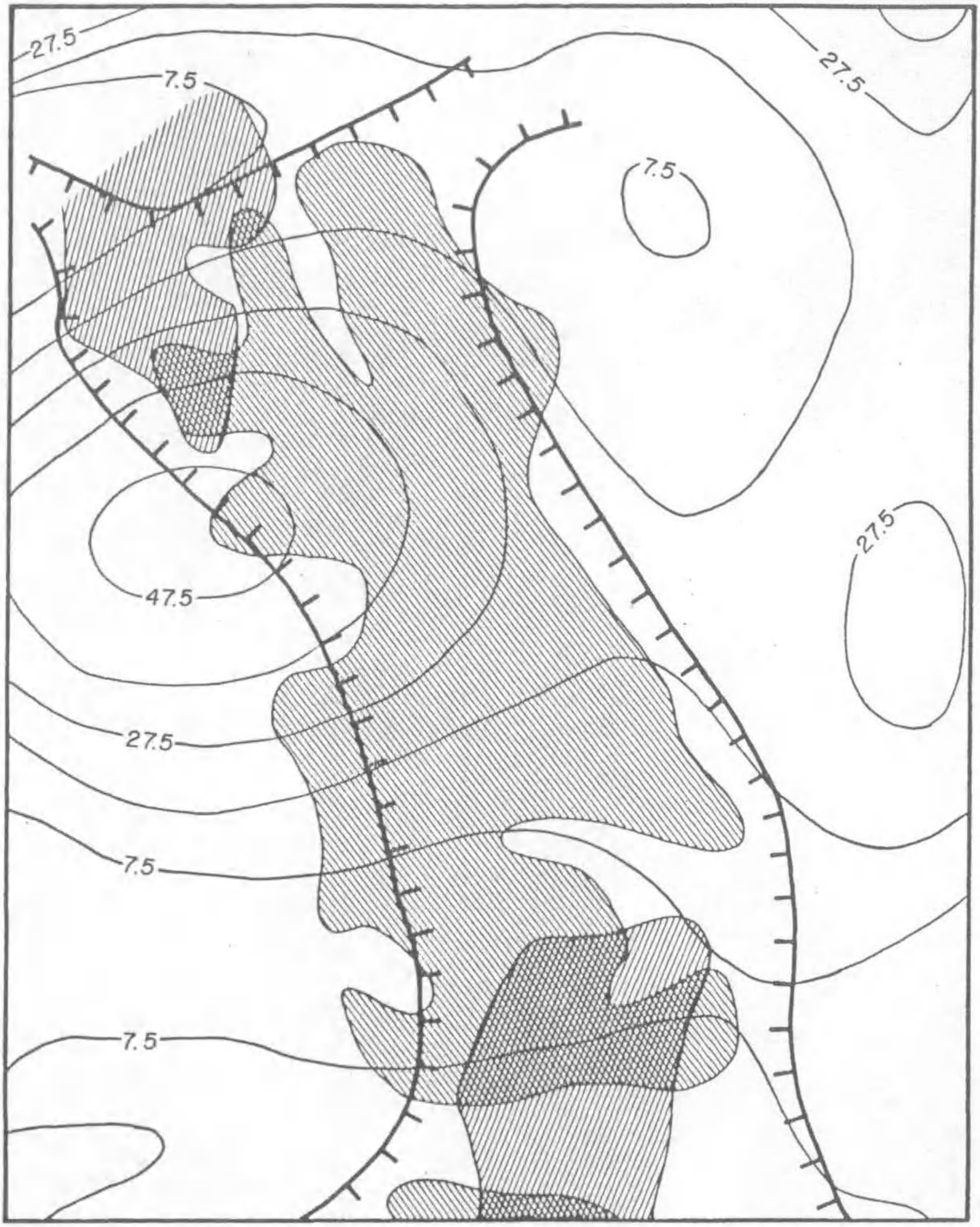


Figure 36 6th ORDER TREND SURFACE COLD EXTRACTABLE HEAVY METALS

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 10 PPM

r = CORRELATION COEFFICIENT
r = 0.52

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.27

N

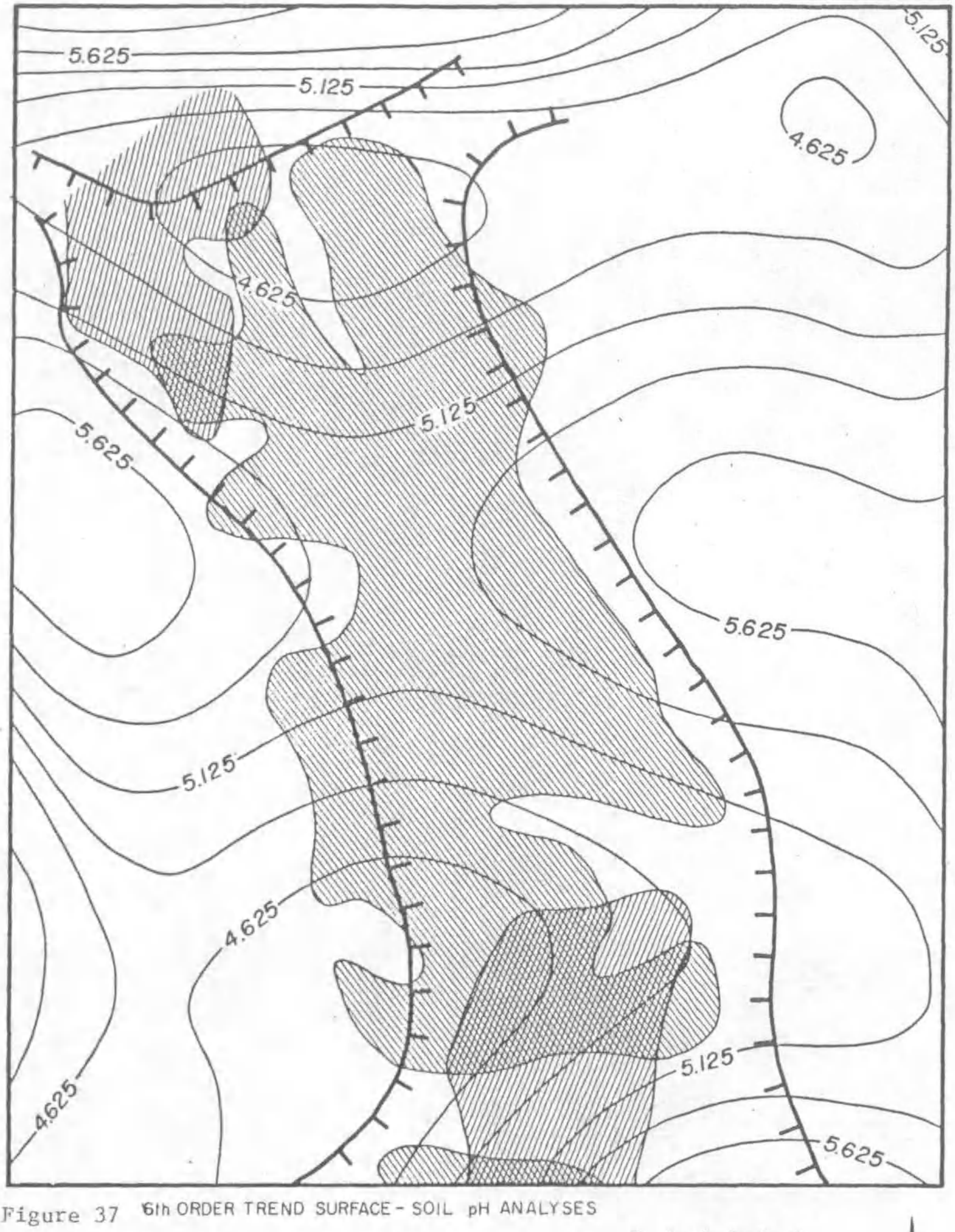


Figure 37 6th ORDER TREND SURFACE - SOIL pH ANALYSES

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE: 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.25

r = CORRELATION COEFFICIENT
r = 0.63

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.40

N

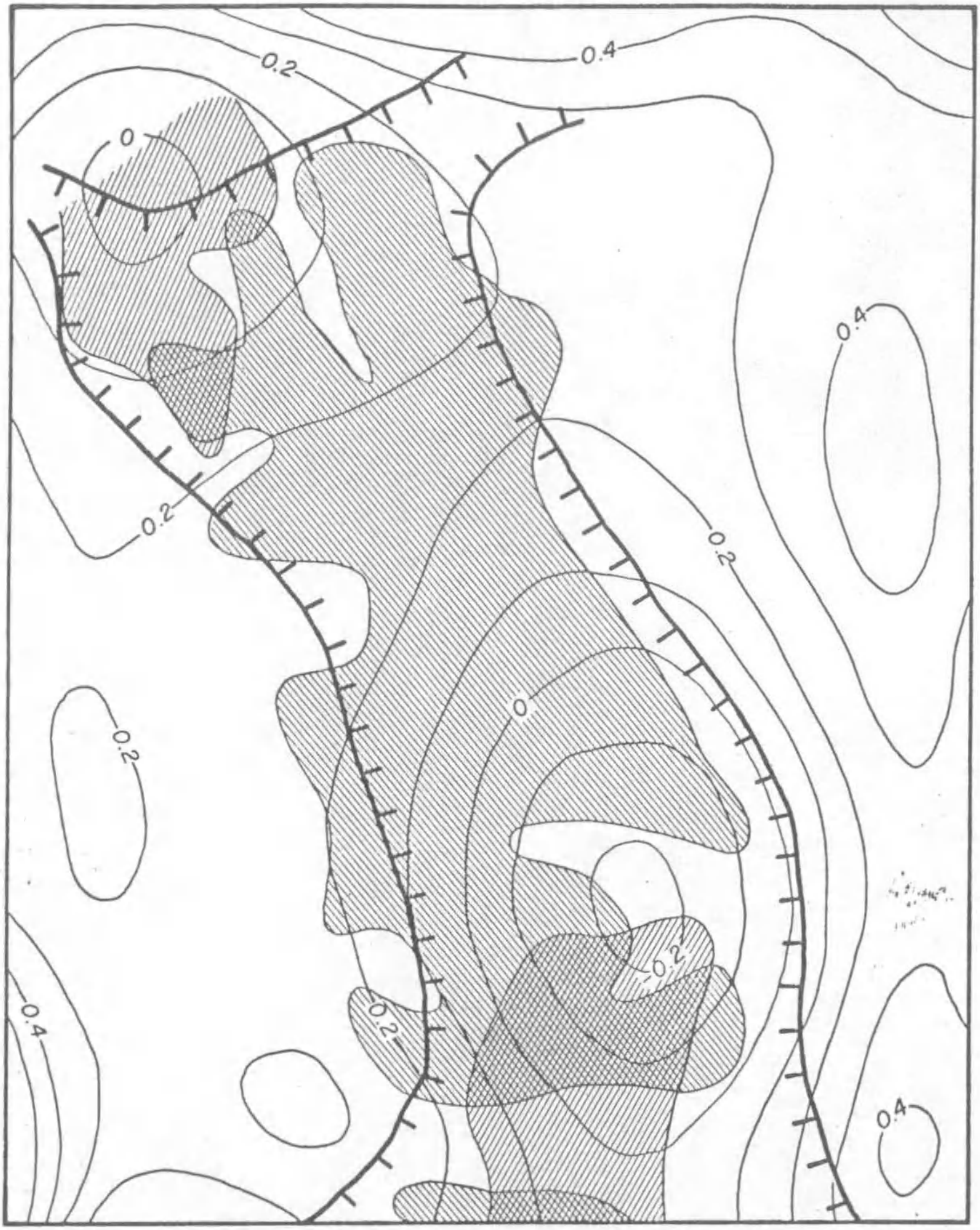


Figure 38 6th ORDER TREND SURFACE—ORGANIC CARBON SOIL ANALYSES ($LOG_{10}$ TRANSFORMED)

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = **0.1 LG of %**

$r$ = CORRELATION COEFFICIENT
$r$ = 0.50

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.25

N

## Synthesis

Weak acid extractable manganese and "oxidizable" manganese emerge as broad indicators of the Heddleston porphyry system. Geochemical "troughs" and "basins" in the trend surfaces for these two data sets spatially coincide with the zone of strong wallrock alteration and subsurface copper-molybdenum mineralization. As was the case with the "total" base metal analyses, these results can be interpreted as reflecting manganese depletion due to pervasive hydrothermal alteration.

Plant analyses. Statistically significant 6th order trend surfaces are obtained for plant lead analyses on both raw and logarithmically transformed data (Figs. 39 & 40). The patterns on both are nearly identical. The most conspicuous feature of the trend surface is the large, bullseye shaped high in the northwest corner. Since Montana Highway 200 occurs in the center of this high, it seems logical to assume that the enhanced lead content is the direct result of vehicular pollution. The remaining lead patterns appear to be unrealted to the known wallrock alteration or subsurface mineralization.

Plant zinc analyses also yield statistically significant 6th order trend surfaces for raw and logarithmically transformed data (Figs. 41 & 42). Both show strong east-west "grain." Plant zinc content appears to be enhanced in the low-lying, alluvium filled valley, but shows no obvious relationship to large scale alteration and/or mineralization patterns.

Sixth and 7th order trend surfaces for raw and logarithmically transformed plant manganese analyses are shown in Figure 43 and 44.

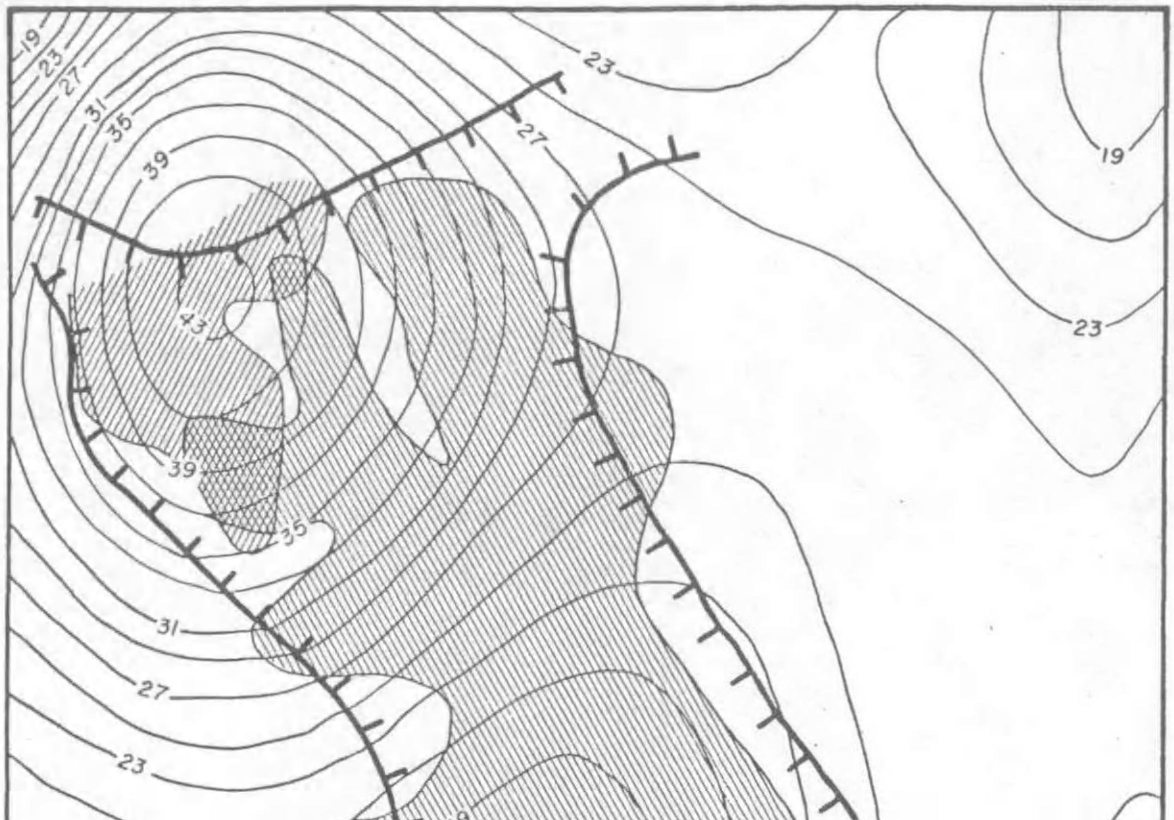


Figure 39 6th ORDER TREND SURFACE - PLANT LEAD ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE: 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 2 ppm

r = CORRELATION COEFFICIENT
r = 0.61

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.38

N

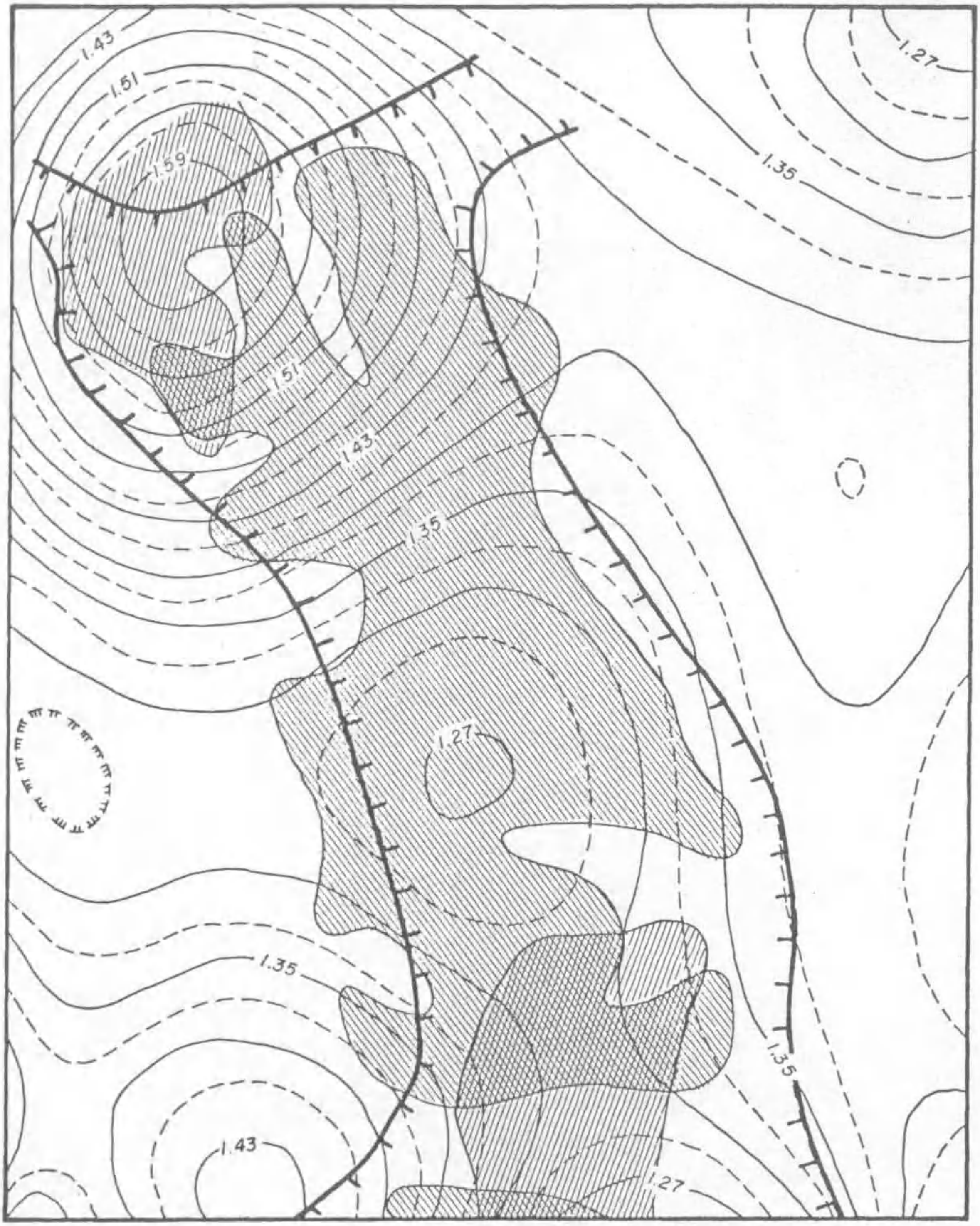


Figure 40 6th ORDER TREND SURFACE-PLANT LEAD ANALYSES ($LOG_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE - 0 2 4 6 8 10
HUNDRED FEET

CONTOUR INTERVAL = 04 LG of PPM
— — — — HALF-INTERVAL CONTOURS
$r$ = CORRELATION COEFFICIENT
$r = 0.59$

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2 = 0.39$

N

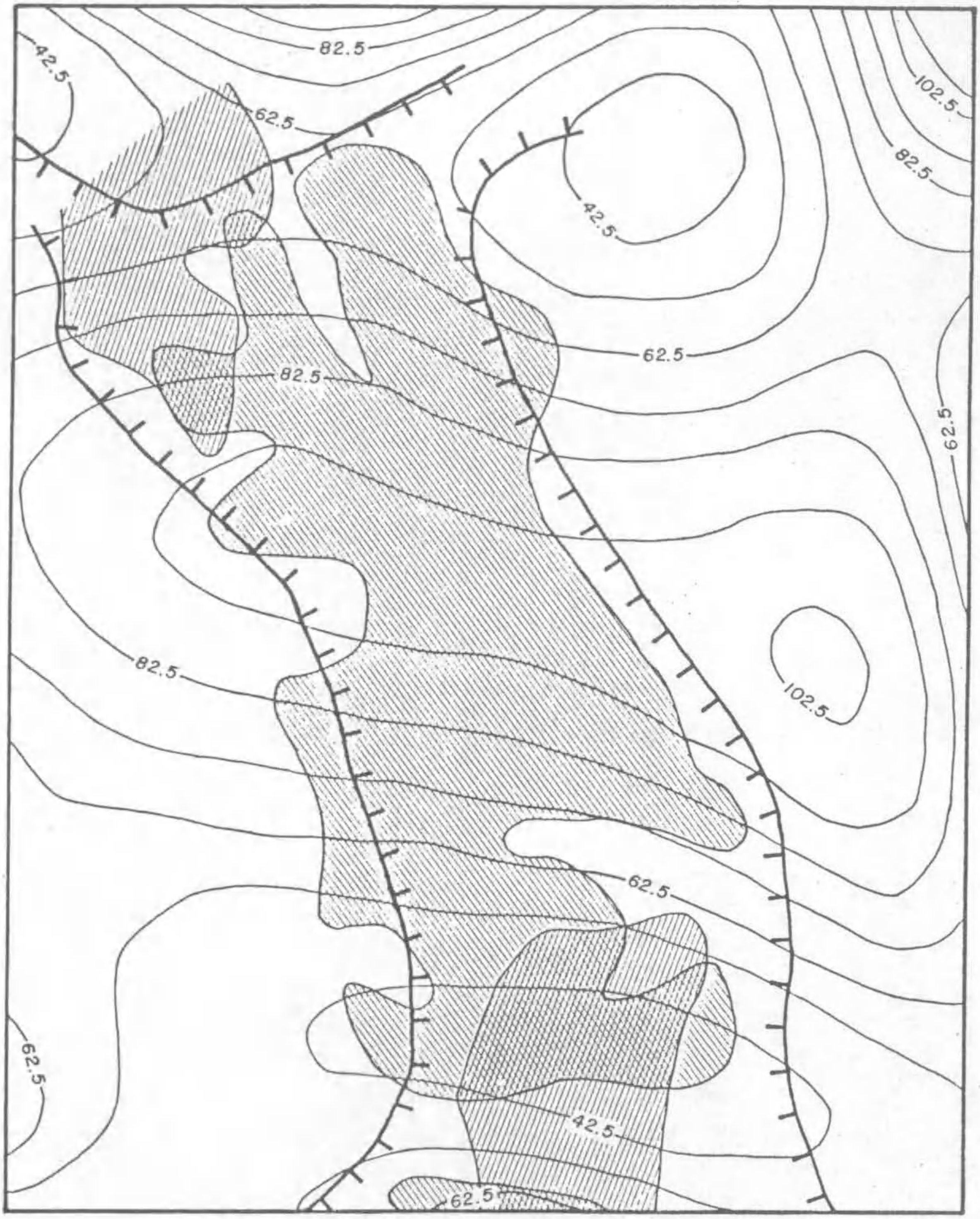


Figure 41 6th ORDER TREND SURFACE - PLANT ZINC ANALYSES

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE: 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 10 ppm

r = CORRELATION COEFFICIENT
r = 0.51

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.26

N

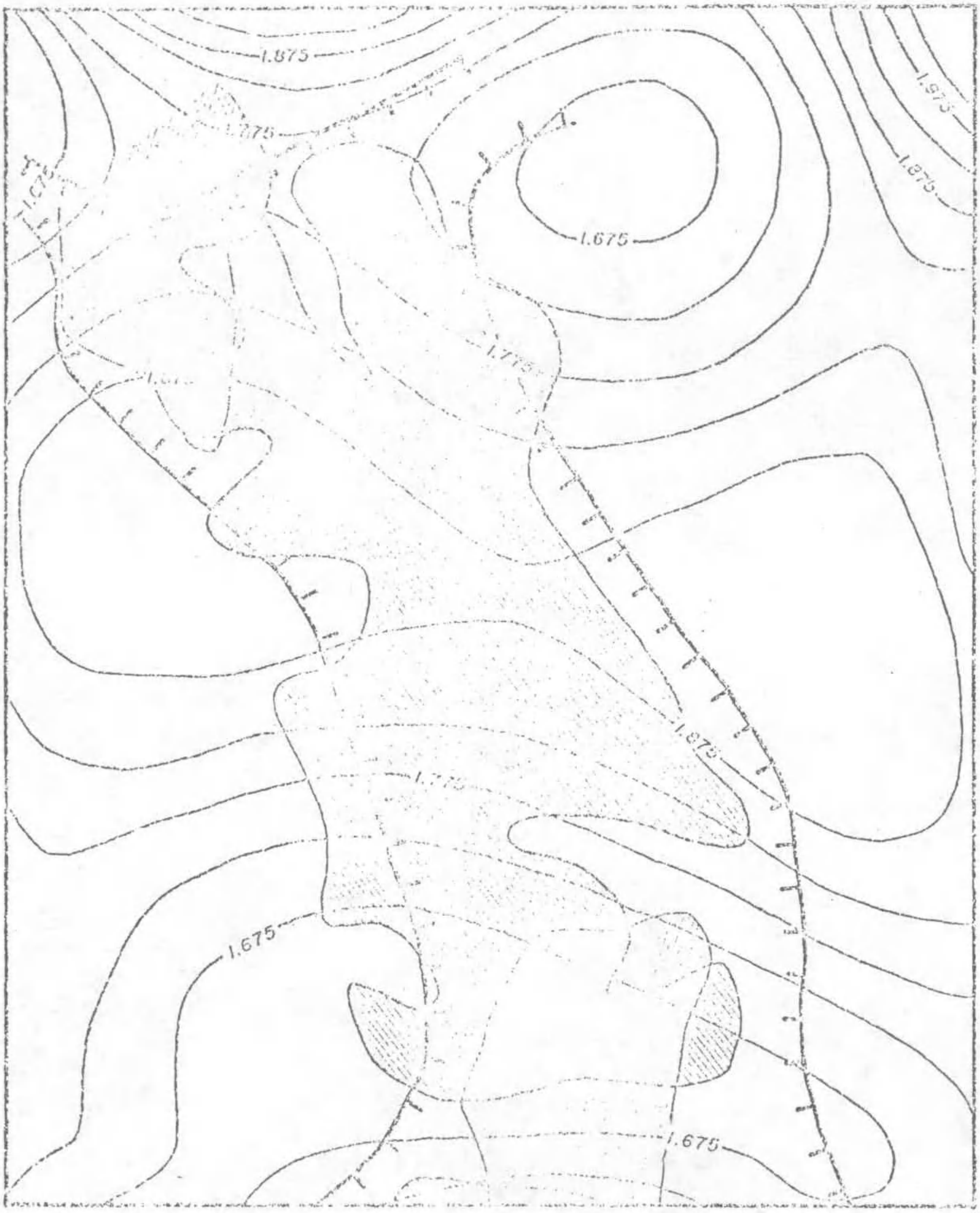


Figure 42 6th ORDER TREND SURFACE - PLANT ZINC ANALYSES ($LOG_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = .05 lg of ppm

r = CORRELATION COEFFICIENT
r = 0.53

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.28

N

The patterns depicted on each are very similar. Although there appears to be a local spatial relationship between plant manganese and alteration/subsurface mineralization, the nature of this relationship varies. In the northeast quadrant of Figure 43, a plant manganese "low" is associated with QMP I porphyry and a zone of deep molybdenum potential. On the other hand, an elongate plant manganese "high" occurs predominantly over QMP I porphyry and a second zone of deep molybdenum potential.

Referring back to the discussion of correlation analysis, it was suggested that the degree to which the manganese content of Lodgepole pines reflects its substrate depends upon the amount of copper-iron sulfides introduced with the manganese. Where significant copper-iron sulfides occur rhodocrosite will be dissolved by acid weathering solutions and the manganese either leached from the soil or precipitated as oxides. Alternatively, where sulfide minerals were absent, rhodocrosite could remain as a source of manganese more available to the plants than in the oxide form. Hence the plant manganese low in the northeast may be the result of increased sulfide content in the altered porphyry with respect to the plant manganese high to the south. This is further evidence that fundamental geochemical differences exist between the porphyry system exposed in the north versus that exposed in the south.

Statistically significant 6th order trend surfaces for plant iron analyses, both raw and logarithmically transformed, are shown in Figures 45 and 46 respectively. The most prominent feature on either trend surface is a circular "high" located in the north-western corner.

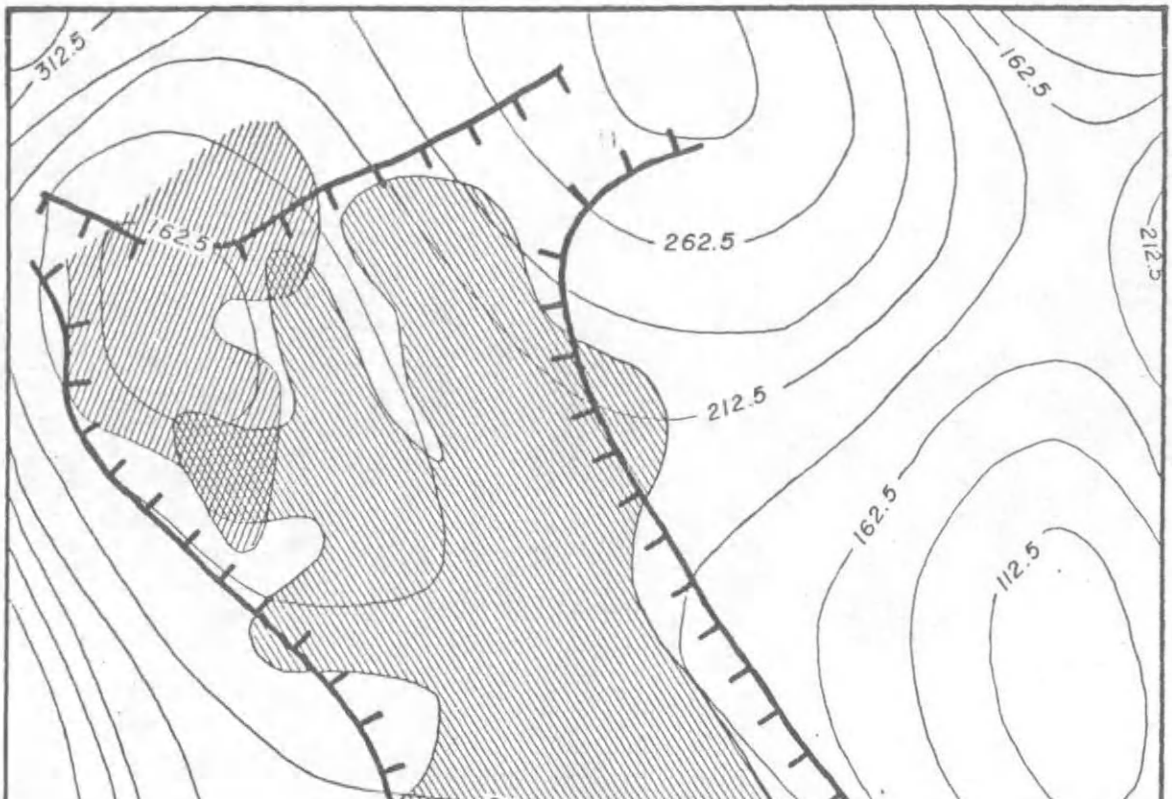


Figure 43 6th ORDER TREND SURFACE - PLANT MANGANESE ANALYSES

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 25 PPM

$r$ = CORRELATION COEFFICIENT
$r = 0.49$

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2 = 0.24$

N

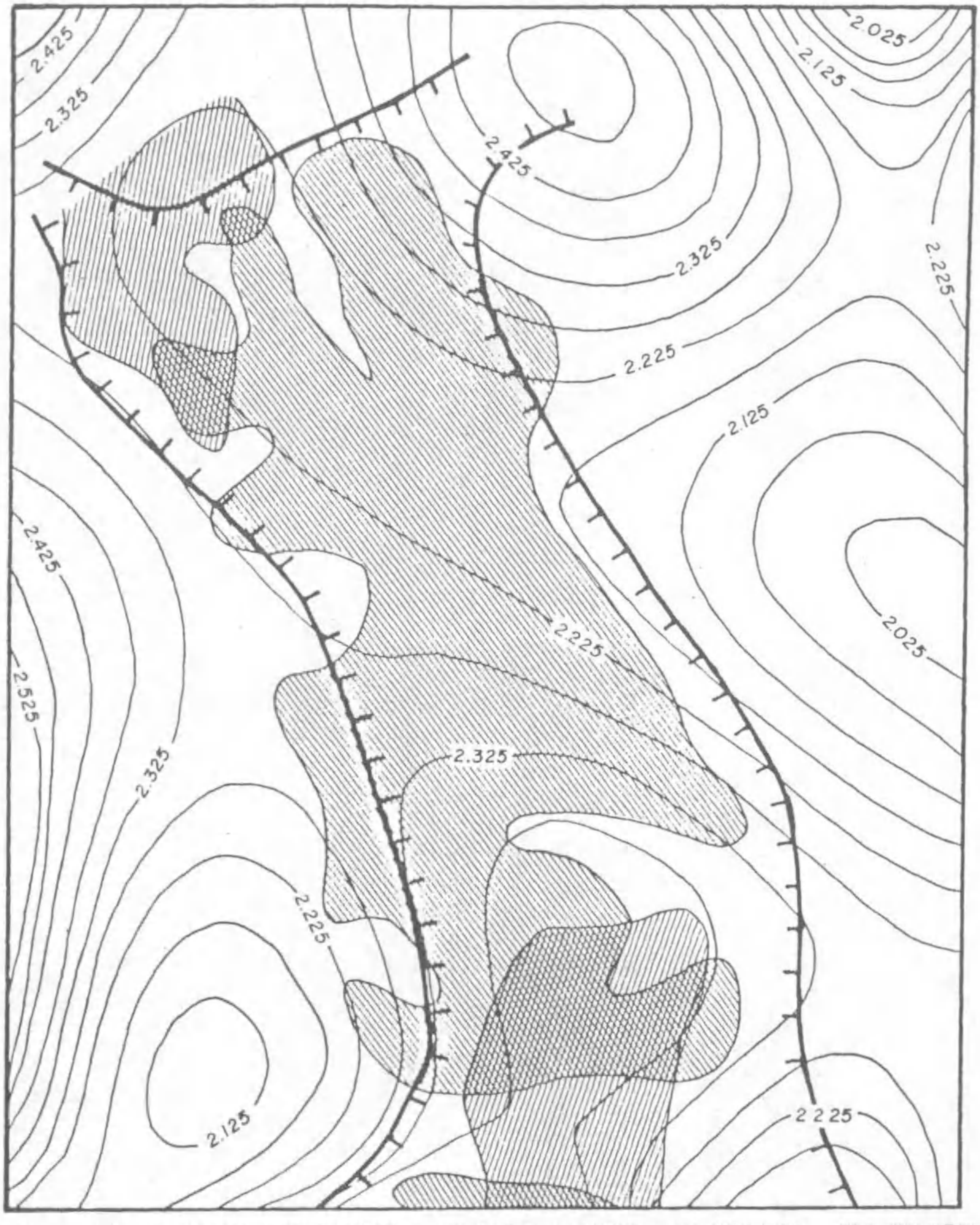


Figure 44 7th ORDER TREND SURFACE - PLANT MANGANESE ANALYSES ($LOG_{10}$ TRANFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE: 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = .05 Lg of PPM

r = CORRELATION COEFFICIENT
r = 0.52

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.27

N

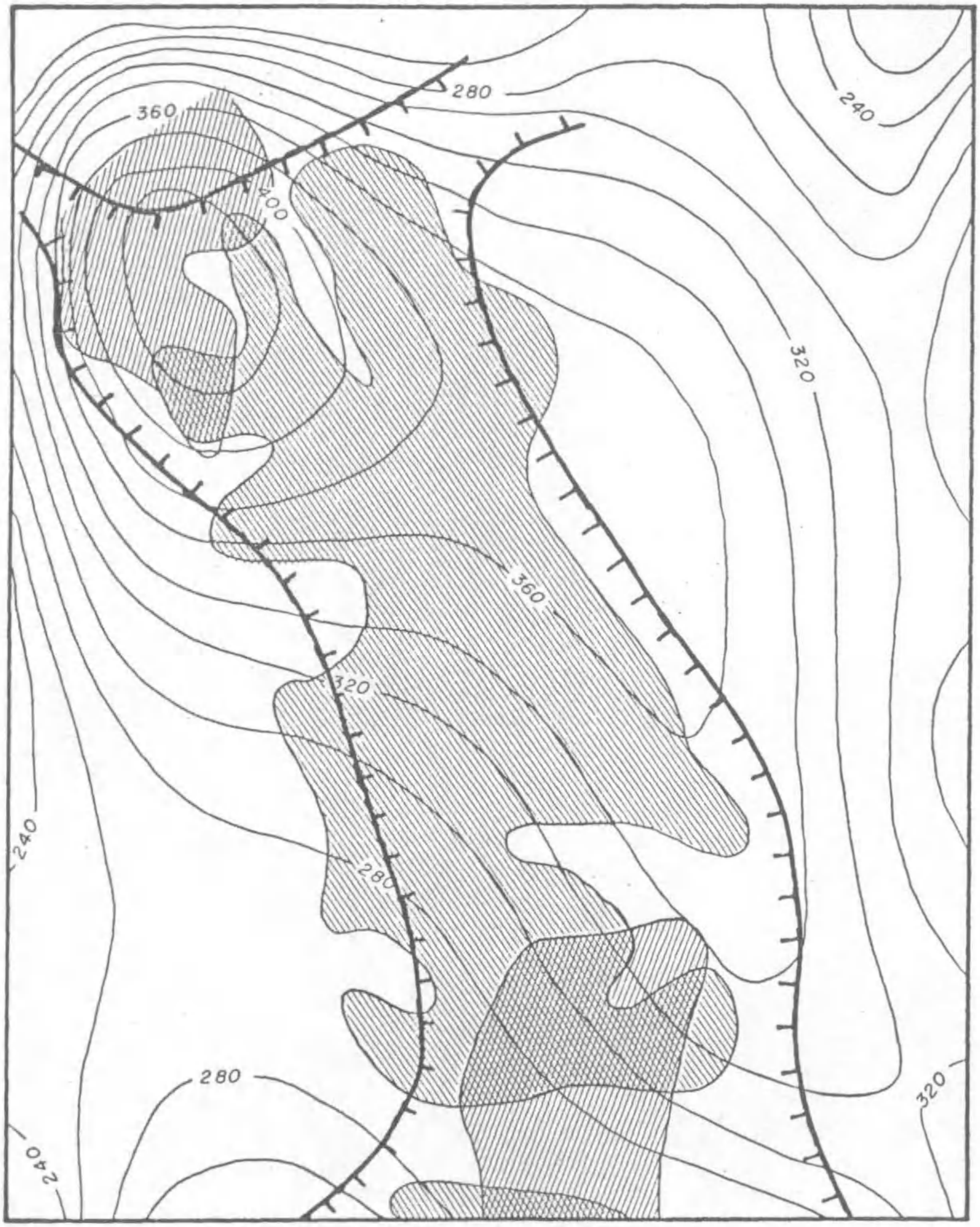


Figure 45 6th ORDER TREND SURFACE - PLANT IRON ANALYSES

| | |
|---|---|
| ▨ | KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL |
| ▨ | AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL |
| ⅄ | OUTER EDGE OF STRONG WALL ROCK ALTERATION |

SCALE 0 2 4 6 8 10
HUNDRED FEET

CONTOUR INTERVAL = 20 PPM

r - CORRELATION COEFFICIENT
r = 0.52

$r^2$ : COEFFICIENT OF DETERMINATION
$r^2$ = 0.27

N

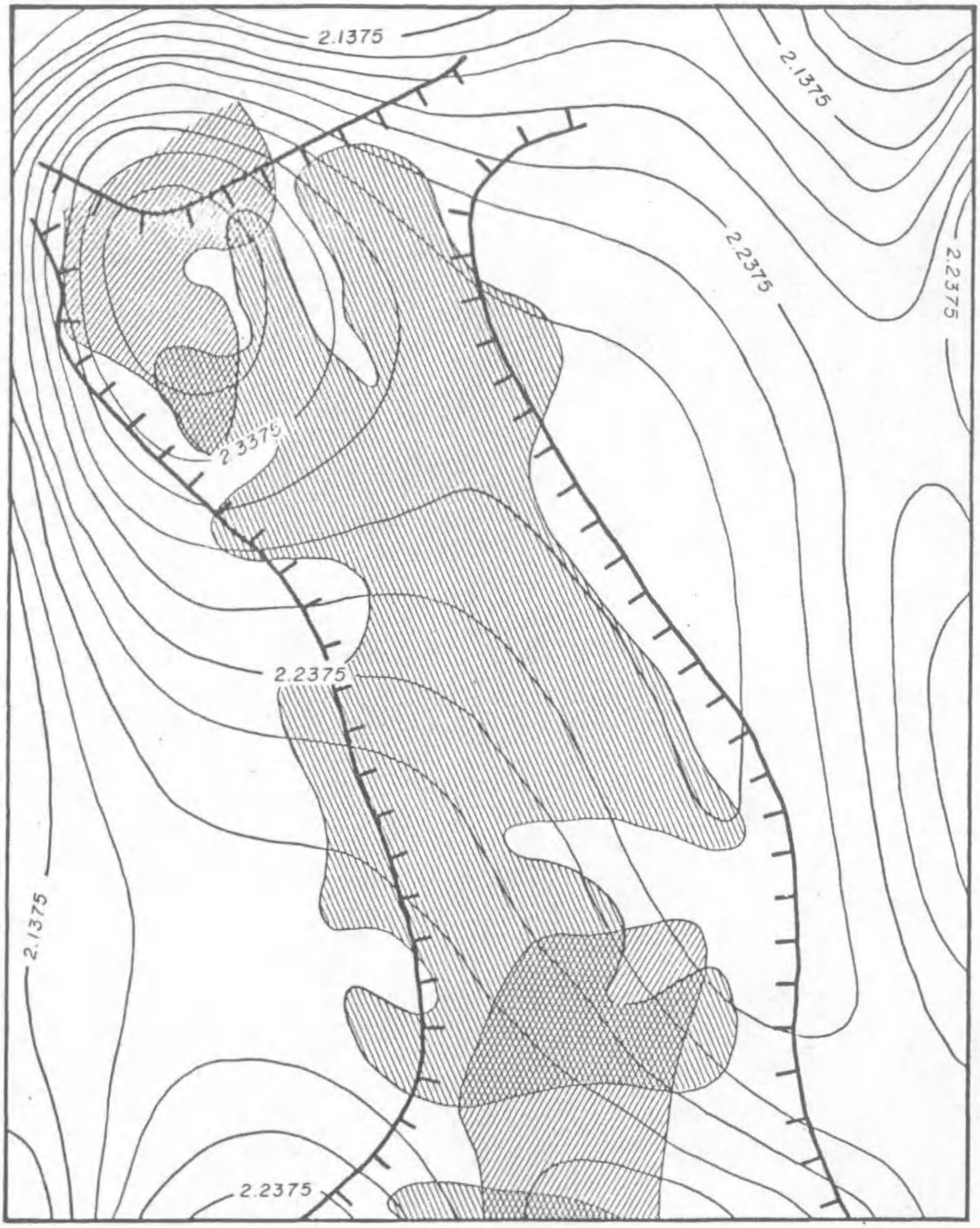


Figure 46 6th ORDER TREND SURFACE - PLANT IRON ANALYSES ($LOG_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = .05 Lg of PPM

r = CORRELATION COEFFICIENT
r = 0.52

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.27

N

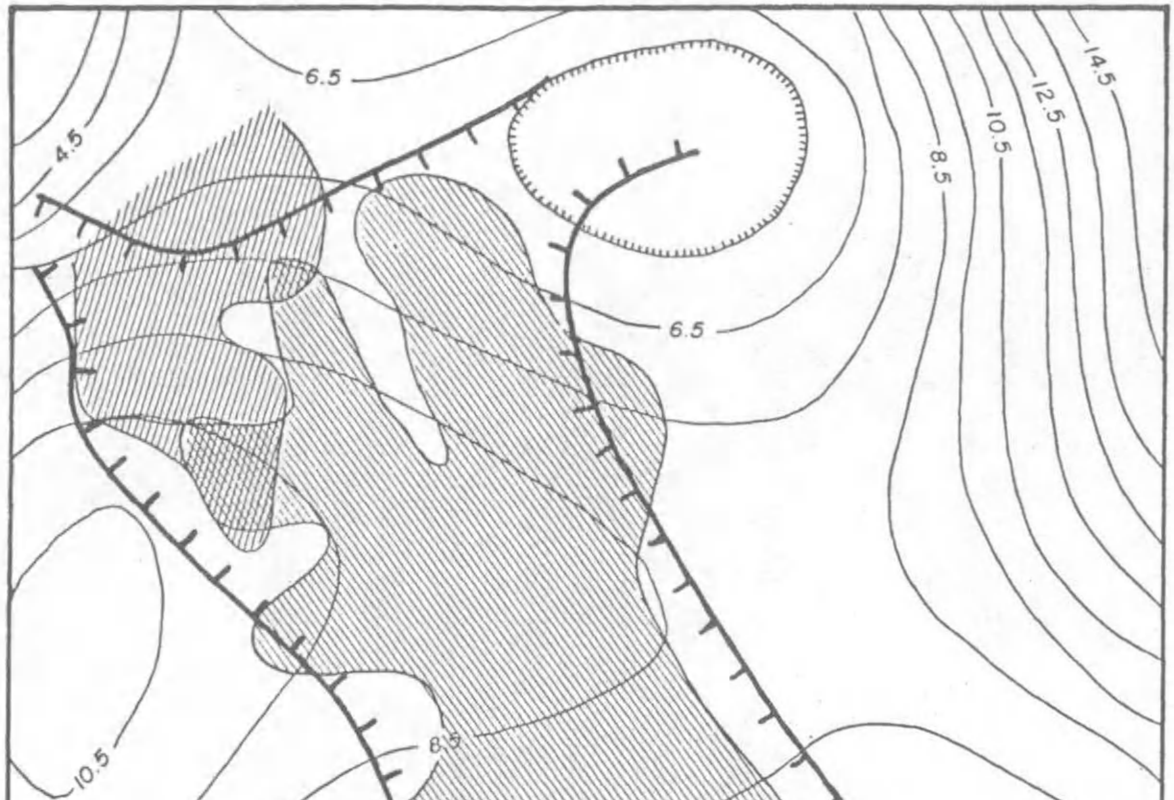


Figure 47 6th ORDER TREND SURFACE - PLANT CADMIUM ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 1 PPM

r = CORRELATION COEFFICIENT
r = 0.68

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.46

N

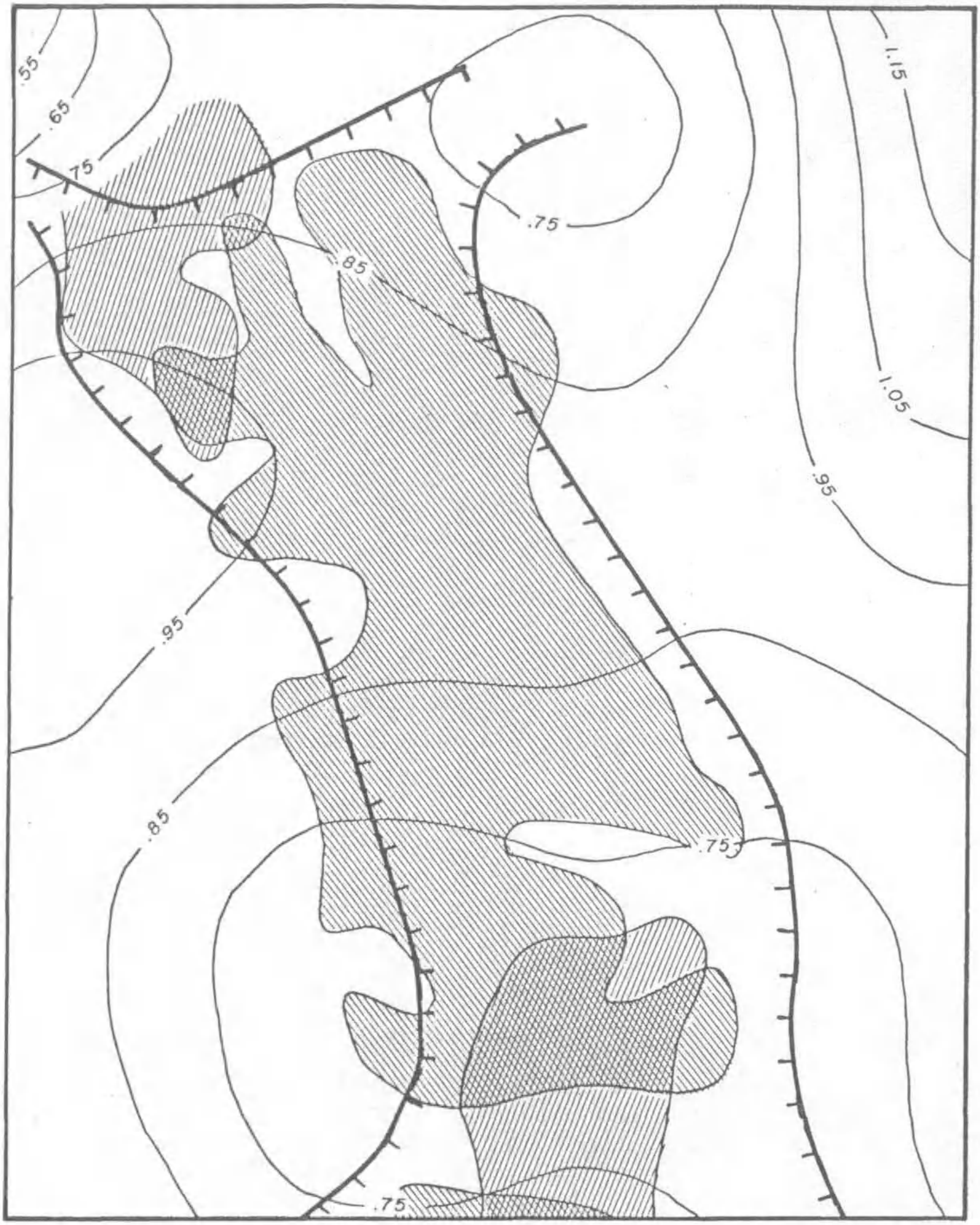


Figure 48 6th ORDER TREND SURFACE - PLANT CADMIUM ANALYSES ($LOG_{10}$ TRANSFORMED)

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE: 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = .1 Lg of PPM

r = CORRELATION COEFFICIENT
r = 0.66

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.44

N

The "high" is underlain by QMP I porphyry and an area of deep molybdenum potential. It also coincides with the previously discussed plant manganese "low" (Figs. 43 & 44), a ridge of high soil iron (Fig. 32) and a "trough" of low pH (Fig. 37). Hence the plant iron high is probably a direct reflection of abundant pyritic alteration developed above the zone of deep molybdenum potential.

Plant cadmium analyses yield very highly significant trend surfaces for both raw and logarithmically trnasformed data (Figs. 47 & 48). The patterns depicted on the trend surfaces are similar to those already discussed for zinc (Figs. 41 & 42). There is a strong tendency for cadmium to increase in an alluvial, valley bottom environment. No obvious relationship exists between plant cadmium abundance trends and either the zone of strong wallrock alteration or subsurface copper-molybdenum potential.

## Synthesis

From the above discussion it is evident that the base metal trends in Lodgepole pine are largely ineffective guides to the Heddelston deposit. Iron was the only element whose trend surface gave an unequivocal bullseye over mineralized/altered ground. This bullseye corresponds spatially with trend of greatly increased available iron. This response may reflect a subtle pyrite halo over the deeply buried molybdenum mineralization.

Manganese produced distinct patterns over both areas of deep molybdenum potential. However, the nature of the response, i.e. geochemical "high" or "low", may depend upon the presence or absence of accompanying sulfides. Also, identical patterns were observed outside the limits of the porphyry system as defined by drilling; hence without corroborative geochemical evidence there would be no way of identifying trends solely related to buried porphyry systems.

The trends for any or all the plant analyses might form a distinctive geochemical "signature" for the Heddleston deposit if the sample coverage was expanded several times over. By incorporating such additional "background" areas, patterns unique to the porphyry environment might become more apparent.

# CHAPTER VIII

## SUMMARY AND RECOMMENDATIONS

Soil samples and Lodgepole pine twig samples were collected over an unexposed porphyry copper-molybdenum deposit near Heddleston, Montana, and analyzed for a suite of elevan base and precious metals. The objective of this work was to determine whether reconnaissance pedogeochemical and/or biogeochemical methods could define all or part of the mineralized system. Correlation analysis, simple graphical techniques, and trend surface analysis were the main techniques utilized for evaluating the resultant data.

In terms of soil geochemistry, hot acid extractable lead, zinc, manganese and iron trends broadly, coincided with the buried porphyry system. However, it was the "lows" which were definitive, not the "highs." This seems to reflect base metal depletion in the zone of strong wall-rock alteration overlying the mineralization. Weak acid extractable manganese and oxidizable managanese showed similarly coincident trends in which the "lows" broadly defined the mineralized system.

Biogeochemical trends proved to be largely ineffective for defining the mineralized system. Iron trends pinpointed an area underlain by porphyry with deep molybdenum potential. This may reflect the presence of a subtle pyritic halo above the molybdenum. Manganese trends showed some spatial correlation with mineralization, but were inconsistent as to whether "lows" or "highs" occurred over the porphyry.

Several ancillary conclusions were also evident from the data collected at Heddleston.

(1) Zinc is the only element whose concentration in Lodgepole pine directly correlated with its total concentration in the soil.

(2) Analyses made utilizing several partial extraction techniques indicated a direct relationship between the concentration of loosely bonded metal in the soil and the concentration of those same metals in Lodgepole pine growing in the soil.

(3) Application of graphical techniques described by Brooks (1972) for defining "essential" versus "non-essential" elements in plants indicated that these plots are a reflection of soil availability factors, not plant selectivity factors.

(4) Although cadmium and zinc trends in Lodgepole pines are not effective in delineating the Heddleston deposit, the strong direct relationship between soil and plant abundance levels indicates a potential for utilizing them in biogeochemical exploration for zinc targets such as volcanogenic massive sulfides.

## Recommendations

In a study of this kind it is customary to recommend analyses for additional elements and/or the collection of additional samples. This is of little real value to practicing explorationists or geology graduate students. The central question is: "what could have been done differently to improve the quality of the data and help 'see' the hidden zone of mineralization?" A brief attempt to answer this question follows below. It is sequential in nature, encompassing the entire exploration process from planning to interpretation.

(1) An orientation study is an absolute prerequisite in this type of study. By collecting no more than a dozen twig and soil samples from the study area and running them through the entire analytical sequence, hundreds of man hours could have been saved. Elements not present in detectable amounts (e.g. cobalt, silver, etc.) could have been dropped from the analytical scheme.

(2) The in situ measurement of pH could be supplemented with Eh and conductivity determinations. Very little additional time required to make the measurements is more than made up by the increased information. Eh and pH together are powerful tools for characterizing the environment and reactions involved in an aqueous chemical system such as a soil. Conductivity is a valid new exploration (electrogeochemical) tool in itself (Govett, 1974) which has been used successfully for several years.

(3) Several additional elements should be added to the analytical scheme. Several "volatile" elements (e.g. arsenic and tellurium) should be included. These elements tend to form anomalous aureoles hundreds of feet above higher temperature sulfide mineralization (e.g. see Watterson et al., 1977). In addition,

gold, could give valuable information in areas of supergene leaching. Learned and Boissen (1973) found that gold was the only element stable enough to remain after leaching over a porphyry copper deposit in Puerto Rico.

(4) An attempt should be made to quantify the amount of "reactive substrate" within the soil samples. Measurements of organic matter and iron and manganese partly accomplish this. A further step would involve utilizing hydrometers to measure the amount of silt and clay in a sample. Thomas (1972) approached it from another direction by measuring the amount of free silica in the sample. The goal of any of these techniques is to allow the removal of the amount of active substrate as a source of metal abundance variability.

(5) The single most useful step that could be taken is to utilize step-wise multiple regression techniques to "remove" layers of extraneous variability. Rose et al. (1970) gives an excellent example of how this works for stream sediment samples.

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# APPENDIX I

## Field Notes

Key:

Tree growth (second and third year twigs)

vigorous - .4" - .5" diam., 3" - 4" long
average - .2" - .4" diam., 2" - 3" long
stagnant - .1" - .2" diam., 1" long

Tree size (trunk diameter)

very small - 1" - 3"
small - 3" - 5"
average - 5" - 10"
large - 10+"

Soil thickness or development

very thin - 1" - 2" on bedrock
thin - up to 1' of soil, unconsolidated rock mixture
others - described specifically

| Sample Location | Remarks |
|---|---|
| 1A | Southwest facing slope; small trees; vigorous, open growth; thin soil. Date collected: 9/11/73 |
| 1B | On brow of ridge; small trees; vigorous, open growth; thin soil. Date collected: 9/11/73 |
| 1C | Traversing up southeast facing slope; average tree size; average growth; thin soil. Date collected: 9/11/73 |
| 1D | Traversing up southeast facing slope; average tree size; average growth. Date collected: 9/11/73 |
| 1E | Starting up southeast facing slope; average tree size; average growth; thin soil. 100' west of highway. Date collected: 9/11/73 |
| 1F | Average tree size; average growth; thin soil. 361' east of highway. Date collected: 9/11/73 |
| 1G | Northwest facing slope; average tree size; average growth; thin soil. 200' below drill road. Date collected: 9/11/73 |
| 1H | Northwest facing slope; average tree size; average growth; thin soil. 60' below one drill pad and 100' upslope from another drill pad. Date collected: 9/11/73 |

## Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 1I | West facing slope; average tree size; average growth; thin soil on porphyry outcrop. North edge of drill pad. Date collected: 9/11/73 |
| 1J | Southeast facing slope; average to large tree size; average growth; thin soil. 10' west of adit portal. Date collected: 9/12/73 |
| 1K | Southeast facing slope; large trees; average growth; thin soil. Date collected: 9/12/73 |
| 1L | Southeast facing slope; large trees; average growth; thin soil. Numerous fir trees present. Date collected: 9/12/73 |
| 1M | Southeast facing slope; average size trees; average growth; thin soil on gabbroic sill material. Date collected: 9/12/73 |
| 2A | Southwest facing slope; small trees; average growth; thin soil on porphyry outcrop. Traversing down ridge top. Date collected: 9/11/73 |
| 2B | Southeast facing slope; large trees; average growth; thin soil. Date collected: 9/11/73 |
| 2C | Southeast facing slope; average trees; average growth; thin soil. 50' west of dirt road near drill collar. Date collected: 9/11/73 |
| 2D | Southeast facing slope; large trees; average growth; thin soil. Traversing down, 256' west of highway. Date collected 9/11/73 |
| 2E | Southeast facing slope; average size trees; average growth; soil has deep dark horizon under thick humus mat. 468' down traverse from 2D and 168' east of highway; very marshy ground. Date collected: 9/11/73 |
| 2F | West facing slope; average size trees; average growth; thin soil. Very open. Date collected: 9/11/73 |
| 2G | West facing slope; average size trees; average growth; thin soil. 210' up slope of dead end drill pad. Date collected: 9/11/73 |
| 2H | West facing slope; small trees; average growth; thin soil. 10' east of main dirt road. Date collected: 9/11/73 |
| 2I | Southeast facing slope; large trees; average growth; thin soil. Edge of drill pad. Date collected: 9/11/73 |
| 2J | South facing slope; large trees; average growth; thin soil. West of small nondescript mine dump. Date collected: 9/12/73 |
| 2K | South facing slope; large trees; average growth; thin soil. Date collected: 9/12/73 |

## Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 2L | South facing slope; large trees; average growth; thin soil on gabbroic material. Date collected: 9/12/73 |
| 2M | Southeast facing slope; large trees; thin soil on gabbroic material. Date collected: 9/12/73 |
| 3A | West facing slope just over brow of ridge; small trees (20' - 25' tall); average growth; good A soil horizon developed. Date collected:9/12/73 |
| 3B | Southeast facing slope; fairly large trees; average growth; thin soil. Date collected: 9/12/73 |
| 3C | Southeast facing slope; large trees; average growth; thin soil. Date collected: 9/12/73 |
| 3D | Southeast facing slope; average trees; average growth; fair to thin soil. 100' west of highway, 60' west of designated sample location. Date collected: 9/12/73 |
| 3E | Northwest facing slope; average size trees; average growth; thin soil on porphyry. Sample taken on northwest side of drill road. Date collected: 9/12/73 |
| 3F | Northwest facing slope; small trees; average growth; thin soil. Date collected: 9/12/73 |
| 3G | West facing slope; average size trees; stagnant growth; thin soil. 50' above one drill pad and 125' below other drill road and pad. Date collected: 9/12/73 |
| 3H | Flat brow of ridge; small trees; average growth; thin soil on light red argillites. 125' west of claim corner; 225' east of drill road. Date collected: 9/12/73 |
| 3I | Southeast facing slope; average trees; average growth; thin soil above strongly oxidizing sulfide dump (pyrite). 50' above Midnight Mine buildings and 275' east of claim corner. Date collected: 9/12/73 |
| 3J | Southeast facing slope; 500' east of Midnight Mine dump (diagonally downhill). Date collected: 9/12/73 |
| 3K | Southeast facing slope; average size trees; average growth; thin soil. Date collected: 9/12/73 |
| 3L | Southeast facing slope; average size trees; average growth; soil taken next to steep stream cut bank. Date collected: 9/12/73 |
| 3M | Northwest facing slope; average tree size; average growth; thin soil. East of stream bottom on second road uphill on that side of stream. Date collected: 9/12/73 |
| 4A | Southwest facing slope; very small trees; average growth; thin soil. Date collected: 9/12/73 |

## Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 4B | Southeast facing slope; average size trees; average growth; fair to thin soil. 50' west of road. Date collected: 9/12/73 |
| 4C | Southeast facing slope; average trees; average growth; thin soil. 137' above highway. Date collected: 9/12/73 |
| 4D | No sample; in swampy ground. |
| 4E | Northwest facing slope; average trees; average growth; thin soil. 70' east (uphill) of drill pad. Date collected: 9/12/73 |
| 4F | Northwest facing slope; average trees; average growth. Near downhill edge of drill road. Fairly good A and ? horizons developed. Sample taken after digging through drill cutting wash with sulfur smell of oxidizing pyrite. Date collected: 9/12/73 |
| 4G | Northwest facing slope; average trees; average growth; thin to fair soil. 85' above drill collar. Date collected: 9/12/73 |
| 4H | Southeast facing slope; average trees; average growth; thin soil. Near old mine road. Date collected: 9/12/73 |
| 4I | Southeast facing slope; large trees (12"-14" diam.); nearly stagnant growth; thin soil. 100+' south of Midnight Mine dump. Date collected: 9/12/73 |
| 4J | Southeast facing slope; average tree size; average growth; thin soil. Date collected: 9/14/73 |
| 4K | Average tree size; average growth; thin soil. Edge of stream bed near buildings. Date collected: 9/14/73 |
| 4L | Average tree size; average growth; thin soil. 200' east of road; east of stream bed and mine dump. Date collected: 9/14/73 |
| 4M | Northwest facing slope; average trees; average growth; thin soil on gabbroic outcrop. Date collected: 9/14/73 |
| 5A | South facing slope; average tree size; average growth; thin soil on leached porphyry outcrop. 300' above and north of highway. Date collected: 9/16/73 |
| 5B | South facing slope; average tree size; average growth; thin soil near leached porphyry outcrop. 150' above and north of highway. Date collected: 9/16/73 |
| 5C | No samples collected; in swampy or saturated ground. |
| 5D | Southeast edge of swamp; average trees; average growth; thin soil. 500' east of junction of two main roads. Date collected: 9/16/73 |
| 5E | Northwest facing slope; average tree size; average growth; thin soil. Date collected: 9/16/73 |

## Field Notes (continued)

| Sample Location | Remarks |
|---|---|
| 5F | Northwest facing slope; small trees; average growth; thin soil. Date collected: 9/16/73 |
| 5G | South facing slope; average tree size; average growth; thin soil. Date collected: 9/16/73 |
| 5H | Southeast facing slope; average trees; average growth; thin soil. Date collected: 9/16/73 |
| 5I | Southeast facing slope; average size trees; average growth; thin soil. Date collected: 9/16/73 |
| 5J | Southeast facing slope; average tree size; average growth; thin soil. Tree sample taken on downhill edge of nondescript mine dump. Date collected: 9/16/73 |
| 5K | Average tree size; average growth; thin soil. East side of road above creek. Date collected: 9/16/73 |
| 5L | West facing slope; average tree size; average growth; thin soil. 25' above older road. Date collected: 9/16/73 |
| 5M | West facing slope; average size trees; average growth; thin soil. Date collected: 9/16/73 |
| 6A | No samples collected; in swampy or saturated ground with few trees. |
| 6B | No samples collected; in swampy or saturated ground with few trees. |
| 6C | No samples collected; in swampy or saturated ground with few trees. |
| 6D | Near main valley floor; open growth of average size trees; average growth; thin soil. 50' north of main valley road. Date collected: 9/16/73 |
| 6E | South facing slope; average tree size; average growth; thin soil profile. 500+' above main valley road. Near edge of slash. Date collected: 9/16/73 |
| 6F | South facing slope; average tree size; average growth; thin soil. On national forest boundary line, 30' below drill road. Date collected: 9/16/73 |
| 6G | South facing slope; average tree size; average growth; thin soil. Date collected: 9/16/73 |
| 6H | Southeast facing slope; average tree size; average growth; thin soil. Near drill pad. Date collected: 9/16/73 |
| 6I | Southeast facing slope; average tree size; average growth. Date collected: 9/16/73 |
| 6J | Average size trees; average growth; thin soil. West of a main drill road on the east side of creek on terrace above stream bed. Date collected: 9/16/73 |
| 6K | West facing slope; average trees; average growth; thin soil. Date collected: 9/16/73 |

## Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 6L | West facing slope; average trees; average growth; thin soil. Date collected: 9/16/73 |
| 6M | West facing slope; average trees; average growth; thin soil. Date collected: 9/16/73 |
| 7A | No sample, swampy or saturated ground with few trees. |
| 7B | Within swamp; average tree size; stagnant growth; soil has thick humic mat and deep A horizon rich in roots and other organics. Water saturated; browning needles. Date collected: 9/17/73 |
| 7C | In saturated ground; no lodgepole pine present; no samples taken. |
| 7D | In saturated ground; no lodgepole pine present; no samples taken. |
| 7E | North edge of swampy area; open growth of average size trees; average growth; thin soil. South of main road. Date collected: 9/17/73 |
| 7F | Average tree size; average growth; thin soil probably on stream terrace material. 100' southeast of adit. 75' east of pad built perpendicular to and crossing road. Samples taken on south edge of road. North edge of open area. Date collected: 9/16/73 |
| 7G | Average tree size; average growth; thin soil. North edge of open area on north edge of main valley road. Date collected: 9/16/73 |
| 7H | Average tree size; average growth; thin soil. 50' north of main valley road near small stream bed. Open growth. Date collected: 9/16/73 |
| 7I | Average to large tree size; average growth; thin to fairly well developed soils. Northeast corner of "G" Mill site or 200' east of Anaconda core shed. Open growth. Date collected: 9/16/73 |
| 7J | Average tree size; average growth; thin soil. Next to road going north from main valley road. Date collected: 9/16/73 |
| 7K | West facing slope; average tree size; average growth; thin to fair soil on gabbroic sill material. East of and uphill of drill pad. Date collected: 9/16/73 |
| 7L | West facing slope; average tree size; average growth; thin soil on diabase outcrop. Near drill pad. Date collected: 9/16/73 |
| 7M | West facing slope; average tree size; average growth; thin soil. Date collected: 9/16/73 |

## Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 8A | Average tree size; average growth; fair to rocky soil development in wet environment adjacent to swampy area. Open tree growth. Date collected: 9/17/73 |
| 8B | Average tree size; average growth; near perimeter of saturated swampy ground. Date collected: 9/17/73 |
| 8C | Average tree size; average growth; thin soil. In main valley bottom but south and slightly uphill from present stream course. Open growth. Date collected: 9/17/73 |
| 8D | Average tree size; average growth; thin soil (very thin?) on stream gravels; very wet. Stream bottom. Open growth. Date collected: 9/17/73 |
| 8E | Average tree size; average growth; thin soil. In stream bottom near present channel. Open growth. Date collected: 9/17/73 |
| 8F | Average tree size; average growth; very thin soil. In stream bottom. Open growth. Date collected: 9/17/73 |
| 8G | Average tree size; average growth; thin soil. South of main valley road near stream course. Open growth. Date collected: 9/17/73 |
| 8H | No sample collected; no lodgepole pine available. |
| 8I | No sample collected; no lodgepole pine available. Only stream gravel present. Open growth. |
| 8J | Average size trees; thin to non-existent (very thin) soils on stream gravels. South edge of main valley road. Open growth. Date collected: 9/16/73 |
| 8K | Southwest facing slope; average tree size; average growth; thin soil. Date collected: 9/16/73 |
| 8L | West facing slope; average tree size; average growth; thin soil on gabbroic outcrop. Near north-south trending drill road. Date collected: 9/16/73 |
| 8M | South facing slope; large trees; average growth; very thin soil on talus slope. Open growth. Date collected: 9/16/73 |
| 9A | North facing slope; small trees; average growth. Dense growth. Date collected: 9/17/73 |
| 9B | North facing slope; average tree size; average growth; thin soil (could be disturbed). In slash. Date collected: 9/17/73 |
| 9C | East facing slope; average tree size; average growth; thin soil. Steep. Open growth. 200' east and uphill of dump. Date collected: 9/17/73 |
| 9D | North facing slope; small trees; vigorous growth; thin soil (disturbed possibly). Next to east-west trending drill road. Open slash area. Date collected: 9/17/73 |

## Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 9E | North facing slope; average tree size; average growth; disturbed soil (?). Open slash. Date collected: 9/17/73 |
| 9F | North and downhill at boundary of slash; small trees; thin soil on pyritic (?) gossan. Dense growth. Date collected: 9/17/73 |
| 9G | Large trees; average growth; thin soil. In valley bottom south of stream course. Date collected: 9/17/73 |
| 9H | Average tree size; average growth; thin soil. North edge of slash, downhill of slash boundary. Edge of swampy ground. Date collected: 9/17/73 |
| 9I | Average tree size; average growth; thin soil. North and downhill of edge of slash near swamp edge. Date collected: 9/17/73 |
| 9J | Average tree size; average growth; thin possibly disturbed soil. Northern edge of slash - downhill boundary. Date collected: 9/17/73 |
| 9K | Average tree size; average growth; thin sandy soil on stream gravels. Sample 50' south of main road. Open tree growth. Date collected: 9/17/73 |
| 9L | Southwest facing slope; average tree size; average growth; thin soil. North of stream on south facing slope. Date collected: 9/17/73 |
| 9M | Southwest facing slope; large trees; average growth; very thin soil on gabbroic talus slope. Open growth. Date collected: 9/17/73 |
| 10A | North facing slope; small trees; average growth; thin soil. Date collected: 9/17/73 |
| 10B | North facing slope; small trees; average growth; thin soil on gabbroic outcrop. Date collected: 9/17/73 |
| 10C | Northeast facing slope; average size trees; average growth; fair to thin soil on gabbroic float. Date collected: 9/17/73 |
| 10D | Northwest facing slope; small trees; average growth; thin soil. Just east of drill pad. Date collected: 9/17/73 |
| 10E | North facing slope; small trees; average growth; thin and possibly disturbed soil. In slash. Date collected: 9/17/73 |
| 10F | North facing slope; average tree size; average growth; thin soil on gossan indicative of pyrite (?). Open slash. Date collected: 9/17/73 |
| 10G | North facing slope; average tree size; average growth; disturbed soil with abundant porphyry float. Open slash. Date collected: 9/17/73 |

## Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 10H | North facing slope; small trees; average growth; disturbed soil with abundant porphyry float. Open slashed area. Date collected: 9/17/73 |
| 10I | North facing open slope; average tree size; thin soil. Date collected: 9/17/73 |
| 10J | Average to large trees; average growth; thin soil. Samples taken downslope of and on edge of large dump with abundant moly and pyrite. Open growth. Date collected: 9/17/73 |
| 10K | North facing slope; average size trees; average growth; thin soil. South and uphill of main stream course. Open growth. Date collected: 9/17/73 |
| 10L | Average tree size; average growth; thin soil. Sample taken on south side of road. Very open growth. Date collected: 9/17/73 |
| 10M | Southwest facing slope; average size trees; average growth; thin soil on talus. At edge of stream channel embankment. Date collected: 9/17/73 |
| 11A | North facing slope; small trees; stagnant growth; thin soil. Dense growth. Date collected: 9/18/73 |
| 11B | East facing slope; average tree size; average growth; thin soil. Dense growth. Near old road. Date collected: 9/18/73 |
| 11C | East facing slope; average tree size; average growth; thin soil. Near adit and pyritic mine dump. Date collected: 9/18/73 |
| 11D | Northwest facing slope; small trees; stagnant and vigorous growth sampled; thin soil. Edge of power line slash. Date collected: 9/18/73 |
| 11E | Northwest facing slope; small trees; average growth. Dense growth. South and upslope of drill pad. Date collected: 9/18/73 |
| 11F | North facing slope; average tree size; stagnant growth; thin soil on altered fine grained felsic intrusive. Dense growth. Date collected: 9/18/73 |
| 11G | North facing slope; average tree size; average growth; thin soil. Dense growth. Date collected: 9/18/73 |
| 11H | Northeast facing slope; average tree size; stagnant growth; thin soil on porphyry. Date collected: 9/18/73 |
| 11I | Northeast facing slope; small trees; average growth; thin soil on porphyry. Dense growth. Date collected: 9/18/73 |
| 11J | Average tree size; average growth; thin soil. Sample taken next to road. Next to acid mine drainage. Recently subject to dilution raising pH conditions since ferrous hydroxides had precipitated. Date collected: 9/18/73 |

## Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 11K | North facing slope; average tree size; average growth; thin soil. Dense growth. Date collected: 9/18/73 |
| 11L | North facing slope; average size trees; average growth; thin soil. Dense growth. Date collected: 9/18/73 |
| 11M | North facing slope; average tree size; average growth; thin soil. Near east-west facing road. Small slash. Date collected: 9/18/73 |
| 12A | Crest of ridge; small trees; average growth; fair to thin soil development on interbedded quartzites and argillites. Yellowing needles. Date collected: 9/18/73 |
| 12B | East facing slope; average tree size; average growth; thin soil. Date collected: 9/18/73 |
| 12C | Northwest facing slope; average tree size; average growth; thin soil on gabbroic outcrop. Date collected: 9/18/73 |
| 12D | Northwest facing slope; large trees; stagnant growth; thin soil. Date collected: 9/18/73 |
| 12E | Northwest facing slope; large trees; stagnant growth. Slope wash of drill cuttings. Soil taken 40' downslope in road cut. Date collected: 9/18/73 |
| 12F | North facing slope; average tree size; vigorous growth; very thin soil on quartzite outcrop. Open growth. Date collected: 9/18/73 |
| 12G | North facing slope; average tree size; dense vigorous growth; thin soil. North of drill pad. Date collected: 9/18/73 |
| 12H | East facing slope; large trees; vigorous growth; thin soil. Near road near open slash. Date collected: 9/18/73 |
| 12I | East facing slope; average size trees; average growth; fair to thin soil on porphyry outcrop. Date collected: 9/18/73 |
| 12J | Northwest facing slope; average tree size; dense stagnant growth; well-developed red soil horizon on porphyry. Date collected: 9/18/73 |
| 12K | North facing slope; large trees; dense stagnant growth; thin soil. Date collected: 9/18/73 |
| 12L | North facing slope; average tree size; average growth. Dense growth. Near road. Date collected: 9/18/73 |
| 12M | North facing slope; large trees; dense stagnant growth; thin soil. Date collected: 9/18/73 |
| 13A | No field notes. |
| 13B | Northeast facing slope; average tree size; average growth. Open growth. Date collected: 9/22/73 |
| 13C | Northwest facing slope; average tree size; average growth. Dense growth. Soil taken north of porphyry talus. Date collected: 9/22/73 |

## Field Notes (continued)

| Sample Location | Remarks |
|---|---|
| 13D | Northwest facing slope; small trees and large trees; large tree sampled, vigorous growth; thin soil. Date collected: 9/22/73 |
| 13E | Northwest facing slope; predominantly small trees with a few very large trees; vigorous growth; thin soil. Date collected: 9/18/73 |
| 13F | Northeast facing slope; small trees; vigorous growth; thin soil. Date collected: 9/18/73 |
| 13G | Northeast facing slope; average tree size; average growth; thin soil on quartzite. West side of main drill road. Date collected: 9/18/73 |
| 13H | Northeast facing slope; average tree size; average growth; thin soil on quartzite. 50' east of main drill road. Date collected: 9/18/73 |
| 13I | Northeast facing slope; average tree size; stagnant growth; thin soil. 25' below road. Date collected: 9/21/73 |
| 13J | Northwest facing slope; average tree size; average growth; thin soil. 20' upslope of road. Date collected: 9/21/73 |
| 13K | Northwest facing slope; average tree size; average growth. 120' west of main drill road. Talus slope. Soil sampled 120' to east near road. Date collected: 9/21/73 |
| 13L | Northeast facing slope; average tree size; average growth; thin soil. Dense growth. Date collected: 9/21/73 |
| 13M | Northeast facing slope; large trees; average growth; thin soil. Date collected: 9/21/73 |
| 14A | Open ridge top; average tree size; vigorous growth; thin soil on red argillites. Date collected: 9/22/73 |
| 14B | East facing slope; average tree size; stagnant growth; thin soil. Dense growth. Date collected: 9/22/73 |
| 14C | Northwest facing slope; average tree size; average growth; thin soil. Quartzite talus. Date collected: 9/22/73 |
| 14D | Northwest facing slope; very small trees; average growth; thin soil on quartzite talus. Date collected: 9/22/73 |
| 14E | Northwest facing slope; small trees; average growth; thin soil. Date collected: 9/18/73 |
| 14F | Just east of ridge top; small trees; average growth; thin soil. Date collected: 9/18/73 |
| 14G | East facing slope; average tree size; average growth; thin soil. 227' west of drill road and drill collar #C235162. Date collected: 9/21/73 |
| 14H | East facing slope; average tree size; vigorous growth; thin soil. 275' east of drill collar #C235162. Date collected: 9/21/73 |

## Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 14I | Northeast facing slope; average tree size; stagnant growth; thin soil. Date collected: 9/21/73 |
| 14J | Northwest facing slope; average tree size; average growth; thin soil. Near road. Date collected: 9/21/73 |
| 14K | Northwest facing slope; average tree size; average growth; pocket of soil on talus. Date collected: 9/21/73 |
| 14L | Northeast facing slope; average tree size; average growth; thin soil on argillites. Date collected: 9/21/73 |
| 14M | Northeast facing slope; average tree size; vigorous growth; thin soil. Dense growth. Date collected: 9/21/73 |
| 15A | Bald knob; average tree size; average growth; thin soil on medium grained argillites. Date collected: 9/22/73 |
| 15B | Northeast facing slope; small trees; average growth; thin soil. Dense growth. Date collected: 9/22/73 |
| 15C | West facing slope; small trees; average growth; thin soil on quartzite talus. Date collected: 9/22/73 |
| 15D | West facing slope; average tree size; stagnant growth; thin soil on quartzite talus. Date collected: 9/22/73 |
| 15E | Northwest facing slope; average tree size; average growth; thin soil on quartzite talus. 350' west and down slope of main drill road. Date collected: 9/22/73 |
| 15F | Northeast facing slope; average tree size; vigorous growth; thin soil. 100' east of main drill road, brow of ridge. Date collected: 9/18/73 |
| 15G | Northeast facing slope; average tree size; vigorous growth; thin soil with quartzite float. Edge of main drill road. Date collected: 9/18/73 |
| 15H | Northeast facing slope; average tree size; average growth; thin soil. Abundant porphyry float. West edge of main drill road, south of pad. Date collected: 9/21/73 |
| 15I | No field notes. |
| 15J | Northwest facing slope; small trees; average growth; thin soil on altered quartz veined fine grained felsic. Date collected: 9/21/73 |
| 15K | West facing slope; average tree size; average growth; thin soil. 20' east of main drill road. Date collected: 9/21/73 |
| 15L | Northeast facing slope; average tree size; average growth; thin soil. Date collected: 9/21/73 |
| 15M | Northeast facing slope; average tree size; average growth; thin soil. Dense growth. Date collected: 9/21/73 |

# Field Notes
(continued)

| Sample Location | Remarks |
|---|---|
| 16A | Brow of ridge; old trees; average growth; thin soils on argillites, quartzites. Open growth. Date collected: 9/22/73 |
| 16B | Northeast facing slope; small trees; stagnant growth; thin soil. West of creek. Dense growth. Date collected: 9/22/73 |
| 16C | West facing slope; small trees; average growth; thin soil. 130' below main drill road; 30' east of creek. Date collected: 9/22/73 |
| 16D | Northwest facing slope; average tree size; stagnant growth; very thin soil on thinner, fine grained quartzitic talus. Date collected: 9/22/73 |
| 16E | West facing slope; average tree size; average growth; thin soil. Area of fine grained quartzitic talus. Date collected: 9/22/73 |
| 16F | Near brow of ridge; average tree size; average growth; thin soil. 80' east of drill collar. Date collected: 9/18/73 |
| 16G | Northeast facing slope; small trees; vigorous growth; thin soil. On main drill road. Date collected: 9/18/73 |
| 16H | Northeast facing slope; small trees; vigorous growth; thin soil. Date collected: 9/21/73 |
| 16I | Northeast facing slope; average tree size; average growth; thin soil. Date collected: 9/21/73 |
| 16J | Northwest facing slope; average tree size; vigorous growth; thin soil. East and 15' upslope of road. Date collected: 9/21/73 |
| 16K | West facing slope; average tree size; average growth; thin soil on altered porphyry (propylitized?). 30' below main drill road. Date collected: 9/21/73 |
| 16L | Northeast facing slope; average tree size; average growth; thin soil. Date collected: 9/21/73 |
| 16M | Northeast facing slope; large trees; stagnant growth; thin soil. Date collected: 9/21/73 |

# APPENDIX II

## Laboratory Procedures

## Soils

### A. pH

The only geochemical determination made in the field was soil pH. All soil samples collected during the day were analyzed the same evening at base camp utilizing an Orion model 406 pH meter. A small amount of soil was transferred from the sample bag into a glazed porcelain evaporating dish and made into a thick paste with distilled water. The pH meter electrodes were inserted into this and allowed to remain in contact with the sample for 1 minute at which time a reading was taken. The pH meter was calibrated between every reading utilizing fresh buffer solutions prepared each evening. Temperature readings of both soil solution and buffer solution were also noted in order to correct the pH determinations.

### B. Organic Carbon

This procedure, the Walkley-Black method, is described in detail in Black (1968). A 0.5 gram sample of sieved, dried soil was used. Results were calculated utilizing a correction factor of 1.33.

### C. Available Cations

This procedure is a modified version of one originally proposed by Stark (1973). The only major change involves substitution of dilute sulfuric acid for ammonium acetate as the extracting medium. By so doing, a more accurate approximation of the chemical environment immediately surrounding Lodgepole pine root systems should be obtained

(N. Stark, personal communication).

Weigh 5.000 grams of sieved, dried soil onto weighing paper. Transfer this material carefully to labeled 50 ml centrifuge tubes. Pipette 25 mls of 0.002 N $H_2SO_4$ into each tube, carefully stopper, and shake vigorously by hand to mix the soil and the liquid. Place tubes in a holder and shake for 8 minutes on a Kahn shaking machine. Place tubes in a centrifuge for 8 minutes at about 2400 rpm. Carefully pour off the surface liquid into a funnel and filter through Wattman No. 40 filter paper into a 100 ml volumetric flask. Do not pour off soil. Repeat extraction three times more starting with 25 mls of 0.002 N $H_2SO_4$ each time and decanting the liquid into the funnel with filter paper to make just under 100 mls of extractment. Bring the liquid in the 100 ml volumetric flask to exactly 100 mls at room temperature with a squirt bottle of 0.002 N $H_2SO_4$. If samples are not to be run the same day, transfer solutions to labeled polyethylene bottles. Analyze subsequently on the AAS.

### D. Cold Extractable Metals

Subsequent to completion of the field work, cold extractable copper and "heavy metal" determinations were made in the laboratory on sieved, dried soil samples. This work involved significant modification of the methodologies proposed by Holman (1963) and Smith (1964).

Two serious problems were encountered in attempting to utilize Holman's (1963) procedure. First, buffer solutions prepared in accordance with the author's instructions were much more acid than the desired 2.0 pH, a value critical to the selective extraction of loosely bonded copper. Hence a pH meter had to be utilized in buffer preparation. Secondly, standard copper solutions did not yield the desired colorimetric response, indicating that the dithizone solution was not quantitatively extracting the copper from the aqueous phase. This problem was solved by replacing the benzene used as the dithizone solvent with hexane.

Smith's (1964) method was similarly modified.

Both CxCu and CxHM determinations were made on 0.2 gram samples weighed on an analytical balance. Analytical results were calculated utilizing the formulas given by Holman (1963) and Smith (1964).

E. Hot Acid Extractable Metals

A hot nitric acid extraction was utilized in determining the "total" metal content of all soil samples. 1.000 grams of dried, sieved soil material was weighed out on an analytical balance and transferred to numbered 250 ml Erlenmeyer flasks. 30 mls. of concentrated $HNO_3$ was added to each flask, and the resultant solution boiled for 30 minutes on an electric hot plate. Subsequent to cooling, the solution was filtered through Wattman No. 40 filter paper into 100 ml volumetric flasks, brought to volume with distilled water, and transferred to acid-washed polyethylene bottles.

Cu, Pb, Zn, Mo, Cd, Ni, Co, Ag, Bi, Fe and Mn analyses were performed on all sample solutions utilizing a Techtron AA-6 atomic absorption spectrophotometer.

## Plants

Plant samples were analyzed for the same suite of major and minor elements as the soil samples. Two grams of dried, ground plant material were weighed on an analytical balance and transferred to numbered 250 ml Erlenmeyer flasks. Next 20 mls of 7 N $HNO_3$ were pipetted into the flask, and the mixture boiled gently on an electric hot plate for 25 minutes. When the solution cooled, it was filtered through Wattman No. 30 filter paper into 100 ml volumetric flasks, brought to volume with distilled water, and transferred to acid-washed polyethylene bottles. Subsequent analyses of these sample solutions were made on a Techtron AA-6 atomic absorption spectrophotometer.

## APPENDIX III

### Soil Sample Analyses

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 1A | 15.0 | 60.0 | 64 | ND | ND | 162 | 8,250 |
| 1B | 15.0 | 40.0 | 38 | ND | ND | 105 | 7,500 |
| 1C | 25.0 | 50.0 | 77 | ND | 10.5 | 550 | 10,250 |
| 1D | 26.5 | 75.0 | 72 | ND | 10.0 | 270 | 10,250 |
| 1E | 35.0 | 85.0 | 114 | ND | ND | 470 | 11,500 |
| 1F | 30.0 | 230.0 | 37 | ND | ND | 219 | 11,000 |
| 1G | 22.5 | 280.0 | 42 | ND | 10.0 | 105 | 9,250 |
| 1H | 12.5 | 380.0 | 135 | ND | ND | 575 | 7,500 |
| 1I | 12.5 | 325.0 | 135 | ND | ND | 498 | 8,000 |
| 1J | 40.0 | 590.0 | 37 | ND | ND | 135 | 14,750 |
| 1K | 117.5 | 135.0 | 197 | 1.5 | 15.0 | 650 | 13,000 |
| 1L | 290.0 | 300.0 | 330 | 1.5 | 20.5 | 465 | 19,250 |
| 1M | 75.0 | 100.0 | 210 | ND | 13.0 | 270 | 12,150 |
| 2A | 20.0 | 60.0 | 45 | ND | ND | 163 | 12,500 |
| 2B | 35.0 | 40.0 | 23 | ND | ND | 180 | 12,750 |
| 2C | 27.5 | 75.0 | 22 | ND | ND | 93 | 19,000 |
| 2D | 17.5 | 85.0 | 62 | ND | ND | 148 | 9,750 |
| 2E | 35.0 | 45.0 | 130 | ND | 11.0 | 675 | 9,750 |
| 2F | 20.0 | 45.0 | 29 | ND | ND | 130 | 11,000 |
| 2G | 10.0 | 80.0 | 26 | ND | ND | 130 | 10,500 |
| 2H | 22.5 | 110.0 | 33 | ND | ND | 153 | 7,750 |
| 2I | 87.5 | 240.0 | 52 | ND | ND | 148 | 24,500 |
| 2J | 20.0 | 250.0 | 110 | ND | ND | 190 | 9,250 |
| 2K | 32.5 | 270.0 | 70 | ND | 34.0 | 155 | 11,500 |
| 2L | 75.0 | 145.0 | 270 | 12.5 | 17.0 | 395 | 12,500 |
| 2M | 117.5 | 160.0 | 187 | ND | 12.0 | 223 | 13,500 |
| 3A | 55.0 | 50.0 | 22 | ND | ND | 105 | 32,250 |
| 3B | 35.0 | 75.0 | 28 | ND | ND | 145 | 21,200 |
| 3C | 35.0 | 80.0 | 24 | ND | ND | 103 | 12,250 |
| 3D | 47.5 | 50.0 | 41 | ND | 10.5 | 165 | 15,500 |
| 3E | 105.0 | 50.0 | 64 | ND | ND | 25 | 7,000 |
| 3F | 10.0 | 35.0 | 22 | ND | ND | 135 | 10,500 |
| 3G | 12.5 | 70.0 | 38 | ND | 14.5 | 260 | 10,500 |
| 3H | 7.5 | 90.0 | 34 | ND | ND | 205 | 7,250 |
| 3I | 85.0 | 80.0 | 21 | ND | 12.0 | 100 | 30,750 |
| 3J | 60.0 | 235.0 | 117 | ND | 10.0 | 95 | 14,500 |
| 3K | 21.0 | 225.0 | 49 | ND | ND | 197 | 9,150 |
| 3L | 50.0 | 220.0 | 72 | ND | ND | 285 | 13,500 |
| 3M | 34.0 | 165.0 | 167 | ND | 12.0 | 383 | 9,750 |

## Soil Sample Analyses
(continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 4A | 52.5 | 60.0 | 18 | ND | ND | 88 | 26,500 |
| 4B | 34.0 | 110.0 | 19 | ND | ND | 111 | 15,350 |
| 4C | 20.0 | 110.0 | 38 | ND | 23.5 | 185 | 8,250 |
| 4D | NS | NS | NS | NS | NS | NS | NS |
| 4E | 96.5 | 70.0 | 32 | ND | ND | 68 | 14,000 |
| 4F | 20.0 | 30.0 | 16 | ND | ND | 50 | 11,000 |
| 4G | 12.5 | 35.0 | 14 | ND | ND | 23 | 8,500 |
| 4H | 70.0 | 55.0 | 20 | ND | ND | 89 | 19,650 |
| 4I | 90.0 | 50.0 | 23 | ND | 11.0 | 20 | 19,000 |
| 4J | 85.0 | 120.0 | 42 | ND | ND | 70 | 17,250 |
| 4K | 60.0 | 205.0 | 109 | 1.3 | 10.0 | 448 | 14,000 |
| 4L | 32.5 | 210.0 | 245 | ND | 14.0 | 499 | 9,500 |
| 4M | 35.0 | 170.0 | 240 | 1.3 | 11.0 | 358 | 8,000 |
| 5A | 165.0 | 40.0 | 12 | ND | ND | 15 | 45,750 |
| 5B | 45.0 | 45.0 | 20 | ND | ND | 70 | 13,000 |
| 5C | NS | NS | NS | NS | NS | NS | NS |
| 5D | 30.0 | 90.0 | 33 | ND | ND | 138 | 7,500 |
| 5E | 40.0 | 260.0 | 14 | ND | ND | 18 | 10,250 |
| 5F | 115.0 | 95.0 | 11 | ND | ND | 25 | 29,750 |
| 5G | 37.5 | 25.0 | 16 | ND | ND | 130 | 16,750 |
| 5H | 40.0 | 40.0 | 21 | ND | ND | 255 | 17,000 |
| 5I | 125.0 | 50.0 | 20 | ND | 10.0 | 43 | 23,000 |
| 5J | 35.0 | 70.0 | 42 | ND | ND | 215 | 12,150 |
| 5K | 110.0 | 140.0 | 96 | ND | 12.0 | 80 | 14,000 |
| 5L | 70.0 | 120.0 | 265 | ND | 12.5 | 385 | 8,500 |
| 5M | 15.0 | 85.0 | 193 | ND | 11.0 | 289 | 6,900 |
| 6A | NS | NS | NS | NS | NS | NS | NS |
| 6B | NS | NS | NS | NS | NS | NS | NS |
| 6C | NS | NS | NS | NS | NS | NS | NS |
| 6D | 40.0 | 155.0 | 31 | ND | ND | 70 | 8,500 |
| 6E | 40.0 | 230.0 | 22 | ND | ND | 100 | 10,500 |
| 6F | 47.5 | 60.0 | 20 | ND | ND | 400 | 7,750 |
| 6G | 32.5 | 90.0 | 16 | ND | 14.5 | 60 | 13,500 |
| 6H | 40.0 | 35.0 | 22 | ND | ND | 288 | 18,500 |
| 6I | 34.0 | 40.0 | 50 | ND | ND | 370 | 12,750 |
| 6J | 57.5 | 100.0 | 142 | ND | 10.0 | 600 | 12,250 |
| 6K | 57.5 | 90.0 | 220 | 1.3 | 10.0 | 245 | 11,500 |
| 6L | 20.0 | 145.0 | 192 | ND | 13.0 | 410 | 8,750 |
| 6M | 27.5 | 210.0 | 255 | ND | 12.0 | 500 | 13,500 |

## Soil Sample Analyses
(continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 7A | NS | NS | NS | NS | NS | NS | NS |
| 7B | 420.0 | 80.0 | 127 | ND | 12.5 | 98 | 8,750 |
| 7C | NS | NS | NS | NS | NS | NS | NS |
| 7D | NS | NS | NS | NS | NS | NS | NS |
| 7E | 100.0 | 80.0 | 180 | ND | 12.5 | 195 | 10,500 |
| 7F | 56.5 | 85.0 | 96 | ND | 10.0 | 70 | 12,250 |
| 7G | 50.0 | 180.0 | 34 | ND | ND | 50 | 11,750 |
| 7H | 70.0 | 125.0 | 116 | ND | 11.0 | 368 | 15,750 |
| 7I | 76.5 | 115.0 | 114 | ND | 11.5 | 423 | 13,500 |
| 7J | 45.0 | 40.0 | 57 | ND | ND | 90 | 10,250 |
| 7K | 75.0 | 50.0 | 39 | ND | 11.0 | 133 | 15,500 |
| 7L | 19.0 | 80.0 | 105 | ND | 11.5 | 124 | 8,500 |
| 7M | 12.5 | 75.0 | 175 | ND | 39.0 | 215 | 8,000 |
| | | | | | | | |
| 8A | 80.0 | 330.0 | 199 | ND | 11.0 | 195 | 12,500 |
| 8B | 30.0 | 160.0 | 52 | ND | ND | 175 | 7,750 |
| 8C | 157.0 | 90.0 | 30 | ND | 14.5 | 30 | 85,750 |
| 8D | 50.0 | 80.0 | 215 | 1.3 | ND | 190 | 9,750 |
| 8E | 67.0 | 80.0 | 1,575 | 3.3 | 12.5 | 330 | 9,500 |
| 8F | NS | NS | NS | NS | NS | NS | NS |
| 8G | 47.5 | 75.0 | 165 | ND | 12.0 | 490 | 9,750 |
| 8H | NS | NS | NS | NS | NS | NS | NS |
| 8I | NS | NS | NS | NS | NS | NS | NS |
| 8J | 520.0 | 10,000.0 | 3,375 | 6.5 | 18.0 | 1,550 | 33,250 |
| 8K | 64.0 | 50.0 | 107 | ND | 12.5 | 168 | 13,000 |
| 8L | 35.0 | 40.0 | 50 | ND | ND | 78 | 8,500 |
| 8M | 105.0 | 120.0 | 200 | 1.3 | 14.0 | 675 | 13,500 |
| | | | | | | | |
| 9A | 32.5 | 160.0 | 162 | 1.3 | 11.0 | 360 | 9,250 |
| 9B | 47.5 | 190.0 | 100 | ND | ND | 288 | 10,500 |
| 9C | 110.0 | 190.0 | 83 | ND | 12.5 | 88 | 17,000 |
| 9D | 130.0 | 30.0 | 117 | ND | 14.5 | 440 | 14,250 |
| 9E | 220.0 | 70.0 | 14 | ND | ND | 13 | 41,000 |
| 9F | 70.0 | 90.0 | 93 | ND | 11.0 | 165 | 11,900 |
| 9G | 77.5 | 80.0 | 220 | ND | 14.0 | 188 | 9,500 |
| 9H | 25.0 | 25.0 | 59 | ND | 14.0 | 60 | 8,750 |
| 9I | 17.5 | 30.0 | 34 | ND | ND | 95 | 6,500 |
| 9J | 752.5 | 50.0 | 665 | 2.0 | 53.0 | 1,775 | 36.650 |
| 9K | 2,725.0 | 3,200.0 | 5,000 | 9.0 | 22.0 | 425 | 63,000 |
| 9L | 37.5 | 40.0 | 27 | ND | 10.0 | 43 | 10,500 |
| 9M | 80.0 | 120.0 | 132 | 1.3 | 11.0 | 550 | 11,000 |

## Soil Sample Analyses
(continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 10A | 15.0 | 175.0 | 64 | ND | ND | 233 | 5,250 |
| 10B | 60.0 | 235.0 | 157 | ND | 14.0 | 170 | 10,500 |
| 10C | 52.5 | 80.0 | 73 | ND | ND | 80 | 8,750 |
| 10D | 129.0 | 35.0 | 18 | ND | 13.0 | 32 | 30,500 |
| 10E | 45.0 | 40.0 | 16 | ND | ND | 40 | 13,000 |
| 10F | 130.0 | 35.0 | 9 | ND | ND | 15 | 27,500 |
| 10G | 49.0 | 45.0 | 10 | ND | ND | 17 | 10,900 |
| 10H | 35.0 | 35.0 | 7 | ND | ND | 10 | 13,000 |
| 10I | 81.0 | 40.0 | 23 | ND | 10.0 | 38 | 12,750 |
| 10J | 86.5 | 45.0 | 22 | ND | ND | 32 | 16,250 |
| 10K | 27.5 | 90.0 | 47 | ND | 10.0 | 75 | 10,650 |
| 10L | 65.0 | 130.0 | 200 | 1.5 | 12.5 | 550 | 10,650 |
| 10M | 60.0 | 60.0 | 36 | ND | ND | 87 | 8,650 |
| 11A | 10.0 | 40.0 | 132 | ND | 10.0 | 550 | 7,900 |
| 11B | 45.0 | 120.0 | 59 | ND | ND | 153 | 12,150 |
| 11C | 35.0 | 70.0 | 61 | ND | ND | 113 | 8,750 |
| 11D | 185.0 | 35.0 | 26 | ND | 15.0 | 53 | 27,150 |
| 11E | 90.0 | 50.0 | 12 | ND | ND | 30 | 19,000 |
| 11F | 40.0 | 60.0 | 9 | ND | ND | 13 | 15,000 |
| 11G | 40.0 | 70.0 | 7 | ND | ND | 20 | 10,000 |
| 11H | 35.0 | 40.0 | 11 | ND | ND | 22 | 11,250 |
| 11I | 35.0 | 40.0 | 20 | ND | 12.0 | 90 | 9,500 |
| 11J | 85.0 | 100.0 | 64 | ND | 14.5 | 40 | 16,000 |
| 11K | 47.5 | 90.0 | 20 | ND | ND | 35 | 19,000 |
| 11L | 25.0 | 70.0 | 132 | ND | 14.5 | 165 | 11,500 |
| 11M | 55.0 | 165.0 | 39 | ND | ND | 40 | 11,750 |
| 12A | 17.5 | 115.0 | 23 | ND | ND | 85 | 5,000 |
| 12B | 17.5 | 60.0 | 30 | ND | ND | 50 | 7,500 |
| 12C | 215.0 | 35.0 | 55 | ND | 13.0 | 58 | 15,000 |
| 12D | 20.0 | 40.0 | 21 | ND | ND | 30 | 8,500 |
| 12E | 20.0 | 60.0 | 32 | ND | 12.0 | 35 | 9,000 |
| 12F | 17.5 | 90.0 | 12 | ND | 11.0 | 18 | 12,250 |
| 12G | 30.0 | 80.0 | 16 | ND | ND | 35 | 8,500 |
| 12H | 65.0 | 60.0 | 9 | ND | ND | 15 | 15,000 |
| 12I | 47.5 | 50.0 | 7 | ND | ND | 10 | 16,000 |
| 12J | 121.5 | 205.0 | 10 | ND | ND | 10 | 29,400 |
| 12K | 20.0 | 30.0 | 25 | ND | 12.0 | 78 | 9,750 |
| 12L | 50.0 | 110.0 | 12 | ND | ND | 23 | 12,250 |
| 12M | 20.0 | 255.0 | 144 | ND | ND | 85 | 7,750 |

# Soil Sample Analyses
(continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 13A | 10.0 | 50.0 | 65 | ND | ND | 95 | 5,000 |
| 13B | 9.0 | 55.0 | 73 | ND | 37.5 | 363 | 6,000 |
| 13C | 10.0 | 40.0 | 25 | ND | ND | 110 | 6,500 |
| 13D | 22.5 | 30.0 | 20 | ND | ND | 125 | 10,500 |
| 13E | 19.0 | 20.0 | 39 | ND | 16.5 | 99 | 9,250 |
| 13F | 12.5 | 25.0 | 39 | ND | 12.5 | 60 | 10,000 |
| 13G | 22.5 | 45.0 | 18 | ND | ND | 25 | 7,900 |
| 13H | 84.0 | 95.0 | 7 | ND | ND | 8 | 15,000 |
| 13I | 45.0 | 50.0 | 26 | ND | ND | 145 | 8,250 |
| 13J | 85.0 | 60.0 | 10 | ND | ND | 20 | 25,000 |
| 13K | 61.5 | 85.0 | 28 | ND | 13.0 | 63 | 15,400 |
| 13L | 47.5 | 25.0 | 60 | ND | 16.0 | 225 | 10,000 |
| 13M | 20.0 | 40.0 | 36 | ND | ND | 40 | 9,500 |
| | | | | | | | |
| 14A | 10.0 | 40.0 | 154 | ND | 11.0 | 1,000 | 7,750 |
| 14B | 10.0 | 35.0 | 146 | ND | ND | 150 | 7,000 |
| 14C | 7.5 | 20.0 | 26 | ND | ND | 250 | 6,250 |
| 14D | 7.5 | 30.0 | 27 | ND | ND | 420 | 8,250 |
| 14E | 10.0 | 40.0 | 35 | ND | 11.0 | 345 | 8,000 |
| 14F | 10.0 | 20.0 | 24 | ND | 11.0 | 100 | 8,250 |
| 14G | 15.0 | 30.0 | 10 | ND | ND | 20 | 11,500 |
| 14H | 200.0 | 85.0 | 25 | ND | 11.0 | 30 | 8,250 |
| 14I | 45.0 | 70.0 | 24 | ND | ND | 64 | 7,750 |
| 14J | 201.5 | 925.0 | 11 | ND | ND | 17 | 39,750 |
| 14K | 35.0 | 290.0 | 8 | ND | ND | 20 | 22,000 |
| 14L | 27.5 | 20.0 | 27 | ND | ND | 125 | 8,750 |
| 14M | 25.0 | 35.0 | 32 | ND | ND | 55 | 8,250 |
| | | | | | | | |
| 15A | 10.0 | 55.0 | 205 | 1.3 | 18.0 | 1,650 | 12,500 |
| 15B | 10.0 | 35.0 | 99 | ND | ND | 280 | 5,750 |
| 15C | NS | NS | NS | NS | NS | NS | NS |
| 15D | 10.0 | 50.0 | 28 | ND | 12.0 | 213 | 9,000 |
| 15E | 12.5 | 100.0 | 45 | ND | 12.0 | 550 | 9,250 |
| 15F | 5.0 | 55.0 | 31 | ND | ND | 95 | 6,750 |
| 15G | 20.0 | 100.0 | 10 | ND | ND | 15 | 10,250 |
| 15H | 30.0 | 110.0 | 17 | ND | ND | 20 | 10,500 |
| 15I | 62.5 | 125.0 | 8 | ND | ND | 15 | 11,000 |
| 15J | 102.5 | 230.0 | 13 | ND | 13.0 | 43 | 22,500 |
| 15K | 60.0 | 25.0 | 15 | ND | 53.5 | 28 | 18,250 |
| 15L | 25.0 | 40.0 | 42 | ND | 11.0 | 140 | 10,500 |
| 15M | 49.0 | 55.0 | 23 | ND | 11.0 | 43 | 9,400 |

# Soil Sample Analyses
(continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 16A | 15.0 | 60.0 | 295 | ND | 17.0 | 975 | 12,000 |
| 16B | 14.0 | 40.0 | 107 | ND | 14.5 | 57 | 7,650 |
| 16C | 16.5 | 30.0 | 10 | ND | ND | 26 | 8,250 |
| 16D | 10.0 | 35.0 | 28 | ND | ND | 430 | 9,750 |
| 16E | 25.0 | 30.0 | 14 | ND | ND | 38 | 14,000 |
| 16F | 10.0 | 40.0 | 36 | ND | 12.0 | 180 | 10,450 |
| 16G | 15.0 | 110.0 | 19 | ND | 17.0 | 25 | 9,250 |
| 16H | 15.0 | 25.0 | 7 | ND | ND | 13 | 7,250 |
| 16I | 28.5 | 80.0 | 9 | ND | ND | 17 | 9,500 |
| 16J | 85.0 | 140.0 | 22 | 1.3 | ND | 150 | 33,000 |
| 16K | 55.0 | 210.0 | 28 | ND | ND | 83 | 19,500 |
| 16L | 34.0 | 125.0 | 37 | ND | ND | 179 | 12,000 |
| 16M | 37.5 | 140.0 | 22 | ND | ND | 33 | 9,500 |

*ND = Not detected
**NS = No sample

# APPENDIX IV

## Plant Sample Analyses

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 1A | 10.6 | 25.5 | 62 | 4.0 | 4.9 | 302 | 248 |
| 1B | 8.8 | 22.0 | 58 | 4.0 | 4.4 | 180 | 184 |
| 1C | 13.2 | 27.0 | 58 | 8.0 | 4.0 | 120 | 300 |
| 1D | 9.4 | 20.0 | 86 | 6.0 | 7.2 | 226 | 192 |
| 1E | 9.2 | 29.0 | 110 | 6.0 | 7.2 | 176 | 212 |
| 1F | 12.4 | 26.0 | 126 | 10.0 | 8.0 | 186 | 232 |
| 1G | 10.6 | 25.0 | 52 | 4.0 | 4.0 | 296 | 312 |
| 1H | 11.6 | 29.0 | 56 | 6.0 | 3.6 | 456 | 356 |
| 1I | 10.0 | 21.0 | 58 | 6.0 | 2.0 | 272 | 268 |
| 1J | 11.5 | 21.5 | 62 | 5.2 | 6.8 | 304 | 216 |
| 1K | 13.4 | 25.0 | 88 | 18.0 | 4.0 | 80 | 268 |
| 1L | 12.4 | 16.0 | 112 | 18.0 | 4.0 | 68 | 128 |
| 1M | 13.7 | 18.5 | 118 | 16.0 | 5.4 | 128 | 248 |
| 2A | 12.4 | 27.0 | 60 | 6.0 | 5.2 | 408 | 348 |
| 2B | 10.8 | 23.5 | 57 | 7.2 | 4.4 | 170 | 268 |
| 2C | 13.6 | 45.0 | 56 | 6.0 | 7.2 | 232 | 348 |
| 2D | 10.8 | 39.0 | 72 | 6.0 | 9.6 | 492 | 296 |
| 2E | 10.8 | 25.0 | 116 | 4.0 | 2.4 | 100 | 192 |
| 2F | 10.8 | 24.0 | 58 | 8.0 | 2.4 | 632 | 268 |
| 2G | 12.2 | 27.0 | 46 | 8.0 | 4.6 | 352 | 336 |
| 2H | 11.2 | 25.0 | 46 | 4.0 | 3.6 | 314 | 296 |
| 2I | 15.8 | 25.5 | 58 | 6.0 | 14.8 | 126 | 376 |
| 2J | 9.6 | 20.0 | 50 | 6.0 | 3.6 | 124 | 220 |
| 2K | 12.4 | 20.0 | 46 | 8.0 | 11.8 | 245 | 328 |
| 2L | 10.0 | 16.0 | 72 | 10.0 | 2.4 | 66 | 208 |
| 2M | 25.8 | 19.5 | 172 | 12.0 | 27.0 | 145 | 260 |
| 3A | 16.4 | 30.0 | 44 | 4.0 | 15.2 | 180 | 288 |
| 3B | 8.6 | 24.0 | 50 | 4.0 | 2.0 | 120 | 240 |
| 3C | 25.6 | 53.0 | 56 | 6.0 | 36.8 | 224 | 620 |
| 3D | 10.8 | 53.0 | 70 | 6.0 | 13.6 | 116 | 440 |
| 3E | 20.0 | 36.0 | 68 | 8.0 | 6.2 | 164 | 392 |
| 3F | 12.4 | 20.0 | 38 | 4.0 | 4.6 | 88 | 268 |
| 3G | 11.2 | 26.0 | 44 | 6.0 | 5.6 | 215 | 332 |
| 3H | 8.6 | 21.0 | 44 | 6.0 | 3.6 | 332 | 240 |
| 3I | 11.2 | 19.0 | 64 | 4.0 | 5.6 | 132 | 172 |
| 3J | 11.0 | 24.0 | 48 | 12.0 | 5.1 | 164 | 288 |
| 3K | 12.0 | 25.0 | 68 | 10.0 | 4.6 | 412 | 276 |
| 3L | 8.6 | 19.0 | 64 | 10.0 | 2.8 | 108 | 220 |
| 3M | 19.2 | 25.0 | 64 | 12.0 | 19.0 | 148 | 316 |

## Plant Sample Analyses
(continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 4A | 8.8 | 19.0 | 46 | 6.0 | 2.0 | 192 | 212 |
| 4B | 13.2 | 29.5 | 54 | 8.0 | 9.0 | 192 | 328 |
| 4C | 10.8 | 68.0 | 76 | 8.0 | 4.6 | 168 | 468 |
| 4D | NS | NS | NS | NS | NS | NS | NS |
| 4E | 11.8 | 26.0 | 82 | 10.0 | 5.6 | 308 | 276 |
| 4F | 11.0 | 29.0 | 38 | 5.2 | 4.9 | 186 | 320 |
| 4G | 16.2 | 40.0 | 68 | 10.0 | 4.0 | 218 | 588 |
| 4H | 11.6 | 22.7 | 46 | 6.0 | 5.4 | 206 | 304 |
| 4I | 12.4 | 18.0 | 52 | 6.0 | 4.6 | 160 | 196 |
| 4J | 14.0 | 31.0 | 62 | 12.0 | 4.0 | 358 | 420 |
| 4K | 15.4 | 17.0 | 67 | 10.0 | 5.1 | 114 | 264 |
| 4L | 15.6 | 27.0 | 99 | 12.0 | 5.2 | 328 | 356 |
| 4M | 13.6 | 21.0 | 98 | 22.0 | 4.6 | 260 | 268 |
| | | | | | | | |
| 5A | 11.2 | 34.0 | 40 | 6.0 | 5.2 | 128 | 356 |
| 5B | 11.6 | 70.0 | 58 | 6.0 | 5.6 | 172 | 456 |
| 5C | NS | NS | NS | NS | NS | NS | NS |
| 5D | NS | NS | NS | NS | NS | NS | NS |
| 5E | 17.2 | 38.0 | 52 | 6.0 | 7.4 | 220 | 368 |
| 5F | 12.8 | 27.0 | 50 | 8.0 | 5.2 | 172 | 404 |
| 5G | 10.4 | 24.0 | 46 | 4.0 | 2.4 | 192 | 264 |
| 5H | 11.2 | 26.0 | 50 | 6.0 | 4.0 | 279 | 380 |
| 5I | 10.6 | 20.0 | 41 | 4.0 | 5.2 | 116 | 264 |
| 5J | 16.0 | 22.0 | 60 | 8.0 | 7.2 | 444 | 228 |
| 5K | 13.6 | 25.0 | 48 | 8.0 | 4.0 | 128 | 336 |
| 5L | 12.8 | 31.0 | 58 | 20.0 | 4.4 | 132 | 356 |
| 5M | NS | NS | NS | NS | NS | NS | NS |
| | | | | | | | |
| 6A | NS | NS | NS | NS | NS | NS | NS |
| 6B | NS | NS | NS | NS | NS | NS | NS |
| 6C | NS | NS | NS | NS | NS | NS | NS |
| 6D | 12.4 | 31.0 | 54 | 8.0 | 4.6 | 116 | 560 |
| 6E | 17.8 | 35.0 | 55 | 6.0 | 6.4 | 205 | 460 |
| 6F | 13.2 | 29.0 | 46 | 6.0 | 4.6 | 208 | 364 |
| 6G | 11.6 | 21.0 | 40 | 6.0 | 4.4 | 171 | 416 |
| 6H | NS | NS | NS | NS | NS | NS | NS |
| 6I | 15.9 | 34.0 | 47 | 6.0 | 4.5 | 161 | 492 |
| 6J | NS | NS | NS | NS | NS | NS | NS |
| 6K | 4.6 | 29.0 | 50 | 12.0 | 52.4 | 204 | 424 |
| 6L | 16.0 | 24.0 | 62 | 10.0 | 3.6 | 112 | 304 |
| 6M | 16.2 | 31.0 | 58 | 16.0 | 5.6 | 208 | 388 |

## Plant Sample Analyses
(continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 7A | NS | NS | NS | NS | NS | NS | NS |
| 7B | 28.8 | 20.0 | 112 | 18.0 | 6.8 | 144 | 296 |
| 7C | NS | NS | NS | NS | NS | NS | NS |
| 7D | NS | NS | NS | NS | NS | NS | NS |
| 7E | 12.8 | 18.0 | 186 | 16.0 | 4.0 | 172 | 356 |
| 7F | 10.4 | 21.0 | 57 | 8.8 | 3.4 | 72 | 408 |
| 7G | 15.6 | 32.0 | 94 | 14.0 | 5.2 | 248 | 668 |
| 7H | 20.0 | 33.0 | 80 | 10.0 | 7.2 | 172 | 552 |
| 7I | 15.6 | 22.5 | 70 | 6.0 | 3.7 | 47 | 292 |
| 7J | 10.8 | 24.0 | 60 | 6.0 | 7.2 | 144 | 360 |
| 7K | 13.2 | 25.0 | 50 | 6.0 | 5.2 | 152 | 352 |
| 7L | 13.4 | 26.0 | 47 | 7.2 | 4.9 | 64 | 332 |
| 7M | 17.6 | 24.0 | 74 | 10.0 | 15.6 | 92 | 208 |
| 8A | 11.6 | 27.0 | 70 | 12.0 | 4.0 | 272 | 296 |
| 8B | 10.8 | 21.0 | 56 | 8.0 | 4.6 | 296 | 308 |
| 8C | 24.8 | 26.0 | 66 | 10.0 | 6.8 | 178 | 392 |
| 8D | 10.8 | 19.0 | 82 | 12.0 | 4.0 | 344 | 292 |
| 8E | 10.2 | 21.0 | 298 | 10.0 | 4.9 | 39 | 332 |
| 8F | NS | NS | NS | NS | NS | NS | NS |
| 8G | 19.6 | 18.0 | 144 | 16.0 | 10.8 | 136 | 176 |
| 8H | NS | NS | NS | NS | NS | NS | NS |
| 8I | NS | NS | NS | NS | NS | NS | NS |
| 8J | 15.8 | 50.5 | 250 | 8.0 | 4.3 | 74 | 432 |
| 8K | 12.8 | 24.0 | 52 | 8.0 | 4.0 | 168 | 288 |
| 8L | 16.8 | 19.0 | 76 | 8.0 | 6.2 | 102 | 228 |
| 8M | 14.4 | 19.0 | 78 | 4.0 | 7.2 | 84 | 216 |
| 9A | 9.2 | 19.0 | 92 | 14.0 | 4.0 | 666 | 212 |
| 9B | 9.6 | 15.0 | 70 | 8.0 | 2.0 | 304 | 196 |
| 9C | 12.2 | 22.0 | 68 | 8.0 | 4.6 | 248 | 312 |
| 9D | 8.2 | 15.0 | 88 | 6.0 | 5.2 | 452 | 308 |
| 9E | 11.2 | 25.0 | 68 | 8.0 | 5.2 | 176 | 392 |
| 9F | 16.8 | 26.0 | 56 | 6.0 | 6.8 | 210 | 332 |
| 9G | 8.2 | 16.0 | 196 | 12.0 | 10.0 | 176 | 196 |
| 9H | 8.0 | 13.0 | 68 | 6.0 | 3.6 | 440 | 180 |
| 9I | 7.2 | 12.0 | 112 | 10.0 | 4.0 | 216 | 260 |
| 9J | 12.2 | 19.0 | 98 | 6.0 | 5.2 | 168 | 252 |
| 9K | 23.8 | 46.0 | 298 | 13.2 | 14.6 | 108 | 424 |
| 9L | 17.6 | 19.0 | 92 | 8.0 | 5.6 | 94 | 248 |
| 9M | 14.4 | 18.0 | 48 | 10.0 | 4.6 | 60 | 248 |

## Plant Sample Analyses
(continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 10A | 17.0 | 26.0 | 56 | 6.0 | 17.3 | 238 | 260 |
| 10B | 14.4 | 16.0 | 130 | 26.0 | 4.4 | 572 | 256 |
| 10C | 9.0 | 21.5 | 40 | 6.0 | 3.7 | 100 | 224 |
| 10D | 12.4 | 26.0 | 50 | 4.0 | 9.1 | 134 | 344 |
| 10E | 10.4 | 20.0 | 70 | 6.0 | 4.6 | 134 | 208 |
| 10F | 10.4 | 18.0 | 68 | 4.0 | 4.6 | 392 | 288 |
| 10G | 13.0 | 22.0 | 46 | 7.2 | 4.5 | 188 | 336 |
| 10H | 12.4 | 18.0 | 70 | 4.0 | 2.8 | 136 | 236 |
| 10I | 12.2 | 20.0 | 62 | 6.0 | 5.6 | 260 | 460 |
| 10J | 23.4 | 17.5 | 84 | 6.0 | 4.1 | 306 | 272 |
| 10K | 18.4 | 35.0 | 58 | 6.0 | 15.2 | 120 | 409 |
| 10L | 13.2 | 29.0 | 190 | 6.0 | 5.6 | 68 | 304 |
| 10M | 12.0 | 27.0 | 74 | 7.2 | 4.8 | 168 | 340 |
| 11A | 10.8 | 19.0 | 96 | 10.0 | 4.0 | 456 | 272 |
| 11B | 11.2 | 20.0 | 58 | 8.0 | 3.6 | 228 | 252 |
| 11C | 12.2 | 18.0 | 64 | 6.0 | 4.6 | 300 | 304 |
| 11D | 8.0 | 15.0 | 48 | 2.0 | 4.0 | 40 | 156 |
| 11E | 9.6 | 15.0 | 52 | 6.0 | 2.4 | 140 | 296 |
| 11F | 11.6 | 22.0 | 46 | 6.0 | 4.0 | 182 | 364 |
| 11G | 9.2 | 20.0 | 48 | 6.0 | 3.6 | 276 | 236 |
| 11H | 14.8 | 30.0 | 54 | 6.0 | 4.0 | 144 | 548 |
| 11I | 11.2 | 19.0 | 46 | 6.0 | 5.2 | 206 | 440 |
| 11J | 12.2 | 19.0 | 74 | 6.0 | 6.2 | 272 | 376 |
| 11K | 9.6 | 24.0 | 54 | 4.0 | 4.4 | 164 | 312 |
| 11L | 12.2 | 24.0 | 68 | 6.0 | 4.6 | 124 | 304 |
| 11M | 11.0 | 17.0 | 74 | 7.2 | 4.6 | 182 | 196 |
| 12A | 8.6 | 21.0 | 54 | 6.0 | 4.0 | 272 | 220 |
| 12B | 11.2 | 29.0 | 54 | 8.0 | 5.6 | 144 | 212 |
| 12C | 10.4 | 18.0 | 96 | 8.0 | 4.6 | 268 | 364 |
| 12D | 16.2 | 27.0 | 50 | 8.0 | 5.2 | 244 | 320 |
| 12E | 19.2 | 18.0 | 90 | 4.0 | 5.2 | 248 | 256 |
| 12F | 13.6 | 20.0 | 60 | 4.0 | 2.8 | 352 | 292 |
| 12G | 12.0 | 22.0 | 56 | 6.0 | 12.0 | 340 | 340 |
| 12H | 8.8 | 19.0 | 44 | 6.0 | 2.4 | 286 | 312 |
| 12I | 12.4 | 16.0 | 66 | 4.0 | 9.2 | 296 | 328 |
| 12J | 14.8 | 25.0 | 78 | 8.2 | 5.6 | 192 | 468 |
| 12K | 20.6 | 32.0 | 44 | 6.0 | 31.8 | 128 | 324 |
| 12L | 12.2 | 20.0 | 46 | 6.0 | 5.6 | 151 | 244 |
| 12M | 16.2 | 30.0 | 120 | 10.0 | 5.6 | 296 | 452 |

## Plant Sample Analyses
## (continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 13A | 12.0 | 21.0 | 42 | 4.0 | 5.2 | 214 | 252 |
| 13B | 14.3 | 26.5 | 57 | 11.2 | 5.1 | 163 | 284 |
| 13C | 13.2 | 31.0 | 48 | 8.0 | 6.4 | 160 | 400 |
| 13D | 11.6 | 26.0 | 40 | 4.0 | 5.6 | 84 | 308 |
| 13E | 12.4 | 26.0 | 49 | 6.0 | 3.8 | 148 | 260 |
| 13F | 8.8 | 26.0 | 52 | 6.0 | 2.8 | 316 | 192 |
| 13G | 11.6 | 19.0 | 42 | 6.0 | 5.4 | 196 | 276 |
| 13H | 11.3 | 19.0 | 53 | 4.0 | 5.3 | 187 | 232 |
| 13I | 12.2 | 19.0 | 58 | 4.0 | 5.2 | 416 | 352 |
| 13J | 11.2 | 20.0 | 64 | 10.0 | 2.8 | 244 | 392 |
| 13K | 10.8 | 23.9 | 50 | 5.2 | 4.1 | 170 | 360 |
| 13L | 14.0 | 26.0 | 50 | 6.0 | 4.6 | 268 | 356 |
| 13M | 15.6 | 25.0 | 58 | 8.0 | 3.6 | 316 | 392 |
| 14A | 24.4 | 19.0 | 54 | 6.0 | 35.2 | 324 | 276 |
| 14B | 12.4 | 20.0 | 50 | 12.0 | 4.0 | 168 | 212 |
| 14C | 8.8 | 21.0 | 46 | 4.0 | 2.8 | 174 | 212 |
| 14D | 11.4 | 27.0 | 37 | 4.0 | 3.0 | 121 | 268 |
| 14E | 9.6 | 21.0 | 48 | 6.0 | 5.2 | 276 | 228 |
| 14F | 12.8 | 26.5 | 50 | 5.2 | 4.3 | 238 | 384 |
| 14G | 10.8 | 22.0 | 60 | 6.0 | 5.2 | 258 | 288 |
| 14H | 30.8 | 31.0 | 54 | 6.0 | 30.0 | 152 | 308 |
| 14I | 10.6 | 23.0 | 44 | 4.0 | 5.2 | 156 | 280 |
| 14J | 10.4 | 17.0 | 54 | 5.2 | 3.2 | 172 | 260 |
| 14K | 9.2 | 19.0 | 46 | 4.0 | 2.8 | 202 | 260 |
| 14L | 14.0 | 17.0 | 61 | 5.2 | 2.8 | 117 | 212 |
| 14M | 11.6 | 29.0 | 42 | 4.0 | 4.4 | 108 | 252 |
| 15A | 11.6 | 27.0 | 54 | 8.0 | 7.4 | 220 | 184 |
| 15B | 12.4 | 27.0 | 54 | 8.0 | 4.6 | 144 | 228 |
| 15C | 12.0 | 20.0 | 38 | 6.0 | 4.0 | 248 | 316 |
| 15D | 14.6 | 31.0 | 42 | 6.0 | 11.0 | 120 | 336 |
| 15E | 12.8 | 27.5 | 38 | 6.0 | 5.1 | 92 | 296 |
| 15F | 11.6 | 26.0 | 44 | 6.0 | 2.8 | 308 | 344 |
| 15G | 9.6 | 12.0 | 70 | 4.0 | 4.0 | 280 | 232 |
| 15H | 8.6 | 13.0 | 42 | 4.0 | 2.4 | 132 | 180 |
| 15I | 10.8 | 18.0 | 66 | 6.0 | 3.6 | 242 | 204 |
| 15J | 12.0 | 19.0 | 46 | 4.0 | 4.0 | 100 | 332 |
| 15K | 10.4 | 21.0 | 50 | 4.0 | 4.0 | 184 | 296 |
| 15L | 15.6 | 29.0 | 50 | 6.0 | 4.0 | 584 | 376 |
| 15M | 16.0 | 27.0 | 48 | 6.0 | 9.0 | 228 | 254 |

# Plant Sample Analyses
(continued)

| Grid Location | Cu (ppm) | Pb (ppm) | Zn (ppm) | Cd (ppm) | Ni (ppm) | Mn (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|
| 16A | 12.0 | 25.0 | 48 | 8.0 | 5.2 | 148 | 252 |
| 16B | 12.2 | 18.0 | 54 | 6.0 | 4.0 | 196 | 272 |
| 16C | 12.1 | 31.5 | 51 | 7.2 | 4.6 | 150 | 276 |
| 16D | 14.6 | 24.0 | 52 | 6.0 | 2.4 | 100 | 316 |
| 16E | 11.6 | 31.0 | 40 | 6.0 | 4.0 | 228 | 332 |
| 16F | 9.6 | 16.5 | 53 | 5.2 | 5.1 | 362 | 188 |
| 16G | 10.0 | 21.0 | 80 | 6.0 | 4.0 | 468 | 368 |
| 16H | 9.6 | 26.0 | 50 | 6.0 | 4.6 | 256 | 256 |
| 16I | 10.8 | 24.0 | 50 | 7.2 | 5.1 | 245 | 280 |
| 16J | 10.8 | 18.0 | 42 | 4.0 | 2.8 | 148 | 252 |
| 16K | 14.8 | 21.0 | 46 | 6.0 | 4.6 | 116 | 316 |
| 16L | 11.7 | 24.3 | 48 | 8.0 | 5.3 | 152 | 268 |
| 16M | 14.8 | 25.0 | 64 | 6.0 | 5.6 | 168 | 376 |

*NS = no sample

## APPENDIX V

### Miscellaneous Soil Analyses

| Grid Location | Avail. Cu (ppm) | Avail. Zn (ppm) | Avail. Mn (ppm) | Avail. Fe (ppm) | pH | Organ. Carbon (%) | CxCu (ppm) | CxHM (ppm) |
|---|---|---|---|---|---|---|---|---|
| 1A | 0.2 | 1.8 | 26.0 | 8.0 | 6.2 | 1.5 | ND | 7.5 |
| 1B | ND | 4.2 | 36.0 | 12.0 | 5.6 | 2.2 | ND | 27.0 |
| 1C | 0.4 | 0.4 | 15.0 | 12.0 | 6.2 | 1.5 | ND | 19.0 |
| 1D | ND | 1.4 | 16.0 | 11.6 | 6.4 | 1.3 | ND | 15.0 |
| 1E | 0.2 | 2.0 | 14.0 | 10.0 | 6.3 | 3.9 | ND | 17.0 |
| 1F | ND | 2.4 | 30.0 | 6.0 | 5.4 | 2.4 | 1.0 | 45.0 |
| 1G | 0.2 | 2.6 | 48.6 | 7.0 | 5.5 | 2.9 | ND | 18.0 |
| 1H | ND | 3.4 | 100.0 | 6.0 | 5.5 | 4.7 | ND | 18.0 |
| 1I | 0.4 | 4.4 | 168.0 | 5.0 | 5.5 | 2.6 | ND | 22.0 |
| 1J | 0.6 | 1.4 | 56.0 | 29.6 | 4.2 | 2.0 | 2.0 | 25.0 |
| 1K | 0.6 | 0.6 | 4.0 | 10.0 | 5.4 | 5.3 | 10.0 | 25.0 |
| 1L | 0.4 | 1.8 | 12.0 | 6.0 | 5.0 | 3.6 | 40.0 | 65.0 |
| 1M | 0.4 | 1.8 | 9.0 | 25.0 | 5.4 | 3.5 | 2.5 | 19.5 |
| 2A | ND | 2.4 | 43.0 | 6.0 | 5.5 | 1.7 | ND | 12.0 |
| 2B | 0.2 | 1.2 | 30.0 | 16.0 | 5.8 | 2.1 | ND | 9.0 |
| 2C | ND | 2.8 | 20.0 | 8.0 | 5.8 | 1.4 | ND | 10.0 |
| 2D | 0.2 | 3.8 | 32.0 | 8.0 | 5.9 | 1.0 | ND | 26.0 |
| 2E | 0.8 | 1.2 | 10.0 | 32.0 | 6.8 | 5.0 | 5.0 | 50.0 |
| 2F | 0.2 | 1.6 | 8.0 | 8.0 | 5.5 | 1.0 | ND | 3.0 |
| 2G | 0.2 | 2.4 | 56.0 | 22.0 | 5.1 | 2.7 | ND | 2.0 |
| 2H | 0.2 | 0.8 | 18.0 | 2.0 | 6.2 | 2.2 | ND | 6.0 |
| 2I | 0.2 | 2.0 | 27.0 | 13.0 | 5.5 | 1.0 | 2.0 | 11.0 |
| 2J | 0.2 | 2.4 | 12.0 | 9.0 | 5.1 | 1.9 | 1.0 | 35.0 |
| 2K | 0.2 | 4.0 | 48.0 | 14.0 | 4.4 | 1.4 | ND | 9.0 |
| 2L | 0.4 | 0.8 | 9.0 | 8.6 | 4.5 | 5.2 | 4.0 | 24.0 |
| 2M | 0.8 | 4.2 | 3.0 | 40.0 | 5.5 | 3.4 | 5.0 | 62.0 |
| 3A | 0.2 | 2.8 | 31.0 | 9.0 | 4.5 | 2.0 | 1.0 | 11.0 |
| 3B | 0.2 | 0.8 | 10.0 | 22.0 | 5.2 | 1.9 | 1.0 | 4.0 |
| 3C | 0.2 | 2.0 | 37.0 | 6.0 | 4.4 | 0.2 | ND | 5.0 |
| 3D | 0.2 | 2.4 | 21.0 | 4.0 | 4.1 | 2.8 | 2.0 | 9.0 |
| 3E | 7.8 | 3.2 | 3.0 | 4.0 | 4.1 | 2.9 | 12.0 | 22.0 |
| 3F | 0.2 | 2.4 | 42.0 | 12.0 | 4.3 | 1.5 | ND | 2.0 |
| 3G | ND | 1.2 | 80.0 | 10.0 | 4.3 | 3.0 | ND | 6.0 |
| 3H | 0.2 | 2.2 | 57.0 | 5.0 | 4.3 | 1.7 | ND | 3.0 |
| 3I | 0.4 | 0.6 | 2.6 | 23.0 | 5.7 | 3.0 | 4.0 | 10.0 |
| 3J | 0.6 | 6.0 | 40.0 | 11.6 | 4.1 | 1.4 | 1.0 | 11.0 |
| 3K | 0.2 | 1.4 | 42.0 | 16.0 | 4.6 | 2.5 | ND | 9.0 |
| 3L | 0.2 | 1.0 | 10.0 | 7.0 | 5.7 | 1.5 | 2.0 | 14.0 |
| 3M | 0.4 | 2.0 | 78.0 | ND | 4.3 | 1.8 | ND | 4.0 |

## Miscellaneous Soil Analyses (continued)

| Grid Location | Avail. Cu (ppm) | Avail. Zn (ppm) | Avail. Mn (ppm) | Avail. Fe (ppm) | pH | Organ. Carbon (%) | CxCu (ppm) | CxHM (ppm) |
|---|---|---|---|---|---|---|---|---|
| 4A | ND | 3.0 | 29.0 | 6.0 | 4.5 | 1.5 | 1.0 | 3.0 |
| 4B | 0.4 | 7.2 | 54.6 | 8.0 | 3.7 | 1.2 | ND | 13.0 |
| 4C | 0.2 | 3.6 | 25.0 | 3.0 | 4.4 | 0.8 | ND | 7.0 |
| 4D | NS | NS | NS | NS | NS | NS | NS | NS |
| 4E | 32.2 | 10.2 | 59.6 | 2.6 | 3.5 | 1.3 | 18.5 | 30.0 |
| 4F | 0.4 | 1.8 | 25.0 | 11.0 | 3.9 | 1.2 | 21.0 | 25.0 |
| 4G | 0.2 | 4.6 | 7.0 | 18.0 | 3.7 | 1.3 | ND | 27.0 |
| 4H | 0.2 | 1.8 | 8.6 | 3.6 | 4.9 | 2.1 | 1.5 | 6.5 |
| 4I | 0.4 | ND | 24.0 | 12.0 | 5.0 | 1.3 | 4.0 | 11.0 |
| 4J | 0.6 | 3.0 | 12.0 | 14.0 | 4.8 | 1.2 | 2.0 | 8.0 |
| 4K | 0.2 | 0.8 | 3.6 | 12.6 | 5.7 | 3.3 | 8.5 | 21.0 |
| 4L | ND | 2.0 | 74.0 | 2.0 | 4.5 | 2.8 | ND | 17.0 |
| 4M | 0.2 | 3.2 | 33.6 | 4.0 | 4.4 | 2.2 | 2.0 | 19.0 |
| 5A | 0.4 | 2.8 | ND | 244.0 | 5.4 | 0.5 | ND | 4.0 |
| 5B | ND | 1.2 | 11.0 | 8.0 | 6.5 | 0.4 | ND | 4.0 |
| 5C | NS | NS | NS | NS | NS | NS | NS | NS |
| 5D | ND | 1.2 | 10.0 | 6.0 | 5.3 | 1.6 | 1.0 | 9.0 |
| 5E | 0.4 | 1.8 | ND | 9.0 | 4.6 | 0.3 | ND | 2.0 |
| 5F | 0.2 | 3.2 | ND | 2.0 | 4.6 | 9.4 | ND | 40.0 |
| 5G | 0.2 | 1.0 | 26.0 | 15.0 | 5.2 | 1.2 | ND | 1.0 |
| 5H | 0.6 | 5.2 | 109.0 | 12.0 | 4.9 | 2.1 | ND | 6.0 |
| 5I | 0.4 | 1.4 | 4.0 | 2.0 | 5.3 | 0.8 | 3.0 | 56.0 |
| 5J | 0.2 | 0.8 | 17.0 | 6.0 | 5.1 | 2.2 | 2.0 | 6.0 |
| 5K | 0.6 | 2.8 | 6.0 | 2.0 | 5.1 | 1.9 | ND | 6.0 |
| 5L | 0.6 | 6.4 | 64.0 | 4.0 | 4.3 | 2.7 | 6.0 | 42.0 |
| 5M | ND | 3.0 | 76.0 | 2.0 | 5.2 | 3.1 | 1.0 | 8.0 |
| 6A | NS | NS | NS | NS | NS | NS | NS | NS |
| 6B | NS | NS | NS | NS | NS | NS | NS | NS |
| 6C | NS | NS | NS | NS | NS | NS | NS | NS |
| 6D | 0.4 | 9.2 | 10.0 | 2.0 | 4.5 | 0.4 | ND | 28.0 |
| 6E | 0.2 | 2.8 | 30.0 | 8.0 | 4.5 | 0.6 | ND | 3.0 |
| 6F | 0.2 | 2.0 | 12.0 | 6.0 | 4.7 | 0.9 | ND | 7.0 |
| 6G | 0.4 | 2.4 | 18.0 | 8.0 | 4.2 | 1.0 | ND | 4.0 |
| 6H | 0.2 | 3.2 | 54.0 | 2.0 | 5.6 | 1.1 | 7.0 | 5.0 |
| 6I | 0.2 | 0.4 | 37.0 | 16.0 | 6.0 | 2.5 | 1.0 | 16.0 |
| 6J | NA | NA | NA | NA | 5.2 | 5.2 | ND | NA |
| 6K | 0.6 | 5.2 | 70.0 | 10.0 | 4.7 | 1.9 | 2.0 | 22.0 |
| 6L | 0.2 | 1.4 | 18.0 | 8.0 | 6.3 | 2.3 | ND | 15.0 |
| 6M | ND | 4.0 | 70.0 | 4.0 | 5.3 | 2.2 | ND | 11.0 |

## Miscellaneous Soil Analyses
(continued)

| Grid Location | Avail. Cu (ppm) | Avail. Zn (ppm) | Avail. Mn (ppm) | Avail. Fe (ppm) | pH | Organ. Carbon (%) | CxCu (ppm) | CxHM (ppm) |
|---|---|---|---|---|---|---|---|---|
| 7A | NS | NS | NS | NS | NS | NS | NS | NS |
| 7B | 5.4 | 6.4 | 11.0 | 4.0 | 5.5 | 6.9 | 100.0 | 105.0 |
| 7C | NS | NS | NS | NS | NS | NS | NS | NS |
| 7D | NS | NS | NS | NS | NS | NS | NS | NS |
| 7E | 0.8 | 10.0 | 6.0 | 6.0 | 5.8 | 2.4 | 28.0 | 58.0 |
| 7F | 1.0 | 6.8 | 6.0 | 15.0 | 5.0 | 1.8 | 7.5 | 26.0 |
| 7G | 0.6 | 3.2 | 8.0 | 18.0 | 5.0 | 1.0 | 2.0 | 5.0 |
| 7H | ND | 2.4 | 21.0 | 14.0 | 5.7 | 3.8 | 2.0 | 18.0 |
| 7I | 0.6 | 1.0 | 9.0 | 28.6 | 5.5 | 2.5 | 7.0 | 27.0 |
| 7J | 0.4 | 2.2 | 9.0 | 4.0 | 5.5 | 0.8 | ND | 5.0 |
| 7K | 0.8 | 1.4 | 28.0 | 26.0 | 4.9 | 3.9 | 1.0 | 4.0 |
| 7L | 0.4 | 1.2 | 5.6 | 6.4 | 5.6 | 1.1 | ND | 15.0 |
| 7M | ND | 1.8 | 10.0 | 4.0 | 6.0 | 1.2 | ND | 70.0 |
| 8A | 0.8 | 11.2 | 37.0 | 15.0 | 5.8 | 2.5 | 5.0 | 37.0 |
| 8B | 0.8 | 6.6 | 84.0 | 20.0 | 5.0 | 2.4 | ND | 12.0 |
| 8C | 4.6 | 3.4 | ND | 8.0 | 4.4 | 2.9 | 30.0 | 50.0 |
| 8D | 0.6 | 18.2 | 45.0 | 30.0 | 5.7 | 3.7 | 3.0 | 85.0 |
| 8E | 0.4 | 148.0 | 7.0 | 20.0 | 5.9 | 3.5 | 20.0 | 100.0 |
| 8F | 0.6 | 6.8 | 10.0 | 12.0 | 5.5 | 4.0 | 14.0 | 45.0 |
| 8G | 0.6 | 15.4 | 61.0 | 18.0 | 5.2 | 1.6 | 4.0 | 55.0 |
| 8H | NS | NS | NS | NS | NS | NS | NS | NS |
| 8I | NS | NS | NS | NS | NS | NS | NS | NS |
| 8J | 2.0 | 332.0 | 24.0 | 9.0 | 5.0 | 1.6 | 76.0 | 105.0 |
| 8K | 0.2 | 4.4 | 38.0 | 4.0 | 5.5 | 1.3 | ND | 9.0 |
| 8L | 0.4 | 3.4 | 4.0 | 10.0 | 5.6 | 2.5 | ND | 22.0 |
| 8M | 0.2 | 2.2 | 12.0 | 4.0 | 5.2 | 2.5 | 11.0 | 37.0 |
| 9A | 0.2 | 4.0 | 88.0 | 5.0 | 5.4 | 0.8 | ND | 15.0 |
| 9B | 0.2 | 4.2 | 80.0 | 1.0 | 5.7 | 1.3 | ND | 72.5 |
| 9C | 0.6 | 2.8 | 14.0 | 11.0 | 5.8 | 1.8 | 2.0 | 15.0 |
| 9D | 0.6 | 2.4 | 22.0 | 10.0 | 5.8 | 3.0 | NA | NA |
| 9E | 0.8 | 4.8 | ND | 6.0 | 5.8 | 0.7 | ND | 1.0 |
| 9F | 0.6 | 2.8 | 27.0 | 3.0 | 5.7 | 1.4 | 2.0 | 8.0 |
| 9G | 0.6 | 6.8 | 7.0 | 18.0 | 5.8 | 4.4 | 13.0 | 90.0 |
| 9H | 0.2 | 0.8 | 5.0 | ND | 6.4 | 2.1 | ND | 4.0 |
| 9I | 0.2 | 2.8 | 11.0 | 8.0 | 5.7 | 0.8 | ND | 4.0 |
| 9J | 0.6 | 0.6 | 3.6 | 2.6 | 6.8 | 5.2 | 100.0 | 105.0 |
| 9K | 5.0 | 234.0 | 39.0 | 6.0 | 5.9 | 1.8 | 100.0 | 105.0 |
| 9L | 0.2 | NA | 13.6 | 4.0 | 6.4 | 1.0 | 6.0 | 31.0 |
| 9M | 0.2 | 1.0 | 13.0 | 4.0 | 6.6 | 3.8 | 5.0 | 25.0 |

## Miscellaneous Soil Analyses
(continued)

| Grid Location | Avail. Cu (ppm) | Avail. Zn (ppm) | Avail. Mn (ppm) | Avail. Fe (ppm) | pH | Organ. Carbon (%) | CxCu (ppm) | CxHM (ppm) |
|---|---|---|---|---|---|---|---|---|
| 10A | 0.2 | 6.4 | 88.8 | 2.6 | 5.2 | 2.7 | ND | 12.0 |
| 10B | 0.2 | 3.6 | 44.0 | 5.0 | 5.5 | 2.6 | 2.0 | NA |
| 10C | 0.4 | 4.0 | 14.0 | 9.0 | 5.7 | 0.8 | ND | 17.0 |
| 10D | 0.4 | 1.8 | ND | 7.4 | 5.4 | 3.0 | ND | 36.0 |
| 10E | 0.2 | 1.6 | 29.0 | 11.0 | 5.7 | 1.0 | ND | 6.0 |
| 10F | 0.8 | 7.6 | 3.0 | 6.0 | 5.8 | 0.7 | ND | 27.0 |
| 10G | 0.6 | 4.8 | 1.0 | 20.0 | 4.5 | 1.5 | ND | 16.5 |
| 10H | 0.6 | 3.8 | ND | 10.0 | 5.7 | 0.3 | ND | 8.0 |
| 10I | 0.6 | 2.4 | 2.0 | 1.0 | 5.7 | 0.2 | ND | 23.0 |
| 10J | 0.6 | 3.6 | 2.6 | 1.0 | 5.7 | 0.3 | ND | 4.5 |
| 10K | 0.2 | 2.4 | 22.0 | 4.0 | 5.7 | 3.6 | 1.0 | 11.0 |
| 10L | 0.2 | 4.8 | 9.0 | 18.0 | 6.0 | 5.1 | 5.0 | 52.5 |
| 10M | 0.4 | 1.4 | 4.0 | 7.0 | 6.7 | 2.8 | ND | 5.0 |
| 11A | ND | 1.2 | 29.0 | 4.0 | 5.0 | 3.7 | ND | 17.0 |
| 11B | ND | 2.4 | 16.0 | 5.0 | NA | 0.6 | ND | 5.0 |
| 11C | 0.4 | 1.6 | 6.0 | 12.0 | 5.2 | 1.5 | ND | 9.0 |
| 11D | 0.6 | 0.4 | ND | 8.0 | 4.8 | 1.2 | ND | 8.0 |
| 11E | 1.2 | 3.6 | 10.0 | 26.0 | 3.9 | 2.7 | 4.0 | 17.0 |
| 11F | 0.4 | 2.6 | 22.0 | 23.0 | 4.3 | 1.0 | ND | 4.0 |
| 11G | 0.4 | 4.0 | 8.0 | 9.0 | 4.1 | 0.6 | ND | 29.0 |
| 11H | 0.2 | 2.4 | 1.0 | 6.0 | 4.5 | 0.3 | ND | ND |
| 11I | 0.2 | 2.0 | 15.0 | 2.0 | 4.9 | 1.9 | ND | 7.0 |
| 11J | 0.4 | 0.6 | 2.0 | 2.0 | 4.6 | 1.0 | ND | 4.0 |
| 11K | 0.4 | 1.8 | 8.0 | 17.0 | 4.2 | 1.6 | 1.0 | 5.0 |
| 11L | ND | 3.2 | 36.0 | 10.0 | 4.5 | 2.2 | ND | 12.0 |
| 11M | 0.2 | 2.0 | 2.0 | 5.0 | 4.6 | 0.4 | ND | ND |
| 12A | 0.2 | 3.2 | 19.0 | 4.0 | 4.2 | 0.9 | ND | 10.0 |
| 12B | 0.4 | 1.0 | 11.0 | 2.0 | 4.7 | 1.5 | ND | 2.0 |
| 12C | 0.2 | 1.4 | 2.0 | 3.0 | 4.6 | 1.3 | ND | 13.0 |
| 12D | 0.6 | 4.0 | 9.0 | 14.0 | 4.4 | 1.5 | 1.0 | 4.0 |
| 12E | 0.2 | 0.4 | 3.0 | 6.0 | 5.1 | 2.8 | ND | ND |
| 12F | 0.2 | 2.8 | 4.0 | 31.0 | 4.1 | 1.0 | ND | 10.0 |
| 12G | 0.4 | 3.2 | 10.0 | 4.0 | 4.2 | 0.8 | ND | 5.0 |
| 12H | 0.4 | 1.8 | ND | 10.0 | 4.4 | 0.3 | ND | ND |
| 12I | 0.2 | 3.2 | ND | 6.0 | 5.1 | 0.4 | ND | 1.0 |
| 12J | 2.4 | 2.4 | ND | 12.0 | 3.9 | 0.3 | 3.0 | 15.0 |
| 12K | 0.2 | 0.6 | 8.0 | 12.0 | 4.3 | 5.3 | ND | 4.0 |
| 12L | 0.4 | 3.2 | ND | 12.0 | 4.1 | 0.5 | ND | 7.0 |
| 12M | 0.2 | 6.4 | 33.0 | 10.6 | 4.3 | 1.3 | ND | 12.0 |

## Miscellaneous Soil Analyses
(continued)

| Grid Location | Avail. Cu (ppm) | Avail. Zn (ppm) | Avail. Mn (ppm) | Avail. Fe (ppm) | pH | Organ. Carbon (%) | CxCu (ppm) | CxHM (ppm) |
|---|---|---|---|---|---|---|---|---|
| 13A | ND | 4.8 | 27.0 | 14.0 | 3.9 | 3.3 | ND | 7.0 |
| 13B | 0.2 | 1.6 | 40.6 | 6.6 | 4.3 | 2.7 | ND | 4.0 |
| 13C | ND | 1.6 | 12.0 | 13.0 | 5.0 | 1.5 | ND | 5.0 |
| 13D | 0.2 | 2.0 | 94.0 | 26.0 | 4.6 | 1.5 | ND | 10.0 |
| 13E | ND | 0.6 | 16.6 | 5.6 | 4.6 | 2.3 | ND | 6.5 |
| 13F | ND | 1.2 | 15.0 | 8.0 | 4.1 | 2.0 | ND | 3.0 |
| 13G | ND | 1.8 | 3.0 | 4.0 | 4.6 | 1.2 | ND | 1.0 |
| 13H | 0.8 | 4.8 | 1.6 | 5.6 | 4.1 | 0.3 | ND | 4.5 |
| 13I | 12.0 | 3.0 | 50.0 | 6.0 | 5.0 | 1.8 | 2.0 | 15.0 |
| 13J | 0.4 | 4.4 | 2.0 | 11.0 | 5.6 | 0.6 | ND | 2.0 |
| 13K | 0.4 | 5.6 | 16.6 | 2.0 | 5.3 | 1.1 | ND | 8.5 |
| 13L | 0.2 | 0.2 | 12.0 | 5.0 | 5.9 | 3.7 | ND | 7.0 |
| 13M | 0.2 | 2.0 | 4.0 | 9.0 | 5.5 | 3.3 | ND | 17.0 |
| 14A | 0.2 | 2.8 | 95.0 | 2.6 | 4.1 | 3.4 | ND | 10.0 |
| 14B | ND | 1.2 | 20.0 | 8.0 | 4.5 | 1.6 | 1.0 | 6.0 |
| 14C | 0.2 | 1.6 | 32.0 | 8.0 | 4.6 | 1.4 | ND | 2.0 |
| 14D | 0.2 | 0.8 | 236.0 | 4.0 | 4.8 | 1.7 | 2.0 | 35.0 |
| 14E | 0.4 | 2.0 | 92.0 | 4.0 | 4.5 | 3.3 | ND | 5.0 |
| 14F | 0.6 | 5.6 | 38.0 | 2.0 | 4.1 | 1.6 | ND | 4.0 |
| 14G | ND | 2.2 | 8.0 | 19.0 | 5.2 | 1.0 | ND | 6.0 |
| 14H | 1.0 | 2.4 | ND | 15.0 | 5.5 | 2.7 | 4.0 | 10.0 |
| 14I | 0.4 | 2.4 | 16.0 | 19.0 | 5.1 | 4.0 | 2.0 | 12.0 |
| 14J | 1.0 | 3.6 | ND | 8.0 | 4.7 | 0.5 | ND | 11.0 |
| 14K | 0.2 | 2.8 | 9.0 | 10.0 | 5.9 | 1.2 | ND | 7.0 |
| 14L | 0.2 | 1.8 | 19.0 | 5.0 | 5.4 | 1.7 | ND | 3.0 |
| 14M | 0.6 | 5.6 | 10.0 | 18.0 | 5.2 | 3.8 | 1.0 | 5.0 |
| 15A | 0.4 | 0.6 | 17.0 | 2.0 | 4.8 | 4.6 | ND | 13.0 |
| 15B | 0.2 | 5.8 | 98.6 | 5.6 | 4.1 | 1.9 | ND | 15.0 |
| 15C | ND | 0.8 | 55.0 | 9.0 | 4.7 | 2.4 | ND | 27.0 |
| 15D | 0.2 | 1.2 | 16.0 | 12.0 | 5.3 | 2.6 | ND | 3.0 |
| 15E | ND | 0.8 | 20.0 | 3.0 | 4.6 | 3.5 | 1.0 | 6.0 |
| 15F | 0.2 | 5.8 | 44.0 | 6.0 | 3.9 | 2.5 | ND | 15.0 |
| 15G | 0.2 | 5.2 | 4.0 | 7.0 | 3.9 | 0.5 | ND | 8.0 |
| 15H | 0.2 | 4.8 | 4.0 | 18.0 | 5.8 | 0.9 | ND | 8.0 |
| 15I | 0.2 | 2.8 | 2.0 | 8.2 | 5.6 | 0.7 | ND | 1.0 |
| 15J | 0.4 | 1.8 | 22.0 | 10.0 | 5.6 | 1.5 | 1.0 | 9.0 |
| 15K | 1.0 | 3.2 | 2.0 | 16.0 | 5.1 | 0.5 | ND | 6.0 |
| 15L | 0.2 | 3.6 | 45.0 | 6.0 | 5.5 | 3.7 | ND | 8.0 |
| 15M | 0.2 | 1.2 | 2.0 | 17.0 | 5.7 | 1.0 | ND | 4.0 |

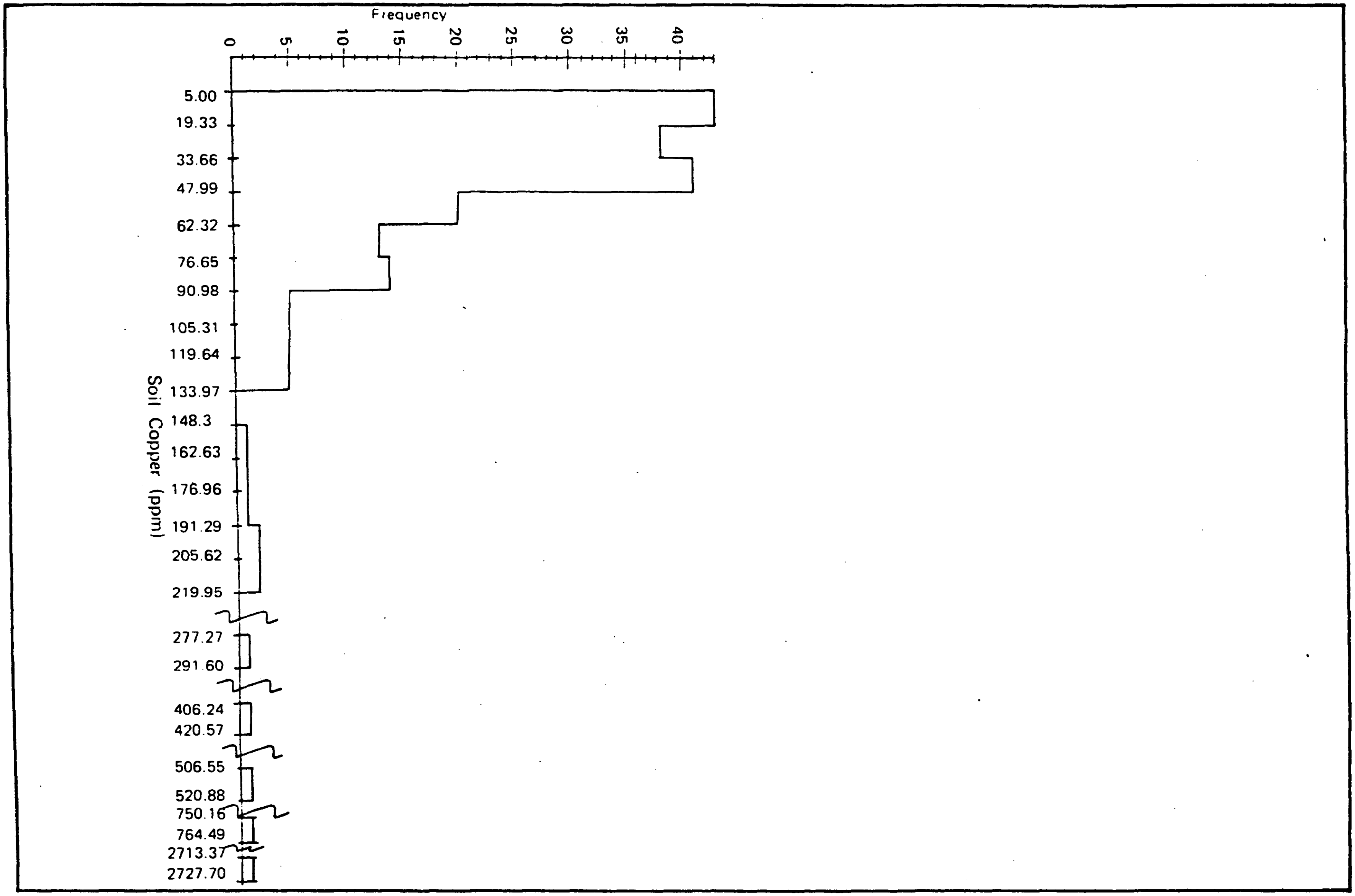
## Miscellaneous Soil Analyses
(continued)

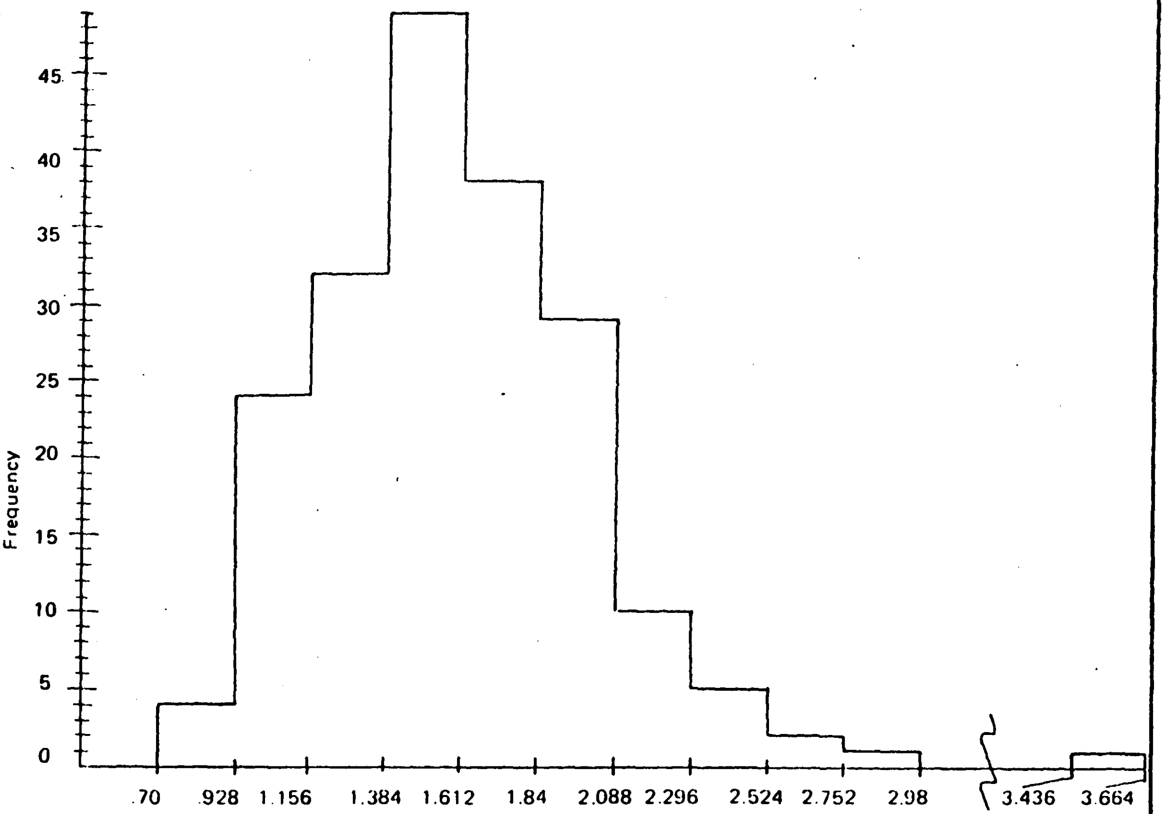
| Grid Location | Avail. Cu (ppm) | Avail. Zn (ppm) | Avail. Mn (ppm) | Avail. Fe (ppm) | pH | Organ. Carbon (%) | CxCu (ppm) | CxHM (ppm) |
|---|---|---|---|---|---|---|---|---|
| 16A | 0.2 | 1.6 | 16.0 | 5.0 | 4.9 | 4.1 | 1.0 | 25.0 |
| 16B | NA | 1.6 | 7.0 | 4.0 | 4.4 | 2.0 | ND | 2.0 |
| 16C | 0.2 | 3.4 | 6.0 | 5.6 | 4.8 | 0.4 | ND | 4.0 |
| 16D | ND | 0.2 | 13.6 | 11.6 | 5.1 | 3.3 | ND | 11.0 |
| 16E | ND | 3.2 | 20.0 | 4.0 | 4.7 | 0.7 | ND | 2.0 |
| 16F | ND | 1.4 | 24.0 | 4.0 | 4.5 | 2.9 | ND | 2.0 |
| 16G | 0.4 | 0.4 | 2.0 | 2.0 | 4.9 | 1.5 | ND | ND |
| 16H | 0.6 | 6.0 | 6.0 | 20.0 | 5.2 | 0.3 | ND | 1.0 |
| 16I | 0.8 | 3.0 | 7.0 | 44.6 | 4.6 | 1.8 | ND | 8.5 |
| 16J | 0.2 | 2.4 | 10.0 | 14.0 | 6.0 | 2.7 | 2.0 | 30.0 |
| 16K | ND | 0.8 | 3.0 | 13.0 | 6.7 | 1.7 | 2.0 | 4.0 |
| 16L | 0.2 | 1.8 | 36.0 | 11.6 | 5.4 | 2.6 | 1.0 | 16.0 |
| 16M | 0.6 | 2.2 | 11.0 | 26.0 | 5.3 | 1.6 | 11.0 | 3.0 |

* ND = Not detected
** NS = No sample
*** NA = Not analyzed

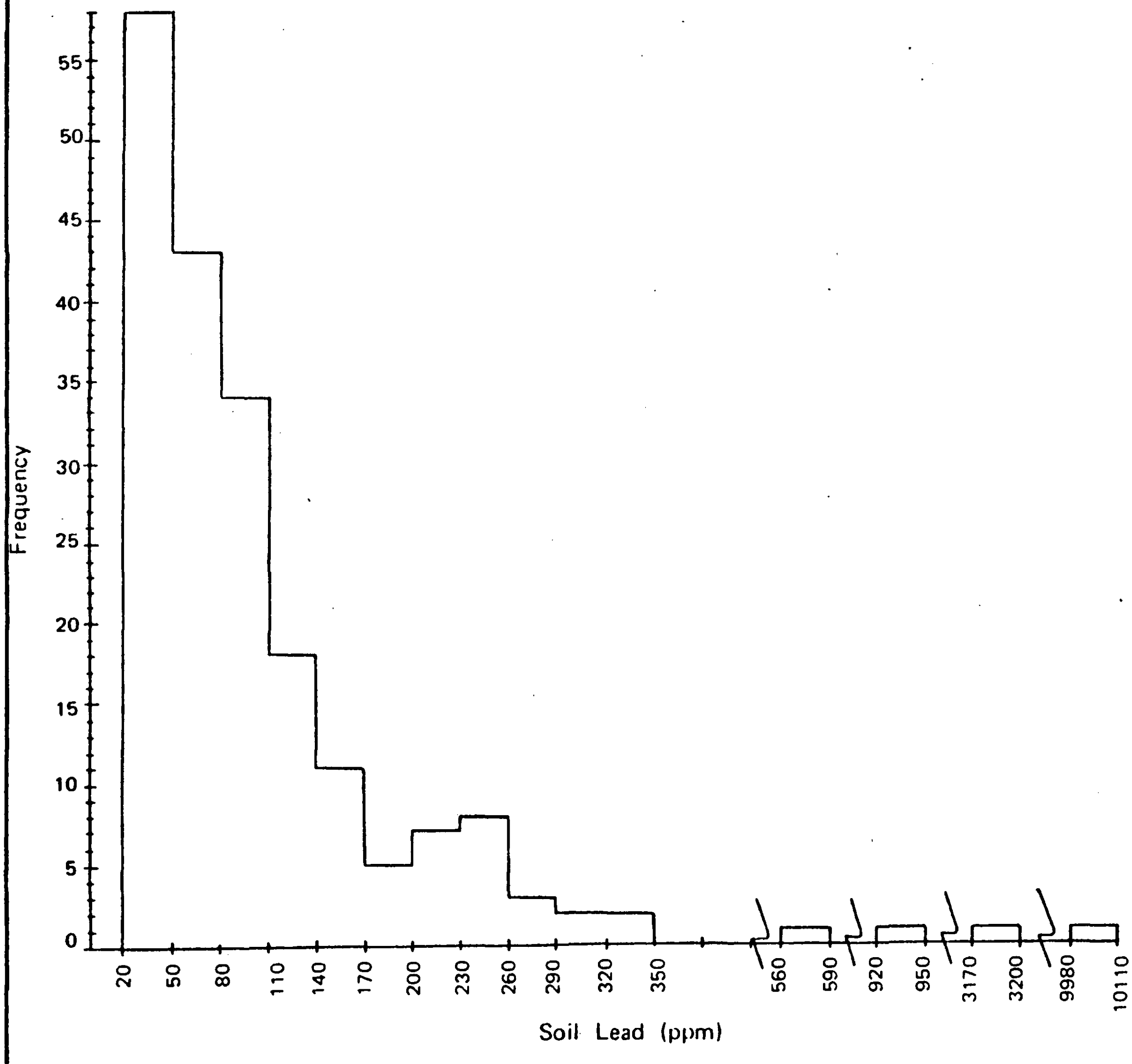
# APPENDIX VI

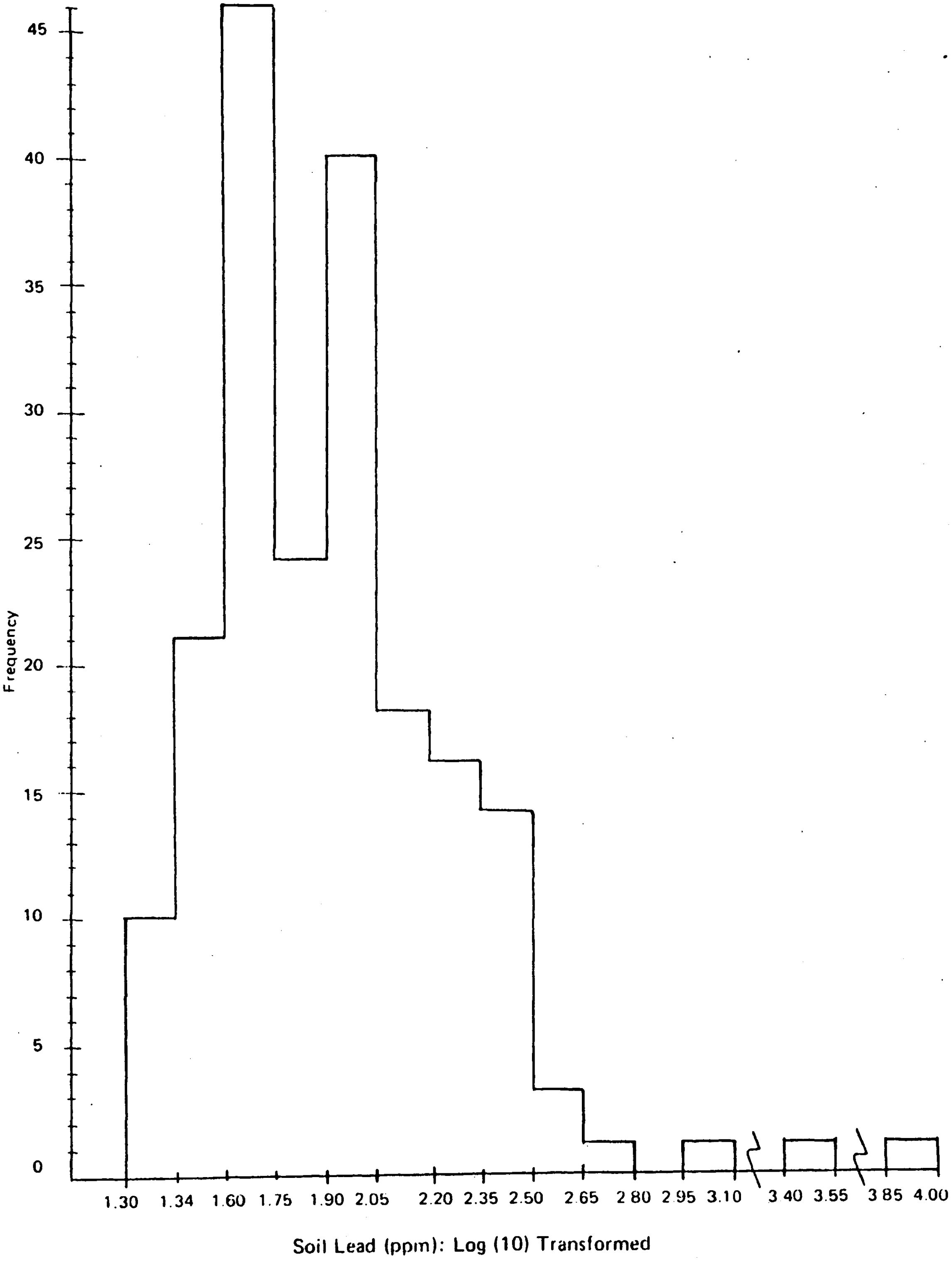
## HISTOGRAMS: SOIL AND PLANT SAMPLES HEDDLESTON DEPOSIT

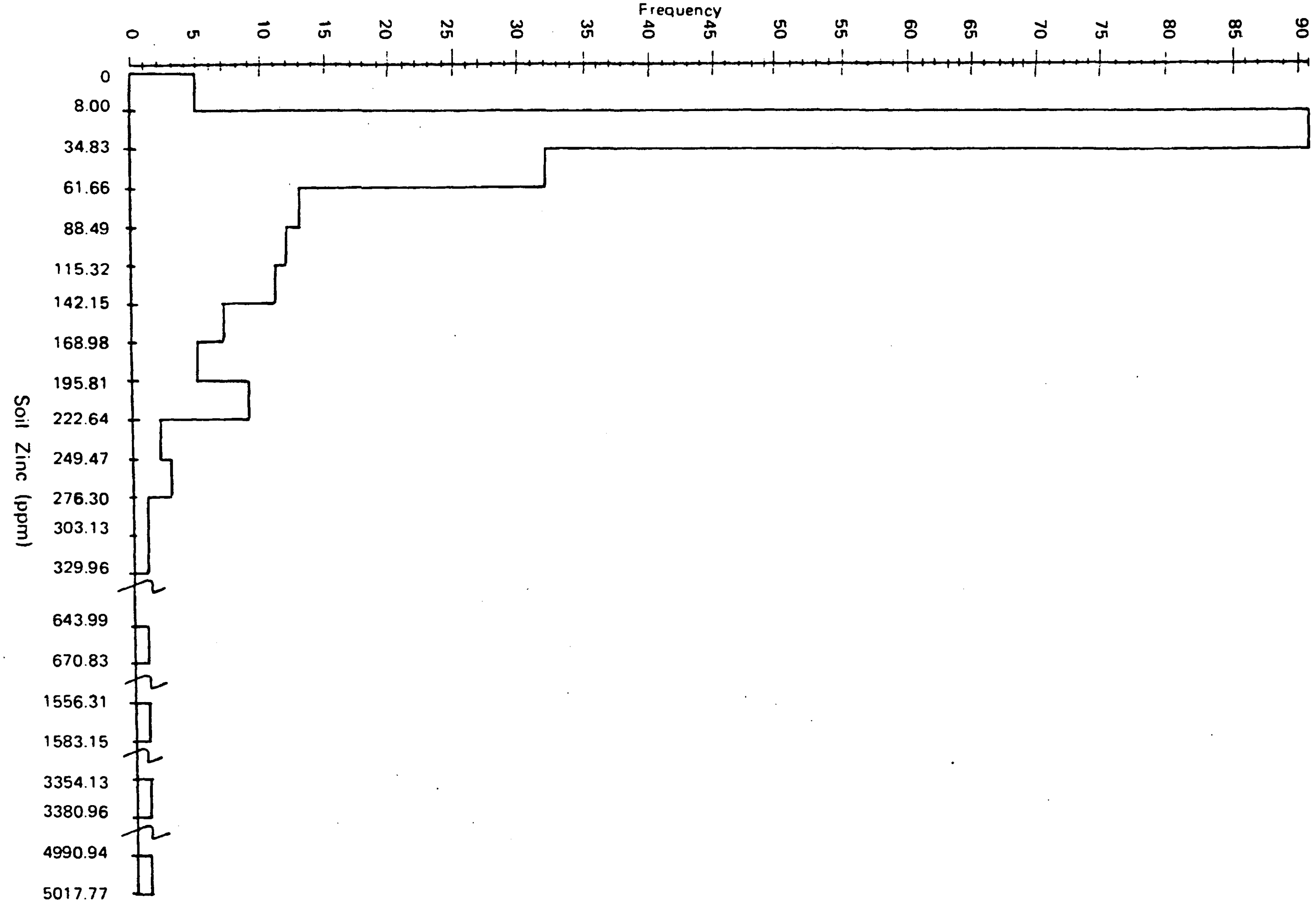

Frequency
0
5
10
15
20
25
30
35
40
Soil Copper (ppm)
5.00
19.33
33.66
47.99
62.32
76.65
90.98
105.31
119.64
133.97
148.3
162.63
176.96
191.29
205.62
219.95
277.27
291.60
406.24
420.57
506.55
520.88
750.16
764.49
2713.37
2727.70

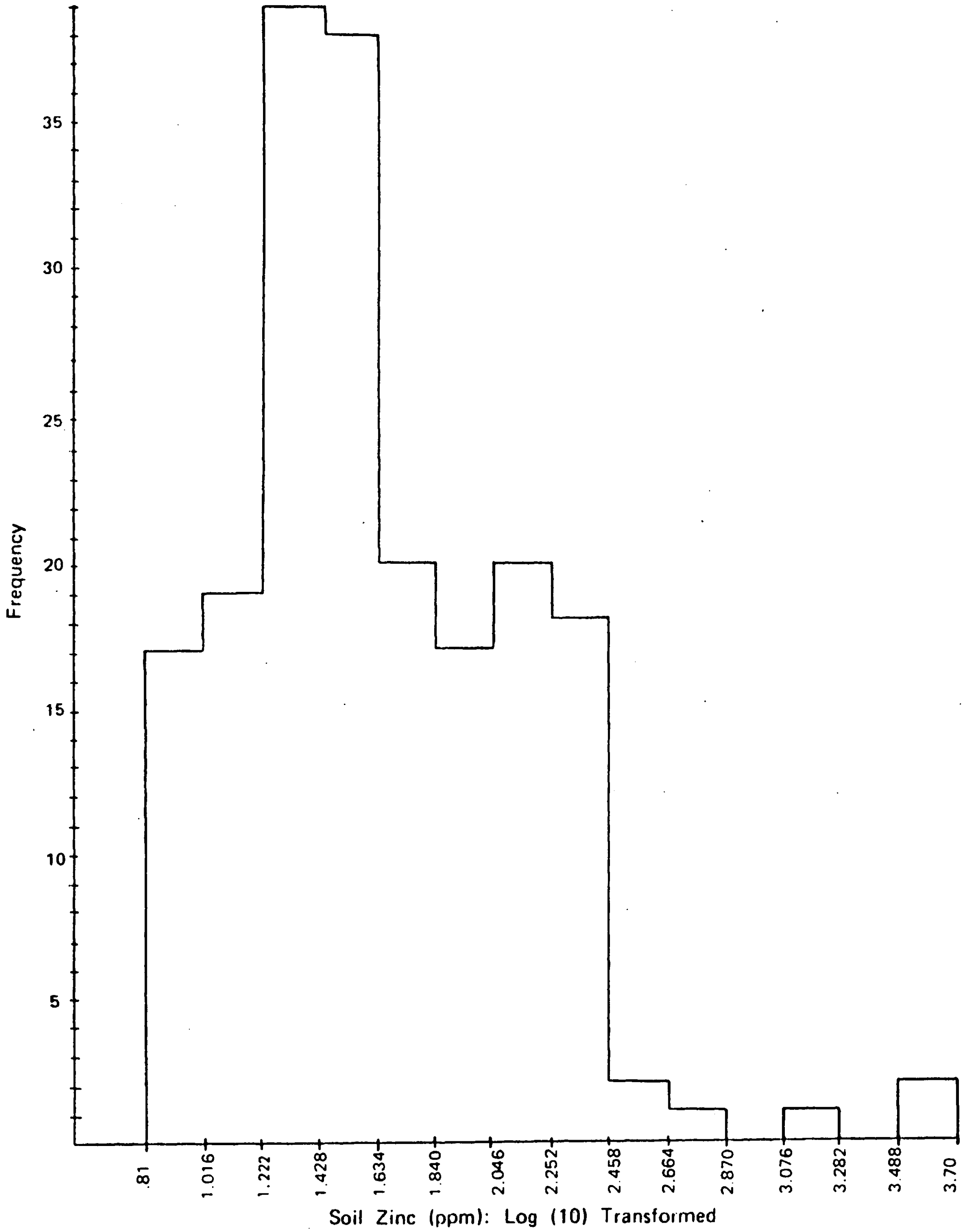


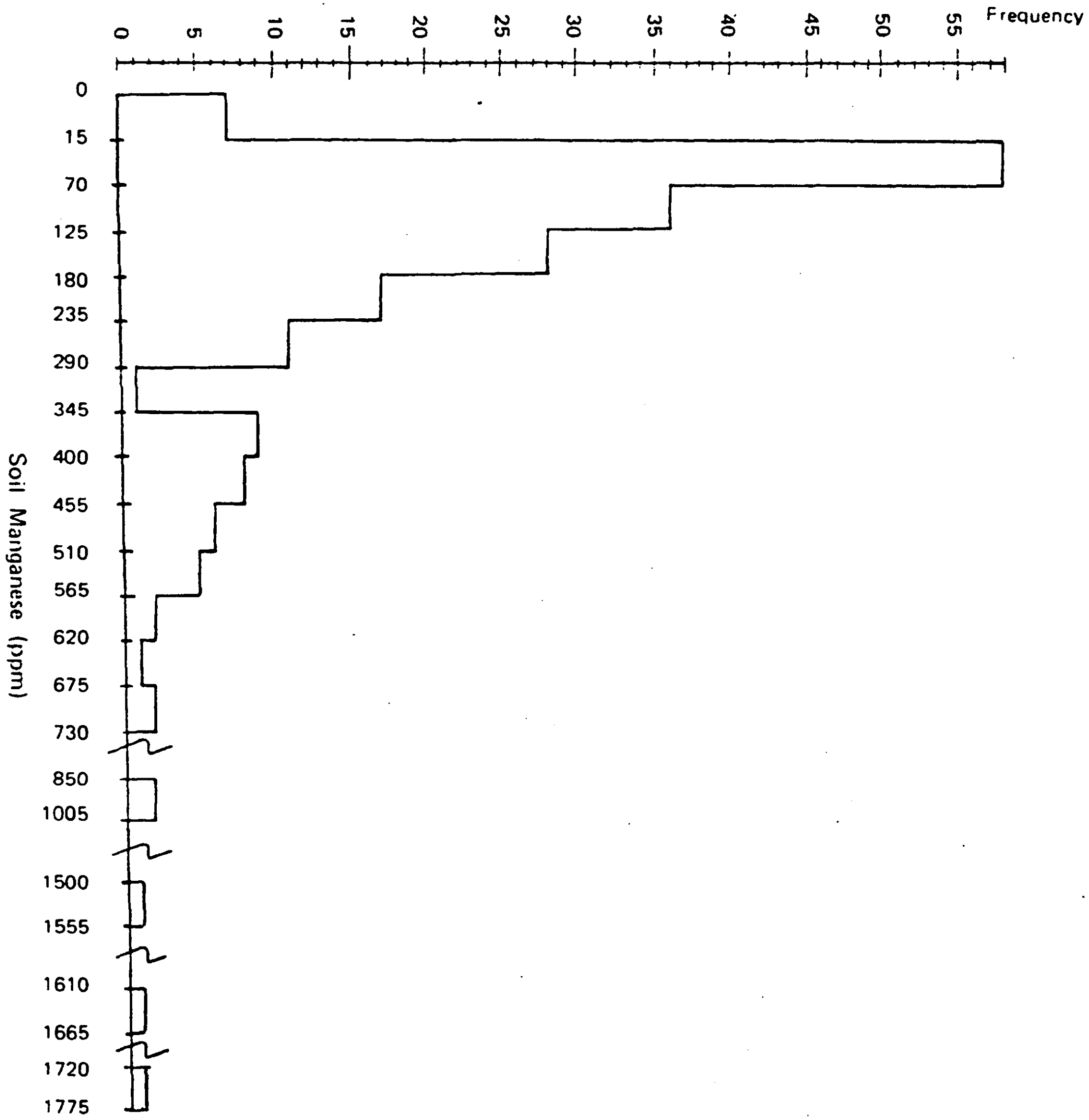
Soil Copper (ppm): Log (10) Transformed

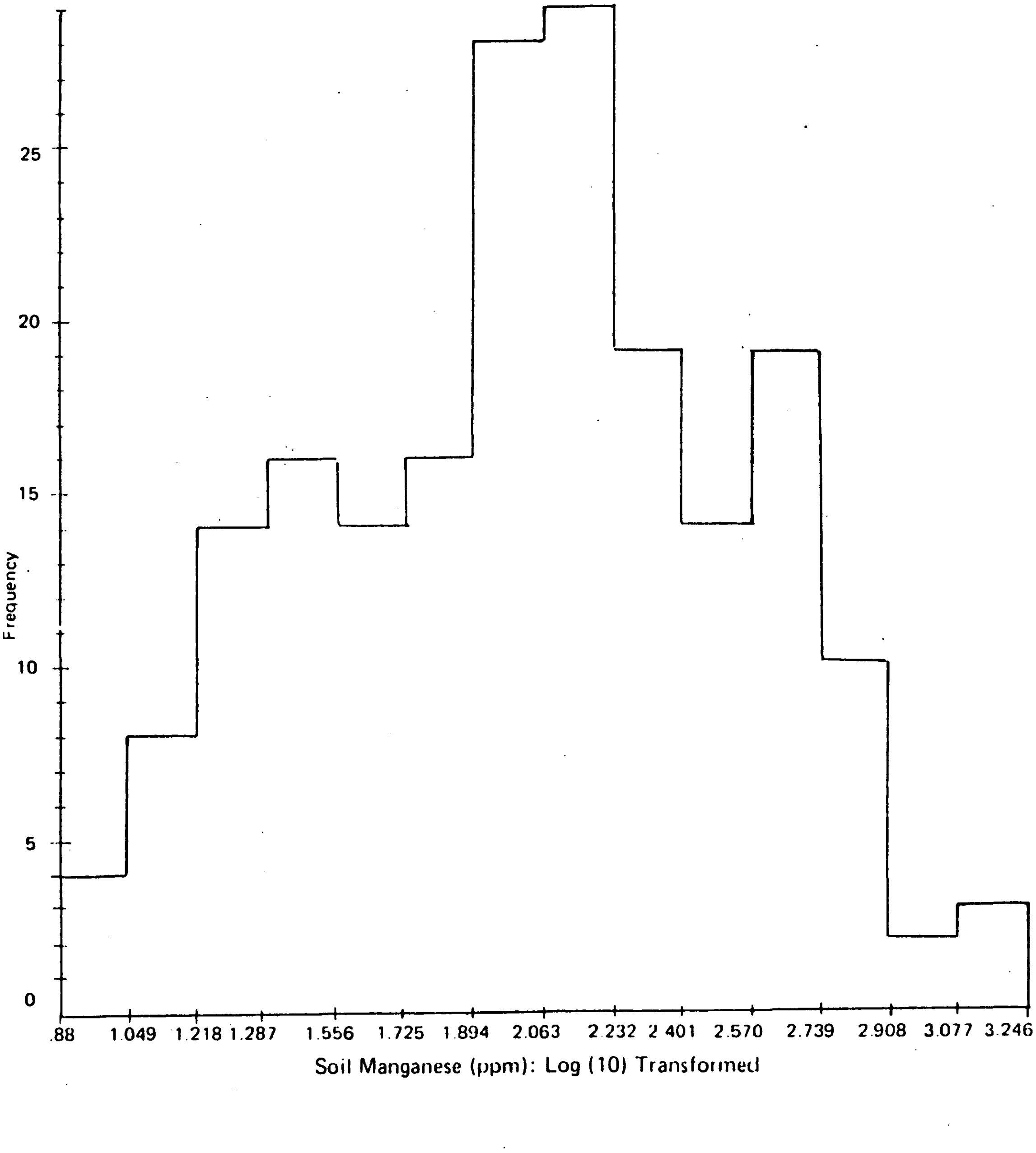

Frequency
0
5
10
15
20
25
30
35
40
45
50
55
20
50
80
110
140
170
200
230
260
290
320
350
560
590
920
950
3170
3200
9980
10110
Soil Lead (ppm)

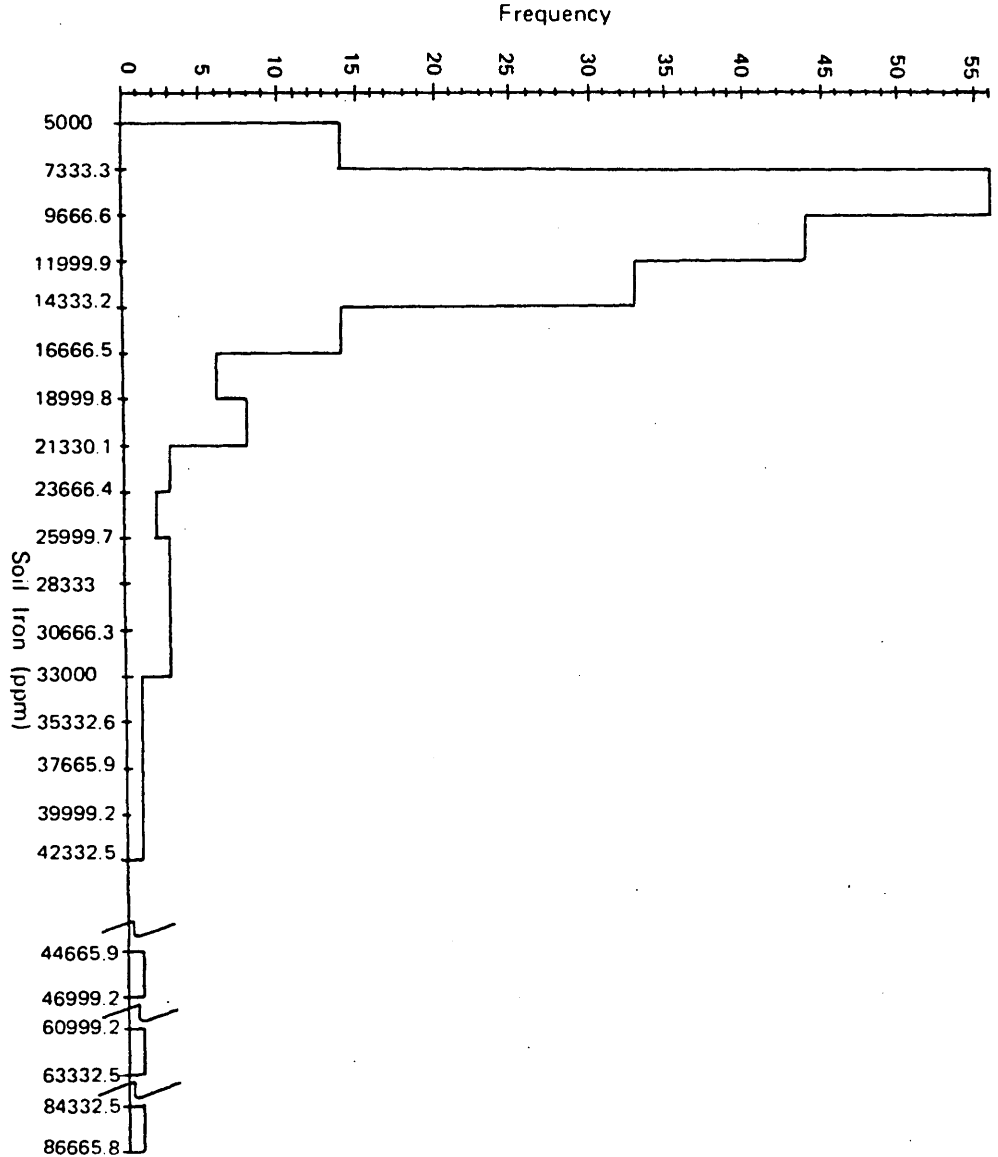

Frequency
0
5
10
15
20
25
30
35
40
45
1.30 1.34 1.60 1.75 1.90 2.05 2.20 2.35 2.50 2.65 2.80 2.95 3.10 3.40 3.55 3.85 4.00
Soil Lead (ppm): Log (10) Transformed

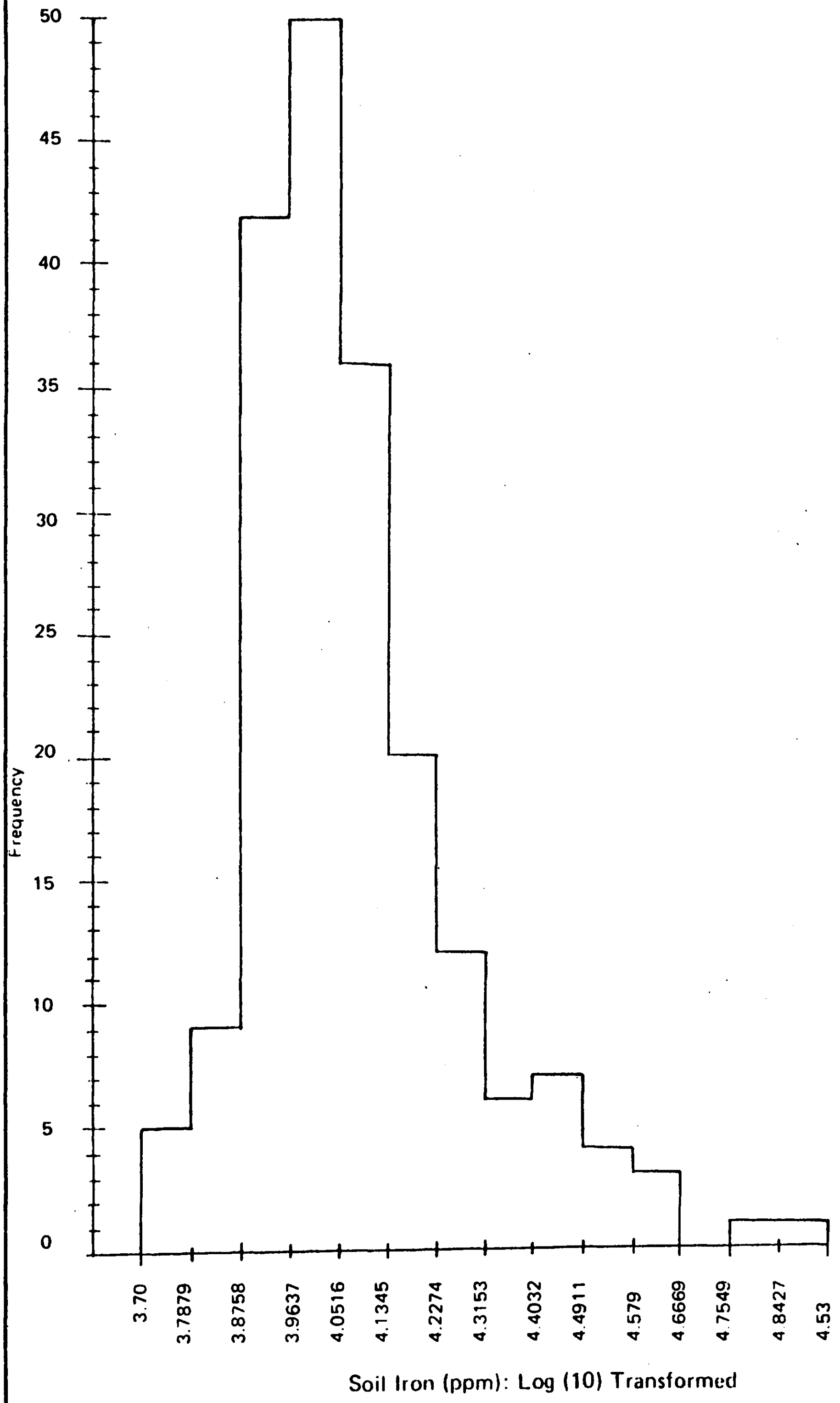

Frequency
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
Soil Zinc (ppm)
0
8.00
34.83
61.66
88.49
115.32
142.15
168.98
195.81
222.64
249.47
276.30
303.13
329.96
643.99
670.83
1556.31
1583.15
3354.13
3380.96
4990.94
5017.77

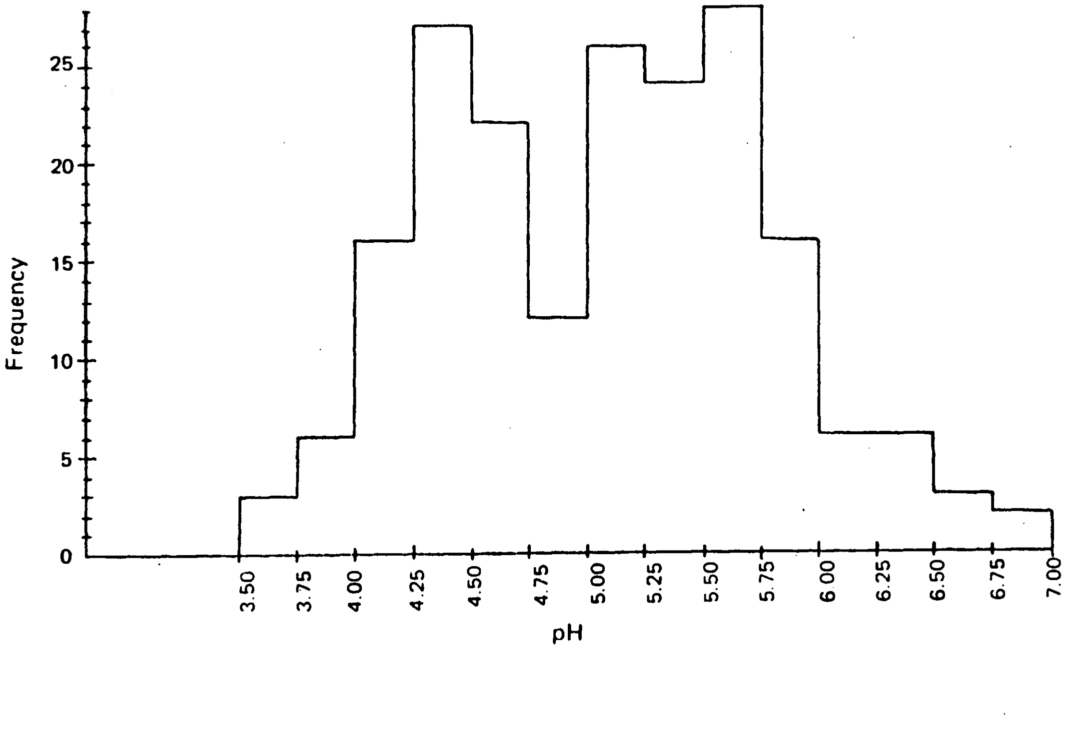

Frequency
35
30
25
20
15
10
5
.81
1.016
1.222
1.428
1.634
1.840
2.046
2.252
2.458
2.664
2.870
3.076
3.282
3.488
3.70
Soil Zinc (ppm): Log (10) Transformed

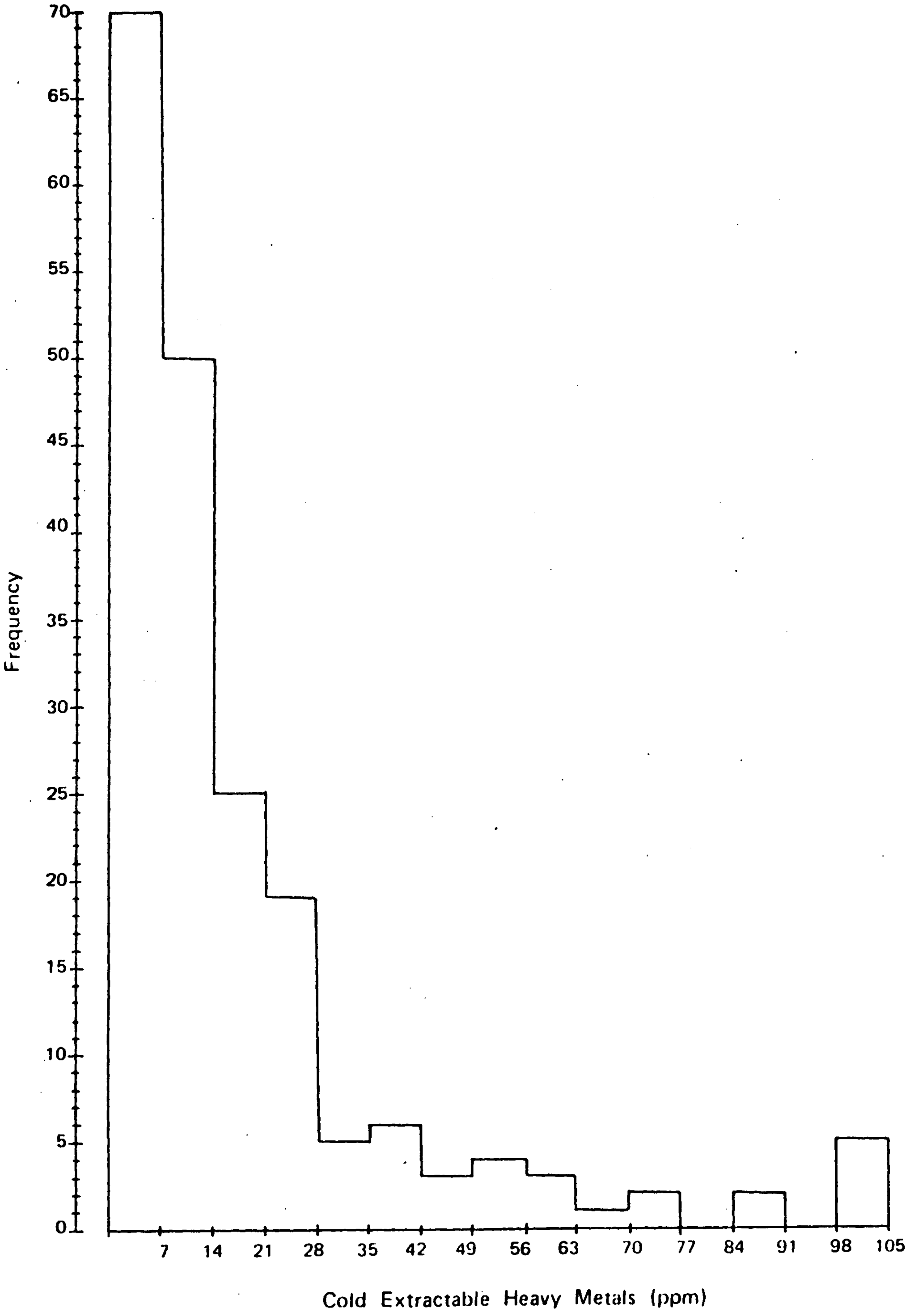

Frequency
0
5
10
15
20
25
30
35
40
45
50
55
Soil Manganese (ppm)
0
15
70
125
180
235
290
345
400
455
510
565
620
675
730
850
1005
1500
1555
1610
1665
1720
1775

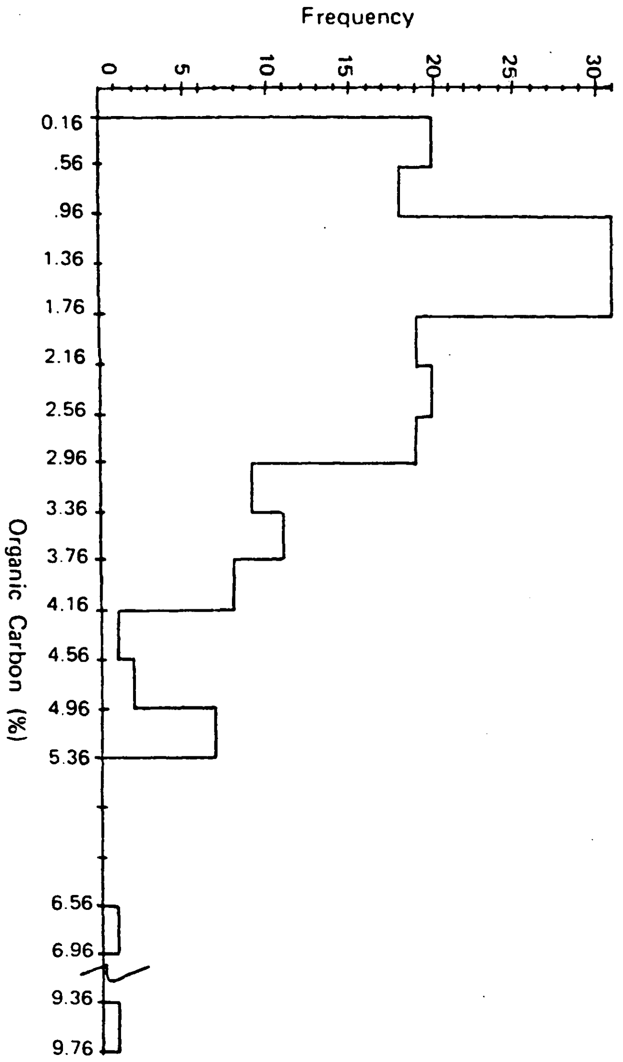

Frequency
25
20
15
10
5
0
.88
1.049
1.218
1.287
1.556
1.725
1.894
2.063
2.232
2.401
2.570
2.739
2.908
3.077
3.246
Soil Manganese (ppm): Log (10) Transformed

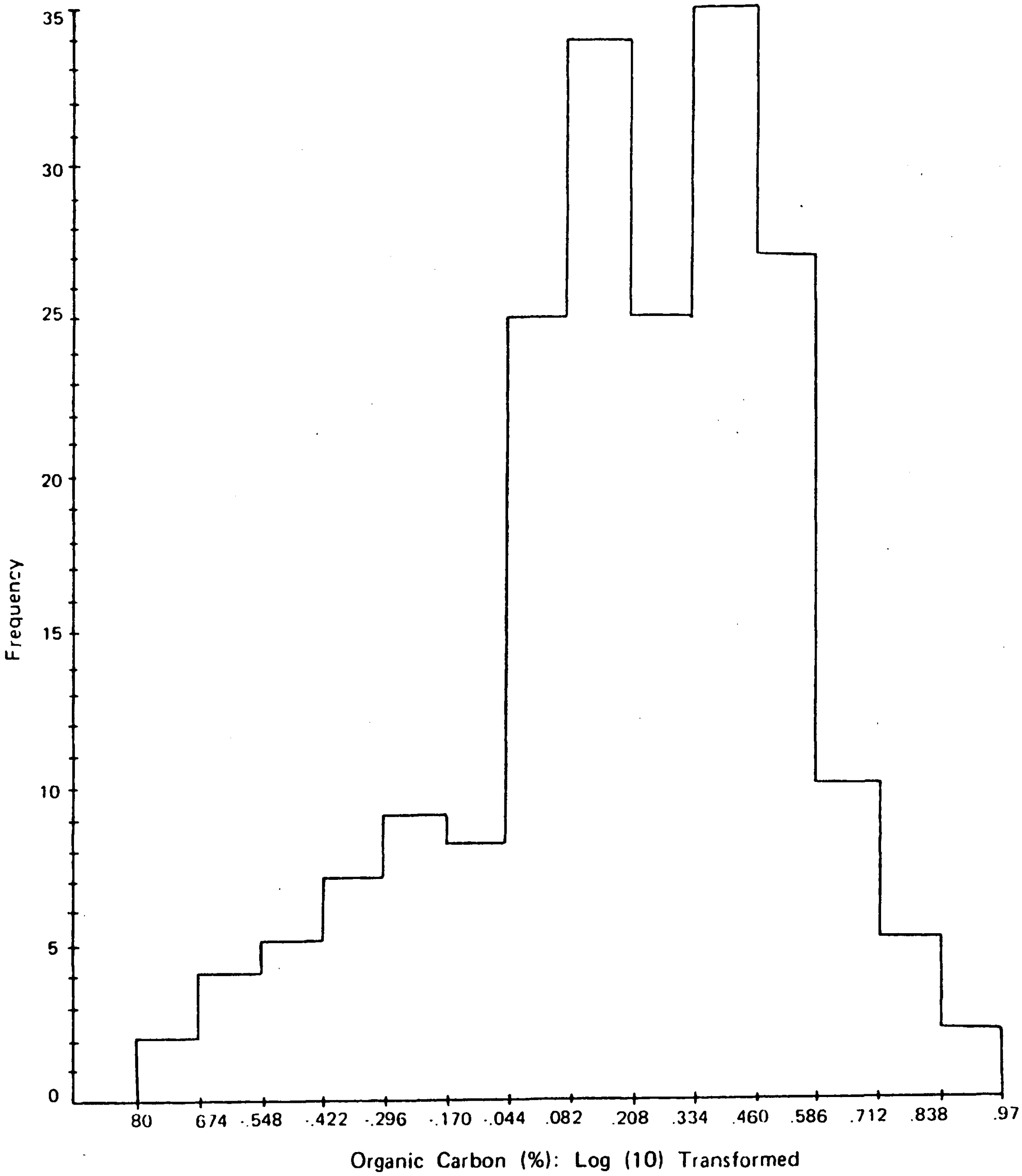

Frequency
0
5
10
15
20
25
30
35
40
45
50
55
Soil Iron (ppm)
5000
7333.3
9666.6
11999.9
14333.2
16666.5
18999.8
21330.1
23666.4
25999.7
28333
30666.3
33000
35332.6
37665.9
39999.2
42332.5
44665.9
46999.2
60999.2
63332.5
84332.5
86665.8

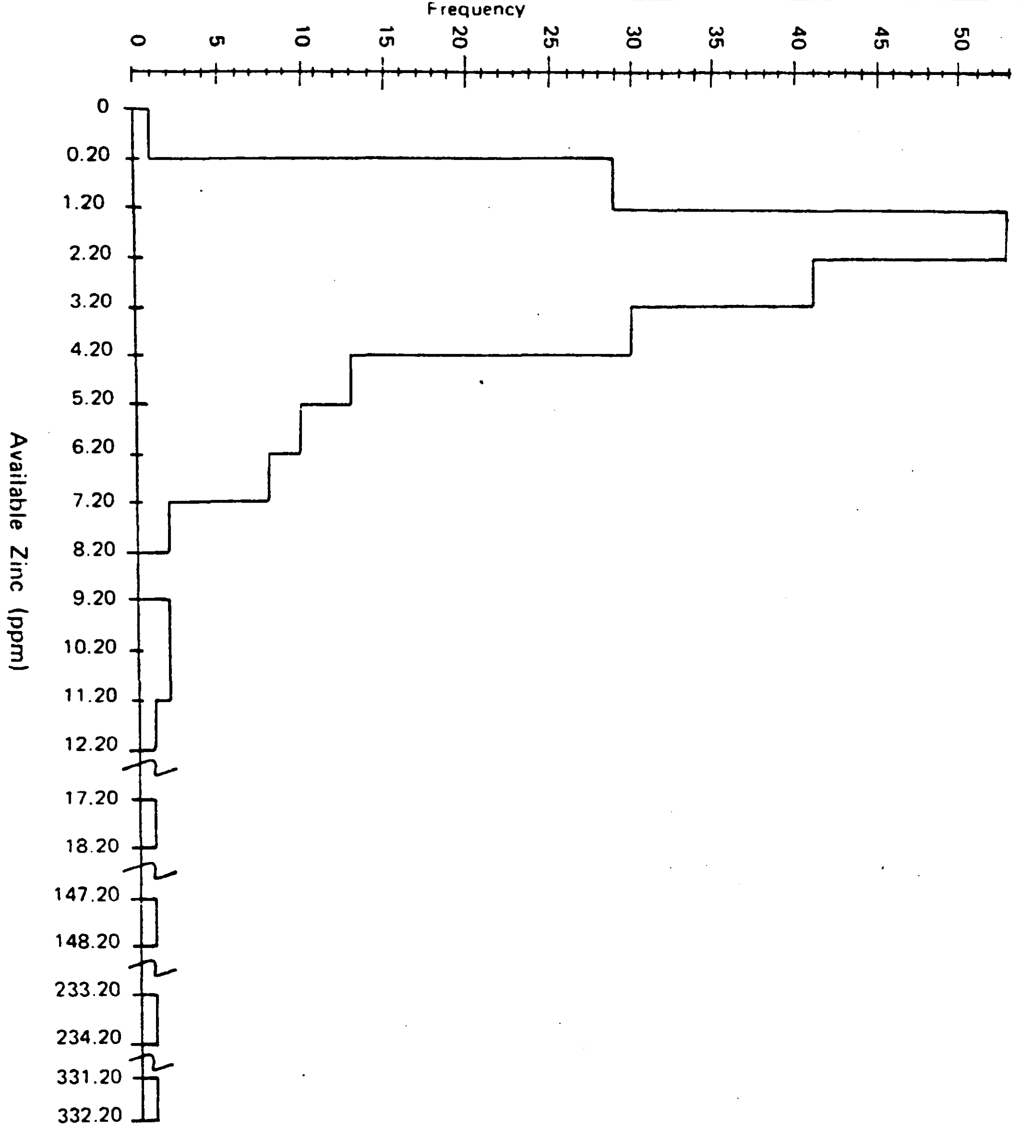

Frequency
0
5
10
15
20
25
30
35
40
45
50
3.70
3.7879
3.8758
3.9637
4.0516
4.1345
4.2274
4.3153
4.4032
4.4911
4.579
4.6669
4.7549
4.8427
4.53
Soil Iron (ppm): Log (10) Transformed

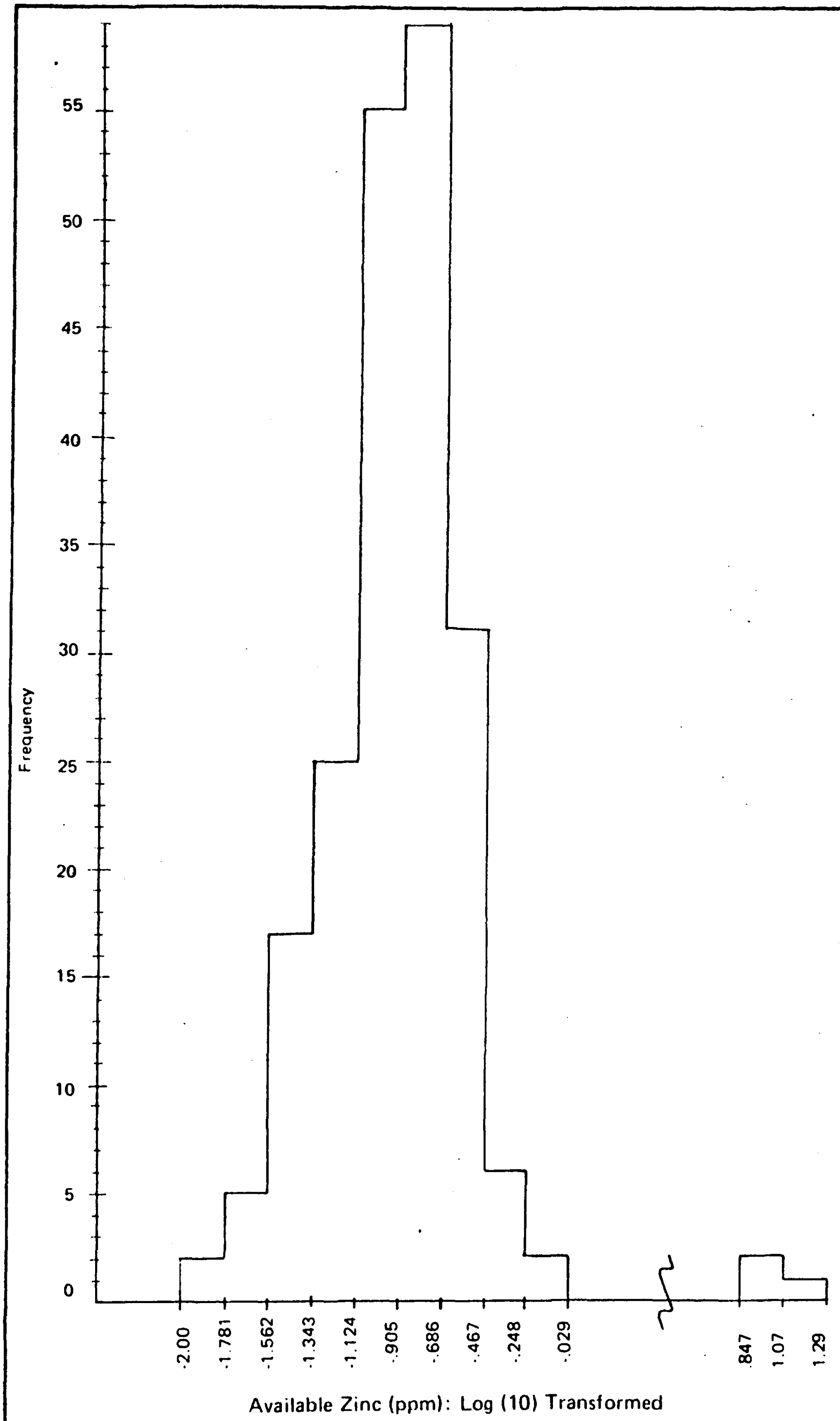

Frequency
0
5
10
15
20
25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
5.25
5.50
5.75
6.00
6.25
6.50
6.75
7.00
pH

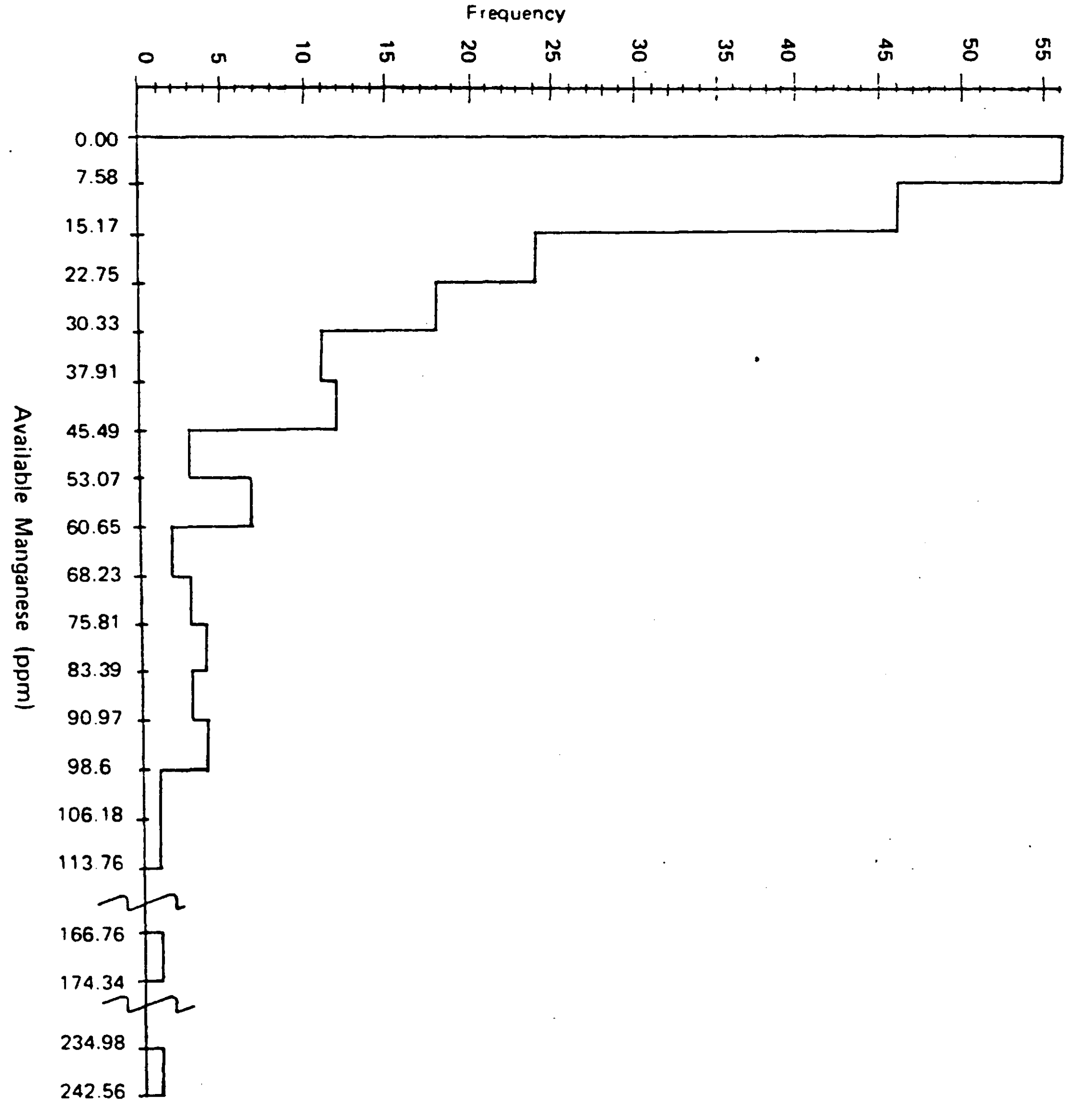

Frequency
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
7
14
21
28
35
42
49
56
63
70
77
84
91
98
105
Cold Extractable Heavy Metals (ppm)

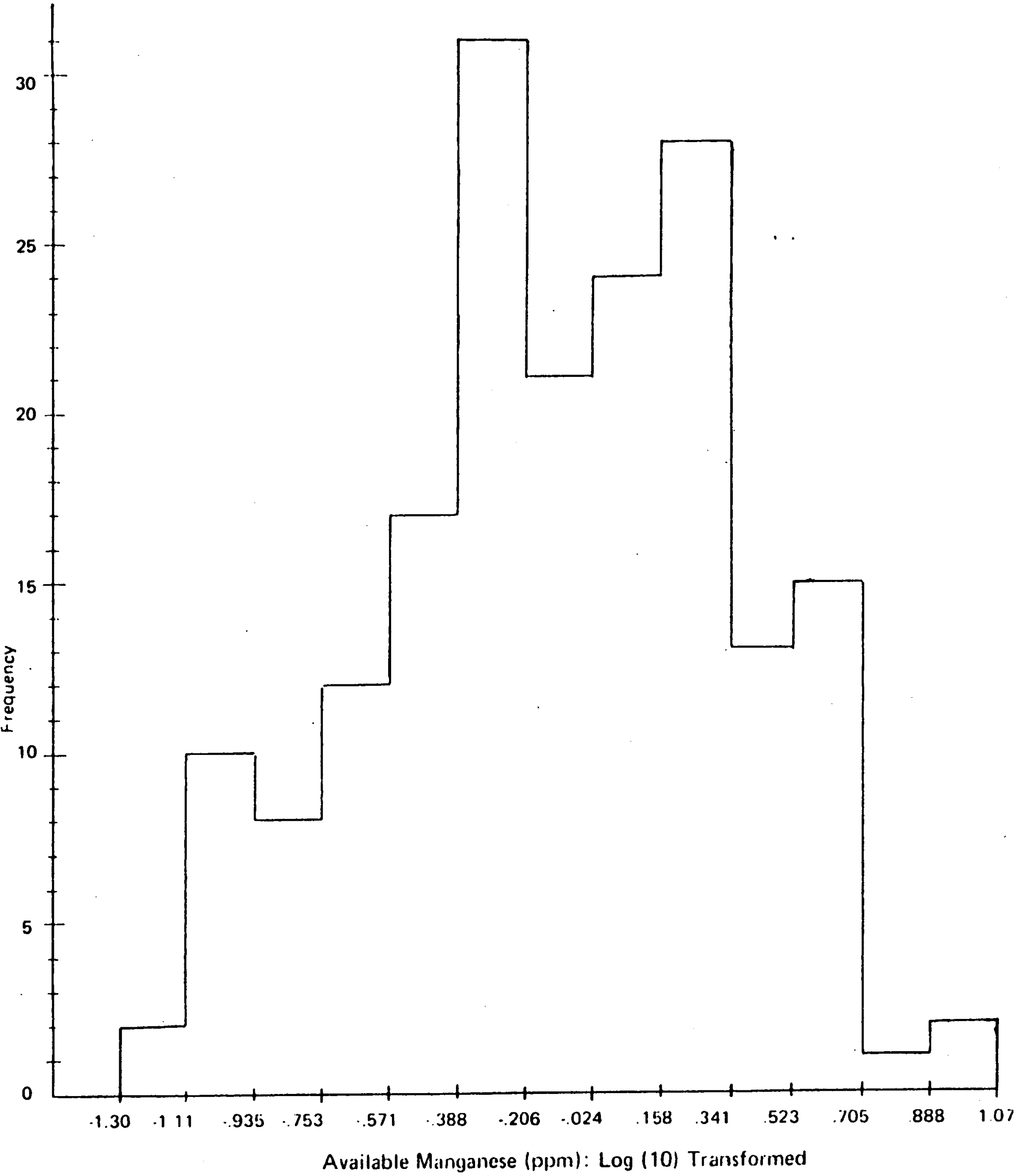

Frequency
0
5
10
15
20
25
30
0.16
.56
.96
1.36
1.76
2.16
2.56
2.96
3.36
3.76
4.16
4.56
4.96
5.36
6.56
6.96
9.36
9.76
Organic Carbon (%)

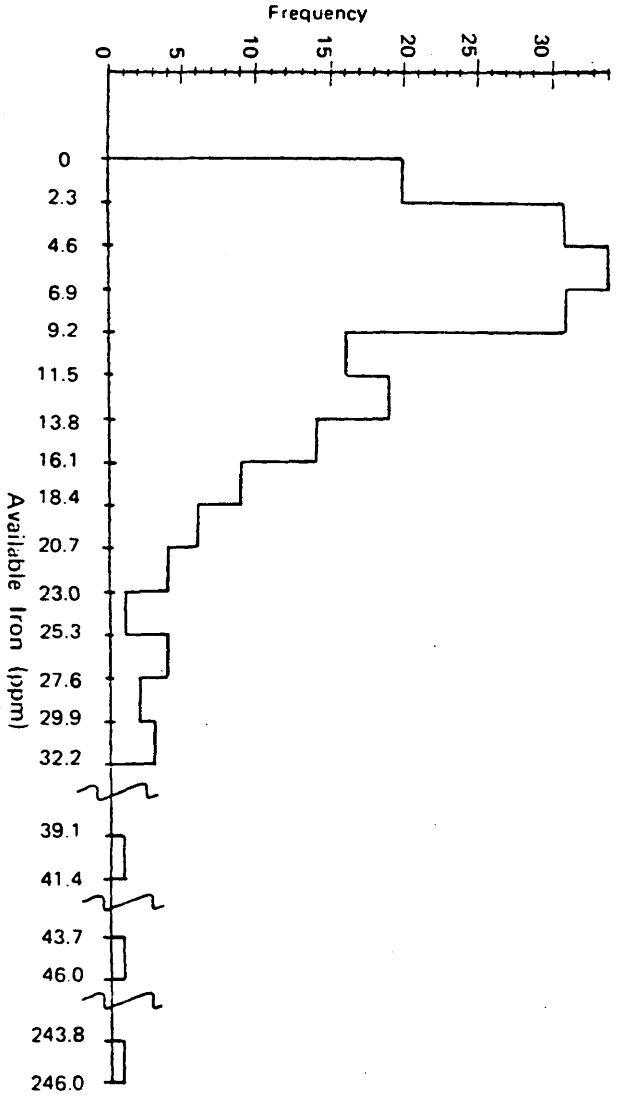

Frequency
35
30
25
20
15
10
5
0
80
674
-.548
-.422
-.296
-.170
-.044
.082
.208
.334
.460
.586
.712
.838
.97
Organic Carbon (%): Log (10) Transformed

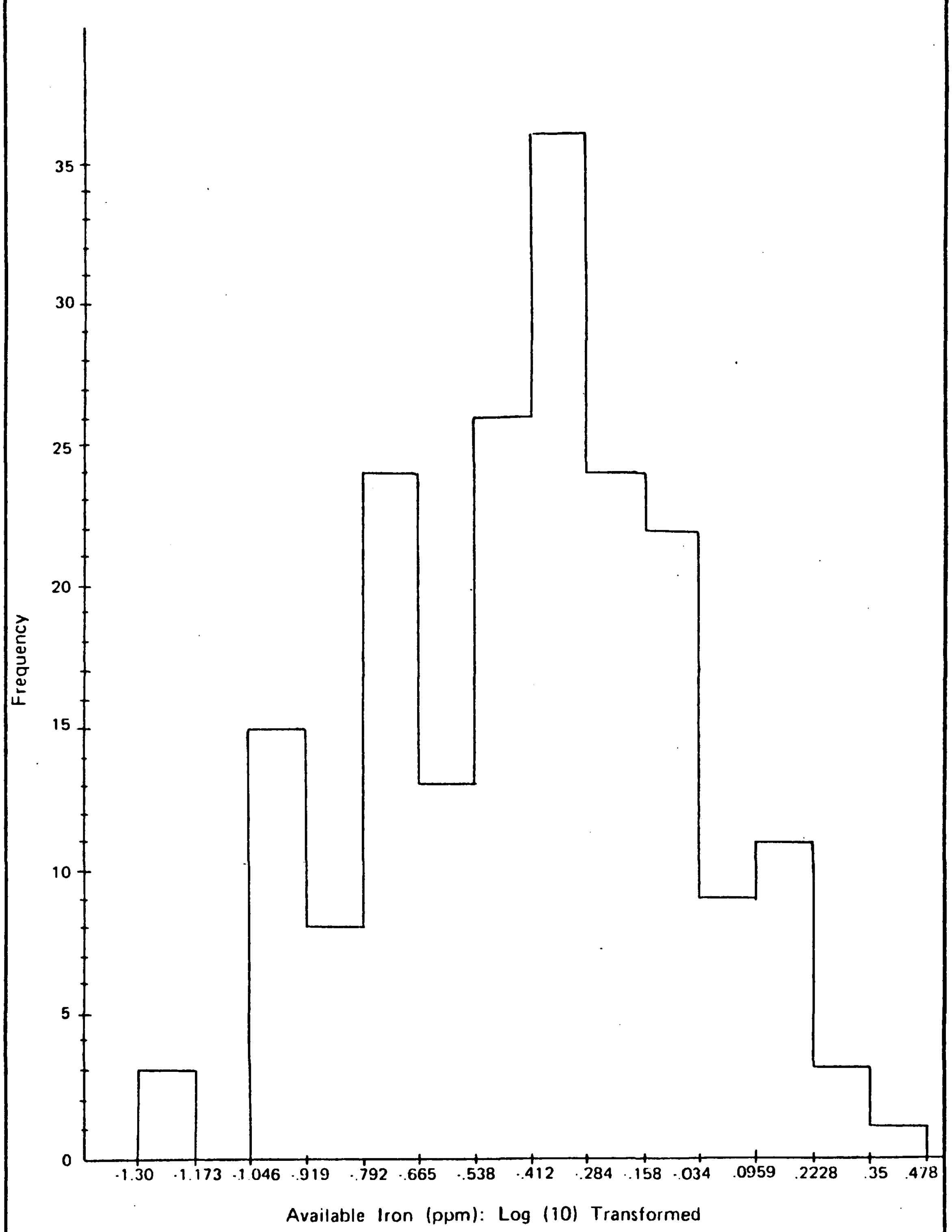

Frequency
0
5
10
15
20
25
30
35
40
45
50
0
0.20
1.20
2.20
3.20
4.20
5.20
6.20
7.20
8.20
9.20
10.20
11.20
12.20
17.20
18.20
147.20
148.20
233.20
234.20
331.20
332.20
Available Zinc (ppm)

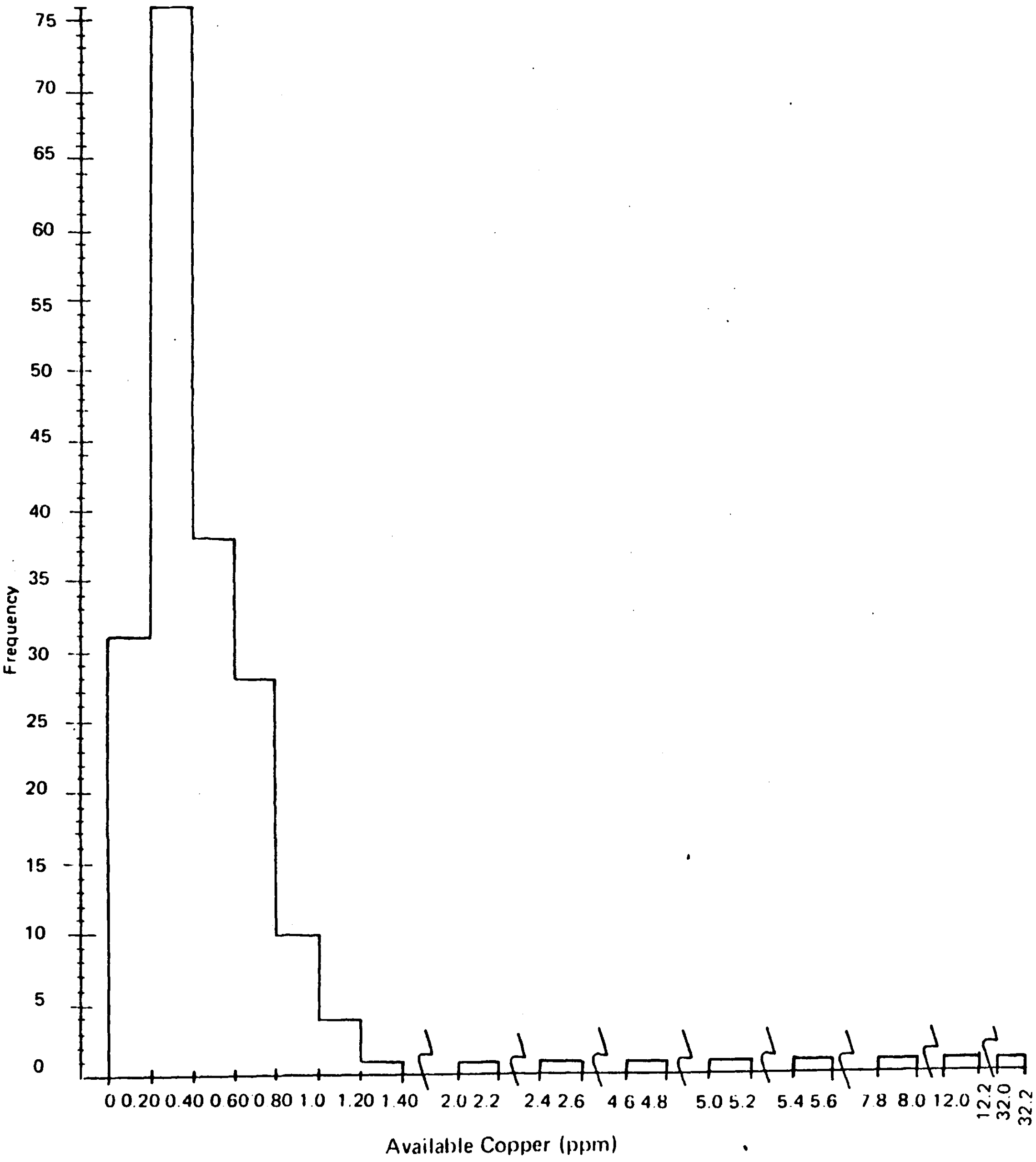

55
50
45
40
35
30
25
20
15
10
5
0
Frequency
-2.00
-1.781
-1.562
-1.343
-1.124
-.905
-.686
-.467
-.248
-.029
.847
1.07
1.29
Available Zinc (ppm): Log (10) Transformed

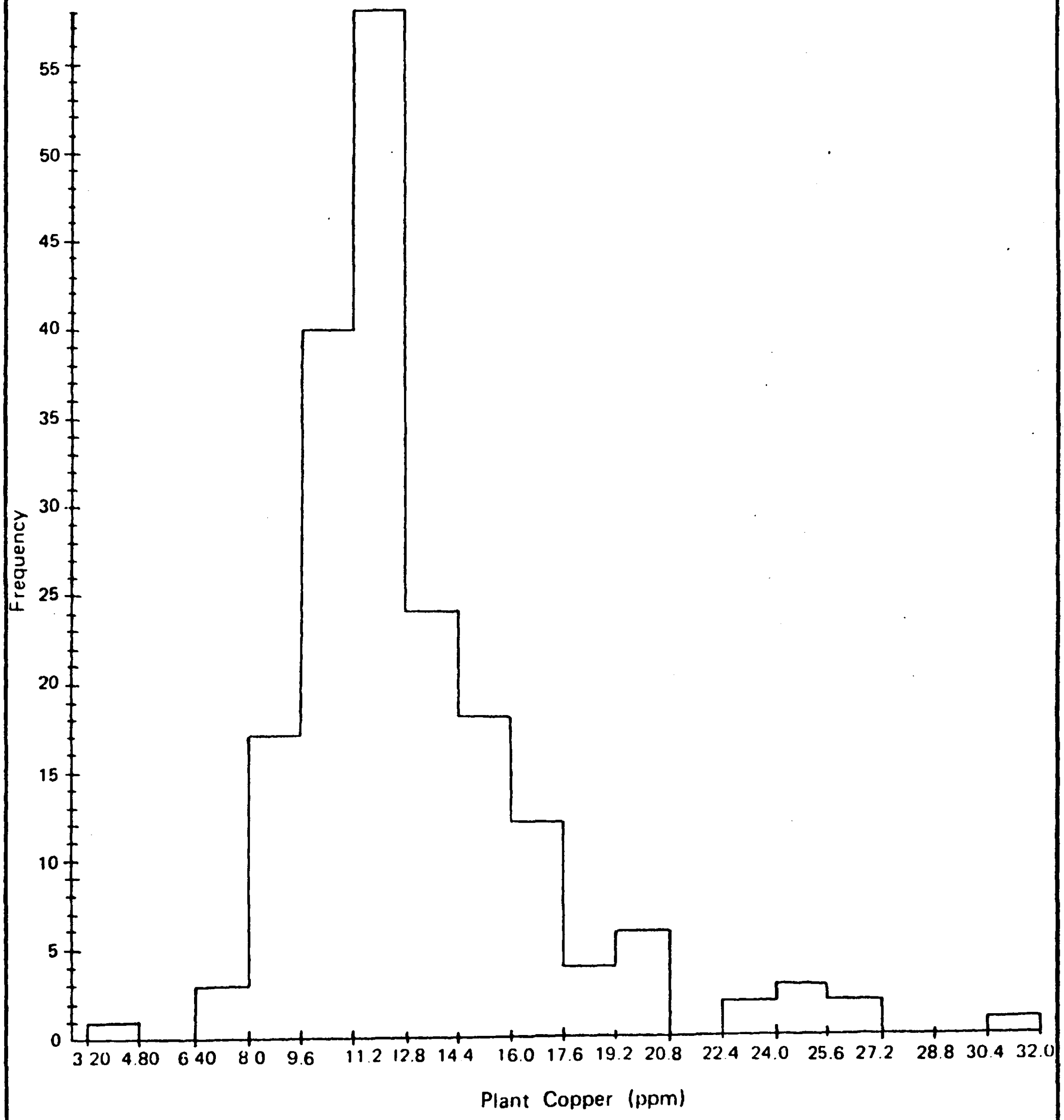

Frequency
0
5
10
15
20
25
30
35
40
45
50
55
0.00
7.58
15.17
22.75
30.33
37.91
45.49
53.07
60.65
68.23
75.81
83.39
90.97
98.6
106.18
113.76
166.76
174.34
234.98
242.56
Available Manganese (ppm)

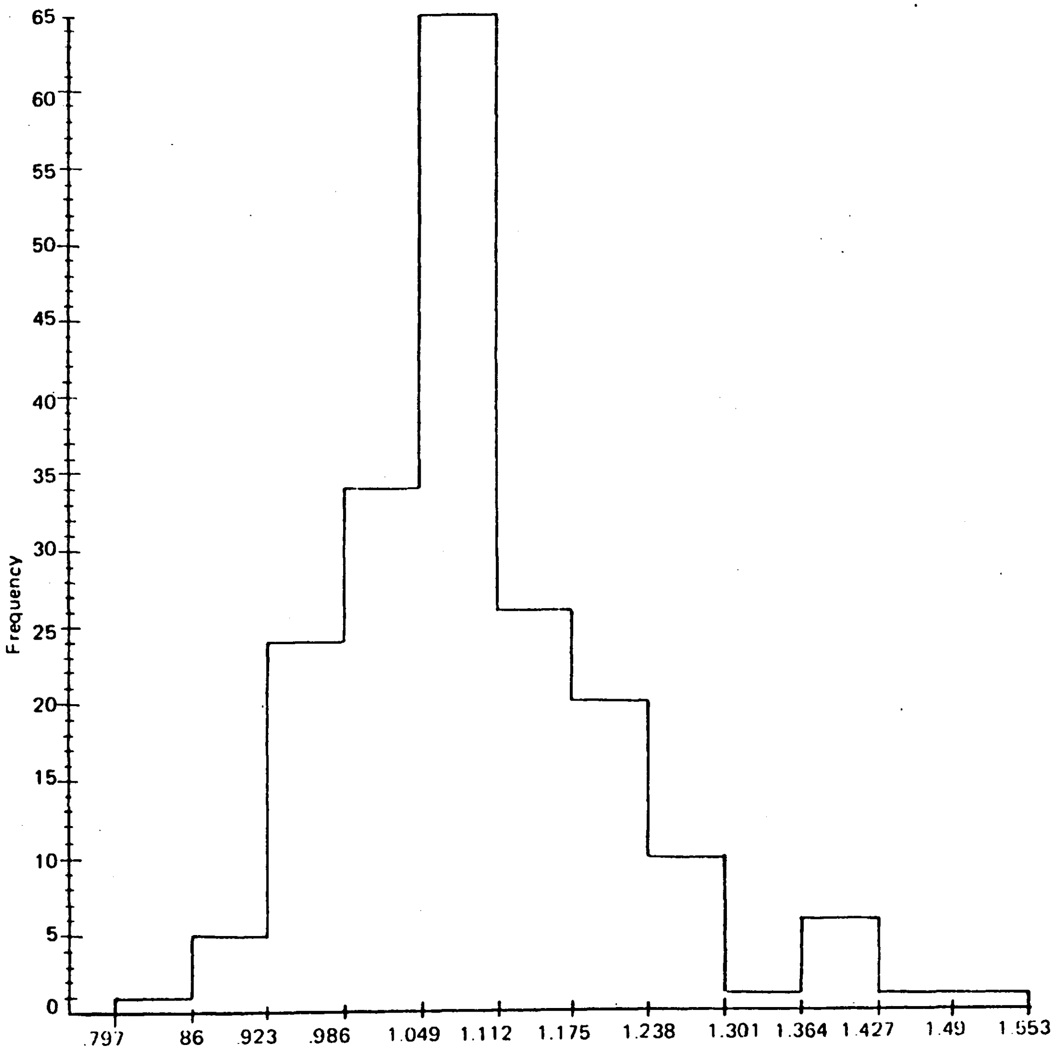

Frequency
0
5
10
15
20
25
30
-1.30
-1.11
-.935
-.753
-.571
-.388
-.206
-.024
.158
.341
.523
.705
.888
1.07
Available Manganese (ppm): Log (10) Transformed


Frequency
0
5
10
15
20
25
30
0
2.3
4.6
6.9
9.2
11.5
13.8
16.1
18.4
20.7
23.0
25.3
27.6
29.9
32.2
39.1
41.4
43.7
46.0
243.8
246.0
Available Iron (ppm)

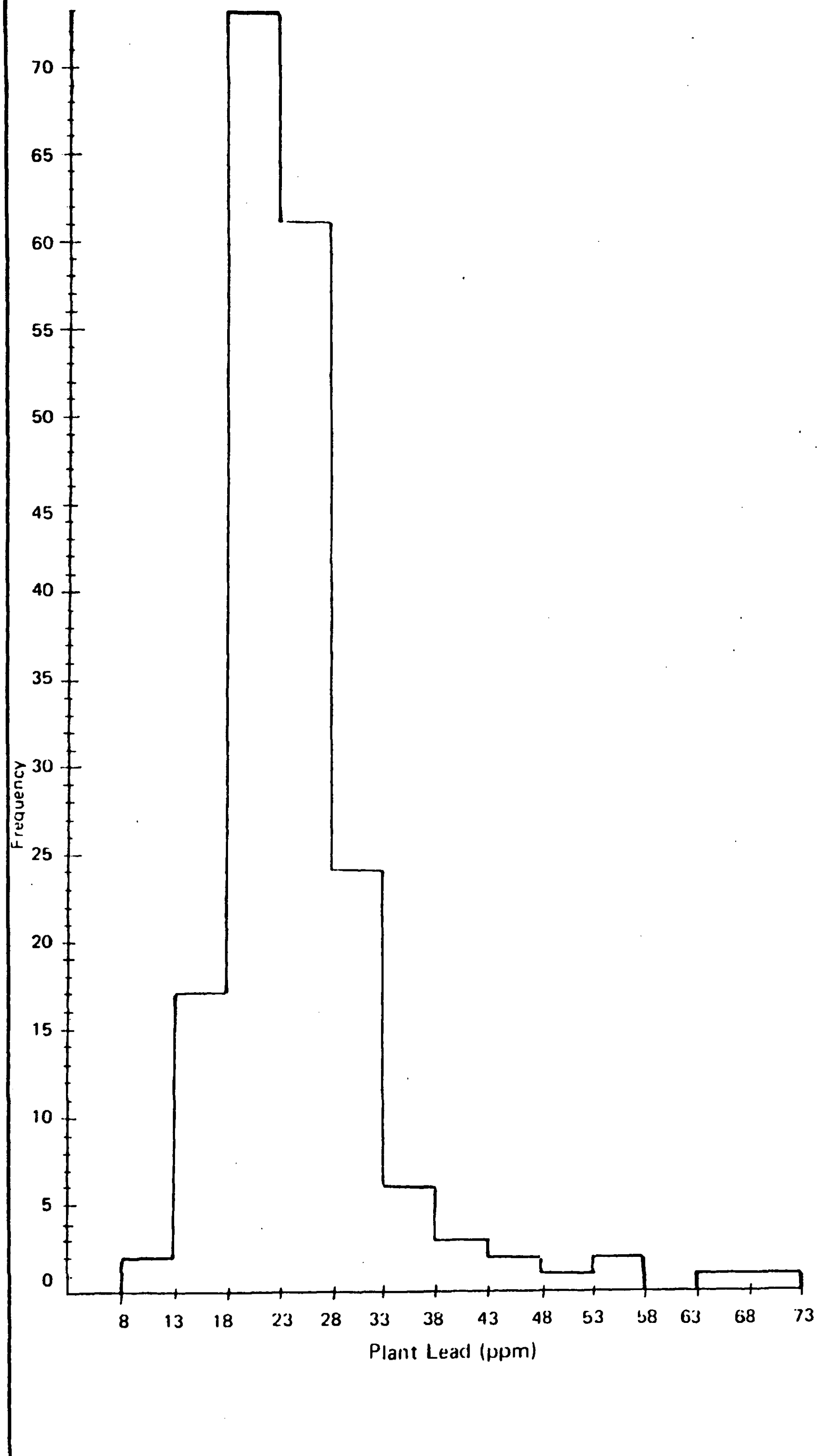

Frequency
35
30
25
20
15
10
5
0
-1.30
-1.173
-1.046
-.919
-.792
-.665
-.538
-.412
-.284
-.158
-.034
.0959
.2228
.35
.478
Available Iron (ppm): Log (10) Transformed

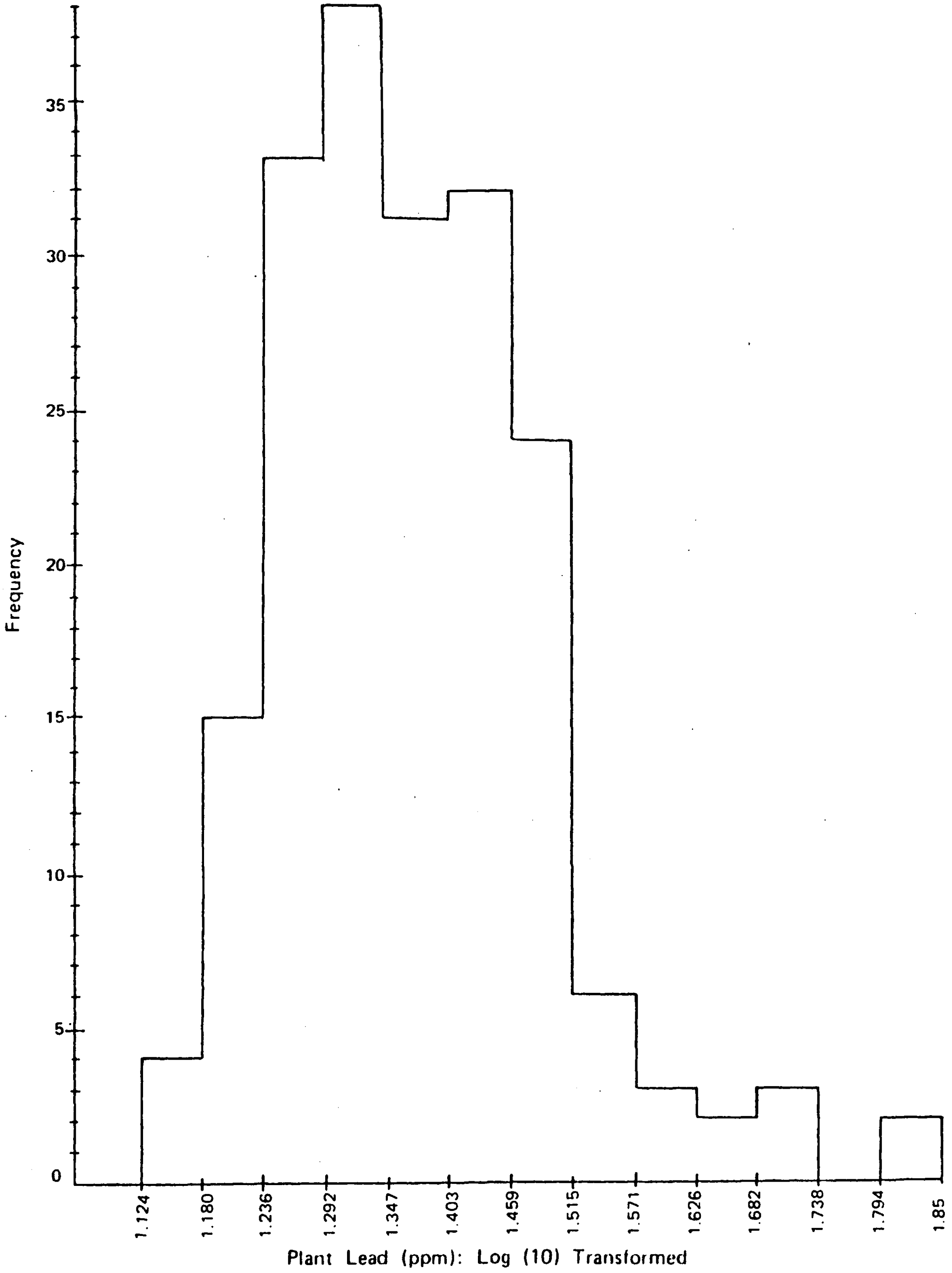

Frequency
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
0.20
0.40
0.60
0.80
1.0
1.20
1.40
2.0
2.2
2.4
2.6
4.6
4.8
5.0
5.2
5.4
5.6
7.8
8.0
12.0
12.2
32.0
32.2
Available Copper (ppm)

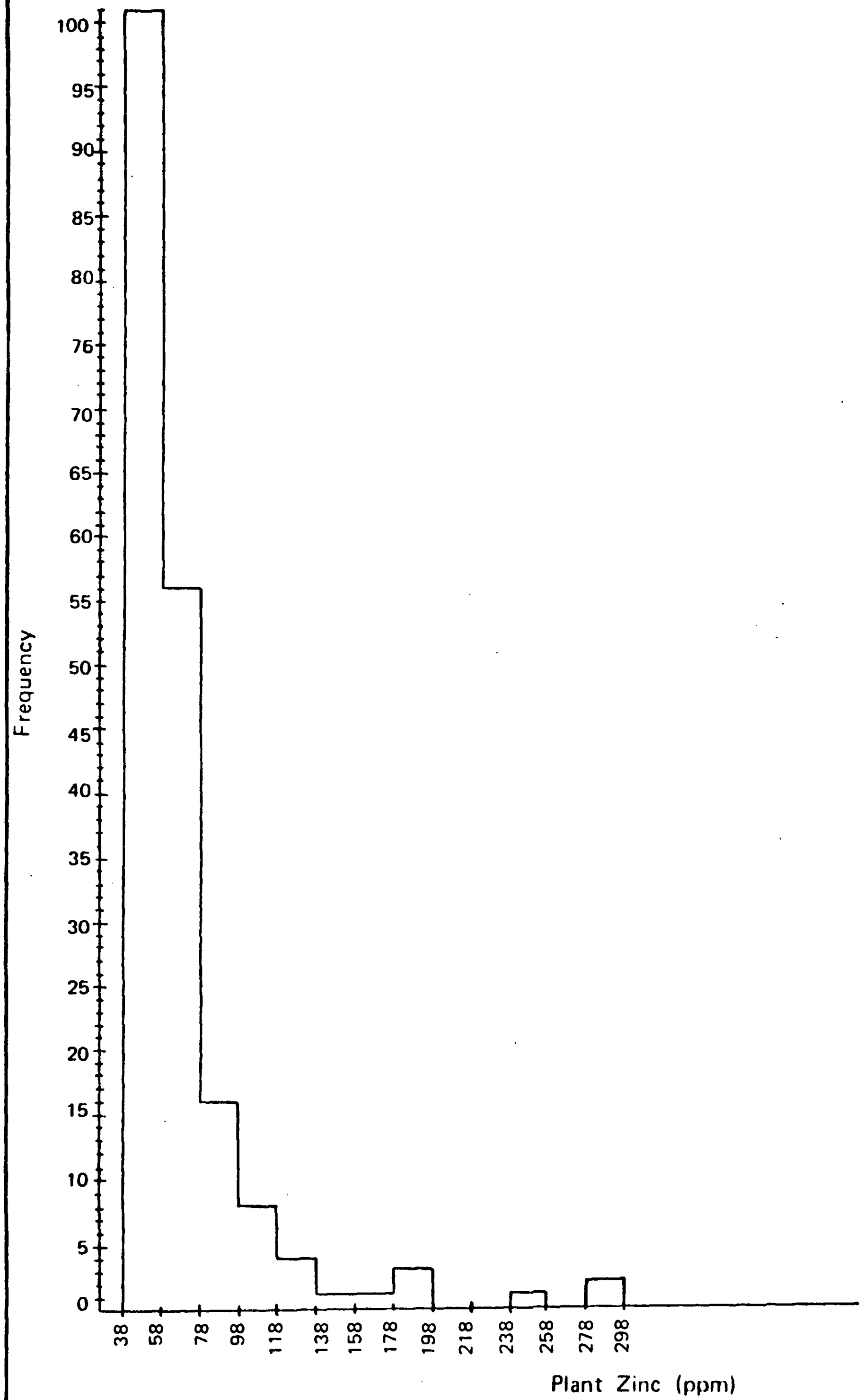

Frequency
55
50
45
40
35
30
25
20
15
10
5
0
3.20
4.80
6.40
8.0
9.6
11.2
12.8
14.4
16.0
17.6
19.2
20.8
22.4
24.0
25.6
27.2
28.8
30.4
32.0
Plant Copper (ppm)

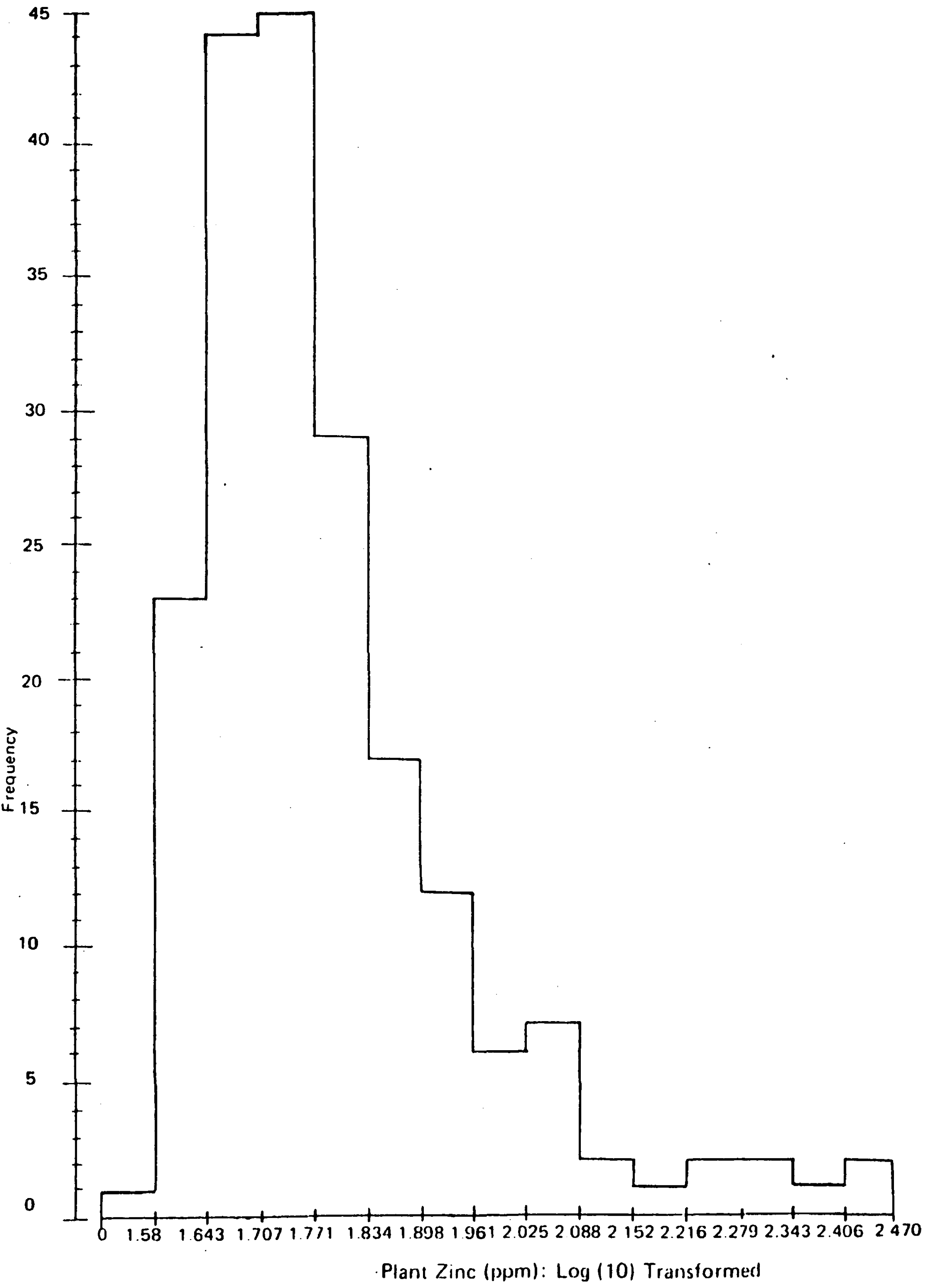


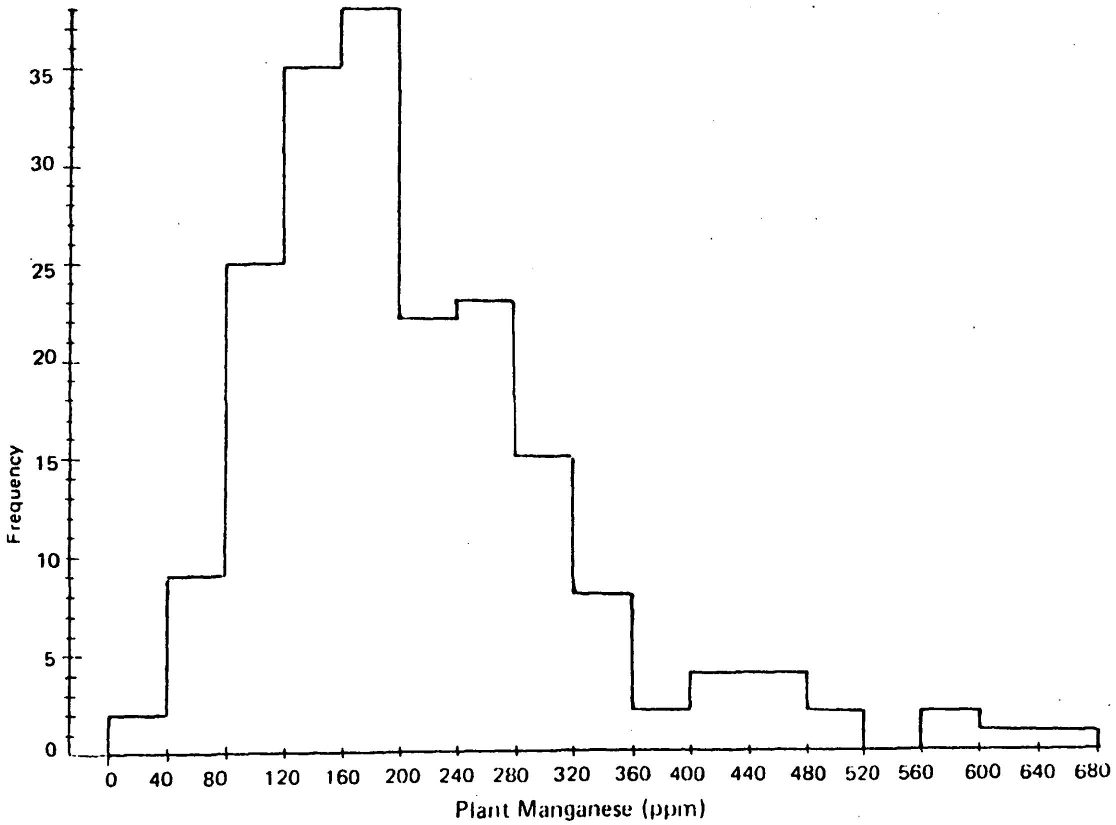
Plant Copper (ppm): Log (10) Transformed

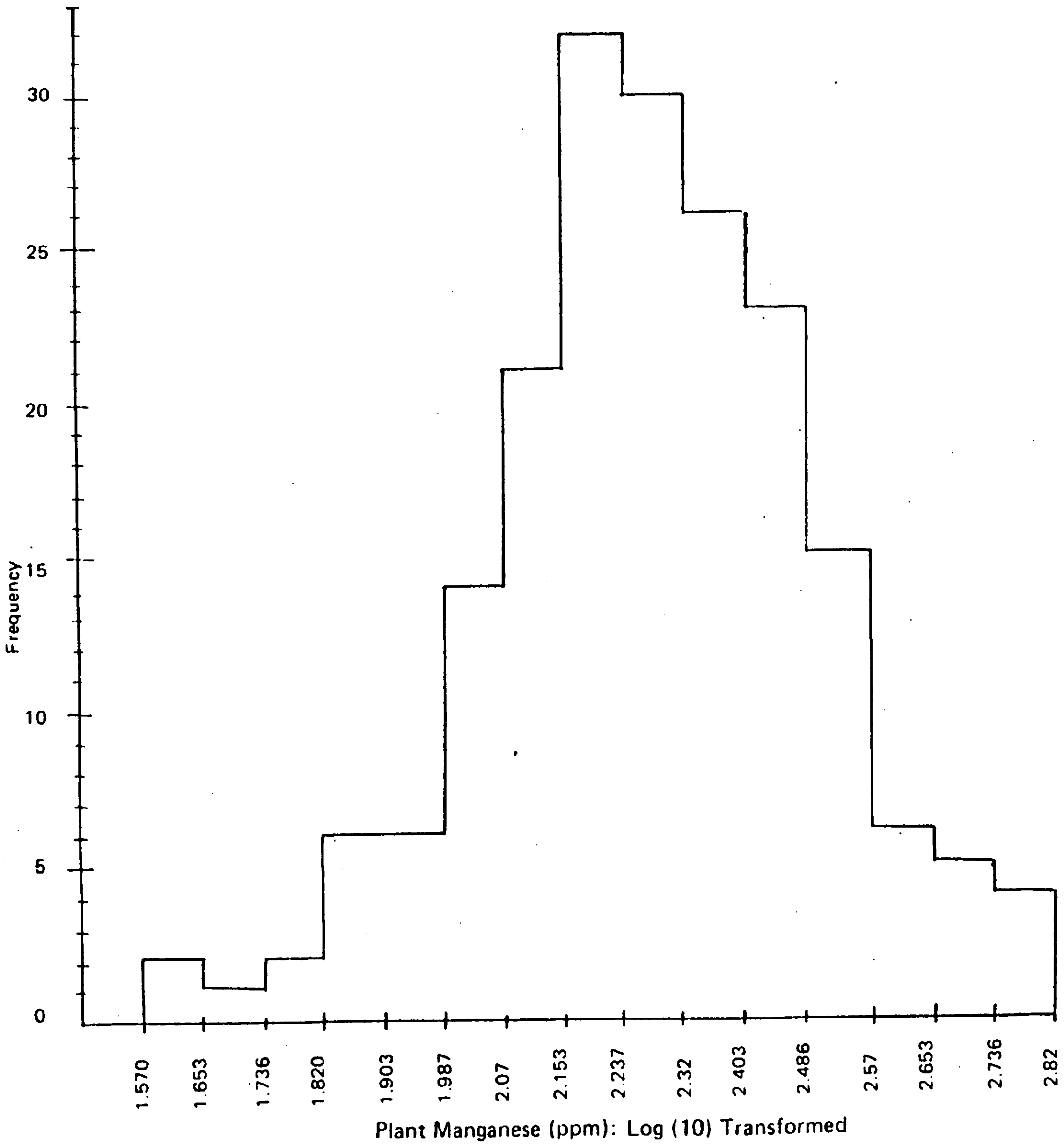

Frequency
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
8
13
18
23
28
33
38
43
48
53
58
63
68
73
Plant Lead (ppm)

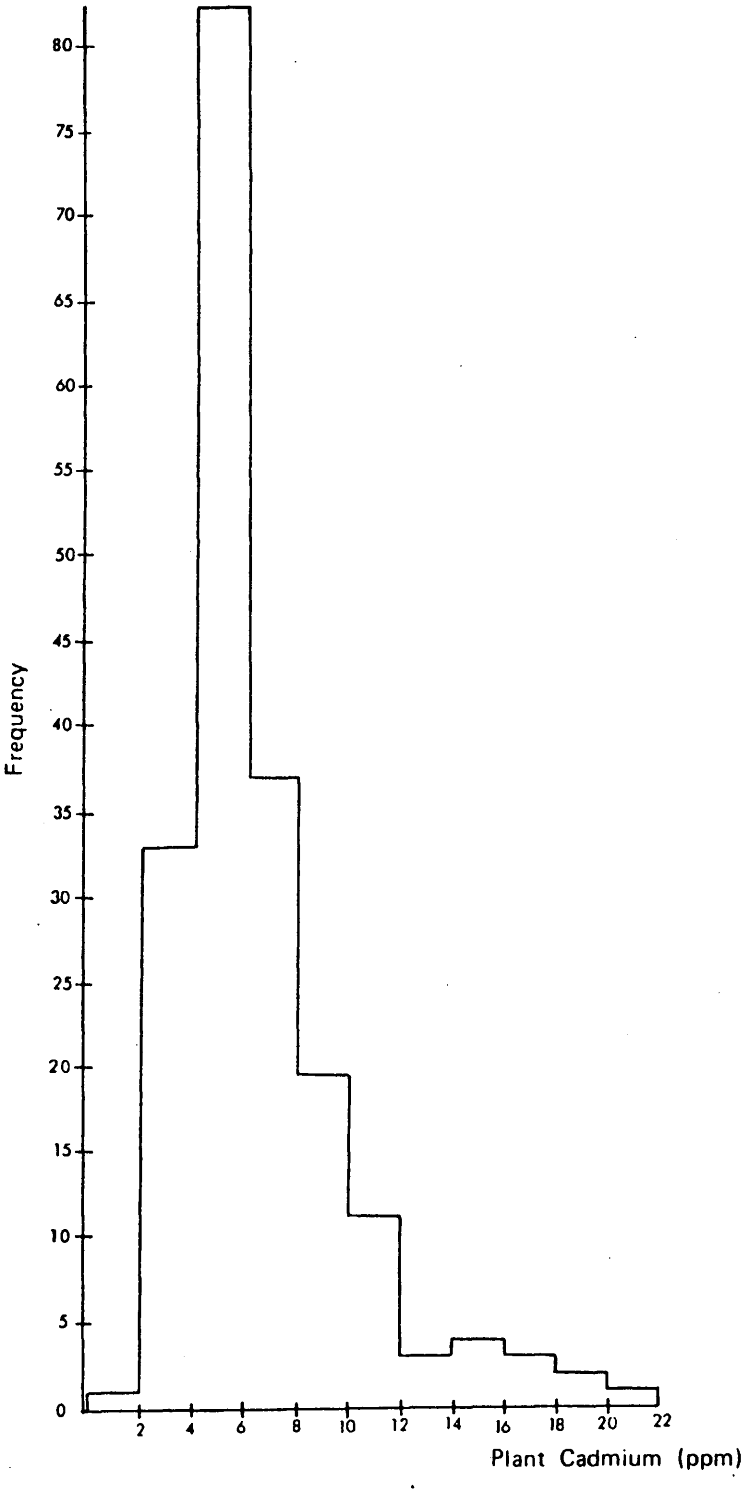

Frequency
35
30
25
20
15
10
5
0
1.124
1.180
1.236
1.292
1.347
1.403
1.459
1.515
1.571
1.626
1.682
1.738
1.794
1.85
Plant Lead (ppm): Log (10) Transformed


Frequency
100
95
90
85
80
76
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
38
58
78
98
118
138
158
178
198
218
238
258
278
298
Plant Zinc (ppm)

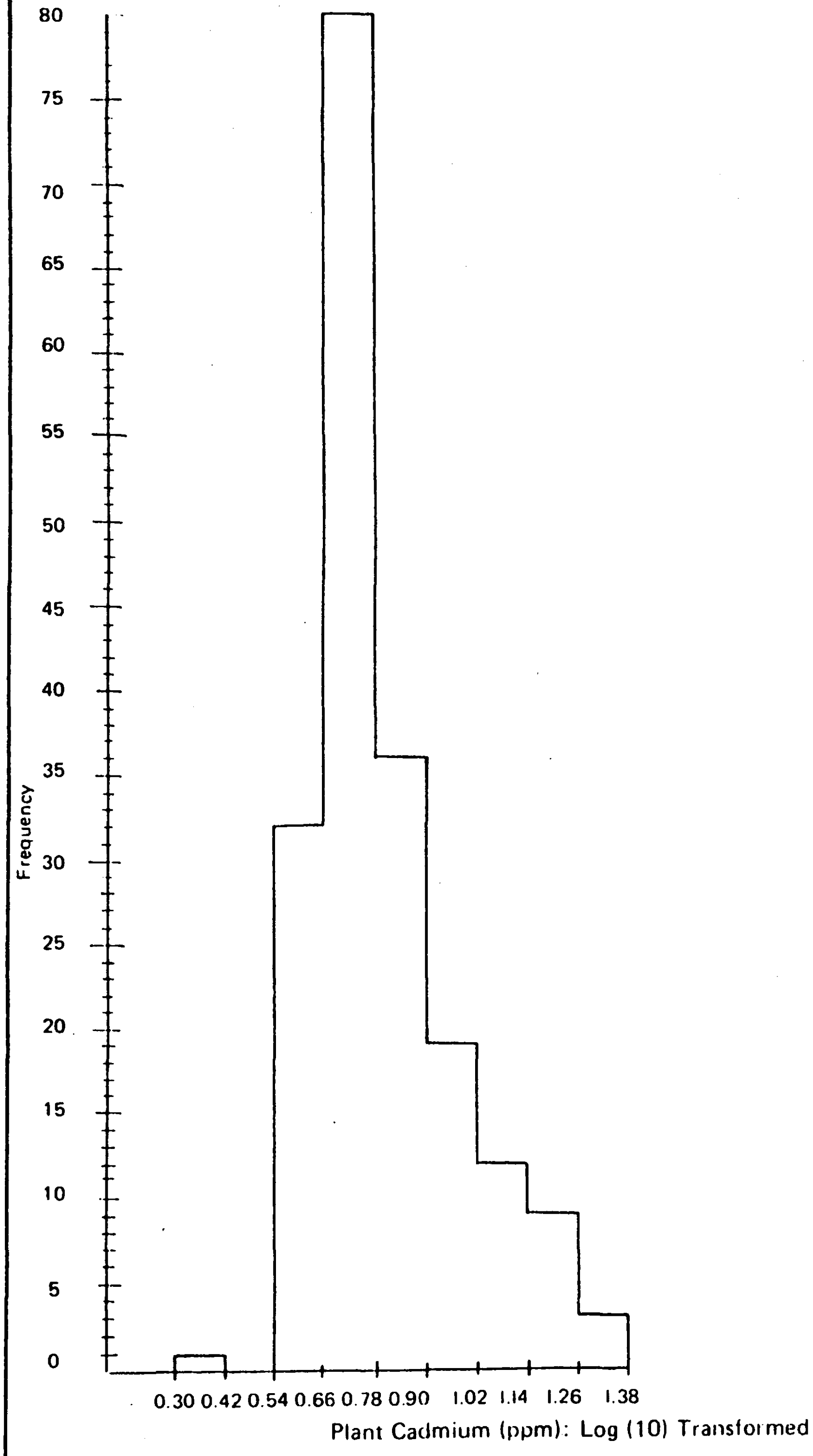

45
40
35
30
25
20
15
10
5
0
Frequency
0
1.58
1.643
1.707
1.771
1.834
1.898
1.961
2.025
2.088
2.152
2.216
2.279
2.343
2.406
2.470
Plant Zinc (ppm): Log (10) Transformed

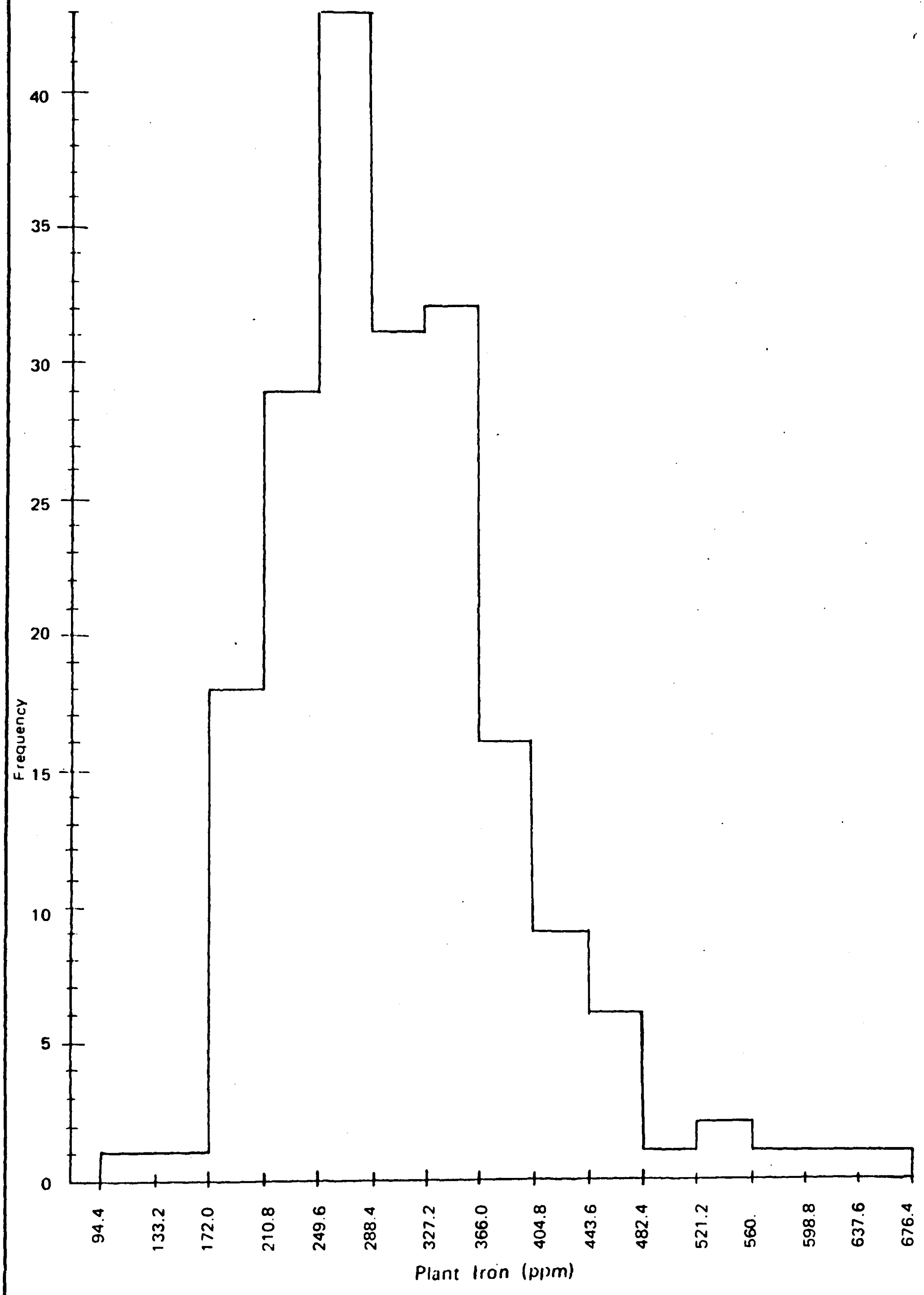

Frequency
0
5
10
15
20
25
30
35
0
40
80
120
160
200
240
280
320
360
400
440
480
520
560
600
640
680
Plant Manganese (ppm)

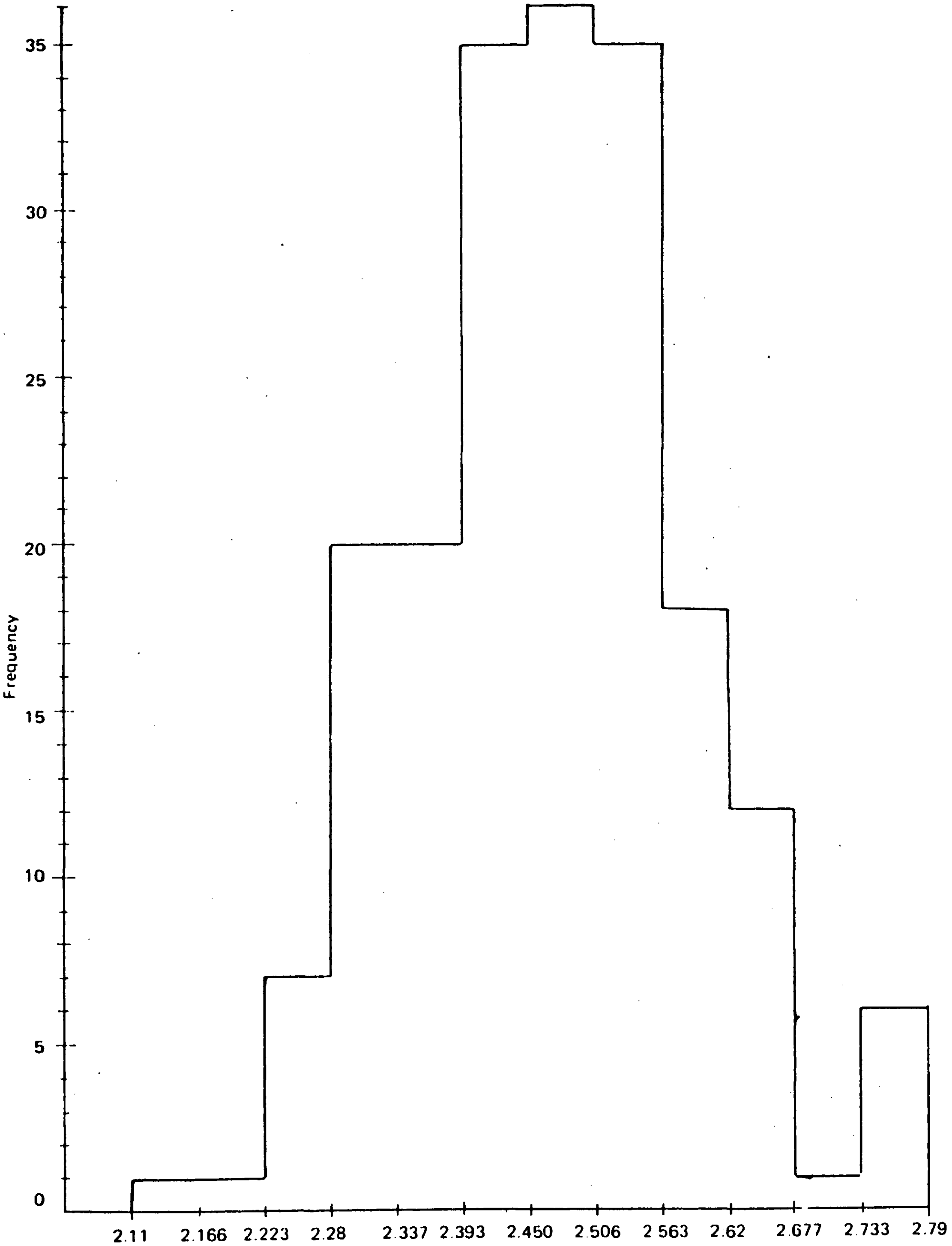

Frequency
30
25
20
15
10
5
0
1.570
1.653
1.736
1.820
1.903
1.987
2.07
2.153
2.237
2.32
2.403
2.486
2.57
2.653
2.736
2.82
Plant Manganese (ppm): Log (10) Transformed

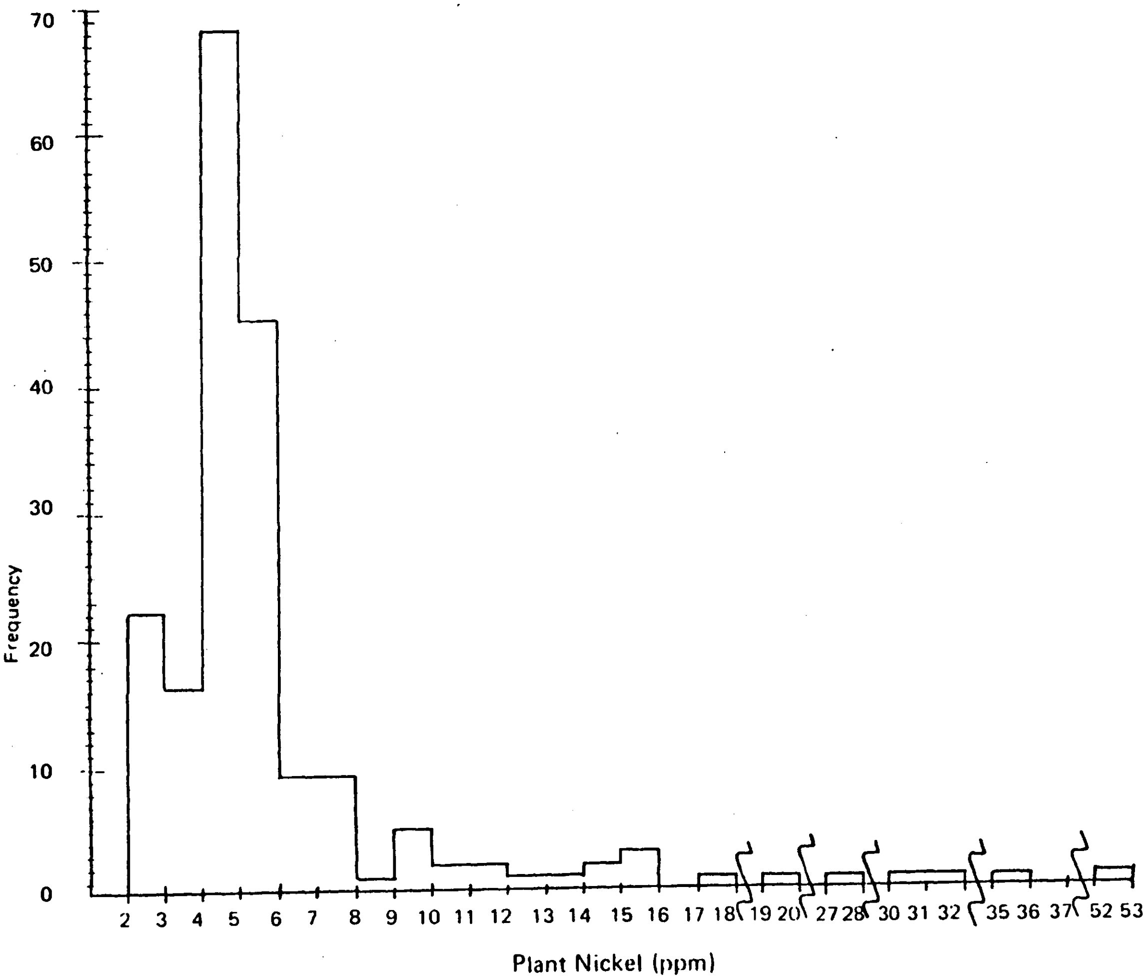


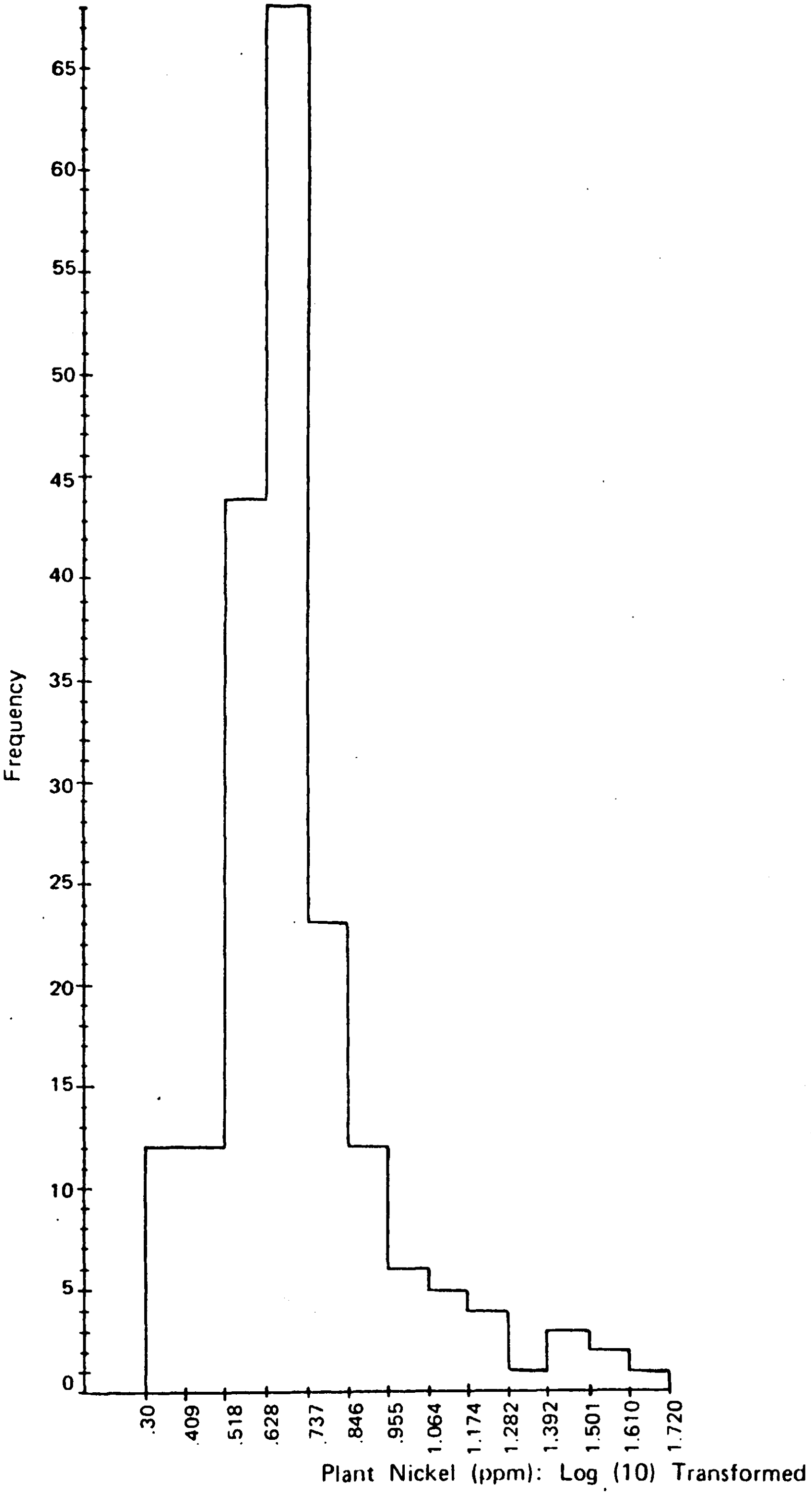
Frequency
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
2
4
6
8
10
12
14
16
18
20
22
Plant Cadmium (ppm)


80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Frequency
0.30 0.42 0.54 0.66 0.78 0.90 1.02 1.14 1.26 1.38
Plant Cadmium (ppm): Log (10) Transformed


Frequency
0
5
10
15
20
25
30
35
40
94.4
133.2
172.0
210.8
249.6
288.4
327.2
366.0
404.8
443.6
482.4
521.2
560.
598.8
637.6
676.4
Plant Iron (ppm)


Frequency
35
30
25
20
15
10
5
0
2.11
2.166
2.223
2.28
2.337
2.393
2.450
2.506
2.563
2.62
2.677
2.733
2.79
Plant Iron (ppm): Log (10) Transformed


Frequency
70
60
50
40
30
20
10
0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
27
28
30
31
32
35
36
37
52
53
Plant Nickel (ppm)


Frequency
0
5
10
15
20
25
30
35
40
45
50
55
60
65
.30
.409
.518
.628
.737
.846
.955
1.064
1.174
1.282
1.392
1.501
1.610
1.720
Plant Nickel (ppm): Log (10) Transformed

# APPENDIX VII

## Statistically Non-Significant Trend Surfaces

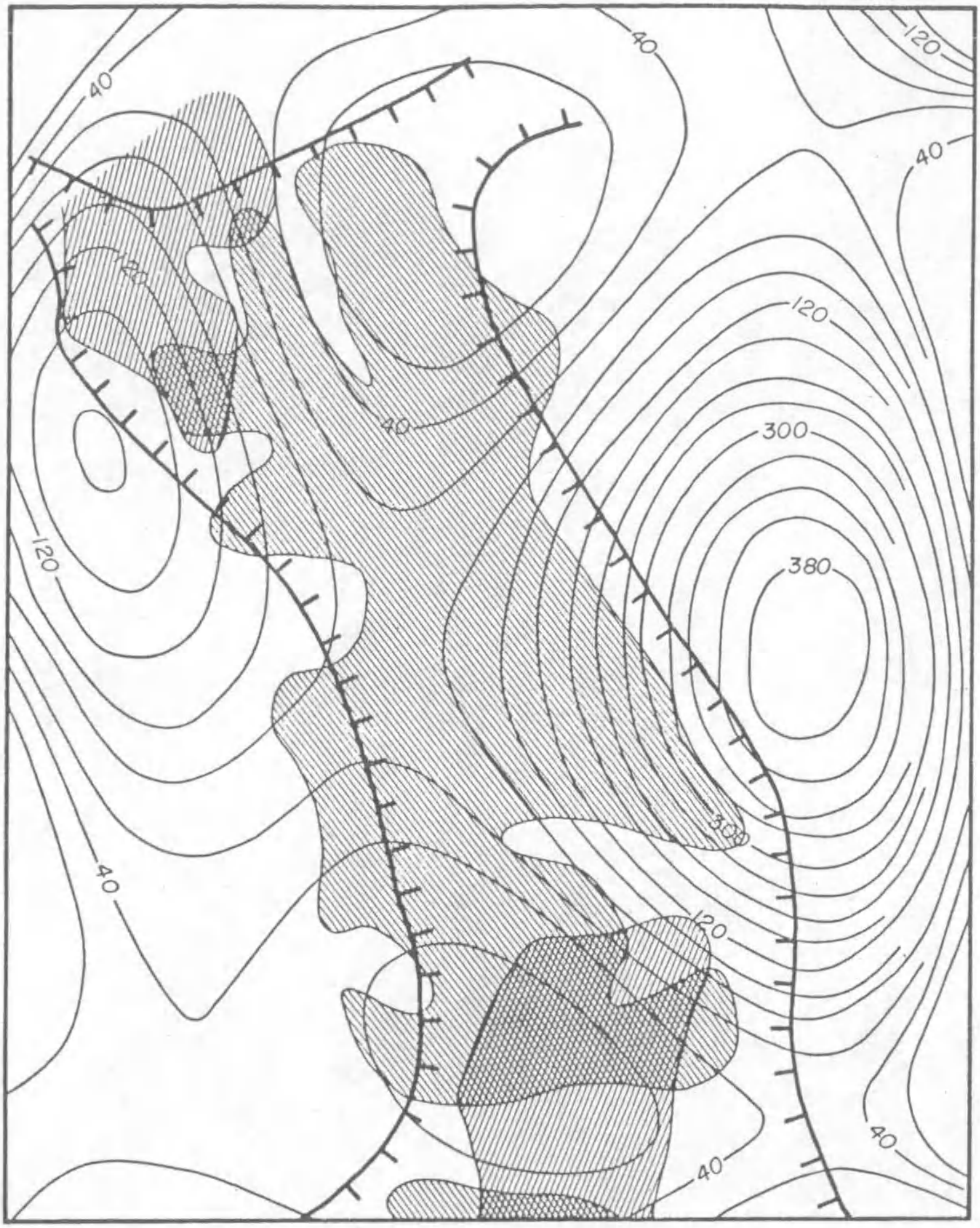


FIGURE 6th ORDER TREND SURFACE – SOIL COPPER ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 20 PPM

r = CORRELATION COEFFICIENT
r = 0.35

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.12

N

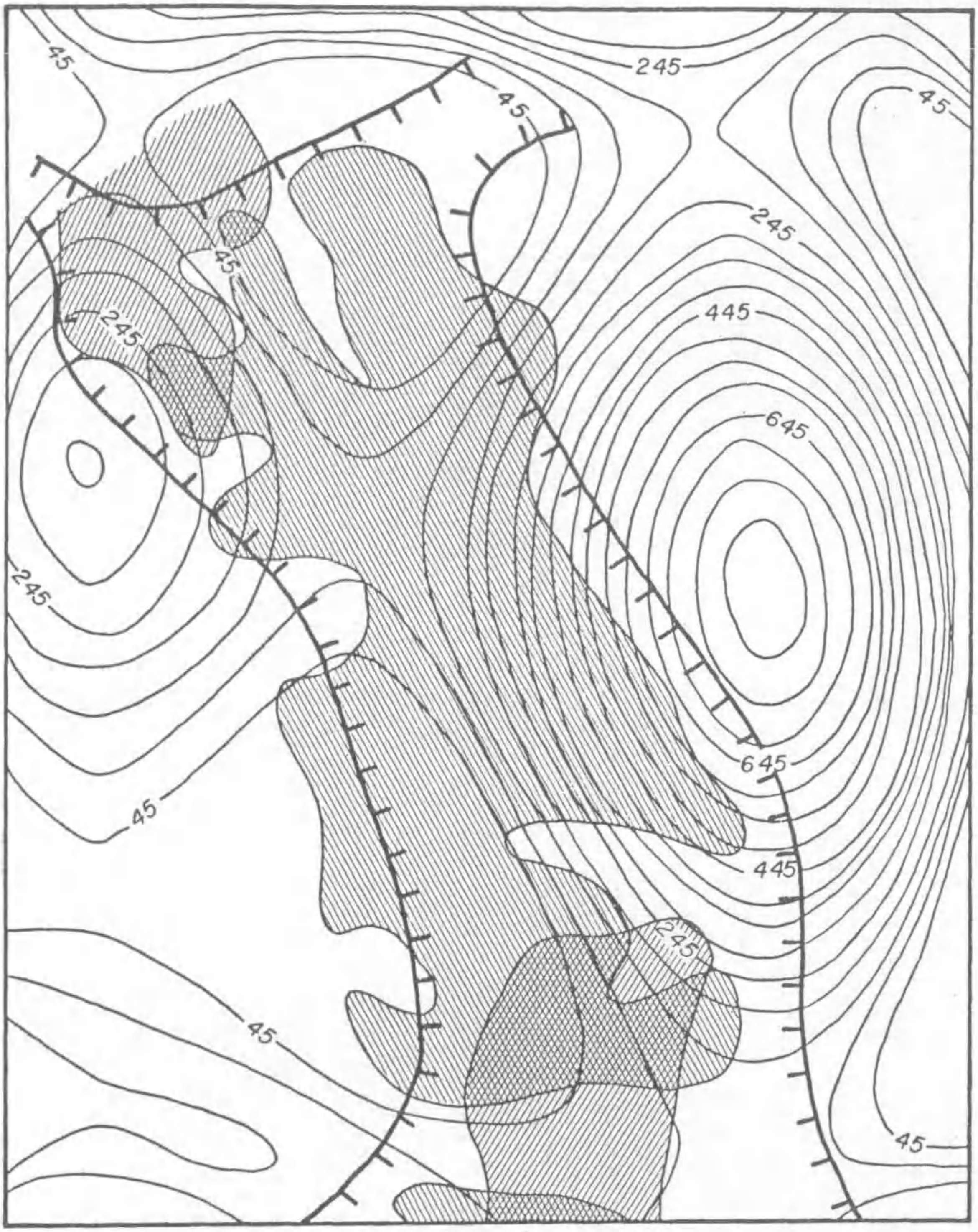


FIGURE 6th ORDER TREND SURFACE-SOIL LEAD ANALYSES.

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 50 ppm

r - CORRELATION COEFFICIENT
r = 0.28

$r^2$ - COEFFICIENT OF DETERMINATION
$r^2$ = 0.08

N

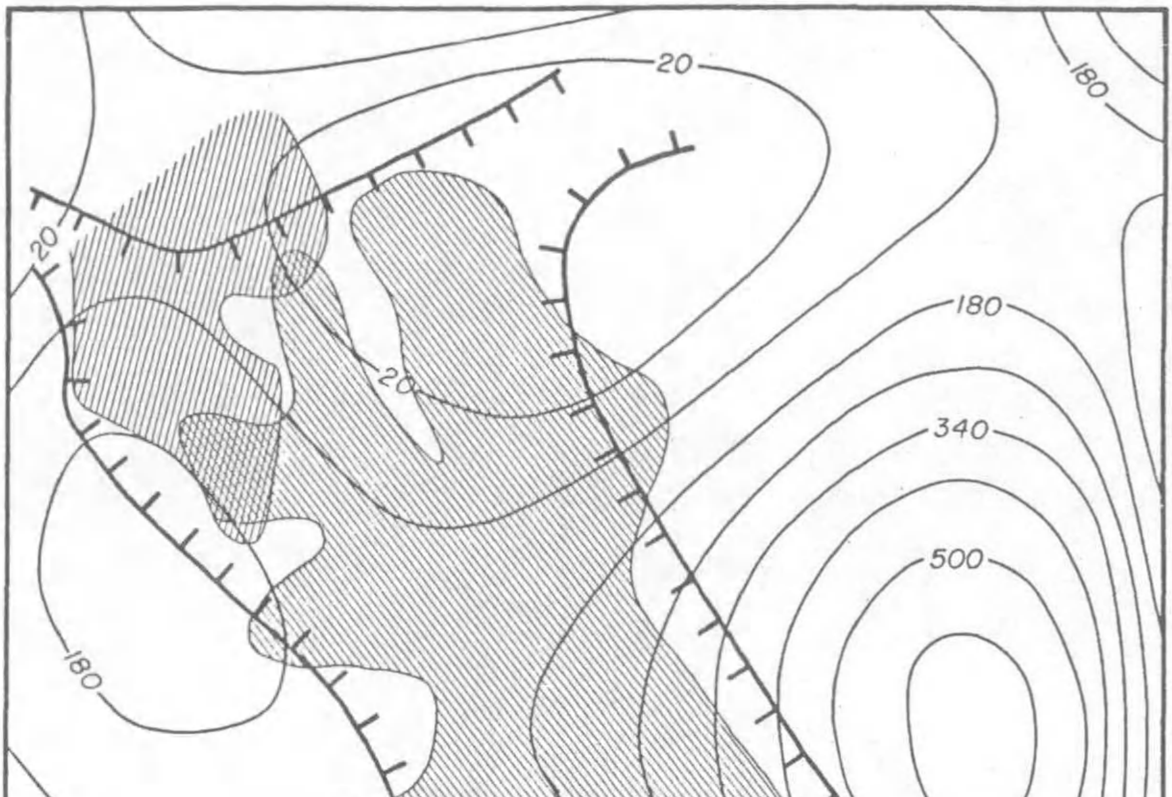


FIGURE 6th ORDER TREND SURFACE – SOIL ZINC ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 80 ppm

r = CORRELATION COEFFICIENT
r = 0.35

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.13

N

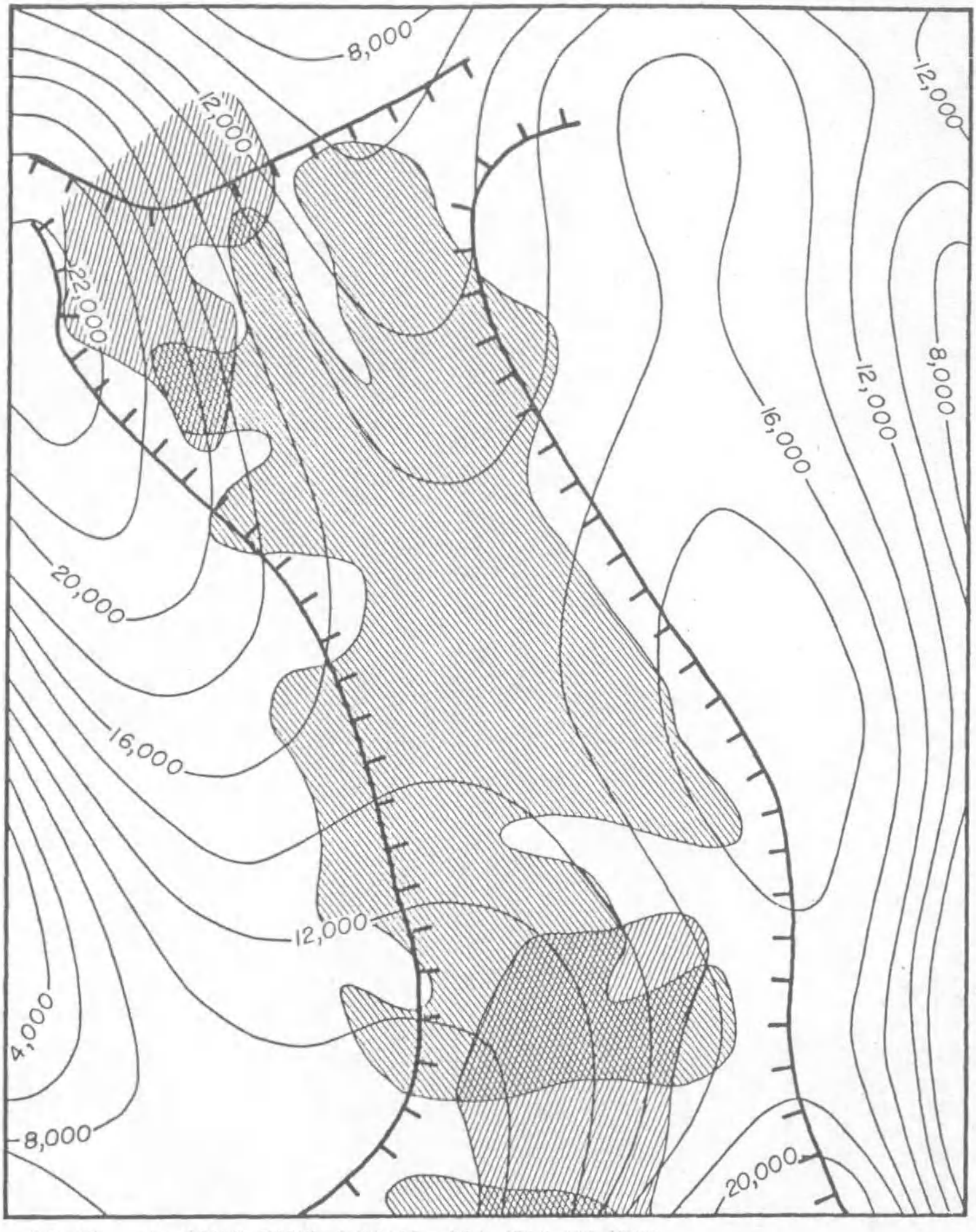


FIGURE 6th ORDER TREND SURFACE – SOIL IRON ANALYSES

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 2,000 PPM

r = CORRELATION COEFFICIENT
r = 0.45

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.21

N

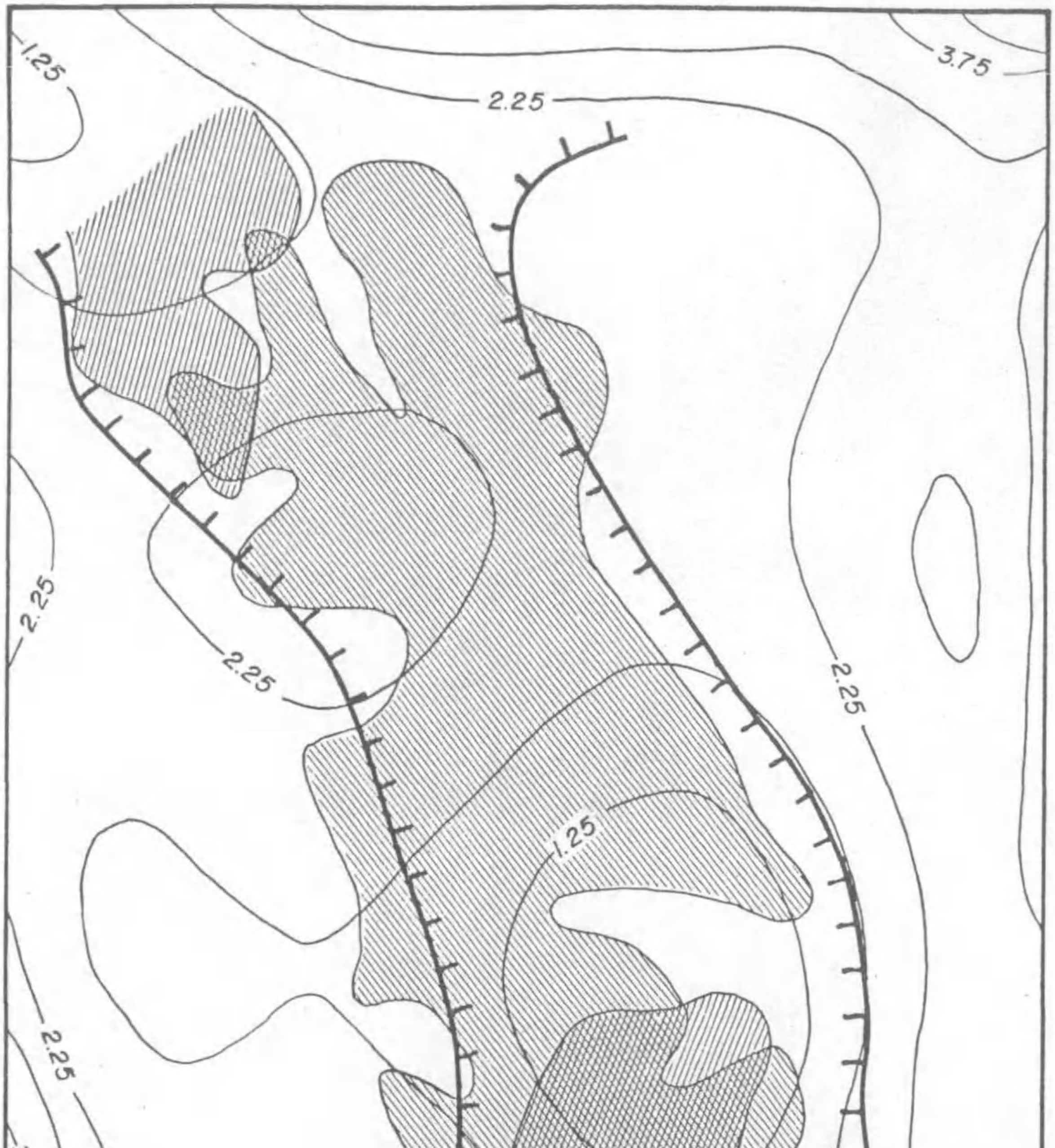


FIGURE 6th ORDER TREND SURFACE - ORGANIC CARBON SOIL ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE 0 2 4 6 8 10
HUNDRED FEET

CONTOUR INTERVAL = 0.5%

r - CORRELATION COEFFICIENT
r = 0.43

$r^2$ - COEFFICIENT OF DETERMINATION
$r^2$ = 0.18

N

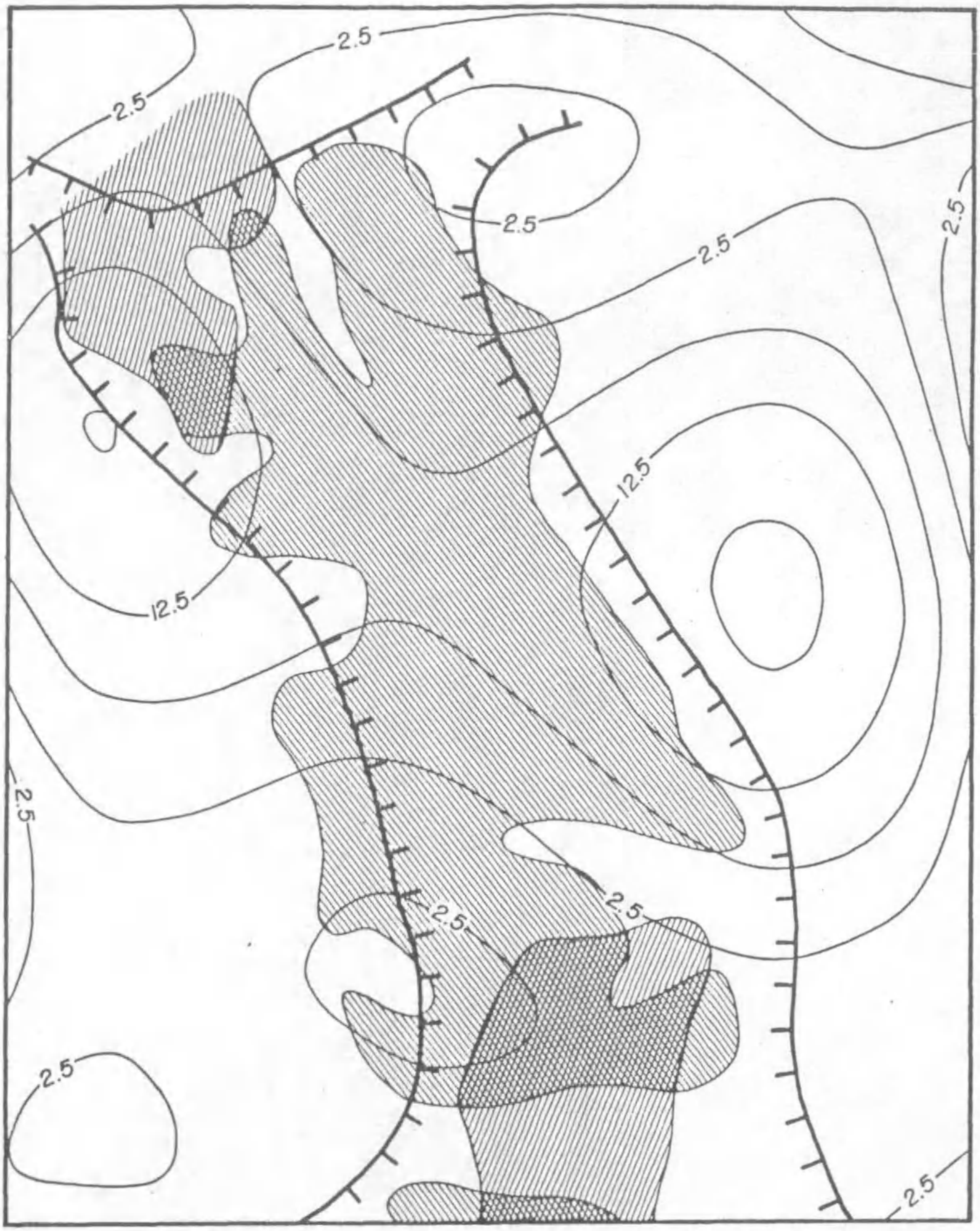


FIGURE 6th ORDER TREND SURFACE – COLD EXTRACTABLE COPPER ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 5 PPM

$r$ = CORRELATION COEFFICIENT
$r$ = 0.40

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.16

N

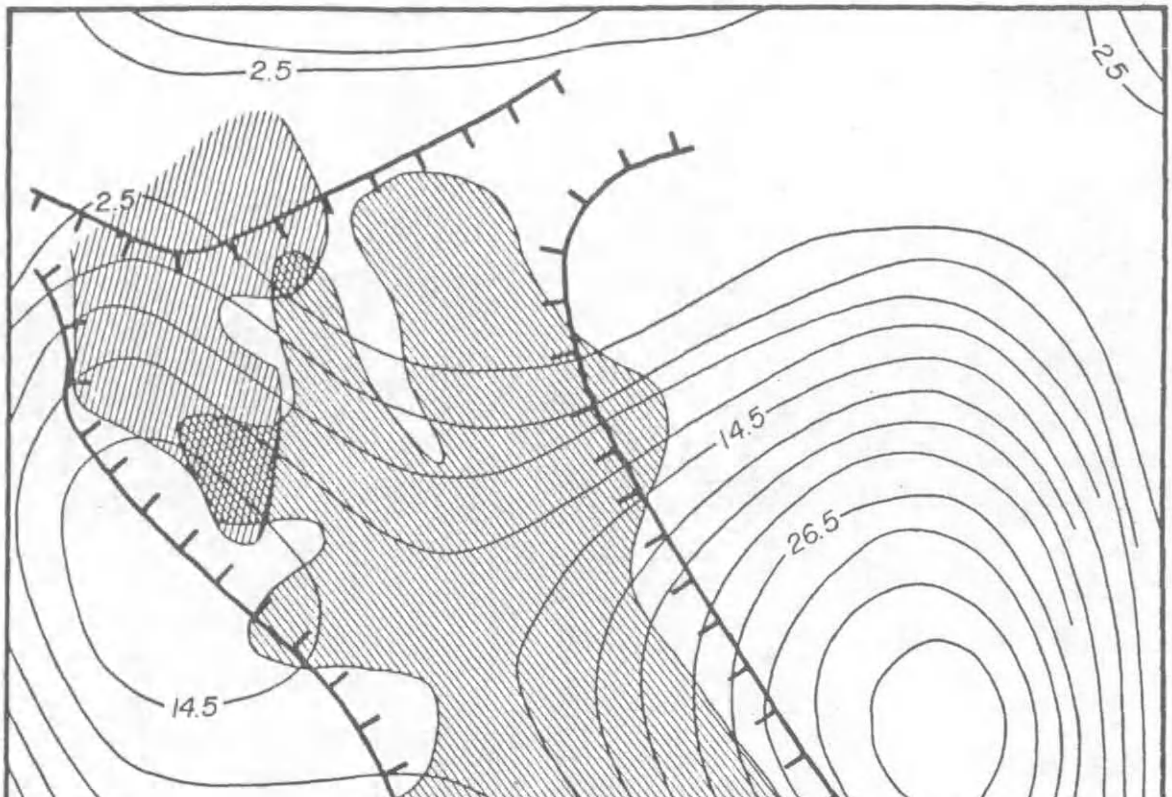


FIGURE 6th ORDER TREND SURFACE - AVAILABLE ZINC ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 3 PPM

$r$ = CORRELATION COEFFICIENT
$r$ = 0.31

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.10

N

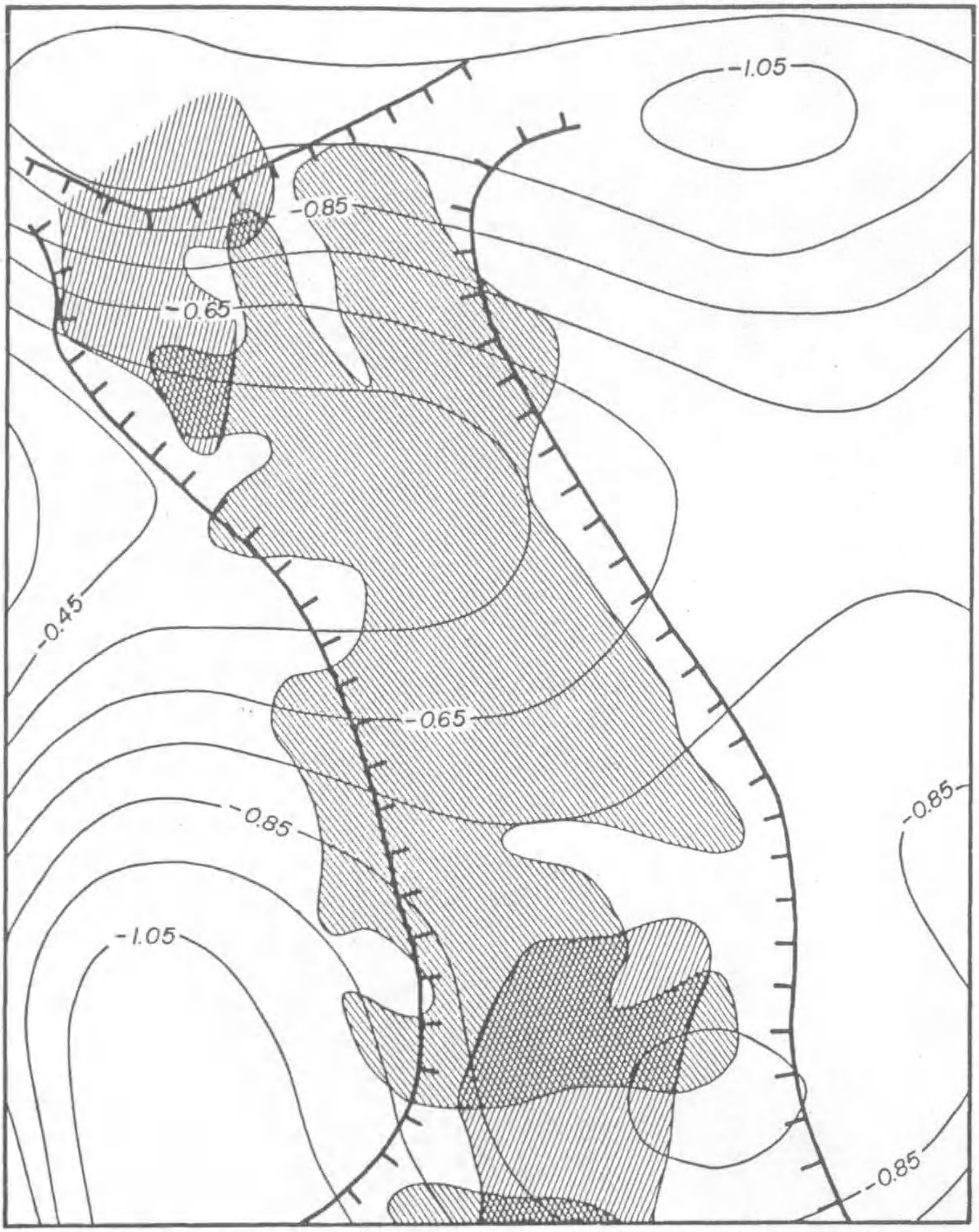


FIGURE 5th ORDER TREND SURFACE - AVAILABLE ZINC ANALYSES (LOG$_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.1 LG OF PPM

$r$ = CORRELATION COEFFICIENT
$r$ = 0.38

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.15

N

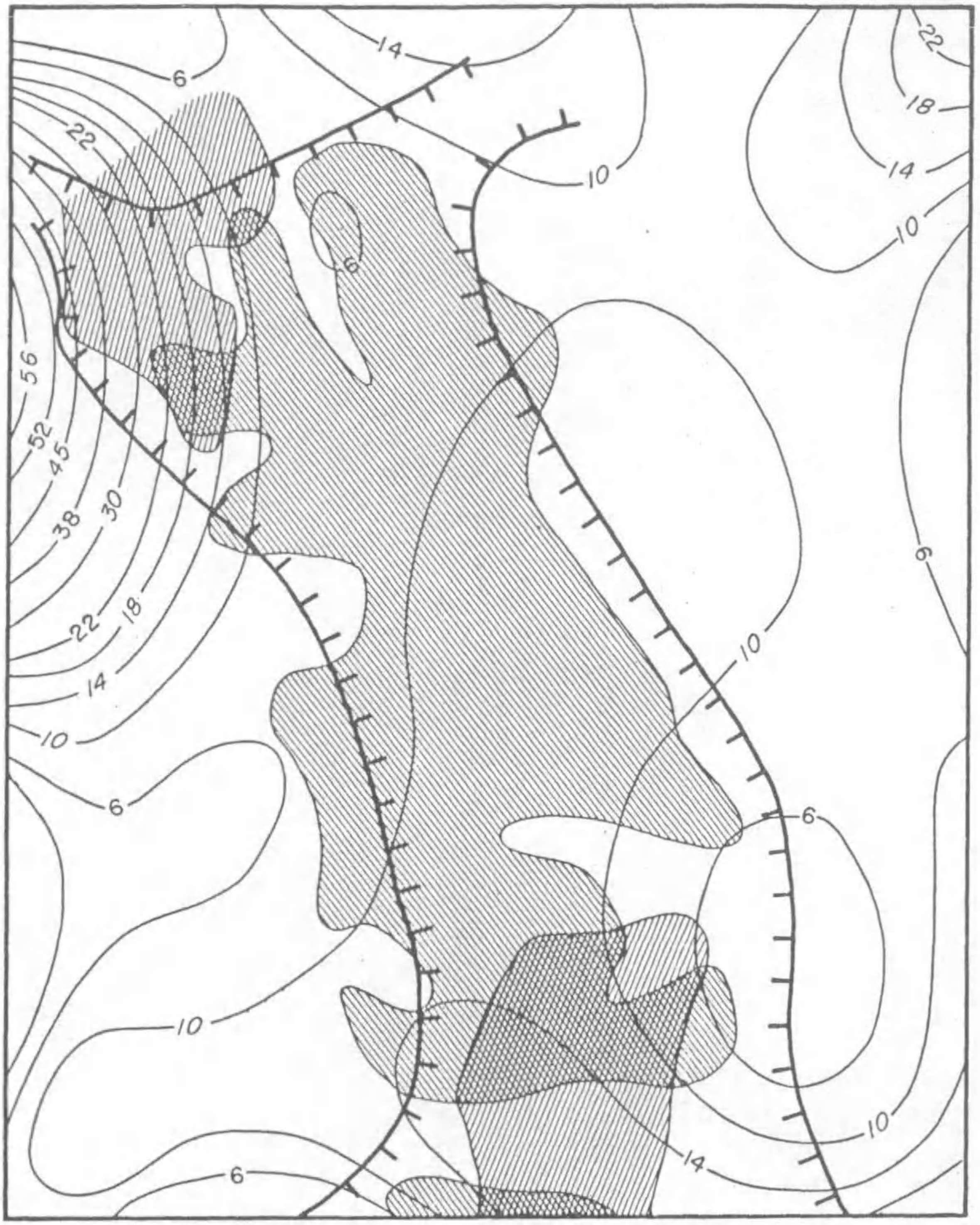


FIGURE 6th ORDER TREND SURFACE — AVAILABLE IRON ANALYSES

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 4 PPM

r = CORRELATION COEFFICIENT
r = 0.47

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.22

N

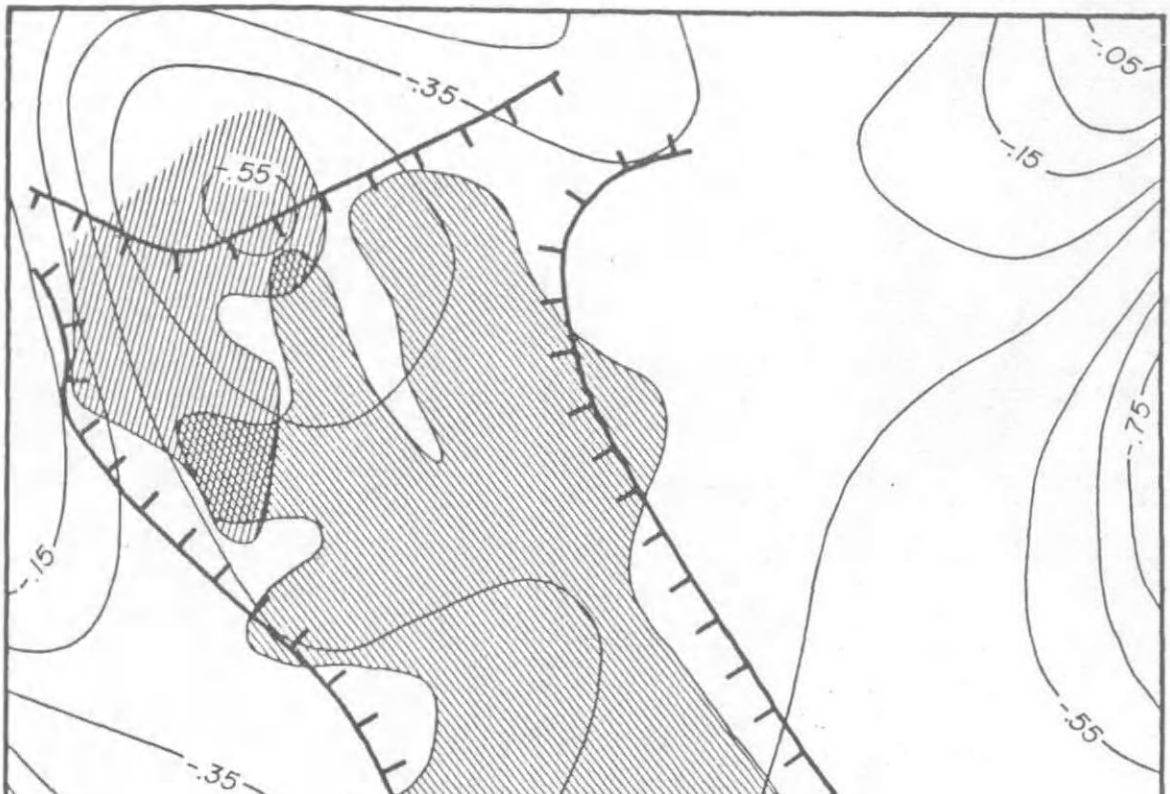


FIGURE 6th ORDER TREND SURFACE - AVAILABLE IRON ANALYSES (LOG$_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE: 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.1 LG OF PPM

r = CORRELATION COEFFICIENT
r = 0.42

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.18

N

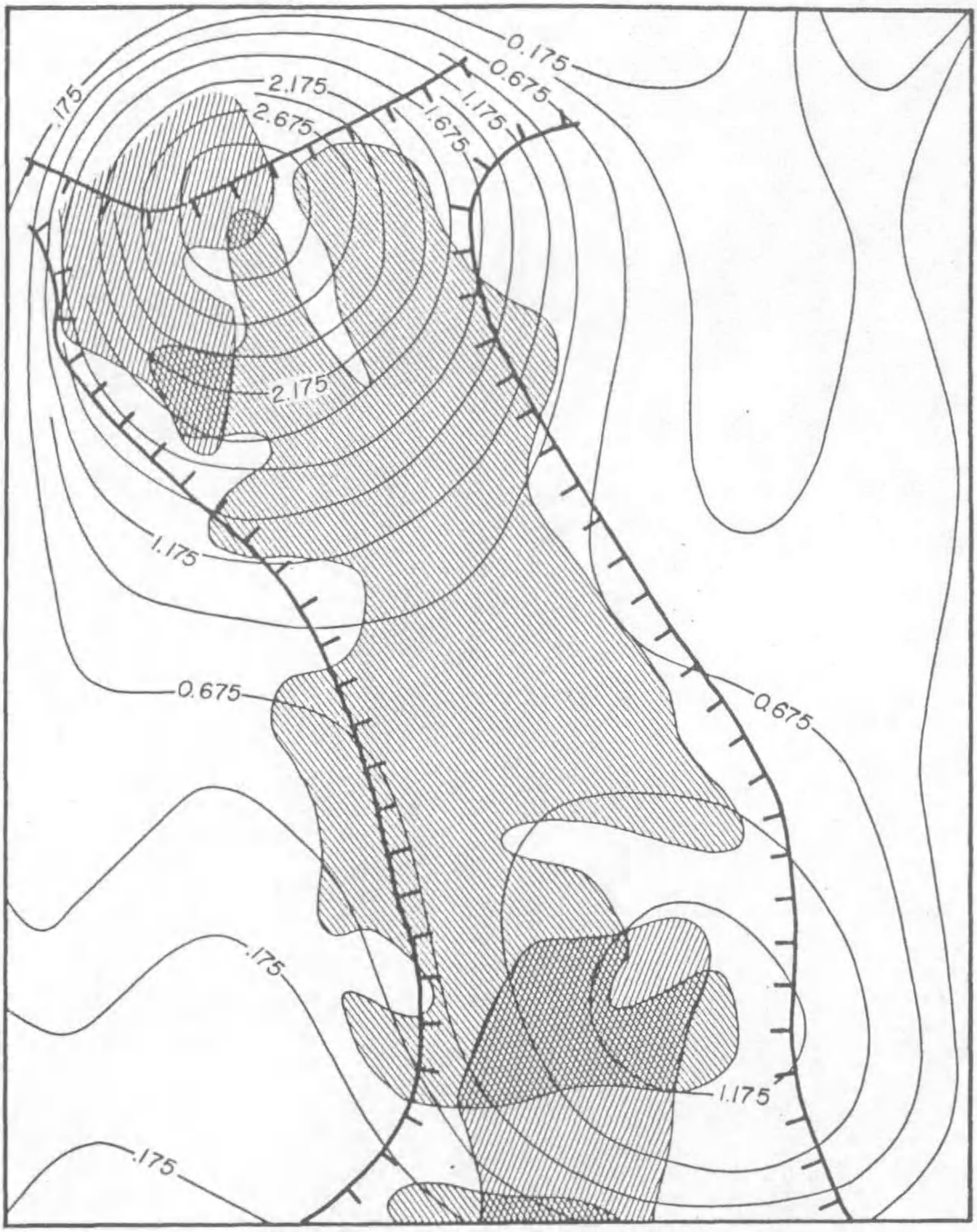


FIGURE 6th ORDER TREND SURFACE - AVAILABLE COPPER ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

⅄ OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.25 PPM

r = CORRELATION COEFFICIENT
r = 0.26

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.07

N

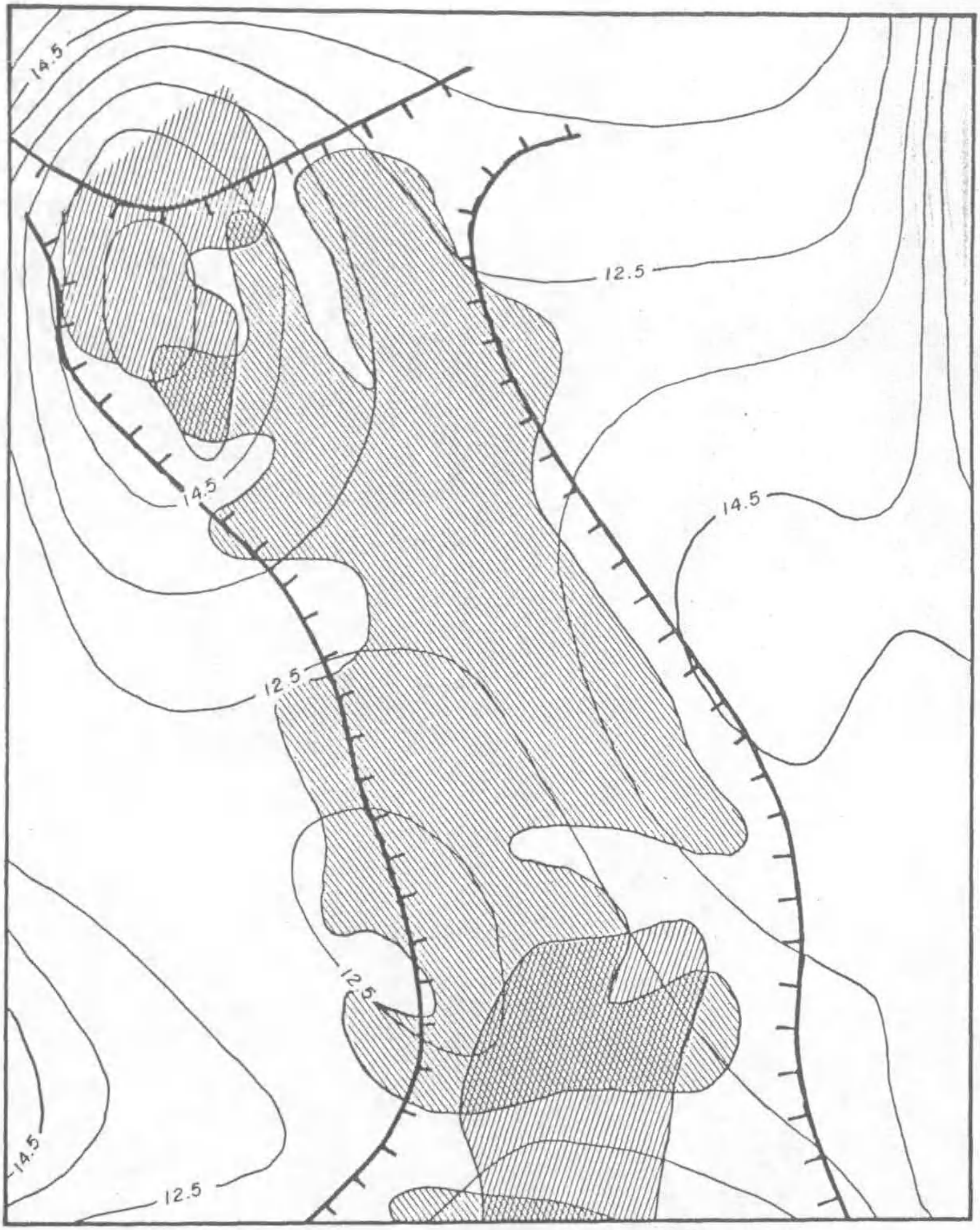


FIGURE 6th ORDER TREND SURFACE - PLANT COPPER ANALYSES

☐ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

☐ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 1 PPM

r = CORRELATION COEFFICIENT
r = 0.38

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.14

N

FIGURE 6th ORDER TREND SURFACE - PLANT COPPER ANALYSES ($LOG_{10}$ TRANSFORMED)

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE: 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = .02 LG of PPM

r = CORRELATION COEFFICIENT
r = 0.37

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.14

N

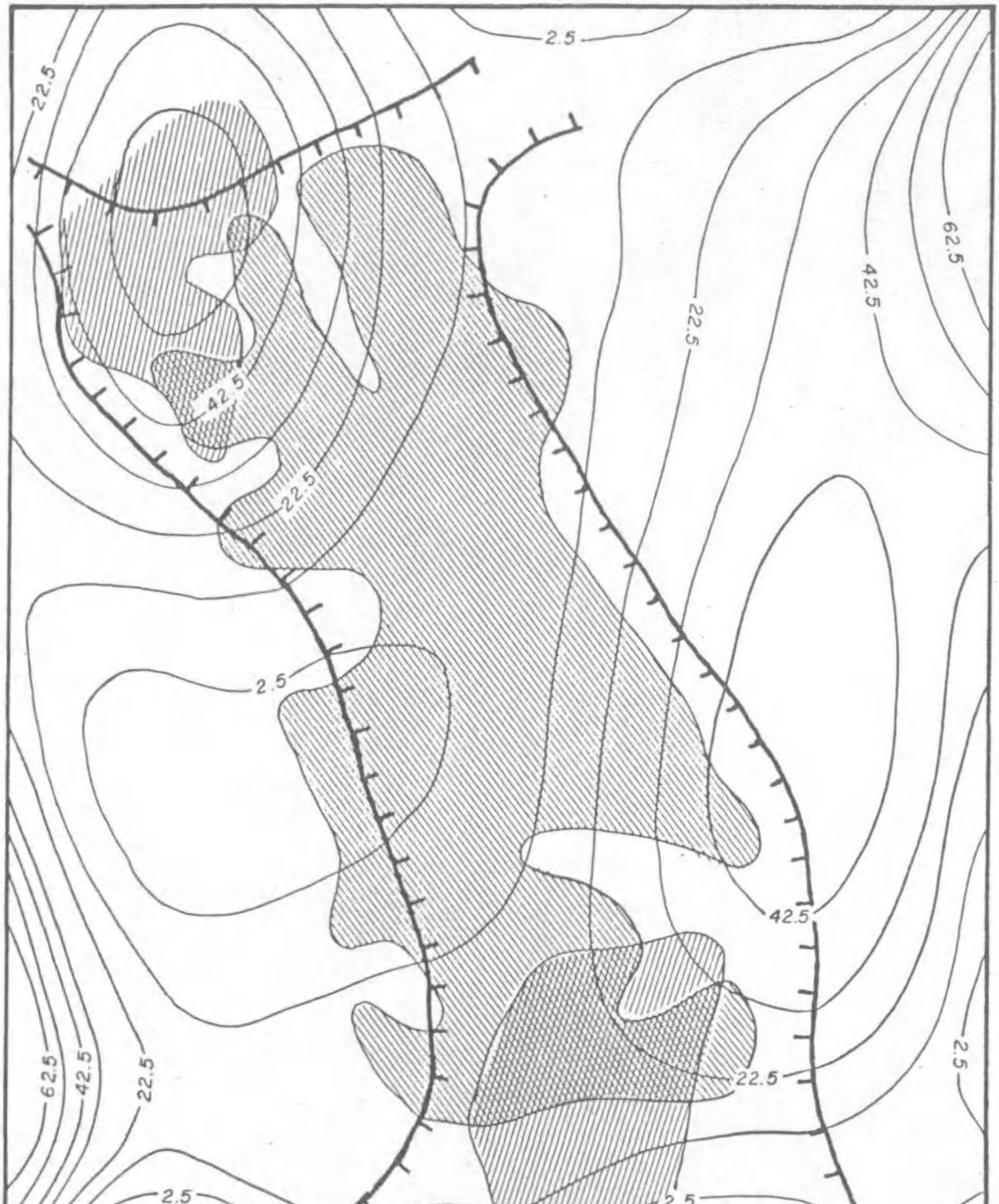


FIGURE 6th ORDER TREND SURFACE - PLANT NICKEL ANALYSES

▧ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE : 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 10 PPM

r = CORRELATION COEFFICIENT
r = 0.36

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.13

N

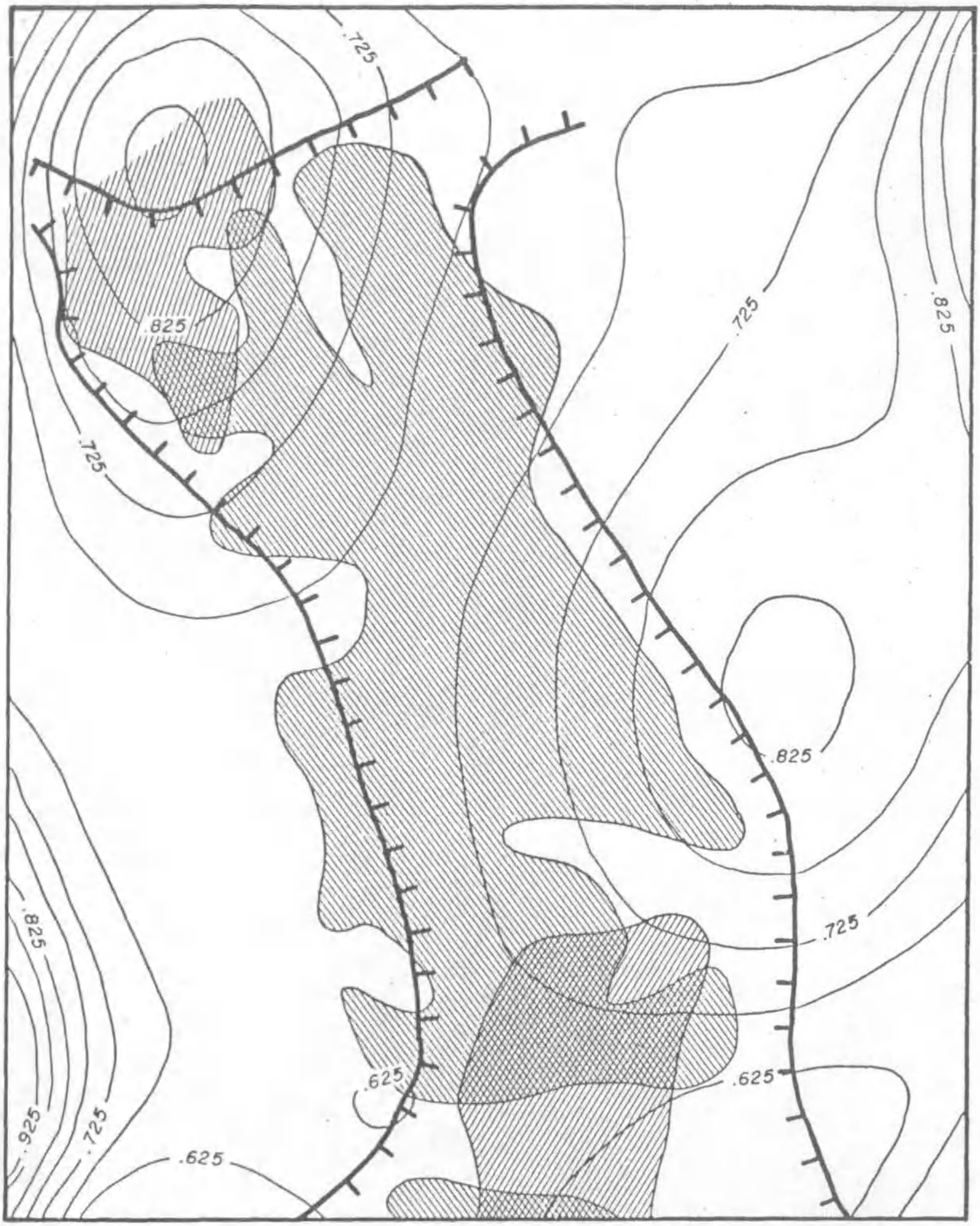


FIGURE 6th ORDER TREND SURFACE - PLANT NICKEL ANALYSES ($LOG_{10}$ TRANSFORMED)

▨ KNOWN LIMITS OF IMPORTANT, SHALLOW TO INTERMEDIATE DEPTH COPPER-MOLYBDENUM POTENTIAL

▨ AREAS OF POSSIBLE DEEP MOLYBDENUM POTENTIAL

OUTER EDGE OF STRONG WALL ROCK ALTERATION

SCALE: 0 2 4 6 8 10 HUNDRED FEET

CONTOUR INTERVAL = 0.05 LG of PPM

r = CORRELATION COEFFICIENT
r = 0.36

$r^2$ = COEFFICIENT OF DETERMINATION
$r^2$ = 0.15

N