THE SIGNIFICANCE OF CU, PB, ZN, AU, AND AG DISTRIBUTIONS IN CANADIAN BASE METAL DEPOSITS

A Thesis
Presented to
the Faculty of Graduate Studies and Research
The University of Manitoba

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

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September 1964

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

FIGURE PAGE

ABSTRACT

Statistically, the study of the copper, lead, zinc, gold, and silver content of the ore reserves of fifty-two Canadian base metal deposits suggests that greater quantities of gold relative to the amount of silver are associated with sulphide deposits composed essentially of copper and zinc. Where lead and zinc are the dominant sulphides present, the amount of gold relative to silver is generally less and silver is often the only significant precious metal present. It is suggested that gold is concentrated in basic and intermediate igneous rocks and silver is concentrated in scidic igneous rocks.

Precious metal associations in three specific base metal deposits were as follows; gold and silver are directly proportional to copper, lead, and zinc at the Vermilion Lake Mine, silver is directly proportional to copper at the Geco Mine, and gold and silver are directly proportional to copper at the Flin Flon Mine. Further, statistical studies of the metal contents of the ores of these three mines suggest that the economic metals have been deposited contemporaneously by the injection of a single ore fluid (sulphide melt) or by deposition, at almost constant temperature and pressure, from a hydrothermal fluid and that the metals were then distributed and deposited according to some particular distribution or partition ratio between the ore fluid and the geologic environment of the deposit.

CHAPTER I

INTRODUCTION

General Statement

Distribution studies of elements in silicate rocks contribute so much to our knowledge of the origin of these rocks that it seemed desirable to extend this type of investigation to the distribution of the metallic elements in ore bodies.

Studies of metal distributions in copper-nickel deposits have already yielded some remarkably consistent results with respect to metal ratios. In consequence, it was decided to extend this form of investigation to copper-lead-zinc deposits containing precious metals. Examinations to-date on the compositions of such deposits have indicated that some noteworthy relationships exist and that the composition of many of these deposits exhibit reasonably consistent metal ratios. The results of such studies may contribute to our knowledge of the varied origins of these ore deposits, and in turn, influence the planning and the course of operations employed in the search for more ore.

To achieve this objective, assay data from mining properties and prospects has been statistically analyzed. Much of the data required for this study is readily available at all mines and much of it was derived from published reports in volumes such as the Canadian Mines Handbook, the Northern Miner Weekly, Surveys of Mines, and in the technical journals.

Compilation and analyses of such assay data from a large number of mining operations would no doubt indicate some important metallic ratio trends. It is the aim of this thesis to test the potentiality of such statistical analyses for indicating any trends that may add to our knowledge of the genesis of such ore deposits and the metal association contained therein. The body of this paper is a progress report on a continuing study which will continue to grow as new data and methods of handling such data are found.

Statement of the Problem

The recent interest in metal distribution studies has initiated new trends in studying ore bodies. It has been statistically shown (Wilson and Anderson, 1959) that Canadian sulphide deposits generally have compositions containing characteristic metal ratios. Further, statistical studies of the compositions of Canadian ore deposits have suggested that the interpretation of paragenesis may be wrong.

The purpose of this thesis is, in general, two fold.

Firstly, from a statistical study of the Cu, Pb, Zn, Au, and Ag content of the ore reserves of fifty-two Canadian base metal deposits, it is hoped that some specific relationship between the base metals and the precious metals can be discovered.

Secondly, the Cu, Pb, Zn, Au, and Ag contents of three specific Canadian Cu - Pb - Zn deposits have been studied in detail to determine: (1) the distribution of the metal ratios, and (2) the existence of a specific base metal - precious metal association in each deposit and if such ratios and associations have any bearing on the genesis of the ore.

Acknowledgements

The writer wishes to thank the following mining Companies who contributed data for the present study; Geco Mines Limited, Hudson Bay Mining and Smelting Company Limited, and the Vermilion Lake Mine of Consolidated Sudbury Basin Mines Limited.

A special note of thanks is due Dr. H.D.B. Wilson who suggested the problem and gave guidance and criticism during the study, and to Dr. G.M. Brownell and Dr. R.B. Ferguson, for their helpful comments.

The writer also extends acknowledgements to Dr. D.T. Anderson who accumulated much of the data used in this study, and to my colleagues at The University of Manitoba for their many stimulating discussions of the problem.

Previous Work

Considerable work has been completed on base metal distributions for Canadian ore deposits. The most significant studies concluded to-date are those by Wilson (1953), and Anderson (1959). Data on the distribution of the precious metals in Canadian ores are generally lacking in published form.

Stanton's (1958) investigation was confined to sulphide ores which are conformable with enclosing sedimentary formations. Wilson and Anderson (1959) have generally limited their research to Canadian ore deposits, their study being essentially a statistical analysis.

This paper is a continuing study using their methods and with a similar objective, but dealing only with Cu - Pb - Zn and Cu - Zn deposits containing some precious metals.

The distribution of elements in sulphide ore deposits according to Wilson and Anderson (1959), suggests that copper, lead, and zinc are deposited simultaneously in relatively constant proportions rather than successively in a paragenetic sequence. Zoning may be due to different ratios of metals being deposited under changing temperature, pressure, and chemical environment, or may be the result of other processes. Metals are produced from many ore bodies in almost the same ratios year after year, or new ore reserves may have metal ratios almost identical to those in ore produced in past years. The conclusion seems valid that Canadian ore bodies containing copper, lead, or zinc do have characteristic compositions. Variations in these compositions may be due to genetic factors which may be discovered by studying the variations in the compositions.

It is apparent from Wilson and Anderson's (1959) study that dominant copper-zinc combinations (in the Canadian Shields) are characteristically related to gabbros and diorites; lead-zinc combinations are related to granite; and high zinc with moderate copper and lead are associates of intermediate rocks.

CHAPTER II

THE DISTRIBUTION OF ELEMENTS IN A CRYSTALLIZING MAGMA

The Magmatic Environment

Magma is essentially a hot silicate melt and is the parent material of igneous rocks. The formation of igneous rocks can be observed in volcanic regions, but considerable magma solidifies within the crust of the earth and the rocks thus formed can only be observed where erosion exposes them at the surface.

Igneous rocks are not the only products of crystallization of a magma. In addition to the major rock forming elements such as O, Si, Al, Ca, Mg, Fe, Na, and K, magmas also contain minor amounts of almost all the remaining elements. The progressive crystallization of minerals from a magma results in a concentration of many of these minor elements in the residual liquid including volatile matter such as H_2O, CO_2, N_2, compounds of sulphur and boron, HCl, and HF. Magma rich in water gives rise to pegmatites and hydrothermal solutions. Thus, the magma progressively gives rise to four types of mineral occurrence: (1) igneous rocks, (2) pegmatites, (3) hydrothermal deposits, and (4) fumarole deposits. The most important base metal deposits are developed in the magmatic and hydrothermal phases.

Fractional Crystallization

The formation of magmas of different compositions can be explained by fractional crystallization of a basaltic magma and the separation of residual melts of different compositions. Many varieties of igneous rock represent the end product of such rock differentiation processes. Differentiation cannot be attributed to any one mechanism. Crystallization differentiation, assimilation, mingling of magmas, etc., may each have played its part and there may be still other processes of which little is currently known.

Basic and ultrabasic rocks, such as dunites, peridotites, pyroxenites, and gabbros are generally considered to have formed from crystallization or crystallization differentiation of the early formed basic minerals from a cooling basaltic melt. Removal of these basic minerals from the system yields a residual liquid enriched in acid components. According to Bowen's reaction principle, the fractional crystallization of a basaltic melt under suitable conditions can lead to the successive formation of more siliceous magmas until finally a granitic composition is reached.

Each of the rocks in the differentiation sequence posses a characteristic mineral assemblage, and the minerals in each rock type have characteristic chemical compositions. The earliest forming crystals will be olivine and pyroxene and these crystals will contain more magnesium than the olivines and pyroxenes formed later. Similarily, the early plagioclase will be enriched in calcium relative to sodium. Continued differentiation yields plagioclose progressively enriched in sodium with respect to calcium. Silica undergoes a very significant change in the differentiation process, gradually increasing from 40% in ultrabasic rocks to approximately 70% in granites. Generally, magnesia decreases in amount from approximately 25% in ultrabasic rocks to about 1% in granites.

Chemical Fractionation by Magmatic Crystallization

The silicate minerals crystallizing from a magma remove from it not only the abundant elements, but also other trace lithophile elements whose ionic size and coordination number enables them to enter the crystal structures of these minerals. Thus nickel is largely camouflaged in the olivine structure in which it substitutes for magnesium; gallium substitutes for aluminum in aluminosilicates; titanium, vanadium, and manganese are largely removed in the ferromagnesian minerals.

The lithophile elements which do not readily substitute for the major elements in the essential minerals of igneous rocks remain in solution and hence are enriched in the residual liquids of magmatic crystallization. These elements, such as Be, W, Sn, U, Li, etc., mainly crystallize as components of minerals in pegmatites and hydrothermal veins.

Chalcophile elements in a magma combine with sulphur and lesser amounts of arsenic, antimony, bismuth, selenium, and tellurium to form sulphides and related compounds. Pyrrhotite and pyrite may separate from a magma at an early stage of crystallization, but sulphide minerals characteristically segregate at a later stage and are ultimately deposited from hydrothermal veins. The separation of sulphides is dependent upon the low thermal stability of most sulphide minerals and also upon a sufficient concentration of sulphur ions in the magma. Sulphides are also removed during silicate crystallization when the concentration of sulphur is at its maximum. There is some question of whether sulphur concentrates in a late phase. Analytical studies of sulphides in igneous rocks indicates that siliceous magmas are much poorer in sulphur than basic magmas (Newhouse, 1936).

The progressive crystallization of a magma results in the formation of a residual liquid and a concentration of the volatile matter present in the magma. These residual solutions give rise to contact metamorphic ore deposits, hydrothermal veins and pegmatites. Chemical and geological evidence indicates that the residual melt from the fractional crystallization of a magma will generally be a siliceous liquid rich in alkalies and aluminum, containing water and other volatiles, and with a concentration of those minor elements that are not incorporated in the structures of the common minerals of igneous rocks.

The Distribution of Sulphides in Igneous Rocks

Studies of igneous rocks suggest that a spacial relation exists between the type of igneous rock and the type of sulphide contained therein. Nickel ore deposits occur within or alongside basic and ultrabasic rocks. Primary platinum deposits occur only in ultrabasic rocks; diamonds in kimberlite; chromite in peridotite or serpentine; corundum in quartz-free rocks; tin in silicic granites; and beryl in granite pegmatite. These associations are so universal as to render inescapable the conclusion that the rock and associated ore were derived from the same magma.

The ratios of copper, zinc, and lead in ore deposits have been compared with the ratios of copper, zinc, and lead in igneous rocks. Wilson (1953), Stanton (1958), and Kilburn (1959) pointed out the similarity between the compositions of ores and the minor constituents of the related igneous rocks. Wilson and Anderson (1959) compared the compositions of 125 ore bodies containing copper, zinc, and lead with Sandell and Goldich's similar copper, zinc, and lead diagram for igneous rocks. The similarity of the ratios of these metals in ore deposits and igneous rocks is obvious and suggests, but does not prove, a genetic relationship. Sandell and Goldich showed that, in general, the ratio of the metals in igneous rocks depends upon the rock type. Wilson and Anderson (1959) show that it is apparent in Canada, that dominant copper-zinc combinations are related to gabbros and diorites; lead-zinc combinations are characteristic of granites; and high zinc with moderate copper and lead are characteristic of intermediate rocks.

Metallic Element Distribution in a Differentiating Silicate Magma

Goldschmidt (1937) classified the elements according to their geochemical affinities as siderophile, chalcophile, or lithophile depending upon whether the elements are concentrated in a metallic iron phase, a sulphide phase, or a silicate phase. The major igneous rock forming elements such as Na, Ca, K, Mg, Al, and Si, are all strongly lithophile and therefore would not appear in the sulphide phase. The metallic elements, Ni, Cu, Co, Pb, Zn, Fe, Cd, Hg, etc., have either chalcophile or siderophile affinities, but because the metallic iron phase (siderophile) is assumed mot to be present in the environments of crustal rock formation, these metallic elements will then concentrate in the chalcophile or sulphide phase. In general, the classification of an element as lithophile, chalcophile, or siderophile refers to its behavior in liquid-liquid equilibria in melts. However, it has been shown that pyrrhotite sulphides can extract nickel from nickeliferous olivine crystals.

Some elements show affinity for more than one group because the distribution of any element is dependent to some extent on the temperature, pressure, and chemical environment of the system as a whole. By comparing the heat and free energy of formation of its sulphide with the sulphate and carbonate, the position of an element in the scale of relative chalcophile affinity may be approximated.

Goldschmidt (1937) realized the significance of crystal structure in controlling the distribution of elements in the earth's crust. The basic unit in all crystal structures is the atom or ion. Among silicate minerals, ionic structures are dominant. The structure of a mineral is a function of the energy relationships existing between the constituent ions or atoms as well as purely space considerations. Ions can be considered as being approximately spherical with a definite radius characteristic for the element in question and the charge on the ion. The stucture of an ionic compound is determined by the size of the ions and the charge on the ions.

In an ionic structure, each cation tends to surround itself with anions. The number that can be grouped around it will depend upon the relative sizes of the cations and anions. The relative size is expressed by the radius ratio. The number of anions that can fit around each cation is called the coordination number of the cation. Assuming that ions act as rigid spheres of fixed radii, the stable arrangement of cations and anions for particular radius ratios can be calculated from purely geometric considerations.

Minor metallic elements that are preferentially concentrated in the sulphide phase, may also concentrate in the silicate phase and in silicate minerals under special conditions. Substitution of such ions and atoms is related to the size and charge of the ions. From studies of crystal structures and independently of energy considerations, Goldschmidt formulated the following empirical rules as a general guide to the course of crystallization of an element during liquid ---> crystal formation in a multicomponent system.

1. If two ions have the same radius and the same charge, they will enter a given crystal lattice with equal facility.
2. If two ions have similar radii and the same charge, the smaller ion will enter a given crystal lattice more readily.
3. If two ions have similar radii and different charges, the ion

with the higher charge will enter a given crystal lattice more readily.

These rules have wide application in the geochemistry of igneous rocks, but have had their greatest utility in predicting the order of removal from a magma not only of the major ions, but of the minor elements also.

Electrical stability is a primary factor in ionic structures. The requirement of electrical stability means that the sum of positive and negative charges on the ions must balance. Pauling's (1927) rule of valency states that :- "In a stable structure the total strength of the valency bonds which reach an anion from all the neighboring cations is equal to the charge on the anion". This rule imposes strict conditions on the substitution of ions in crystals if the substituting ions have different valencies.

The phenomenon of atomic substitution is also an important factor effecting the distribution of elements. In an ionic structure, there is an infinitely extended three-dimensional network. Any ion in the structure may be replaced by another ion of similar radius without causing serious distortion of the structure. Some foreign ions are often incorporated in mineral structures because minerals usually crystallize from solutions containing many ions other than those essential to the mineral. As a general rule, little or no atomic substitution takes place when the difference in charge on the ions is greater than one, even when size is appropriate. Also, a wide range of atomic substitution may be expected at room temperature in a magma or in a hydrothermal solution provided that the radii of the substituting ions do not differ by more than 15%.

The formation of solid solutions and mixed crystals and the existence of defect lattices also effects the distribution of elements during crystallization. The extent to which atomic substitution and solid solution formation takes place is determined by the nature of the structure, the closeness of correspondence of the ionic radii, and the temperature of formation of the substance. Many of the ore minerals are capable of solid solution. The processes involved appear analogous to those shown by metals.

Three types of solid solution are possible:

1. Substitutional solid solution where atoms of the solute metal replace atoms of the solvent metal in their normal positions in the lattice of the solvent metal.
2. Interstitial solid solution where the solute atoms are dispersed in otherwise vacant lattice positions between the solvent atoms. The atoms are introduced in addition to the solvent atoms in the lattice.
3. Omission solid solution (proxy solid solution) where a small number of metal atoms may occupy positions normally occupied by sulphur or metal atoms so that the minerals concerned have a metal content slightly in excess of their ideal compositions.

Wide solid solution is favored by high temperature. The consequence of atomic substitution is that most minerals contain not only the elements characteristic of the particular species but also other elements able to fit into the crystal lattice.

It is apparent that the fate of an element during magmatic crystallization is largely controlled by the size and the charge of the elemental ion. Ions with small ionic radii are the first to be removed from a cooling magma or melt. Thus, the Mg ion, being somewhat smaller than the ferrous ion, is always concentrated in the early formed ferromagnesian minerals. Ions with large radii and charge tend to remain longer in the residual melts though many other factors control the ultimate fate of these elements.

Magmatic crystallization is controlled by temperature, pressure, the nature of the ions present, their concentration, and the types of crystal lattices formed. Changes in the composition and physical conditions of the magma affect the solubilities of the many different possible compounds. Temperature and pressure variations undoubtedly exert a strong influence upon the crystallization of silicates and sulphides. Other factors, such as chemical potential, lattice energies, reaction rates, and vapor pressure also exert an effect on the fate of elements during magmatic crystallization.

The total amount of an element available for crystallization in later differentiates will be greatly reduced where the element is concentrated in the early crystallizing fractions of a differentiating magma. The later differentiates will become progressively enriched in an element if this element is not concentrated in the early crystallizing fractions. Hence, during crystallization of a basaltic magma composed of liquid silicates plus sulphur, the first crystallization products will be high magnesian olivine and pyroxene. The residual or rest magma containing liquid silicates plus sulphur will be progressively impoverished in a metallic element if this element is concentrated in the early formed silicate minerals.

Magmas containing a low concentration of a particular element can never produce a relatively high concentration of it in any phase except possibly in the late pegmatitic or hydrothermal phases.

Studies of the solubility of sulphur (Vogt, 1918) indicate that the solubility of sulphur decreases with increasing silica. Newhouse's (1936) studies on sulphides in igneous rocks pointed to the greater abundance of sulphides in basic rocks although sulphides were present to some extent throughout the series of basic to acid igneous types. This too, suggests a higher solubility of sulphur in low-silica differentiates. That is, if a silicate melt separates into a low silica-high magnesia liquid and a high silica-low magnesia liquid, sulphur will be much more soluble in the low silica liquid. Crystallization from these liquids should result in the early formation of sulphides in the high silica liquid as contrasted to both early and late sulphides in the low silica liquid.

Gold, Silver, and Copper in Solid Solutions

Gold and silver, and also copper and gold fulfill the conditions required for solid solution formation (Edwards 1954, p-47).

Copper and gold may form a continuous solid solution series. Both elements crystallize in a face-centered cubic lattice. The atomic diameters of gold and copper are 2.87 A^o and 2.55 A^o respectively and their difference is within the 15% limit. Silver and copper are capable of limited solid solution formation and they may form two restricted solid solutions which yield a eutectic. Gold and silver also form a continuous solid solution series. Gold and silver crystallize in a face-centered cubic lattice and their atomic diameters are very similar, being 2.87 A^o respectively.

Gold in solid solution with other minerals has also been noted. Pyrite and pyrrhotite containing as much as 300 grams of gold per ton as particles of submicroscopic size have been synthesized by Maslinitsky (1944). Such solid solution of gold in pyrite must occur as an interstitial solid solution. Pyrite and pyrrhotite are notably non-stoichiometric and the departure from stoichiometric proportions must arise from defects or vacant sites in the iron lattice. In metals showing lattice defects of this kind, the vacant metal sites may be filled by atoms of other metals, giving rise to restricted interstitial solid solutions. In pyrite, the atomic diameters of gold and iron are 2.88 A^o and

2.50 A° respectively. Gold has been detected as crystal grains of the order of 10^{-6} cm in diameter (Edwards, 1954, p-113).

Metals containing invisible (submicroscopic) gold should unmix and segregate from such a solid solution during the auto-annealing of the ore deposit. Auto-annealing is a process in which partial recrystallization takes place during slow cooling of the ore deposit. Invisible gold has been reported in arsenopyrite (Stillwell and Edwards, 1946) and sphalerite (Hoffmann, 1931). Chalcopyrite is not a perfectly stoichiometric compound above 525°C, so that a similar phenomenon may be possible in chalcopyrite. In the extreme case of refractoriness, gold may occur as particles of submicroscopic size distributed through the contemporaneous sulphide or in solid solution in it, and it has been suggested that much fine gold is deposited in this manner and subsequently aggregates by solid diffusion into visible grains whose size depends on the initial temperature and rate of cooling during auto-annealing of the ore.

The Distribution of Metallic Elements in a Silicate-Sulphide Liquid

In a melt composed of a metallic iron phase, a sulphide phase and a silicate phase under equilibrium conditions, the metallic elements would be distributed according to their siderophile, chalcophile, or lithophile affinities. Nickel and gold should be highly concentrated in the metallic iron phase, less strongly in the sulphide phase, and least strongly in the silicate phase. Copper, lead, zinc, and silver should be highly concentrated in the sulphide phase and least concentrated in the metallic iron and silicate phases. Nickel and gold, which are both strongly siderophile, are both found with sulphides in crustal environments due to the absence of the iron phase.

Some elements may have affinities for more than one geochemical group since the type of compounds an element may form is dependent not only on the nature of the element, but also on the temperature, the pressure, and the other elements present. Thus, gold may be concentrated in the metallic iron phase or the sulphide phase. Molybdenum, which is strongly siderophile, should be greatly enriched in the metallic iron phase. In the absence of an iron phase, molybdenum tends to be moderately concentrated in the silicate phase and must be present to a minor extent in the sulphide phase. Tin is strongly siderophile but also possesses chalcophile and lithophile tendencies. In crustal environments, tin is enriched in the silicate phase.

Vogt accounts for the origin of certain sulphide deposits by considering that dissolved sulphides separate with lowering temperature in part as immiscible droplets that settle out as a molten fraction, in the same manner that molten copper matte settles to the bottom of a copper furnace while the silicate slag floats at the top.

F.G. Smith (1961) has recently reviewed and condensed the data available on artificial sulphide-oxide-silicate liquids and applied them to the natural system pyrrhotite-magnetite-silicate, tracing out the cooling and crystallization history for liquids initially rich in silicates, some with a low and others with a higher magnetite-silicate ratio. Only in the former does liquid immiscibility appear to play an important role. Wager et al (1957) postulated that the miscibility gap between silicates plus some oxides and sulphides plus oxides and silicates increases with lowering temperatures. Smith has noted that factors other than temperature affect this miscibility gap, which appears to be reduced by oxides of iron, alkalies, and increased by CaO, Al_2O_3, and Cu_2S. Wager et al contend that once the solubility of sulphides in silicates has been exceeded, two liquids will form and will begin to separate by gravity. With falling temperatures and decreasing solubility of one in the other, the compositions of the two liquids will gradually change to a silicate liquid crystallizing dominantly silicate minerals and a sulphide liquid crystallizing mainly sulphide minerals. Smith indicates a slightly different cooling history, in which the miscibility gap decreases with falling temperatures and that at a ternary eutectic, oxides, silicates, and sulphides crystallize out together. Isolation of the predominantly sulphide liquid would eliminate such a eutectic crystallization.

The hypothesis presented by F.G. Smith (1961) states that "Separation of a metallic sulphide liquid from the residual silicate liquid during crystallization of silicates is possible if the oxidation potential of the magma is below some critical value."

Other variables exist in addition to oxidation potential and thus many complications must be considered in detailed analyses of possible phase sequences during cooling. It is reasonably certain however, that we can accommodate physico-chemical data by adopting the working hypothesis that in basic magmas, two classes of sequences are possible, based on the ratio of ferrous to ferric iron. One, where this ratio is below some critical value, involves the separation of a sulphide melt from the silicate melt during crystallization of silicates or the sulphides may become immiscible before crystallization of silicates begins. The other, where this ratio is greater than the critical value, involves no liquid immiscibility during crystallization. Both classes may develop a final liquid fraction rich in pyrrhotite, but this terminal liquid, expected in a dry magma, may not be reached in hydrous magmas due to the appearance of a separate aqueous phase which would contain much of the sulphides.

The segregation of a sulphide liquid from a dominantly silicate basic magma by differentiation appears to be a valid process. Thus, in a crystallizing basaltic magma composed of molten silicates plus sulphur, the first crystallization products will be magnesian rich ferromagnesian minerals and the system will be made up of two phases: a solid silicate phase, and silicate plus sulphur liquid phase. With falling temperatures, this liquid phase may form an immiscible liquid consisting of a liquid silicate phase with minor sulphur, and an immiscible sulphide liquid phase. The system would then be composed of three phases: a solid silicate phase, a liquid silicate phase with minor sulphur, and an immiscible sulphide liquid phase.

Two important factors which affect the partitioning of metals between the silicate and sulphide liquid fractions are the concentration of sulphur and the relative affinity of the metals for sulphur (their chalcophile affinity). Copper is more chalcophile than nickel or iron, so that the Skaergaard intrusion, which was low in sulphur, yielded a copper rich liquid from which copper minerals crystallized while nickel and most of the iron remained in the liquid. In the sulphur-rich Sudbury intrusion, much nickel and iron separated along with the copper.

The Distribution of Metallic Elements in a Sulphide Melt

The course of crystallization of sulphide liquids is largely controlled by the mode of crystallization of solid solutions, which in turn, depends on whether this occurs under equilibrium or nonequilibrium conditions. Bowen (1928) considered such processes vital in the crystallization differentiation of igneous rocks. Under nonequilibrium conditions, early formed crystals fail to react for one reason or another, and thus have a different composition than those formed later. Uniform metal ratios should be expected from crystallization under equilibrium conditions. Separation of silicate and sulphide liquids, and volatiles from contact with the solid phases present in the system, would establish a new set of equilibrium conditions and a new crystallization sequence would occur in a different magma chamber.

Solubilities of metallic elements in sulphide liquids is still another factor. Data from many magmatic sulphide deposits indicates that elements such as Pb, Zn, Sn, Bi, Te, As, Se, and the precious metals, under suitable fractionation (non-equilibrium) conditions, appear to be enriched in copper-rich sulphide liquids, but as solubilities in crystals of copper minerals is low, the removal of copper by crystallization tends to enrich the residual liquid further in these elements until their solubility products are reached, at which time they would crystallize, along with remaining copper sulphides to form sulphides, tellurides, bismuthides, arsenides, and native metals.

Liquid immiscibility between liquid silicates and sulphur would create three phases in a crystallizing silicate melt. At high temperature, the three phases in equilibrium would then be; (1) a solid silicate, (2) a silicate plus minor sulphur liquid and (3) an immiscible sulphide liquid. With decreasing temperatures, some solid sulphide would be expected. The relative concentration of sulphur and chalcophile elements probably increases in the late liquid fractions of a crystallizing magma as a result of the removal of the lithophile elements in the silicate minerals. In a magma containing such elements as S, Ni, Cu, Zn, Pb, Au, and Ag, the compositions of the phases in equilibrium with each other should be; (1) a solid silicate with relatively high Ni; (2) a residual silicate-sulphide melt containing Ni, Cu, Zn, Pb, Au, and Ag, and finally, (3) an immiscible sulphide melt containing Ni, Cu, Zn, Pb, Au, and Ag.

Olivine and pyroxene would predominate in the solid silicate phase. Much of the Ni would be camouflaged in these high Mg minerals. In general, depending on the original composition of the melt, the sulphide liquid should contain the higher proportion of metallic elements. With decreasing temperature and increasing crystallization, the residual silicate-sulphide liquid should become more and more impoverished in Cu and Ni, and sulphur would become less soluble in the silicate melt. The immiscible sulphide melt should therefore be enriched in Cu and Ni. High temperature sulphides containing Cu and Ni will begin to crystallize. Most of the Cu and Ni should have been removed either as Ni-bearing silicates or as high temperature sulphides when the solid silicate phase has reached the composition of a gabbro.

Virtually all of the Cu and Ni should have been removed from the silicate-sulphide liquid when the composition of the solid silicate phase is that of a diorite. The immiscible sulphide melt should be crystallizing high copper and low nickel sulphides. The residual liquid will be relatively enriched in Pb, Zn, Au, and Ag and impoverished in Cu and Ni due to the higher chalcophile affinities of Cu and Ni. The final crystallization should be a granitic silicate and low temperature sulphides of Cu, Pb, Zn, and Ag, plus native Au.

An original melt with a low sulphur content, on the other hand, would result in a distribution whereby Ni would be camouflaged in the early magnesian silicate minerals, and the remaining metallic elements would be progressively enriched and distributed in the residual silicate-sulphide liquid and any immiscible sulphide liquid that tended to form.

Removal of the rest liquid from contact with the solid phases at any stage in the crystallization sequence would also influence the distribution of the elements. A new equilibrium and crystallization sequence in a different magma chamber will result if the liquid silicate and sulphides are removed from contact with the solid silicates and sulphides.

The Partition Ratio hypothesis of H. Neumann (1948) is also important in understanding the distribution of the elements. Metals extracted from a magma by any mechanism will not be removed in the proportions in which they occur in the magma, but will be extracted according to some partition ratio. Consider the case where Cu and Zn occur in a silicate melt in the ratio of 1:1. That a sulphide globule separating from the silicate melt would be composed of equal parts Cu and Zn appears very unlikely. Either Cu or Zn would be relatively enriched in the sulphide and impoverished in the silicate. Early crystallization products will be enriched in one element and as this element becomes impoverished in the liquid, later products will become increasingly enriched in the second element. This hypothesis is discussed in detail by Anderson (1959) and Wilson and Anderson (1959).

Hydrothermal Processes

Progressive differentiation of silicate magmas results in a residual (alkaline) liquid that becomes enriched in volatiles and other constituents including metals that were formerly dispersed throughout the magma. With continuing crystallization of this magma, an aqueous residue charged with volatiles and metals may be produced. An additional distribution of the metallic elements would take place when a highly volatile phase formed. Some Ni, Cu, Pb, Zn, Ag, and Au may be carried away from the magma in the resulting hydrothermal solutions to form medium to low temperature sulphide veins or replacement deposits of these elements.

Two distinct schools of thought regarding the state of hydrothermal solutions exist. One group postulates that the ore forming material was expelled from the magma chamber as a gaseous emanation that later condensed to a hydrothermal liquid which deposited the ore. The liquids formed by the condensation of such gaseous emanations were acidic at first but later became alkaline upon reaction with the wall rocks. A second group proposes that the hydrothermal solutions leave the magma originally as liquid aqueous solutions. Since metallic sulphides are extremely insoluble in pure water, but are more or less soluble in alkaline liquids, it is presumed that these liquids are alkaline from the begining.

Definite criteria do not exist for determining whether a deposit was formed from a gaseous or liquid solution. It follows that if the temperature was above the critical temperature, then transportation and deposition should take place in a gas phase, no matter how high the pressure. If the temperature was below the critical temperature, then the depositing solutions were probably liquid since pressures at moderate depths are usually greater than the critical pressures of moderately dilute solutions. It seems probable that hydrothermal solutions originate in both ways. On proceeding outward from the magma chamber, the temperature will decrease and material leaving the magma in a gas phase may be expected to condense to a liquid when it cools below the critical temperature.

A gas phase associated with a magma at depth would have a density of the same order of magnitude as liquid water at the earth's surface. This dense phase would be capable of dissolving and transporting many non-volatile substances. It has been proposed that the presence of halogen compounds aids the solution and transportation of metallic compounds. As the chlorides of the common metals have high vapor pressures, it is considered probable that chlorides are the most important form in which metals are removed from a magma. The physico-chemical principles governing the conditions under which the metallic halides may exist in a gas phase together with such precipitating agents as H_2O and H_2S are expressed by the Law of Mass Action.

Considerations of this kind suggest that gases containing halogen acids would be efficient transporting agents of many rocks. Bowen states that the gas phase escaping from residual magmatic liquids must be acid because it will contain HCl, HF, H_2S, CO_2, H_2SO_4, and other volatile acids. Present in this gas should be H, O_2, Cl, S, F, B, K, Na, Fe, Ti, and Al along with minor Sn, Pb, Zn, Cu, Ag, and other metals (Zies, 1924). Direct observation of hot gases of fumarolic areas confirms this. Neutralization of the acid by reaction with country rock would cause precipitation of various oxides and sulphides.

With decreasing temperatures at increasing distances from the magma, the gases would condense to liquids. If the gases or liquids were originally acidic, then reactions with alkalies in the wall rocks would tend to change the pH and the fluids would become weakly alkaline. Many other types of reaction are possible with the various mineral assemblages present in the ore channels.

The existence of gas phase in a magma chamber would have a profound effect on the distribution of elements undergoing hydrothermal differentiation. In a magma containing 1% of dissolved water, the remaining residual liquid would become relatively enriched in water as crystallization progressed. Such an enrichment in water would continue until either water is forced out of the magma chamber by differential pressure or until the true saturation point has been reached. At this time, further crystallization would result in the production of water vapor as a separate phase and this process would continue until crystallization is complete. Neumann (1948) thus suggests that three phases are present in the magma chamber; (1) a solid phase (rock); (2) a liquid phase (magma); and (3) a vapor phase; which may develop gradually into hydrothermal solutions.

In the magma chamber, every compound in the magma will distribute itself between these three phases in proportion to their solubilities in each phase in accordance to the distribution law. As crystallization of the magma proceeds, the composition of the vapor phase will change. H. Neumann has used the term "endomagmatic hydrothermal differentiation" for this phenomenon of a magma yielding gases and solutions of different chemical compositions at different times.

Using the distribution law, Neumann was able to indicate that a compound will be enriched in the youngest or in the oldest vapor phase or hydrothermal solutions according to whether the distribution coefficient of the compound was greater or less than the fraction of water dissolved in the magma. Two general cases must be considered; (1) where the vapor or fluid remains in the magma chamber in equilibrium with other phases until final solidification of the magma and; (2) where the vapor or fluid continuously escapes from the magma chamber immediately on its formation.

The actual course in nature would most likely lie between these two extremes as it appears most likely that either the vapor or hydrothermal fluid will be removed by degrees from the magma chamber, or the rest of the magma will at some time be removed from contact with the solid and vapor phases. The gaseous or liquid nature of the fluid phase which appears when the magma is saturated with water is disputed.

The composition of the vapor phase or hydrothermal solution expelled by the magma must vary with time. In the early stages of crystallization of the magma the compounds or metallic sulphides of high relative solubilities or volatilities in the vapor or fluid phase (i.e. the more volatile compounds) will predominate, and in the later stages, the relative amounts of the less soluble or volatile compounds will increase.

It has been contended that the various heavy metals are transported by vapors giving rise to ore deposition. The metals will be only minor constituents of the vapor and the form in which the metals occur will be partly determined by the nature of the major gaseous constituents.

Vapors must play an important part in transporting metals whereever a vapor phase forms in appreciable quantity because many of the heavy metals will necessarily vaporize at 600°C and 1000 atmospheres pressure if given an opportunity to do so (Krauskopf, D.B., 1961). Such conditions should be possible at an intrusive contact at a depth of several kilometers below the earth's surface. The gas phase may be important due to physical transport of solid particles in the gas or absorbed on gas-liquid interfaces, or because of the solvent action of highly compressed water vapor. Water vapor at 1000 atmospheres will have a density of roughly one third that of liquid water. This gaseous (or supercritical) water should be capable of acting as a solvent for some substances.

The major magmatic gases having left their magmatic source and partly condensed to hydrothermal solutions, will change in chemical composition during their progress along ore channels, partly due to fractional precipitation and partly because of reactions between the solution and the wall rock. Hydrothermal differentiation of this type partially explains why the compositions of volcanic emanations varies rather rapidly from place to place and from time to time.

Some authorities postulate that the ore material left the magma originally as liquid aqueous solutions. Since metallic sulphides are extremely insoluble in pure water, but are more or less soluble in alkaline liquids, it has been assumed that these liquids are alkaline from the begining. One of the main criticisms of this theory is the decrease in sulphur solubility with increasing acidity as shown by Vogt. Also, it can be shown that the solubilities of the ore minerals are greater in gases than in liquids.

The dominant factors affecting mineral deposition from gaseous or hydrothermal solutions are chemical changes in the solutions, reactions between the solutions and wall rocks or vein material, and changes in temperature and pressure. Further changes in the deposits may be brought about after deposition has taken place.

As indicated by Wilson and Anderson (1959), the factors controlling ore compositions and metal ratios appear to be;

(1) the initial composition of the magma.

(2) the distribution ratios of the metals (i.e. if the elements are extracted by gaseous or hydrothermal solutions).

(3) the nature of the ore deposition (i.e. conditions at the site of deposition).

The influence of pH, oxidation-reduction potential, and chemical composition of the liquid phases on the partition coefficients of the elements in chemical patterns in ores is not clearly understood at the present time. Much data based on physico-chemical and thermodynamic considerations is required. In general, deposition of metallic elements from hydrothermal solutions should result in varying metal ratios.

The Geochemistry and Distribution of Ag, Au, Cu, Pb, Zn and S

The geochemical distribution of elements is controlled primarily by the structure of the ions or atoms - their size, their valence, and the configuration of their electron shell structures. Goldschmidt's (1937) principles of the distribution of elements in minerals and rocks hold only for ionic compounds. Pauling's rules for determining the nature of possible packing arrangements apply only to ionic compounds, but to a large extent they also are applicable to other compounds with very little modification (Azaroff, 1960, p-83). Notable exceptions are pure metals and organic compounds.

Many pairs of substances with similar structures form either a limited or complete range of solid solution (mixed crystals). Other factors than similar structure are important for the formation of solid solutions. The size of atoms (size factor) must not differ by more than approximately 15% of the radius of the smaller atom and the bonds in the two crystals must be of similar type. In simple ionic crystals, there are similar restrictions (Wells, 1962, p-185).

The distributions of Ag, Au, Cu, Pb, and Zn in silicate minerals, which are primarily ionic, are therefore governed by general empirical rules of crystal chemistry.

Sulphide minerals are characterized by covalent and mixtures of covalent and ionic bonding. Electronegativity differences can be used as a guide to the percentage ionic character of bonds (Wells, 1962,p-33). A comparison of Pauling's electronegativity values for sulphur (2.5) and oxygen (3.5) show that the bonding in binary sulphides has less ionic character than is present in the structurally related oxides (Azaroff, 1960, p-368). Further, the stoichiometric compositions of sulphides do not bear a simple relationship to the number of valence electrons present.

The only ionic sulphides are those of the most electropositive metals, the alkalis and the alkaline-earths. The fact that simple sulphides exhibit such a variety of different structures, often of considerable complexity, is attributed to the essentially homopolar nature of the metal-sulphur bonds in sulphides of elements other than the most electropositive. Such bonds tend to be formed at definite angles to one another and are also limited in number. Further, the semi-metallic properties of many sulphides show that all the bonding electrons are probably not behaving as in simple covalent crystals. All these factors underlie the complexity of the crystal structures of sulphides, and complex sulphides have the additional complication that metal atoms of more than one kind are present, each with individual requirements to be satisfied. A great variety of complex sulphides are found in the mineral world, and comparatively little systematic examination of these compounds has yet been made.

A characteristic of sulphide minerals is that the composition is rarely that of the "ideal" formula, partial replacement of one kind of atom by another being extremely common (Wells, 1962, p-529). For example, ZnS may contain as much as 20% Fe and in the related mineral colusite Zn is partly replaced by Cu, Fe, Mo, and Sn. Isomorphous replacement is common in oxides structures but the relation between atoms capable of replacing one another in oxides is different from that which holds for sulphide structures, a point which illustrates the difference between the types of bonding in the two classes of compounds. In ionic oxides, the possibility of isomorphous replacement depends largely on ionic size, since the ions concerned both have to occupy a hole of a certain size in a lattice of oxygen ions which are usually close-packed or approximately so. In sulphides, on the other hand, the criterion is the formation of a similar number of bonds and we find such atoms as Cu, Mo, Fe, Sn, Ag, and Hg replacing Zn in sphalerite or compounds closely related to it. In crystals exhibiting isomorphous substitution, there is random arrangement of the various metal atoms among the available positions.

Minor and trace amounts of many elements have been reported present in chalcopyrite, e.g. Ag, Au, Pt, Pb, Co, Ni, Mn, Sn, and Zn, replacing Cu or Fe; and As or Se replacing S. For some specimens however, these elements may be present in admixed impurities, for example, As in arsenopyrite, Sn in stannite, and Zn in sphalerite (Deer, Howie, and Zussman, 1962, Vol. 5, p-153).

The minor and trace elements of sphalerite have been studied extensively and there is general agreement that Fe, Mn, Cd, Ga, Ge, In, Co, and Hg all occur in sphalerite substituting for Zn. Cu, Ag, and Sn are also recorded but some of these elements may be present in small inclusions of other minerals (Deer, Howie, and Zussman, 1962, Vol.5, p-168).

The estimation of the extent of substitution of other elements for Pb in galena is often uncertain because many of them may be present in associated minerals. It appears, however, that substitution for Pb in galena is not very extensive. Sb, As, and Bi have all been reported, though some Sb may be present in tetrahedrite, and some of the As in arsenopyrite or sphalerite impurities. Bi occurs together with Ag, both in solid solution in galena and as exsolved matildite. Traces of Au, Pt, Pd, Mo, Ni, and Hg have been recorded. Cd, Fe, Mn, Cu, Sn, and Zn occur but are probably mostly present in associated sphalerite, chalcopyrite, or in other sulphides. It has been concluded that Ag, Bi, Sb, Sn, and Cu do not enter the crystal lattice but occur as microscopic inclusions of other minerals (Deer, Howie, and Zussman, 1962, Vol. 5, p-182).

Modified crystal chemistry principles should also govern the distribution and substitution of many metallic elements in sulphide minerals during crystallization of a sulphide melt. Many sulphide minerals exhibit non-stoichiometric compositions. These compositional variations may be due to admixed minerals or to the direct substitution of foreign elements in the lattices. Substitution or incorporation of foreign elements should be possible if the size of the structural units (atoms or simple ions) is comparable and a similar bond type exists. Ionic and atomic radii of some of the elements are shown in Table I.

Silver

Silver shows definite chalcophile affinities and therefore should exhibit a strong attraction for sulphur.

The silicate minerals constituting the normal igneous rocks contain only very small amounts of silver.

Silver associations in ore deposits appear to be associated with a three-part thermal sequence (Goldschmidt, 1954, p-191):

TABLE 1.

Ionic and Atomic Radii of Elements.

Element	Ionic Radii Å	Tetrahedral Covalent Radii Å	Metallic Radii Å
Ag	1+(1.26) 2+(0.89)	1.53	1.44
Au	1+(1.37) 3+(0.85)	1.50	1.44
Cu	1+(0.96) 2+(0.72)	1.35	1.28
Pb	2+(1.20) 4+(0.84)	1.46	1.75
Zn	2+(0.74)	1.31	1.33 - 1.45
S	2-(1.74)	1.02	1.27
Fe	2+(0.74) 3+(0.64)		1.24

(After L.V.Azaroff, 1960, p-438.)

(1) High temperature magmatic, and high, medium, and low temperature hydrothermal deposits associated with gabbroic magmas.

(2) Hydrothermal deposits associated with residual solutions from more siliceous magmas, such as andesites and phonolites.

(3) Hydrothermal deposits associated mainly with plutonic rocks of the granite family.

Sphalerite, chalcopyrite, and galena appear to be favorable hosts for silver.

Gold

Silicate minerals forming the normal igneous rocks contain only very small amounts of gold.

Occurrences of gold in hydrothermal deposits associated with sulphides and related minerals suggests a chalcophile affinity for gold

(Goldschmidt, 1954, p-197). However, Goldschmidt's investigations clearly show that gold is strongly siderophile. Gold readily accompanies the chalcophile elements copper and silver in the upper lithosphere.

Gold has been found in olivine rocks, peridotites, pyrite-pyrrhotite ore magmas, and in high temperature hydrothermal deposits associated with dacitic and andesitic volcanic rocks, and with diorites, quartz-diorites, granodiorites, and in places, granites. Usually, gold is found in part as the metal and in part combined with Te, Se, Bi, Sb, and Ag (Goldschmidt, 1954, p-198).

Gold and silver, which both have similar atomic radii and crystallize in a face-centered cubic lattice, form a continuous solid solution series (Goldschmidt, 1954, p-200). Similarily, copper and gold also form a continuous series of solid solutions (Edwards, A.B., 1954, p-48).

Silver is found associated with sulphides and tellurides, and gold combines only with tellurides to any extent. Like copper, gold and silver also readily become enriched in sulphides separated during the early stages of magmatic differentiation (Rankama and Sahama, 1950, p-703). In the ease of silver, which is geochemically chalcophile, this behavior is natural. Gold, which is strongly siderophile, may be combined with the chalcophile elements copper or silver.

Pegmatitic and hydrothermal formations are the most characteristic abodes of silver and gold. Native silver is never pure; it usually contains copper, gold, and other metals as impurities. Native gold is also impure; with silver, copper, iron, and the platinum metals being the foremost impurities.

The geochemistry of copper, lead, zinc, and sulphur have been well reviewed by Wilson (1953). In the following paragraphs, brief summaries of the geochemistry and associations of these elements will be noted.

Copper

The ionic and atomic radii of copper are shown in Table I. Copper is strongly chalcophile in character.

In igneous rocks, copper varies inversely with silica. The copper in igneous rocks has usually been observed to be most abundantly present in the form of sulphides, although apparently it may also be concentrated in the silicate minerals (Wager and Mitchell, 1948).

Two types of segregated sulphide magmas have been recognized associated with basic magmatic rocks (Goldschmidt, 1954, p-179). The first type is characterized by pyrrhotite, pentlandite, and chalcopyrite which appear to have separated at high temperatures during the late stages of norite crystallization. The second type of sulphide rock consists mainly of iron pyrite with subordinate chalcopyrite. Sphalerite is often present to the extent of several percent. This second type of sulphide deposit has been formed at lower temperatures than the first, several independent criteria suggesting the high hydrothermal range. Copper ores are sometimes associated with pyro-metasomatic deposits which grade continuously into hydrothermal veins and zones of impregnation.

Zinc

The ionic and atomic radii of zinc are shown in Table I. Geochemically, zinc exhibits both lithophile and chalcophile affinities. The silicate geochemistry of zinc is mainly determined by the similarity of radii between divalent zinc and the metals of the magnesium-iron group, especially Fe^{2+}. In silicate crystal structures and in sphalerite, zinc tends strongly to tetrahedral coordination. The structural arrangement in chalcopyrite is very similar to that of sphalerite.

The distribution of zinc in silicate rocks is still contradictory to some extent. Wedepohl (1953) however found that zinc was most concentrated in gabbro (basalt, diabase), peridotite, and pyroxenite, with lesser amounts in intermediate and acid rocks. Most major ore deposits of zinc are of the hydrothermal replacement type where zinc is present as zinc sulphide which may be associated with copper, lead, silver and gold.

Zinc also occurs to some extent in copper-nickel deposits but the relative concentration is much less than that of nickel and copper. Kilburn (1960, p-134) has shown that many Zn-rich ores are not associated as closely with igneous rocks as Cu and Cu-Zn-rich varieties, and that lead-ores commonly occur in areas where igneous rocks do not outcrop. Many Cu-rich and Cu-Zn-ores are closely associated with intermediate to acidic igneous rocks.

Lead

The ionic and atomic radii for lead are given in Table I. The geochemistry of lead in the minerals and rocks of the upper lithosphere is dominated by its properties both as a chalcophile and as a lithophile element (Goldschmidt, 1954, p-398). As a chalcophile element it is found mostly as the sulphide galena, and in related compounds with selenium and tellurium, where it is highly concentrated in hydrothermal deposits.

Lead is also a lithophile element occurring in a large number of rock-forming minerals. Its ionic radius makes it possible for lead to replace diodochically such elements as strontium, barium, potassium, and even calcium. Therefore, lead may be present in potassium feldspars, in which it replaces potassium. Geochemically, the distribution of lead in magmatic rocks is generally controlled by the laws of crystal chemistry whereby lead ions are concentrated in potassium minerals, especially the early crystallizates. The concentration of lead during crystallization processes, follows rather closely that of potassium. As potassium follows silicon rather closely in the main line of evolution of magmatic rocks, so silicon, potassium, and lead are concentrated in residual magmas (Goldschmidt, 1954, p-400). As lead is usually a very minor element in basic rocks, its concentration in residual magmas derived from basic magmas should never be very large.

Sulphur

As sulphur may exist in volatile form or separate as an immiscible liquid, its distribution in igneous rocks is very complex. The solubility of sulphur in rocks and magmas is difficult to determine as both dissolved and suspended sulphides must be considered. Vogt (1918) determined the sulphur solubility in slags considering dissolved and suspended sulphides separately. Wilson (1953) has plotted Vogt's results and it is apparent from the graphical spread of the points, that sulphide solubility differs in slags of different composition but all follow the same tendency of lower sulphide solubility with higher silica. It is probable, therefore, that sulphur solubility decreases with increasing silica content of magmas and that the relative solubility in magma is similar to that in slag. Thus, in magmas with a low silica content, large amounts of sulphide should separate from a fractionally crystallizing magma, providing sufficient sulphur is present. Experimental and field evidence clearly indicate that an immiscible sulphide liquid can separate from a basic silicate magma during fractional crystallization. This magmatic sulphide is apparently enriched in the chalcophile elements concentrated in the basic and ultrabasic silicate magmas, that is Ni, Cu, and Co. The minor metallic elements present in the basic magma, such as Pb, Zn, Au, and Ag are also present in this sulphide liquid, but tend to concentrate and become enriched in later magmatic liquids and hydrothermal fluids.

CHAPTER III

METHODS OF STUDY

General Statement

The distribution of metallic elements has been reviewed in the foregoing pages with respect to theoretical considerations. The following sections contain the results of a study of the relationships between the base metals copper, lead, and zinc and the precious metals gold and silver in Canadian base metal deposits in general, and more specifically in the following three deposits:

1. The Vermilion Lake Mine of Consolidated Sudbury Basin Mines Limited.
2. Geco Mines Limited.
3. The Flin Flon Mine of Hudson Bay Mining and Smelting Company Limited.

Assay data utilized in the study were collected from Canadian publications covering fifty-two deposits in general and from the assay files of the three mines listed above. It is hoped that this study will establish the existence of proportional relationships which will be applicable to all such deposits.

A brief description of the statistical methods employed in evaluating this data is given on the following pages.

Assay Data Evaluation by Statistical Methods

Canadian Base Metal Deposits in General. The sampling must be random and a sufficient number of assays must be considered in the distribution if the distribution characteristics are to be indicative of the ore deposits as a whole. In this study, the following metallic distributions are considered:-

(1) the distribution of gold and silver with each of the base metals present in the deposit.

(2) the distribution of the base metals with respect to each other in the deposit.

The obvious method of determining these relationships is by a statistical evaluation of the assay data.

The median value was used throughout whenever an average value was required.

The Median

The median is the value of the middle item when the items are arranged according to magnitude. It is an average position.

The median was computed from data by interpolation. The number of desired items was first determined by N/2 where N= the number of items (assays). The enterpolation for the median value was then calculated using the following equation:

$$\text{Median} = L + \frac{i}{f} c$$

where L = value of the lower limit of the class interval containing the median assay determined by N/2.

C = class interval or the difference between the upper and lower limits as indicated in the grouping of the data.

i = number of assays required within the group.

f = total number of assays within the group.

The characteristics of the median are such that the median is affected only by the number of assays, not by the magnitude of the extreme values (i.e. it is an average of position).

Advantages of the median are:

(1) It is easily calculated from grouped data.

(2) It is not distorted in value by unusual assays and is therefore more typical of the series because of its independence of unusual value.

The principal disadvantages are that the data must be grouped or arranged according to magnitude before the median can be computed, and also that it possesses larger standard and probable errors than the arithmetic mean.

Grouping of Assay Data

Use of the median requires that all data must be grouped according to size or magnitude. The base metal percent may be used as a base for this grouping and the variation of the precious metal value determined with increases in base metal content, or conversely, the precious metal content may be used as the base and the variation of base metal content determined with increases in precious metal content. In general, the variation in gold and silver values has been determined with respect to increases in base metal content. The major portion of the graphical work has been carried out on an arithmetic base and the base metal value has been used as the independent variable.

It is first necessary to arrange or group the data systemmatically in order to analyze numerical data. The data may be arranged in a number of ways. Technically, such an arrangement is known as a "distribution or series". When the data is grouped according to magnitude, the resulting series is called a "frequency distribution". In this thesis, the median was calculated for each class interval of the independent variable in a multicolumn frequency distribution table.

Graphical representation has been shown by the following:

(1) line or curve graphs on arithmetic ruling.

(2) line or curve graphs on semi-logarithmic or logarithmic ruling.

(3) histograms or rectangular frequency polygons.

(4) Logarithmic frequency percentage cumulative curves on a semi-logarithmic base.

Unless otherwise specified, all graphs have been plotted on an arithmetic base.

CHAPTER IV

THE DISTRIBUTION OF GOLD AND SILVER IN CANADIAN BASE METAL DEPOSITS

General Statement

The assembled base metal assays were converted to weight percent values assuming that these metal values equalled 100% for plotting on triangular Cu-Pb-Zn diagrams. The converted weight percent value for Cu, Pb, and Zn were also changed to atomic percent by dividing by the atomic weights of the elements. Assay values for gold and silver were converted from oz/ton to parts per million (ppm) and to atomic proportions. Where used in this study, the atomic proportions of Au and Ag were multiplied by the same factor (atomic factor) as that used to convert the base metal weight percent values to atomic precent for each deposit. This was done to give the precious metals the approximate same order of magnitude as the copper, lead, and zinc atomic percent values.

The data was compiled and tabled (Table 2) and the following triangular diagrams were constructed:

a. Cu-Pb-Zn (weight %) combined with Au (ppm).

b. Cu-Pb-Zn (weight %) combined with Ag (ppm).

c. Cu-Pb-Zn (weight %) combined with $\frac{Ag}{Au}$ (oz/ton).

d. Cu-Pb-Zn (weight %) combined with $\frac{Au}{Ag}$ (1000) (oz/ton).

e. Cu-Pb-Zn (atomic %) combined with Au (atomic proportion X atomic factor).

f. Cu-Pb-Zn (atomic %) combined with Ag (atomic proportion X atomic factor).

g. Cu-Pb-Zn (atomic %) combined with $\frac{Ag}{Au(1000)}$ (atomic proportions) x atomic factor.

Base metal values were plotted on the triangular diagrams and the precious metal values, convential or atomic, were entered with their corresponding base metal values. These precious metal values were contoured after obtaining the median value contained in a hexagon having an area of about 1/25 of that of the triangular diagram. Area centers are shown on the diagrams with the median values obtained.

Results of the Study

The results of this portion of the study are shown in Table 2 and illustrated in Figures 1 to 7 inclusive. Figure 8 has been includ to indicate the silica contents of igneous rocks (after Wilson and Anderson, 1959). The triangular diagram (Figure 1), illustrating the possible relation between Cu-Pb-Zn (weight percent) and Au (ppm) shows a concentration of higher Au values toward the Cu-Zn-side of the diagram. Very similar results were obtained in Figure 4 which illustrates the possible relation between Cu-Pb-Zn (weight percent) and the ratio $\frac{Au}{Ag}$ (oz/ton x 1000), and in Figure 5 which illustrates the possible relation between Cu-Pb-Zn (atomic percent) and Au (atomic proportion x atomic factor). Comparing these three figures with the silica contours in Figure 8, it will be noted that the higher Au values appear to be associated with a low silica content in igneous rocks. In figure 1 and 4, the small high occuring along Pb-Zn side has been attributed to an erratic value, possibly

TABLE 2

COMPOSITIONS OF CANADIAN BASE METAL DEPOSITS																				
1 NO.	2 PROPERTY NAME	3 CU	4 PB	5 ZN	6 AU	7 AG	8 AU	9 AG	10 AG/AU	11 AU/AG	12 CU	13 PB	14 ZN	15 CU	16 PB	17 ZN	18 Atomic Factor	19 AU	20 AG	21 AG/AU
1	BERENS RIVER MINE	—	0.63	0.57	0.24	7.82	8	268	33	0.033	—	52.5	47.5	—	25.6	74.4	8593	355.5	213.6	516
2	FRONTENAC LEAD MINE	—	4.2	0.3	—	0.22	—	0.8	∞	0	—	93.3	6.7	—	81.5	18.5	4015	—	2.8	∞
3	GECO MINES LTD.	1.76	—	3.75	—	1.74	—	60	∞	0	31.9	—	68.1	32.5	—	67.5	1173	—	6.5	∞
4	NAMA CREEK MINES	1.05	—	3.44	—	0.01	—	0.3	∞	0	23.4	—	76.6	23.9	—	76.1	1448	—	—	0
5	OILMAN PROPERTY	—	1.45	7.28	—	8.27	—	284	∞	0	—	16.6	83.4	—	5.8	94.2	8405	—	21.9	∞
6	PENN COBALT MINE	0.5	1.50	3.00	—	0.75	—	26	∞	0	10.0	30.0	60.0	12.9	11.8	75.3	1633	—	4.3	∞
7	SILVER CHIEF MINE	1.10	4.20	—	—	6.60	—	263	∞	0	20.7	79.3	—	46.0	54.0	—	2660	—	56.7	∞
8	ERRINGTON MINE	1.02	0.75	3.24	0.017	1.49	0.6	51	87	0.011	20.4	15.0	64.6	23.3	5.2	71.5	1447	4.3	6.8	227
9	VERMILION LAKE MINE	1.43	1.10	4.56	0.02	1.78	0.7	61	89	0.011	20.2	15.5	64.3	23.1	5.4	71.5	1027	3.6	5.8	167
10	VACHERESSE PROPERTY	0.03	0.19	6.76	—	0.18	—	6	∞	0	0.5	2.7	96.8	0.5	0.9	98.6	941	—	0.6	∞
11	WHITE RIVER PROPERTY	1.00	7.60	—	—	2.30	—	79	∞	0	11.6	88.4	—	30.0	70.0	—	1911	—	14.0	∞
12	WILLROY MINE	1.09	0.25	6.49	0.003	2.34	0.1	80	936	0.001	13.9	3.2	82.9	14.6	1.0	84.4	850	0.4	6.3	1258
13	CONIAGUS MINE	—	1.04	15.7	—	8.77	—	301	∞	0	—	6.3	93.7	—	2.0	98.0	400	—	11.3	∞
14	EAST SULLIVAN MINE	1.18	—	0.74	0.009	0.40	0.3	14	44	0.022	61.4	—	38.6	62.2	—	37.8	3344	5.0	4.3	291
15	MATTAGAMI SYNDICATE	0.65	—	13.5	0.016	1.11	0.5	38	69	0.014	4.6	—	95.4	4.7	—	95.3	462	1.2	1.6	65
16	MAYBRUN MINE	0.69	—	2.18	0.52	0.62	18	21	1.2	0.84	24.1	—	75.9	24.7	—	75.3	2262	204	4.5	4
17	NEW CALUMET MINE	—	1.50	6.19	0.015	3.18	0.5	109	212	0.005	—	19.5	80.5	—	7.1	92.9	982	2.5	9.9	397
18	ORCHAN MINE	0.54	—	7.67	0.016	1.25	0.5	43	78	0.013	6.6	—	93.4	7.7	—	92.3	795	2.0	3.2	127
19	PANET METALS	0.40	0.43	2.67	0.06	0.58	2	20	10	0.010	11.4	12.4	76.2	12.8	4.3	82.9	2032	20.5	3.9	39
20	QUEMONT MINE	1.33	0.02	2.77	0.176	1.12	6	38	6	0.16	32.3	0.50	67.2	33.0	0.2	66.8	1580	48.0	5.5	19
21	SUFFIELD MINE	1.28	0.59	6.45	0.018	2.40	0.6	82	133	0.008	15.4	7.1	77.5	16.6	2.3	81.1	822	2.5	6.2	208
22	UNGAVA COPPER	1.40	—	1.80	0.06	—	2	—	0	∞	43.7	—	56.3	44.4	—	55.6	2020	20.4	0	0
23	VENDOME MINE	0.47	0.34	7.30	0.034	1.63	1	56	48	0.021	5.8	4.2	90.0	7.0	1.5	91.5	945	5.8	3.3	80
24	WAITE AMULET MINE	4.90	0.04	3.90	0.03	0.93	1	32	31	0.032	55.4	0.5	44.1	56.4	0.1	43.5	729	3.6	2.2	44
25	WEEDON PYRITE MINE	1.25	—	0.55	0.002	0.212	1	7	106	0.009	69.4	—	30.6	70.1	—	29.9	3559	1.1	2.1	712
26	BATHURST M. & S.	0.52	2.28	5.61	—	1.92	—	66	∞	0	6.2	25.9	66.7	7.8	10.5	81.7	951	—	5.8	∞
27	BRUNSWICK M. & S.	0.45	2.00	5.30	—	1.70	—	58	∞	0	5.8	25.8	68.4	7.2	9.9	82.9	1014	—	5.5	∞
28	HEATH STEEL MINE	1.30	1.20	3.50	0.02	0.02	0.7	0.7	1	1	21.6	20.0	58.4	25.6	7.3	67.1	1253	4.4	0	0
29	HEATH STEEL MINE	1.10	2.90	7.10	1.90	3.20	65	110	1.6	0.59	9.9	26.1	64.0	12.4	10.0	77.6	715	236.4	7.3	2
30	KEYMET MINE	0.55	4.41	4.31	—	1.42	—	49	∞	0	5.9	47.6	46.5	9.0	22.0	69.0	1034	—	4.6	∞

TABLE 2 (CONTINUED)

1 NO.	2 PROPERTY NAME	3 CU	4 PB	5 ZN	6 AU	7 AG	8 AU	9 AG	10 $\frac{AG}{AU}$	11 $\frac{AU}{AG}$	12 CU	13 PB	14 ZN	15 CU	16 PB	17 ZN	18 Atomic Factor	19 AU	20 AG	21 $\frac{AG}{AU}$
31	NEW CALUMET MINE	0.20	3.20	7.13	0.017	2.52	0.6	86	148	0.007	1.9	30.4	67.7	2.4	12.1	85.5	784	2.4	6.3	209
32	ST. STEPHEN MINE	0.90	—	0.10	0.01	0.25	0.3	9	25	0.04	90.0	—	10.0	90.4	—	9.6	6369	9.5	5.1	338
33	STURGEON RIVER MINE	—	2.28	3.30	—	3.20	—	110	∞	0	—	40.9	59.1	—	17.9	82.1	1627	—	16.6	∞
34	CUPRUS MINE	3.25	—	6.40	0.038	0.84	1	29	22	0.045	33.7	—	66.3	34.4	—	65.6	671	4.4	1.8	33
35	FLIN FLON MINE	3.21	—	3.60	0.067	0.96	2	33	14	0.07	47.1	—	52.9	47.9	—	52.1	947	11.1	2.8	25
36	SNOW LAKE (H.B.M.&S.)	1.37	0.70	8.70	0.051	1.51	2	52	34	0.034	12.7	6.5	80.8	13.7	2.2	84.1	633	5.4	3.0	35
37	SHERRITT GORDON	2.14	—	0.87	0.012	0.378	0.4	13	32	0.032	71.1	—	28.9	71.7	—	28.3	2127	4.3	2.5	128
38	SHERLYNN MINE	2.63	—	1.21	0.06	—	2	—	0	∞	68.5	—	31.5	69.1	—	30.9	1669	17.7	0	0
39	PARAMOUNT MINE	0.55	—	4.70	0.003	0.16	1	5	53	0.019	10.5	—	89.5	10.8	—	89.2	1240	0.6	0.6	124
40	WESTORE MINE	0.61	—	6.10	0.003	0.21	1	7	70	0.014	9.1	—	90.9	9.3	—	90.7	971	0.5	0.6	117
41	GIANT MASCOT MINE	0.037	3.32	0.318	—	0.645	—	22	∞	0	1.0	90.3	8.7	2.8	74.4	22.8	4650	—	9.3	∞
42	SHEEP CREEK MINE	—	5.0	9.20	—	4.60	—	158	∞	0	—	35.2	64.8	—	14.6	85.4	606	—	8.9	∞
43	SHEEP CREEK MINE	0.031	1.12	3.67	—	0.304	—	10	∞	0	0.7	23.2	76.1	0.8	8.7	91.5	1611	—	1.5	∞
44	SILBAK PREMIER MINE	—	1.80	2.70	0.28	2.80	10	96	10	0.10	—	40.0	60.0	—	17.4	82.6	2000	97.4	17.8	36
45	SILVER STANDARD MINE	0.112	7.40	7.90	—	49.5	—	1697	∞	0	0.7	48.0	51.3	1.1	22.3	76.6	635	—	99.8	∞
46	MABRUN MINE	0.69	—	2.18	0.052	0.62	2	21	12	0.084	24.1	—	75.9	24.6	—	75.4	2262	20.6	4.3	48
47	NEW CALUMET MINE	—	2.57	8.72	0.021	5.34	0.7	183	254	0.004	—	22.8	77.2	—	8.5	91.5	686	2.4	11.5	327
48	MATTAGAMI LAKE MINE	0.68	—	12.76	0.018	1.31	0.6	45	73	0.014	5.1	—	94.9	5.2	—	94.8	487	1.5	2.0	68
49	HASTING MINING CO.	3.81	0.59	3.53	0.023	1.35	0.8	46	59	0.017	48.0	7.5	44.5	51.3	2.4	46.3	856	3.4	3.7	92
50	CONSOLIDATED VAUZE	6.00	—	4.70	0.054	2.20	2	75	40	0.024	56.1	—	43.9	56.8	—	43.2	601	5.8	4.2	44
51	BARVALLEE MINE	1.23	—	5.71	—	1.42	—	49	∞	0	17.7	—	82.3	18.1	—	81.9	938	—	4.2	∞
52	NEW LARDER U MINE	—	3.26	7.74	—	3.00	—	69	∞	0	—	29.6	70.4	—	11.7	88.3	745	—	6.9	∞

Column 3-ORE GRADE ASSAY, CU (WEIGHT %).
" 4- " " " , PB " " .
" 5- " " " , ZN " " .
" 6- " " " , AU (OZ / TON).
" 7- " " " , AG " " .
" 8- " " " , AU (PPM).
" 9- " " " , AG " .
" 10- RATIO AG / AU (OZ / TON).
" 11- " AU (1000) / AG (OZ / TON).

Column 12-CU ASSAY REDUCED TO 100 WEIGHT %.
" 13-PB " " " " " " .
" 14-ZN " " " " " " .
" 15-REDUCED CU ASSAY CONVERTED TO ATOMIC %.
" 16- " PB " " " " " .
" 17- " ZN " " " " " .
" 19-AU (ATOMIC PROPORTION)(10,000)(ATOMIC FACTOR).
" 20-AG (ATOMIC PROPORTION)(100)(ATOMIC FACTOR).
" 21-RATIO $\frac{AG}{AU(1000)}$ (ATOMIC PROPORTION)(ATOMIC FACTOR).

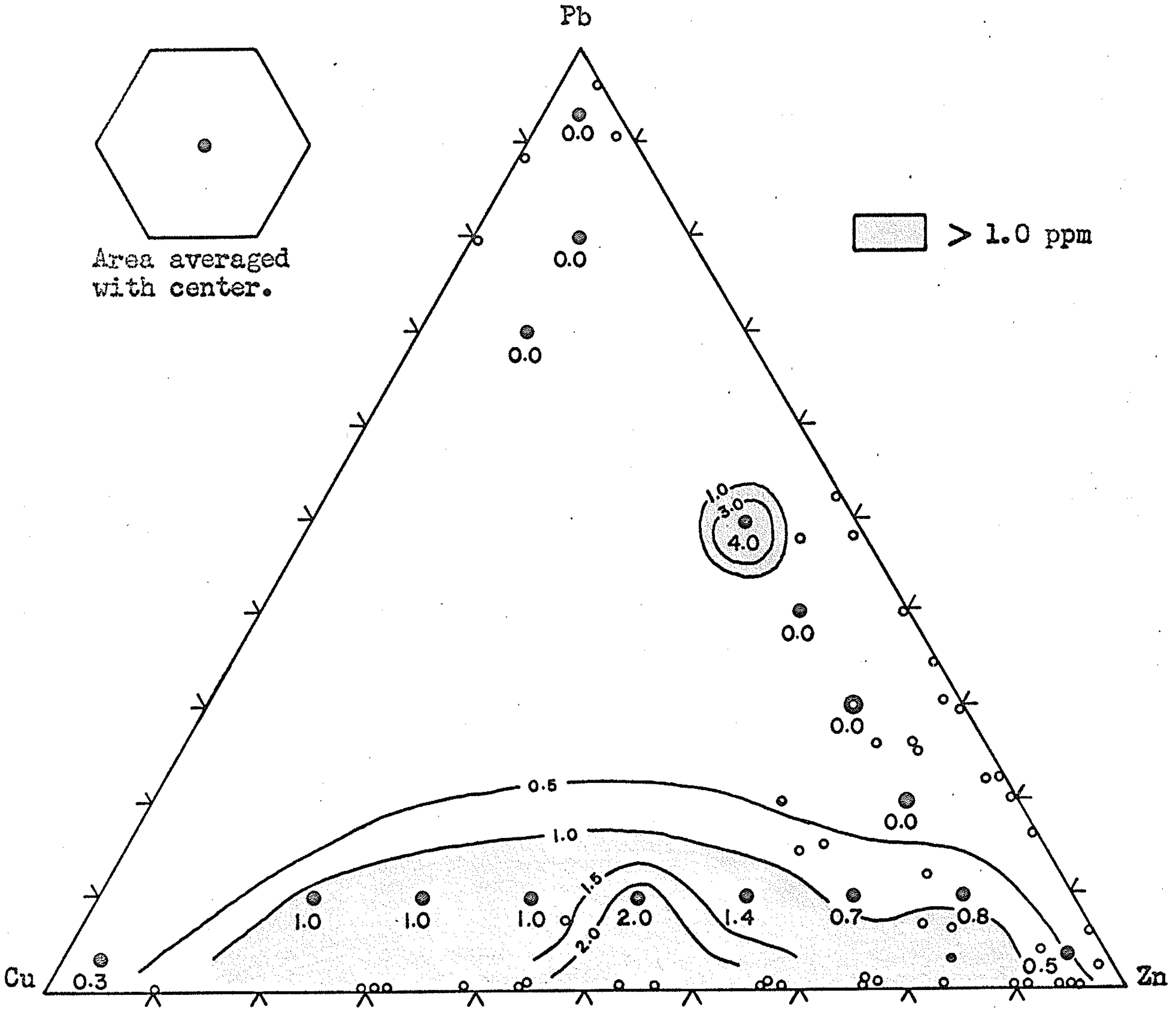

Figure 1. Copper-lead-zinc ratios (weight percent) in some Canadian ore deposits showing median value contours for the respective gold content (ppm) in each deposit.

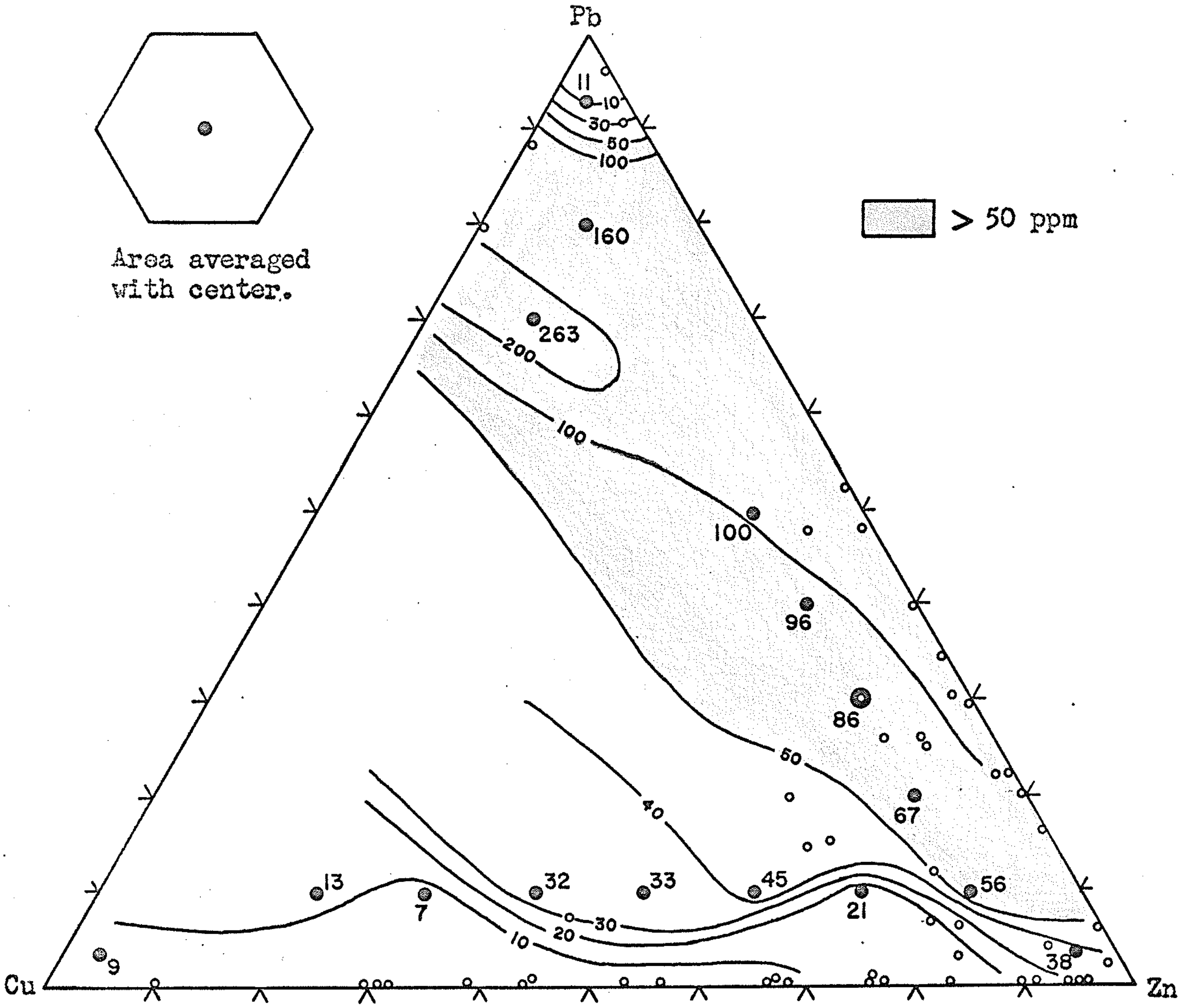

Figure 2. Copper-lead-zinc ratios (weight percent) in some Canadian ore deposits showing median value contours for the respective silver content (ppm) in each deposit.

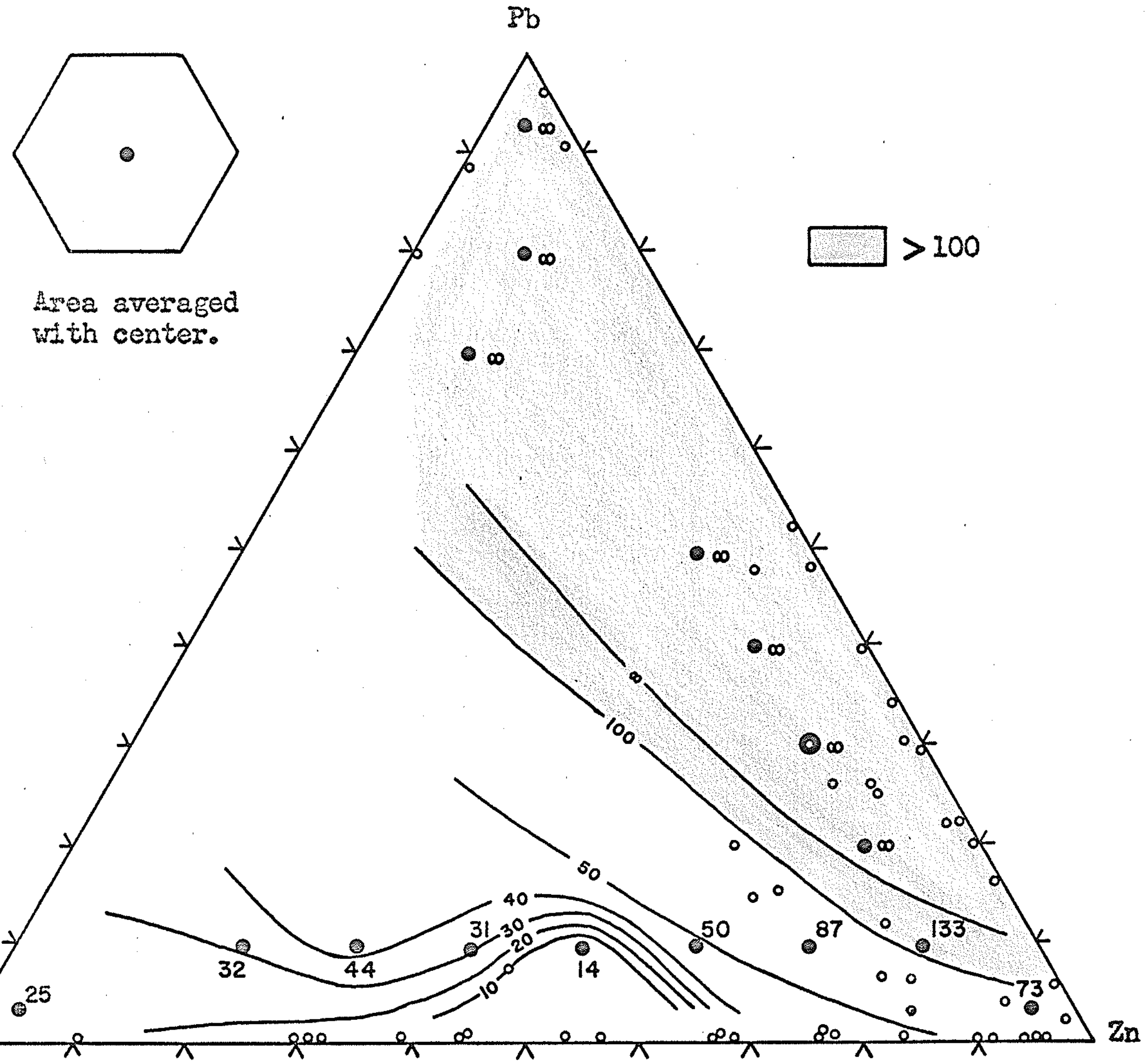

Figure 3. Copper-lead-zinc ratios (weight percent) in some Canadian ore deposits showing median value contours for the respective Ag/Au ratio (oz./ton) in each deposit.

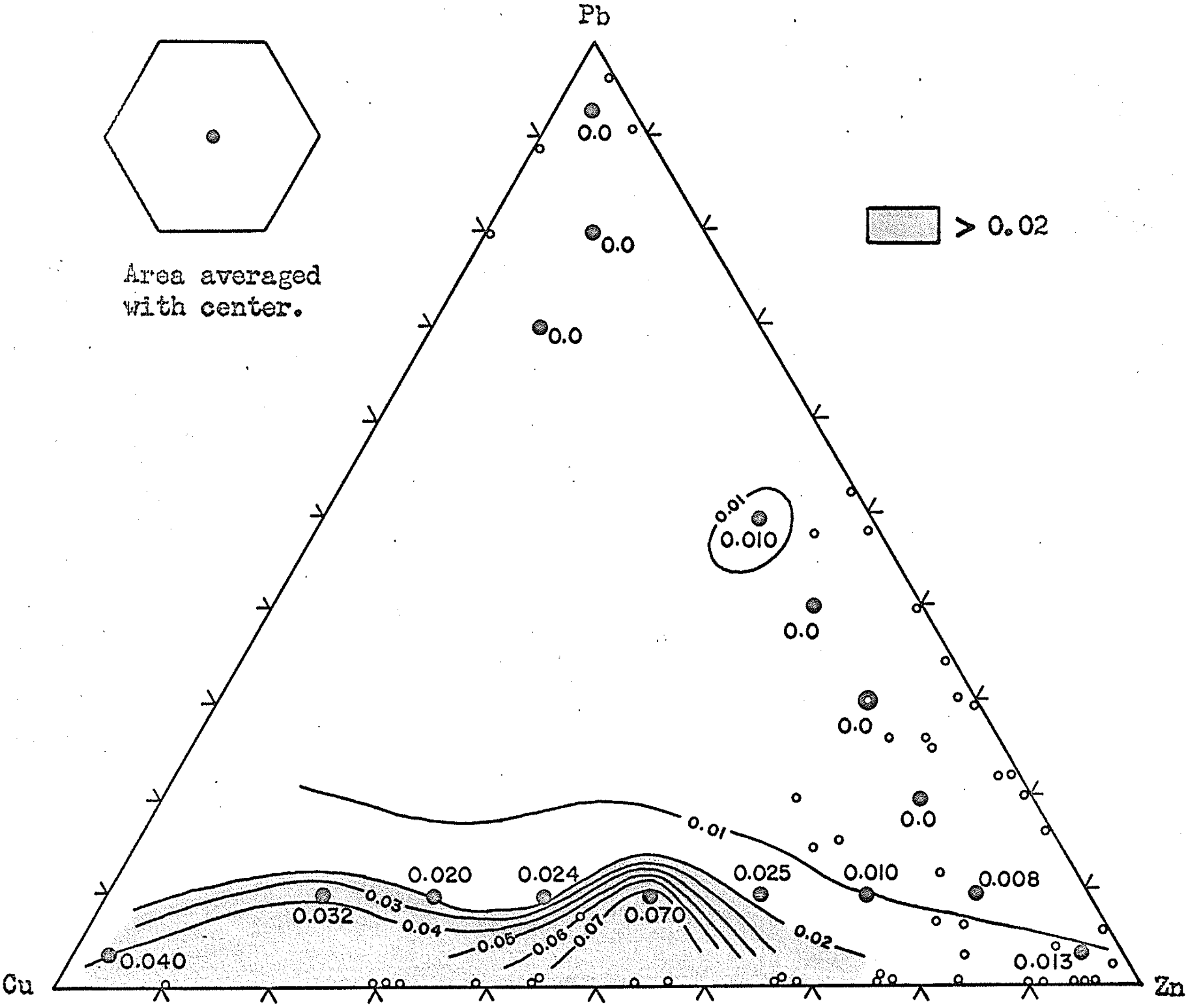

Figure 4. Copper-lead-zinc ratios (weight percent) in some Canadian ore deposits showing median value contours for the respective Au/Ag ratio (oz./ton) in each deposit.

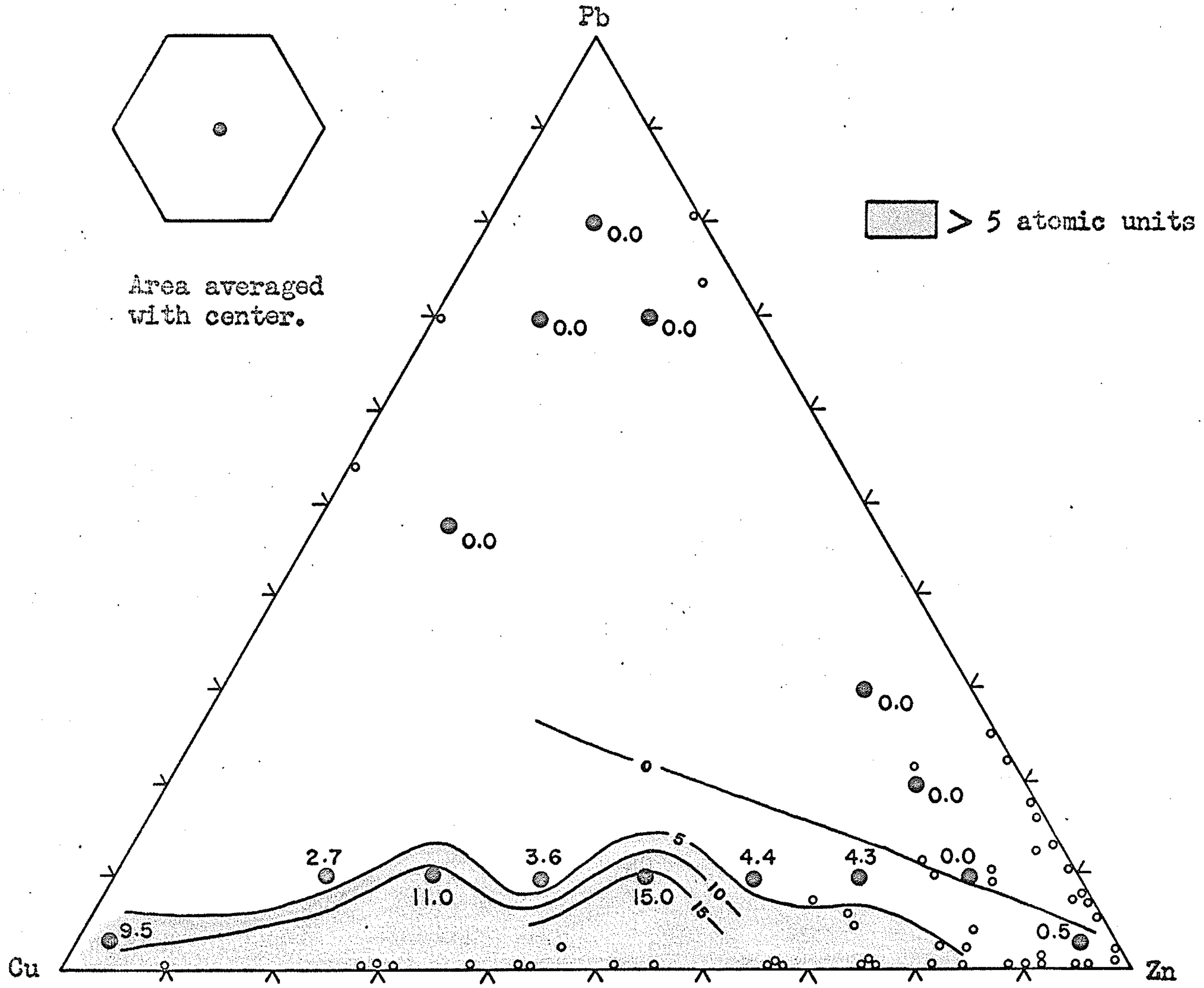

Figure 5. Copper-lead-zinc ratios (atomic percent) in some Canadian ore deposits showing median value contours for the respective gold content (atomic proportion X atomic factor) in each deposit.

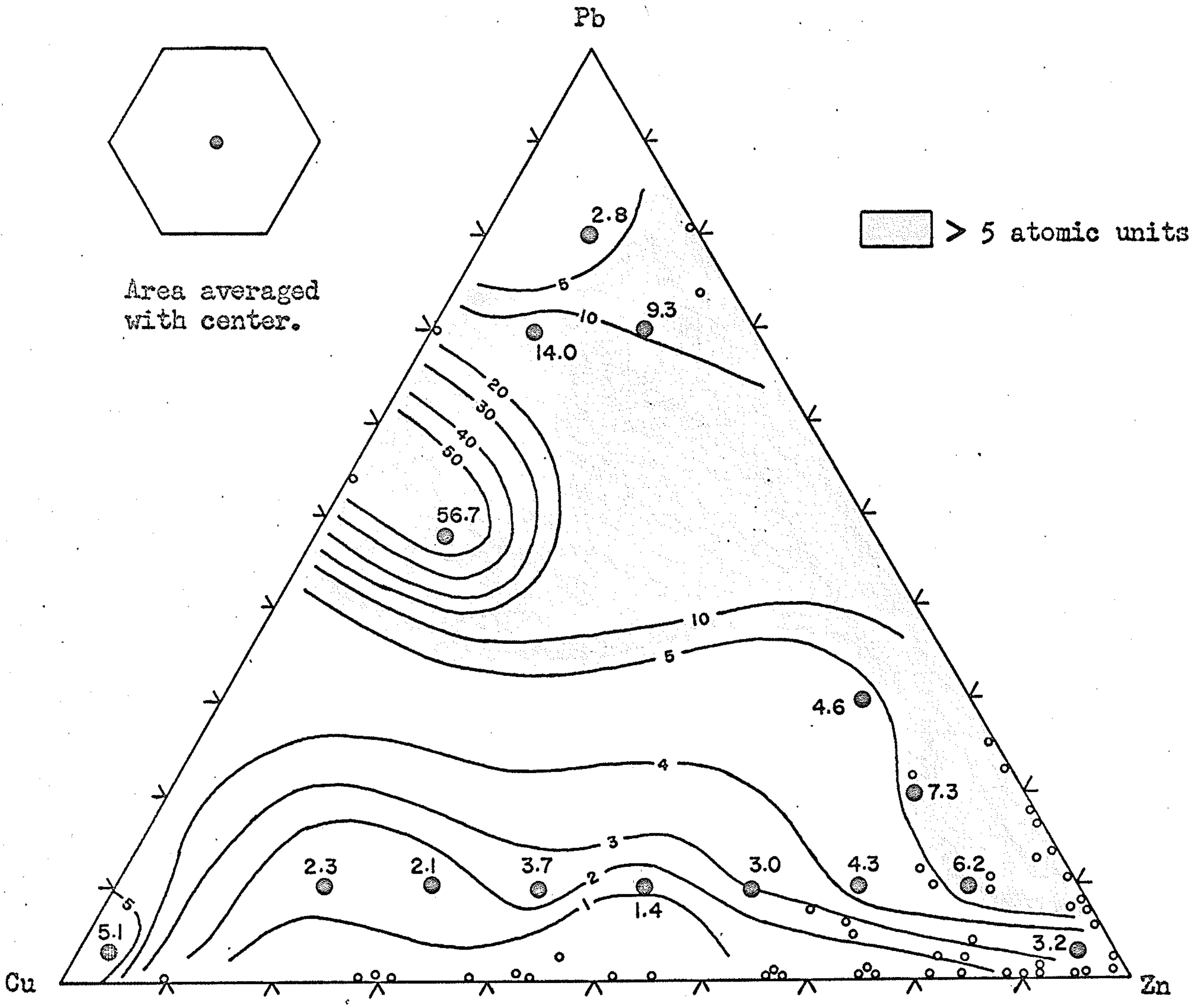

Figure 6. Copper-lead-zinc ratios (atomic percent) in some Canadian ore deposits showing median value contours for the respective silver content (atomic proportion X atomic factor) in each deposit.

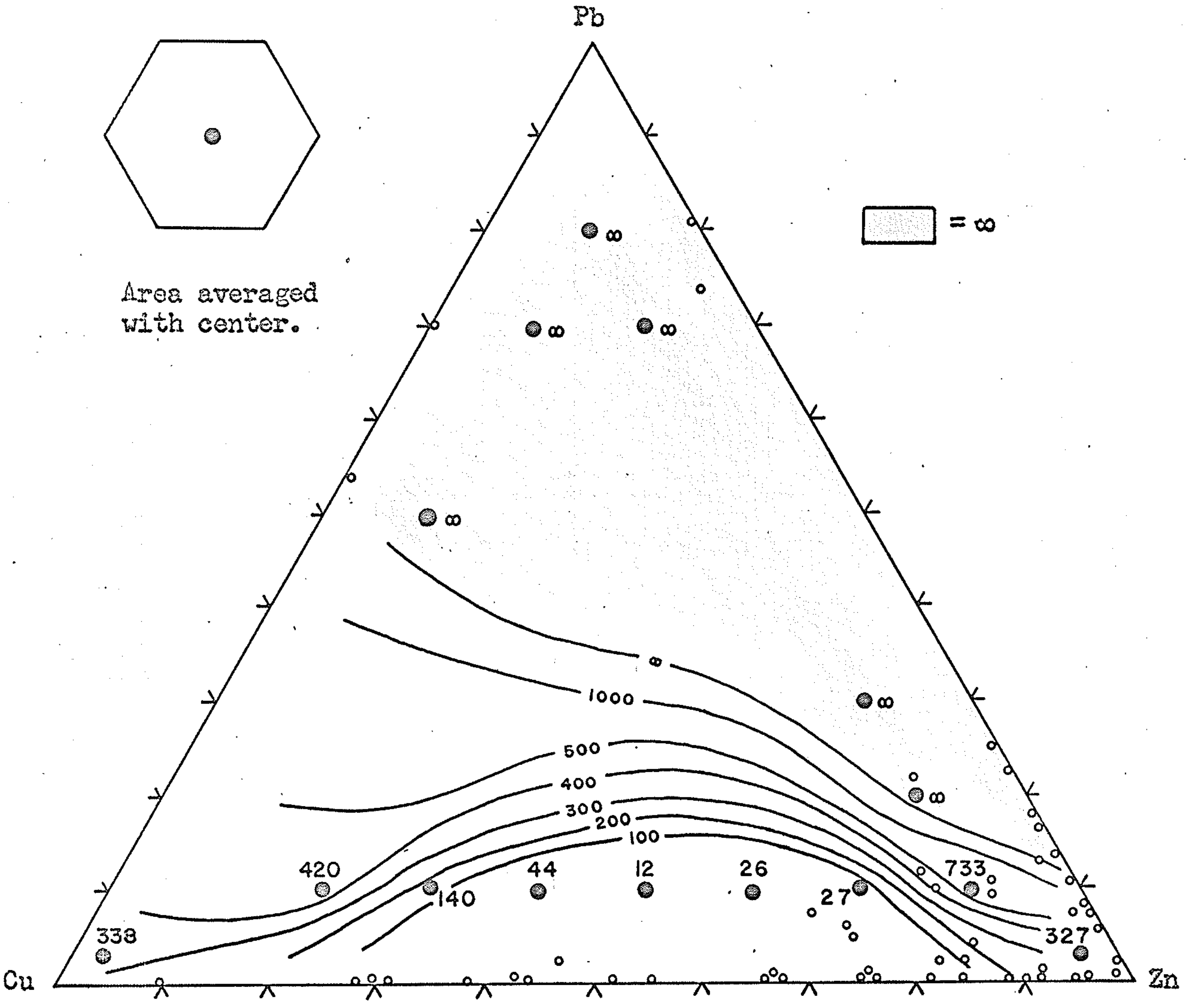

Figure 7. Copper-lead-zinc ratios (atomic percent) in some Canadian ore deposits showing median value contours for the respective Ag/Au ratio (atomic proportion X 1000 X atomic factor) in each deposit.

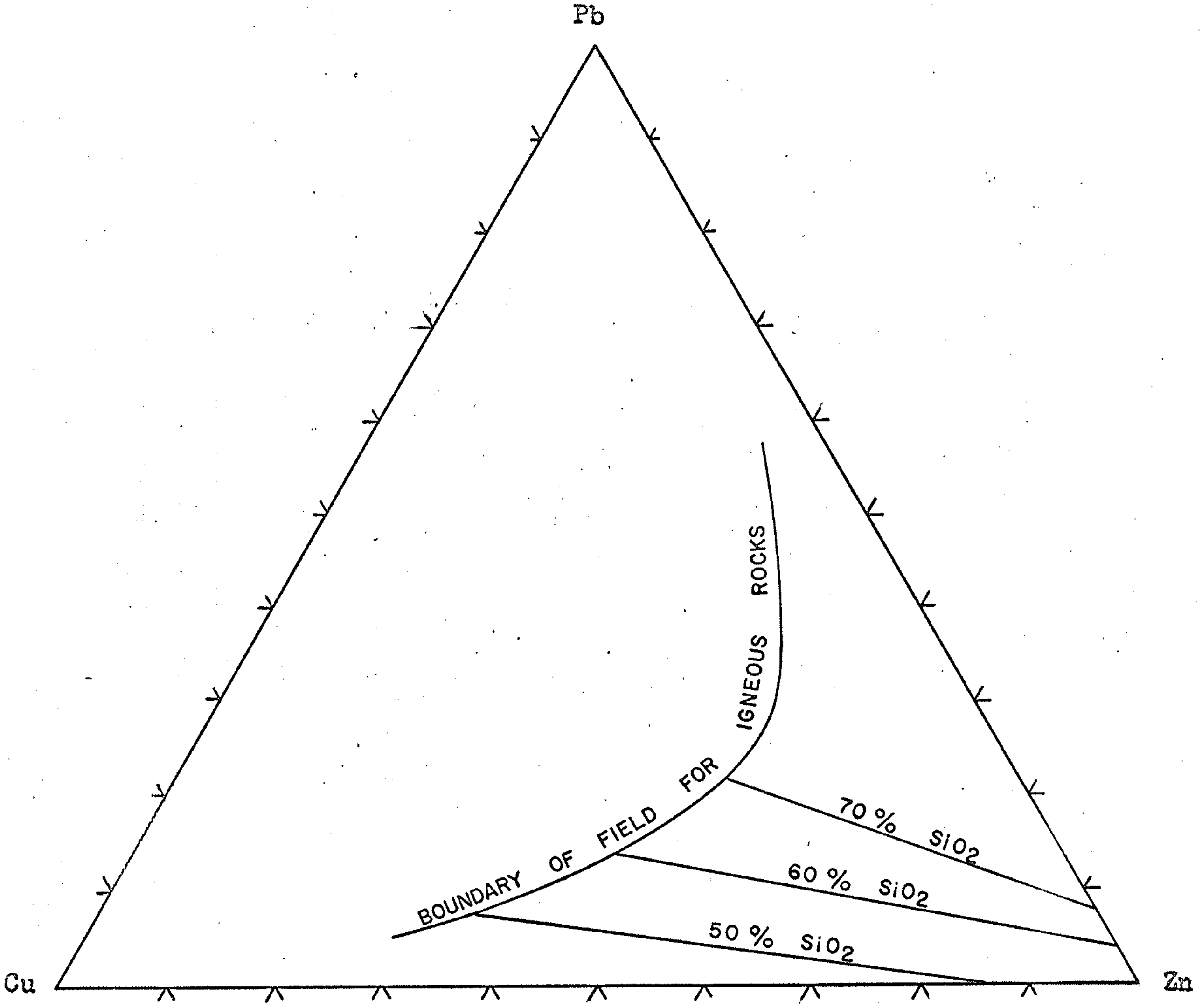

Figure 8. The field of copper-lead-zinc ratios in igneous rocks. The approximate percentage of silica in the igneous rocks is shown by contour lines. After Wilson and Anderson (1959).

due to another phase of mineralization.

The triangular diagram (Figure 2) illustrating the possible relation between Cu-Pb-Zn (weight percent) and Ag (ppm) shows a concentration of Ag values along the Pb-Zn side of the diagram with a peaking towards the Pb end. Comparison of Cu-Pb-Zn (weight percent) and the ratio $\frac{Ag}{Au}$ (oz/ton) (Figure 3) also gives a similar trend with the higher ratio values, generally lone Ag, occurring along the Pb-Zn side. In Figure 6, which illustrates the possible relation between Cu-Pb-Zn (atomic percent) and Ag in atomic proportions (multiplied by atomic factor), a general concentration of high Ag values occur along the Pb-Zn side. Several erratic values are present, but again, these appear to be due to a second phase of mineralization or to a high gold content in the silver. Similar results are obtained when Cu-Pb-Zn (atomic percent) is arranged against the ratio $\frac{Ag}{Au}$ (atomic proportion multiplied by atomic factor), where again the concentration of high Ag values is along the Pb-Zn side of the diagram with a general peaking near the Pb end. Comparison of Figures 2, 3, 6, and 7 with the silica contours in Figure 8 indicates a possible association of high silver values with high silica content in igneous rocks.

Discussion of Results

The limited amount of data show that gold and silver are preferentially distributed between the combinations Cu-Zn and Pb-Zn respectively. Higher gold values are associated with Cu-Zn ore deposits containing minor amounts of Pb, and high silver values are associated with Pb-Zn ore deposits which contain minor amounts of Cu. Comparison of these trends (Figures

1 to 7) to the diagram illustrating the silica contents of igneous rocks on a Cu-Pb-Zn diagram (Figure 8) suggests that the high gold values are associated with lower silica rocks. Geochemical studies on the distributions of gold and silver in igneous rocks is generally lacking, and the limited data does not show any significant concentration of gold or silver in any igneous rock type (Goldschmidt, 1954). Thus, the distributions of these metals in ore deposits may be an indirect method of determining the concentration of gold and silver in an associated igneous rock.

In the chapter on theoretical considerations, it was shown that the elements Cu, Zn, Pb, Au, and Ag should be preferentially enriched in the immiscible sulphide liquid during fractional crystallization of a basic magma containing these metallic elements. When the solid silicate phase has the composition of a diorite, the sulphides crystallizing from the sulphide liquid should be mainly Cu and Zn accompanied by Au and Ag. Continued differentiation of the silicate-sulphide liquids would result in the crystallization of igneous rocks containing higher silica and Pb-Zn sulphides accompanied by remaining Ag. The present distribution study suggests that the largest portion of the Au is removed during crystallization of the Cu-Zn sulphides and that the Ag is removed during the crystallization of both Cu-Zn and Pb-Zn sulphides and is generally the only precious metal present in the Pb-Zn stage. Similar effects might be expected if a highly volatile phase resulted rather than an immiscible sulphide liquid.

The nature of the precious metal association must await further research into the problem of the state of occurrence of these elements, especially for gold. Investigations are required to determine if the gold is present in the native state or incorporated in an accompanying sulphide mineral.

CHAPTER V

THE DISTRIBUTION OF METALS IN THREE CANADIAN BASE METAL DEPOSITS

Results of the Distribution Studies

1. The Vermilion Lake Mine of Consolidated Sudbury Basin Mines Limited, Sudbury District, Ontario.

This mining property is located in Northern Ontario and lies near the southwest end of the Sudbury Basin. All rocks in the vicinity of the mine area are of Precambrian age. The mine area is underlain by sedimentary and tuffaceous rocks which have been complexily folded and faulted. The main rock types are volcanic fragmentals and tuffs, argillite, carbonate, cherty carbonate, chert breccia, limestone, and slate. Several late diabase dykes traverse the formations (Martin, 1957).

Structurally, the mine lies within the Sudbury Basin and along the Vermilion fault. Folding and faulting are generally complex. The main structural feature at the Vermilion Lake Mine is an anticline with axis striking N60° E. All ore to-date has been found on the south limb of this anticline.

The ore consists of chalcopyrite, sphalerite, galena, with pyrite, marcasite, and minor pyrrhotite. The sulphides occur in both massive and disseminated form. The massive pyrite type is generally high in zinc and low in copper, and occurs mainly along the stratigraphic footwall of the Vermilion carbonate member. Higher copper values are mainly associated with the margins of the deposits.

An epigenic origin was postulated for the deposit. Collins (1937) thought that as crystallization of the Sudbury magmatic nickel ores proceeded, the end fluids would be enriched in volatiles and would thus account for the late quartz-carbonate and lead-zinc veins, both in the main nickeliferous ores and also within the basin to form the Cu-Pb-Zn ores at the Errington and Vermilion Lake properties. Thompson (Hawley, J.E., 1962, p-19) postulated that in the southwest part of the Sudbury Basin, the fine-grained copper, lead, and zinc deposits are of a non-nickeliferous variety and have resulted from contemporaneous fumarolic activity. Stanton (1958) believes that these Cu-Pb-Zn deposits have a syngenetic sedimentary origin.

A maximum of 2800 samples were utilized from the assay files. Assay data from this property contained values for Cu, Pb, Zn, Au, Ag and some for iron. This assay data was not divided into massive and disseminated types.

Metal Ratios

Figure 9. Wilson and Anderson (1959) have discussed the distribution of Cu and Zn in Cu-Zn ore bodies. A similar frequency distribution for $\frac{Cu}{Cu + Pb + Zn}$ was compiled and compared to the graph presented by Wilson and Anderson. This figure shows that the Vermilion Lake curve is similar to the curves for the Flin Flon Mine, Geco Mine, and for all Canadian copper-zinc sulphide ore bodies. The Vermilion Lake distribution curve exhibits very sharp peaks at both the high zinc end and at the high copper end. The Flin Flon massive ore has a distribution curve with a broad peak at the zinc

end and a sharp peak at the copper end. The curve for the Geco massive ore exhibits only one sharp peak at the zinc end whereas the disseminated ore exhibits a rather sharp peak at the copper end.

Figure 10. Frequency distribution histograms for $\frac{Cu}{Cu + Pb + Zn}$, $\frac{Zn}{Cu + Pb + Zn}$, $\frac{Pb}{Cu + Pb + Zn}$ for the Vermilion Lake Mine are shown in this figure. The $\frac{Au}{Au + Ag}$ histogram (1520 assays) shows a unimodal right skewed distribution, peaking between 0.01 and 0.02. The histogram for $\frac{Pb}{Cu + Pb + Zn}$ (1634 assays) resulted in a unimodal, right skewed distribution, but the peak was much broader than that for the $\frac{Au}{Au + Ag}$ and occurred at about 0.05. The histograms for $\frac{Zn}{Cu + Pb + Zn}$ (1605 assays) and $\frac{Cu}{Cu + Pb + Zn}$ (2807 assays) are bimodal with peaks occurring at 0.05 and 0.75 for the zinc and 0.05 and 0.95 for the copper.

Metal Ratios in the No. 4 Zone

Studies of the base metal ratios in the No. 4 ore zone are shown in Figures 11, 12, and 13. In these histograms, the distributions of the various base metals are shown for the whole zone and for the ore bodies on the 4th, 7th, and 9th levels of the Vermilion Lake Mine.

Figure 11. The No. 4 zone $\frac{Cu}{Cu + Pb + Zn}$ distribution is bimodal and shows the same form as the Cu ratio distribution for the mine. The distributions of the Cu ratio by levels are also bimodal and are identical in form to the mine distribution. Examination of these histograms indicates a small decrease with depth in the low Cu ratio

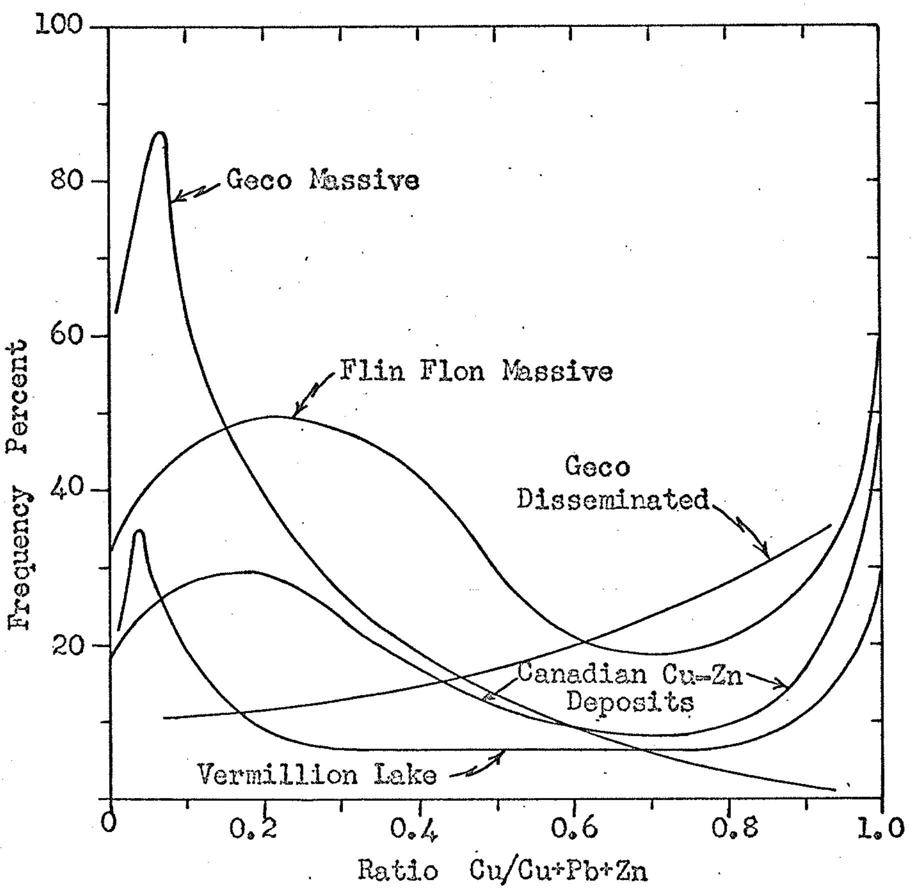

Figure 9. Comparison of the frequency distribution of Cu/Cu+Pb+Zn ratios in samples of Flin Flon massive ore, Geco massive and disseminated ores, Vermilion Lake ore, and compositions of Canadian copper and zinc deposits. In part, after Wilson and Anderson (1959).

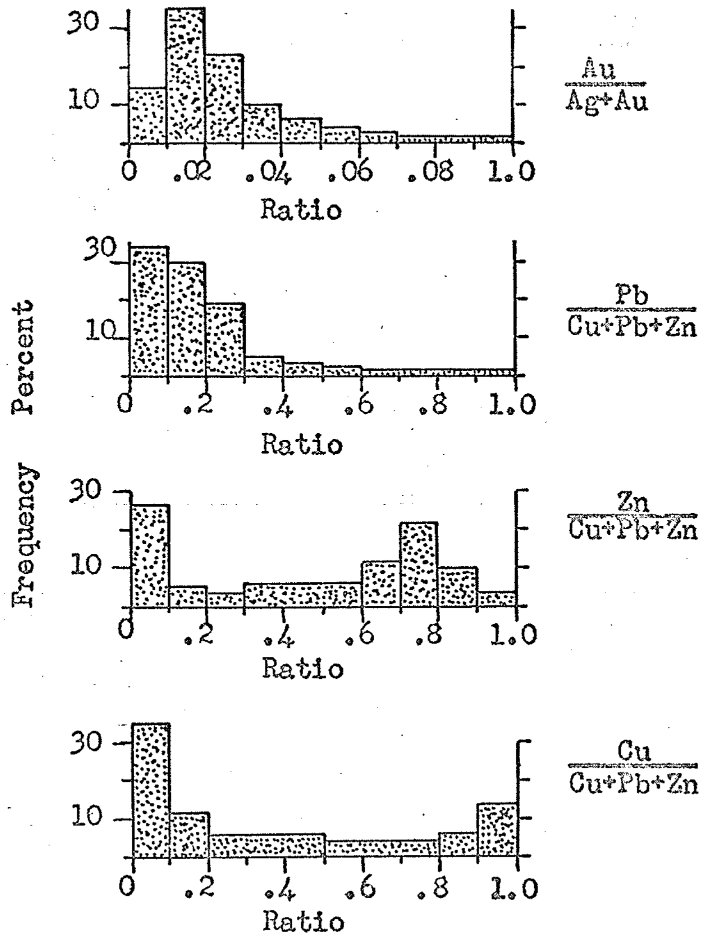

Figure 10. Frequency distribution histograms of copper, lead, zinc, and gold ratios at the Vermilion Lake Mine.

peak at the Pb-Zn end and a corresponding small increase in the high Cu ratio peak at the Cu end.

Figure 12. The No. 4 zone $\frac{Pb}{Cu + Pb + Zn}$ distribution is unimodal and right skewed and is similar to the mine distribution. The distributions of the Pb ratios by level are also unimodal and similar to the mine distribution in form. Examination of the level distributions indicates an increase in the Pb ratio frequency with increasing depth plus a shift to a lower Pb value of the central tendancy or peak.

Figure 13. The frequency distribution of the $\frac{Zn}{Cu + Pb + Zn}$ ratio for the No. 4 zone is bimodal and is similar in form to the Zn ratio distribution for the mine. The distributions of the Zn ratios by level are also similar in form to the mine distribution and show a slight decrease in frequency at the high Zn end with increasing depth. The frequency at the low Zn end of the diagram remains fairly constant with changes in depth.

Figure 14. This figure illustrates the variation in Zn ratios in the No. 4 zone by means of a logarithmic cumulative frequency graph. The similarity in form and the slight variations with depth are well illustrated.

Figure 15. The same data as was utilized in Figure 12 has been plotted as a logarithmic cumulative frequency curve and clearly illustrates the small variations in the Pb ratios with depth.

Figure 16. Logarithmic cumulative frequency curves are shown here for the Cu, Pb, Zn, and Au ratios for the No. 4 ore zone and for the mine Cu ratio. In general, the various curves show little relation

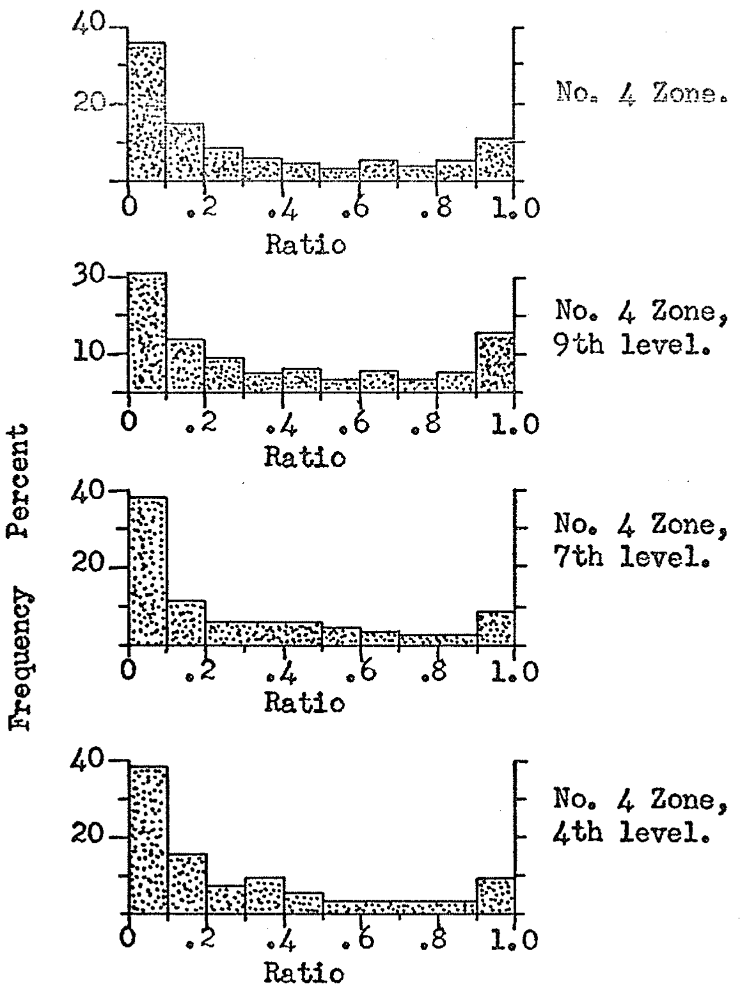

Figure 11. Frequency distribution histograms of Cu/Cu+Pb+Zn ratios by levels in the No. 4 Zone, Vermilion Lake Mine.

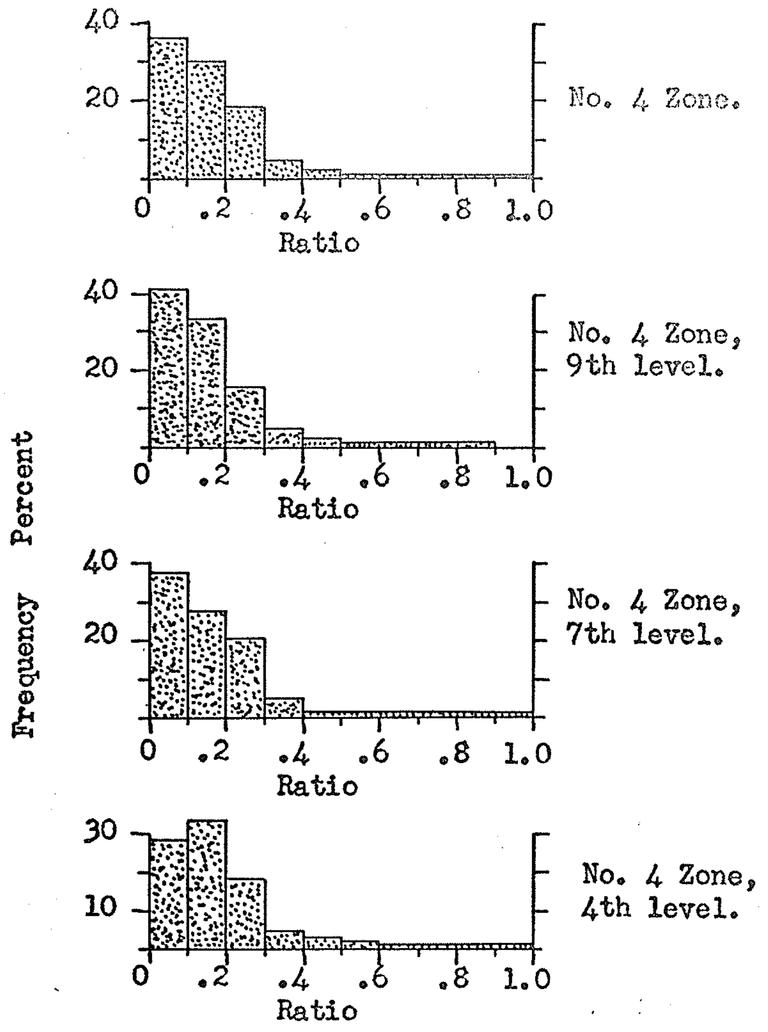

Figure 12. Frequency distribution histograms of Pb/Cu+Pb+Zn ratios by levels in the No. 4 Zone, Vermilion Lake Mine.

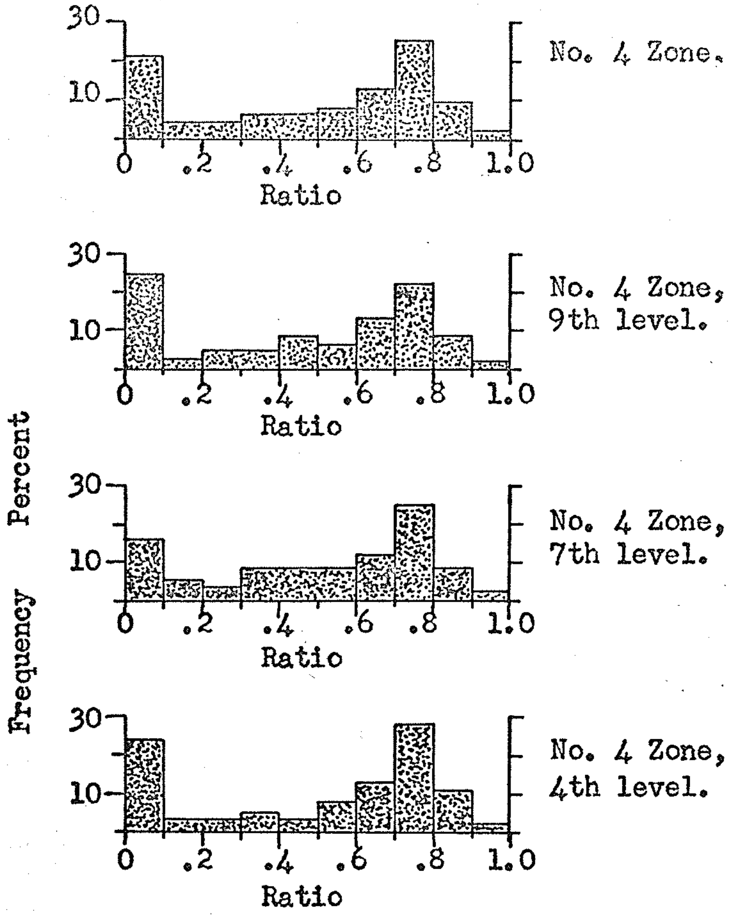

Figure 13. Frequency distribution histograms of Zn/Cu+Pb+Zn ratios by levels in the No. 4 Zone, Vermilion Lake Mine.

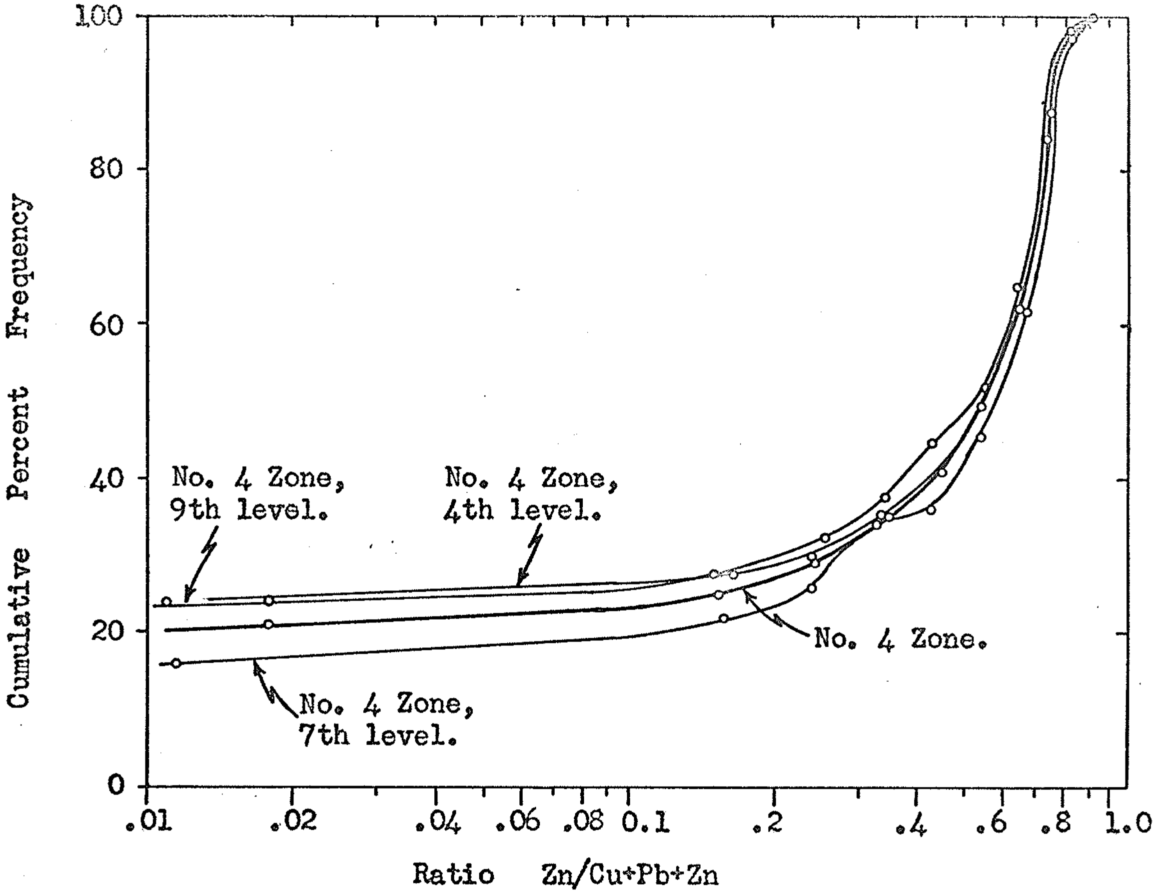

Figure 14. Logarithmic cumulative frequency curves of Zn/Cu+Pb+Zn ratios by levels in the No. 4 Zone, Vermilion Lake Mine.

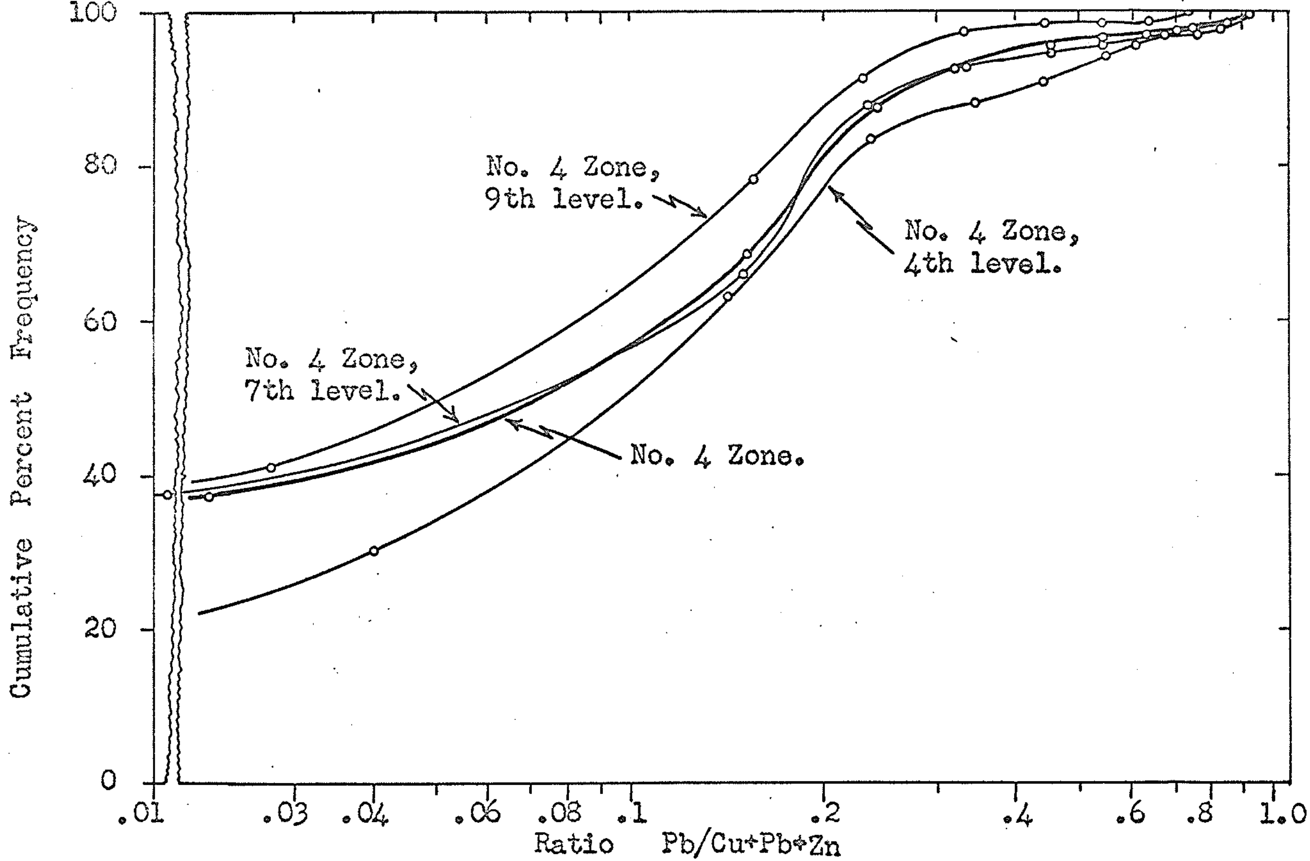

Figure 15. Logarithmic cumulative frequency curves of Pb/Cu+Pb+Zn ratios by levels in the No. 4 Zone, Vermilion Lake Mine.

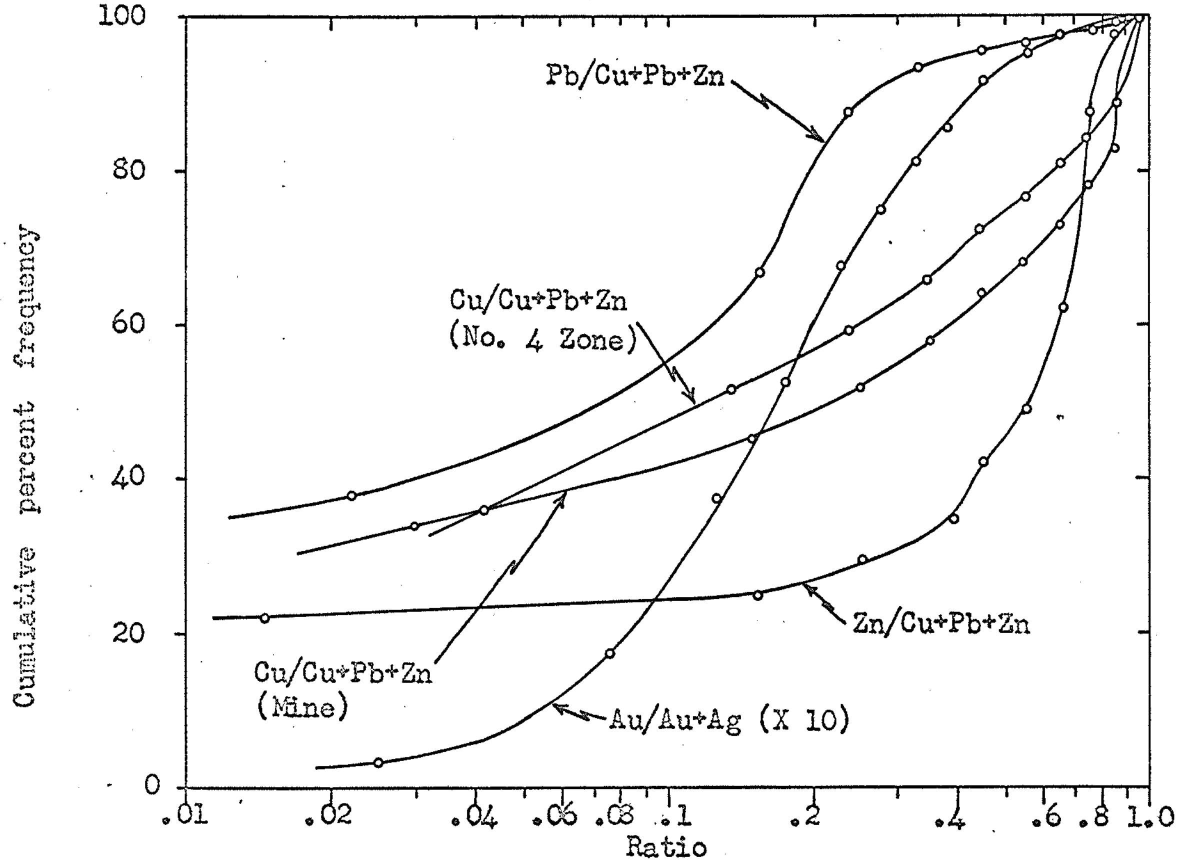

Figure 16. Comparison of cumulative frequency curves of Au, Cu, Pb, and Zn ratios in the No. 4 Zone and for the mine Cu ratio, Vermilion Lake Mine.

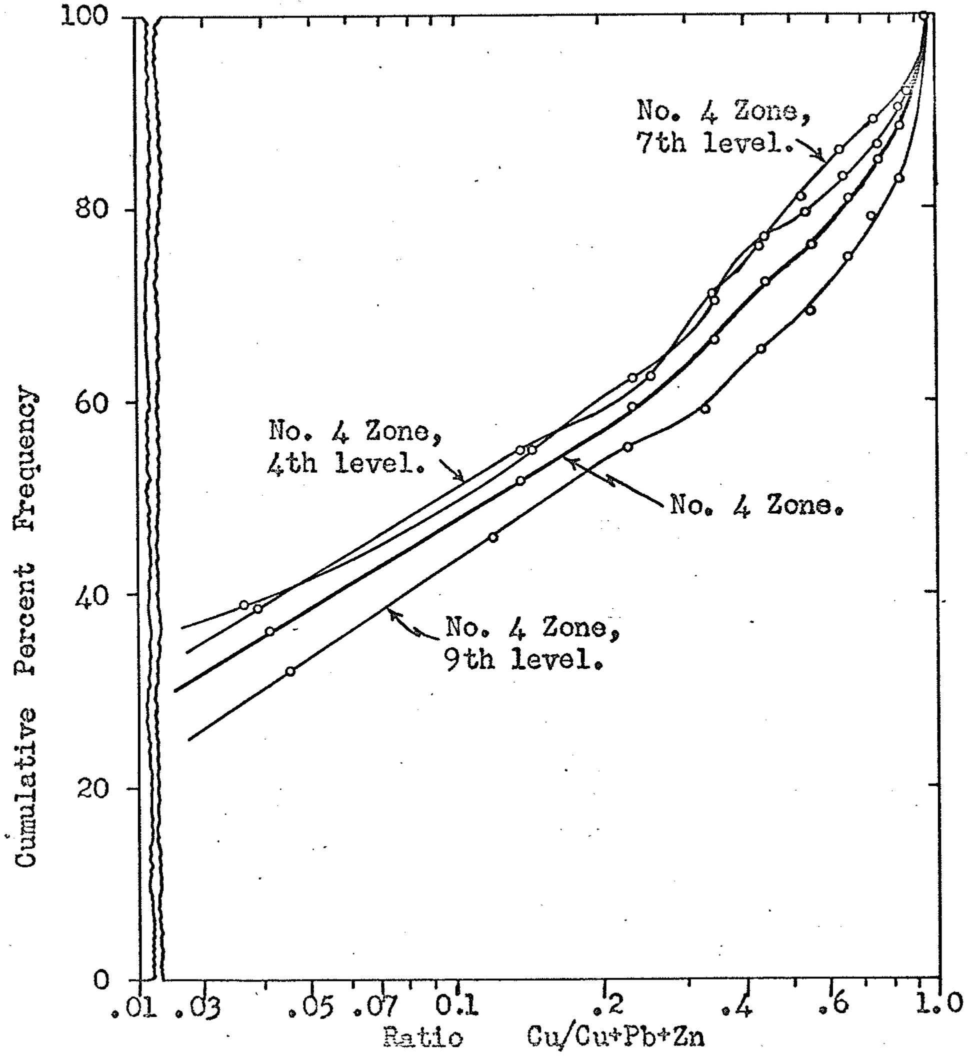

Figure 17. Logarithmic Cumulative Frequency curves of Cu/Cu+Pb+Zn ratios by levels in the No. 4 Zone, Vermilion Lake Mine.

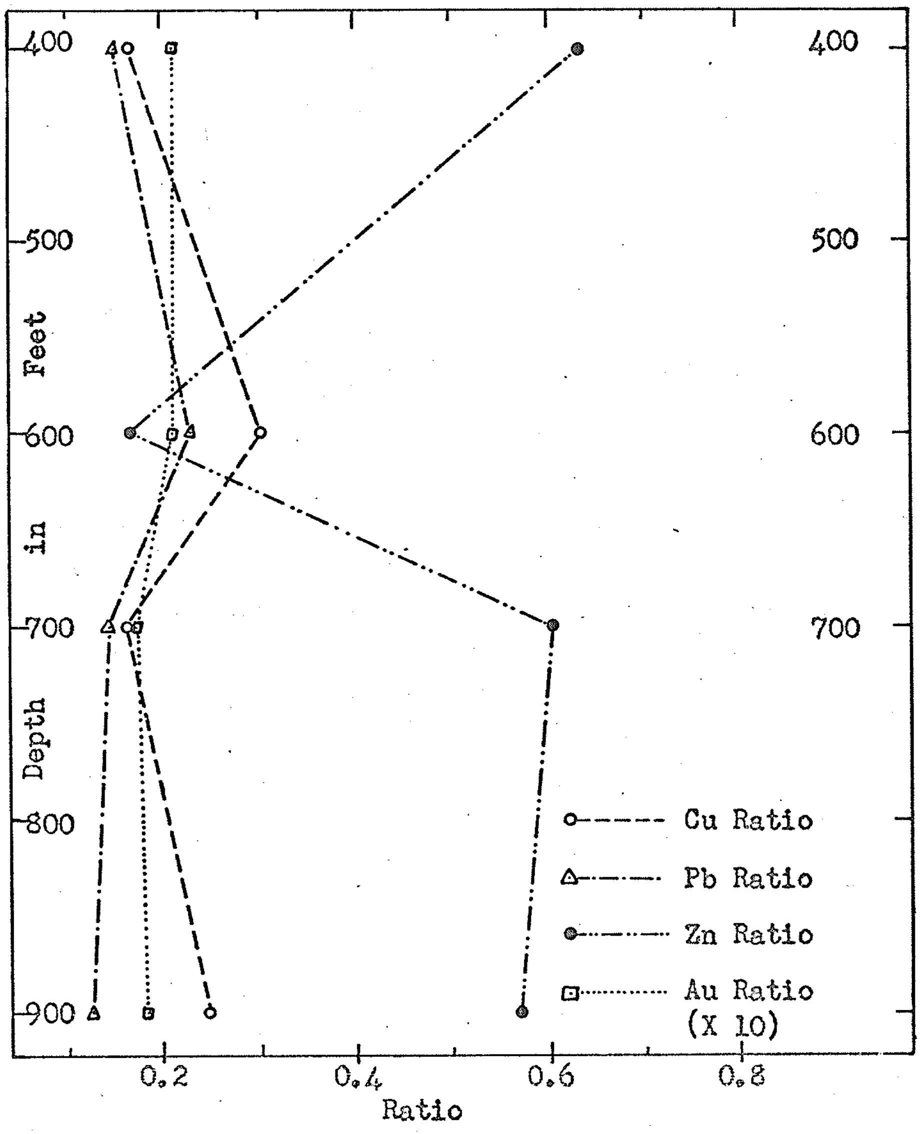

Figure 18. Diagram illustrating vertical distribution of Cu, Pb, Zn, and Au ratios at the Vermilion Lake Mine.

to one another. The Cu ratios show the greatest dispersion about the mid point, followed by Pb, Au, and Zn.

Figure 17. This logarithmic cumulative frequency curve of the Cu ratios in the No. 4 zone again illustrates the similarity in form of ratio distributions within the mine and the small increase in high copper values with depth.

Figure 18. This figure graphically illustrates the variations with depth of the Cu, Pb, Zn, and Au ratios. $\frac{Pb}{Cu + Pb + Zn}$ and $\frac{Au}{Au + Ag}$ (x10) exhibit parallel decreases in median values with depth. $\frac{Cu}{Cu + Pb + Zn}$ median values increase with depth and $\frac{Zn}{Cu + Pb + Zn}$ median values decrease with depth. These ratios are for the No. 4 ore zone.

Metal Associations in the Mine

Figures 19, 20, and 21. Arithmetic rectangular graphs with Au (oz/ton) have been plotted against each of Cu, Pb, and Zn (weight %) in these figures. The resulting graphs are all linear with positive slopes. While none of the straight lines pass through the origins, the y-intercept value for Au was less than 0.01 oz/ton which is within the limit of error of the reported gold assays.

Figures 22, 23 and 24. Similar graphs with Ag (oz/ton) plotted against each of Cu, Pb, and Zn (weight %) also resulted in straight lines with positive slopes. The y-intercept was much closer to zero than for the golds.

Figure 25. This graph of the relation between Ag and Au (oz/ton) for the No. 4 zone plus random samples from other sections of the mine resulted in a straight line with a positive slope, passing through the origin, thus indicating a very close relation between these two metals.

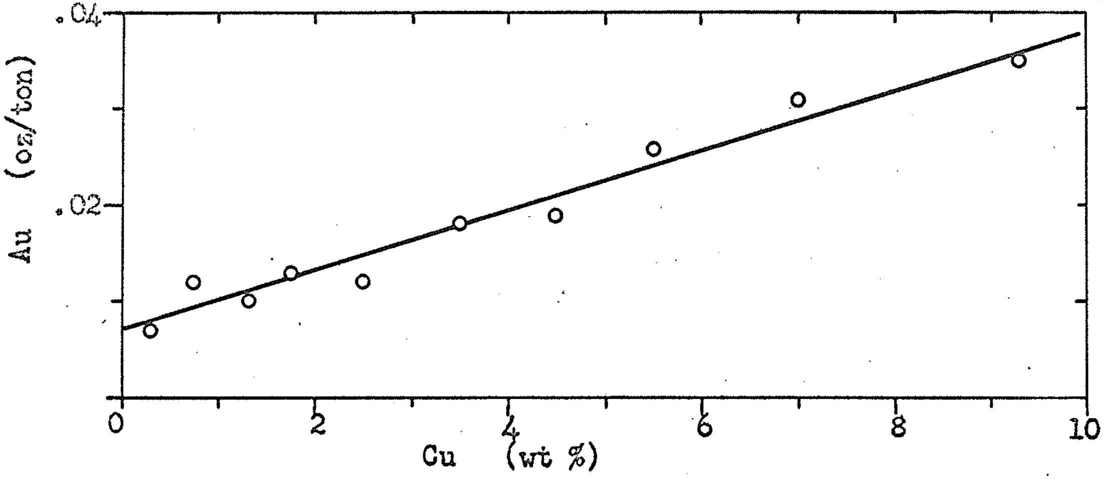

Figure 19. Cu-Au relations (wt %) at the Vermilion Lake Mine.

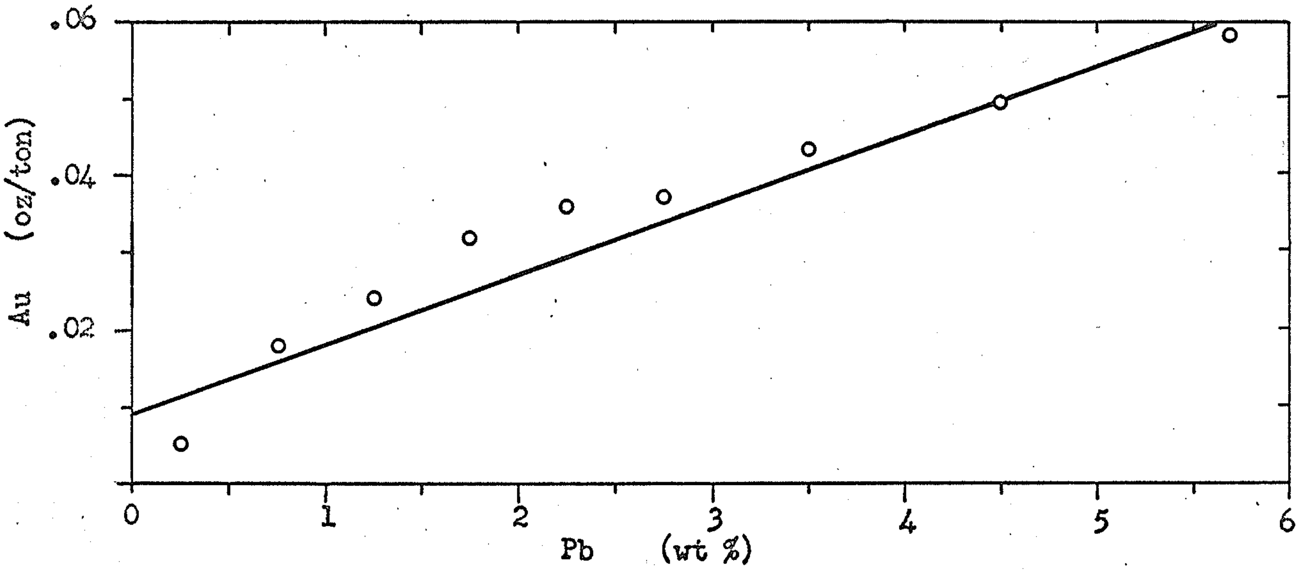

Figure 20. Pb-Au relations (wt %) at the Vermilion Lake Mine.

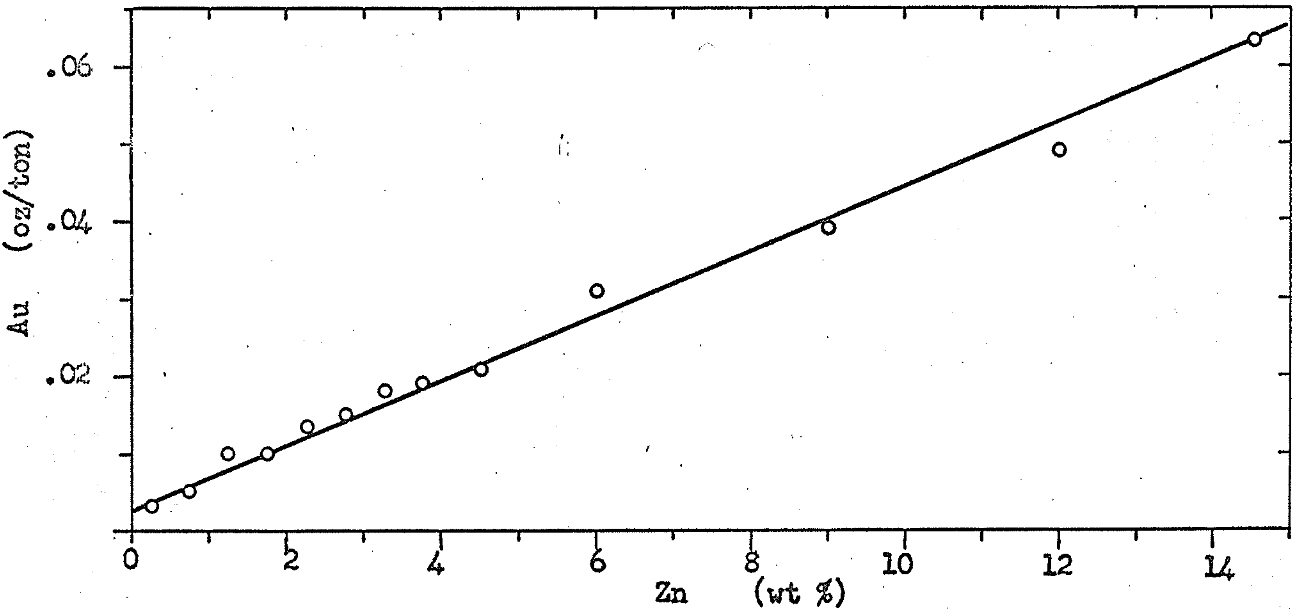

Figure 21. Zn-Au relations (wt %) at the Vermilion Lake Mine.

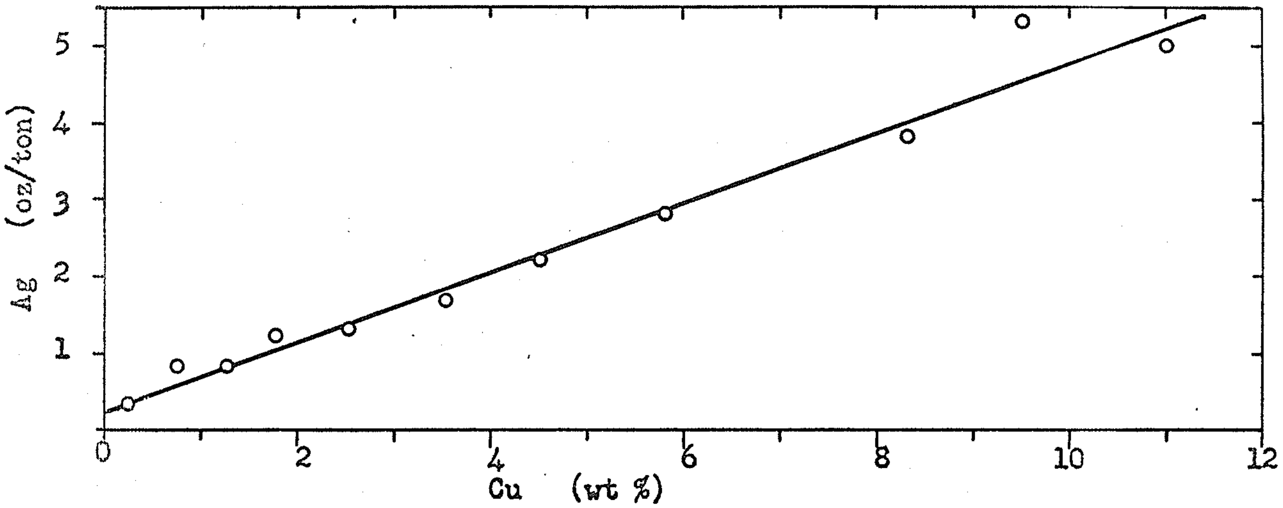

Figure 22. Cu-Ag relations (wt %) at the Vermilion Lake Mine.

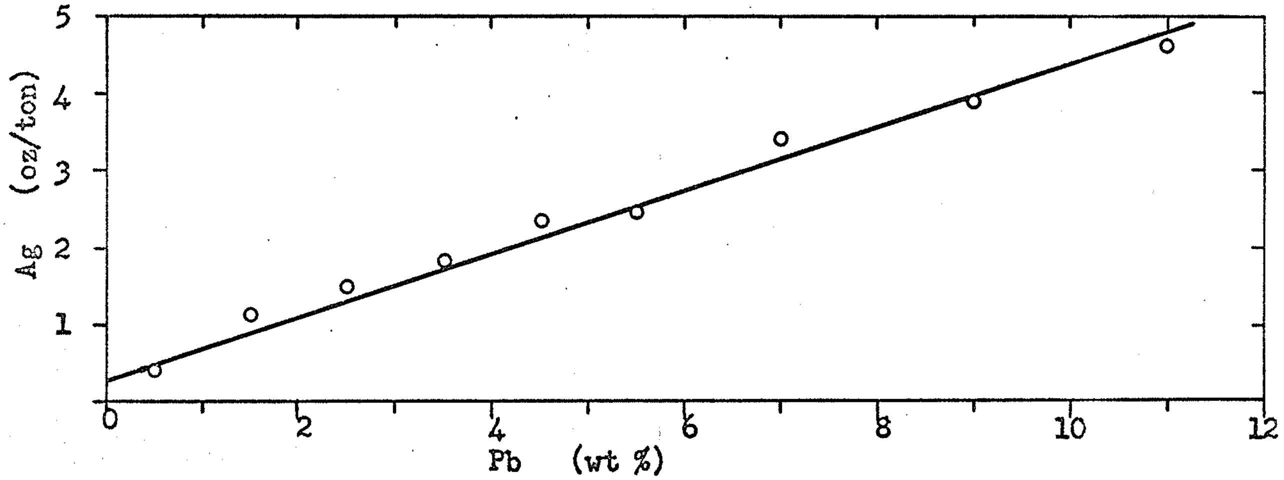

Figure 23. Pb-Ag relations (wt %) at the Vermilion Lake Mine.

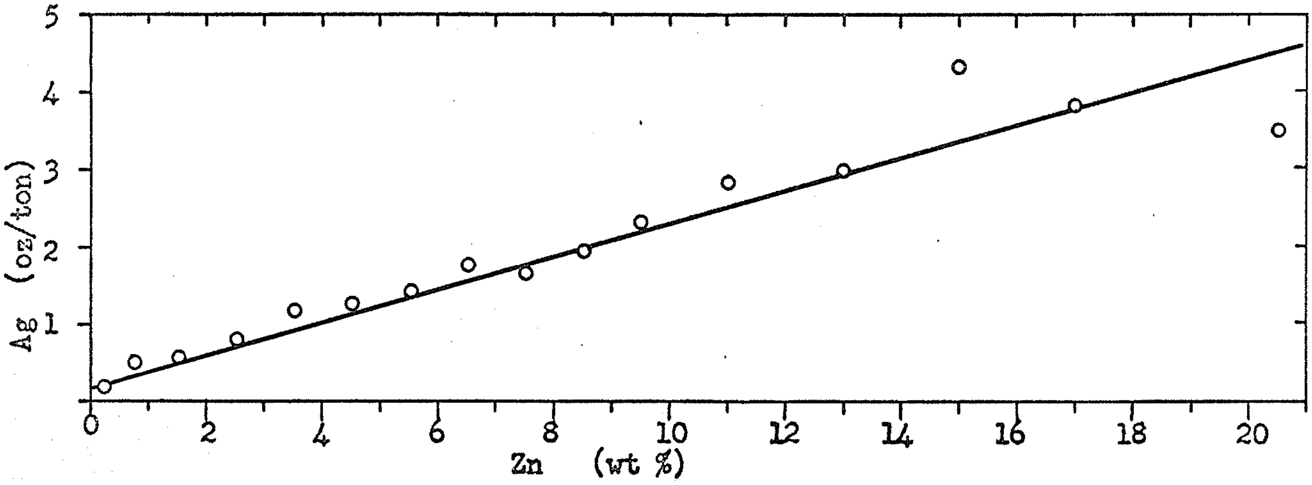

Figure 24. Zn-Ag relations (wt %) at the Vermilion Lake Mine.

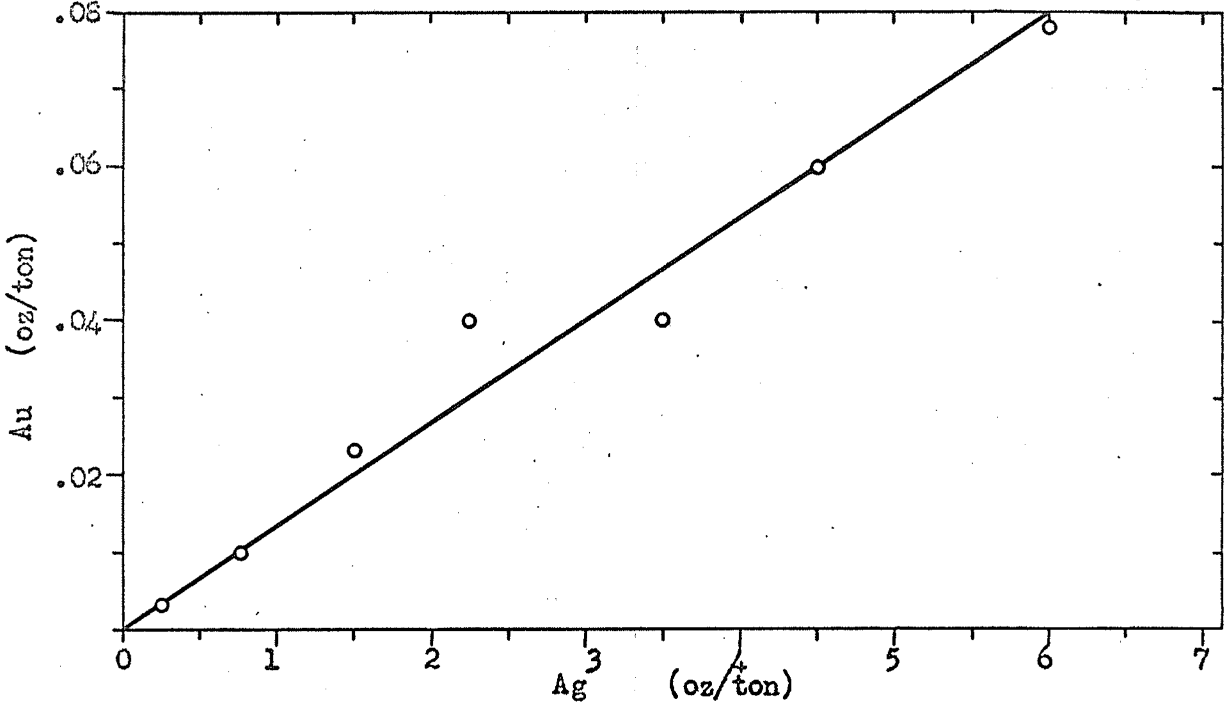

Figure 25. Ag-Au relations (wt %) in the No. 4 Zone, Vermilion Lake Mine.

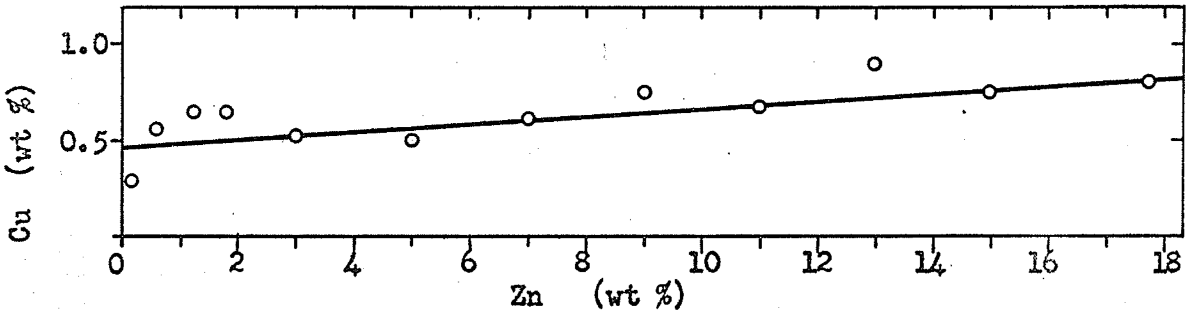

Figure 26. Zn-Cu relations (wt %) at the Vermilion Lake Mine.

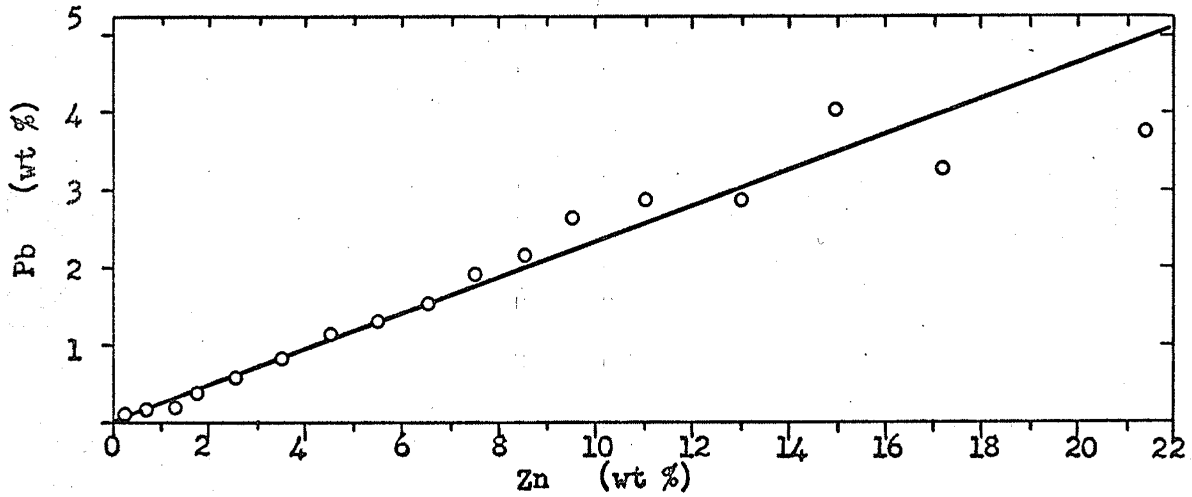

Figure 27. Zn-Pb relations (wt %) at the Vermilion Lake Mine.

Figure 26. Plotting of random samples from the Vermilion Lake Mine for Cu and Zn (weight %) resulted in a straight line plot with a positive slope. The y-intercept value of 0.50% Cu indicates a separation of the ore into high copper and high zinc portions.

Figure 27. Plotting of random samples of Zn and Pb (weight %) from the mine yielded a straight line with a positive slope, passing through the origin.

Iron Associations

Arithmetic graphs involving Fe assays were rather inconsistent but general trends could be noted. The actual source of the Fe could not be determined from the assays alone. Only Zn versus Fe (weight %) was plotted for the mine because Cu, Pb, and Zn appear to be closely related.

Figure 28. In the No. 4 zone, 9th level, zinc and iron show a linear relation between 0-3.0% Zn and 12-16% Fe. Above 3% Zn, the Fe content of the ore shows very little variation.

Figure 29. This graph indicates a linear relation between Zn and Fe at 0-5% Zn and 10-19% Fe. Above 5% Zn, the Fe values tend to decrease rapidily.

Figure 30. The relation between Cu and Fe in the No. 6 zone, 7th level is shown in this figure. The relation is similar to the trends shown in Figures 28 and 29. Fe increases with increasing Cu up to about 8% where, with continued increases in Cu, the Fe tends to decrease slightly.

Zone Variations

Numerous statistical analyses were carried out on individual ore zones in an attempt to detect any variations in these zones from the mine distributions and to further delineate a specific base metal-

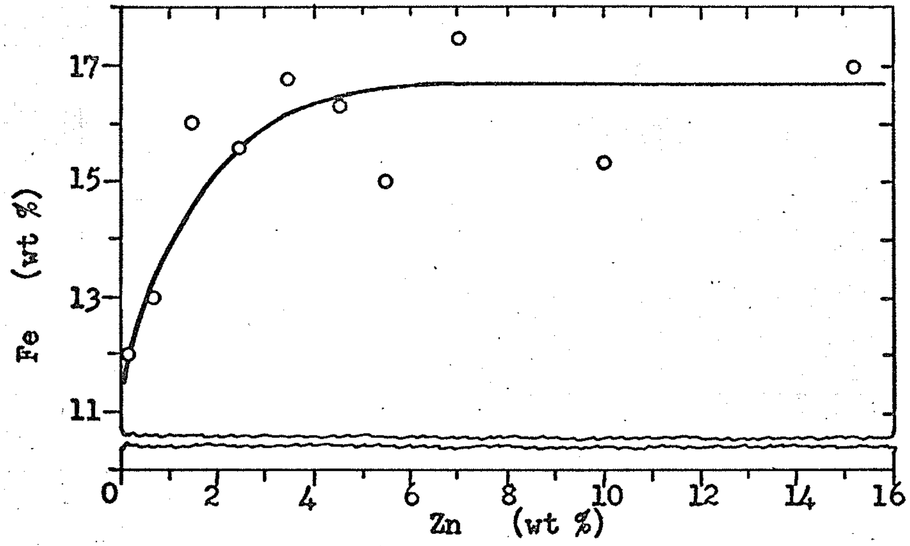

Figure 28. Zn-Fe relations (wt %) in the No. 4 Zone, Vermilion Lake Mine.

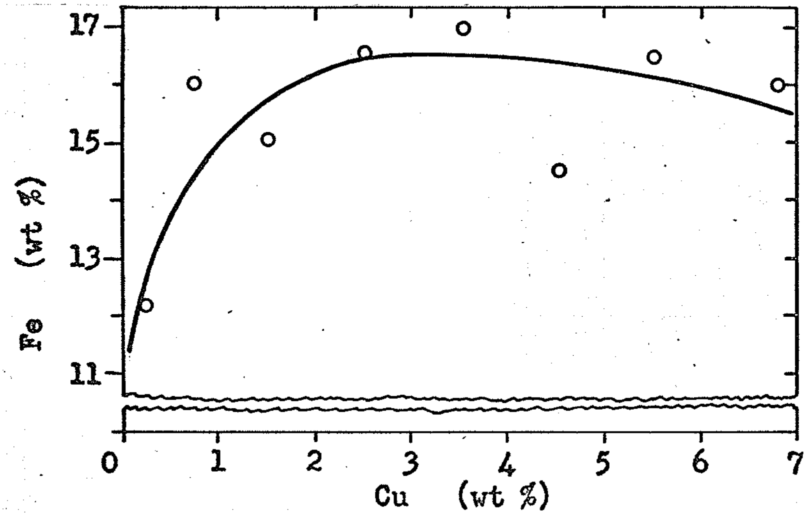

Figure 30. Cu-Fe relations (wt %) in the No. 6 Zone, Vermilion Lake Mine.

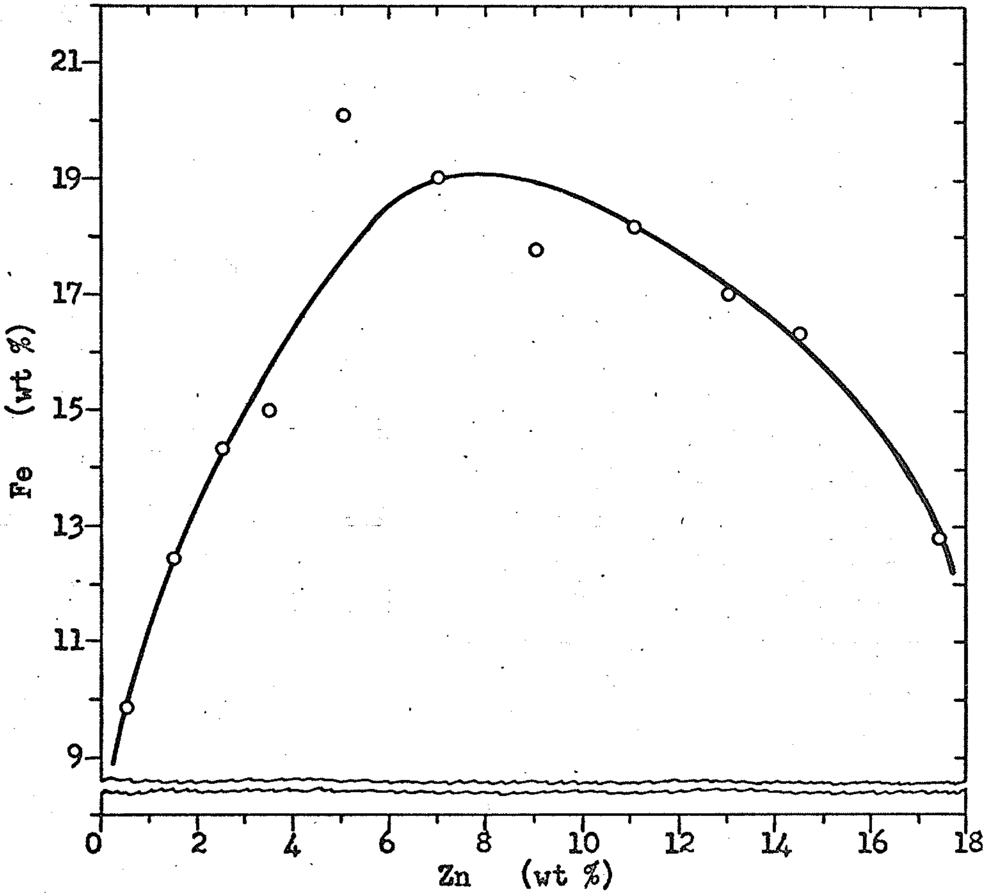

Figure 29. Zn-Fe relations (wt %) at the Vermilion Lake Mine.

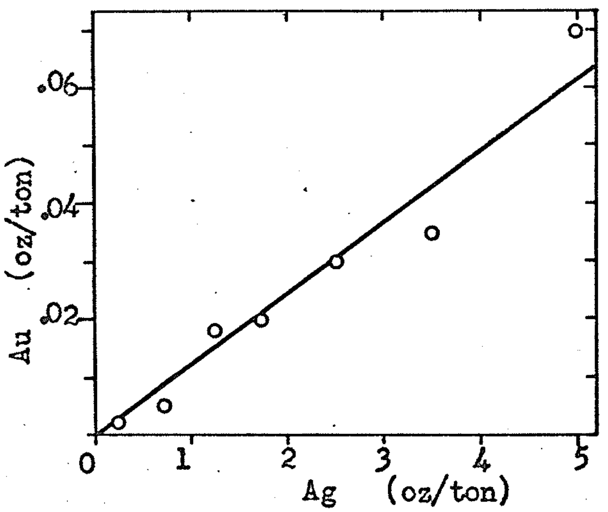

Figure 31. Ag-Au relations (wt %) in the Nos. 4 and 6 Zones, 6th level, Vermilion Lake Mine.

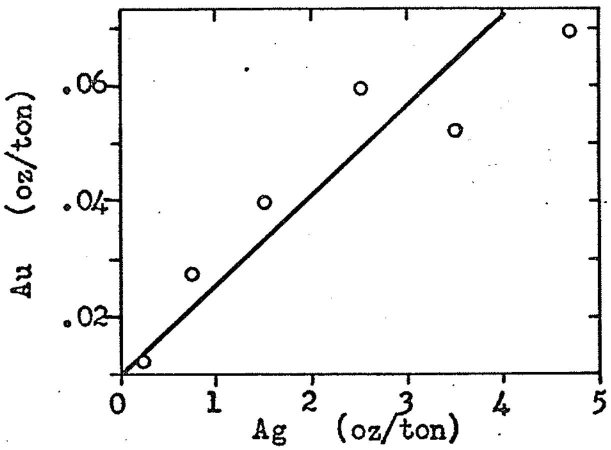

Figure 32. Ag-Au relations (wt %) in the No. 4 Zone, Vermilion Lake Mine. (4th level.)

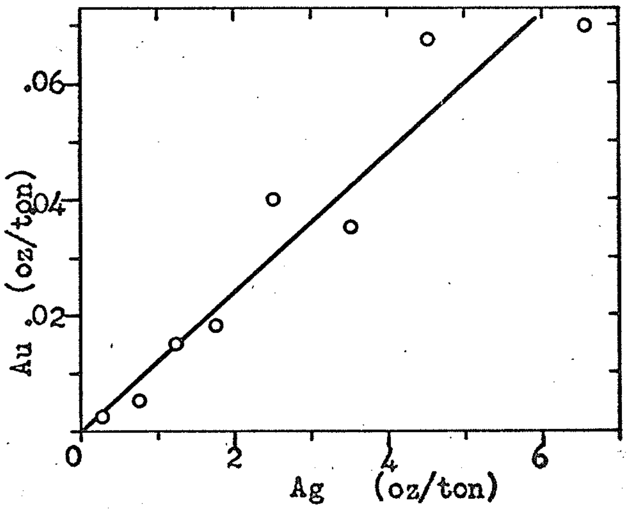

Figure 33. Ag-Au relations (wt %) in the No. 6 Zone, 7th level, Vermilion Lake Mine.

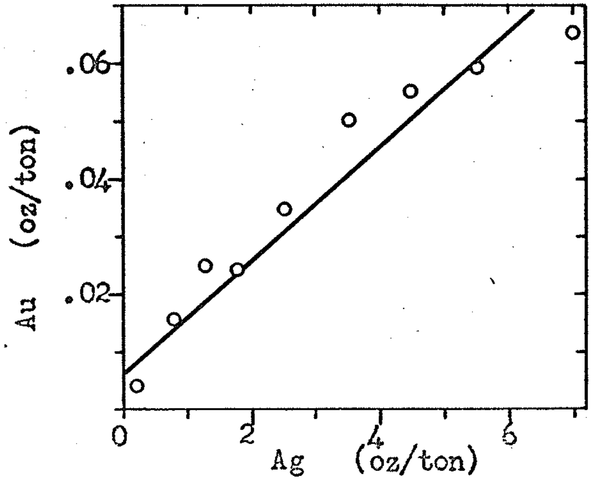

Figure 34. Ag-Au relations (wt %) in the No. 4 Zone, 7th level, Vermilion Lake Mine.

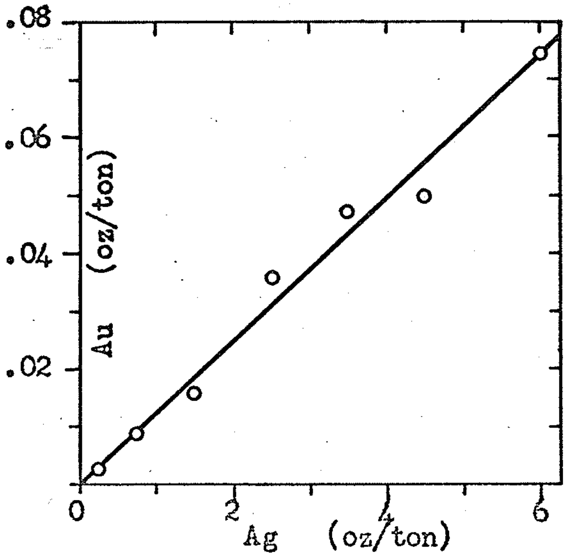

Figure 35. Ag-Au relations (wt %) in the No. 4 Zone, 9th level, Vermilion Lake Mine.

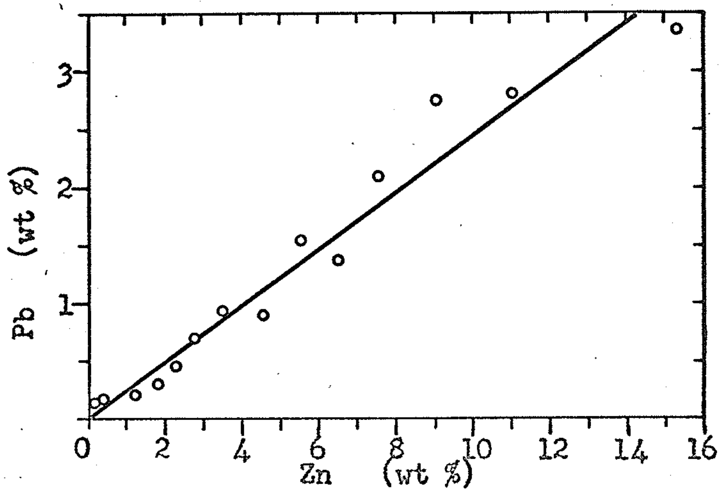

Figure 36. Zn-Pb relations (wt %) in the No. 4 Zone, 9th level, Vermilion Lake Mine.

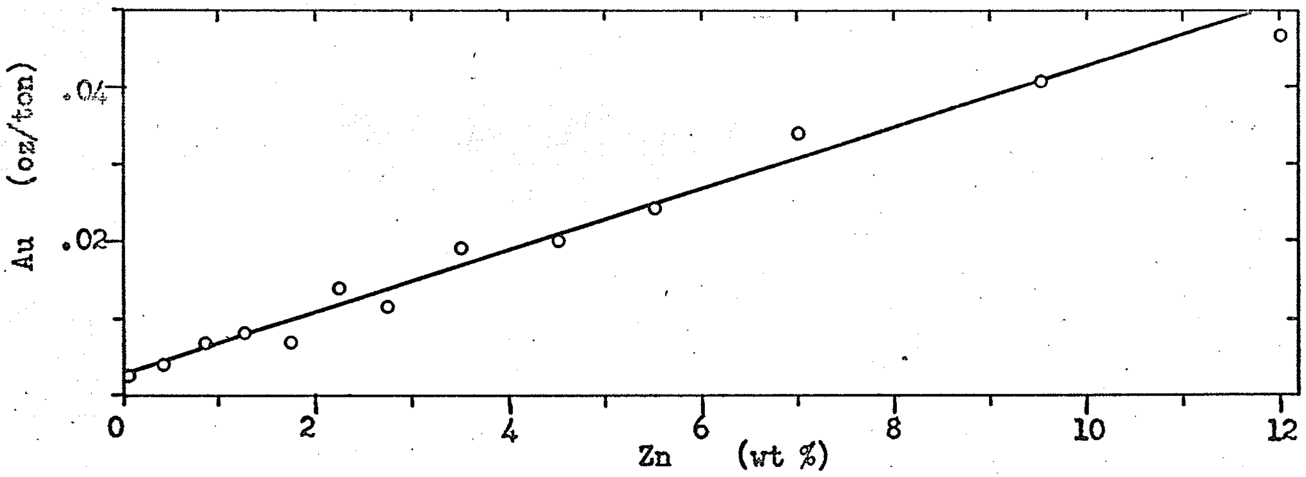

Figure 37. Zn-Au relations (wt %) in the No. 4 Zone, 9th level, Vermilion Lake Mine.

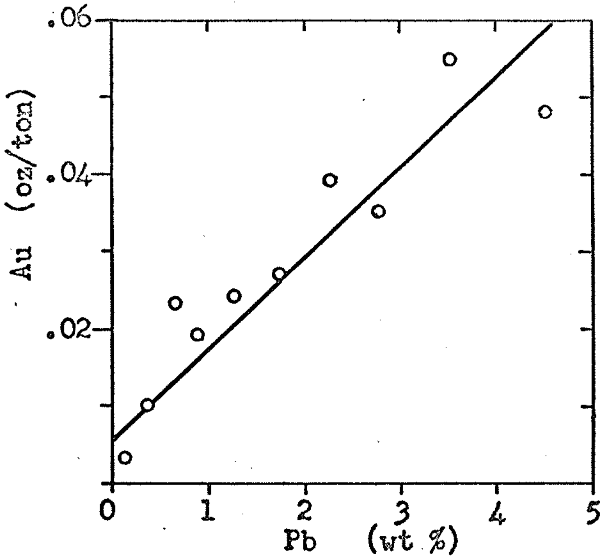

Figure 38. Pb-Au relations (wt %) in the No. 4 Zone, 9th level, Vermilion Lake Mine.

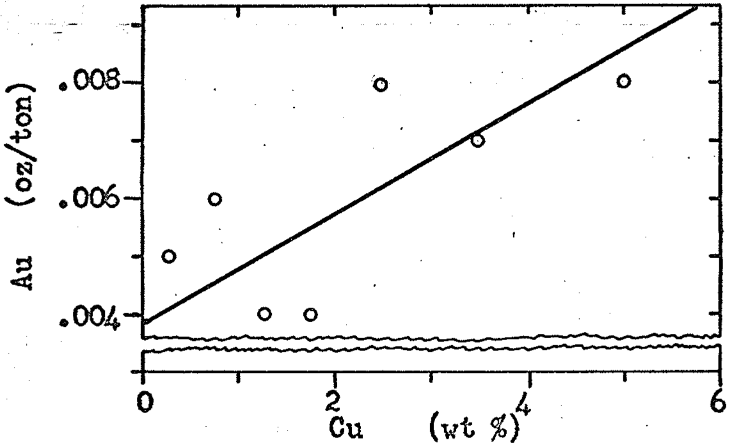

Figure 39. Cu-Au relations (wt %) in the No. 6 Zone, 7th level, Vermilion Lake Mine.

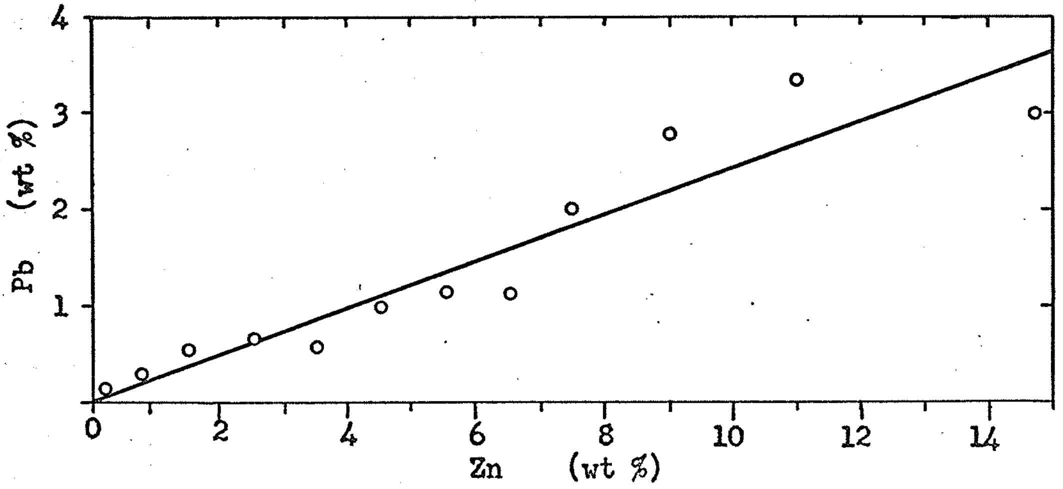

Figure 40. Zn-Pb relations (wt %) in the No. 6 Zone, 7th level, Vermilion Lake Mine.

precious metal affiliation.

Figures 31, 32, 33, 34 and 35. Arithmetic graphs of Au versus Ag (weight %) from various ore zone and levels were constructed. As previously noted, Figure 25 has been assumed to represent the mine Au-Ag relation. Figures 31 to 35 inclusive yielded linear graphs with positive slopes, all passing through the origins. Some change in slope is to be expected as it has been shown that there is a small variation in $\frac{Au}{Au + Ag}$ with depth (Figure 18). The ore zones studied were; No. 4 zones on the 4th, 6th, 7th, and 9th levels and, No. 6 zone on the 6th and 7th levels.

Figures 36, 37, and 38. In the No. 4 zone of the 9th level, graphs of Zn versus Pb; Zn versus Au; and Pb versus Au (weight %) have been drawn up. In these three cases, linear plots with positive slopes were obtained. All lines passed through the origins. In Figure 38 (Pb-Au relations for No. 4 zone, 9th level), only three assay values could be found in the 4-5% Pb range so that the resulting Au median value was assumed to be erratic and was not considered in the graphical interpretation.

Figure 39. Cu-Au relations (weight %) in the No. 6 zone, 7th level are linear with a positive slope. The y-intercept value of 0.005 (Tr. gold) is due to the fact that an assay value of 0.005 oz/ton was used for assays reported as trace.

Figures 40 and 41. In the No. 6 zone, 7th level, graphs of Zn-Pb; Pb-Ag; (weight %) resulted in straight lines with positive slopes, passing through the origins.

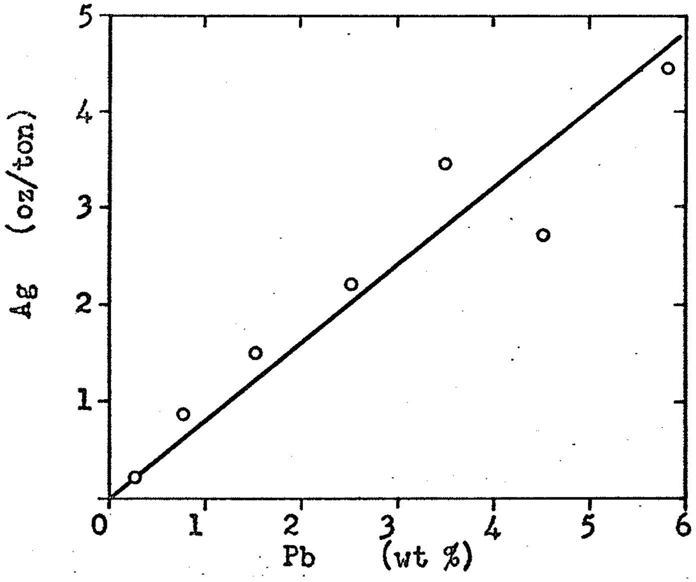

Figure 41. Pb-Ag relations (wt %) in the No. 6 Zone, 7th level, Vermilion Lake Mine.

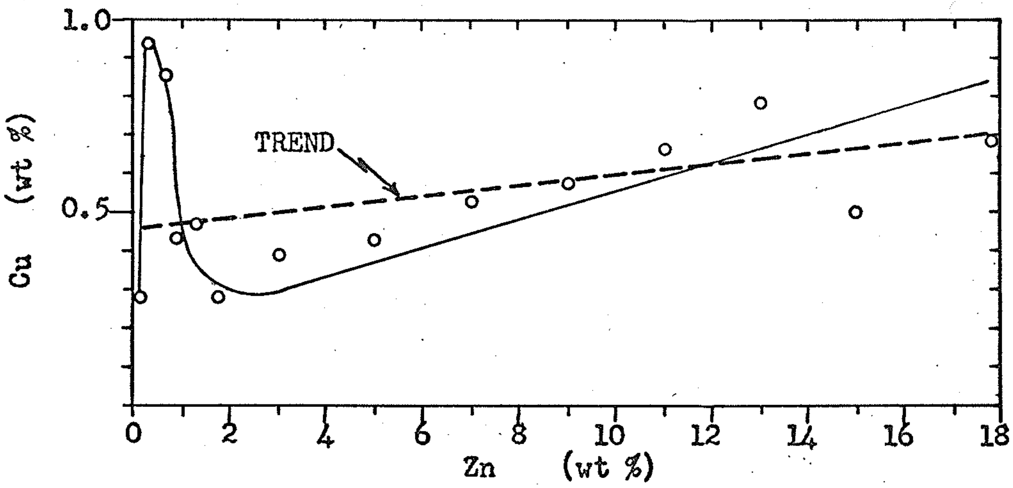

Figure 42. Zn-Cu relations (wt %) in the No. 6 Zone, Vermilion Lake Mine.

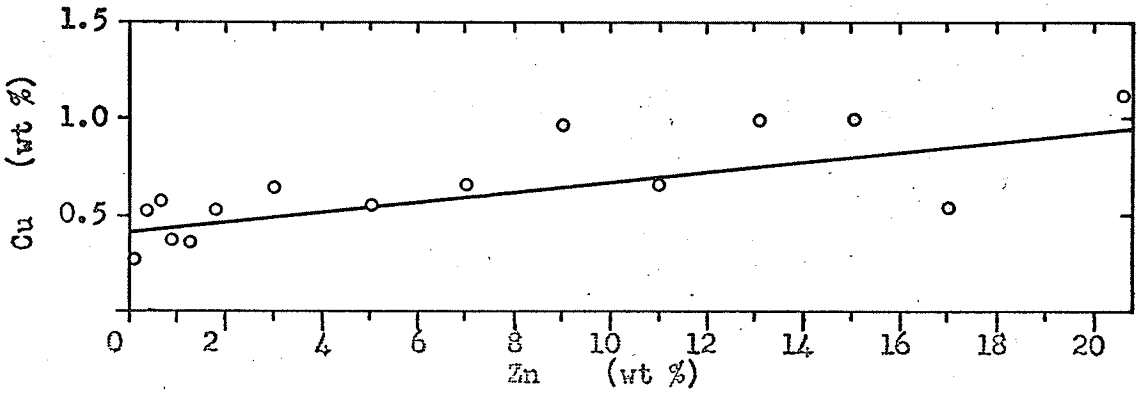

Figure 43. Zn-Cu relations (wt %) in the No. 4 Zone, Vermilion Lake Mine.

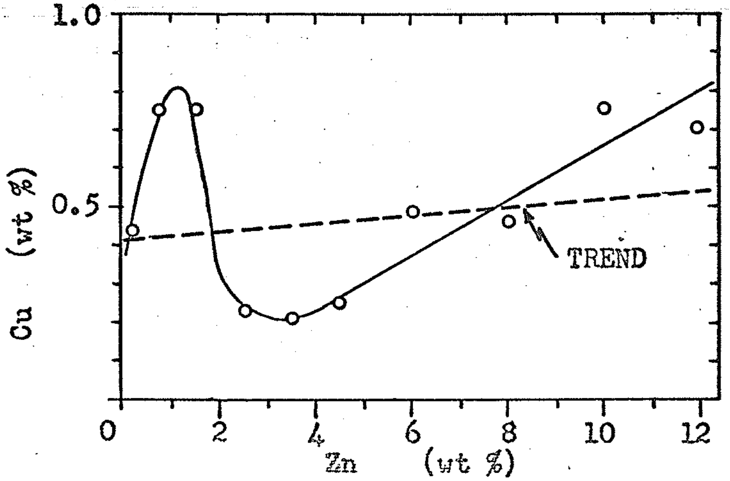

Figure 44. Zn-Cu relations (wt %) in the No. 6 Zone, 7th level, Vermilion Lake Mine.

Figure 42. The relation between Zn and Cu (weight %) in the No. 6 zone is shown here. A linear relation exists between Cu and Zn above 2% Zn. Some high Cu values appear to be associated with the low Zn values and this scatter at the low zinc end of the diagram is assumed to be due to the separation of Cu and Zn ore types.

Figure 43. Cu-Zn relations (weight %) for the No. 4 zone are represented by a straight line with a positive slope. The y-intercept value of 0.40% Cu again points to a separation of ore into Cu-rich and Zn-rich portions.

Figure 44. Cu-Zn relations (weight %) in the No. 6 zone, 7th level are similar to the results for the No. 6 zone (Figure 42), in that the relation between the elements is linear above 2% Zn and that Cu may be present in the absence of Zn.

Figure 45 and 46. In the No. 6 zone, 7th level, graphs of Zn-Au and Pb-Au (weight %) resulted in straight lines with positive slopes passing through the origins.

Figure 47. Combined Pb and Au values (weight %) for the Nos. 4 and 6 zones, 7th and 9th levels, again resulted in a straight line passing through the origin. Some scatter of points can be noted, especially for the high Pb values. The relations between Ag and Au in these zones has been discussed previously (Figures 31, 33, 34 and 35).

Atomic Proportions

In a further study to determine a specific base metal-precious metal affiliation, statistical studies in atomic proportions were

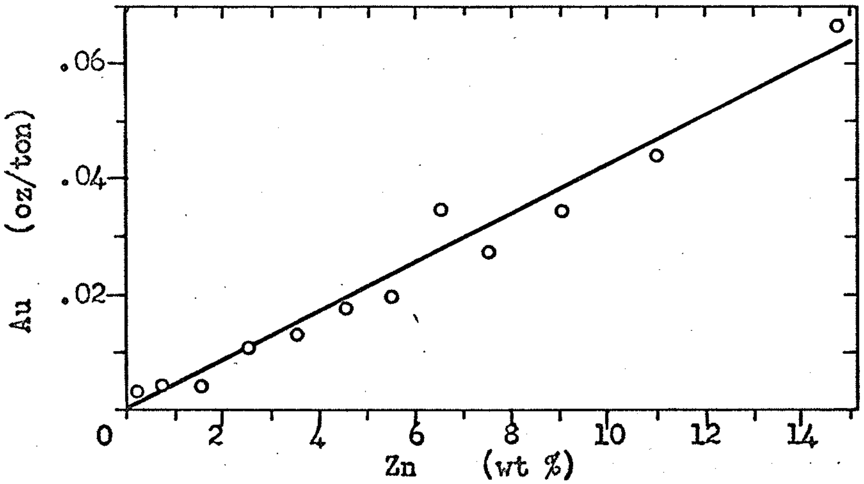

Figure 45. Zn-Au relations (wt %) in the No. 6 Zone, 7th level, Vermilion Lake Mine.

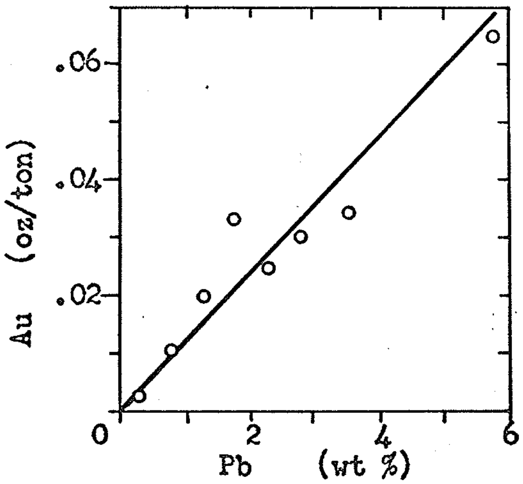

Figure 46. Pb-Au relations (wt %) in the No. 6 Zone, 7th level, Vermilion Lake Mine.

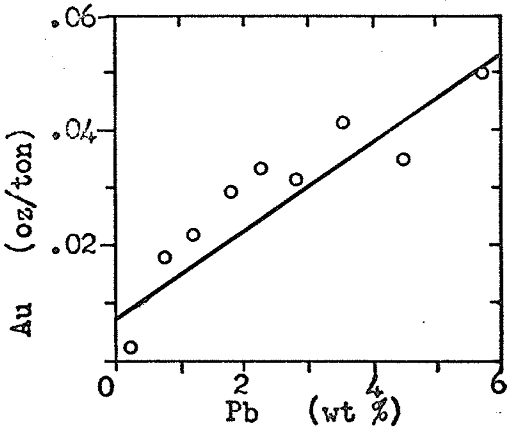

Figure 47. Pb-Au relations (wt %) in the Nos. 4 and 6 Zones, Vermilion Lake Mine.

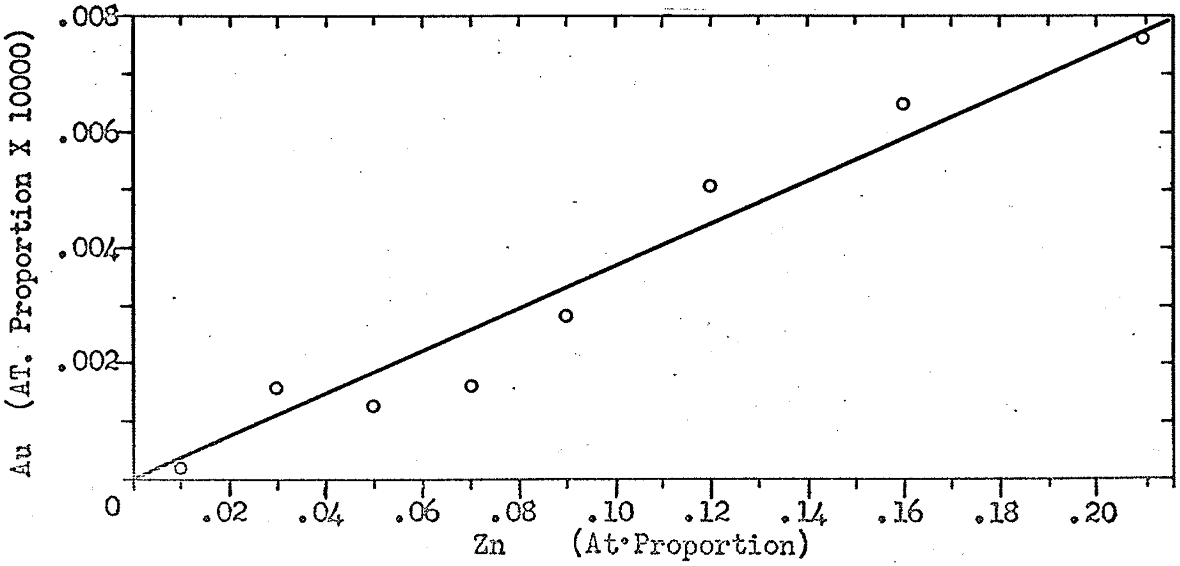

Figure 48. Zn-Au relations (At. Proportion) in the No. 6 Zone, 7th level, Vermilion Lake Mine.

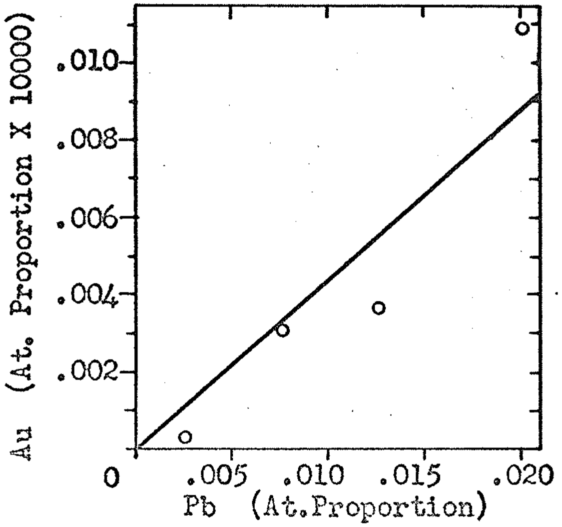

Figure 49. Pb-Au relations (At. Proportion) in the No. 6 Zone, 7th level, Vermilion Lake Mine.

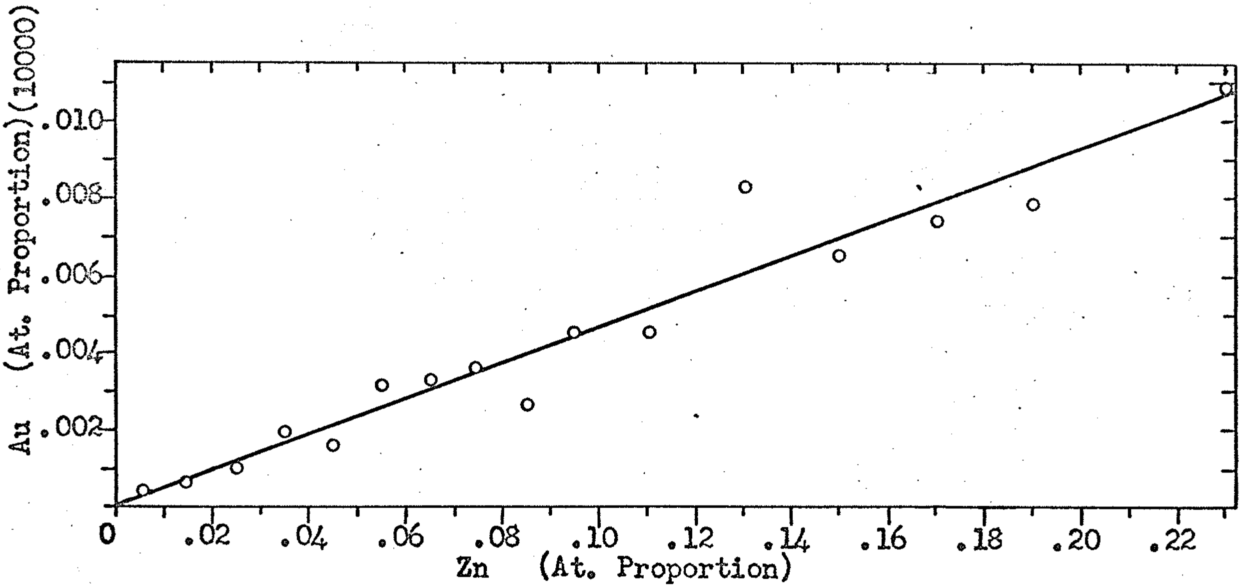

Figure 50. Zn-Au relations (At. Proportion) in the No. 4 Zone, 9th level, Vermilion Lake Mine.

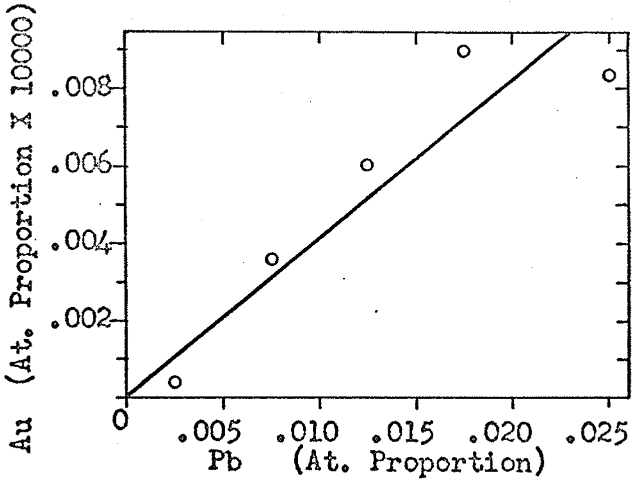

Figure 51. Pb-Au relations (At. Proportion) in the No. 4 Zone, 9th level, Vermilion Lake Mine.

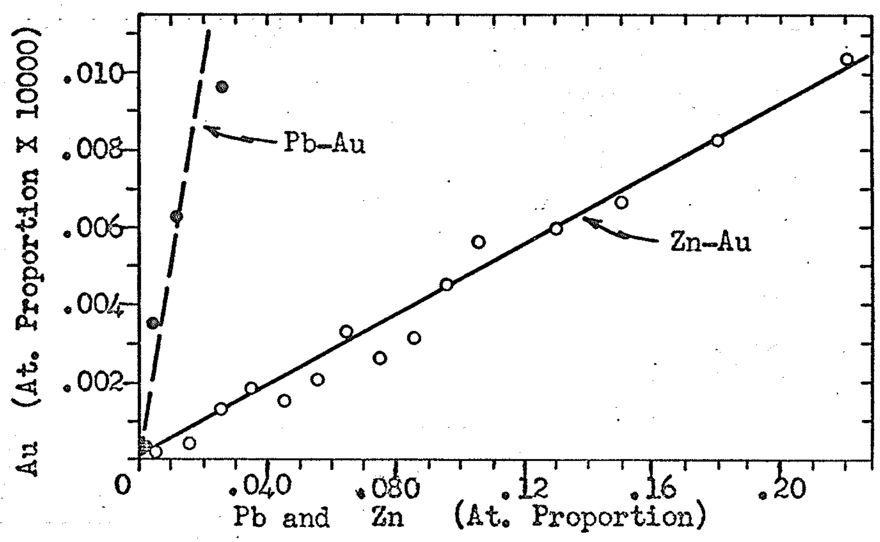

Figure 52. Zn-Au relations (At. Proportion) for combined values No. 4 Zone, 9th level, and No. 6 Zone, 7th level, Vermilion Lake Mine. Pb-Au relations also shown.

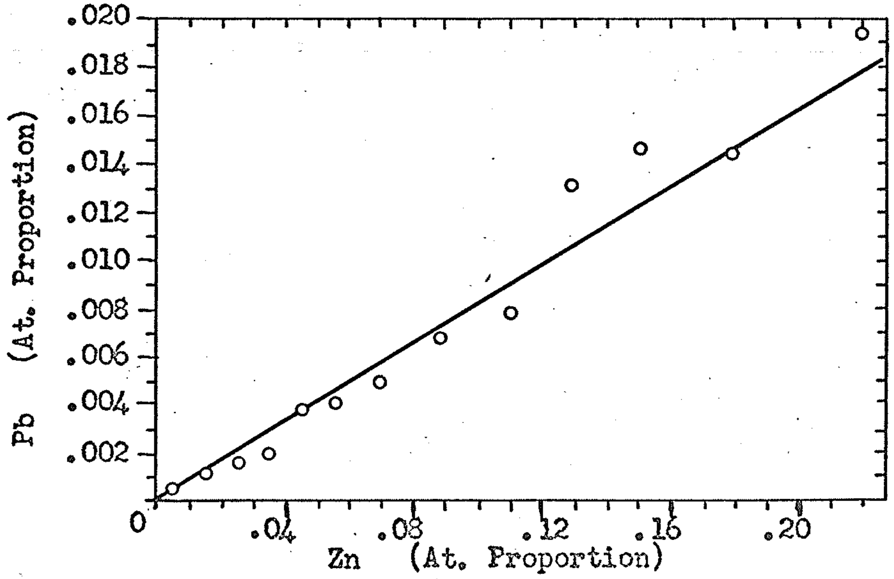

Figure 53. Zn-Pb relations (At. Proportion) for combined values No. 4 Zone, 9th level, and No. 6 Zone, 7th level, Vermilion Lake Mine.

carried out on lead, zinc, and gold in the No. 4 zone, 9th level, and the No. 6 zone, 7th level of the Vermilion Lake Mine.

Figures 48 and 49. Graphs of Zn versus Au and Pb versus Au (atomic proportions) in the No. 6 zone, 7th level, resulted in straight lines with positive slopes passing through the origins, indicating a very close relation between these three metals.

Figures 50 and 51. Graphs of Zn versus Au and Pb versus Au (atomic proportions) in the No. 4 zone, 9th level, again resulted in straight lines and results similar to those obtained in Figures 48 and 49.

Figure 52. The data for Zn versus Au and Pb versus Au (atomic proportions) for the Nos. 4 and 6 zones, 7th and 9th levels, was combined and plotted in this figure. Here again, straight line plots with positive slopes passing through the origins resulted.

Figure 53. Combined atomic values for Zn versus Pb were also compiled for the Nos. 4 and 6 zones and again a linear graph resulted. The line had a positive slope and passed through the origin.

Graphical plots of Pb, Zn, and Au in atomic proportions resulted in straight lines indicating direct proportionality between these metals.

Figure 54. It has been shown that there is a very close relation between Cu, Pb, and Zn and the precious metals Au and Ag. To illustrate the variation in gold distribution with base metal grade, a logarithmic cumulative frequency curve was drawn up for the combined assays (weight %) of Zn and Au in the No. 4 zone, 9th level and

the No. 6 zone, 7th level. Due to the similarity of relation between the base metals and gold, the figure should be representative of the distribution of gold assays with any of the three economic base metals at the mine. The change in frequency from low gold values with increasing zinc values is readily apparent. The coefficient of variation also shows a significant decrease with increasing zinc content.

Individual Element Distribution

Figure 55. Frequency distribution histograms of the abundances of individual metallic elements occurring in the deposit have been prepared. Stanton (1958) carried out similar distribution studies for Cu, Pb, and Zn in some sulphide deposits. Histograms for Cu, Pb, Zn, Au, Ag and Fe are shown in Figure 55. The distributions for Cu, Pb, Zn, Au, and Ag are all unimodal and right skewed and exhibit sharp central tendancies. The Cu, Ag, and Au content of the ore generally remains low and very constant as shown by the rapid, regular decline in frequency. The Zn and Pb content of the ore is somewhat higher and the distributions appear to be much more variable.

The Fe content of the ore exhibits a bimodal distribution with one sharp peak at the low Fe end of the diagram and a very broad peak ranging from 2% Fe to 32% Fe. The Fe distribution differs greatly from the distributions of the other metals and shows a wide range of values. Median metal content of the ore as determined from these distributions is as follows: Zn = 1.18%, Cu = 0.71%, Pb = 1.09%, Ag = 0.64 oz/ton, Au = 0.10 oz/ton, and Fe = 13.5%.

Frequency distribution tables compiled for this mine are shown

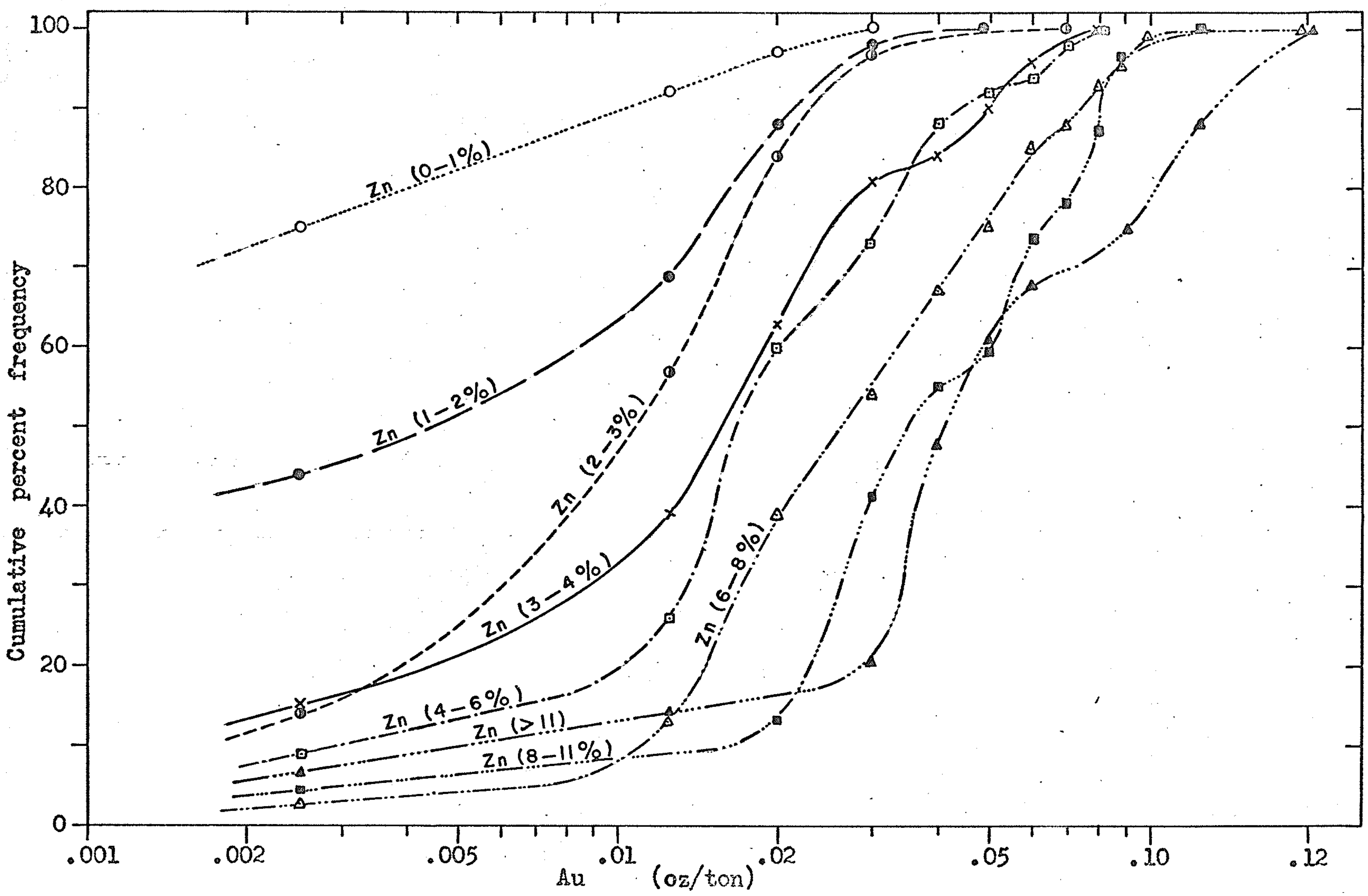

Figure 54. Cumulative frequency curves showing the effect of Zn grade on the Au content of the ore in the No. 4 Zone, 9th level, Vermilion Lake Mine.

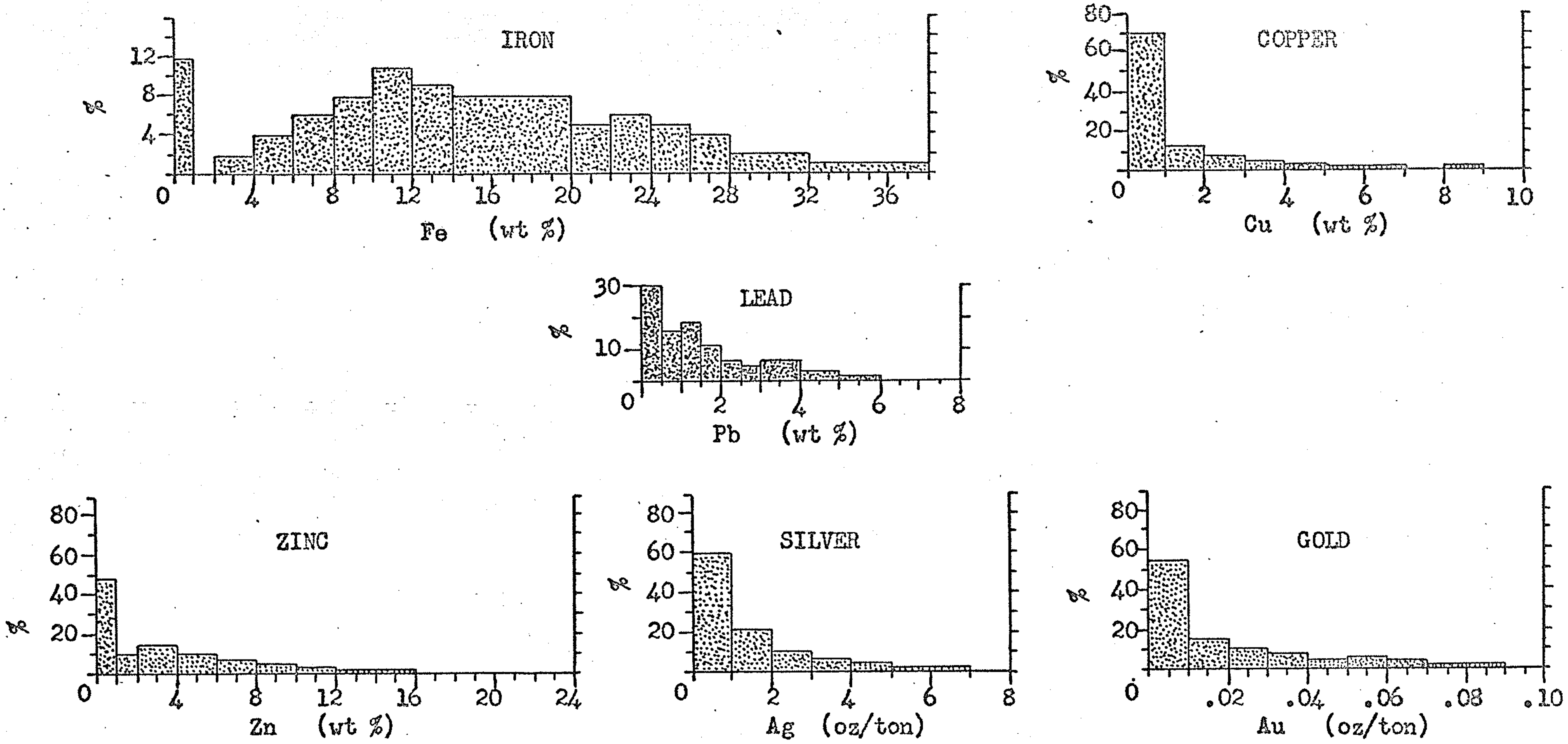

Figure 55. Distribution histograms of abundances of individual elements (Cu, Pb, Zn, Au, Ag, and Fe) at the Vermilion Lake Mine.

in the appendix.

Summary of Results

1. The distribution of $\frac{Cu}{Cu + Pb + Zn}$ at the Vermilion Lake Mine is similar to the copper: zinc distribution curves for the Flin Flon Mine, Geco Mine, and for all Canadian copper-zinc sulphide ore bodies (Figure 9).

2. $\frac{Au}{Au + Ag}$ and $\frac{Pb}{Cu + Pb + Zn}$ distributions for the mine are unimodal and right skewed (Figure 10).

3. $\frac{Cu}{Cu + Pb + Zn}$ and $\frac{Zn}{Cu + Pb + Zn}$ distributions for the mine are bimodal with sharp peaks at the high Zn and high Cu ends of the diagrams (Figure 10) indicating separation of the ore into high Zn and high Cu zones.

4. High Cu ratio frequency shows a small increase with depth (Figure 11) in the No. 4 zone.

5. Pb ratio frequency increases slightly with depth and the peak shifts to a lower Pb value (Figure 12) in the No. 4 zone.

6. High Zn ratio frequency shows a small decrease with depth (Figure 13) in the No. 4 zone.

7. The distributions of Cu, Pb, and Zn ratios in various sections of the mine show no variation in form with respect to the mine distributions (Figures 10 to 17 inclusive).

8. Pb, Zn, and Au ratios show small decreases in value with increasing depth. Cu ratios increase slightly with depth (Figure 18).

9. Au and Ag are directly proportional to Cu, Pb, and Zn in the mine (Figures 19 to 24 inclusive).

10. Au is directly proportional to Ag in all parts of the mine (Figures 25, 31, 32, 33, 34, and 35).

11. Cu is directly proportional to Zn in the mine. At nil Zn, the median Cu value is about 0.50% indicating separation of the ore body into Zn rich and Cu rich portions (Figures 26, 42, 43, and 44).

12. Pb is directly proportional to Zn in the mine (Figure 27).

13. Iron shows a linear relation to Cu, Pb, and Zn at low to moderate base metal assay values. Above 5-8% Zn and Cu, the iron content of the ore generally decreases (Figures 28, 29, and 30).

14. Direct proportionality relations between Cu, Pb, Zn, Au, and Ag exist in all parts of the mine. No zonal variations were noted (Figures 31 to 47 inclusive).

15. Pb, Zn, and Au are directly proportional also in atomic units (Figures 48 to 53 inclusive). A specific precious metal-base metal association could not be found.

16. The individual element distributions of Cu, Pb, Zn, Au, and Ag all have similar form (Figure 55).

2. Geco Mines Limited, Manitouwadge Area, Ontario

This property is located in the Manitouwadge Lake mining area of Northern Ontario. All consolidated rocks in the mine area are of Precambrian age (E.G. Pye, 1957). The property is underlain by a series of metasediments and iron formation having an east-west trend and dipping north. Granodiorite intrudes this series in the form of dykes and irregular bodies. Small bodies of pegmatite, micro-granodiorite, basic intrusions and diabase also make up a portion of the rocks in the mine area.

The principal structural feature on the property is a large right-hand deflection in strike. It is believed to represent an open or incipient drag fold compatible with the major structure in the area.

The main ore body is composed of two types of ore; massive sulphide rich in zinc with copper and silver; and disseminated sulphide which is poor in zinc but contains copper and silver. The massive ore is principally composed of pyrite, pyrrhotite, chalcopyrite, and sphalerite, and it is made up of three principal ore mixtures:-

a) pyrite and chalcopyrite with minor sphalerite and pyrrhotite.

b) pyrite and sphalerite with minor chalcopyrite and pyrrhotite.

c) pyrite and pyrrhotite with minor chalcopyrite and sphalerite. The disseminated sulphide ore is composed of pyrite, pyrrhotite, and chalcopyrite with subordinate sphalerite.

The ore body has been classed as a replacement deposit of the fissure type where a core of massive sulphides is enclosed by an envelope of disseminated mineralization. The host rock is a muscovite-quartz schist.

The paragenesis of the ore is as follows:-

1. pyrite
2. quartz-pyrrhotite
3. formation of chalcopyrite, sphalerite, and cubanite
4. formation of galena, tetrahedrite, marcasite and sericite followed by or accompanied by the formation of argentite, pyrragyrite and native silver.

Spectrographic analysis (F.F. Langford, 1955) has shown that silver is closely associated with chalcopyrite.

Approximately 1500 assays were evaluated in the study. Assay data from the Geco Mine contain values for Cu, Zn, and Ag, and have been broken down into massive and disseminated ore at the mine office. Individual metal ratios were investigated and separate graphs were compiled for massive and disseminated ore types. Where linearity appeared vague on arithmetic based graphs, plots were done on logarithmic paper to ascertain whether the relations were logarithmic. Histrograms of the distributions of individual metal assays were compiled. Considerable work on the $\frac{Cu}{Cu + Zn}$ ratios has been completed by H.D.B. Wilson and D.T. Anderson. The relationship between total base metal content and silver was also investigated.

The distribution of the ratio $\frac{Cu}{Cu + Zn}$ (wight percent) for this property has been dealt with previously by Anderson and Wilson (1959). It was shown that the Cu ratio distribution for the Geco massive ore was unimodal and right skewed with sharp peak or central tendancy at the high Zn end of the diagram. The frequency distribution for the Geco disseminated ore was again unimodal but was left skewed and the central tendancy was very broad and occurred at the high Cu end of the diagram (Figure 9). The vertical distribution of copper: zinc ratios was found to be relatively uniform in shape and median value.

In this study individual metal ratios were studied separately in the massive and disseminated ore types and for the mine in general.

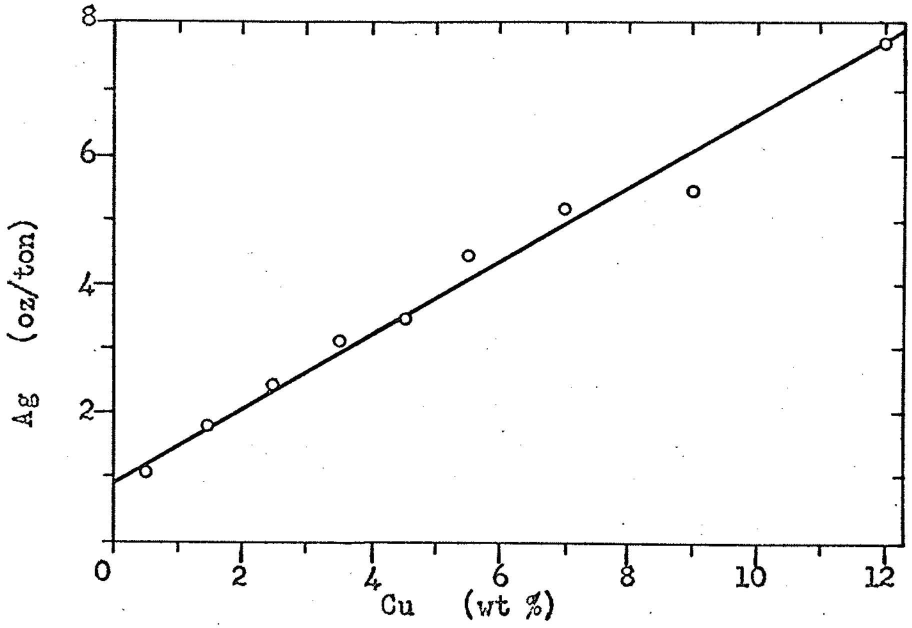

Figure 56. Cu-Ag relations (wt %) in the massive ore, Geco Mines Limited.

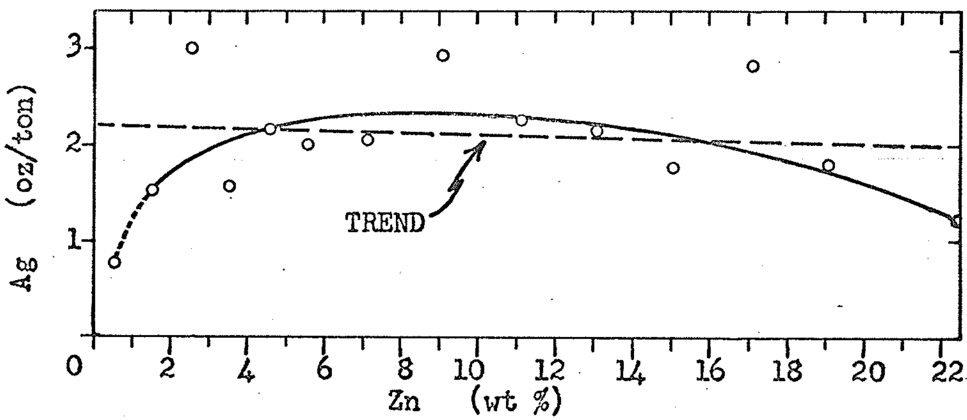

Figure 57. Zn-Ag relations (wt %) in the massive ore, Geco Mines Limited.

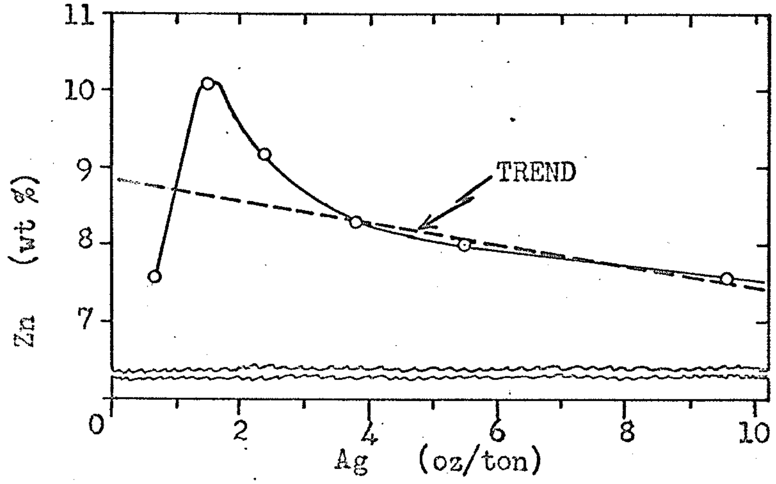

Figure 58. Ag-Zn relations (wt %) in the massive ore, Geco Mines Limited.

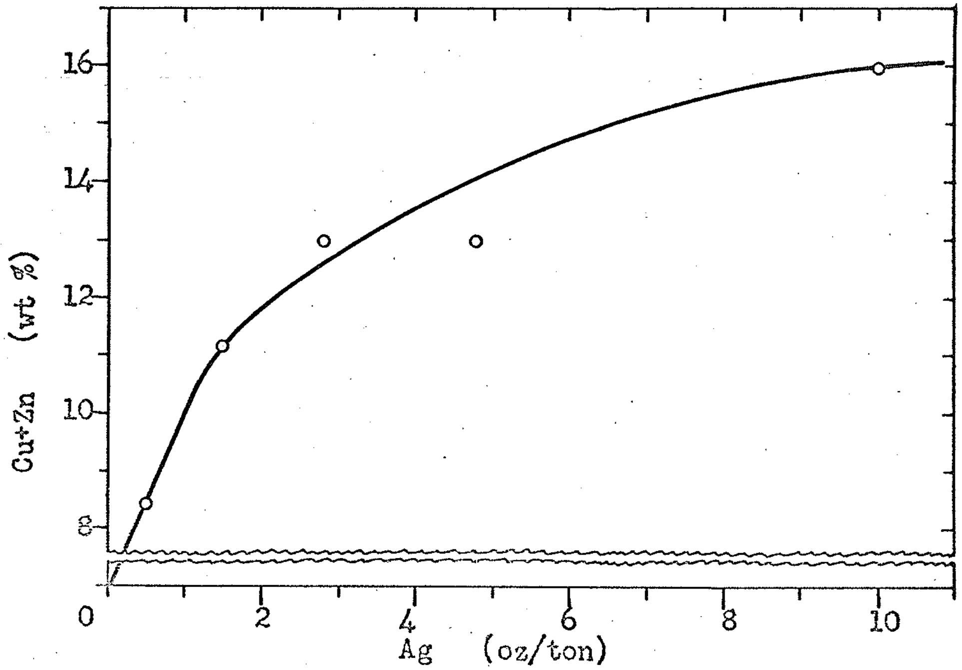

Figure 59. Ag-Cu+Zn relations (wt %) in the massive ore, Geco Mines Limited.

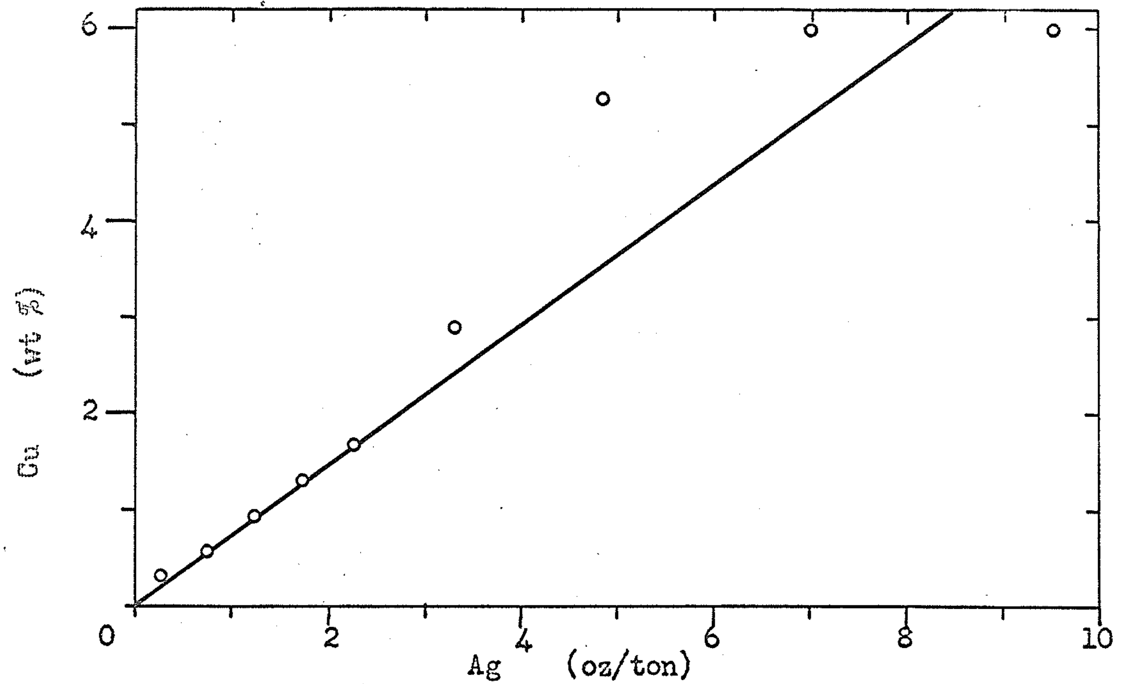

Figure 60. Ag-Cu relations (wt %) in the massive ore, Geco Mines Limited.

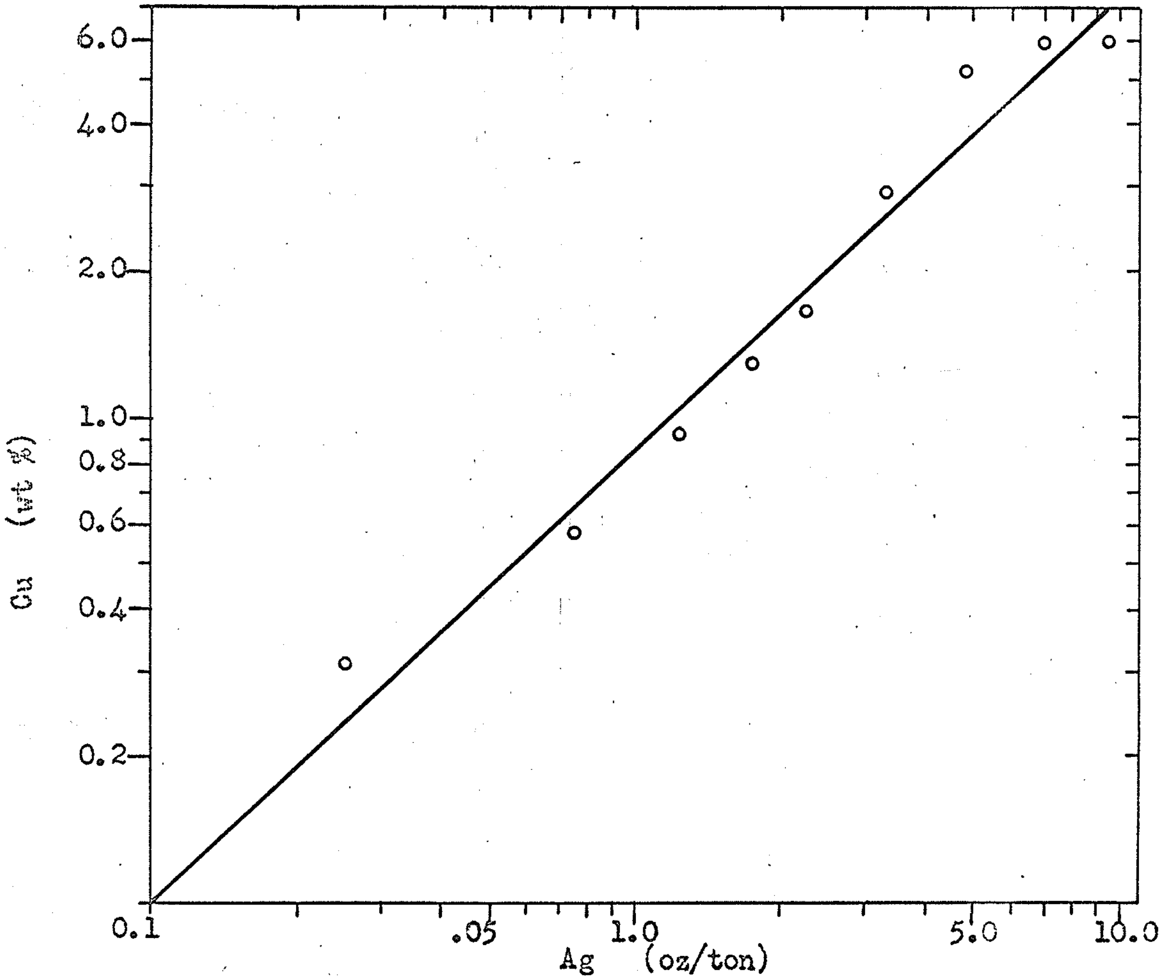

Figure 61. Ag-Cu relations (wt %) in the massive ore, Geco Mines Limited. (logarithmic base).

Massive Ore

Figure 56. The arithmetic graph of Cu versus Ag (weight %) resulted in a straight line with a positive slope. The y-intercept for Ag being about 0.75 oz/ton.

Figure 57. The graph of Zn versus Ag (weight %) yielded a general scattering of points over a small range of Ag along the total range of Zn values. In the low assay range, only a single point is lower than the trend and this represents almost no mineralization at all. Analysis of Zn values greater than 1% results a straight with a small negative slope, indicating little or no relation between Zn and Ag. The negative slope indicates that Ag values decrease with increasing Zn.

Figure 58. Analysis of the Zn-Ag data using Ag as the independent variable yielded the results shown in Figure 58. The trend is linear with a negative slope indicating decreasing Zn value with increasing Ag values.

Figure 59. Analysis of Cu + Zn values using Ag (weight %) as the independent variable resulted in a exponential type curve. The graph shows a linear trend up to 13% Cu + Zn, where a break occurs and the trend changes to one showing no relation between Ag and Cu + Zn.

Figure 60 and 61. The graph of Cu versus Ag, with Ag being the independent variable (same data as Figure 56) using an arithmetic base resulted in a straight line with a positive slope and passed through the origin (Figure 60). Plotting of this same data on logarithmic paper (Figure 61) yielded a straight line with a

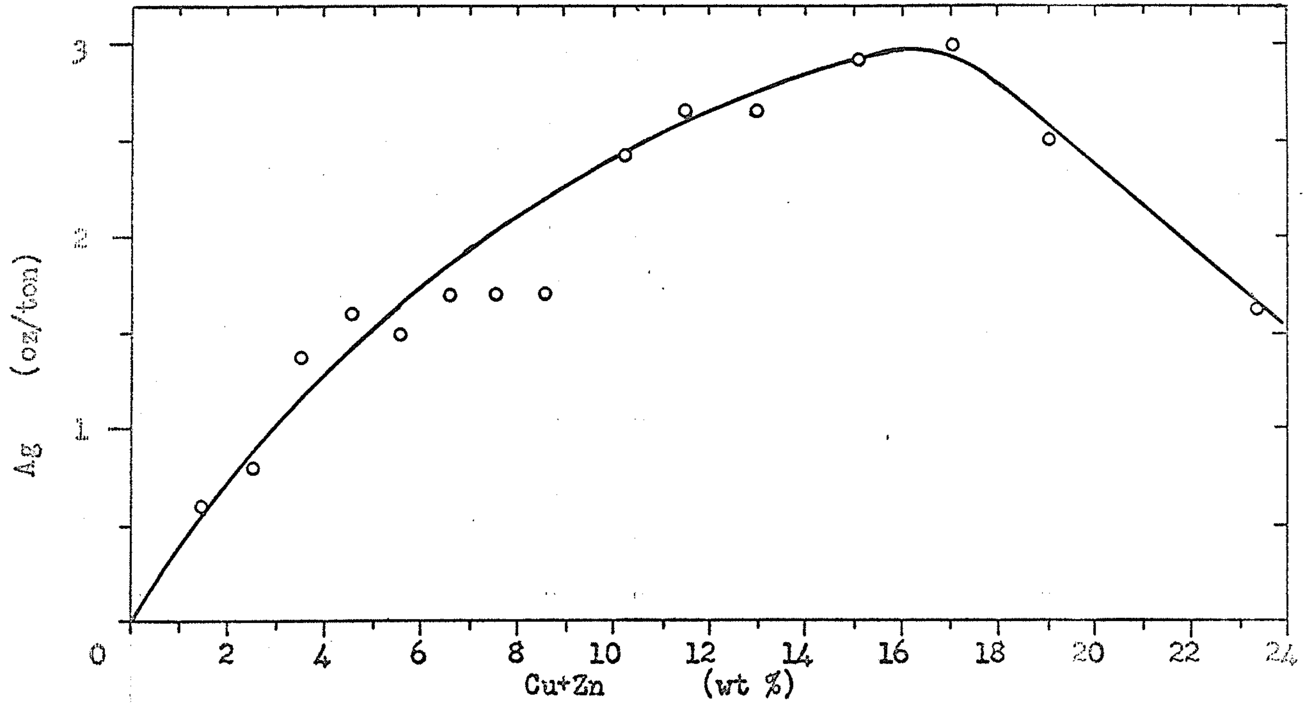

Figure 62. Cu+Zn-Ag relations (wt %) in the massive ore, Geco Mines Limited.

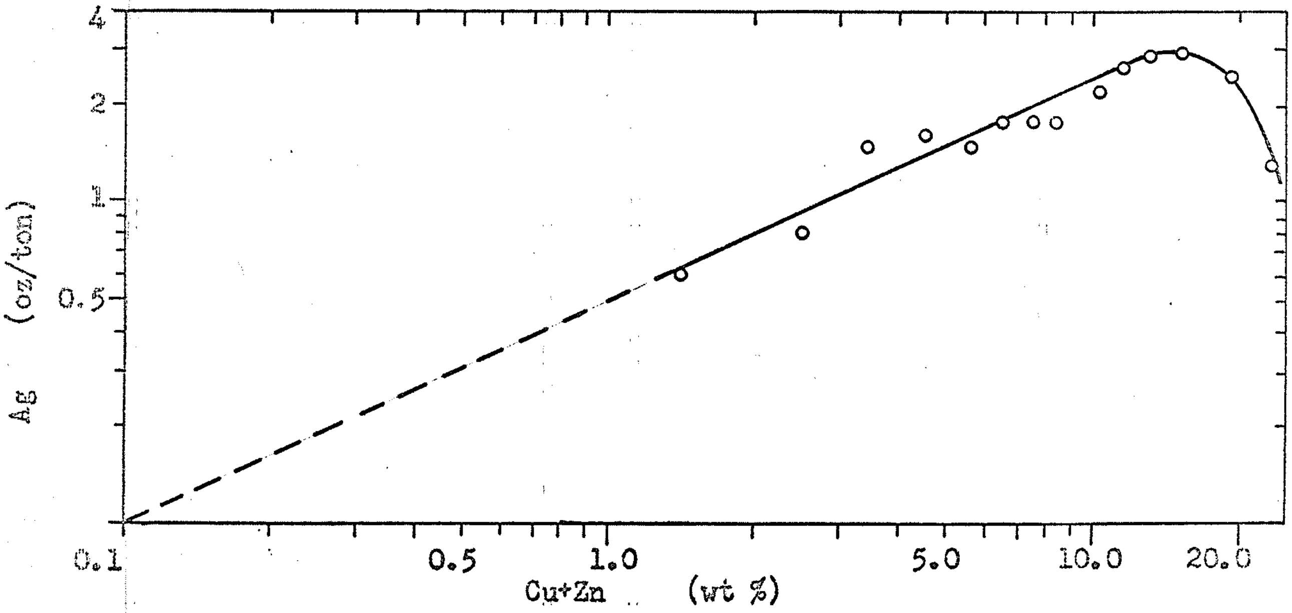

Figure 63. Cu+Zn-Ag relations (wt %) in the massive ore (logarithmic base), Geco Mines Limited.

positive slope which passed through the origin. Similar trends were obtained in Figures 56, 60 and 61 and indicate a direct relation between Cu and Ag.

Figure 62 and 63. The arithmetic relation between Ag and Cu + Zn (weight %), as shown in Figure 62, is exponential. The graph, while being somewhat linear, rises to a maximum and falls off with increasing Cu + Zn values. The maximum silver content occurs at about 17% Cu + Zn. Plotting of this same data on logarithmic paper (Figure 63) resulted in a linear trend with a rapid drop off at the high Cu + Zn end of the graph. The relations shown in Figures 59, 62, and 63 indicate that Ag is not directly proportional to combined Cu + Zn values.

Figure 64. Plotting of Cu against Zn (weight %) in the massive ore resulted in a linear trend with a negative slope. There is a fair amount of scatter about this line, but the trend of decreasing Zn values with increasing Cu content is real and apparent.

Disseminated Ore

A similar statistical analysis was carried out on the metal content of the disseminated ore.

Figure 65. Plotting of Cu against Zn (weight %) yielded a linear trend (A) with a small positive slope, indicating only small changes in Zn with large changes in Cu. This line suggests an apparent relation between Cu and Zn. However, if one considers that the Zn associated with low Cu values represents little or no mineralization at all and can be represented by a line with a zero slope

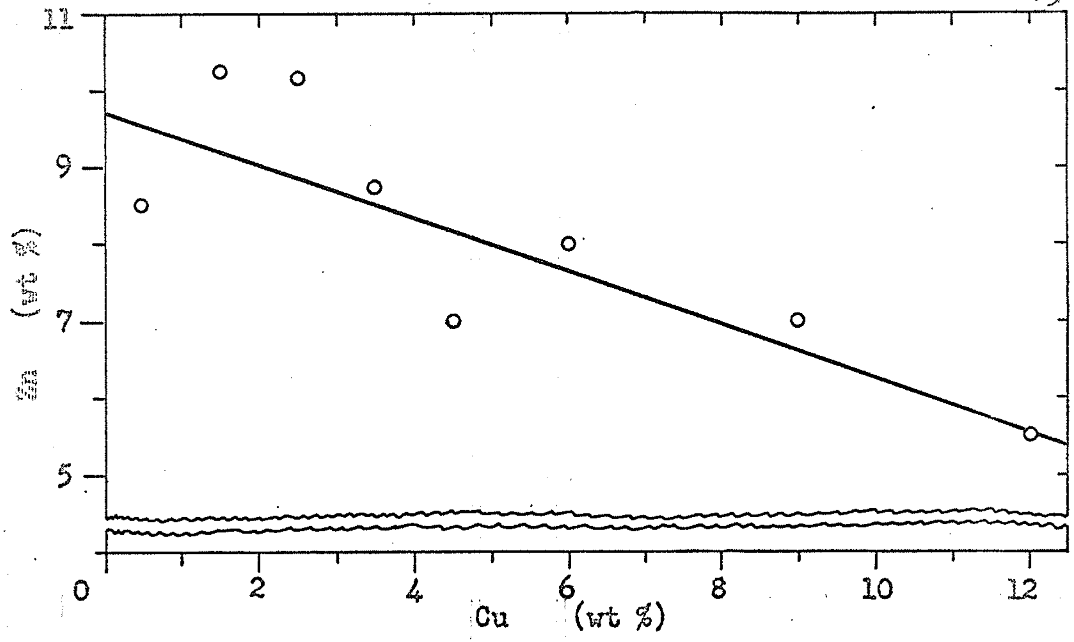

Figure 64. Cu-Zn relations (wt %) in the massive ore, Geco Mines Limited.

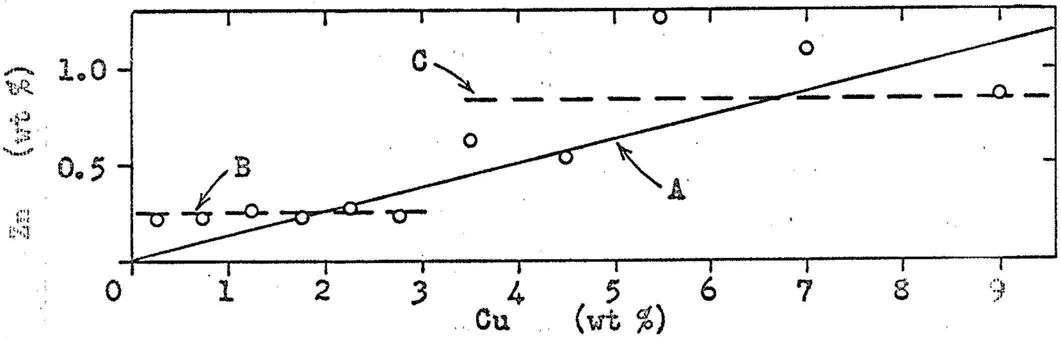

Figure 65. Cu-Zn relations (wt %) in the disseminated ore, Geco Mines Limited.

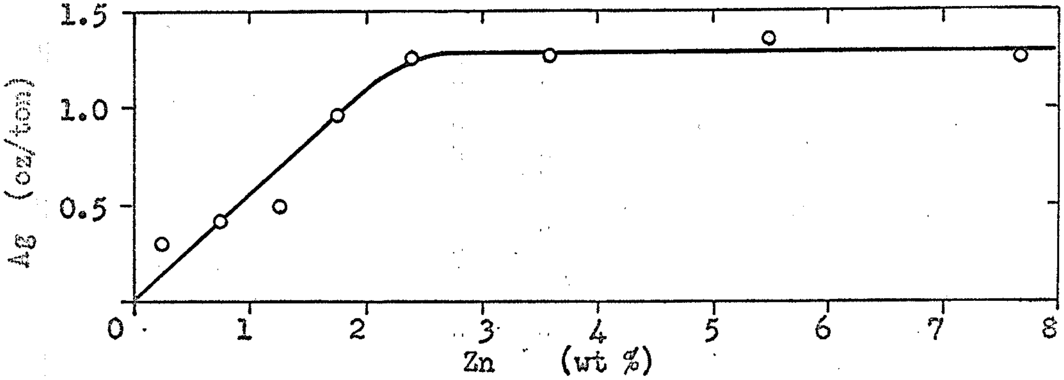

Figure 66. Zn-Ag relations (wt %) in the disseminated ore, Geco Mines Limited.

(line B), then the higher Zn values associated with Cu mineralization can be represented by a line with a zero slope (line C). Lines B and C indicate that no relation exists between Cu and Zn.

Figure 66. The graph of Ag versus Zn (weight %) shows two trends, Ag and Zn are directly related to about 2.75% Zn, where the curve breaks and the slope changes from a positive value to zero. About 2.75% Zn, Ag shows no relation to the Zn content of the ore.

Figure 67. Analysis of the Zn-Ag data from Figure 66 on a logarithmic base resulted in a more linear relation, suggesting that the Zn-Ag relation is exponential.

Figure 68, 69, and 70. The relation between Cu and Ag (weight %) on an arithmetic scale is shown in Figure 68. The resulting straight line has a large positive slope and passes through the origin. Plotting of these Cu and Ag values on logarithmic paper (Figure 69) resulted in a sinuous linear trend, indicating that the relation between Ag and Cu is arithmetic rather than exponential. Plotting of the Ag values on a logarithmic scale with Cu values on an arithmetic scale tended to make the linear relation between these two metals more apparent.

Figure 71. This graph shows the relation between Ag and Cu + Zn (weight %) in the disseminated ore. The resulting straight line passed through the origin and had a positive slope. As Zn is a minor constituent in the disseminated ore, its effect in the Cu + Zn relation will be very small.

The Mine

Figure 72. The relation between Cu and Ag (weight %) for the mine

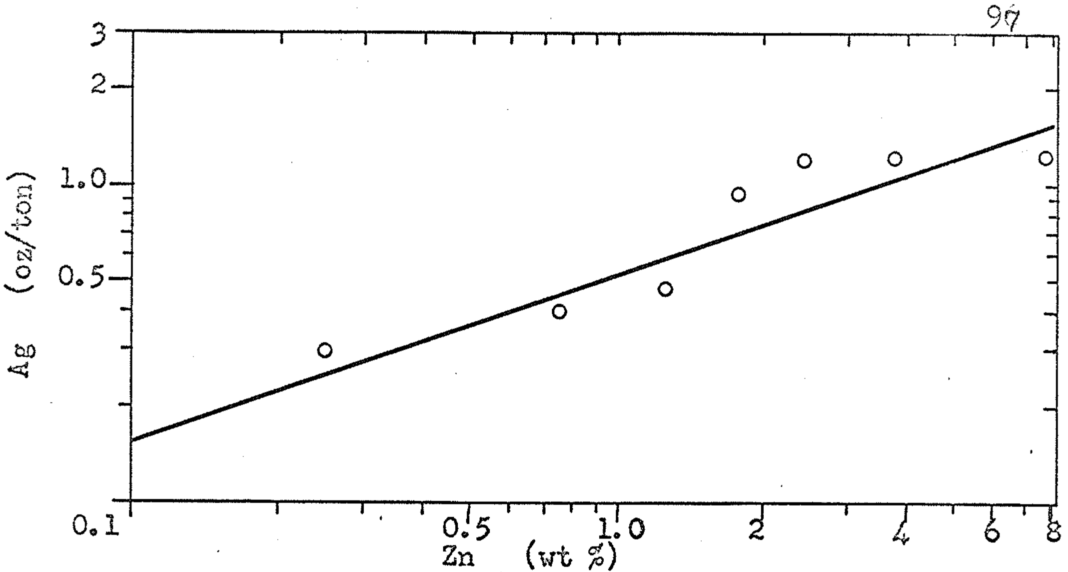

Figure 67. Zn-Ag relations (wt %) in the disseminated ore (logarithmic base), Geco Mines Limited.

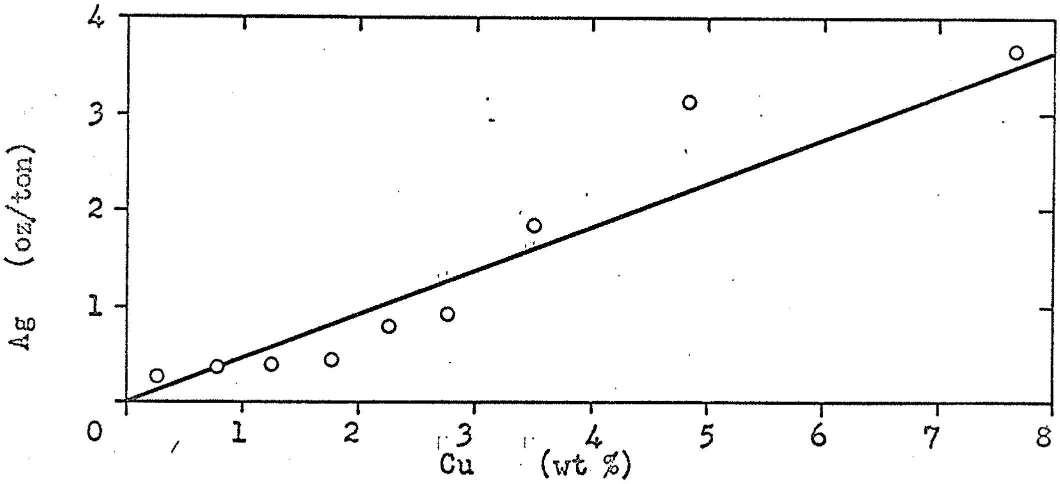

Figure 68. Cu-Ag relations (wt %) in the disseminated ore, Geco Mines Limited.

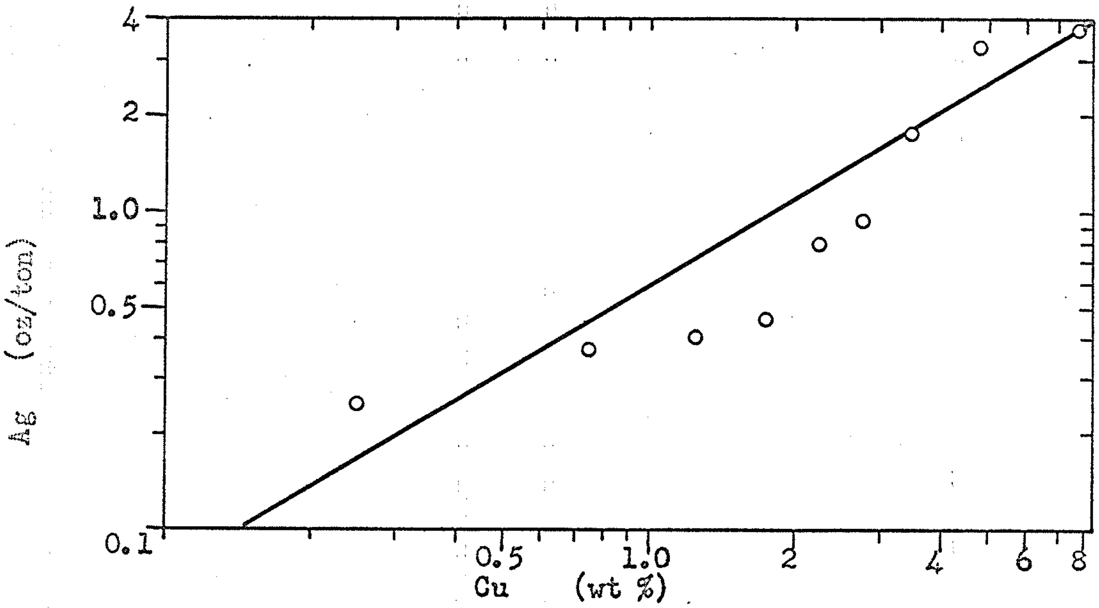

Figure 69. Cu-Ag relations (wt %) in the disseminated ore (logarithmic base), Geco Mines Limited.

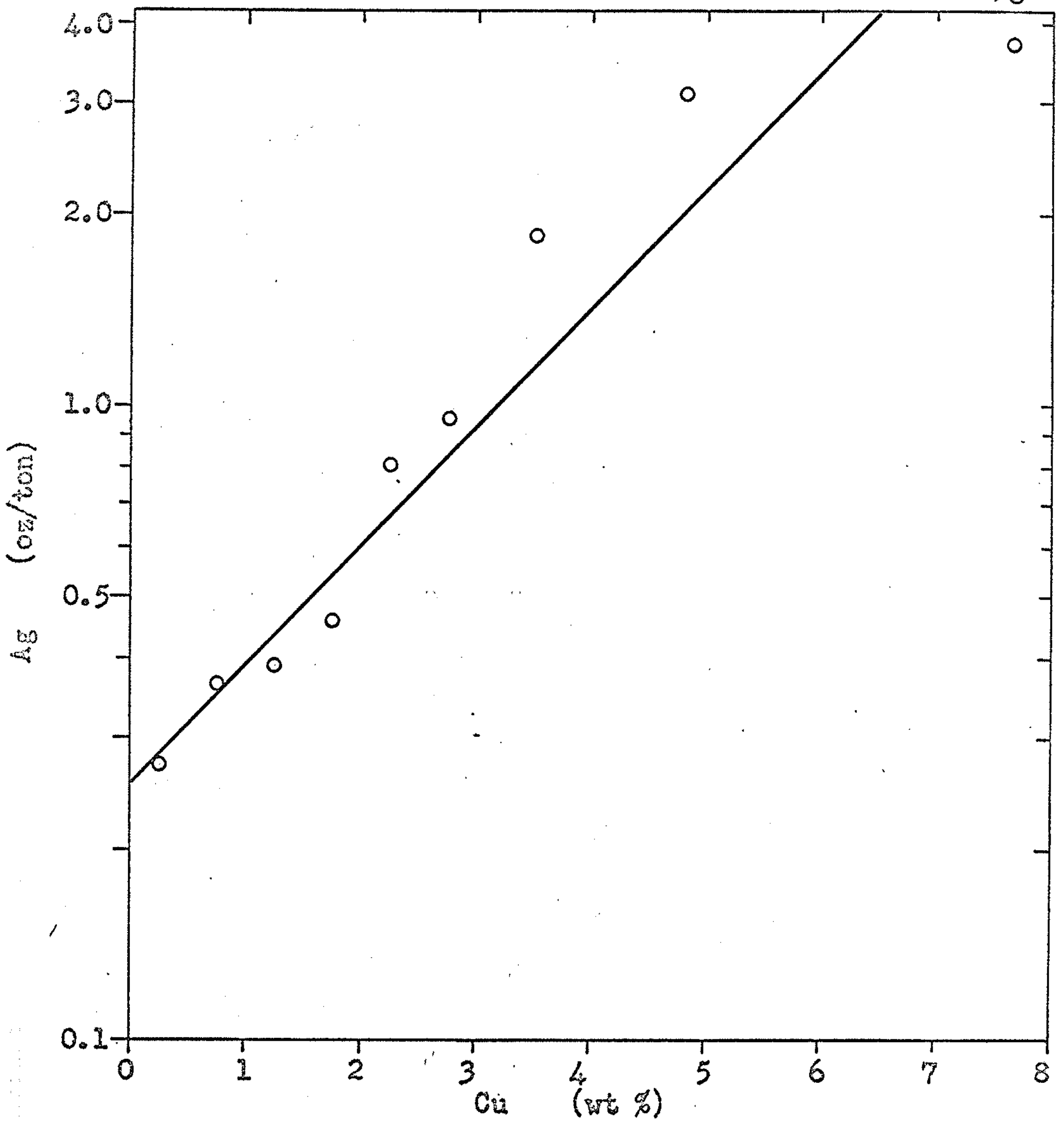

Figure 70. Cu-Ag relations (wt %) in the disseminated ore (semi-logarithmic base), Geco Mines Limited.

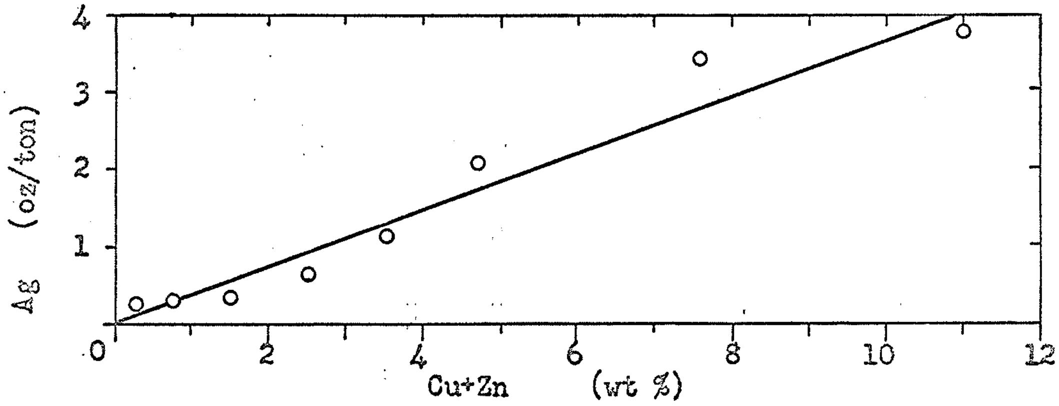

Figure 71. Cu+Zn-Ag relations (wt %) in the disseminated ore, Geco Mines Limited.

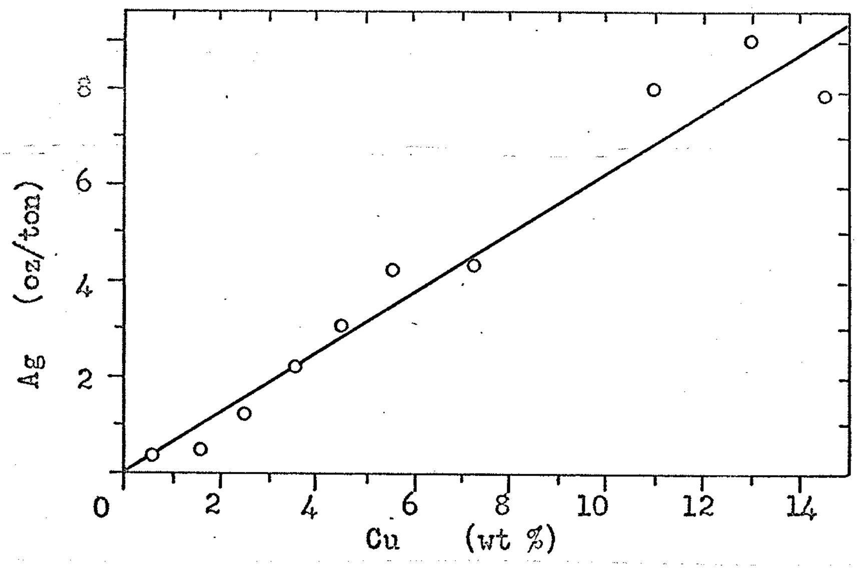

Figure 72. Cu-Ag relations (wt %) for the Geco Mine.

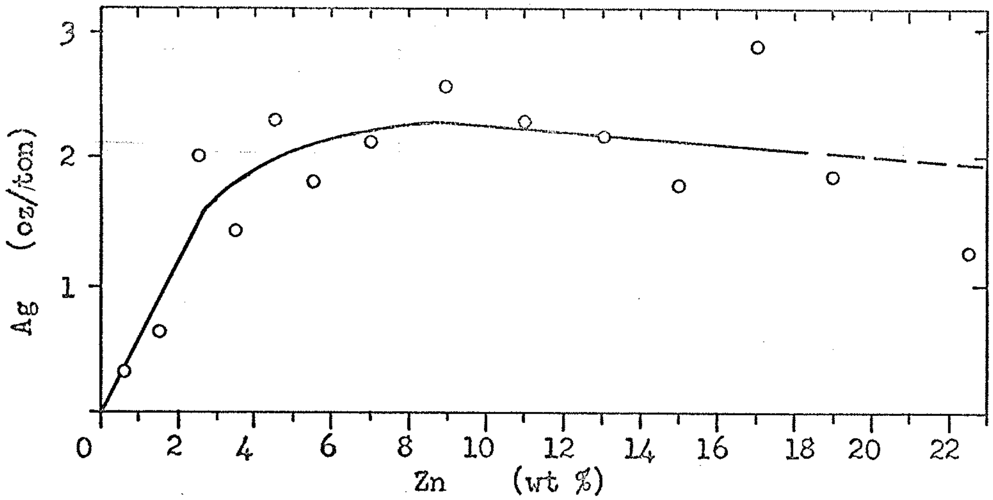

Figure 73. Zn-Ag relations (wt %) for the Geco Mine.

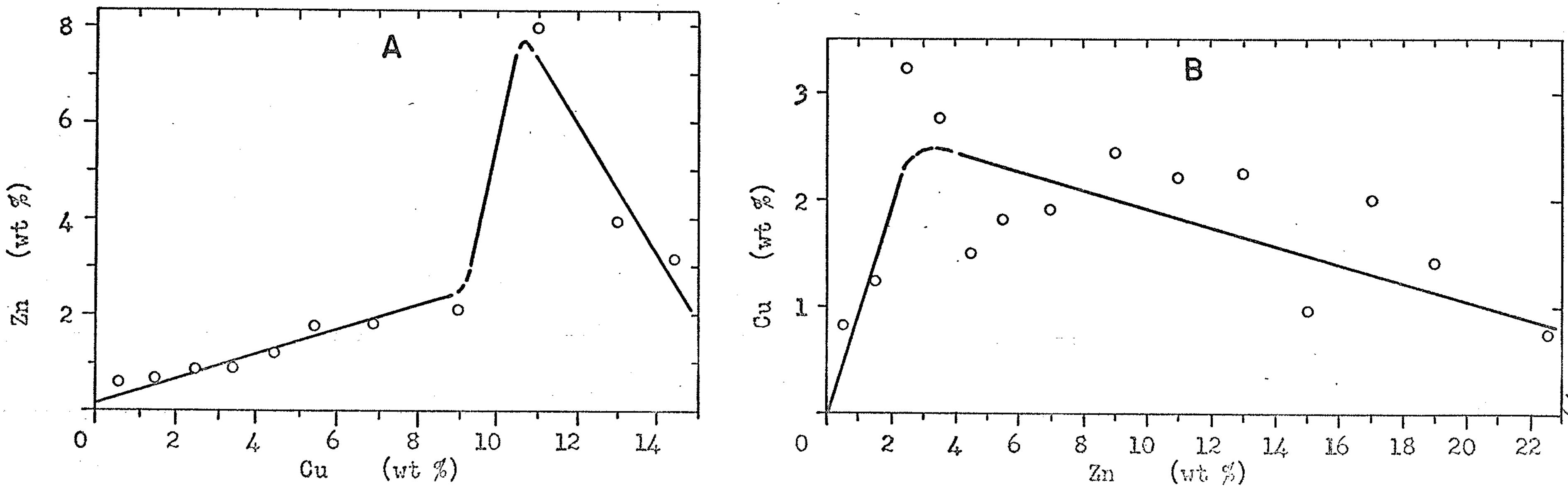

Figure 74 (A and B). Zn-Cu and Cu-Zn relations (wt %) for the Geco Mine.

is shown in this figure. The resulting graph is a straight line with a positive slope and passes through the origin.

Figure 73. This graph again suggests that Zn and Ag (weight %) are not directly related. Zn and Ag show a linear relation up to about 2.5% Zn where the curve breaks and the slope of the line begins to decrease. A second break in the curve occurs at about 8% Zn where the slope of the line becomes negative.

Figure 74. Zn-Cu relations using Cu as the independent variable are shown in Figure 74A. Cu and Zn appear to be directly related up to 9% Cu and 2.5% Zn. At the point, the curve shows a large break. Above 9% Cu, Zn values decrease with increasing Cu. Analysis of the data using Zn as the independent variable yielded similar results (Figure 74B). In this case, Cu increases proportionally to Zn up to about 2.5% Zn, where the curve shows a sharp break. With increasing Zn values, Cu shows a rapid decrease. These figures suggest that Cu and Zn are related over the lower grade ranges.

Individual Element Distribution

Figure 75. Frequency distribution histograms of abundances of individual metallic elements occurring in the Geco deposit have been prepared and the following distributions have been noted (Figure 75).

In the massive ore, copper and silver show similar distributions, being unimodal and right skewed with sharp central tendancies in the low assay range. Such distributions indicate that the Cu and Ag values generally remain low and show a constant distribution. The zinc distribution is characterized by a large degree of dispersion

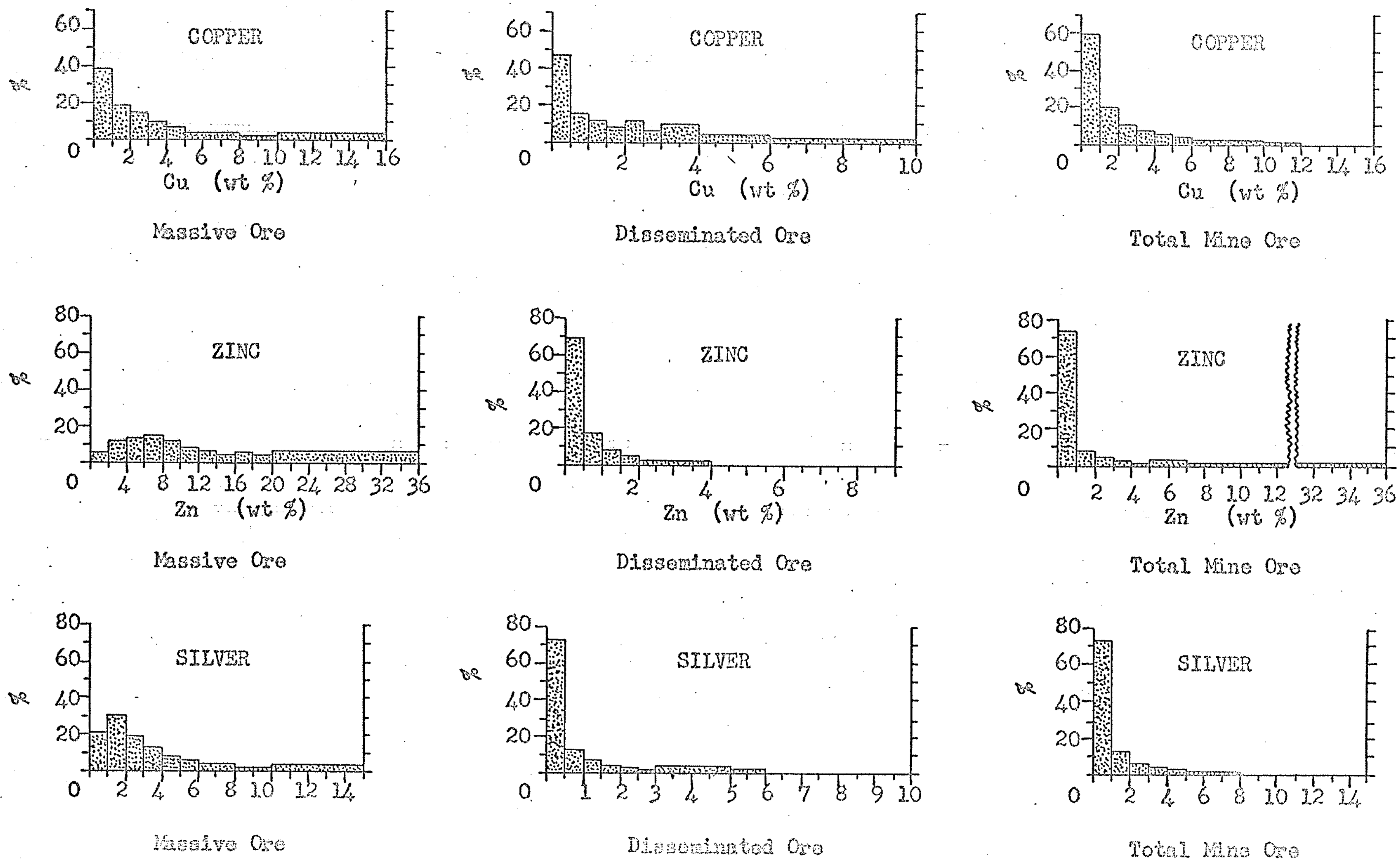

Figure 75. Distribution histograms of abundances of individual elements (Cu, Zn, and Ag) at the Geco Mine.

and by two broad peaks. No definite central tendancy is clearly shown. Median metal values for the massive ore as determined from these distributions are; Cu= 1.61%, Zn= 8.84%, and Ag= 1.98 oz/ton.

In the disseminated ores, Cu, Zn and Ag have similar distribution being unimodal and right skewed. Peaking is very sharp in all cases and occurrs in the lowest assay ranges. The distribution for Cu is slightly more variable in that the Cu values do not fall off as rapidly as the distributions of Zn and Ag. Median metal values for the disseminated ore, as calculated from these distributions are; Cu= 0.60%, Zn= 0.36%, and Ag= 0.34 oz/ton.

The copper distribution for the mine, includes massive and disseminated ores, remains unimodal and right skewed. The peak is very sharp and occurs in the low Cu assay range. The mine distribution of Zn values becomes strongly right skewed and unimodal with a very sharp peak at 0.69% Zn. The silver distribution for the mine is strongly right skewed and unimodal. Peaking is sharp and occurs at the low Ag end. Median values for the elements are; Cu= 0.85%, Zn= 0.69%, and Ag= 0.73 oz/ton.

Frequency distribution tables used in the Geco study are included in the Appendix.

Summary of Results

Massive Ore.

1. Cu and Ag occur in direct proportions (Figures 56, 60 and 61).

2. Zn and Ag show very little relation to one another. In

general, Ag decreases with increasing Zn (Figures 57 and 58).

3. Ag shows no direct relation to combined Cu + Zn values. The relation appears to be exponential (Figures 59, 62, and 63).

4. Cu and Zn show indirect proportionality. Zn decreases with increasing Cu (Figure 64).

Disseminated Ore.

5. Cu and Zn show little or no relation in this ore type (Figure 65).

6. Ag and Zn show a direct relation up to about 2.75% Zn. Above 2.75% Zn, Ag is unrelated to Zn (Figures 66 and 67).

7. Cu and Ag are directly related (Figures 68, 69, and 70).

8. Ag shows an apparent direct relation to Cu + Zn, possibly due to the minor effect of low zinc assays in the disseminated ore (Figure 71).

Mine Distribution.

9. Cu and Ag show a direct relation (Figure 72).

10. Zn and Ag show an apparent direct relation in the low Zn assay range only. With higher Zn values, Ag tends to decrease with increasing Zn (Figure 73).

11. Cu and Zn appear to be directly related over low assay ranges only. In the higher assay ranges, Cu and Zn show indirect proportionality (Figure 74).

12. Distribution histograms of the abundances of individual elements are generally similar in form for Cu, Zn, and Ag in all ore types. The Zn content of the massive ore is an exception however,

and is characterized by a large amount of dispersion. Such histograms do not suggest any specific element associations at the Geco Mine.

3. The Flin Flon Mine of Hudson Bay Mining and Smelting, Northern Manitoba.

The Flin Flon Mine is located in Northern Manitoba, about 400 miles north of Winnipeg, Manitoba. All rock formations in the mine area are Precambrian in age and consist of a series of volcanic rocks overlain unconformably by a clastic-sedimentary series. This sedimentary-volcanic series has been intruded by acidic and basic intrusions. The volcanic series is made up of acidic and basic flows, tuffs, agglomerates, plus some irregular intrusive bodies and minor schists. The sedimentary series is mainly arkose and conglomerate.

The earlier intrusive rocks are of basic composition and have been emplaced as dykes and small masses. These were followed by batholithic intrusions of granite and granite gneiss accompanied by dykes of granite and quartz porphyry. Later dioritic dykes cut these granites (Alcock, F.J., 1930, and Brownell, G.M., and Kinkel, A.R., 1935).

In the mine area, the lava flows and pyroclastics trend N30° W and dip 70° East. Faulting is parallel to these beds. Pre-ore shearing and reverse faulting provided channels for the mineralizing solutions.

The principal minerals in the orebodies are pyrite, sphalerite, chalcopyrite, plus minor amounts of gold and silver.

Two distinct types of ore are mined, but three ore types have been recognized;

1. Solid sulphide ore (massive) composed of pyrite, sphalerite, chalcopyrite, with minor pyrrhotite, arsenopyrite, **calcite** , gold, and silver.

2. Disseminated ore composed of country rock impregnated with sulphides. Chalcopyrite and some pyrite are the main sulphides present. Minor amounts of sphalerite, gold, and silver have been noted.

3. Interbanded ore which represents the transition between massive and disseminated ores and contains sphalerite, chalcopyrite, pyrite, gold, and silver.

The solid sulphide bodies form the central portion of the ore lenses whereas the disseminated sulphide ore is largely confined to the footwall and hanging wall zones.

A hydrothermal replacement origin has been postulated for the deposit. Paragenesis of the sulphide minerals has been indicated as pyrite, arsenopyrite, chalcopyrite, cubanite, galena, and precious metals. Mineralizing solutions have been assumed to come from the granite but the basic intrusions have also been considered as a possible source. However, the most recent paper presented by the mine staff postulates an origin related to sulphide injection (Koffmann, A.A., Cairns, R.B., and Price, R.L., 1962).

Assay sheets from this property give the values for Cu, Zn, Au, and Ag for both massive and disseminated ore types. Approximately 2400 random assay values were utilized in this study. Wilson and Anderson (1959) have carried out a preliminary study on the $\frac{Cu}{Cu+Zn}$ ratio at this property. Currently, individual metal ratios were invetigated in both the massive and disseminated ore types. Statistical analyses were also carried out to determine the relation between precious metal values and the total base metal content, and to determine the relation, if any, between $\frac{Cu}{Cu+Zn}$ and the precious metal values. Histograms of the distribution of individual assays were also compiled.

Metal Ratios

The distribution of the $\frac{Cu}{Cu+Zn}$ ratio for the Flin Flon massive ore has been described by Wilson and Anderson (1959). While their study was incomplete, it was apparent that the massive ore was mainly composed of zinc and that the type of distribution for the Cu:Zn ratios was very similar on the 2700' and 3000' levels. Cu:Zn ratio distribution in the massive ore is bimodal (Figure 9). One peak is broad and occurs on the zinc end of the diagram. The second peak is sharp and occurs at the copper end of the diagram. It was postulated that this double peaking indicated a greater separation of chalcopyrite and sphalerite at the Flin Flon Mine than in the massive ore at Geco, or that the massive and disseminated types may be intermixed at the Flin Flon Mine.

Separate statistical analyses were carried out for both the massive and disseminated ore types at the Flin Flon Mine.

Massive Ore

Figure 76. Cu and Ag (weight %) show a definite relation in this diagram. Up to 2.5% Cu, the Ag content increases proportionally with increasing Cu, the relation being very close to linear. Above 2.5% Cu, the slope of the line decreases abruptly, but direct proportionality is maintained at a much smaller slope.

Figure 77. Zn and Ag (weight %) are related in a similar manner as Cu and Ag. Ag increases rapidily and proportionally with increasing Zn up to about 6% Zn. Here, the curve breaks and the slope of the line decreases to almost zero, indicating little or no relation between Zn and Ag above 6% Zn.

Figure 78. The relation between Cu and Au (weight %) is similar to that for Cu and Ag (Figure 76). Cu and Au increase proportionally and rapidily up to about 6% Cu. Above 6% Cu, the linear relation is maintained but the slope of the line has decreased to almost zero.

Figure 79. Plotting of Zn versus Au (weight %) yielded similar results to those for Zn and Ag. Zn and Au occur in direct proportion up to about 6% Zn. Above 6% Zn, the slope of the curve decreases rapidly to a negative value, indicating an indirect relation between Zn and Au, especially above 14% Zn.

Figure 80. Analysis of Cu + Zn versus Ag (weight %) resulted in a straight line with a positive slope. The y-intercept has a value of about 0.40 oz/ton Ag.

Figure 81. The plotting of Au versus Cu + Zn (weight %) yielded

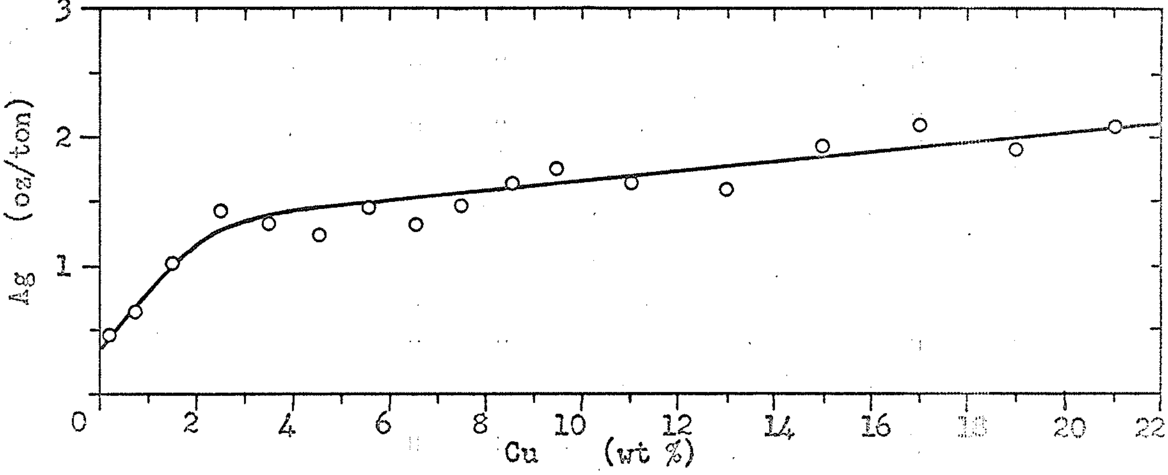

Figure 76. Cu-Ag relations (wt %) in the massive ore, Flin Flon Mine.

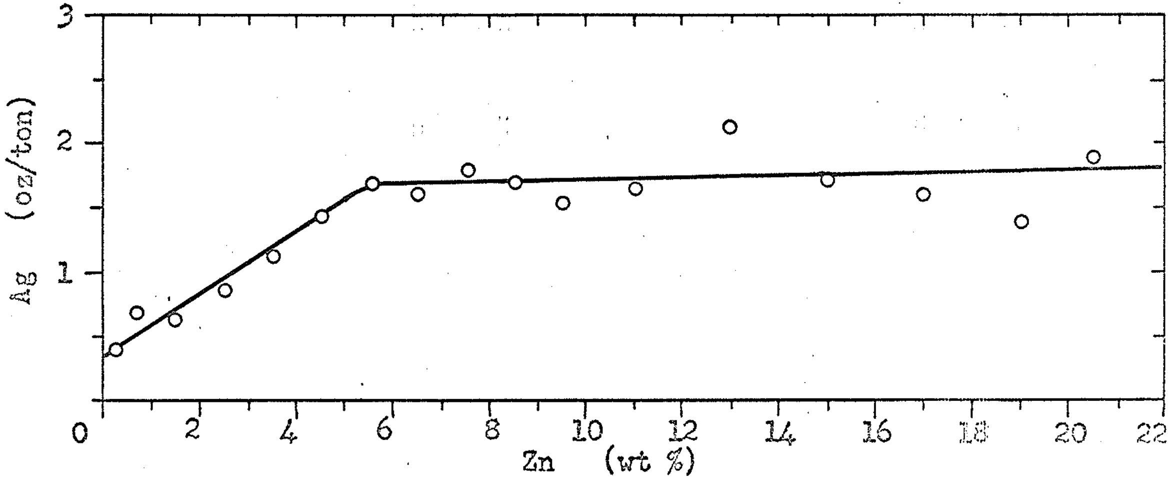

Figure 77. Zn-Ag relations (wt %) in the massive ore, Flin Flon Mine.

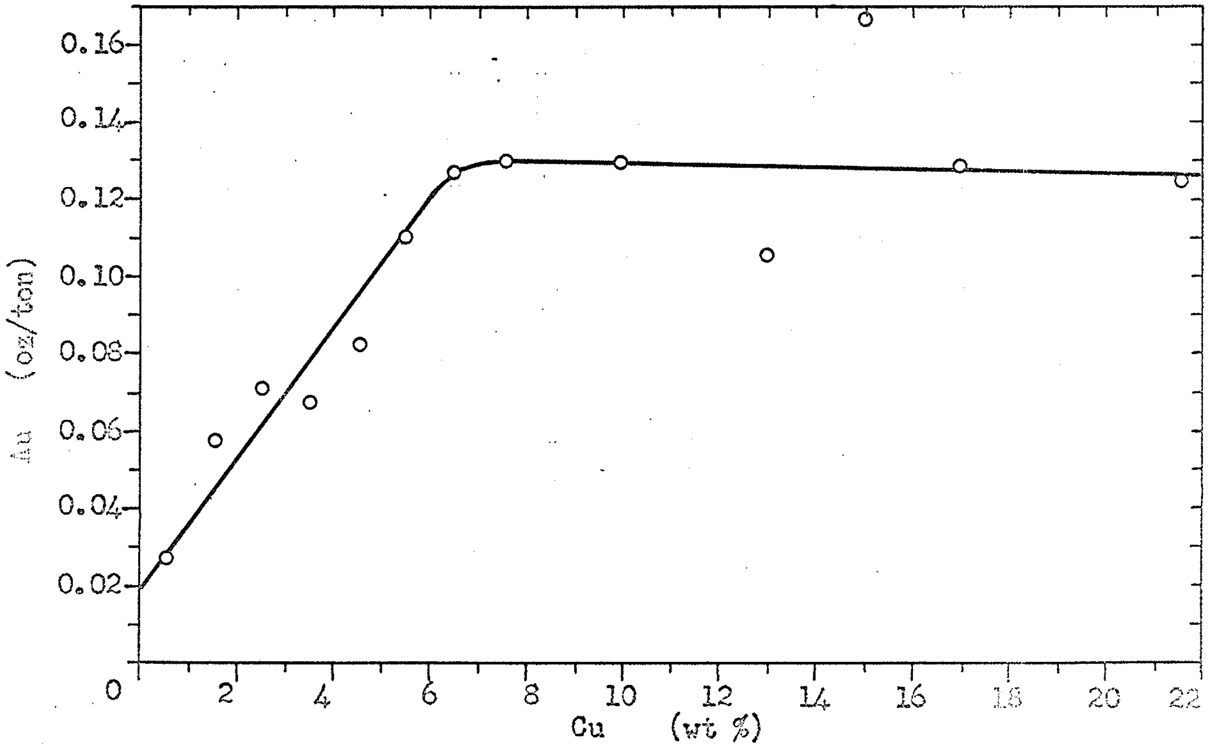

Figure 78. Cu-Au relations (wt %) in the massive ore, Flin Flon Mine.

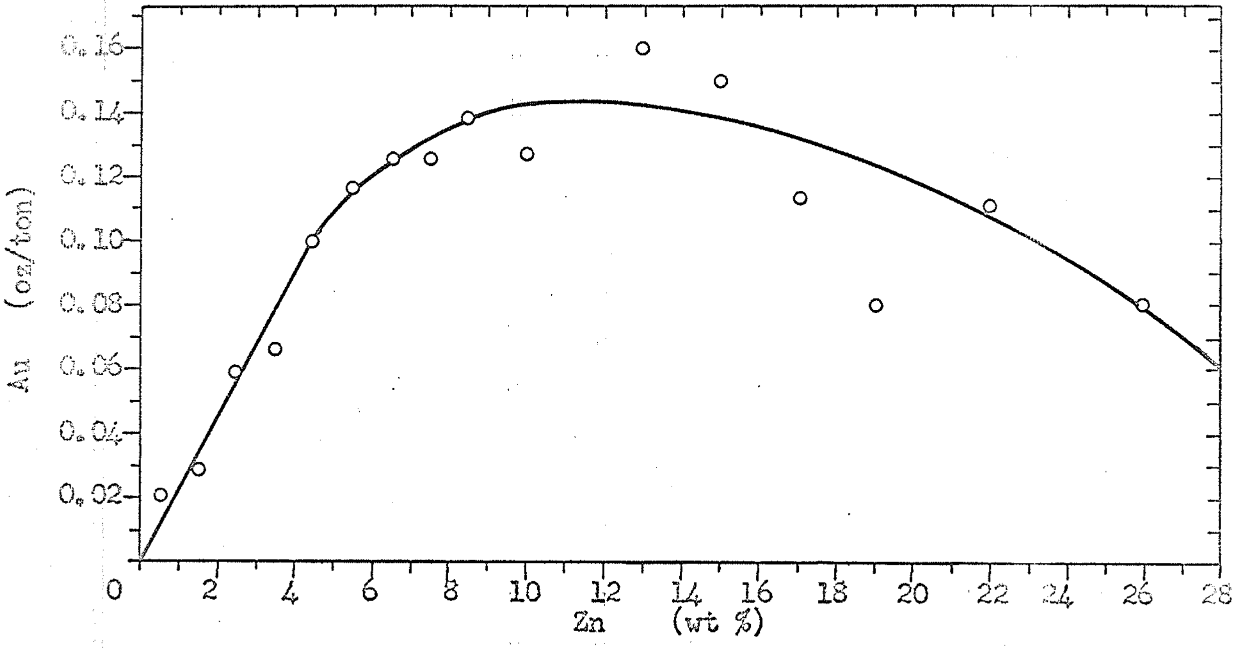

Figure 79. Zn-Au relations (wt %) in the massive ore, Flin Flon Mine.

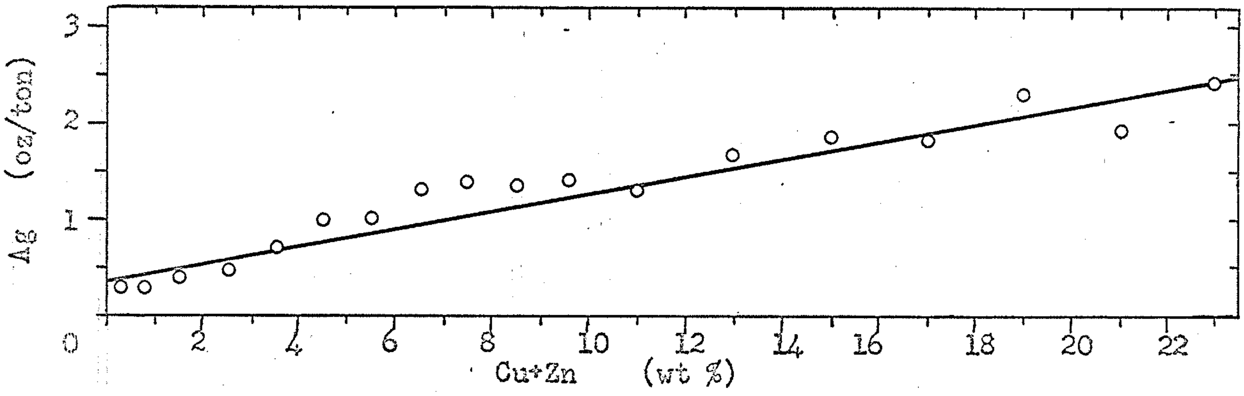

Figure 80. Cu+Zn-Ag relations (wt %) in the massive ore, Flin Flon Mine.

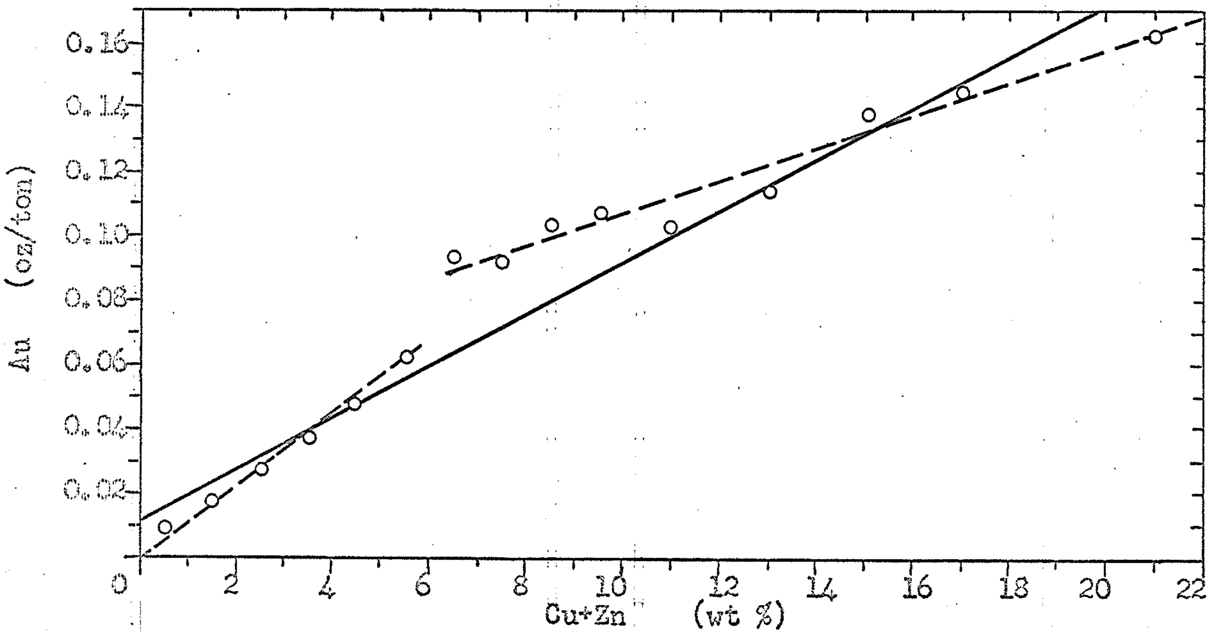

Figure 81. Cu+Zn-Au relations (wt %) in the massive ore, Flin Flon Mine.

a linear trend with a positive slope and a y-intercept value of about 0.01 oz/ton Au. Some scatter of points occurred about this trend in the 6 to 11% Cu + Zn range suggesting a break in the line such that the relation between Au and Cu + Zn may be graphically represented by two linear trends (dashed lines). In this case, the break in the relation would occur at about 6% Cu + Zn.

Figure 82. Additional statistical studies were carried out with median $\frac{Ag}{Au}$ ratio values arrayed against Cu, Zn, and Cu + Zn (weight %). The trends for the three base metal combinations are such that $\frac{Ag}{Au}$ decreases rapidly from an initial high value at low base metal contents, reaches a minimum value in the moderate base metal assay ranges, and increases slightly in the higher assay ranges. The initial high $\frac{Ag}{Au}$ in the low assay ranges is probably due to very low Au assays in the weakly mineralized material. Above the 6% base metal assay range, the variation in $\frac{Ag}{Au}$ is generally small and may be due to changes in the precious metal ratio in various sections of the mine. For example, $\frac{Ag}{Au}$ may vary with depth.

Figure 83. Analysis of Au with respect to $\frac{Cu}{Cu + Zn}$ (weight %) suggests that Au is related to one of the base metals, Cu or Zn. The resulting curve is parabolic in form and the maximum Au value occurs when Cu and Zn are approximately equal to 3% and 6% respectively. Au decreases from this maximum toward the high Zn and high Cu ends of the diagram.

Figure 84. The Zn-Cu relation is characterized by a scattering of points in the low to moderate Cu assay range and by a trend with

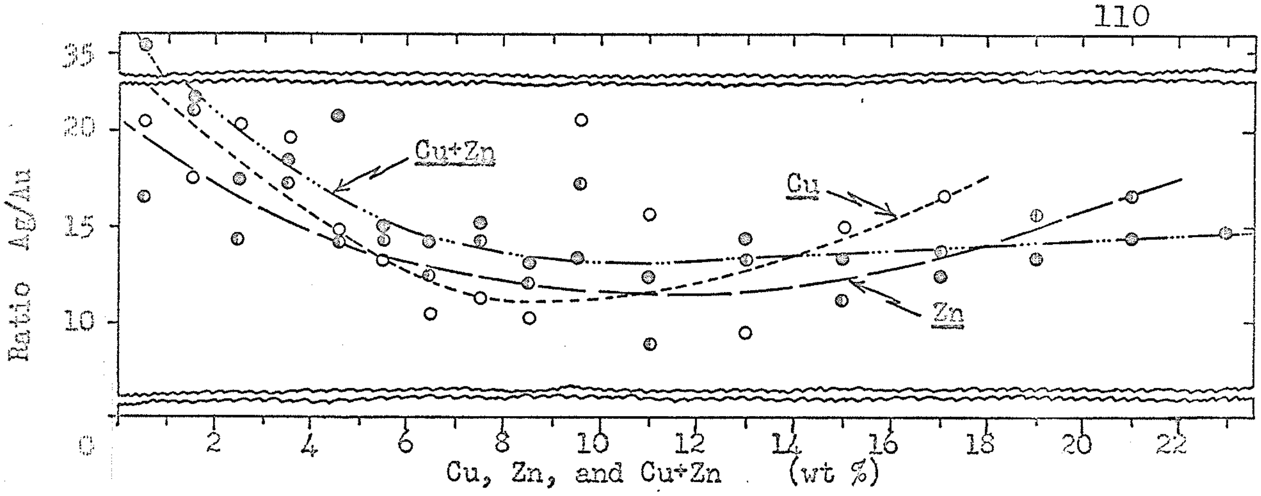

Figure 82. Relations between Ag/Au-ratio and Cu, Zn, and Cu+Zn (wt %) in the massive ore, Flin Flon Mine.

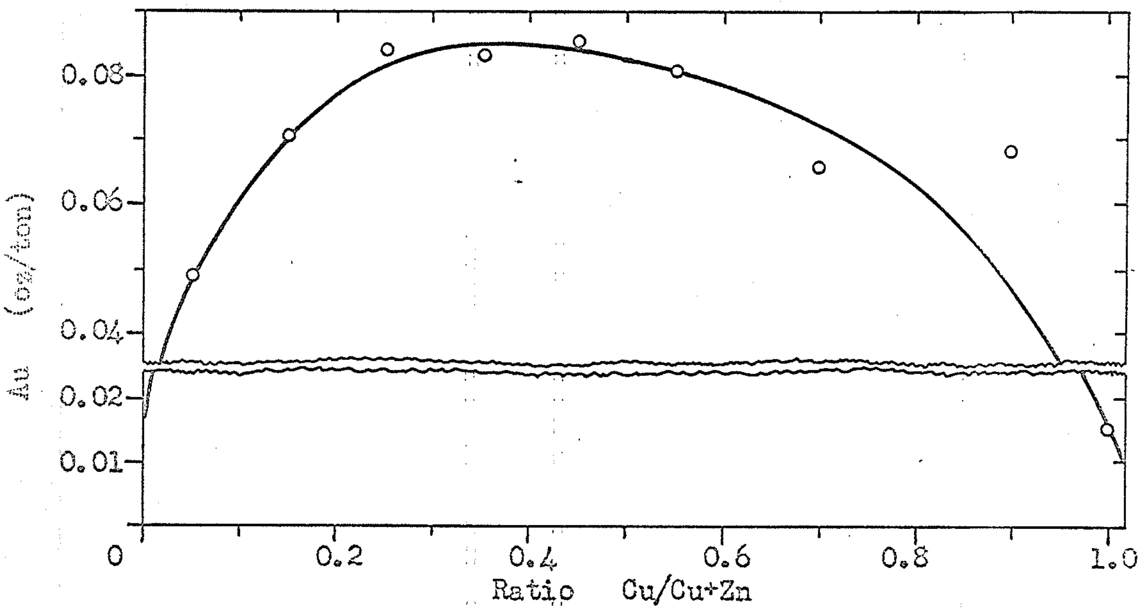

Figure 83. Relations between Cu/Cu+Zn ratio and Au (wt %) in the massive ore, Flin Flon Mine.

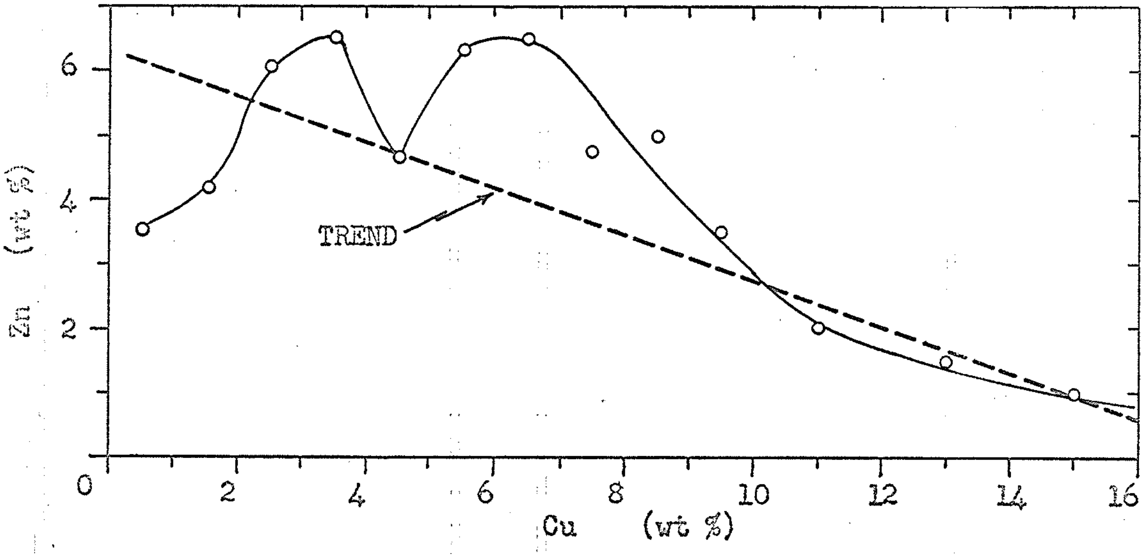

Figure 84. Cu-Zn relations (wt %) in the massive ore, Flin Flon Mine.

a negative slope. Above 8% Cu, the Zn content of the ore shows a definite decrease. The low Zn values associated with low Cu are due to the incomplete separation of massive and disseminated ore types during ore generation. Separation of the assay data into ore types also may not be fully reliable.

Figure 85. Au and Ag data (weight %) were analyzed with respect to the upper (0-2200') levels and the lower (2700-3500') levels of the mine. In both cases, Au and Ag are present in direct proportions. However, the plot for the lower levels has a steeper positive slope indicating slightly higher grades of gold relative to silver at lower levels in the mine.

Figure 86. Plotting of Ag against Au (weight %) resulted in a straight line with a positive slope which passed through the origin. Au and Ag are present in direct proportions in the massive ore. $\frac{Au}{Ag}$ in the massive ore equals 0.05.

Disseminated Ore

Figure 87. The graph of Cu versus Au (weight %) resulted in a linear trend with a positive slope and a y-intercept value of about 0.005 oz/ton Au. However, the distribution of points also suggests the possibility of a break in the trend at about 3% Cu. In this case, Cu and Au would be directly proportional up to 3% Cu. Above 3% Cu, linearity is maintained, but the slope of the line has decreased appreciably.

Figure 88. A linear relation exists between Cu and Ag in the

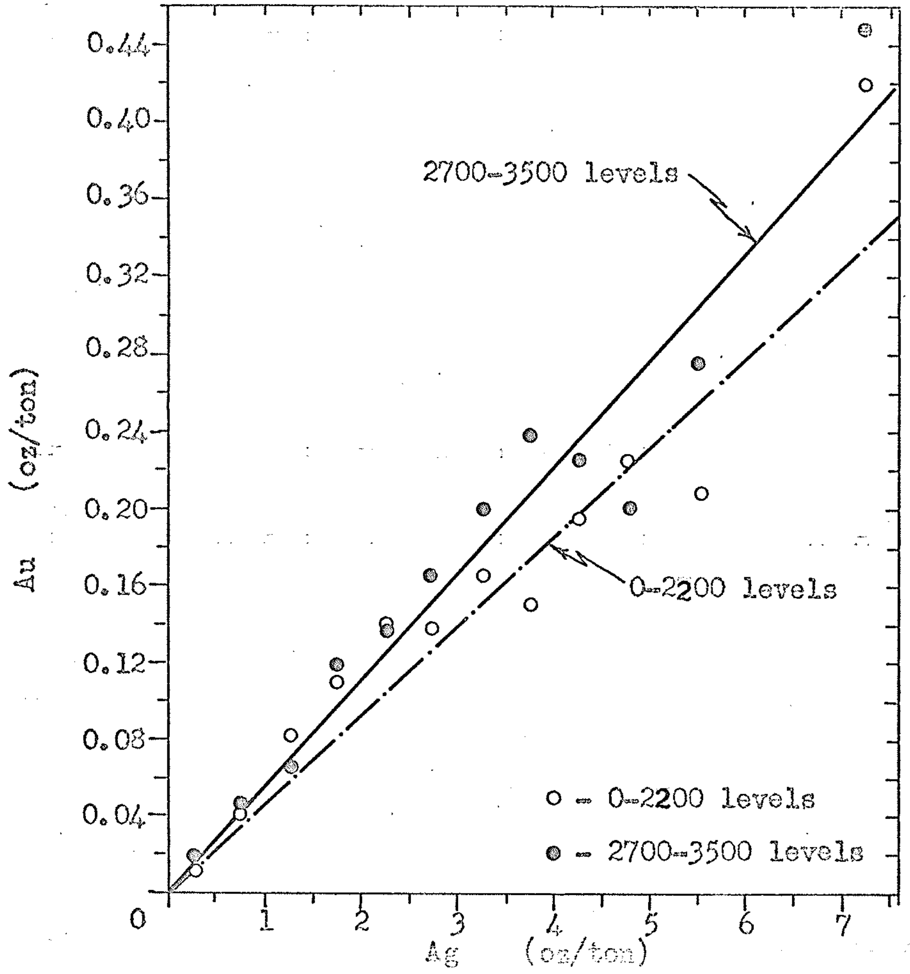

Figure 85. Comparison of Ag-Au relations (wt %) in the upper and lower portions of the Flin Flon Mine for the massive ore.

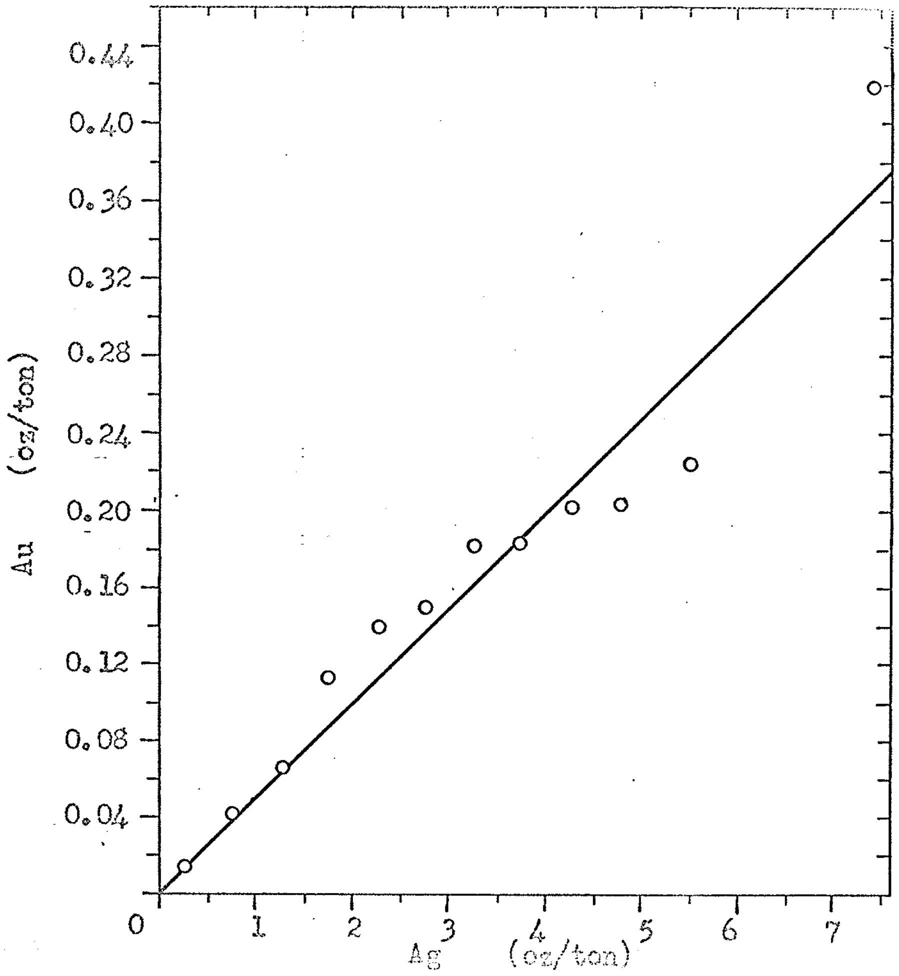

Figure 86. Ag-Au relations (wt %) for the Flin Flon Mine, massive ore.

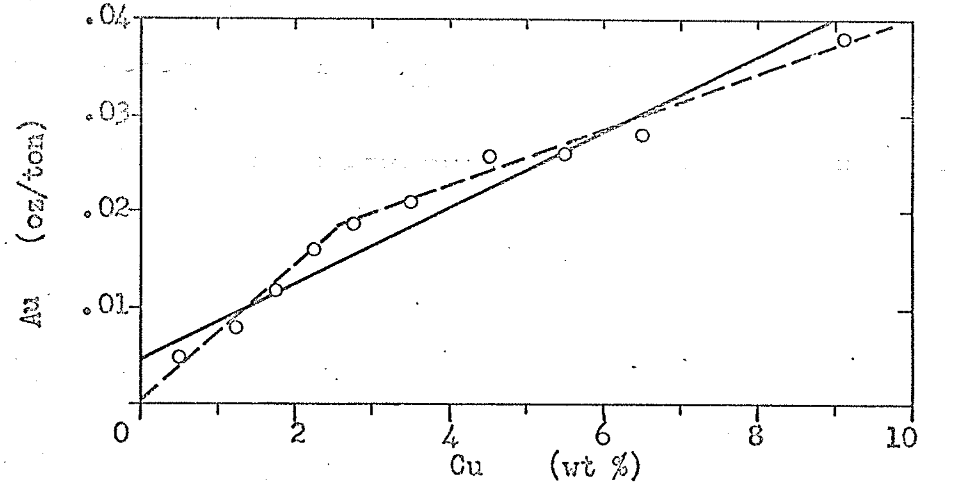

Figure 87. Cu-Au relations (wt %) in the disseminated ore, Flin Flon Mine.

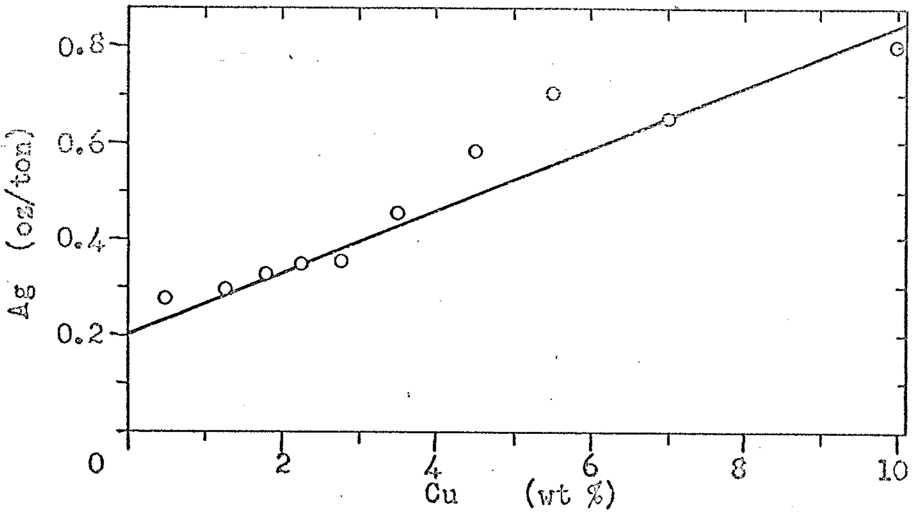

Figure 88. Cu-Ag relations (wt %) in the disseminated ore, Flin Flon Mine.

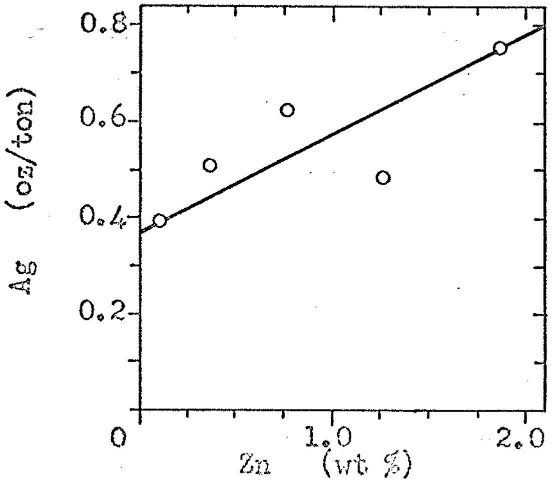

Figure 89. Zn-Ag relations (wt %) in the disseminated ore, Flin Flon Mine.

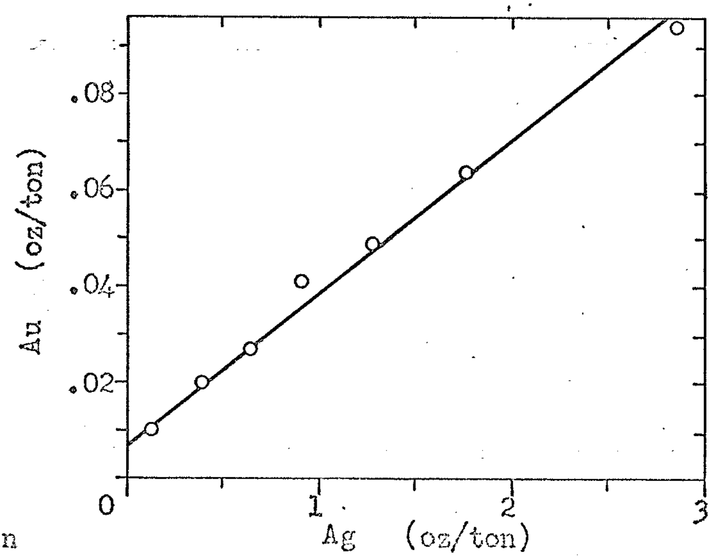

Figure 90. Ag-Au relations (wt %) in the disseminated ore, Flin Flon Mine.

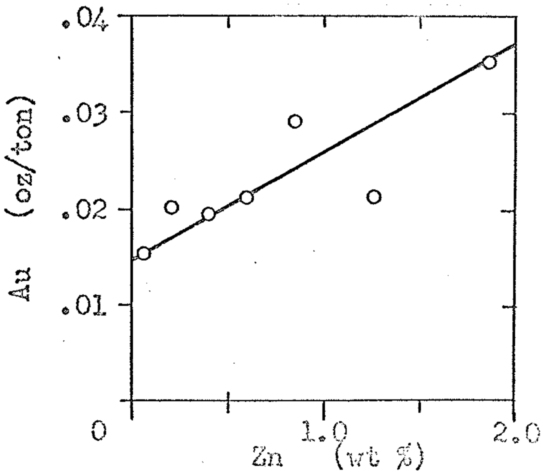

Figure 91. Zn-Au relations (wt %) in the disseminated ore, Flin Flon Mine.

disseminated ore. The resulting plot is a straight line with a positive slope and a y-intercept of 0.2 oz/ton Ag.

Figure 89. The graph of Ag versus Zn (weight %) resulted in a straight line with a positive slope and a y-intercept value of about 0.4 oz/ton Ag.

Figure 90. Ag and Au show a direct relationship in the disseminated ore. The slope of the line is positive and passes through the origin. $\frac{\text{Au}}{\text{Ag}}$ equals 0.35 in the disseminated ore and 0.50 in the massive ore, indicating a lower Au content with respect to Ag in the disseminated ore.

Figure 91. Zn and Au show a direct relation in this graph. The slope of the line is positive and the y-intercept is at about 0.015 oz/ton Au.

Figure 92. Analyses of Cu versus Zn (weight %) in the disseminated ore yielded a straight line with a near zero slope. The y-intercept is at about 0.18% Zn. This graph suggests that Cu and Zn show little or no relation to each other. However, in the low assay range, much weakly mineralized country rock has been included in the sample so that the slope of the line may actually be more positive.

Figure 93. The relation between $\frac{\text{Ag}}{\text{Au}}$ and the Ag content of the disseminated ore is such that the $\frac{\text{Ag}}{\text{Au}}$ ratio increases with increasing Ag values. The relation is linear with a positive slope and suggests that in the disseminated ore, Ag is enriched with respect to Au.

Figure 94. This diagram illustrates the partial relation between Au and $\frac{\text{Cu}}{\text{Cu}+\text{Zn}}$ (weight %). As the disseminated ore is mainly

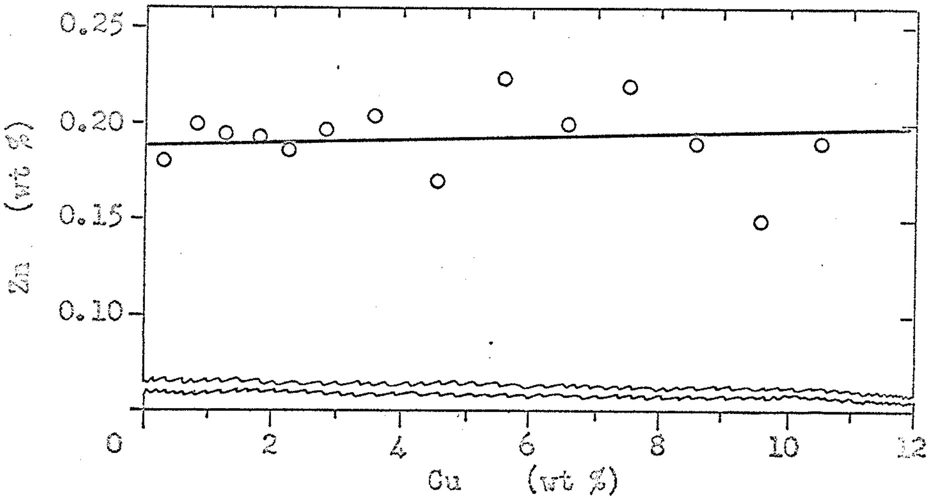

Figure 92. Cu-Zn relations (wt %) in the disseminated ore, Flin Flon Mine.

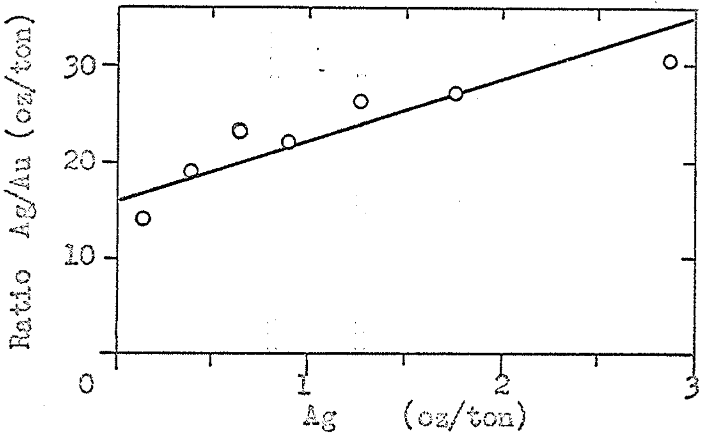

Figure 93. Ag-Ag/Au relations (wt %) in the disseminated ore, Flin Flon Mine.

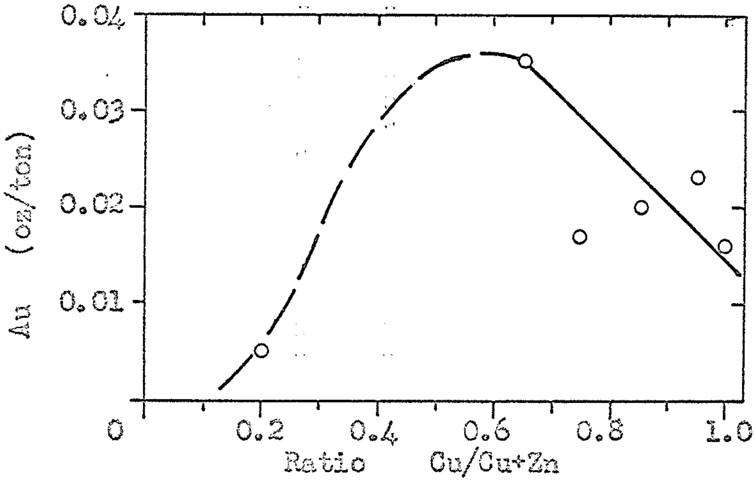

Figure 94. Relation between Cu/Cu+Zn and Au (wt %) in the disseminated ore, Flin Flon Mine.

composed of copper with minor zinc, the bulk of the ratio values lie between 0.8 and 1.0, with only about 15% of the values occurring below 0.8. Therefore, any interpretation made between ratio values of 0.0 and 0.8 would be unreliable. The form of the curve appears to be parabolic and is similar to the Cu ratio-Au relations in the massive ore (Figure 83).

The Mine

Figure 95. The relationship between Cu and Au for all ore types at the mine can be represented by a straight line with a positive slope and a y-intercept of 0.02 oz/ton Au. As Au and Ag are directly related in the massive and disseminated types (Figures 86 and 90) and in the whole mine (Figure 98), then it can be assumed that Cu and Ag are also directly related in the whole mine.

Figure 96. This diagram illustrates the relationship between Zn and Au for the mine. Zn and Au are present in direct propertions up to about 6% Zn, where the curve breaks and the slope changes to a zero value. Above 14% Zn, the slope of the line is negative, indicating decreasing Au content with increasing Zn. Similar relations are to be expected between Zn and Ag.

Figure 97. Au and Ag occur in direct proportions as shown by the linear relation between these two metals. The line has a positive slope and passes through the origin.

Figure 98. Analysis of Cu with respect to Zn for the mine resulted in a sinuous curve, especially up to values of 10% Zn. Above 10% Zn, Cu shows a definite decrease with increasing Zn. The scattering

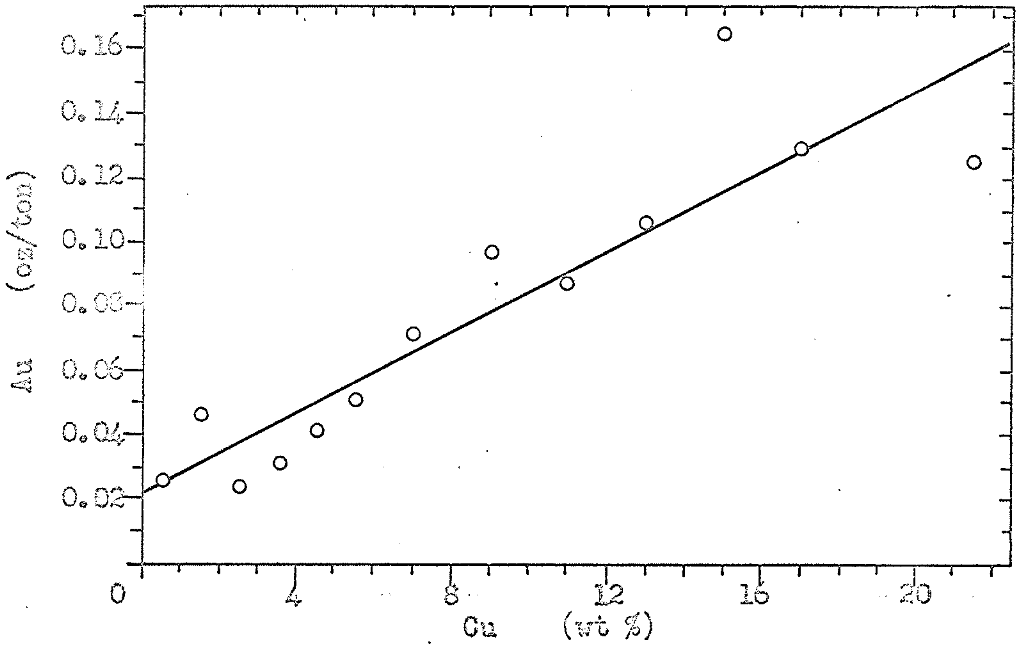

Figure 95. Cu-Au relations (wt %) for the Flin Flon Mine.

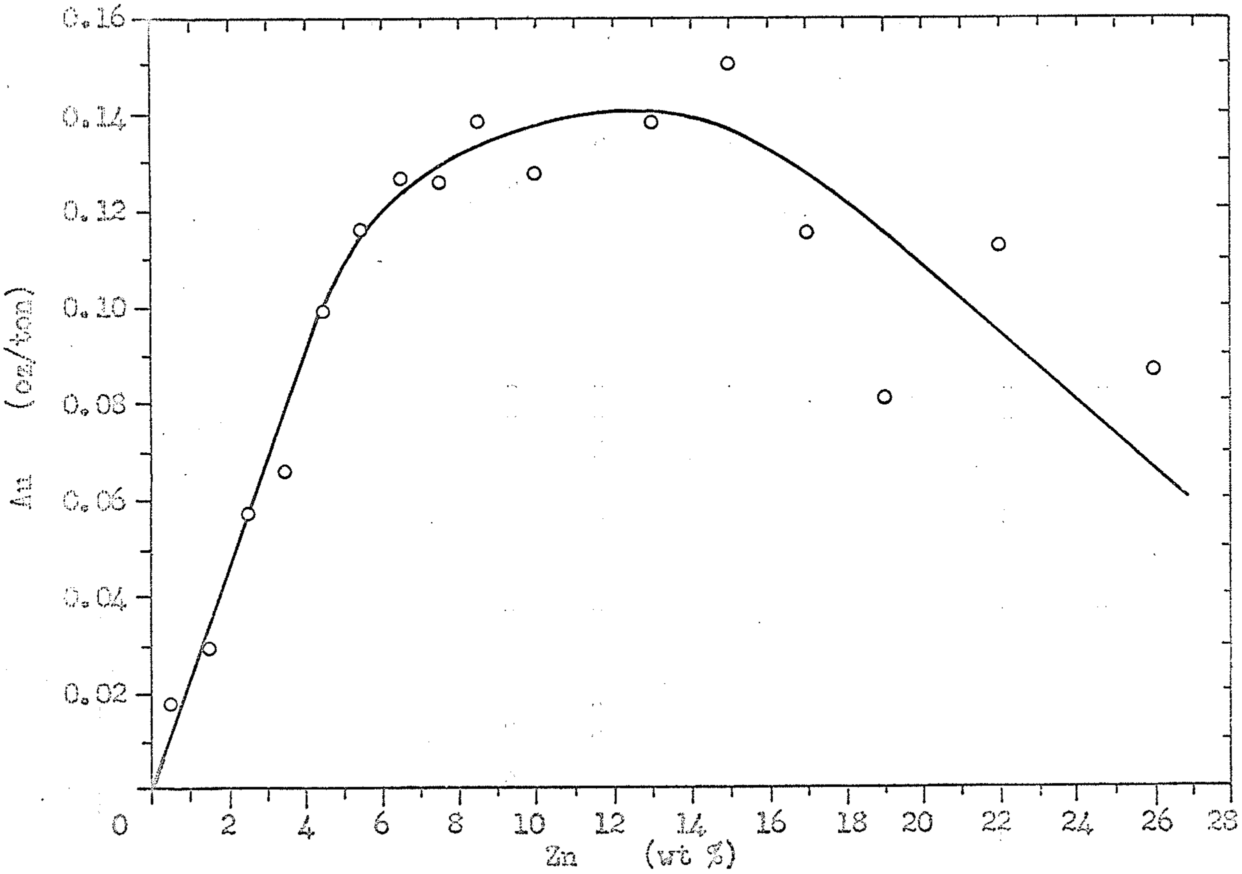

Figure 96. Zn-Au relations (wt %) for the Flin Flon Mine.

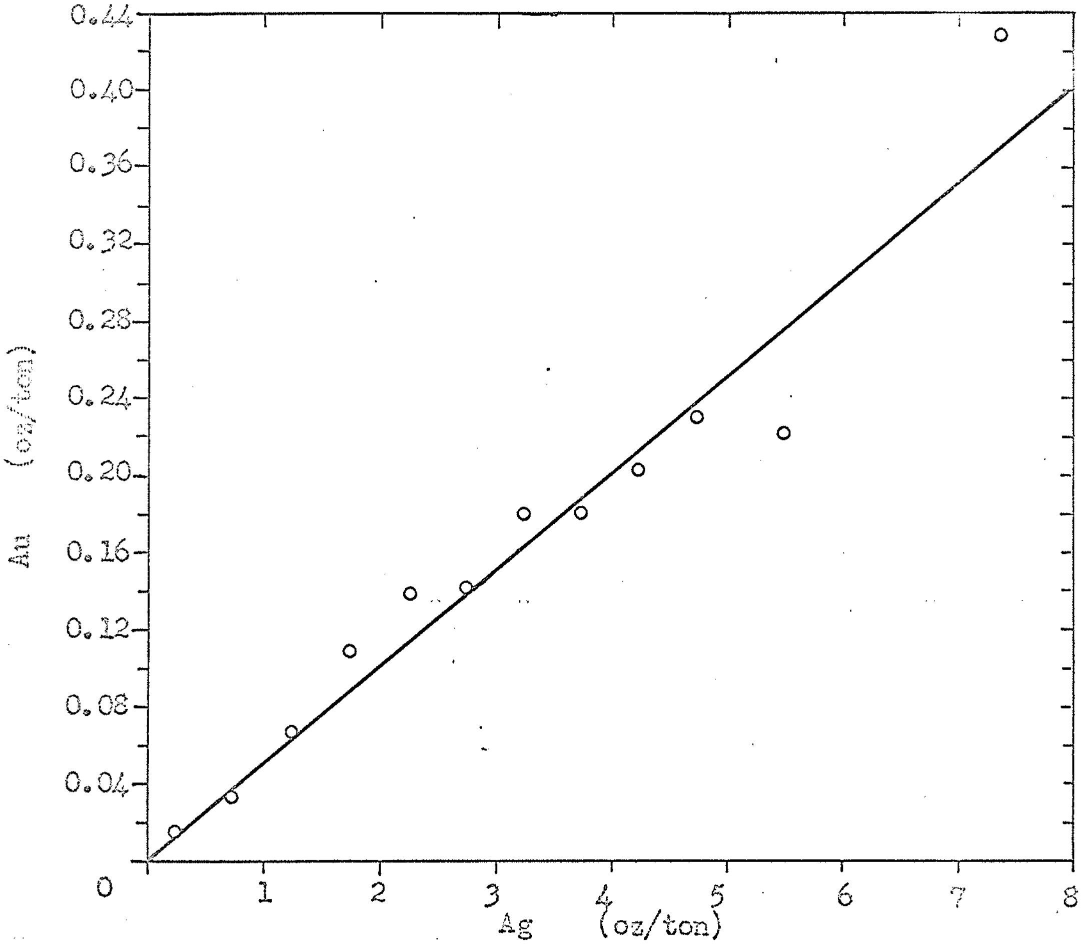

Figure 97. Ag-Au relations (wt %) for the Flin Flon Mine.

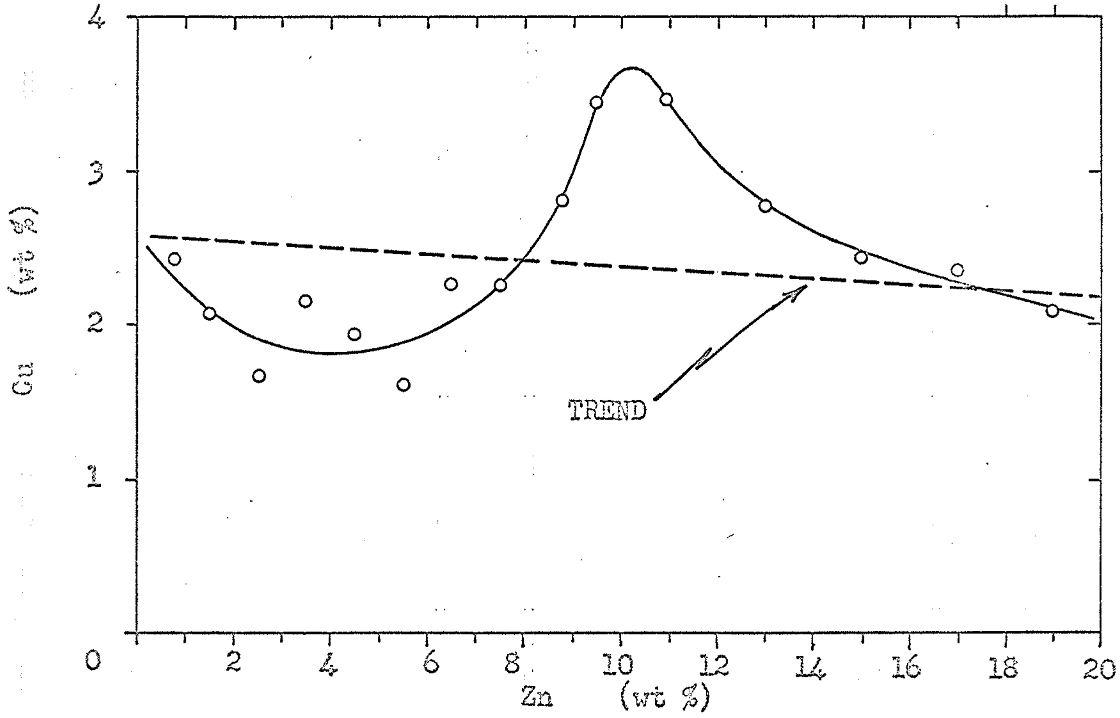

Figure 98. Zn-Cu relations (wt %) for the Flin Flon Mine.

of points in the lower zinc range is possibly due to the intermixing of massive and disseminated types. The general trend of points has a negative slope indicating decreasing Cu with increasing Zn values.

Figure 99. This figure illustrates the fluctuations in zinc values with respect to the grade of copper for assays from the 2700 to 3500 foot levels. The distribution histograms for each range of copper assay is bimodal, containing one strong peak at low zinc values and a second weaker peak at a much higher zinc value, especially in the low to moderate copper assay ranges. Each copper range is dominated by a strong frequency distribution of low zinc values which indicates one trend for the Cu-Zn relationship such that Cu and Zn show no association (red trend). The position of the second weaker peak varies with the grade of copper and indicates another trend for the Cu-Zn relationship (green trend). The position of this second peak varies in value from high zinc in the low copper ranges to low zinc in the high copper assay ranges, indicating an inverse relationship between Cu and Zn. The bimodal distribution of Zn assays indicates that there is considerable mixing of ore types throughout the mine and that the separation of massive from disseminated ore is incomplete. Also, the differentiation of massive and disseminated types on the assay data sheets may not be completely reliable. A similar relation between Cu and Zn is to be expected in other portions of the mine.

Figures 100, 101, and 102. These figures illustrate the relation between Cu and Zn on the upper levels (0-2200'), lower levels (2700-

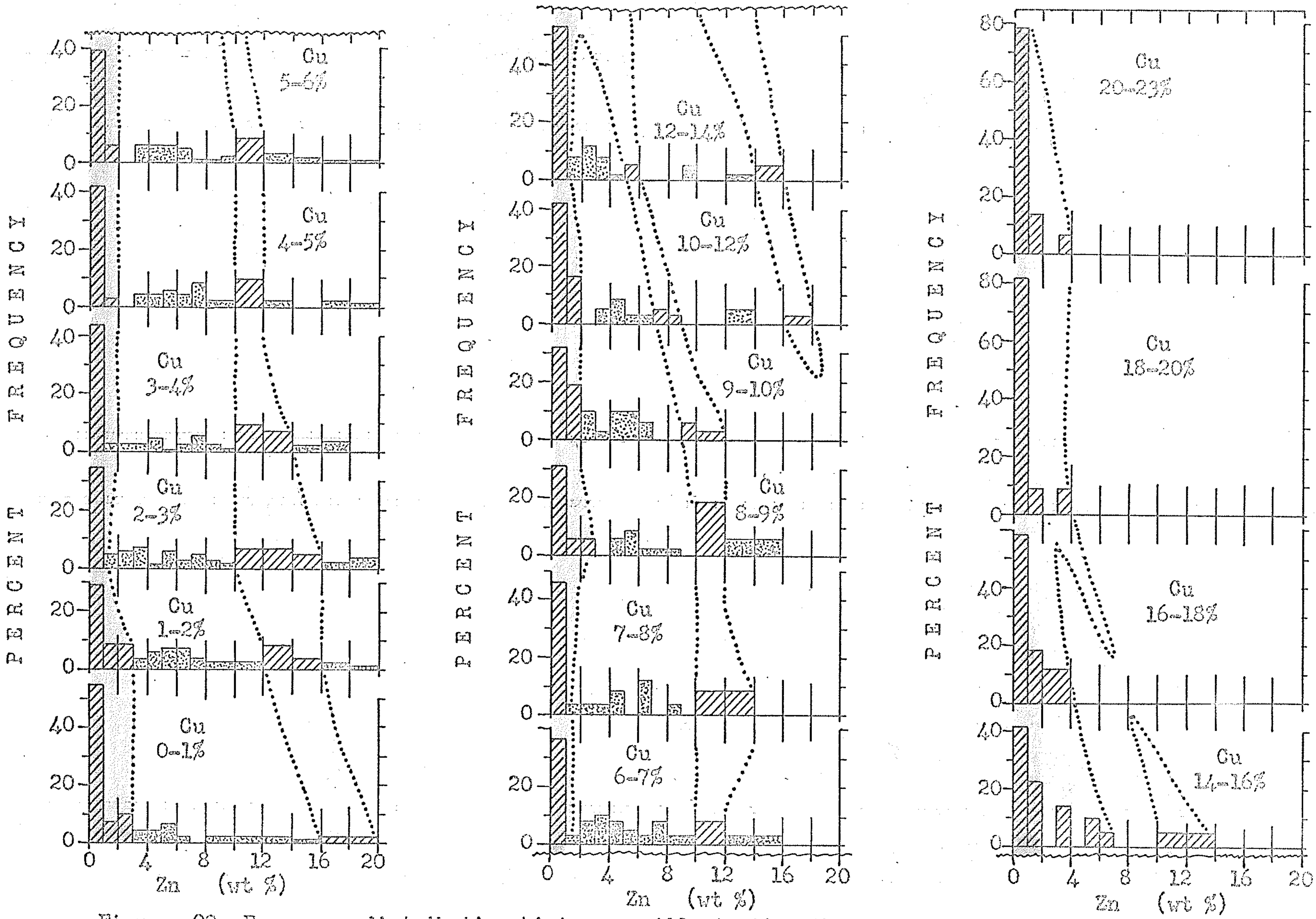

Figure 99. Frequency distribution histograms illustrating the variation in Zn distribution with changing Cu grade for all ore types , 2700–3500' levels, Flin Flon Mine. (trends shown in Red and Green).

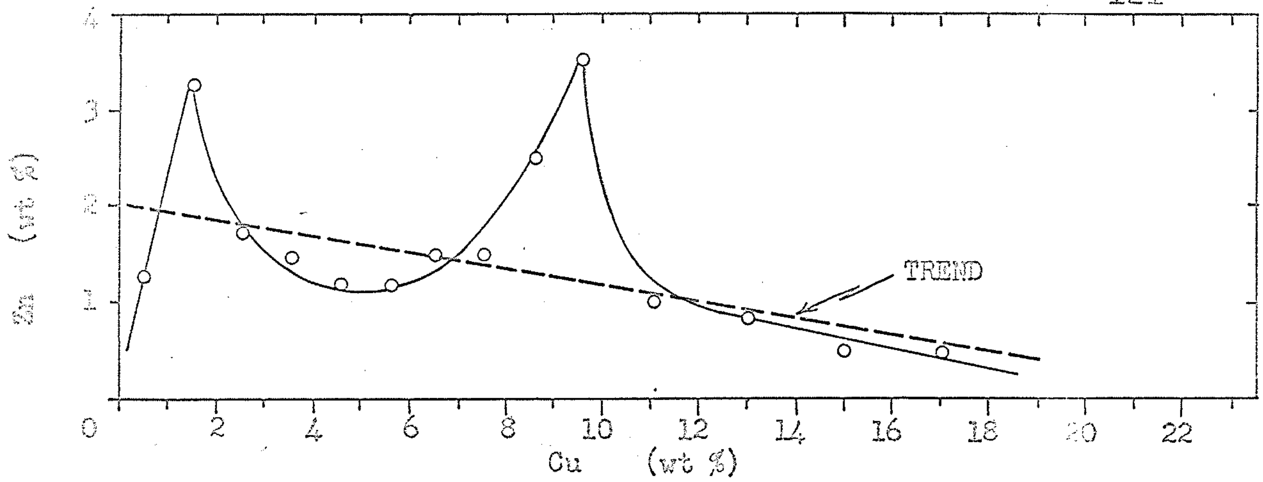

Figure 100. Cu-Zn relations (wt %) for the 0-2200' levels, Flin Flon Mine.

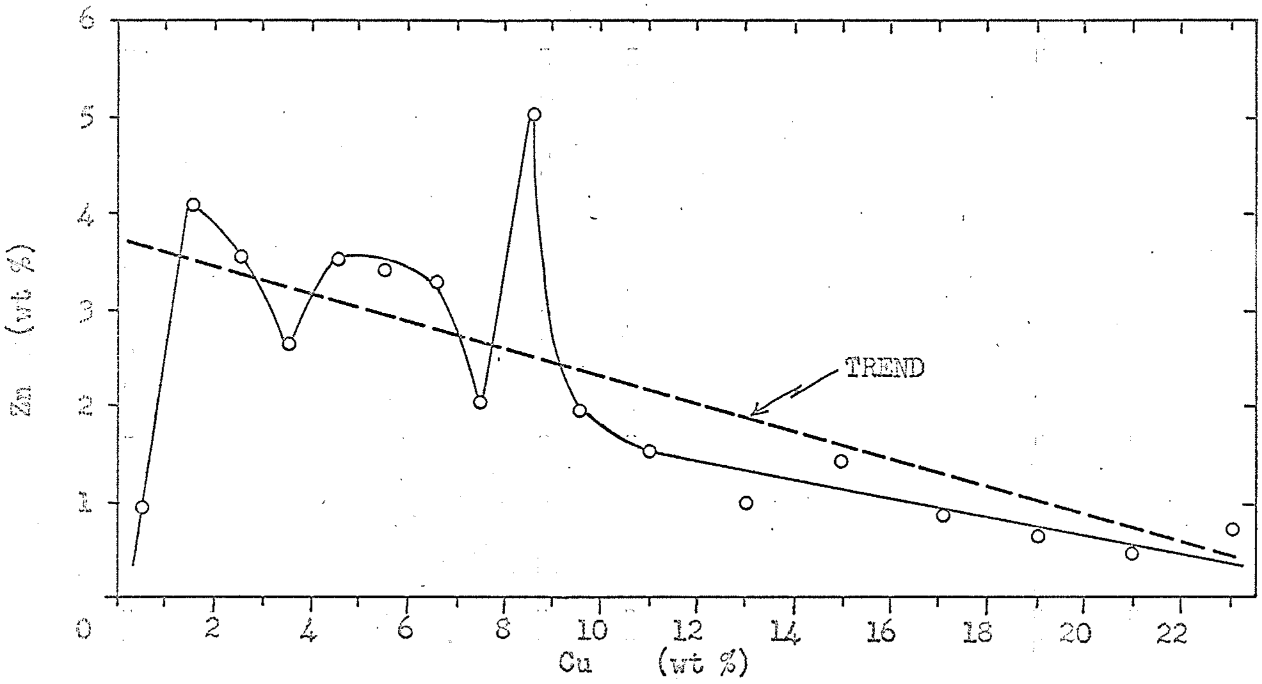

Figure 101. Cu-Zn relations (wt %) for the 2700-3500' levels, Flin Flon Mine.

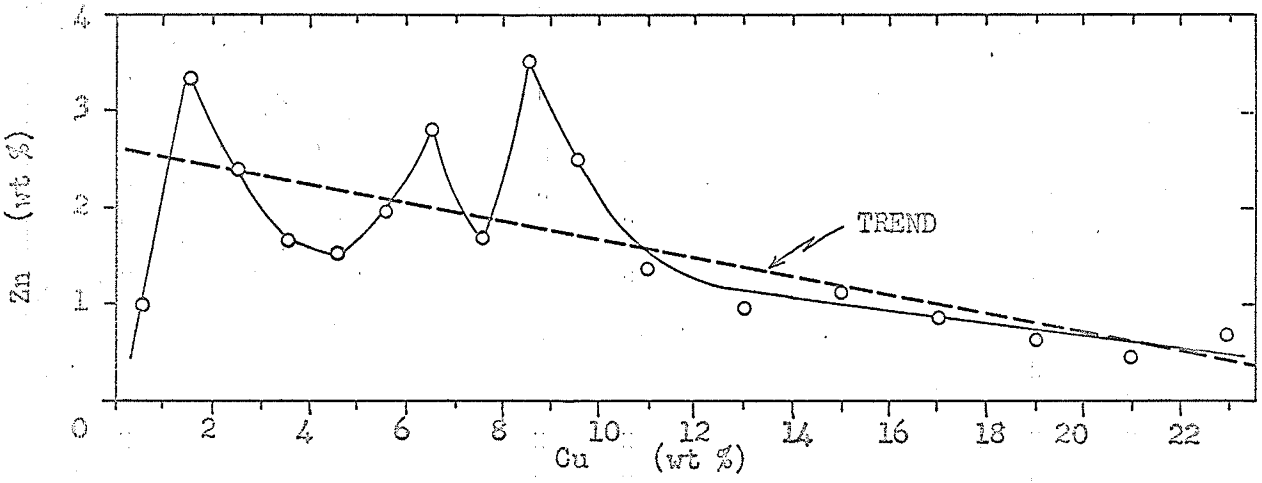

Figure 102. Cu-Zn relations (wt %) for the 0-3500' levels, Flin Flon Mine.

3500'), and for the complete mine section. Considerable variation in the zinc content can be noted up to 10% Cu at which point there is a definite decrease in Zn with increasing Cu. As illustrated in Figure 99, the mixing of massive and disseminated ore types in the lower Cu grades appears to be responsible for the observed fluctuation in Zn values, when Cu is less than 10%. Low zinc values of the disseminated type are more frequent and tend to mask the occurrence of any high zinc values that are also associated with these lower copper grades. However, there is an apparent trend indicating decreasing Zn with increasing Cu in three diagrams. The trend line with the largest negative slope occurs on the lower mine levels indicating higher grades of copper ore in this section of the mine. Calculated median values for copper and zinc are:

Level	Cu	Zn
0-2200'	1.89%	1.85%
2700-3500'	2.76%	1.79
0-3500'	2.23%	1.82%

Individual Element Distribution

Figure 103. Frequency distribution histograms of the abundances of individual elements for the Flin Flon Mine are illustrated in this figure.

In the massive ore, copper assays exhibit a unimodal right skewed distribution with a broad peak and a central tendancy in the 0 to 1% assay range. The distribution for zinc is also basically unimodal and

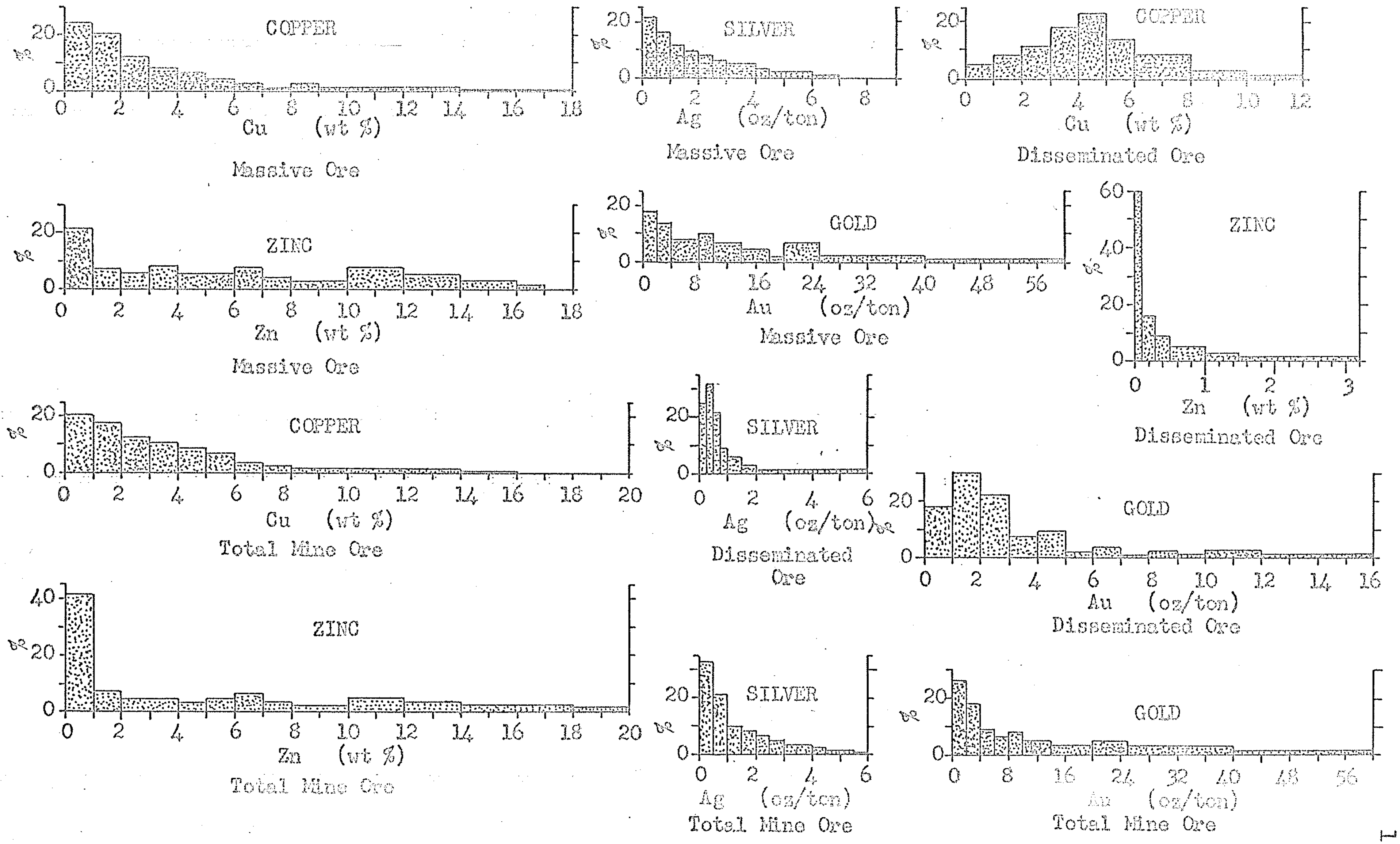

Figure 103. Distribution histograms of abundances of individual elements (Cu, Zn, Ag, and Au.) at the Flin Flon Mine.

right skewed. Several other small peaks occur in the distribution pointing to the fact that the distribution is not too regular. All peaks are generally sharp. The distribution of silver is unimodal and right skewed and in form, generally resembles that of copper as the peak is rather broad. The unimodal right skewed distribution of gold has a very broad peak and a fairly regular distribution over the higher assay ranges.

In the disseminated ore, copper assays approach a normal distribution being only slightly right skewed and having a fairly sharp peak. The distributions of silver and gold are very similar. In form they are unimodal and right skewed with fairly broad peaks and in general they resemble the copper distribution more closely than the zinc distribution. The zinc distribution is characterized by a very sharp peak or central tendancy. The form is unimodal and right skewed and the central tendancy contains over 60% of the assay values.

Median metal values for the various ore types calculated from these frequency distributions are as follows. In the massive ore, Cu= 2.26%, Zn= 3.64%, Ag= 1.97 oz/ton, and Au= 0.086 oz/ton. In the disseminated ore, Cu= 4.32%, Zn=0.082%, Ag= 0.44 oz/ton, and Au= 0.021 oz/ton.

For the mine, the copper distribution remained unimodal and right skewed, but it can be seen that the peak has become broader and that the distribution is quite regular. Zinc also remains unimodal and right skewed, but here the skewness and peakedness factors have increased. Peaking is higher and sharper and the distributions at higher Zn values have become less erratic, tending to show very little change with higher Zn values. The silver distribution is unimodal and right skewed and has a very regular form, resembling the silver distribution in the massive ore. The distribution of gold content is again unimodal and right skewed and the form shows more regularity than in the massive ore. In general, individual metal distributions have tended to become more regular in form. Zinc, silver, and gold have greater skewness and peaking has become more sharp. Very little change in the copper distribution is apparent.

Frequency distribution tables used the the Flin Flon study are included in the appendix.

Summary of Results

Massive Ore

1. Cu and Ag are directly related and the ratio Cu:Ag is different above and below 2.5% Cu (Figure 76).

2. Zn and Ag are directly related up to 6% Zn. Above 6% Zn, the slope of the line approaches zero indicating little or no relation between Zn and Ag (Figure 77).

3. Cu and Au are directly related up to 6% Cu. Above 6% Cu, Au shows no apparent relation to Cu (Figure 78).

4. Zn and Au show a direct relation up to 6% Zn. Above 6% Zn, Au tends to decrease with increasing Zn (Figure 79).

5. Cu + Zn and Ag are present in direct proportions (Figure 80).

6. Cu + Zn and Au show an apparent linear trend indicating direct

proportionality. However, the scatter of points may also suggest that the ratio of Cu + Zn to Au changes at 6% Cu + Zn and that two linears are present (Figure 81).

7. The ratio $\frac{Ag}{Au}$ is reasonably constant for all values of Cu, Zn, and Cu + Zn. The major variation occurs in the low base metal assay ranges where low Au assays may be due to weakly mineralized material (Figure 82).

8. Au is at a maximum when Cu and Zn are approximately 3% and 6% respectively (Figure 83).

9. Cu and Zn are indirectly proportional (Figure 84).

10. Ag and Au occur in direct proportions. The Au content of the massive ore increases with depth with respect to Ag. $\frac{Ag}{Au}$ decreases with depth (Figures 85 and 86).

Disseminated Ore

11. Ag and Au show a direct relationship to Cu (Figures 87 and 88).

12. Ag and Au show an apparent direct relation to Zn (Figures 89 and 91).

13. Ag and Au are directly related (Figure 90).

14. Cu shows little or no relation to Zn as the slope of the line is almost zero (Figure 92).

15. $\frac{Ag}{Au}$ increases proportionally with increasing Ag (Figure 93).

16. The relationship between Au and $\frac{Cu}{Cu + Zn}$ is similar in form to the $\frac{Cu}{Cu + Zn}$ -Au relation in the massive ore, and does not indicate

a base metal-precious metal affiliation (Figure 94).

Mine Distribution

17. Cu is directly proportional to Au and Ag (Figures 95 and 97).

18. Ag and Au are directly related to Zn up to 6% Zn. Above 6% Zn, Ag and Au generally decrease with increasing Zn. Zn and the precious metals are not directly related for all zinc values (Figures 96 and 97).

19. Ag and Au are directly related (Figure 97).

20. Analyses of the Cu-Zn relation suggests indirect proportionality (Figures 98, 100, 101, and 102).

21. Massive and disseminated ore types are incompletely separated (Figure 99).

22. The distribution histograms of the individual elements generally have similar forms and do not indicate any specific element associations at the Flin Flon Mine (Figure 103).

Discussion of Distributions at the Three Mines

Comparison of the distribution of the Vermilion Lake $\frac{Cu}{Cu + Pb + Zn}$ ratio with those of the Flin Flon, Geco, and Canadian base metal deposits (Figure 9) indicates that the Vermilion distribution corresponds with the Cu:Zn ratios of these other orebodies. The form of the Vermilion distribution shows greater correspondence to the Geco orebody with its two sharp peaks. Two ore types occur at Geco;

massive and disseminated, which contain high zinc and high copper respectively. The sharpness and amount of separation of the two peaks indicates a high degree of separation of the copper and zinc in these two ore types. The existence of two peaks at the Vermilion Lake property must also indicate a similar separation of this orebody into a Pb-Zn rich portion and a Cu rich portion. However, at the Vermilion Mine, the peaks are very sharp and of limited percent. High copper and high zinc ores make up only about 50% of the orebody and the remaining 50% is composed of ore in which Cu and Pb-Zn are uniformily distributed and of low ratio value. The distribution of the Cu:Zn ratio in the massive ore at the Flin Flon Mine is bimodal indicating the existence of high zinc and high copper ore sections. The presence of the two modes in the massive ore is possibly due to an incomplete separation of massive and disseminated ore types (Wilson and Anderson, 1959). Such differences in composition in these orebodies may be due to a greater migration of copper to marginal zones or to two pulses of ore-forming fluid.

Vermilion Lake Mine

Distribution of the $\frac{Cu}{Cu + Pb + Zn}$, $\frac{Zn}{Cu + Pb + Zn}$, $\frac{Pb}{Cu + Pb + Zn}$, and $\frac{Au}{Au + Ag}$ ratios at the Vermilion Mine suggest that gold, silver, and lead are in general, uniformily distributed in all parts of the orebody (Figures 10 to 18 inclusive). Gold is always subordinate to silver and lead is always associated with zinc and is subordinate to the combined copper-zinc values. Copper and zinc, on the other hand, have bimodal distributions indicating two different types of occurrence in that zones exist which are rich in lead and zinc and low in copper, and zones rich in copper and low in lead and zinc. These zones must correspond to the massive and disseminated ore types of the Flin Flon and Geco deposits.

Comparison of metal ratios by level in the major No. 4 ore zone indicates very little change in ratio value with depth (Figures 11 to 18 inclusive). No factor has greatly influenced the metal ratios in a vertical field. Copper ratios do show a slight increase with depth in the high copper sections (Figure 11). However, the amount of change is relatively small. Pb, Zn, and Au ratios show a slight decrease with depth. These variations in ratio may be due to the migration of copper to the base or margins of the ore zone. The concentration of copper values around the margins of the ore zone suggests a migration of copper away from a high temperature center. As many of the Vermilion Lake ore zones have been cut by post-mineralization faults, correlation between fault slices has not been completed so that ore zones that are now adjacent may have been separated by considerable distance before faulting. Figure 18 summarizes the metal ratio variations with depth and it can be seen that the magnitude of the variations is very small. Lead, zinc, and gold ratios show parallel decreases whereas the copper ratio shows a small increase with depth. The magnitude of the changes are not great enough to be detected by any grade changes with depth.

Figures 19 to 27 and 31 to 54 inclusive show that a straight line relation exists between Cu, Pb, Zn, Au, and Ag in all portions of the mine. The occurrence of these elements in constant proportions points to a single period of ore deposition. The small variations in ratios which do occur are no doubt related to minor variations in temperature, pressure, and chemical conditions at each deposition site and to the partial migration of copper to the margins of the orebodies.

Figures 26, 42, 43, and 44, showing the relation betweem Cu and Zn in the Nos. 4 and 6 ore zones and for the mine, indicate that the Cu:Zn relationship undergoes very minor chamges throughout the mine even though copper has moved to marginal areas. The scatter of points in the low Zn assay range may be due to the incomplete separation of Cu rich and Pb-Zn rich ores. Examination of the assay data sheets shows that zones of high grade copper appear to be rare and scattered.

Figure 54 illustrates the variation in gold values with changing zinc grade. The amount of deviation from a central tendancy (median value) in gold decreases with increasing zinc content, leading to closer correlation at higher zinc values. Similar distributions must be expected for gold relative to copper and lead as all these metals are closely associated in this deposit.

Analyses of the relation between iron and the base metals Cu and Zn (Figures 28, 29, and 30) indicate that iron is only partially related to these ore metals, being linear up to 16-19% Fe. As the exact sources of the iron are not known, it is assumed that iron from sulphides and from iron silicates is present. This analogous distribution of iron indicates that some of the iron was deposited with the ore minerals as shown by the partial linearity. The change from a direct proportion relation may be due to a deficiency of Fe in the ore fluid or to emplacement by an Fe rich fluid in the pre-ore period. The divergence of the iron relationship may also be due to the association of a large part of the iron with high iron silicates of early magmatic origin.

Frequency distribution histograms showing the abundances of the individual elements (Figure 55) failed to aid in determining the origin or an understanding of the metal associations in this deposit. From these histograms, it can be seen that the variation in abundances of Cu, Pb, Zn, Au, and Ag are regular and of the same form. Fe , on the other hand, possesses a bimodal distribution, suggesting a different form of occurrence, possibly resulting from two pulses of ore fluid.

Investigations carried out to determine a specific base metal association for the precious metals at the Vermilion Lake Mine failed to show that such an affiliation exists as all of the economic metals were found to be closely associated. Direct proportionality exists between Cu, Pb, Zn, Au, and Ag. The exact manner of the association is not known but incorporation in the base metal sulphide structures or in solid solution with Cu or Zn are possible. Detailed microscopic and analytical studies of the ore minerals may offer a solution to the problem. That the precious metals are uniformily distributed is shown by the presence of appreciable precious metal values in both the copper rich and the zinc rich zones.

Statistical studies at the Vermilion Mine show that metal ratios vary little with depth. Ore grades also appear to be reasonably constant throughout the mine and the metals, Cu, Pb, Zn, Au, and Ag, occur in constant proportions. Copper does show some minor variation with depth but the metal ratio studies indicate that there has been a separation of Cu and Zn into Cu rich and Zn rich zones, so that small differences in ratios are to be expected. Minor variations in metal distributions in the different zones are no doubt due to temperature, pressure, pH, and Eo factors in the deposition site. That the ore metals are present in such constant proportions suggests that the metals were deposited simultaneously or under relatively constant pressure and temperature conditions.

Geco Mine

In the massive ore, the distributions of individual metal ratios (Figures 56 to 64 inclusive) show that Cu and Ag occur in direct proportions whereas Zn and Ag are present in indirect proportions. The relation between Ag and Cu + Zn is exponential. Cu and Zn are also present in inverse proportions.

In the disseminated ore, Cu and Zn show little or no relation to one another. Ag and Zn do not appear to be related. The apparent relation between Ag and Zn in the lower grades may be due to weak sulphide mineralization or to dominant unrelated iron sulphide mineralization lowering both Ag and Zn assays. Cu and Ag appear to be directly related. Analyses of Cu + Zn with respect to Ag indicates that Ag is related to Cu + Zn, but as zinc is subordinate to copper in the disseminated ore, the low zinc values have an insignificant effect on the Cu + Zn values (Figures 65 to 71 inclusive).

For the mine as a whole, copper and silver show a definite affiliation in that they are always present in a constant ratio. The relation between zinc and silver is such that they exhibit a direct relationship up to 2.5% Zn and little or no relationship above 2.5% Zn. This apparent relation in lower grades may be simply due to sparce sulphide mineralization as in the case for the disseminated ore. Similarily, the partial direct relationship between Cu and Zn in the lower grades may also result from weak sulphide mineralization. In the higher grades, Cu and Zn show an inverse relation (Figures 72 to 74 inclusive).

Frequency distributions of the individual element abundances (Figure 75) indicate that all metals present have very similar distributions when all mine assays are evaluated. The distributions are unimodal and strongly right skewed. In the massive ore, copper and silver show similar tendancies whereas zinc approaches a normal distribution with a very broad peak. Copper is subordinate to zinc and zinc values are evenly distributed within the massive ore. In the disseminated ore, Cu, Zn, and Ag all have the same type of distribution being unimodal and strongly right skewed, such that one would suspect similar metal associations. Whether such histograms contribute information regarding metal associations and origins is questionable, but metals with different distributions do show different metal associations.

Silver is definitely associated with copper at the Geco Mine. The exact nature of the affiliation is not presently known.

Statistical studies of the metal distributions at the Geco Mine suggest that the metals were deposited contemperaneously as the relations between the metals are not random. At the deposition site, copper and silver have migrated to the margins while zinc solidified in the central portions. This is indicated by the inverse relation between Cu and Zn and by the existence of two peaks in the Cu:Zn ratio diagram (Figure 9). Silver values in the massive ore are associated with copper that was trapped with the solidifying zinc. Consequently, in the massive ore, low values of zinc are associated with moderate grades of copper. As silver is affiliated with copper, the Zn-Ag relation should be such that with low zinc values (high copper values), silver should be at its highest. Similarily, the relation between Ag and Cu + Zn in the massive ore will be exponential. Ag is low with low Cu + Zn values, and with increasing base metal content, both Cu and Zn increase and Ag increases proportionally until Zn becomes the dominant metal where the Ag begins to decrease.

In the high copper-low zinc disseminated ore, copper and silver remain directly proportional. As zinc is subordinate to copper and shows no relation to copper, the Cu + Zn-Ag relation should be linear.

Low zinc values in the disseminated ore appear to be related to weakly mineralized country rock. Zn and Ag are inversely related as the metals Cu and Zn show little or no relation to each other.

Flin Flon Mine

In the massive ore, Cu and the precious metals (Au and Ag) do show a relation in which increasing Cu results in increasing precious metal content but each curve (Figures 76 and 78) exhibits two different rates of increase. The Cu-Ag graph breaks at 2.5% Cu and the Cu-Au graph breaks at 6%Cu. The double peak of the Cu:Zn ratio distribution at the Flin Flon Mine (Figure 9) may mean a greater separation of chalcopyrite and sphalerite than in the Geco massive ore, or the massive and disseminated types at Flin Flon may intermix (Wilson and Anderson, 1959). This intermixing of ore types is more prominent in the low to moderate grade ranges of Cu and Zn. As the massive ore contains higher Au and Ag values than the disseminated, it is suggested that Au and Ag have also undergone differentiation in the deposition site. If the precious metals have entered the deposit as ions or atoms substituted into the chalcopyrite structure at high temperatures, such foreign elements will be expelled from the structure at lower temperatures if in excess of the solubility limit. As copper moves to a more suitable energy level at a lower temperature or pressure, gold and silver may be forced out of the sulphide structure to aggregate into discreet particles, the bulk of which remain associated with the zinc rich massive sulphide ore. Some of the precious metals should migrate with the copper minerals, but the amount of Au and Ag will be reduced. If the precious metals are in solid solution with copper, a similar distribution should result. Thus, the precious metal content has been enriched in the low copper ranges due to the associated high zinc portions of the ore. As Cu and Zn have undergone some separation (Figures 9 and 84), considerable massive zinc will be associated with low copper ore which should account for the bulk of the precious metals associated with the massive ore. Also, small amounts of precious metals may be associated with zinc such that the high zinc ore associated with low copper significantly alters the rate of increase of the base metal-precious metal relation or alters the content of precious metals in the low copper assay range. All precious metal values associated with zinc appear to be due to copper which remains with zinc as a result of the mixing of massive and disseminated ore types. However, small amounts of Au and Ag may be associated with zinc, suggesting that Au and Ag were limited in amount in the ore fluid. The bulk of the precious metals have been incorporated in the copper minerals to the limit of their solubilities, leaving a small amount of Au and Ag available in the fluid for incorporation in the zinc sulphide structures.

Zinc and the precious metals are related in a similar manner to Cu and the precious metals. Up to 6% Zn, Au and Ag increase proportionally to zinc, the relation having a steep slope (Figures 77 and 79). Above 6% Zn, the precious metal-zinc relationship becomes very small, and in the case of Au, shows an inverse relation. The resulting distributions are again related to the Cu-Zn relation in the massive ore. On the basis of the assay data, considerable intermixing of ore types is present in the moderate grade ranges and both high and low zinc values are affiliated with low copper. Figure 84 indicates that Zn increases with copper up to about 4% Cu, so that Au and Ag, which appear to be closely to copper, show parallel increases. However, as the general trend is for Zn to decrease with increasing Cu, the Au and Ag begin to show little or no relation to Zn in the higher Zn grades. Small amounts of precious metal associated with Zn also compound the early increase in Au and Ag. The precious metal relation with Zn is closely related to the precious metal-copper association.

Direct proportionality generally exists between Cu + Zn and the precious metals (Figures 80 and 81). This proportionality suggests a direct relation between these metals in the original magma or ore fluid and in the residual liquid. The apparent break in the Cu + Zn-Au curve (Figure 81) may be the result of mixing of massive and disseminated assay data.

The relation between $\frac{Ag}{Au}$ and the various base metals in the massive ore shows reasonable constancy over all base metal grade ranges. The apparent increase in $\frac{Ag}{Au}$ with respect to higher Cu and Zn grades (Figure 82) indicates a relative change in Ag content with respect to Au. The large variation in the low Cu and Zn assay ranges could be due to an incomplete separation of ore types during ore generation or to low Au assays associated with weakly mineralized material.

The parabolic relation between Au and $\frac{Cu}{Cu + Zn}$ (Figure 83) is the result of the intermixing of massive and disseminated ore types. Due to this mixing, this graph fails to indicate any specific precious metal association. The maximum Au value occurs at 0.35 $\frac{Cu}{Cu + Zn}$. As the break in the Cu-precious metal relation (Figure 76 and 78) occurs at about 4.2% Cu and the break in the Zn-precious metal relation (Figure 77 and 79) is at about 6% Zn, substitution of 4.2% Cu and 6.0% Zn into $\frac{Cu}{Cu + Zn}$ results in a value of 0.35.

The distribution of points in Figure 84 indicates considerable mixing of ore types up to about 6% Cu. In general, assay values of Zn increase slowly with Cu up to 6% Cu, above which Zn decreases rapidly with increasing Cu. The general trend indicates an inverse relation between Cu and Zn which suggests separation of these metals in the deposition site.

In the massive ore Au and Ag occur in a constant proportion (Figure 85 and 86). The slope of Au-Ag relation is larger for the lower levels (Figure 85) indicating an increase in Au content with respect to Ag such that $\frac{Ag}{Au}$ decreases with depth. This change in $\frac{Ag}{Au}$ suggests that there has been some differentiation of Ag with respect to gold. In a later discussion, it will be shown that the Cu content of the ore is greater at depth, so that this increase in Au must be associated with this increase in Cu. Also, at depth, less separation of ore types may be the governing factor.

In the disseminated ore, copper predominates over zinc and the zinc content of the ore is generally very low. The relation between

Cu and Zn (Figure 92) is such that the slope of the line has only a very small positive value, indicating little or no relation between Cu and Zn. Direct proportionality exists between Au and Ag and base metals Cu and Zn (Figures 87,88,89, and 91) indicating a proportional relation between Cu and Zn. However, the point scatter about the Cu-precious metal linears is much less than for the Zn-precious metal linear, indicating a closer association of precious metal to Cu. In general, the Zn content maintains a very low level, so that higher Zn values associated with higher precious metal values must be related to massive sulphide intermixed in the disseminated zones. Zn assays of +1% must be related to transition and massive ore. Cu and the precious metals are more closely associated; the apparent Zn association resulting from the intermixing of ore types.

Figure 90 shows that Ag and Au are directly related in the disseminated ore. $\frac{Ag}{Au}$ values in the massive and disseminated ore are about 22.0 and 33.0 respectively, indicating a decrease in Au with respect to Ag in the disseminated ore. Variation of $\frac{Ag}{Au}$ with respect to Ag (Figure 91) indicates an increase in ratio with increasing Ag, again pointing to a decrease in Au with respect to Ag in lower grade disseminated ore, so that some differentiation has taken place between these two metals. During cooling of the ore body, some Au and Ag may be removed from sulphide structures so that the amount of precious metal associated or combined with minerals in the disseminated ore will be somewhat less than in the original ore fluid.

The relation between Au and $\frac{Cu}{Cu + Zn}$ in the disseminated ore failed to indicate any specific precious metal association. In form this curve is very similar to that for Au - $\frac{Cu}{Cu + Zn}$ in the massive ore (Figure 83).

Combination of massive and disseminated assay data, which should indicate the mine trends, indicates that Cu and Au occur in direct proportions (Figure 95). As the mine relation between Au and Ag is also linear (Figure 97), it is suggested that Cu and Ag are also directly related. Figure 96 shows that Zn and Au are only partially related, being linear up to 6% Zn. Again, as Au and Ag occur in direct proportions, the Zn and Ag will exhibit only partial linearity. Up to 6% Zn, Au increases proportionally with the Zn. With increasing Zn values, the slope of the line changes, becoming negative at about 15% Zn indicating an inverse relation between Zn and Au (and Ag). It is suggested that the precious metals are preferentially associated with copper in this deposit.

Figure 99 shows that the separation of massive and disseminated ore types was only partial as there is considerable mixing of ore types, especially in the low copper grade range. Nowhere is the separation complete as all ore samples contain some Cu or Zn. Figures 98 to 102 inclusive, illustrate a general relation between Cu and Zn such that with increasing Cu, the Zn content of the ore decreases. It is suggested that this points to the simultaneous deposition of the ore minerals and that the partial separation of Cu and Zn occurred in the site of deposition.

Individual element abundances are illustrated in Figure 102.

In the massive ore, histograms indicate that copper and zinc have similar distributions but the zinc distribution has a broader, more gentle peak, bordering on multi-modal. Gold and silver have very similar distributions, the forms of which more closely resemble that of copper.

In the disseminated ore, it can be seen that copper is the dominant metal, and its distribution very closely approaches a normal curve. The distributions of gold and silver also show an approach to a normal distribution curve, which again is somewhat similar to that for copper. Zinc has become strongly right skewed.

For the mine in general, the copper distribution is right skewed with a broad gentle peak. Gold and silver also have this same curve form as copper. The zinc distribution is strongly right skewed and exhibits a very sharp peak indicating a predominance of low assay values.

The significance of the histograms of the abondance of the elements is doubtful, but if the form of the curve has any significance, then it is apparent that Cu, Au, and Ag are closely affiliated because of the similarities in their distributions.

Comparison of Distributions at the Three Mines

At the Vermilion Lake Mine, very little variation in distribution was noted with the exception of Fe. Cu, Pb, Zn, Au, and Ag are present in constant proportions in all parts of the mine. Some separation of Cu and Pb-Zn has occurred, but in general, the amount of separation is minor considering all ore types. Separate analyses of

Cu rich and Pb-Zn rich portions may show modifications of the metal ratio distribution patterns.

Silver is always directly proportional to copper at the Geco Mine and is generally inversely proportional to zinc. Copper ratio distributions indicate a high degree of separation of massive and disseminated ore types. As the distributions are not random, definite relations exist between the economic metals present.

Similarily, at the Flin Flon Mine, the precious metals, gold and silver appear to be preferentially associated with copper. For all ore types, Ag and Au are directly proportional to Cu over the full range of Cu values whereas Au and Ag show only a partial relation to Zn. Copper ratio distribution indicates only a partial separation of massive and disseminated ore types. A partial separation of ore types is also indicated by the Cu-Zn relationship. Further, as the distributions are not random, definite relations must exist between all metals present.

Theories of Ore Genesis

In the following and subsequent pages, much of the discussion will deal with the possible reasons for the metal ratios and associations observed. If the ore minerals do show reasonably constant relations to one another, then what possible processes were responsible?

For the metallic elements to occur in reasonably constant proportions, they, in general, must have been introduced and deposited at the same time. Therefore, one very good cause for such metallic relations is the injection of the ore fluid as a single injection. J.E. Spurr (1923) was a strong proponent of such ore magmas, and he believed that there was no sharp line between the magma solutions depositing igneous rocks and those depositing ore minerals. Ore magmas are highly concentrated fluids which have been injected as plastic sulphides to form ore deposits. Intrusions of this type should result in constant metal ratios if all the metals were introduced simultaneously.

Opposed to this theory of genesis is one involving transportion of the ore minerals in gaseous or liquid solutions and deposition from these solutions at different times. Deposition in such a time sequence should not result in constant metal ratios, except under special circumstances, such as constant temperature and pressure conditions.

As previously noted, the factors affecting the distribution of metals from a differentiating basic magma generally fall into two groups:

1. those effective in partitioning the metals between silicate and sulphide liquids, such as the concentration of sulphur and the relative chalcophile character of the elements and,
2. those which operate especially during crystallization of the sulphide fraction such as;

a) during crystallization under non-equilibrium conditions, early formed minerals fail to react with the residual liquid. This residual liquid changes in composition, becoming impoverished in early crystallizing compounds and enriched in the later crystallizing

The mechanism of the migration of the different chemical species - ions, atoms, molecules - is highly debatable. The process is very complex and probably involves diffusion in the intergranular films and mosaic fissures as well as volume diffusion in the different phases. Migration of ions or atoms along crystal boundaries or even through solids appears to be universally accepted. However, the magnitude of the effects that this form of material transfer actually produces in rocks is a matter of great controversy.

Other processes of transportation are readily available. Water and other volatile substances are practically always present, at least in small amounts, in all rocks, and are liberated in large amounts by igneous activity, thereby providing a universal and effective medium for the transportation of material.

Also, in many areas, an alkali-rich mobile phase, some kind of emanation, is produced, which by means of infiltration, permeation, and diffusion, effects metasomatic granitization by processes of ionic migration through solids. This involves not only the addition of elements characteristic of granite rocks, such as Na, K, and silica, but also the removal of the superfluous ones, such as Ca, Mg, and Fe. The nature of the mobile agent is again controversial but such movement must be along crystal and grain boundaries and through crystal lattices.

Diffusion in the solid state can occur only over limited distances in magmatic silicates. Solid diffusion in the sulphides, on the other hand, is extremely important and takes place most readily

(McKinstry and Kennedy, 1957, p-389). Also, diffusion in the presence of gases and liquids, along lattice boundaries, etc., can take place over much greater distances and is no doubt an important method of material transfer. Both processes must also be important and active during the formation of many sulphide ore deposits.

The following theories of origin have been suggested for the three deposits:

- Hydrothermal solutions
- Sulphide injection
- Fumarolic
- Sedimentary

The data for the three deposits indicates the following:

Possible theories

a. Hydrothermal solutions with constant temperature and pressure conditions. Composition of the solution remaining unchanged.

b. Sulphide injection. Elements deposited contemporaneously.

In the section on theoretical considerations, it has been indicated that copper-zinc combinations are characteristic of gabbros and diorites, and high zinc with moderate copper and lead are characteristic of intermediate rocks in Canadian ore deposits. Residual solutions resulting from the differentiation of a basic or intermediate magma containing Cu, Pb, Zn, Au, and Ag should be enriched in these elements due to their ionic properties and thermodynamic relations. If the sulphur concentration of the magma was very low, then these elements, if present, would be enriched in the hydrothermal phase if one formed. Transport to and deposition in the deposit site under constant temperature and pressure conditions would result in an orebody containing reasonably constant metal ratios and distributions. If the parent magma contained sufficient sulphur so that an immiscible sulphide liquid formed and in which Cu, Pb, Zn, Au, and Ag became enriched, injection of this sulphide liquid into the deposition site should again yield an orebody containing reasonably constant metal ratios and distributions. Further differentiation of either of these fluids in the deposition site should result in the distributions of metals observed at these three deposits. Metal distributions suggest that all metals were carried simultaneously by the ore fluid and were deposited according to the partition ratios between ore fluid and solid rock.

Unlikely theories

a. Hydrothermal solutions under varying temperature and pressure conditions resulting in successive deposition from solutions of changing composition.

b. Fumarolic. Temperature, pressure, and composition of the gaseous phase would be continually changing.

c. Sedimentary (syngenetic). The base metal content of common sedimentary rocks is similar to the average content of metals in the crust whereas the base metals are greatly concentrated in common igneous rocks and, moreover, are concentrated in the same groups and ratios as are found in Canadian sulphide ore deposits (Wilson and Anderson, 1959, p-20).

Deposition resulting from these "unlikely" origins would not yield deposits with constant metal ratios. In general, completely random distributions should be expected. The relatively constant composition of many hydrothermal ores from level to level leads to questioning of the theory that metals are always deposited successively in a time or temperature sequence.

CHAPTER VI

CONCLUSIONS

The Distribution of Metals in Canadian Base Metal Deposits

This limited study of the compositions of Canadian base metal deposits containing copper, lead, or zinc and precious metals suggests that in the presence of significant amounts of copper and zinc and minor lead, greater amounts of gold are preferentially associated with the copper-zinc combination. In the presence of significant amounts of lead and zinc where copper is a minor constituent, greater amounts of silver are preferentially associated with the lead-zinc combination. This study suggests that greater quantities of gold relative to the amount of silver are associated with sulphide deposits composed essentially of copper and zinc. Where lead and zinc are the essential sulphides present, the amount of gold relative to silver is generally less and silver is often the only significant precious metal present. The distributions of gold and silver in base metal deposits may be an indirect method of determining the concentrations of these precious metals in an associated igneous rock.

Comparison of these results with a triangular diagram containing contours for the silica content of igneous rocks further suggests that the low silica rocks contain higher gold values. With increasing silica content, silver becomes the dominant precious metal.

The Distribution of Metals in Three Canadian Base Metal Deposits

Precious metal associations in the three ore deposits were found to be as follows:

1. Vermilion Lake Mine. Au and Ag directly proportional to Cu, Pb, and Zn.
2. Geco Mines Limited. Ag directly proportional to Cu.
3. Flin Flon Mine. Au and Ag directly proportional to Cu.

The study of the compositions of three Canadian base metal deposits with respect to the distributions of the economic metals contained therein has suggested that the metals have been deposited contemporaneously by the injection of a single ore fluid (sulphide melt) or by deposition, at almost constant temperature and pressure, from a hydrothermal fluid, and that the metals were then distributed and deposited according to some particular distribution or partition ratio between the ore fluid and the geologic environment of the deposit. The deposition of minerals in a time sequence, one after the other, is difficult to justify when statistical analyses indicate that the metals occur in relatively constant proportions to one another.

During fractional crystallization of a basic magma, certain metallic elements will be preferentially enriched in the different phases that tend to form. The distribution of the elements is controlled by their ionic properties and thermodynamic potentials. Depending on the concentration of sulphur in the original magma, an immiscible sulphide liquid may form. Cu, Pb, Zn, and Ag, if present, should be enriched in this sulphide liquid due to the strong chalcophile tendencies of these elements. Au, due to its apparent preferential association with Cu and Zn and in the absence of a siderophile phase, would also become enriched in the sulphide liquid. Injection of this enriched sulphide liquid into a deposition site should result in the formation of an orebody typified by relatively constant metal ratios. In the absence of an immiscible sulphide phase, Cu, Pb, Zn, Au, and Ag, if present, would tend to be enriched in the hydrothermal phase that formed. Injection (in a single stage) of this enriched hydrothermal fluid into a deposition site under constant temperature and pressure conditions should also result in the formation of an orebody containing relatively constant metal ratios.

Variation in metal ratios may be caused by the formation or expulsion of the ore fluid from the magma chamber at different stages so that the composition of the fluid varies with the amount of magma crystallized as suggested by H. Neumann (1948), by varying physical-chemical conditions at the deposition site and, by varying thermodynamic relations of the minerals involved, giving rise to various partition ratios for the elements.

An interpretation based on the constancy of metal ratios leads to the assumption that the ore minerals (or metals) such as chalcopyrite, sphalerite, galena, gold, and silver, may not be deposited successively in a time sequence at any one location in an orebody, but are deposited more or less contemporaneously. Consequently, the observed textures of the ore minerals may be due to metamorphism or reheating, or to cooling processes such as in the annealing of alloys, and not with the order of crystallization. The distributions of the various elements and the timing of depositional events are too perfectly synchronized to be coincidental.

The formation of massive and disseminated ore types may possibly be the result of ore minerals migrating out from a center due to changing temperature, pressure, and chemical conditions in the site of deposition or may be due to two successive mineralization periods. However, plotting and statistical analyses of the median values indicates that there is considerable consistency of metal ratios in the deposits studied. That such agreement could be obtained from successive periods of mineralization appears unlikely.

Although some definite genetic relations are suggested by statistical studies of metal ratios and distributions, the results are not conclusive. In any statistical study, the larger the amount of data analyzed, the more conclusive the findings. Similar treatment is required for a greater number of Canadian base metal deposits. Increased studies may result in the establishing of several groups into which most ore deposits would fall. Comparison of the geology of the deposits falling in the same groups may lead to new lines of approach regarding genesis. Much of the statistical work could be initiated at the mining properties, followed by compilation of the data at a central location.

It is readily apparent that the metal content of ore reserves is lacking in important data. It would be beneficial if reserve figures included values for metals present but not considered to be of economic value, such as minor lead at copper-zinc properties.

From the data compiled in this study, it is apparent that such statistical studies may contribute to the knowledge of the formation of orebodies.

The histograms of abundances of individual elements in each of the properties studied, whatever their form, are usually regular and close to unimodal. Such distributions are most frequently right skewed and J-shaped while others do approach normal types. Histograms indicate the central tendency and the degree of dispersion or deviation from the central tendency. Sharp peaks generally indicate very little dispersion whereas broad peaks are the result of considerable dispersion about the mean or median. In general, such histograms yield no clue as to the origin of the deposit. They give only the mean, mode, or median value of the assay of the elements and give a general picture of the distribution of the elements in the various ore types or for the mine in general. Stanton (1958) believes that similarity in shape in any single deposit indicates that some major factor has governed the deposition of the metals. However, similar distributions tudies at mining properties of igneous origin yield distributions similar to those proposed to indicate a sedimentary origin. It is suggested that such individual element histogram studies do not aid in the determination of genesis of sulphide orebodies.

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APPENDIX

TABLE 1A. Distribution of Metal Ratios in the No. 4 Zone, Vermilion Lake Mine.

Level	$\frac{Zn}{Cu+Pb+Zn}$ Frequency										Median Value
	0.0 0.1	0.1 0.2	0.2 0.3	0.3 0.4	0.4 0.5	0.5 0.6	0.6 0.7	0.7 0.8	0.8 0.9	0.9 1.0	
4	69	8	7	14	8	21	37	79	31	6	.6352
6	162	10	5	24	10	10	32	46	28	11	.1700
7	88	28	21	42	41	42	66	132	51	16	.6023
9	113	14	23	22	36	31	62	109	42	8	.5710
Total	432	60	56	102	95	104	197	366	152	41	.5552

(Figure 14 in part)

TABLE 2A. Distribution of Metal Ratios in the No. 4 Zone, Vermilion Lake Mine.

Level	$\frac{Pb}{Cu+Pb+Zn}$ Frequency										Median Value
	0.0 0.1	0.1 0.2	0.2 0.3	0.3 0.4	0.4 0.5	0.5 0.6	0.6 0.7	0.7 0.8	0.8 0.9	0.9 1.0	
4	84	96	55	14	10	7	5	4	2	3	.1585
6	78	71	65	33	27	21	9	11	10	12	.2300
7	211	159	120	29	10	9	1	5	10	8	.1440
9	185	159	74	24	6	2	4	-	1	-	.1266
Total	558	485	314	100	53	39	19	20	23	23	.1535

(Figure 15 in part)

TABLE 3A. Distribution of Metal Ratios in the Vermilion Lake Mine.

Level	$\frac{Au}{Au+Ag}$ Frequency										Median Value
	0.00 0.01	0.01 0.02	0.02 0.03	0.03 0.04	0.04 0.05	0.05 0.06	0.06 0.07	0.07 0.08	0.08 0.09	0.09 0.10	
4	40	145	90	49	38	12	11	6	6	1	.0209
6	56	98	65	29	34	19	11	2	2	13	.0211
7	74	154	88	42	16	12	3	2	1	8	.0169
9	79	136	108	30	19	10	6	2	1	2	.0183
Total	249	533	351	150	107	53	31	11	11	24	.0195

(Figure 16 in part)

TABLE 4A. Distribution of Metal Ratios in the No. 4 Zone, Vermilion Lake Mine.

Level	$\frac{Cu}{Cu+Pb+Zn}$ Frequency										Median Value
	0.0 0.1	0.1 0.2	0.2 0.3	0.3 0.4	0.4 0.5	0.5 0.6	0.6 0.7	0.7 0.8	0.8 0.9	0.9 1.0	
4	108	47	20	24	14	10	10	9	11	27	.1681
6	116	27	22	29	24	25	17	17	22	34	.3052
7	197	85	36	39	35	23	21	15	16	41	.1671
9	154	66	41	22	31	16	30	18	21	80	.2476
Total	575	225	119	114	104	74	78	59	70	182	.2000
Mine	950	342	176	169	177	130	143	134	156	430	.2635

(Figure 17 in part)

FREQUENCY DISTRIBUTION TABLE 5A

MINE: VERMILION LAKE MINE (Figure 19)

ORE TYPE: Mine ORE ZONE: Mine Randoms

CLASS INTER-VAL. Au (oz/T.)	FREQUENCY — ASSAY INTERVAL COPPER (WEIGHT PERCENT) 0 — 0.5	0.5 — 1.0	1.0 — 1.5	1.5 — 2.0	2.0 — 3.0	3.0 — 4.0	4.0 — 5.0	5.0 — 6.0	6.0 — 8.0	8.0 — 11.0		
0 .008	518	113	73	26	29	17	6	5		1		
008 .0125	100	36	32	21	35	10	10	2	1			
0125 .0175	37	15	12	7	9	11	1			2		
0175 .0225	70	23	6	14	19	14	11	4		1		
0225 .0275	17	4	5	2	3	5	4	4	1	1		
0275 .0325	46	19	6	5	9	6	3		9	3		
0325 .0375	5	13	3	1		5				1		
0375 .0425	27	16	9	3	4	4	4	6	1	3		
0425 .0475	6	5	2	4		3		1				
0475 .0525	7	7	3	3	4	3			1	3		
0525 .0575	4		1	1			1					
0575 .0625	10	11	9	4	2	1		2	2			
0625 .0675	3	2	1									
0675 .0725	3	6	3		2							
0725 .0775			3	1					1			
0775 .0825	3	2	3			1				2		
0825 .0875		1	1	1	1							
0875 .0925	2	2	1	2	3			1				
0925 .0975		3	1									
0975 .105	2	2			1							
105 .125	4	2										
125 .150	1	1	1	1								
TOTAL	865	283	175	96	121	79	40	27	17	17	=	1720
TOTAL/2	432.5	141.5	87.5	48	60.5	39.5	20	13.5	8.5	8.5		
MEDIAN Au	.0066	.012	.010	.013	.012	.018	.019	.026	.031	.035		

V-60

FREQUENCY DISTRIBUTION TABLE 6A

MINE: VERMILION LAKE MINE (Figure 20)

ORE TYPE: Mine ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY										
	ASSAY INTERVAL LEAD (WEIGHT PERCENT).										
Au (oz/T.)	0 — 0.5	0.5 — 1.0	1.0 — 1.5	1.5 — 2.0	2.0 — 2.5	2.5 — 3.0	3.0 — 4.0	4.0 — 5.0	5.0 (5.70) 8.0		
0 .005	293	67	25	6	5	4	1				
005 .015	76	40	42	12	7	11	3	2	2		
015 .025	39	52	77	38	21	12	16	5	2		
025 .035	15	38	44	38	18	7	11	12	2		
035 .045	6	20	33	26	19	13	17	6	4		
045 .055	5	8	19	15	10	4	9	10	1		
055 .065	1	5	18	11	10	9	12	4	6		
065 .075		6	8	4	6	4	8	3	2		
075 .085		4	6	5	7	3	2	4			
085 .095		2	5	4	3	2	4	2	1		
095 .105		3	3	2		3	1	3	3		
105 .115		1						1	2		
115 .125							3				
125 .135		2		1							
.135 .145					1						
>.145	1	2		1		1	1	2			
TOTAL	436	250	280	163	107	73	88	54	25	=	1476
TOTAL/2	218	125	140	81.5	53.5	36.5	44	27	12.5		
MEDIAN Au	.005	.018	.024	.032	.036	.037	.043	.047	.058		

FREQUENCY DISTRIBUTION TABLE 7A

MINE: VERMILION LAKE MINE (Figure 21)

ORE TYPE: Mine ORE ZONE: Mine Randoms

CLASS INTERVAL Au (oz/T.)	FREQUENCY ASSAY INTERVAL ZINC (WEIGHT PERCENT) 0 – 0.4	0.4 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	3.0 – 3.5	3.5 – 4.0	4.0 – 5.0	5.0 – 7.0	7.0 – 11.0	11.0 – 13.0	>13.0 (14.55)		
0 .005	699	95	44	58	[illegible]4	20	15	12	18	20	5				
005 .0125	110	53	31	25	25	21	26	22	27	25	10	2			
0125 .0175	34	9	17	12	10	8	9	8	4	12	8	4	1		
0175 .0225	46	12	12	24	24	10	19	17	34	33	33	1	5		
0225 .0275	6	3	3	9	4	7	6	5	10	8	14				
0275 .0325	14	4	7	10	13	7	11	14	25	35	27	2	4		
0325 .0375	4				1	1		1	7	9	14		5		
0375 .0425	8	3	5	1	3	8	8	8	11	31	29	7	2		
0425 .0475	2		2		1	1	3	1	2	9	6	3			
0475 .0525			3	6	1	2		4	4	13	12	9	5		
0525 .0575	1	2		1		1		1		4	5	1	1		
0575 .0625	4	3			2	1	3	2	2	12	30	5	5		
0625 .0675										5	1		3		
0675 .0725			1		1	2	1		6	6	9	2	9		
0725 .0775								1		2	3		1		
0775 .0825							1	1	1	6	15	2	2		
0825 .0875										1	2		1		
0875 .0925						1				5	8	2	2		
0925 .0975						1				1	2				
0975 .105				1						3	1				
.105 .125					1					1	1				
>.125	4									2		2	10		
TOTAL	938	184	129	147	120	91	102	96	151	243	235	42	56	=	2534
TOTAL/2	469	92	64.5	73.5	60	45.5	51	48	75.5	121.5	117.5	21	28		
MEDIAN Au	.003	.005	.010	.010	.013	.015	.018	.019	.021	.031	.039	.049	.063		

FREQUENCY DISTRIBUTION TABLE 8A

MINE: VERMILION LAKE MINE (Figure 22)

ORE TYPE: Mine ORE ZONE: Mine Randoms

CLASS INTERVAL. A8 (oz/T.)	FREQUENCY													
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)													
	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 –(8.3) 9.0	9.0 – 10.0	10.0 – 12.0		
0 .25	491	62	19	1										
.25 .50	215	60	58	14	15	3								
.50 .75	110	43	33	19	31	10	2	1	1					
.75 1.0	66	27	24	22	24	8	3	4						
1.0 1.25	58	25	23	13	20	18	6	1						
1.25 1.50	56	22	16	14	18	7	7	2	3					
1.50 1.75	22	16	9	13	9	10	5	4						
1.75 2.00	21	16	6	6	13	5	4							
2.0 3.0	34	49	25	16	38	19	16	8	8	[illegible]	1			
3.0 4.0	14	14	12	6	16	11	8	9	2	[illegible]		1		
4.0 5.0	5	10	13	8	7	10	5	6	[illegible]	3	1			
5.0 6.0	2	3	3	3		4	2	1	[illegible]			1		
6.0 7.0	3	3		2	1		2			3	3			
7.0 8.0			1				1		1			1		
>8.0								1	1	1				
TOTAL	1097	350	242	137	192	105	61	37	21	16	5	3	=	2266
TOTAL / 2	548.5	175	121	68.5	96	52.5	30.5	18.5	10.5	8	2.5	1.5		
MEDIAN A8	0.32	0.84	0.86	1.24	1.33	1.66	2.22	2.77	2.72	3.80	5.33	5.00		

FREQUENCY DISTRIBUTION TABLE 9A

MINE: VERMILION LAKE MINE (Figure 23)

ORE TYPE: Mine ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY										
	ASSAY INTERVAL LEAD (WEIGHT PERCENT)										
Ag (oz/T.)	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0		
0 .25	305		3		1	1					
.25 .50	208	17	3			3					
.50 .75	109	29	17	4	1	1	1				
.75 1.0	72	30	16	9	1	3	1		1		
1.0 1.25	50	18	45	18	9		1				
1.25 1.50	21	28	54	26	8	5	3	1			
1.50 1.75	12	15	28	20	14	6	3	1			
1.75 2.00	3	9	34	14	8	7	1	2			
2.0 3.0	16	14	54	39	42	24	27	14	1		
3.0 4.0	2	6	12	18	11	13	24	10	6		
4.0 5.0	1	2	7	6	11	6	26	13	4		
5.0 6.0		1		2	1	3	3	10	5		
6.0 7.0			1	4	2	2	1	1	1		
7.0 8.0				1			1		1		
>8.0	1		1					2			
TOTAL	900	169	275	161	109	74	92	54	19	=	1854
TOTAL/2	450	84.5	137.5	80.5	54.5	37	46	27	9.5		
MEDIAN Ag	0.42	1.12	1.50	1.81	2.30	2.46	3.38	3.90	4.62		

FREQUENCY DISTRIBUTION TABLE 10A

MINE: VERMILION LAKE MINE (Figure 24)

ORE TYPE: Mine ORE ZONE: Mine randoms

CLASS INTERVAL Ag (oz/T.)	FREQUENCY																	
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)																	
	0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	>18.0 20.6		
0 0.25	198	16	17	5	1	1		2										
0.25 0.50	74	24	47	23	14	4	2		1			1						
0.50 0.75	47	14	28	29	14	6	7	6	4		5							
0.75 1.00	15	7	20	19	19	13	6	3	6	2	1	1						
1.0 1.5	23	13	16	28	26	39	36	23	16	5	1	12	5					
1.5 2.0	7	3	2	11	17	14	20	16	10	13	5	10	2	2	1	1		
2.0 3.0	3	4	12	10	12	7	14	23	10	9	17	27	6	5	2	2		
3.0 4.0	4			1	9	5	9	7	6	5	2	19	6	3	5	4		
4.0 5.0			4	1	3	1	2	6	7	3	3	12	6	12	4	1		
5.0 6.0					1			1	1	1	2	7	1	3	2	2		
6.0 7.0	1	1		1	1	1	1			1	1	3		2				
7.0 8.0					1									2				
>8.0	2		1															
TOTAL	374	82	147	128	118	91	97	87	61	39	37	92	26	29	14	10	=	1432
TOTAL/2	187	41	73.5	64	59	45.5	48.5	43.5	30.5	19.5	18.5	46	13	14.5	7	5		
MEDIAN Ag	0.24	0.52	0.57	0.84	1.21	1.28	1.47	1.80	1.68	1.98	2.38	2.82	3.00	4.37	3.80	3.50		

V-58

FREQUENCY DISTRIBUTION TABLE 11A

MINE: VERMILION LAKE MINE (Figure 25)

ORE TYPE: Mine ORE ZONE: #4 zone

CLASS INTERVAL Au (oz/T.)	FREQUENCY ASSAY INTERVAL SILVER (oz/TON) 0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 7.0		
0 .005	582	115	41	3	1				
005 .015	65	70	55	9	2				
015 .025	24	64	78	15	9	2	1		
025 .035	7	21	54	23	8	4	1		
035 .045	2	14	36	18	14	5			
045 .055		6	21	12	5	6	1		
055 .065		1	15	13	6	7	3		
065 .075			8	7	2	6	1		
075 .085		1	2	4	3	3	2		
085 .095			2	3	3	4	2		
095 .105			1	5		3	2		
105 .115		1		2	1		2		
115 .125			1	1		1			
125 .135			1	2					
135 .145									
145 .155		1							
155 .165		1			1				
>.165			2	1					
TOTAL	680	295	317	118	55	41	15	=	1521
TOTAL/2	340	147.5	158.5	59	27.5	20.5	7.5		
MEDIAN Au	.003	.010	.023	.040	.040	.060	.078		

FREQUENCY DISTRIBUTION TABLE 12A

MINE: VERMILION LAKE MINE (Figure 26)

ORE TYPE: Mine ORE ZONE: Mine Randoms

CLASS INTER-VAL. Cu (WT%)	FREQUENCY													
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)													
	0 (.13) 0.5	0.5 (.63) 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 4.0	4.0 – 6.0	6.0 – 8.0	8.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	>16.0 (17.7)		
0 .25	539	70	55	61	123	72	39	6	15	2	1	7		
.25 .50	182	18	17	22	78	69	42	23	15	4	9	1		
.50 .75	92	13	5	13	47	35	37	21	22	5	5	2		
.75 1.0	68	12	4	6	23	27	17	11	11	6	2	8		
1.0 1.25	58	11	8	7	20	7	13	7	4	3	3			
1.25 1.50	36	9	6	6	9	5	9	4	6			2		
1.50 2.0	40	12	9	9	22	16	11	7	7	3	6	1		
2.0 3.0	69	23	13	10	35	15	11	9	6	4	2	2		
3.0 4.0	33	5	7	2	24	16	7	4	2	2	1	1		
4.0 5.0	16	6	4	4	13	8	3	2	2		1			
5.0 6.0	12	2	3	1	9	4	4	4						
6.0 7.0	5		1	3	4	2	4	2	1					
7.0 8.0	1			1	1		1							
8.0 10.0	3	2		4	4	3		1						
>10.0	3				1	1								
TOTAL	1157	183	132	149	413	280	198	101	91	29	30	24	=	2787
TOTAL / 2	578.5	91.5	66	74.5	206.5	140	99	50.5	45.5	14.5	15	12		
MEDIAN Cu	.30	.57	.66	.65	.53	.50	.62	.75	.68	.90	.75	.81		

V-67.

FREQUENCY DISTRIBUTION TABLE 13A

MINE: VERMILION LAKE MINE (Figure 27)

ORE TYPE: Mine ORE ZONE: Mine Randoms

CLASS INTERVAL Pb (WT %)	FREQUENCY																		
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)																		
	0 0.5	0.5 1.0	1.0 1.5	1.5 2.0	2.0 3.0	3.0 4.0	4.0 5.0	5.0 6.0	6.0 7.0	7.0 8.0	8.0 9.0	9.0 10.0	10.0 12.0	12.0 14.0	14.0 16.0	16.0 (17.2) 20.0	20.0 (21.4) 24.0		
0 .25	783	109	70	44	56	17	5	11	4	3									
25 .50	39	38	30	50	33	38	12	8	3	1	1	1	1						
50 .75	12	12	14	32	49	27	14	15	7	3	2	3	1	1					
75 1.0	8	1	2	9	30	35	23	10	7	4	2		4	1		1			
1.0 1.5	12	5	2	10	20	58	55	39	34	16	11	5	5	2		1	1		
1.5 2.0	3	3	4	2	8	9	19	36	36	18	7	4	10	2	1				
2.0 2.5	1	2	2		5	9	6	12	12	16	8	9	12	5	1		2		
2.5 3.0	2	2		1	4	2	4	5	4	15	10	6	15	5	1				
3.0 4.0	1			1	1	5	4	2	4	7	8	14	21	6	10	9			
4.0 5.0				1	2	3	1	1	2	1	1	4	18	4	9	2	1		
5.0 6.0					1					1		2	2	3	4	3	1		
6.0 8.0										1	1				2	1	1		
8.0 10.0																			
10.0 12.0																	1		
TOTAL	861	172	124	150	209	203	143	139	118	86	51	48	89	29	29	17	7	=	2564
TOTAL/2	430.5	86	62	75	104.5	101.5	71.5	69.5	59	43	25.5	24	44.5	14.5	14.5	8.5	3.5		
MEDIAN Pb	0.13	0.20	0.22	0.40	0.58	0.85	1.16	1.33	1.56	1.94	2.16	2.67	2.88	2.85	4.06	3.30	3.75		

FREQUENCY DISTRIBUTION TABLE 14A

MINE: VERMILION LAKE MINE (Figure 28)

ORE TYPE: Mine ORE ZONE: #4 on 9th level

CLASS INTER-VAL.	FREQUENCY											
	ASSAY INTERVAL ZINC (WEIGHT %)											
FE (WT%)	0 – 0.4	0.4 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 8.0	8.0 – 12.0	>12.0 (15.2)		
0 – 2.0												
2.0 – 4.0	1	1	1		1		1					
4.0 – 6.0	1	5		1		1	1	2	2			
6.0 – 8.0	4	1	3	2	2		1	3	3			
8.0 – 10.0	22	1	2	2	2	1	1	1	1	1		
10.0 – 12.0	24	4	2	4	3	1	5	1		1		
12.0 – 14.0	15	1	2	5	2	2	2	3	3	1		
14.0 – 16.0	12	4	5	3	4	3	3	2	3			
16.0 – 18.0	9	2	2	4	4	3	1	5	6	1		
18.0 – 20.0	4		6		1	2	2	3	1	1		
20.0 – 22.0	3	1	1	2			2	2	2	1		
22.0 – 24.0	1		3	1	3	2	2	2	1	1		
24.0 – 26.0	6			3		2		4				
26.0 – 28.0		1	1	2	3		3	1				
28.0 – 30.0				1	1							
30.0 – 32.0			2	2	2		1	1				
32.0 – 34.0	2	2			2							
>34.0		2		1	1			1				
TOTAL	104	25	30	33	31	17	25	31	22	7	=	325
MEDIAN FE	12.0	13.0	16.0	15.6	16.8	16.3	15.0	17.4	15.3	17.0		

FREQUENCY DISTRIBUTION TABLE 15A

MINE: VERMILION LAKE MINE (Figure 29)

ORE TYPE: Mine ORE ZONE: Mine Randoms

CLASS INTER-VAL. Fe (wt %)	FREQUENCY										
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)										
	0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 6.0	6.0 – 8.0	8.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	>16.0 (17.50)
0 – 1.0	52	18	9	8	11	5	5	3			
1.0 – 2.0											
2.0 – 4.0	14	1	2		1						
4.0 – 6.0	29	3	1		2	3	1	1			
6.0 – 8.0	37	5	5	5	2	2	2		1	1	1
8.0 – 10.0	42	10	2	9	2	2	1	3	1	1	2
10.0 – 12.0	56	11	8	4	6	6	2	4	2	2	1
12.0 – 14.0	29	9	10	7	7	9	6	3	1	3	5
14.0 – 16.0	25	7	15	4	9	4	3	8	2	1	
16.0 – 18.0	15	11	2	3	7	11	7	12	5		
18.0 – 20.0	8	9	5	11	7	12	5	13	2	6	1
20.0 – 22.0	10	4	5	4	8	8	3	3	2		
22.0 – 24.0	6	3	1	5	10	10	7	7	1	3	
24.0 – 26.0	5	1	2	3	14	11	2	7			1
26.0 – 28.0	3	2	4	2	13	5	5	1			1
28.0 – 30.0	2	2	2	2	1	3	1	1	2		
30.0 – 32.0	5	1	2	1	5	1	1	1			
32.0 – 34.0		2	2	1	2	1					
34.0 – 36.0	2	1		1	1	1	1	1			
36.0 – 38.0	1		2			2					
38.0 – 40.0	1				1						
TOTAL	342	100	79	70	109	96	52	68	19	17	12 = 964
TOTAL / 2	171	50	39.5	35	54.5	48	26	34	9.5	8.5	6
MEDIAN FE	10.82	14.57	14.95	17.33	20.12	19.00	17.71	18.23	17.00	16.33	12.80

V-33

FREQUENCY DISTRIBUTION TABLE 1, 16A

MINE: VERMILION LAKE MINE (Figure 30)

ORE TYPE: Mine ORE ZONE: Mine Randoms

CLASS INTER-VAL. FE (WT %)	FREQUENCY									
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)									
	0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	>6.0 (6.85)		
0 – 1.0	7	6	6	3						
1.0 – 2.0										
2.0 – 4.0										
4.0 – 6.0	11			1	1	1	1			
6.0 – 8.0	28	2	4	2		2				
8.0 – 10.0	36	11	3	3	6	1	1	3		
10.0 – 12.0	31	16	10	7	2	2	2			
12.0 – 14.0	26	7	12	6	4	4	1	1		
14.0 – 16.0	23	7	9	7		2	2	2		
16.0 – 18.0	2	13	10	9	2	2	2			
18.0 – 20.0	12	9	7	3	5	2	2			
20.0 – 22.0	11	5	5	6	1	2	1			
22.0 – 24.0	10	9	2	5	1		2	2		
24.0 – 26.0	11	5	3	3	4	1		1		
26.0 – 28.0	10	2	4	2	1	1	1			
28.0 – 30.0	3	7	4	2	1					
30.0 – 32.0	5	1	1	1	1			2		
32.0 – 34.0	1			3				1		
34.0 – 36.0	2		1			1				
36.0 – 38.0	2	1								
38.0 – 40.0	1									
TOTAL	232	101	81	63	29	21	15	12	=	554
TOTAL / 2	116	50.5	40.5	31.5	14.5	10.5	7.5	6		
MEDIAN FE	12.23	16.23	15.22	16.55	17.00	14.50	16.50	16.00		

FREQUENCY DISTRIBUTION TABLE 17A

MINE: VERMILION LAKE MINE (Figure 31)

ORE TYPE: Mine ORE ZONE: # 4 and 6 on 6th level

CLASS INTERVAL	FREQUENCY								
	ASSAY INTERVAL SILVER (oz/T.)								
Au (oz/T.)	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 6.0		
0 .005	176	26	11	3	2				
005 .015	9	8	6	2	2	1			
015 .025	3	8	9	3	2	6			
025 .035	3	3	5	1	2				
035 .045	1	1	3	1	4	3	1		
045 .055		1	2	2	1	4			
055 .065				1			1		
065 .075			1		1	1	2		
075 .085		1				1			
085 .095						1	1		
095 .105							1		
105 .115									
115 .125			1						
125 .135			1						
TOTAL	192	48	39	13	14	17	6	=	329
MEDIAN Au	.003	.005	.018	.020	.030	.035	.070		

V-4

FREQUENCY DISTRIBUTION TABLE 18A

MINE: VERMILION LAKE MINE (Figure 32)

ORE TYPE: Mine ORE ZONE: #4 on 4th level

CLASS INTER-VAL Au (oz/T.)	FREQUENCY							
	ASSAY INTERVAL SILVER (OZ/TON)							
	0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0		
0 .005	114	17	3	1	1			
005 .015	20	21	9	1	1			
015 .025	9	21	26	3				
025 .035	4	9	14	7	2			
035 .045		9	16	4	5	4		
045 .055		3	7	10	2	2		
055 .065			11	6	2	4		
065 .075			3	1	1	1		
075 .085				2	1	3		
085 .095			1	2	1	1		
095 .105			1					
105 .115		1			1			
.115 .125								
125 .135				2				
135 .145								
145 .155		1						
155 .165		1						
>.165			1	1				
TOTAL	147	83	92	40	17	15	=	394
TOTAL / 2	73.5	41.5	46	20	8.5	7.5		
MEDIAN Au	.003	.017	.030	.049	.042	.059		

FREQUENCY DISTRIBUTION TABLE 19A

MINE: VERMILION LAKE MINE (Figure 33)

ORE TYPE: Mine ORE ZONE: #6 on 7th level

CLASS INTERVAL	FREQUENCY									
	ASSAY INTERVAL SILVER (oz/ton)									
Au (oz/T.)	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	6.5		
0 .005	182	39	9	3						
005 .015	5	21	7	7	1					
015 .025	7	14	7	4	4		1			
025 .035		6	5	2	6	3	1	1		
035 .045	1	2	2	4	2	4				
045 .055		2	1	1						
055 .065				1	4		2	1		
065 .075					2		3			
075 .085								1		
085 .095			1				2			
095 .105					4		1			
.105 .115					2			2		
115 .125										
.125 .135										
135 .145										
145 .155										
TOTAL	195	84	32	22	25	7	10	5	=	380
TOTAL/2	97.5	42	16	11	12.5	3.5	5	2.5		
Au MEDIAN	.003	.006	.015	.018	.042	.036	.068	.070		

FREQUENCY DISTRIBUTION TABLE 20A

MINE: VERMILION LAKE MINE (Figure 34)

ORE TYPE: Mine ORE ZONE: #4 on 7th level

CLASS INTERVAL Au (oz/T.)	FREQUENCY										
	ASSAY INTERVAL SILVER (oz/TON)										
	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 8.0		
0 .005	74	15	4	1							
005 .015	20	22	10	11	8	1					
015 .025	10	23	27	18	19	4	4	1	1		
025 .035	1	13	19	11	13	4	2	1			
035 .045		4	8	8	16	3	4	2			
045 .055		1	5	3	6	2	2	2	1		
055 .065			5	1	7	3	2	2			
065 .075		1		3	7	4	3	2			
075 .085					4	2	4	1	1		
>.085		1	2		1	3	3	2	1		
TOTAL	105	80	80	56	81	26	24	13	4	=	469
TOTAL/2	52.5	40	40	28	40.5	13	12	6.5	2		
MEDIAN Au	.004	.016	.025	.024	.035	.050	.055	.058	.065		

FREQUENCY DISTRIBUTION TABLE 21A

MINE: VERMILION LAKE MINE (Figure 35)

ORE TYPE: Mine ORE ZONE: #4 on 9th level

CLASS INTER-VAL. Au (oz/T)	FREQUENCY								
	ASSAY INTERVAL SILVER (OZ./TON)								
	0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 7.0		
0 .005	110	33	12						
005 .015	31	20	24	5					
015 .025	5	21	29	6	3	1	1		
025 .035		3	27	8	3	3			
035 .045		2	10	8	2				
045 .055			8	1	2		1		
055 .065		1	2	3	4	2			
065 .075			4	3		1			
075 .085			2	2	1	1			
085 .095			1	1	1		2		
095 .105				1		1	2		
105 .115									
115 .125				1		1			
125 .135									
135 .145									
145 .155									
155 .165					1				
165 .175			1						
TOTAL	146	80	120	39	17	10	6	=	418
TOTAL / 2	73	40	60	19.5	8.5	5	3		
MEDIAN Au	.003	.009	.016	.036	.047	.050	.075		

FREQUENCY DISTRIBUTION TABLE 22A

MINE: VERMILION LAKE MINE (Figure 36)

ORE TYPE: Mine ORE ZONE: #4 on 9th level

CLASS INTERVAL Pb. (wt %)	FREQUENCY															
	ASSAY INTERVAL ZINC (WEIGHT %)															
	0 0.4	0.4 1.0	1.0 1.5	1.5 2.0	2.0 2.5	2.5 3.0	3.0 4.0	4.0 5.0	5.0 6.0	6.0 7.0	7.0 8.0	8.0 10.0	10.0 12.0	>12.0 (15.3)		
0 .25	125	26	12	10	5	3	1	1	2	1						
.25 .50		7	3	5	7	2	4	2	1							
.50 .75	1		2	5	4	3	5	1	3	2	1	1				
.75 1.0				1	2	5	8	8	1	1	2					
1.0 1.25			1		2	1	5	3	3	4	2	1				
1.25 1.50				1	1		4	2	3	4						
1.50 1.75						1			6	2	2					
1.75 2.0							1	2	5	2	2					
2.0 2.5			1				2		2	2	2	3	3			
2.5 3.0					1		1		2	1	3	5	6	1		
3.0 3.5										1		1	3	4		
3.5 4.0											2	2		1		
4.0 4.5							1				1	2	1			
4.5 5.0							1						1	1		
>5.0											2			1		
TOTAL	126	33	19	22	22	15	33	19	28	20	19	15	14	8	=	393
MEDIAN Pb	0.13	0.16	0.20	0.30	0.46	0.71	0.95	0.92	1.54	1.38	2.13	2.75	2.83	3.38		

FREQUENCY DISTRIBUTION TABLE 23A

MINE: VERMILION LAKE MINE (Figure 37)

ORE TYPE: Mine ORE ZONE: #4 on 9th level

CLASS INTERVAL Au (oz/T)	FREQUENCY: ASSAY INTERVAL Zinc (weight percent) 0 – 0.1	0.1 – 0.7	0.7 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 8.0	8.0 – 11.0	12.0		
0 .005	82	26	8	8	10	3	2	5	1	3	1	1	1		
005 .015	7	11	8	5	5	9	7	8	5	3	4		1		
015 .025	5	4	3	4	4	8	2	8	7	9	10	2			
025 .035	1			2	2	3	2	6	1	5	6	6	1		
035 .045								1	2	5	5	3	4		
045 .055				1	1			2	1	1	3	1	2		
055 .065								2	1		4	3	1		
065 .075						1	1		1	1	1	1			
075 .085								1	1	1	2	2			
085 .095											1	2	1		
095 .105											1	1	2		
.105 .115															
.115 .125											1		2		
TOTAL	95	41	19	19	22	23	14	33	19	28	39	22	15	=	389
TOTAL 2	47.5	20.5	9.5	9.5	11	11.5	7	16.5	9.5	14	19.5	11	7.5		
MEDIAN Au	.003	.004	.007	.008	.007	.014	.012	.019	.020	.024	.034	.041	.047		

FREQUENCY DISTRIBUTION TABLE 24A

MINE: VERMILION LAKE MINE (Figure 38)

ORE TYPE: Mine ORE ZONE: #4 on 9th level

CLASS INTER-VAL.	FREQUENCY											
	ASSAY INTERVAL LEAD (WEIGHT PERCENT)											
Au (oz/T.)	0 .25	.25 .50	.50 .75	.75 1.0	1.0 1.5	1.5 2.0	2.0 2.5	2.5 3.0	3.0 4.0	4.0 5.0		
0 .005	142	11	4	6	2	2	1	2				
005 .015	29	11	7	5	6	2	1	1		1		
015 .025	15	8	6	7	14	7		5	2	2		
.025 .035	6	2	5	3	8	10	4	2	1	8		
035 .045		1	2	3	5	1	5	2	3			
045 .055	1			1	2		3	1	1	4		
055 .065			2		1	1	1	3	2	1		
065 .075			2		1	1			1	4		
075 .085			2	2	1			1		1		
085 .095					1		1	1		2		
095 .105						1		2	1			
105 .115										1		
115 .125			1						2			
125 .135												
>.135									1	1		
TOTAL	193	33	31	27	41	25	16	20	14	25	=	414
TOTAL/2	96.5	16.5	15.5	13.5	20.5	12.5	8	10	7	12.5		
MEDIAN Au	.0034	.010	.023	.019	.024	.027	.039	.035	.055	.048		

FREQUENCY DISTRIBUTION TABLE 25A

MINE: VERMILION LAKE MINE (Figure 39)

ORE TYPE: Mine ORE ZONE: #6 on 7th level

CLASS INTER-VAL. Au (oz/T.)	FREQUENCY								
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)								
	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 6.0		
0 .005	130	47	31	16	15	11	8		
005 .015	22	7	2	4	8	6	7		
015 .025	36	8	5	6	8	3	2		
025 .035	28	9	3	1	1				
035 .045	13	11	2	1		3	1		
045 .055	6	3			1	1	1		
055 .065	4	2	1	1	1		1		
065 .075	3	3	1						
075 .085	1	1	1						
085 .095	2	1	2						
095 .105	2	1	1						
.105 .115	1	2							
TOTAL	248	95	49	29	34	24	20	=	499
TOTAL/2	124	47.5	24.5	14.5	17	12	10		
MEDIAN Au	.005	.006	.004	.004	.008	.007	.008		

FREQUENCY DISTRIBUTION TABLE 26A

MINE: VERMILION LAKE MINE (Figure 40)

ORE TYPE: Mine ORE ZONE: #6 on 7th level

CLASS INTER-VAL. Pb (WT. %)	FREQUENCY ASSAY INTERVAL ZINC (WEIGHT PERCENT) 0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 10.0	10.0 – 12.0	>12 14.7		
0 .25	192	8	9	5	3									
.25 .50	5	7	10	1	5	3	1			1				
.50 .75			3	4	3	3	1	2			1			
.75 1.0		1		1	4	2	1	4			1	1		
1.0 1.5	2			4	3	7	2	4	4			1		
1.5 2.0		1				1	1	2	1	1				
2.0 2.5		1		2			1	1		1	1	1		
2.5 3.0									3	3	1			
3.0 3.5									1	2	2	1		
3.5 4.0									1		1			
4.0 4.5												1		
4.5 5.0								1		1	2			
>5.0											2	2		
TOTAL	199	18	22	17	18	16	7	14	10	9	11	7	=	348
TOTAL/2	99.5	9	11	8.5	9	8	3.5	7	5	4.5	5.5	3.5		
MEDIAN Pb	0.19	0.29	0.55	0.66	0.58	1.00	1.13	1.13	2.00	2.75	3.38	3.00		

FREQUENCY DISTRIBUTION TABLE 27A

MINE: VERMILION LAKE MINE (Figure 41)

ORE TYPE: Mine ORE ZONE: #6 on 7th level

CLASS INTERVAL A8 (oz/T.)	FREQUENCY								
	ASSAY INTERVAL LEAD (WEIGHT PERCENT)								
	0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	>5.0 5.8		
0 .25	128								
.25 .50	58	4							
.50 .75	26	6	6						
.75 1.0	15	7	2	2					
1.0 1.5	14	7	8	1	1				
1.5 2.0	4	3	11	2					
2.0 2.5	1	2	3	5	1	2			
2.5 3.0			3	2	1	1			
3.0 3.5			1	1	1	1			
3.5 4.0									
4.0 4.5					4		1		
4.5 5.0				1			1		
5.0 6.0						1			
6.0 7.0			1	1			2		
TOTAL	246	30	35	15	8	5	4	=	343
TOTAL/2	123	15	17.5	7.5	4	2.5	2		
MEDIAN A8	0.24	0.93	1.57	2.25	3.50	2.75	4.50		

FREQUENCY DISTRIBUTION TABLE 28A

MINE: VERMILION LAKE MINE (Figure 42)

ORE TYPE: Mine ORE ZONE: #6 zone

CLASS INTERVAL Cu (WT %)	FREQUENCY															
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)															
	0 – .25	.25 – .50	.50 – .75	.75 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 4.0	4.0 – 6.0	6.0 – 8.0	8.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	>16.0 (17.8)		
0 – .25	320	10	10	12	19	29	66	38	18	2	5	2		3		
.25 – .50	99	2	6	2	7	11	32	23	18	13	8	1	3	1		
.50 – .75	61	2	3	1	3	2	15	12	14	10	6	2	2	2		
.75 – 1.0	45	3	3	1	1	4	11	8	9	3	4	3		3		
1.0 – 1.25	29	4	7		3	1	5	4	6	2	3	1	1			
1.25 – 1.50	23	1		3		1	2	2	2	1	5			1		
1.50 – 2.0	21	1	4	1	3	2	8	9	4	2	3					
2.0 – 3.0	36	6	5	3	6	5	11	7	2	1		2		1		
3.0 – 4.0	22	1	2	1	4		10	4	1	1						
4.0 – 5.0	6	3		2	2	1	5	1								
5.0 – 6.0	6		1	1	2	1	1	1	1							
6.0 – 7.0	4				1	1										
7.0 – 8.0							1									
8.0 – 10.0						3		1		1						
>10.0	1															
TOTAL	673	33	41	27	51	61	167	110	75	36	34	11	6	11	=	1336
TOTAL/2	336.5	16.5	20.5	13.5	25.5	30.5	83.5	55	37.5	18	17	5.5	3	5.5		
MEDIAN Cu	.29	.95	.87	.44	.47	.28	.39	.43	.53	.58	.67	.79	.50	.69		

FREQUENCY DISTRIBUTION TABLE 29A

MINE: VERMILION LAKE MINE (Figure 43)

ORE TYPE: Mine ORE ZONE: #4 zone

CLASS INTER-VAL.	FREQUENCY																
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)																
Cu (WT%)	0 .25	.25 .50	.50 .75	.75 1.0	1.0 1.5	1.5 2.0	2.0 4.0	4.0 6.0	6.0 8.0	8.0 10.0	10.0 12.0	12.0 14.0	14.0 16.0	16.0 18.0	18.0 24.0		
0 .25	196	13	18	30	36	32	57	34	21	4	10		1	2	2		
.25 .50	75	6	6	4	10	11	46	46	24	10	7	3	6				
.50 .75	22	7	3	6	2	11	32	23	23	11	16	3	3				
.75 1.0	19	1	5	3	3	2	12	19	8	8	7	3	2	5			
1.0 1.25	23	2	4		5	6	15	3	7	5	1	2	2				
1.25 1.5	11	1	3	3	6	5	7	3	7	3	1			1			
1.5 2.0	18		3	4	6	7	14	7	7	5	4	3	6		1		
2.0 3.0	24	3	4	11	7	5	24	8	9	8	6	2	2		1		
3.0 4.0	8	2	1	1	3	2	14	12	6	3	2	2	1		1		
4.0 5.0	6	1	1	3	2	3	8	7	3	2	2		1				
5.0 6.0	6				1		8	3	3	4							
6.0 7.0	1					2	3	2	4	2	1						
7.0 8.0	1					1			1								
8.0 10.0	2	1	2			1	4	2									
>10.0	2						1	1									
TOTAL	414	37	50	65	81	88	245	170	123	65	57	18	24	8	5	=	1450
TOTAL/2	207	18.5	25	32.5	40.5	44	122.5	85	62.5	32.5	28	9	12	4	2.5		
MEDIAN Cu	.27	.52	.58	.38	.36	.52	.64	.55	.67	.98	.67	1.00	1.00	.55	1.13		

FREQUENCY DISTRIBUTION TABLE 30A

MINE: VERMILION LAKE MINE (Figure 44)

ORE TYPE: Mine ORE ZONE: #6 on 7th level

CLASS INTER-VAL.	FREQUENCY											
	ASSAY INTERVAL ZINC (WEIGHT %)											
Cu (WT%)	0 0.5	0.5 1.0	1.0 2.0	2.0 3.0	3.0 4.0	4.0 5.0	5.0 7.0	7.0 9.0	9.0 11.0	>11.0 (11.9)		
0 .25	69	3	7	10	10	8	8	1		2		
.25 .50	36	3	3	2	2	4	4	6	3	4		
.50 .75	21	3	1		1	1	3	2	2	4		
.75 1.0	18	2	1			2	2	1	2			
1.0 1.5	20	1	2	1		1	2	2	2	2		
1.5 2.0	4	3	2	1	3		2			2		
2.0 3.0	10	1	4	3	1				1	1		
3.0 4.0	12			1			1					
4.0 5.0			2									
>5.0	4	2										
TOTAL	194	18	22	18	17	16	22	12	10	15	=	344
TOTAL/2	97	9	11	9	8.5	8	11	6	5	2.5		
MEDIAN Cu	0.44	0.75	0.75	0.23	0.21	0.25	0.48	0.46	0.75	0.60		

FREQUENCY DISTRIBUTION TABLE 31A

MINE: VERMILION LAKE MINE (Figure 45)

ORE TYPE: Mine ORE ZONE: #6 on 7th level

CLASS INTER-VAL.	FREQUENCY													
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)													
Au (OZ/T.)	0 – 0.4	0.4 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 10.0	10.0 – 12.0	>12.0 14.7		
0 .005	165	17	26	18	14	6	6	3	1					
005 .015	13	5	8	10	10	8		2	2	2		1		
015 .025	13	1	10	12	6	6	4	8	4	2	2	2		
025 .035	3	3		1	8	9	2	3	5	6	3	1		
035 .045	3	1		2	4	2	2	6	2	3	8			
045 .055	2	1		1	1		3			2	1	1		
055 .065							1	4	2	2	2	1		
065 .075						1		3		1	2	2		
075 .085								1		2	1			
085 .095	1			2							4	1		
095 .105		1	1					2				1		
105 .115				1							2	4		
TOTAL	200	29	45	47	43	32	18	32	16	20	25	13	=	520
TOTAL/2	100	14.5	22.5	23.5	21.5	16	9	16	8	10	12.5	6.5		
MEDIAN Au	.003	.004	.004	.011	.013	.018	.020	.035	.027	.035	.044	.067		

FREQUENCY DISTRIBUTION TABLE 32A

MINE: VERMILION LAKE MINE (Figure 46)

ORE TYPE: Mine ORE ZONE: #6 on 7th level

CLASS INTERVAL	FREQUENCY									
	ASSAY INTERVAL LEAD (WEIGHT PERCENT)									
Au (oz/T.)	0 0.5	0.5 1.0	1.0 1.5	1.5 2.0	2.0 2.5	2.5 3.0	3.0 4.0	4.0 (5.75) 7.0		
0 .005	378	14	6		2					
005 .015	36	12	8		2	3				
015 .025	38	9	13	3	3	1	2	1		
025 .035	10	7	2	5	3	3	5	2		
035 .045	4	1	7	1	1	3		2		
045 .055	1			2						
055 .065	1		3	3	1		1	1		
065 .075					2		3			
075 .085		4	1			1	2	1		
085 .095								2		
095 .105								1		
.105 .115								2		
>.115										
TOTAL	468	43	40	14	14	11	13	12	=	615
TOTAL/2	234	21.5	20	7	7	5.5	6.5	6		
MEDIAN Au	.003	.011	.020	.033	.025	.030	.034	.065		

V-66

FREQUENCY DISTRIBUTION TABLE 33A

MINE: VERMILION LAKE MINE (Figure 47)

ORE TYPE: Mine (levels7-9) ORE ZONE: Mine Randoms

FREQUENCY

ASSAY INTERVAL LEAD (WEIGHT %)

CLASS INTERVAL Au (oz/T.)	0 0.5	0.5 1.0	1.0 1.5	1.5 2.0	2.0 2.5	2.5 3.0	3.0 4.0	4.0 5.0	5.0 (5.7) 8.0		
0 .005	556	24	10	3	3	2					
005 .015	91	27	16	4	4	5	1	1	1		
015 .025	43	24	31	10	4	6	5	4	1		
025 .035	18	19	10	17	7	5	7	5	1		
035 .045	5	5	11	4	7	6	4	2			
045 .055	5	2	2	3	3	1	1	3			
055 .065	2	3	4	4	2	3	4	1	1		
065 .075		4	3	1	2		4				
075 .085		8	2			2	2	1			
085 .095			3		1	1		3			
095 .105				1		2	1		1		
105 .115									2		
115 .125							2				
>.125		2					1				
TOTAL	720	118	92	47	33	33	32	20	7	=	1102
TOTAL/2	360	59	46	23.5	16.5	16.5	16	10	3.5		
MEDIAN Au	.003	.018	.022	.029	.033	.032	.042	.035	.050		

1-39

FREQUENCY DISTRIBUTION TABLE 34A

MINE: VERMILION LAKE MINE (Figure 48)

ORE TYPE: Mine ORE ZONE: #6 on 7th level

CLASS INTER- VAL. Au *	FREQUENCY											
	ASSAY INTERVAL ZINC (ATOMIC PROPORTIONS)											
	0 .010	.010 .020	.020 .030	.030 .040	.040 .050	.050 .060	.060 .080	.080 .100	.100 .140	.140 .200	>.200 (.210)		
0 .0004	186	15	5	4	3	5	5	3					
0004 .0012													
0012 .0021	7	6	3	2	3	6	5	1	1	1	1		
0021 .0030			1		2			2	1				
0030 .0039			5	5		1	3	2	6	3			
0039 .0047		1					2			2			
0047 .0056	1					4	2	1	4	3	1		
0056 .0065									1	1			
0065 .0074	1	1				1			6	1			
0074 .0081													
0081 .0091													
0091 .0099											1		
0099 .0109								1	2	3			
0109 .0117										1			
0117 .0125								1		1			
0125 .0135										1			
>.0135	1				1				1	3	2		
TOTAL	196	23	14	11	9	17	17	11	22	20	5	=	426
TOTAL 2	98	11.5	7	5.5	4.5	8.5	8.5	5.5	11	10	2.5		
MEDIAN Au	.0002	.0003	.0015	.0017	.0013	.0014	.0016	.0028	.0052	.0065	.0076		

* UNITS = ATOMIC PROPORTIONS. X 10,000

V-40

FREQUENCY DISTRIBUTION TABLE 35A

MINE: VERMILION LAKE MINE (Figure 49)

ORE TYPE: Mine ORE ZONE: #6 on 7th level

CLASS INTER-VAL.	FREQUENCY					
	ASSAY INTERVAL LEAD (ATOMIC PROPORTIONS)					
Au *	0 — .005	.005 — .010	.010 — .015	>.015 (020) .040		
0 .0004	223	5	1			
0004 .0012						
0012 .0021	26	8	4			
0021 .0030	4		1	1		
0030 .0039	13	8	3			
0039 .0047	1	2	1	1		
0047 .0056	8	2	3	3		
0056 .0065			1	1		
0065 .0074	3	6	1			
0074 .0081						
0081 .0091						
0091 .0099		1				
0099 .0109		3	1	2		
0109 .0117				1		
0117 .0125		1		1		
0125 .0134				1		
>.0134	3			5		
TOTAL	281	36	16	16	=	348
TOTAL/2	140.5	18	8	8		
MEDIAN Au	.0003	.0031	.0036	.0109		

* UNITS = ATOMIC PROPORTIONS X 10,000

U-37

FREQUENCY DISTRIBUTION TABLE 36A

MINE: VERMILION LAKE MINE (Figure 50)

ORE TYPE: Mine ORE ZONE: #4 on 9th level

CLASS INTERVAL. Au *	FREQUENCY ASSAY INTERVAL. ZINC (ATOMIC PROPORTIONS)																	
	0 – .010	.010 – .020	.020 – .030	.030 – .040	.040 – .050	.050 – .060	.060 – .070	.070 – .080	.080 – .090	.090 – .100	.100 – .120	.120 – .140	.140 – .160	.160 – .180	.180 – .200	.200 (.230) .260		
0 .0004	11	9	5	2	2	1		1	1	1	1							
0004 .0012																		
0012 .0021	11	7	4	8	7	4	3	2								1		
0021 .0030	1	1	1	3		2	1	1		1	4							
0030 .0039		1	3	3		2	3	3	3	1	3							
0039 .0047				1	2	1				2								
0047 .0056		2		1	1	1	1	1	1	1	3	1	2	1				
0056 .0065								1			1				1			
0065 .0074						1		3	1	1	1		3	1				
0074 .0081						1	1											
0081 .0091						1					1				1			
0091 .0099										1								
0099 .0109					1	1					1	1	1			1		
0109 .0117										1								
0117 .0125					1		1						1					
>.0125											3	1		2	1	2		
TOTAL	23	20	13	18	14	15	10	12	6	9	18	3	7	4	3	4	=	179
TOTAL/2	11.5	10	6.5	9	7	7.5	5	6	3	4.5	9	1.5	3.5	2	1.5	2		
MEDIAN Au	.0004	.0006	.0010	.0019	.0016	.0032	.0033	.0036	.0027	.0045	.0045	.0083	.0065	.0074	.0078	.0109		

* UNITS = ATOMIC PROPORTIONS. X 10,000

FREQUENCY DISTRIBUTION TABLE 37A

MINE: VERMILION LAKE MINE (Figure 51)

ORE TYPE: Mine ORE ZONE: #4 on 9th level

CLASS INTER-VAL- Au *	FREQUENCY ASSAY INTERVAL LEAD (ATOMIC PROPORTIONS)						
	0 — .005	.005 — .010	.010 — .015	.015 — .020	.020 (.026) .040		
0 .0004	149	4	4				
0004 .0012							
0012 .0021	62	8	2		2		
0021 .0030	15	7	3	1			
0030 .0039	21	11	3	2	2		
0039 .0047	7	4	1	1	2		
0047 .0056	9	9	5		1		
0056 .0065	2	1	1	1			
0065 .0074	2	5	6	3			
0074 .0081	2		1	1	1		
0081 .0091			3		2		
0091 .0099		1		1			
0099 .0109	2	1	4	3	2		
0109 .0117			1				
0117 .0125	2	1		1			
0125 .0134							
0134 .0139							
0139 .0144	4	1	1		1		
>.0144		2	2	5	2		
TOTAL	277	55	37	19	15	=	402
TOTAL/2	138.5	27.5	18.5	9.5	7.5		
MEDIAN Au	.0004	.0037	.0061	.0090	.0064		

* UNITS = ATOMIC PROPORTIONS X10,000

FREQUENCY DISTRIBUTION TABLE 38A

MINE: VERMILION LAKE MINE (Figure 52)

ORE TYPE: Mine ORE ZONE: Randoms, 7-9th levels

CLASS INTER-VAL. Au *	FREQUENCY ASSAY INTERVAL LEAD (ATOMIC PROPORTIONS)					
	0 — .005	.005 — .010	.010 (.014) .020	.020 (026) .040		
0 .0004	372	9	5			
0004 .0012						
0012 .0021	88	16	6	2		
0021 .0030	19	7	5	1		
0030 .0039	34	19	7	1		
0039 .0047	8	6	4	2		
0047 .0056	17	11	9	2		
0056 .0065	2	1	2	1		
0065 .0074	5	11	10			
0074 .0081	2		1	1		
0081 .0091			3	1		
0091 .0099		2	1			
0099 .0109	2	4	8	2		
0109 .0117			2			
0117 .0125	2	2	2			
0125 .0134				1		
0134 .0144	4	1	1			
>.0144	3	2	9	4		
TOTAL	558	91	75	18	=	770
TOTAL/2	279	45.5	37.5	9		
MEDIAN Au	.0003	.0036	.0063	.0096		

* UNITS = ATOMIC PROPORTIONS. X 10,000

V-41

FREQUENCY DISTRIBUTION TABLE 39A

MINE: VERMILION LAKE MINE (Figure 52)

ORE TYPE: Mine ORE ZONE: Randoms, 7-9th levels

CLASS INTER-VAL Au *	FREQUENCY																
	ASSAY INTERVAL ZINC (ATOMIC PROPORTIONS)																
	0 – .01	.01 – .02	.02 – .03	.03 – .04	.04 – .05	.05 – .06	.06 – .07	.07 – .08	.08 – .09	.09 – .10	.10 – .12	.12 – .14	.14 – .16	.16 – .20	>.20 (.22)		
0 .0004	197	24	10	6	5	6	2	4	4	1	1						
0004 .0012																	
0012 .0021	18	13	7	10	10	10	5	5		1	1		1		2		
0021 .0030	1	1	2	3	2	2	1	1	1	2	5						
0030 0039		1	8	8		3	6	3	4	2	9		1	2			
0039 .0047		1		1	2	1	2			2			1	1			
0047 .0056	1	2		1	1	5	2	2	1	2	6	2	3	3	1		
0056 .0065								1			1	1	1	2			
0065 .0074	1	1				2		3	1	1	7		3	1			
0074 .0081						1	1										
0081 .0091						1					1			1			
0091 .0099										1					1		
0099 .0109					1	1				1	3	1	3	1	1		
0109 .0117										2				1			
0117 .0125					1		1						2				
0125 .0134												1					
0134 .0149														3			
0149 .0160	1				1									2	4		
>.0160											4			2			
TOTAL	229	43	27	29	23	32	20	19	11	15	38	5	15	19	9	=	534
TOTAL/2	114.5	21.5	13.5	14.5	11.5	16	10	9.5	5.5	7.5	19	2.5	7.5	9.5	4.5		
MEDIAN Au	.0002	.0004	.0013	.0018	.0015	.0021	.0033	.0026	.0031	.0045	.0047	.0060	.0067	.0083	.0104		

* UNITS = ATOMIC PROPORTIONS. X 10,000

FREQUENCY DISTRIBUTION TABLE 40A

MINE: VERMILION LAKE MINE (Figure 53)

ORE TYPE: Mine ORE ZONE: Randoms, 7 and 9th levels

CLASS INTER- VAL.	FREQUENCY														
	ASSAY INTERVAL ZINC (ATOMIC PROPORTIONS)														
Pb *	0 – .01	.01 – .02	.02 – .03	.03 – .04	.04 – .05	.05 – .06	.06 – .08	.08 – .10	.10 – .12	.12 – .14	.14 – .16	.16 – .20	.20 – .24		
0 .0025	229	52	29	23	7	11	8	3	1		1				
0025 .0050		3	9	10	14	14	16	9	5	2		2			
0050 .0075	1		1	2	4	11	17	11	15	1					
0075 .010		2			2		7	9	10	1	1				
010 .015		2		2	1	3		8	6	7	7	11			
015 .020						1			4	3	6	6	5		
.020 .030						1			2	3	2	5	2		
>.030									1				2		
TOTAL	230	59	39	37	28	41	48	40	44	17	17	24	9	=	633
TOTAL / 2	115	29.5	19.5	18.5	14	20.5	24	20	22	8.5	8.5	12	4.5		
MEDIAN Pb	.0006	.0014	.0017	.0020	.0037	.0042	.0050	.0068	.0078	.0132	.0146	.0145	.0195		

* UNITS = ATOMIC PROPORTIONS.

FREQUENCY DISTRIBUTION TABLE 41A

MINE: GECO MINE (Figure 56)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY										
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)										
Ag (OZ/T.)	0 1.0	1.0 2.0	2.0 3.0	3.0 4.0	4.0 5.0	5.0 6.0	6.0 8.0	8.0 10.0	10.0 (12.0) 16.0		
0 0.5	10	1									
0.5 1.0	32	4	1	2							
1.0 1.5	21	11	5		1						
1.5 2.0	13	13	6	1							
2.0 2.5	7	9	8	5	1						
2.5 3.0	1	6	7	2	1						
3.0 4.0	4	2	4	8	9	2					
4.0 5.0	2		5	1	2	3	3	1			
5.0 6.0			2	1			4	4			
6.0 7.0	1		1		1				1		
7.0 8.0				1		1		1	3		
8.0 9.0									1		
9.0 10.0									1		
>10.0	2			1		1	1		1		
TOTAL	93	46	39	22	15	7	8	6	7	=	243
TOTAL/2	46.5	23	19.5	11	7.5	3.5	4	3	3.5		
MEDIAN Ag	1.11	1.77	2.47	3.12	3.50	4.50	5.25	5.50	7.80		

FREQUENCY DISTRIBUTION TABLE 42A

MINE: GECO MINE (Figure57)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTERVAL Ag (oz/T.)	FREQUENCY ASSAY INTERVAL ZINC (WEIGHT PERCENT)															
	0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 8.0	8.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 – 20.0	>20.0 (22.6)		
0 – 0.5	2		3			1	1		1				1	2		
0.5 – 1.0	3	3		1	4	3	5	4	2	2	3	3	1	5		
1.0 – 1.5	1		1	6		3	5	3	3	4	2		3	6		
1.5 – 2.0		1		3	1	3	5	3	2	2	5	2	4	3		
2.0 – 2.5		1	2	1	3	5	4	2	4	2		2	2	2		
2.5 – 3.0		1	1			1	1	3	1	3	1	3	1	1		
3.0 – 4.0		1	3		2	1	3	5	4	2	2	5	1			
4.0 – 5.0			1	2		3	3	4		1	1	1				
5.0 – 6.0			2				3	2	1		1	1	1			
6.0 – 7.0					1			1	1	1						
7.0 – 8.0				2	1		2					1				
8.0 – 9.0						1										
>9.0	1		1				1	2	1				1			
TOTAL	7	7	14	15	12	20	33	29	20	17	15	18	15	19	=	241
TOTAL/2	3.5	3.5	7	7.5	6	10	16.5	14.5	10	8.5	7.5	9	7.5	9.5		
MEDIAN Ag	.75	1.50	3.00	1.58	2.16	2.00	2.06	2.92	2.25	2.12	1.75	2.83	1.81	1.21		

0.54

FREQUENCY DISTRIBUTION TABLE 43A

MINE: GECO MINE (Figure 58)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY							
	ASSAY INTERVAL SILVER (OZ/TON)							
ZN (WT%)	0 (0.68) 1.0	1.0 (1.50) 2.0	2.0 (2.40) 3.0	3.0 (3.80) 4.0	5.0 – 6.0	>6.0 (9.60)		
0 0.5		1		2				
0.5 1.0	5					1		
1.0 2.0	3	1	2	1				
2.0 3.0	3	1	3	4	2	1		
3.0 4.0	1	9	1	2		2		
4.0 5.0	4	1	3	2		2		
5.0 6.0	4	6	6	4				
6.0 7.0	2	6	2	2	3	2		
7.0 8.0	4	4	3	4		2		
8.0 9.0	3	4	3	5	1	1		
9.0 10.0	1	2	2	4	1	2		
10.0 11.0	2	3	3	1				
11.0 12.0	1	2	2	3	1	2		
12.0 14.0	2	6	5	3		1		
14.0 16.0	3	7	1	3	1			
16.0 18.0	3	2	5	8	1	1		
18.0 20.0	2	7	3		1	1		
>20.0	7	9	3					
TOTAL	50	71	47	46	11	18	=	243
TOTAL / 2	25	35.5	23.5	23	5.5	9		
MEDIAN ZN	7.75	10.16	9.25	8.40	8.00	7.50		

FREQUENCY DISTRIBUTION TABLE 44A

MINE: GECO MINE (Figure 59)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTERVAL Cu+Zn (wt%)	FREQUENCY ASSAY INTERVAL SILVER (oz/ton)						
	0 – 1.0	1.0 – 2.0	2.0 (2.80) 4.0	4.0 (4.80) 6.0	>6.0 (10.0)		
0 1.0	1						
1.0 2.0	4		1		1		
2.0 3.0	5	1	2				
3.0 4.0	1	4					
4.0 5.0		5	1				
5.0 6.0	5	2	5				
6.0 7.0	4	6	6		1		
7.0 8.0	3	6	4	2			
8.0 9.0	5	4	3	3	1		
9.0 10.0	1		5	2	1		
10.0 11.0	2	7	5	2			
11.0 12.0	1	3	3	4	1		
12.0 14.0		7	6	2	3		
14.0 16.0	4	2	13	3	1		
16.0 18.0	4	5	5	3	5		
18.0 20.0	3	6	7	4	2		
>20.0	7	13	10	3	2		
TOTAL	50	71	76	28	18	=	242
TOTAL/2	25	35.5	38	14	9		
MEDIAN Cu+Zn	8.40	11.16	13.00	13.00	16.00		

FREQUENCY DISTRIBUTION TABLE 45A

MINE: GECO MINE (Figures 60 &61)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY									
	ASSAY INTERVAL SILVER (OZ/TON)									
Cu (WT %)	0 — 0.5	0.5 — 1.0	1.0 — 1.5	1.5 — 2.0	2.0 — 2.5	2.5 (3.30) 4.0	4.0 (4.83) 6.0	6.0 — 8.0	8.0 (10.0) 11.0		
0 0.5	9	17	9	5	2	1	2	1	1		
0.5 1.0	1	15	11	8	5	4			1		
1.0 2.0	1	4	12	14	9	8					
2.0 3.0		1	4	6	8	11	7	1			
3.0 4.0		2		1	5	10	2	1	1		
4.0 5.0			1		1	10	2	1			
5.0 6.0						2	3	1	1		
6.0 7.0							4		1		
7.0 8.0							3	1			
8.0 9.0							2	4			
9.0 10.0							3		3		
10.0 11.0											
11.0 12.0											
12.0 14.0											
14.0 16.0											
TOTAL	11	39	37	34	30	46	28	10	8	=	235
TOTAL / 2	5.5	19.5	18.5	17	15	23	14	5	4		
MEDIAN Cu	0.31	0.58	0.93	1.29	1.67	2.92	5.33	6.00	6.00		

FREQUENCY DISTRIBUTION TABLE 46A

MINE: GECO MINE (Figures 62 & 63)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTER-VAL Ag (oz/T.)	FREQUENCY																
	ASSAY INTERVAL COPPER + ZINC (WEIGHT PERCENT)																
	0 (1.40) 2.0	2.0 3.0	3.0 4.0	4.0 5.0	5.0 6.0	6.0 7.0	7.0 8.0	8.0 9.0	9.0 (10.2) 11.0	11.0 12.0	12.0 14.0	14.0 16.0	16.0 18.0	18.0 20.0	>20.0 (23.2)		
0 1.0	5	5	1		5	4	3	5	3	1		4	4	3	7		
1.0 2.0		1	4	5	2	6	6	4	7	3	7	2	5	6	13		
2.0 3.0		2		1	3	6	3	1	6	3	3	6	2	4	7		
3.0 4.0	1				2		1	2	4		3	7	3	3	3		
4.0 5.0							2	3	2	2	2	2	2	1	1		
5.0 6.0									2	2		1	1	3	2		
6.0 8.0						1		1		1	1		3	2	1		
8.0 10.0													1		1		
>10.0									1		2	1	1				
TOTAL	6	8	5	6	12	17	15	16	25	12	18	23	22	22	35	=	242
TOTAL / 2	3	4	2.5	3	6	8.5	7.5	8	12.5	6	9	11.5	11	11	17.5		
MEDIAN Ag	0.60	0.80	1.38	1.60	1.50	1.75	1.75	1.75	2.42	2.66	2.66	2.92	3.00	2.50	1.62		

V-27

FREQUENCY DISTRIBUTION TABLE 47A

MINE: GECO MINE (Figure 64)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTERVAL.	FREQUENCY									
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)									
ZN (WT %)	0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 (6.00) 8.0	8.0 – 10.0	>10.0 (12.0)		
0 1.0	5	2								
1.0 2.0	6		1							
2.0 3.0	4		1	3	2	1	1	1		
3.0 4.0	2	6	1	3	1	1				
4.0 5.0	5	3			2	1		1		
5.0 6.0	9	3	4		2	1	1	2		
6.0 8.0	13	4	7	3	1	3	2	1		
8.0 10.0	7	5	6	4	3	2	1	1		
10.0 12.0	5	4	5	2	2	2				
12.0 14.0	5	2	6	3	1					
14.0 16.0	8	3	1	2		1				
16.0 18.0	5	4	7		1	1	1			
18.0 20.0	5	6	2			1				
>20.0	13	5		1						
TOTAL	92	47	41	21	15	14.	6	6	=	244
TOTAL / 2	46	23.5	20.5	10.5	7.5	7	3	3		
MEDIAN ZN	8.57	10.25	10.20	8.75	7.00	8.00	7.00	5.50		

V-30

FREQUENCY DISTRIBUTION TABLE 48A

MINE: GECO MINE (Figure 65)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

CLASS INTER-VAL·	FREQUENCY											
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)											
ZN (WT%)	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	20 – 2.5	2.5 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 (7.73) 10.0		
0 – 0.5	376	154	100	77	48	28	27	14	6	8		
0.5 – 1.0	67	30	28	15	10	5	23	7	3	5		
1.0 – 1.5	26	8	15	6	3	3	7	3	4	5		
1.5 – 2.0	9	3	2	3	1		4	1	3	2		
2.0 – 2.5	4		1			1	1		3	5		
2.5 – 3.0			3		4				2	1		
3.0 – 4.0		3		1	1		1	3				
4.0 – 5.0	1		1			1	1		1			
5.0 – 6.0		3					1	1				
6.0 – 8.0		2		1								
8.0 – 10.0		1			1							
TOTAL	483	204	150	103	68	38	65	29	22	26	=	1188
TOTAL / 2	241.5	102	75	51.5	34	19	32.5	14.5	11	13		
MEDIAN ZN	0.32	0.33	0.37	0.33	0.35	0.34	0.62	0.54	1.25	1.00		

FREQUENCY DISTRIBUTION TABLE 49A

MINE: GECO MINE (Figures 66 & 67)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY								
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)								
Ag (oz/T.)	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 (2.40) 3.0	3.0 (3.73) 5.0	5.0 (6.0) 10.0		
0 0.5	707	130	45	11	5	5	1		
0.5 1.0	71	24	12	5	7	1	1		
1.0 1.5	26	16	8	1	3	4	1		
1.5 2.0	12	12	1	1	1	1			
2.0 2.5	8	7	1	3	2		1		
2.5 3.0	7	4	5	3					
3.0 4.0	9	5	4	1	3	2	1		
4.0 5.0	1	4	5	3	3	3			
5.0 6.0	1	2	2	2					
6.0 7.0		1		1	2				
7.0 8.0	1	1			1				
8.0 9.0	1		1						
9.0 10.0		1							
TOTAL	844	207	84	31	27	16	5	=	1219
TOTAL/2	422	103.5	42	15.5	13.5	8	2.5		
MEDIAN Ag	0.30	0.40	0.47	0.95	1.25	1.25	1.33		

FREQUENCY DISTRIBUTION TABLE 50A

MINE: GECO MINE (Figure 68, 69, & 70)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

CLASS INTER-VAL. Ag (oz/T.)	FREQUENCY										
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)										
	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	3.0 – 4.0	4.0 (4.85) 6.0	6.0 (7.66) 10.0		
0 0.5	579	171	95	55	18	8	10	1	1		
0.5 1.0	22	22	26	23	23	13	11	6	1		
1.0 1.5	6	8	19	11	14	7	7	6	1		
1.5 2.0			2	8	7	7	7	4	3		
2.0 2.5	1			1	2	2	16	2	2		
2.5 3.0		1				2	8	3	1		
3.0 4.0	2	1	3	1			4	14	5		
4.0 5.0	2	2	1			1	1	10	4		
5.0 6.0				1	1			2	3		
6.0 7.0	1			1					2		
7.0 8.0								1	2		
8.0 9.0	1						1				
9.0 10.0							1				
TOTAL	614	205	146	101	65	40	66	49	25	=	1311
TOTAL/2	307	102.5	73	50.5	32.5	20	33	24.5	12.5		
MEDIAN Ag	.27	.36	.39	.46	.81	.96	1.86	3.18	3.70		

FREQUENCY DISTRIBUTION TABLE 51A

MINE: GECO MINE (Figure 71)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

CLASS INTERVAL Ag (oz/T.)	FREQUENCY									
	ASSAY INTERVAL COPPER + ZINC (WEIGHT PERCENT)									
	0 - 0.5	0.5 — 1.0	1.0 — 2.0	2.0 — 3.0	3.0 — 4.0	4.0 (4.70) 6.0	6.0 (7.60) 10.0	10.0 — 12.0		
0 0.5	210	211	195	58	14	6	1	1		
0.5 1.0	1	20	47	33	18	16	5			
1.0 1.5		3	17	21	14	6	4	2		
1.5 2.0			4	17	8	5	4			
2.0 2.5	1			4	5	10	3	1		
2.5 3.0				2	5	10	3			
3.0 4.0			3		4	7	15			
4.0 5.0			1	1		4	13			
5.0 6.0					2		4	1		
6.0 7.0		1			1			2		
7.0 8.0						1	1	1		
8.0 9.0						1				
9.0 10.0						1				
TOTAL	212	235	267	136	71	67	53	8	=	1049
TOTAL / 2	106	117.5	133.5	68	35.5	33.5	26.5	4		
MEDIAN Ag	0.25	0.28	0.34	0.65	1.13	2.03	3.43	3.75		

FREQUENCY DISTRIBUTION TABLE 52A

MINE: GECO MINE (Figure 72)

ORE TYPE: Combined Types ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY									
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)									
Ag (oz/T.)	0 — 1.0	1.0 — 2.0	2.0 — 3.0	3.0 — 4.0	4.0 — 5.0	5.0 — 6.0	6.0 (7.3) 10.0	10.0 (12.0) 16.0		
0 0.5	760	151	26	10	1		1			
0.5 1.0	76	53	37	13	6		1			
1.0 1.5	35	41	26	7	4	3	1			
1.5 2.0	13	23	20	8	4		3			
2.0 2.5	8	10	12	21	3		2			
2.5 3.0	2	6	9	10	3	1	1			
3.0 4.0	7	6	4	12	18	7	5			
4.0 5.0	6	1	6	2	3	12	8			
5.0 6.0		1	3	1		2	11			
6.0 7.0	2	1	1		1		2	1		
7.0 8.0				1		1	3	3		
8.0 9.0	1				1			1		
9.0 10.0				1				1		
>10.0	2			2		1	1	1		
TOTAL	912	293	144	88	44	27	33	7	=	1554
TOTAL / 2	456	146.5	72	44	22	13.5	16.5	3.5		
MEDIAN Ag	0.30	0.48	1.17	2.14	3.05	4.21	4.31	7.83		

FREQUENCY DISTRIBUTION TABLE 53A

MINE: GECO MINE (Figure 73)

ORE TYPE: Combined Types ORE ZONE: Mine Randoms

CLASS INTERVAL Au (oz/T.)	FREQUENCY ASSAY INTERVAL ZINC (WEIGHT PERCENT) 0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 8.0	8.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 – 20.0	20.0 (22.6) 35.0		
0 – 0.5	839	56	8	3	2	1	1	1	1				1	2		
0.5 – 1.0	98	20	7	2	4	4	6	4	2	2	3	3	1	5		
1.0 – 1.5	43	24	4	10		5	5	4	3	4	2		3	6		
1.5 – 2.0	12	14	1	4	1	4	5	3	2	2	5	2	4	3		
2.0 – 2.5	8	9	4	1	3	6	5	2	4	2		2	2	2		
2.5 – 3.0	7	10	1			1	1	3	1	3	1	3	1	1		
3.0 – 4.0	9	10	6	1	3	1	4	5	4	2	2	5	1			
4.0 – 5.0	1	4	4	3	2	3	3	4		1	1	1				
5.0 – 6.0	1	2	2				3	2	1		1	1	1			
6.0 – 7.0		1	2					1	1	1						
7.0 – 8.0	1	1	1	2	1		2					1				
8.0 – 9.0	1				1											
9.0 – 10.0		1				1							1			
>10.0	1		1				1	2	1							
TOTAL	1058	122	41	26	17	25	36	29	20	17	15	8	15	19	=	1460
TOTAL/2	529	61	20.5	13	8.5	12.5	18	14.5	10	8.5	7.5	4	7.5	9.5		
MEDIAN Au	0.31	0.62	2.00	1.40	2.25	1.81	2.10	2.52	2.25	2.12	1.75	2.83	1.81	1.21		

FREQUENCY DISTRIBUTION TABLE 54A

MINE: GECO MINE (Figure 74)
ORE TYPE: Combined types ORE ZONE: Mine Randoms

CLASS INTERVAL.	FREQUENCY										
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)										
ZN (WT%)	0 1.0	1.0 2.0	2.0 3.0	3.0 4.0	4.0 5.0	5.0 6.0	6.0 8.0	8.0 10.0	10.0 (13.0) 20.0		
0 1.0	632	222	91	50	21	9	7	6			
1.0 2.0	51	26	8	11	4	7	5	2			
2.0 3.0	8	4	6	4	2	6	3	4	1		
3.0 4.0	2	7	2	4	4	1			1		
4.0 5.0	6	4	1	1	2	2			1		
5.0 6.0	9	3	4	1	3		1	1	2		
6.0 8.0	13	5	7	3	1	3		2	1		
8.0 10.0	7	5	7	4	3	1	1	1	1		
10.0 12.0	5	4	5	2	2		2				
12.0 14.0	5	2	6	3	1						
14.0 16.0	8	3	1	2			1				
16.0 18.0	5	4	7		1		1	1			
18.0 20.0	5	6	2				1		1		
20.0 35.0	13	5		1							
TOTAL	779	300	147	86	44	29	22	17	7	=	1432
TOTAL/2	389.5	150	73.5	43	22	14.5	11	8.5	3.5		
MEDIAN ZN	0.62	0.67	0.81	0.87	1.25	1.78	1.80	2.12	5.50		

FREQUENCY DISTRIBUTION TABLE 55A

MINE: FLIN FLON MINE (Figure 76)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTERVAL Ag (oz/T.)	FREQUENCY																		
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)																		
	0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 – 20.0	20.0 22.0		
0 0.5	161	94	101	31	19	14	5	3	2	3	2	3	2						
0.5 1.0	55	55	114	66	46	41	26	22	8	6	5	3	3	1	1				
1.0 1.5	28	30	66	39	43	29	26	27	12	16	11	13	15	6	3	2	1		
1.5 2.0	19	21	51	44	26	16	14	12	7	6	11	13	12	6	8	5	4		
2.0 2.5	15	8	31	16	9	9	12	6	3	3	4	3	7	1	11	1	4		
2.5 3.0	5	7	26	18	6	6	6	5		4	2	2	1	3	1	3	2		
3.0 4.0	5	4	30	24	24	9	9	4	6	4	3	6	2	4	2	1			
4.0 5.0	2		8	20	10	4	10	2	2	6	1	1	1	2	1				
5.0 6.0	2	1	2	5	1	2	1		1	5	1	1							
6.0 7.0						5		2			2								
7.0 8.0					2			2	1		1			1					
>8.0			3		1				1		3	1	1						
TOTAL	292	220	432	263	187	135	109	85	43	53	46	46	44	24	27	12	11	=	2029
TOTAL/2	146	110	216	131.5	93.5	67.5	54.5	42.5	21.5	26.5	23	23	22	12	13.5	6	5.5		
MEDIAN Ag	0.45	0.65	1.01	1.44	1.33	1.22	1.45	1.32	1.48	1.63	1.73	1.65	1.58	1.92	2.07	1.90	2.06		

FREQUENCY DISTRIBUTION TABLE 56A

MINE: FLIN FLON MINE (Figure 77)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTERVAL	FREQUENCY																		
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)																		
Ag (oz/T.)	0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 – 20.0	20.0 – 21.0		
0 0.5	193	44	51	28	17	6	12	7	4	4	4	13	1	2	5		1		
0.5 1.0	35	20	43	38	37	20	15	35	17	14	23	21	12	7	15	6	1		
1.0 1.5	22	8	13	26	21	24	20	18	17	14	7	20	17	18	7	2	2		
1.5 2.0	8	1	12	9	23	15	16	24	9	10	14	21	17	13	12	4	2		
2.0 2.5	1	2	1	6	9	12	16	9	6	9	5	10	8	4	3		1		
2.5 3.0	1	2		1	3	9	11	7	8	3	4	7	13	1	7		2		
3.0 4.0			3	1	4	7	12	13	14	6	4	13	18	4	7	2			
4.0 5.0					5		2	9	11	4	1	4	8	11	1	1	2		
5.0 6.0								2	2	3	1	6	2	3	1				
6.0 7.0								1		2	4		1						
7.0 8.0										2	2	1							
>8.0			1					3				4	1	1					
TOTAL	260	77	124	109	119	93	104	128	88	71	69	120	98	64	58	15	11	=	1608
TOTAL/2	130	38.5	62	54.5	59.5	46.5	52	64	44	35.5	34.5	60	49	32	29	7.5	5.5		
MEDIAN Ag	0.39	0.66	0.63	0.85	1.13	1.43	1.66	1.58	1.78	1.68	1.52	1.64	2.12	1.69	1.58	1.38	1.88		

FREQUENCY DISTRIBUTION TABLE 57A

MINE: FLIN FLON MINE (Figure 78)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTERVAL	FREQUENCY															
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)															
Au (oz/T.)	0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 (21.5) 25.0		
0 .01	101	32	9	9	6	1					1			1		
01 .02	51	35	18	12	7	3				2						
02 .03	50	38	22	19	9	2	4	2		2	2		1	1		
03 .04	22	23	10	4	1	4			2	1		1	1			
04 .05	23	29	19	12	8	4	3	2	2	3	3	2	2	2		
05 .06	11	14	6	7						3	4		1			
06 .07	22	25	18	12	7	6	2	2	2	5	5	2	1	7		
07 .08	9	9	3	4	2	2			2	1	2			2		
08 .09	16	28	18	12	11	5	3	1	2	7	4	1	1	1		
09 .10	5	5	7	5	1	1		1	3	1						
10 .12	20	25	17	8	9	1	8	3	3	2	2	4	5	4		
12 .14	9	12	16	12	3	6	7	5	6	4	1		5	5		
14 .16	5	15	7	9	2	5	1	2	2	3	5	1	2	1		
16 .18	10	12	8	3		2	2	1	4	1	2			3		
18 .20	6	11	2	1	5	3	2		3	2	1	3	1	3		
20 .24	9	9	5	5	4	2	4	3	5	3	3	2		4		
24 .28		3	10	3	1	5	2	1	4	1	5	4	1	3		
28 .36	3	6	5	3	5	2	4	2	4	3	1		4	1		
36 .44			1			2	2	1				1				
44 .50			3	2	1						1		1			
>.50	1	3	1	1	3	1	1	1	4	3	2	2	2			
TOTAL	373	334	205	143	85	57	45	27	48	47	44	23	28	38	=	1497
TOTAL / 2	186.5	167	102.5	71.5	42.5	28.5	22.5	13.5	24	23.5	22	11.5	14	19		
MEDIAN Au	.027	.057	.071	.067	.082	.110	.127	.130	.160	.084	.105	.166	.128	.124		
									.129							

V-20

FREQUENCY DISTRIBUTION TABLE 58A

MINE: FLIN FLON MINE (Figure 79)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTER-VAL. Au (oz/T.)	FREQUENCY																		
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)																		
	0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 – 20.0	20.0 – 24.0	24.0 – 28.0		
0 .01	99	13	4	1		2	4												
01 .02	57	13	4	3	2		1	2		3	1					1	1		
02 .03	32	23	12	9	5	3	4	1		2			1		1	2			
03 .04	12	2	4	6	6	6	1		3	4	2			1	3	2	1		
04 .05	20	5	5	17	10	2	6	4	3	6	7	3	1	3		1	1		
05 .06	6	2	9	4	1	7	1	2	1	2			1	2		1	1		
06 .07	24	9	6	5	4	3	5	5	4	9	1	2	5	4	3		2		
07 .08	6	3	2	5	3	4	3	2	2	1			2	3					
08 .09	11	6	7	3	5	8	6	9	4	13	3	6	1	1	1	4	5		
09 .10	1	2	2	1	5	2	2	2	1	1	2			1			1		
10 .12	17	4	4	9	13	7	7	4	6	7	1	4	3	5	2	2	2		
12 .14	9	1	2	4	11	7	12	8	5	4	5	7	5	4	1				
14 .16	4	4	2	6	1	10	10	6	4	2	5	1		3	1	1	2		
16 .18	2	1	2	5	5	8	5	3	8	1	2	3	4	3	1	5	2		
18 .20	3	4	6	1	3	1	6	4	2	2	6	3	2	2	1	2			
20 .24	3	1	1	2	2	11	7	7	3	4	9	3	4	1		2			
24 .28	5	1	3		1	2		6	6	7	6	5	4	1			1		
28 .32	2	2		1	1		4		2		2	2	4						
32 .36	2						3		1	1	1	2	2	1	1				
36 .40				1					2		1			2					
40 .50	1				3			1		2		2	1			1	1		
50 .60										1	4								
>.60		1		3		2				3	3	3				1			
TOTAL	316	97	75	86	81	85	87	66	57	75	61	46	40	37	15	25	20	=	1269
TOTAL/2	158	48.5	37.5	43	40.5	42.5	43.5	33	28.5	37.5	30.5	23	20	18.5	7.5	12.5	10		
MEDIAN Au	.021	.029	.059	.066	.099	.116	.126	.125	.138	.088	.185	.160	.150	.114	.080	.112	.080		
										.127									

FREQUENCY DISTRIBUTION TABLE 59A

MINE: FLIN FLON MINE (Figure 80)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY																			
	ASSAY INTERVAL COPPER + ZINC (WEIGHT PERCENT)																			
Ag (oz/T.)	0 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 – 20.0	20.0 – 22.0	22.0 – 24.0		
0 0.5	42	46	86	52	33	18	19	9	3	9	9	14	5	1	7	3	1	1		
0.5 1.0	2	5	34	35	34	38	36	25	28	26	29	53	23	14	11	10	7	1		
1.0 1.5	2	2	4	4	14	23	29	27	27	25	17	51	27	29	17	8	6	3		
1.5 2.0	2		3	4	9	17	9	18	15	14	12	25	35	29	31	13	10	6		
2.0 3.0		1	1	4	1	10	15	16	19	8	8	24	20	27	22	16	6	11		
3.0 4.0					1	3	4	6	8	16	14	9	9	15	11	12	8	6		
4.0 5.0							1	2	4	3	12	7	5	6	8	9	2	2		
5.0 6.0									1	2		7	1	3		4	3	1		
6.0 7.0													3	3		1				
7.0 8.0													2	2		1	1			
>8.0										1	2		2	1			1			
TOTAL	48	54	128	99	92	109	113	103	105	104	104	190	132	130	109	77	45	31	=	1773
TOTAL/2	24	27	64	48.5	46	54.5	56.5	51.5	52.5	52	52	95	66	65	54.5	38.5	22.5	15.5		
MEDIAN Ag	0.29	0.29	0.37	0.47	0.69	0.98	1.03	1.32	1.40	1.34	1.41	1.28	1.66	1.86	1.81	2.28	1.93	2.41		

FREQUENCY DISTRIBUTION TABLE 60A

MINE: FLIN FLON MINE (Figure 81)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY																		
	ASSAY INTERVAL COPPER + ZINC (WEIGHT PERCENT)																		
Au (oz/T.)	0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 – 20.0	20.0 – 22.0	22.0 – 24.0		
0 .01	79	38	16	10	5	6	3								1				
01 .02	36	20	17	12	8	7	3		1	1	2	1			1	1			
02 .03	20	25	32	19	20	10	8	7	8	4	3	1	1	1	1	2			
03 .04	7	4	8	9	7	10	3	6	3	4	6	1	1		3	2	1		
04 .05	4	6	11	10	26	12	8	4	3	6	8	9	2	5		2	1		
05 .06	1	2	3	1	3	4	7	4	1	1	2	1	3	1			2		
06 .07	1	7	5	12	9	16	5	10	6	7	11	9	6	8	8	5	2		
07 .08	2		2	2	4	5	3	1	2	2	5			4	2				
08 .09	2	2	5	8	9	12	5	11	10	8	18	14	5	5	2		7		
09 .10				1			5	8	5	5	7	3	1	1					
10 .12		1	5	4	10	6	13	8	9	8	8	9	12	10	5	6	6		
12 .14			1	1	4	3	9	6	13	8	15	4	12	6	4	4	3		
14 .16				3	4	2	8	6	5	6	10	8	3	4	2	2	2		
16 .18	1			1	3	2	4	5	4	4	4	2	7	7	8	3	5		
18 .20			3	1	1		3	3	2	1	5	5	5	8	3	2	2		
20 .24	1				1	5	1	5	2	3	7	6	13	5	3	3	3		
24 .28						1		2	1	5	7	6	6	7	7	3	4		
28 .32						2	5		1	1		3	2	2	6	3	2		
32 .36									2	1	1	2	2	4	2	1	2		
36 .40											1	1	1	1		1			
40 .50								2	1	4		3	1	1	3		4		
50 .60										2	2	1	1	1	1				
>.60								1	3		4	2		3	3	1	3		
TOTAL	154	105	108	94	114	103	93	89	81	81	126	91	84	84	65	41	49	=	1562
TOTAL/2	77	52.5	54	47	57	51.5	46.5	44.5	40.5	40.5	63	45.5	42	42	32.5	20.5	24.5		
MEDIAN Au	.009	.017	.027	.037	.047	.062	.093	.092	.103	.106	.103	.114	.138	.145	.169	.132	.162		
															.162	AT	21.0		

FREQUENCY DISTRIBUTION TABLE 61A

MINE: FLIN FLON MINE (Figure 83)

ORE TYPE: Massive ORE ZONE: Mine Randoms

FREQUENCY

Ratio Cu/Cu+Zn (Weight %)

CLASS INTERVAL Au (oz/T.)	0 — .10	.10 — .20	.20 — .30	.30 — .40	.40 — .50	.50 — .60	.60 — .80	.80 — .99	1.00		
0 .005	1	1	2			3	4	3	24		
005 .015	4	3	4	2	2	2	15	13	23		
015 .025	6	3		3	6	3	6	9	8		
025 .035	4	5	3	3	2		5	6	7		
035 .045	9	7	2	5	4	3	2	6	5		
045 .055	5	2	3	2	3	1	1	9	1		
055 .065	5	3	3	2	2	7	8	6	6		
065 .075	1	2	4	3	1	2	3	5	1		
075 .085	2	4	4	9	3	4	6	8	3		
085 .095		1		1	1	1	4		1		
095 .105		3	2	5	2	2	3	7	3		
.105 .115	2	1	1	1	3	1	1	2	1		
115 .125	2		2	2		4	4	4	2		
>.125	11	16	19	17	17	14	25	29	8		
TOTAL	52	51	49	55	46	47	88	107	93	=	588
TOTAL/2	26	25.5	24.5	27.5	23	23.5	44	53.5	46.5		
MEDIAN Au	.049	.072	.084	.083	.085	.081	.066	.068	.015		

FREQUENCY DISTRIBUTION TABLE 62A

MINE: FLIN FLON MINE (Figure 84)

ORE TYPE: Massive ORE ZONE: Mine Randoms

CLASS INTERVAL. ZN (WT%)	FREQUENCY ASSAY INTERVAL COPPER (WEIGHT PERCENT)														
	0 1.0	1.0 2.0	2.0 3.0	3.0 4.0	4.0 5.0	5.0 6.0	6.0 7.0	7.0 8.0	8.0 9.0	9.0 10.0	10.0 12.0	12.0 14.0	>14.0 (15.0)		
0 1.0	68	40	20	11	7	6	4	4	1	3	5	7	20		
1.0 2.0	22	20	11	10	7	5			3	2	4	1	5		
2.0 3.0	24	20	12	7	2	2	3	4	2	3		1	3		
3.0 4.0	20	27	14	6	5	6	1	1	4	1	1	2	8		
4.0 5.0	23	20	9	6	12	4	2	2	2	1	1				
5.0 6.0	21	29	15	3	3	4	1		1	1			1		
6.0 7.0	14	26	24	10	4	5	1	2		3	1				
7.0 8.0	19	18	16	10	5	2	1	1	2		1				
8.0 9.0	4	11	7	4		4	3	3	1	1					
9.0 10.0	7	9	6	4	1	1		1		1		2			
10.0 12.0	6	16	11	4	7	6	1	1	5	1	1				
12.0 14.0	7	10	13	12	4	5	4	1	1		1	1	1		
14.0 16.0	5	5	5	5		1	2	1	2			1			
16.0 18.0	4	7	3	2	1	3					1				
18.0 20.0	2	1	1	1		2					1				
>20.0	4	3	4	2		1					1				
TOTAL	250	262	171	97	58	57	23	21	24	17	18	15	38	=	1051
TOTAL/2	125	131	85.5	48.5	29	28.5	11.5	10.5	12	8.5	9	7.5	19		
MEDIAN ZN	3.55	4.20	6.10	6.55	4.67	6.30	6.50	4.75	5.00	3.50	2.00	1.50	1.00		

FREQUENCY DISTRIBUTION TABLE 63A

MINE: FLIN FLON MINE (Figure 86) (85)

ORE TYPE: Massive ORE ZONE: Mine Randoms

FREQUENCY

ASSAY INTERVAL SILVER (OZ/TON)

CLASS INTERVAL Au (oz/T.)	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	3.0 – 3.5	3.5 – 4.0	4.0 – 4.5	4.5 – 5.0	5.0 – 6.0	>6.0 (7.4)		
0 .01	123	7		1										
01 .02	70	17	2											
02 .03	56	64	10	1		1	1							
03 .04	10	20	12	4	1	1	1							
04 .05	11	27	22	11	3	4	2	1		1				
05 .06	6	4	9	3	3			1	1					
06 .07	7	25	21	11	10	4	1	4		1				
07 .08	2	5	5	4	3	4	2			1				
08 .09	2	27	17	18	12	7	4	6	1					
09 .10		8	10	4		3		1						
10 .12	2	4	23	16	13	12	5	7	5	3	1	2		
12 .14	1	6	8	19	15	10	6	10	8	1	2	2		
14 .16		4	4	20	14	5	6	4	1	1	1			
16 .18	1	1	2	8	9	14	10	2	6	4	7			
18 .20		3	2	4	6	5	7	8	4	2	2	3		
20 .25			4	5	17	10	15	12	9	8	8	2		
25 .30		1	2	4	6	7	2	7	8	6	2			
30 .40		1	1	2	3	5	8	7	6	2	3	2		
40 .50					2		2	1	4	2	1	3		
50 .60						3	2	3		1	2	2		
>.60			1		2	1	2	1		5	5	8		
TOTAL	291	224	155	135	119	96	77	75	53	38	34	24	=	1321
TOTAL/2	145.5	112	77.5	67.5	59.5	48	38.5	37.5	26.5	19	17	12		
MEDIAN Au														
0 – 2200'	.012	.041	.081	.113	.140	.127	.161	.150	.195	.224	.209	.420		
2700'-3500'	.017	.043	.065	.065	.120	.138	.166	.200	.239	.225	.200	.450		
MINE	.013	.041	.066	.113	.139	.148	.181	.184	.203	.203	.203 .225	.430		

FREQUENCY DISTRIBUTION TABLE 64A

MINE: FLIN FLON MINE (Figure 87)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

CLASS INTERVAL Au (oz/T.)	FREQUENCY ASSAY INTERVAL COPPER (WEIGHT PERCENT)											
	0 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 8.0	8.0 (9.12) 12.0		
0 .005	7	6	21	19	15	23	5	2	5			
005 .010			1	1	1		1					
010 .020	3	7	9	31	38	45	23	16	5	4		
020 .030	1	1	8	16	21	36	23	14	11	9		
030 .040	2	1	2	5	8	7	10	1	6	3		
040 .050			2	4	4	17	10	7	3	5		
050 .060	1				3	1	2	3	4	3		
060 .070			1	2	7	5	4	2	1	2		
070 .080			1			2			1			
080 .090			1	1	4	2		2	1			
090 .10							1	1		3		
10 .12			1	1		2	4	1		2		
12 .14						1		2				
14 .16					1	1	1		1			
16 .18			1			1						
18 .20												
20 .40							2	1				
40 .60							1					
>.60												
TOTAL	14	15	48	80	102	143	87	52	38	31	=	610
TOTAL / 2	7	7.5	24	40	51	71.5	43.5	26	19	15.5		
MEDIAN Au	.005	.008	.012	.016	.019	.021	.026	.026	.028	.038		

FREQUENCY DISTRIBUTION TABLE 65A

MINE: FLIN FLON MINE (Figure 88)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

CLASS INTERVAL Ag (oz/T.)	FREQUENCY ASSAY INTERVAL COPPER (WEIGHT PERCENT) 0 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 8.0	8.0 (10.0) 12.0		
0 – 0.5	13	14	38	54	79	78	38	15	16	6		
0.5 – 1.0	1	2	6	15	23	51	33	29	17	14		
1.0 – 1.5			3	3	4	4	10	7	5	7		
1.5 – 2.0				1	1	5	2	1	2			
2.0 – 2.5			1				1	1				
2.5 – 3.0						2			2	1		
3.0 – 4.0					2	1						
4.0 – 5.0												
5.0 – 6.0							2					
TOTAL	14	16	48	73	109	141	86	53	42	28	=	610
TOTAL / 2	7	8	24	36.5	54.5	70.5	43	26.5	21	14		
MEDIAN Ag	.27	.29	.32	.34	.35	.45	.58	.70	.65	.79		

U-24

FREQUENCY DISTRIBUTION TABLE 66A

MINE: FLIN FLON MINE (Figure 89)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

CLASS INTER-VAL	FREQUENCY						
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)						
A8 (oz/T.)	0 — 0.2	0.2 — 0.5	0.5 — 1.0	1.0 — 1.5	1.5 (1.85) 3.0		
0 .25	129	8	8	3	3		
.25 .50	145	40	15	6	1		
.50 .75	84	23	16	4	2		
.75 1.0	30	15	11	2	2		
1.0 1.5	25	7	8	1	2		
1.5 2.0	3	3	2	1	1		
2.0 2.5	2		1				
2.5 3.0	3	1			1		
3.0 4.0	2		1				
4.0 5.0							
5.0 6.0	2						
TOTAL	425	97	62	17	12	=	613
TOTAL/2	212.5	48.5	31	8.5	6		
MEDIAN A8	.39	.51	.62	.48	.75		

FREQUENCY DISTRIBUTION TABLE 67A

MINE: FLIN FLON MINE (Figure 90 & 93)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

CLASS INTER-VAL. Au (oz/T.)	FREQUENCY ASSAY INTERVAL SILVER (OZ/TON)								
	0 — .25	.25 — .50	.50 — .75	.75 — 1.0	1.0 — 1.5	1.5 — 2.0	2.0 (3.8) 6.0		
0 .01	80	13	10	2					
01 .02	60	84	20	5	1				
02 .03	4	49	51	13	8	1	1		
03 .04	1	14	14	7	6				
04 .05		14	16	8	7	2	3		
05 .06		5	2	6	4				
06 .07		3	8	4	5	3			
07 .08			2	1	1				
08 .09		2	1	2	2	2	2		
09 .10			1	3	1				
10 .12		1	2	1	1	1	4		
12 .14				1	2				
14 .16			1		2	1	1		
>.16				1	1		2		
TOTAL	145	185	128	54	41	10	13	=	576
TOTAL/2	72.5	92.5	64	27	20.5	5	6.5		
MEDIAN Au	.009	.019	.027	.040	.048	.063	.094		

FREQUENCY DISTRIBUTION TABLE 68A

MINE: FLIN FLON MINE (Figure 91)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

FREQUENCY

ASSAY INTERVAL ZINC (WEIGHT PERCENT)

CLASS INTERVAL Au (oz/T.)	0 0.1	0.1 0.3	0.3 0.5	0.5 0.7	0.7 1.0	1.0 1.5	1.5 (1.85) 3.3		
0 .005	73	8	11	3	3	2	1		
005 .015	115	26	14	5	5	4	1		
015 .025	76	25	14	11	5	4	3		
025 .035	37	10	6	6	4	2	1		
035 .045	32	11	6	1	3	1			
045 .055	6	2	2		3	1	2		
055 .065	14	6	3		1	1	1		
065 .075		1	2						
075 .085	6	2	1	1		1	1		
085 .095	1	2		1	1				
095 .105	5	1		1	1		1		
>.105	7	1		1	2	1	1		
TOTAL	372	95	56	30	28	17	12	=	610
TOTAL/2	186	47.5	28	15	14	8.5	6		
MEDIAN Au	.015	.020	.019	.021	.029	.021	.035		

FREQUENCY DISTRIBUTION TABLE 69A

MINE: FLIN FLON MINE (Figure 92)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY															
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)															
ZN (WT%)	0 – 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	>10.0 (10.5)		
0 – 0.3	5	6	10	38	65	78	105	72	38	18	13	8	9	7		
0.3 – 0.6	1	2	1	6	7	8	22	9	12	2	3	1				
0.6 – 1.0			1	3	5	8	10	7	1	4	1	1		1		
1.0 – 1.5				1	2	5	4	2	1		1			1		
1.5 – 2.0						4	1	2	2		1					
2.0 – 3.0									1							
3.0 – 4.0			1						1							
4.0 – 5.0																
5.0 – 6.0									1							
6.0 – 7.0																
7.0 – 8.0																
8.0 – 9.0																
9.0 – 10.0				1												
10.0 – 12.0					1											
12.0 – 14.0							1									
TOTAL	6	8	13	49	80	103	143	92	57	24	19	10	9	9	=	357
TOTAL/2	3	4	6.5	24.5	40	51.5	71.5	41	28.5	12	9.5	5	4.5	4.5		
MEDIAN ZN	0.18	0.20	0.195	0.193	0.185	0.198	0.204	0.171	0.225	0.20	0.22	0.19	0.15	0.19		

FREQUENCY DISTRIBUTION TABLE 70A

MINE: FLIN FLON MINE (Figure 94)

ORE TYPE: Disseminated ORE ZONE: Mine Randoms

FREQUENCY

Ratio Cu/Cu+Zn (Weight %)

CLASS INTER-VAL. Au (oz/T.)	.10 – .30		.50 – .60	.60 – .70	.70 – .80	.80 – .90	.90 – 1.0	1.00		
0 .005	1			2	2	2		17		
005 .015				2	5	4	4	37		
015 .025				1	3	8	15	24		
025 .035				2	2	1	7	15		
035 .045				1		1	1	9		
045 .055				3	1	2		1		
055 .065				1			1	5		
065 .075						1				
075 .085			1		1		1	1		
085 .095							2			
095 .105								1		
105 .125				2						
125 .155					1	1		2		
TOTAL	1		1	14	15	20	31	112	=	197
TOTAL/2				7	7.5	10	15.5	56		
MEDIAN Au	.005		.070	.025	.017	.020	023	.016		

FREQUENCY DISTRIBUTION TABLE 71A

MINE: FLIN FLON MINE (Figure 95)

ORE TYPE: Combined Types ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY														
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)														
Au (oz/T.)	0 1.0	1.0 2.0	2.0 3.0	3.0 4.0	4.0 5.0	5.0 6.0	6.0 8.0	8.0 10.0	10.0 12.0	12.0 14.0	14.0 16.0	16.0 18.0	18.0 (21.5) 25.0		
0 .01	108	60	45	32	12	3	5			1			1		
01 .02	54	51	87	57	30	19	5	2	4						
02 .03	51	47	59	55	32	16	17	7	4	2		1	1		
03 .04	24	26	23	11	11	5	6	5	1		1	1			
04 .05	23	31	27	29	18	11	8	7	3	3	2	2	2		
05 .06	12	14	9	8	2	3	4	3	4	4		1			
06 .07	22	26	27	17	11	8	5	4	6	5	2	1	7		
07 .08	9	10	3	6	2	2	1	2	1	2			2		
08 .09	16	28	23	14	11	7	5	2	7	4	1	1	1		
09 .10	5	6	7	5	2	2	1	6	1						
10 .12	20	25	18	10	13	2	11	5	3	2	4	5	4		
12 .14	9	12	16	13	3	8	12	6	4	1		5	5		
14 .16	5	16	8	10	3	5	4	2	3	5	1	2	1		
16 .18	10	12	8	4		2	3	4	1	2			3		
18 .20	6	11	2	1	5	3	2	3	2	1	3	1	3		
20 .24	9	9	5	5	4	2	7	5	3	3	2		4		
24 .28		3	10	3	2	6	3	4	1	5	4	1	3		
28 .36	3	6	5	3	5	2	6	4	3	1		4	1		
36 .44			1			2	3				1				
44 .50			3	2	2					1		1			
>.50	1	3	1	1	3	1	2	4	3	2	2	2			
TOTAL	387	397	296	286	172	109	100	72	54	44	23	28	38	=	2107
TOTAL/2	193	198	148	143	86	54	50	36	27	22	11.5	14	19		
MEDIAN Au	.026	.045	.023	.030	.040	.050	.070	.097	.086	.105	.166	.128	.124		

V-69

FREQUENCY DISTRIBUTION TABLE 72A

MINE: FLIN FLON MINE (Figure 96)

ORE TYPE: Combined Types ORE ZONE: Mine Randoms

CLASS INTERVAL.	FREQUENCY																		
	ASSAY INTERVAL ZINC (WEIGHT PERCENT)																		
Au (oz/T.)	0 1.0	1.0 2.0	2.0 3.0	3.0 4.0	4.0 5.0	5.0 6.0	6.0 7.0	7.0 8.0	8.0 9.0	9.0 10.0	10.0 12.0	12.0 14.0	14.0 16.0	16.0 18.0	18.0 20.0	20.0 24.0	24.0 28.0		
0 .01	278	17	6	1		2	4												
01 .02	203	17	6	3	2		1	2		3	1					1	1		
02 .03	129	26	14	9	5	3	4	1		2			1		1	2			
03 .04	70	4	4	6	6	6	1		3	4	2			1	3	2	1		
04 .05	53	6	6	17	10	2	6	4	3	6	7	3	1	3		1	1		
05 .06	28	3	10	4	1	7	1	2	1	2			1	2		1	1		
06 .07	40	9	7	5	4	3	5	5	4	9	1	2	5	4	3		2		
07 .08	13	4	2	5	3	4	3	2	2	1		1	2	3					
08 .09	16	6	8	3	5	8	6	9	4	13	3	6	1	1	1	4	5		
09 .10	5	2	3	1	5	2	2	2	1	1	2	1		1			1		
10 .12	26	4	4	9	13	7	7	4	6	7	1	4	3	5	2	2	2		
12 .14	15	2	3	4	11	7	12	8	5	4	5	8	5	4	1				
14 .16	4	4	2	6	1	10	10	6	4	2	5	1		3	1	1	2		
16 .18	2	1	2	5	5	8	5	3	8	1	2	3	4	3	1	5	2		
18 .20	3	4	6	1	3	1	6	4	2	2	6	3	2	2	1	2			
20 .24	3	1	1	2	2	11	7	7	3	4	9	3	4	1		2			
24 .28	5	1	3		1	2		6	6	7	6	5	4	1					
28 .32	2	2		1	1		4		2		2	2	4						
32 .36	2						3		1	1	1	2	2	1	1				
36 .40				1					2		1			2					
40 .50	1				3			1		2		2	1			1	1		
50 .60										1	4								
>.60		1		3		2				3	3	3				1			
TOTAL	897	114	87	86	81	85	87	66	57	75	61	49	40	37	15	25	20	=	1882
TOTAL/2	448.5	57	43.5	43	40.5	42.5	43.5	33	28.5	37.5	30.5	24.5	20	18.5	7.5	12.5	10		
MEDIAN Au	.018	.029	.057	.066	.099	.116	.126	.125	.138	.088	.185	.138	.150	.114	.080	.112	.086		
										.127									

U-17E

FREQUENCY DISTRIBUTION TABLE 73A

MINE: FLIN FLON MINE (Figure 97)

ORE TYPE: Combined Types ORE ZONE: Mine Randoms

CLASS INTER-VAL. Au (oz/T.)	FREQUENCY													
	ASSAY INTERVAL SILVER (oz/ton)													
	0 — 0.5	0.5 — 1.0	1.0 — 1.5	1.5 — 2.0	2.0 — 2.5	2.5 — 3.0	3.0 — 3.5	3.5 — 4.0	4.0 — 4.5	4.5 — 5.0	5.0 — 6.0	6.0 (7.4) 9.0		
0 .01	216	19		1										
01 .02	214	42	3											
02 .03	109	128	18	2	1	1	1							
03 .04	25	41	18	4	1	1	1							
04 .05	25	51	29	13	4	5	3	1		1				
05 .06	11	12	13	3	3			1	1					
06 .07	10	37	26	14	10	4	1	4		1				
07 .08	2	8	6	4	3	4	2			1				
08 .09	4	30	19	20	12	7	4	8	1					
09 .10		12	11	4		3		1						
10 .12	3	7	24	17	14	13	5	7	5	3	2	2		
12 .14	1	7	10	19	15	10	6	10	8	1	2	2		
14 .16		5	6	21	15	5	6	4	1	1	1			
16 .18	1	2	3	8	10	15	10	2	6	4	7			
18 .20		3	2	4	6	5	7	8	4	2	2	3		
20 .25			4	5	17	10	15	12	9	8	8	2		
25 .30		1	2	4	6	7	2	7	8	6	2			
30 .40		1	1	2	3	5	8	7	6	2	3	2		
40 .50					2		2	1	4	2	1	3		
50 .60						3	2	3		1	2	2		
>.60			1		2	1	2	1		5	5	8		
TOTAL	621	406	196	145	124	99	78	77	53	38	35	24	=	1897
TOTAL/2	310.5	203	98	72.5	62	48.5	39	38.5	26.5	19	17.5	12		
MEDIAN Au	.015	.033	.067	.109	.139	.142	.180	.181	.203	.230	.222	.430		

V-74

FREQUENCY DISTRIBUTION TABLE 74A

MINE: FLIN FLON MINE (Figure 99 & 101)

ORE TYPE: Combined Types ORE ZONE: Mine Randoms

CLASS INTER-VAL. ZN (WT%)	FREQUENCY																		
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)																		
	0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 – 20.0	20.0 – 22.0	>22.0 (23.0)		
0 – 1.0	161	56	52	51	34	27	14	11	10	10	16	21	9	16	9	10	12		
1.0 – 2.0	21	14	7	4	3	5	1	1	2	6	6	3	5	5	1	1	3		
2.0 – 3.0	26	14	9	4			3	1	2	3		5		3					
3.0 – 4.0	12	7	11	4	4	5	4	1		1	2	3	3	3	1		2		
4.0 – 5.0	11	11	2	6	4	5	3	2	2	3	3	1							
5.0 – 6.0	18	12	9	2	5	5	2		3	3	1	2	2						
6.0 – 7.0	5	13	5	3	4	4	1	3	1	2	1		1						
7.0 – 8.0	2	8	7	7	7	1	3		1		2								
8.0 – 9.0	5	6	4	4	2	1	1	1	1		1								
9.0 – 10.0	6	6	3	2	2	2	1			2		2							
10.0 – 12.0	4	6	10	11	8	6	3	2	6	1	3		1						
12.0 – 14.0	5	15	11	9	2	3	1	2	2			1	1						
14.0 – 16.0	4	7	8	3		2	1		2			2							
16.0 – 18.0	5	6	4	5	2	1					1								
>18.0	7	3	6		1	1					2								
TOTAL	292	184	148	115	78	68	38	24	32	32	31	38	40	27	11	11	17	=	1176
TOTAL / 2	146	92	74	57.5	39	34	19	12	16	15.5	19	20	11	13.5	5.5	5.5	8.5		
MEDIAN ZN	0.91	4.09	3.55	2.62	3.50	3.40	3.25	2.00	5.00	1.92	1.50	0.95	1.40	0.85	0.61	0.55	0.71		

V-73

FREQUENCY DISTRIBUTION TABLE 75A

MINE: FLIN FLON MINE (Figure 100)

ORE TYPE: Combined Types ORE ZONE: Mine Randoms

CLASS INTER-VAL.	FREQUENCY															
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)															
ZN (WT %)	0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 (19.0) 22.0		
0 1.0	137	82	80	57	31	26	17	7	4	2	6	3	3	2		
1.0 2.0	44	31	19	18	10	3	1	2	2	2	2	1				
2.0 3.0	25	32	14	6	4	3	2	3	1	2						
3.0 4.0	27	39	14	9	3	4	1		3	2	2					
4.0 5.0	19	24	9	9	6	1	1	1	2		1					
5.0 6.0	13	29	13	6	1	3	1	1				1				
6.0 7.0	10	26	14	11	3	4	1			4	1					
7.0 8.0	11	17	13	5	1		1									
8.0 9.0	1	8	1	2	1	1	6	1		1						
9.0 10.0	7	7	5	5	4	2		1	1	1						
10.0 12.0	2	9	3			2	1									
12.0 14.0		1	1	1	2	1	2									
14.0 16.0	1	2	1	1			1									
16.0 18.0						1										
>18.0	2			1		2										
TOTAL	299	307	187	131	66	53	35	16	13	14	12	5	3	2	=	1143
TOTAL / 2	149.5	153.5	93.5	65.5	33	26.5	17.5	8	6.5	7	6	2.5	1.5	1		
MEDIAN ZN	1.28	3.22	1.71	1.47	1.20	1.17	1.50	1.50	2.50	3.50	1.00	0.83	0.50	0.50		

FREQUENCY DISTRIBUTION TABLE 76A

MINE: FLIN FLON MINE (Figure 98 & 102)

ORE TYPE: Combined Types ORE ZONE: Mine Randoms

CLASS INTERVAL. ZN (WT %)	FREQUENCY																		
	ASSAY INTERVAL COPPER (WEIGHT PERCENT)																		
	0 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0	6.0 – 7.0	7.0 – 8.0	8.0 – 9.0	9.0 – 10.0	10.0 – 12.0	12.0 – 14.0	14.0 – 16.0	16.0 – 18.0	18.0 – 20.0	20.0 – 22.0	>22.0 (23.0)		
0 – 1.0	298	138	132	108	65	53	31	18	14	12	22	24	12	17	9	10	13		
1.0 – 2.0	65	45	26	22	13	8	2	3	4	8	8	4	5	5	1	1	3		
2.0 – 3.0	51	46	23	10	4	3	5	4	3	5		5		3					
3.0 – 4.0	39	46	25	13	7	9	5	1	3	3	4	3	3	3	1		2		
4.0 – 5.0	30	35	11	15	10	6	4	3	4	3	4	1							
5.0 – 6.0	31	41	22	8	6	8	3	1	3	3	1	3	2						
6.0 – 7.0	15	39	19	14	7	8	2	3	1	6	2		1						
7.0 – 8.0	13	25	20	12	8	1	4		1		2								
8.0 – 9.0	6	14	5	6	3	2	7	2	1	1	1								
9.0 – 10.0	13	13	8	7	6	4	1	1	1	3		2							
10.0 – 12.0	6	15	13	11	8	8	4	2	6	1	3		1						
12.0 – 14.0	5	16	12	10	4	4	3	2	2			1	1						
14.0 – 16.0	5	9	9	4		2	2		2			2							
16.0 – 18.0	5	6	4	5	2	2					1								
>18.0	9	3	6	1	1	3					2								
TOTAL	591	491	335	246	144	121	73	40	45	45	50	45	25	28	11	11	18	=	2319
TOTAL / 2	295.5	245.5	167.5	123	72	60.5	36.5	20	22.5	22.5	25	22.5	12.5	14	5.5	5.5	9		
MEDIAN ZN	0.99	3.36	2.41	1.68	1.54	1.94	2.70	1.66	3.50	2.50	1.37	0.94	1.40	0.83	0.61	0.55	0.69		

ZN-CU RELATIONS

Zn%	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	11.0	13.0	15.0	17.0	>18.0
Cu%	2.39	2.06	1.65	2.14	1.94	1.61	2.24	2.25	2.80	3.44	3.45	2.75	2.39	2.35	2.08