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RECONNAISSANCE ROCK GEOCHEMISTRY OF AISHIHIK LAKE, SNAG AND STEWART RIVER MAP-AREAS IN THE YUKON CRYSTALLINE TERRANE

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RECONNAISSANCE ROCK GEOCHEMISTRY OF AISHIHIK LAKE, SNAG AND STEWART RIVER MAP-AREAS IN THE YUKON CRYSTALLINE TERRANE

Abstract

This is a report on the abundance of zinc, copper, lead, molybdenum, tungsten, mercury, silver and arsenic in 3061 rock samples from part of the Yukon Crystalline Terrane. The data are examined in terms of the geology and it is shown that unique metal abundances and associations exist in some units although most map assemblages are not geochemically distinctive. Of the metamorphic rocks the Nasina quartzite, Klondike schist and Kluane schist have interestingly high concentrations of different metals. For the first two these are thought to indicate possibilities for mineralization. Among the plutonic rocks, nearly all of which have low metal backgrounds, only the Eocene Nisling Range alaskite stands out geochemically. This plutonic suite, together with its dyke swarms and explosive volcanic rocks (Mount Nansen Group), is geochemically active. The alaskite contains molybdenum-copper porphyry occurrences and the acid volcanics locally host gold-silver veins. This volcano-plutonic suite also has possibilities for associated tin and/or uranium mineralization. The upper Triassic Lewes River Group is geochemically rich in copper. The basalt, the time equivalent of the Nicola and Takla Groups of British Columbia, is also host to a number of copper occurrences in Yukon.

This report characterizes the frequency distributions of the various metals emphasizing that the shapes of the cumulative frequency curves are as distinctive as the concentrations and are independent of the way the sample population is broken down. Thus, using probability log scales, cumulative curves for zinc are concave, those for arsenic convex, copper curves are straight while those of lead and silver are concave-convex.

Comparison of the bedrock geochemistry with a stream sediment survey of the same region predictably shows that zinc and molybdenum are more mobile than copper in streams.

Although the geochemistry provides background data on elemental association and abundances in the various suites thus corroborating some of the geological prejudices, it does not lead to new insights into the relations, genesis and history of the rocks. Nor does it specify exploration targets unequivocally. A geochemical study such as this is therefore a luxury justifiable only when the geology is already understood, but unwarranted as an initial examination of a region.

Résumé

Le présent rapport porte sur l'abondance du zinc, du cuivre, du plomb, du molybdène, du tungstène, du mercure, de l'argent et de l'arsenic dans 3061 échantillons de roches provenant d'une partie des terrains cristallins du Yukon. On a examiné les données du point de vue géologique, et constaté qu'il existe des concentrations et associations uniques de métaux dans certaines unités, bien qu'une fois regroupées, les cartes ne présentent pas de caractères géochimiques distinctifs. Parmi les roches métamorphiques, le quartzite de Nasina, le schiste du Klondike et le schiste de Kluane présentent des teneurs élevées en divers métaux. En ce qui concerne les deux premières roches métamorphiques, on pense qu'elles ont peut-être subi une minéralisation. Parmi les roches plutoniques, dont presque toutes ont de faibles valeurs de fond métalliques, seule l'alaskite de Nisling Range d'âge éocène est distinctive du point de vue géochimique. Cette suite plutonique, accompagnée de faisceaux de dykes et roches pyroclastiques (groupe de Mount Nansen), est géochimiquement active. L'alaskite contient parfois des venues porphyriques riches en cuivre et molybdène, et les roches volcaniques acides renferment localement des veines argentifères et aurifères. Cette suite volcano-plutonique est peut-être caractérisée par une minéralisation associée en étain ou uranium, ou les deux à la fois. Le groupe de Lewes River, d'âge triassique supérieur, contient davantage de cuivre. Le basalte, qui est l'équivalent chronologique des groupes de Nicola et Takla de la Colombie-Britannique, contient aussi de nombreuses venues en cuivre au Yukon.

Le présent rapport indique la distribution de fréquences de divers métaux, et montre que la configuration de la courbe des fréquences cumulées est aussi nettement caractérisée que la concentration, et dépend pas de la façon dont l'échantillon de population est fragmenté. Ainsi, si l'on utilise des échelles logarithmiques de probabilité, on constate que les courbes cumulatives du zinc sont concaves, que celles de l'arsenic sont convexes, et que celles du cuivre sont rectilignes tandis que celles du plomb et de l'argent sont concavo-convexes.

Si l'on compare la géochimie de la roche en place avec les valeurs obtenues au cours de la prospection de sédiments fluviatiles de la même région, on constate, comme il était prévisible, que le zinc et le molybdène sont plus mobiles que le cuivre dans les cours d'eau.

Bien que la prospection géochimique nous fournisse des données de fond sur les associations et les concentrations d'éléments dans les diverses suites, et confirme certains jugements d'ordre géologique, elle ne nous permet pas de mieux connaître la genèse et l'évolution des roches, ni les relations qui existent entre celles-ci. Elle ne permet pas non plus de désigner avec certitude les lieux qui doivent être explorés. Une étude géochimique de ce genre est donc un luxe, que l'on peut se permettre seulement lorsque la géologie est déjà bien comprise, et surtout pas pendant la phase préliminaire d'exploration d'une région.

RECONNAISSANCE ROCK GEOCHEMISTRY OF AISHIHIK LAKE, SNAG AND STEWART RIVER MAP-AREAS IN THE YUKON CRYSTALLINE TERRANE

INTRODUCTION

During the summers of 1970, 1971 and 1972 field work was carried out in Aishihik Lake, Snag and Stewart River map-areas to study and map the regional geology. A program of bedrock sampling for geochemical study was done concurrently. It was intended that this would provide useful basic data that could be tested to see if unique metal abundances or associations exist in this region. The information was also anticipated to have value as a guide to mineral exploration in helping to identify rock-units or areas of potential economic importance. It was thought the geochemistry might also shed light on aspects of the genesis and history of the rocks in this region. This is a report of the findings of the geochemical investigation. It is an addition to geological data published earlier (Tempelman-Kluit 1974, 1976; Tempelman-Kluit and Wanless, 1975; Le Couteur and Tempelman-Kluit, 1976).

The basic approach of this study is to examine the geochemistry in terms of stratigraphic assemblages or geological map-units as well as in groupings according to lithology. Thus as well as examining metal content of, for example, all the basalt from the project area, the metal content of stratigraphic units was also studied separately. It was expected that such stratigraphic distinction of the geochemical data might be revealing.

This report begins with a systematic examination of the geographic distribution of metal values in each of the three map-areas. This is accompanied by a comparison of the frequency distributions of the various metals from one map-unit to another. Because of the volume of data only selected units that demonstrate characteristic and uncharacteristic features are studied. This systematic examination is followed by a comparison of the frequency distributions of metals to document differences between map-units from area to area and to show partitioning of metals among associated rock assemblages. Emphasis throughout this report is on diagrams and maps with much of the accompanying text confined to explanatory captions. As much as possible comparisons and contrasts are made graphically, and the styles and scales of the various diagrams have been kept the same throughout. This report also contains a file of the analytical results of all samples.

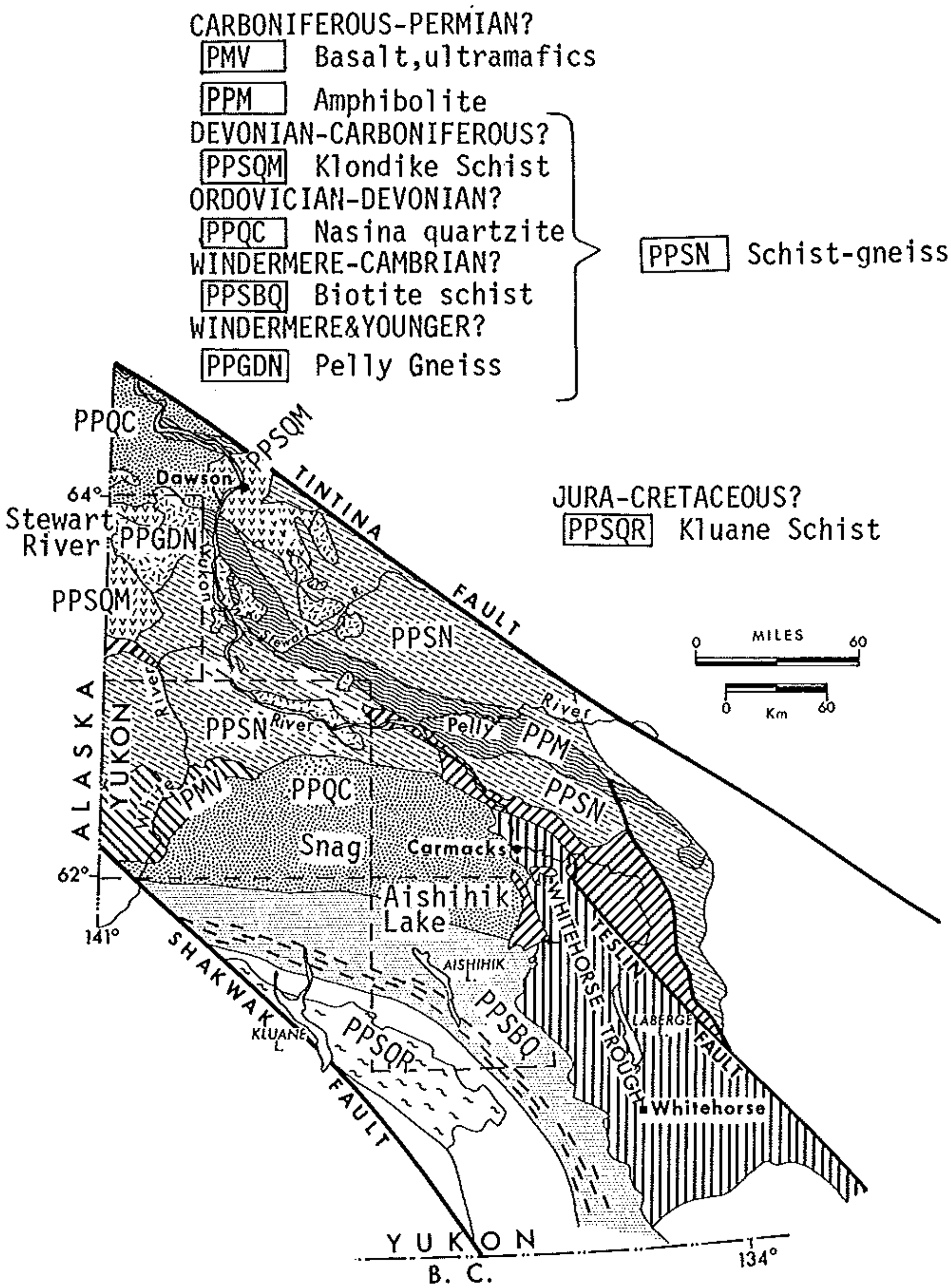


Figure 1. Generalized distribution of metamorphic rocks in the Yukon Crystalline Terrane. For simplicity the younger plutonic and volcanic rocks are omitted. Age assignments are tentative and largely based on lithologic correlation.

Acknowledgments

This study is a product of the coordinated efforts of many individuals at all stages of the work from sampling to publication of the results. Sample collecting was done during the summer field seasons in 1970 by J. Fallon, in 1971 by T. Booth, M. Delich, C. Dodds, A. Edgeworth, I. Gibson, S. Gordey, J. Nitsch and B. Read and in 1972 by T. Booth and S. Gordey. Density determinations, sawing, staining and modal point counting of all the granitic rocks was done during the winter of 1972-73 by P.T. Wilkening and W.G. Blann.

The rock samples were crushed to prepare them for analysis and their magnetic susceptibility was measured by T. Kalnins and G. Dodd in the spring of 1974. The tedious task of transfering certain data from field notes to computer processable cards, determining UTM co-ordinates and checking

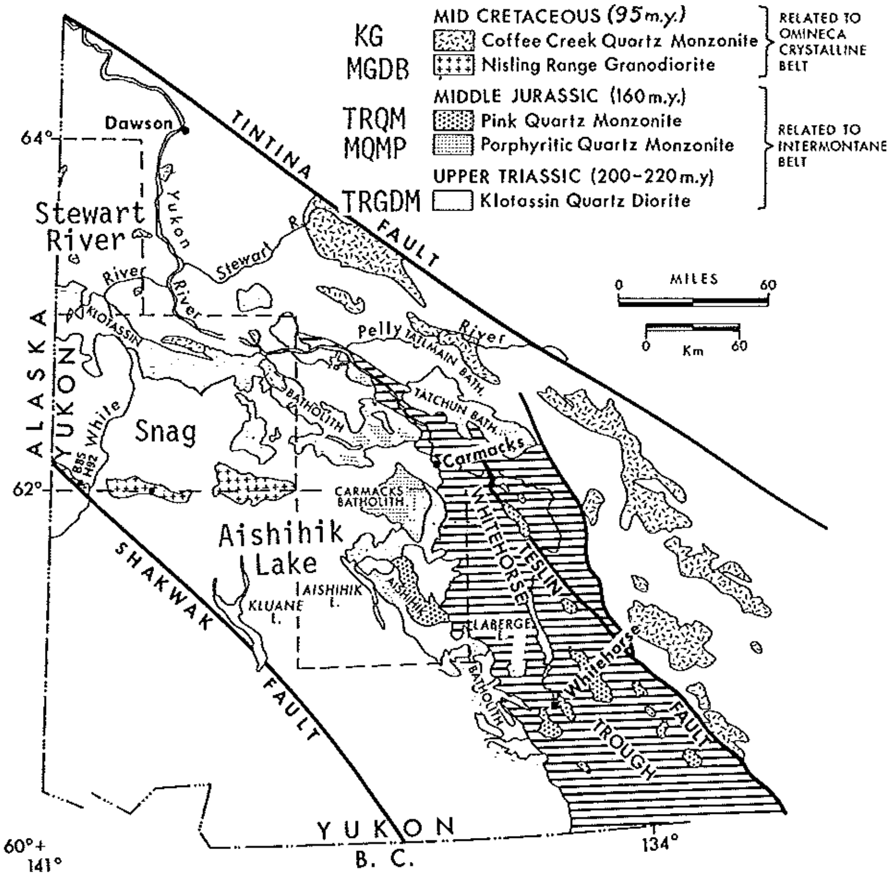


Figure 2.

Distribution of the post-metamorphic Mesozoic plutonic rocks in the Yukon Crystalline Terrane. In their distribution and relationships, the Klotassin and pink quartz monzonite reflect a continuity with the Intermontane Belt, whereas the Coffee Creek shows its affiliation with the Omineca Crystalline Belt. The Whitehorse Trough is shown for reference.

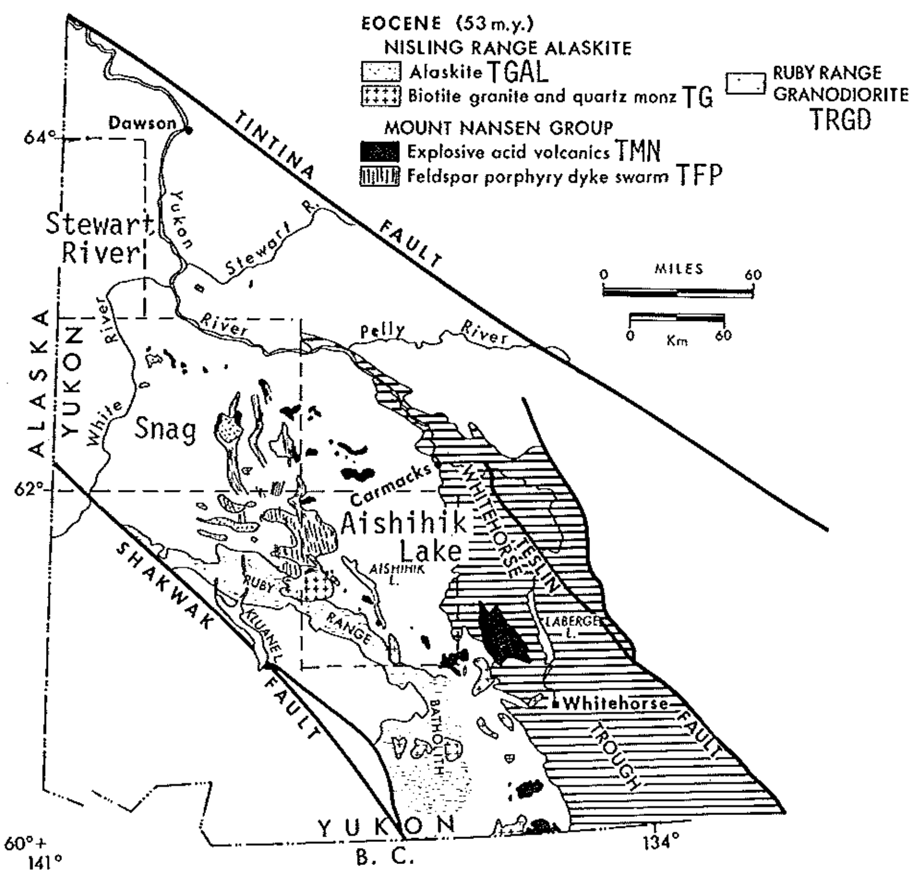


Figure 3.

Distribution of the early Eocene Nisling Range alaskite with its related subvolcanic dyke swarms and explosive volcanic rocks (Mount Nansen Group). The Ruby Range Batholith, part of the Coast Crystalline Complex, is made up of granodiorite modally similar to the Klotassin, but it yields the same K-Ar ages as the alaskite.

and endlessly rechecking the computer file fell to L.C. Struik, R.G. Simpson, R. Turna, P. Sihota and B. Dewonck during the winter 1975-76. Struik and Simpson in particular went far beyond mechanically processing the data. They made valuable suggestions concerning data presentation and discovered some of the conclusions of this report.

The analyses were done under contract by the Vancouver laboratories of Bondar Clegg and Company. S. Courville of the Geological Survey advised on analytical procedures and provided checks on the results by analyzing standard samples as controls on the analyses. W.N. Houston of the Geological Survey kindly made the perspective diagrams using the computer plotting facilities of the Survey.

GEOLOGY OF THE YUKON CRYSTALLINE TERRANE

The following paragraphs outline the geology of the Yukon Crystalline Terrane. For a more comprehensive description and synthesis the reader is referred to earlier reports (Tempelman-Kluit, 1976).

Aishihik Lake, Snag and Steward River map-areas occupy a large part of the Yukon Crystalline Terrane in west-central Yukon. Rocks of this region can be subdivided into three major parcels; a Paleozoic and Late Proterozoic assemblage of metamorphic rocks (Fig. 1) a set of varied Mesozoic and Tertiary plutonic rocks (Figs. 2, 3) and overlying all a sequence of Tertiary volcanic strata (Fig. 4).

The metamorphic rocks include three distinct divisions which are found in southern, central and northern parts of the Yukon Crystalline Terrane. The southern metamorphic rocks are mapped as a single unit, the Kluane schist (PPSQR)*. Though it is physically continuous with the Yukon Crystalline Terrane, it is a part of the Coast Plutonic Complex, as are the associated plutonic rocks that make up the Ruby Range Batholith. The Kluane schist is a staurolite-biotite-quartz schist which is probably the metamorphosed equivalent of the Dezadeash Group, a Jura-Cretaceous flysch (Eisbacher, 1976).

The central metamorphic assemblage includes a biotite schist (PPSBQ) with marble lenses (PPC), which is thought to be the metamorphosed equivalent of Windermere and Early Cambrian rocks. These are continental terrace wedge deposits. Overlying them is a sequence informally referred to as the Nasina quartzite (PPQC). This unit includes graphitic slate, quartzite and some marble and is thought to be the distal equivalent of miogeoclinal rocks that range in age from Ordovician to Devonian.

Metamorphic rocks in the northern part of the Yukon Crystalline Terrane are separated into four map-units, which together are thought to be equivalent to miogeoclinal rocks found to the northeast. The oldest of these are granodiorite gneisses and biotite schists known informally as the Pelly gneiss (PPGDN). These are probably of late Windermere age and equivalent to the "Grit Unit" and to the biotite schist (PPSBQ) mentioned above. The gneiss and schist are overlain locally by marbles that are probably Lower Cambrian in age. A graphitic quartzite and slate lies above the gneisses and marbles. It has been mapped as the Nasina quartzite PPQC) and is the same unit mentioned above by that name. Over the Nasina lies a muscovite-quartz schist and amphibolite locally with important marble lenses. This is the Klondike schist (PPSQM), an informally named unit, thought to be Carboniferous and broadly equivalent to the "Black Clastic" of Selwyn Basin. In much of the area the Pelly gneiss, Nasina quartzite and Klondike schist are not differentiated, but mapped together as schist-gneiss (PPSN).

Locally above the metamorphic rocks in the northern part of the Yukon Crystalline Terrane lie serpentinized ultramafic rocks (PMUB, PMPR), with which are found basalt (PMV) and gabbro (PMB). This late? Paleozoic suite has been emplaced tectonically on the metamorphic rocks.

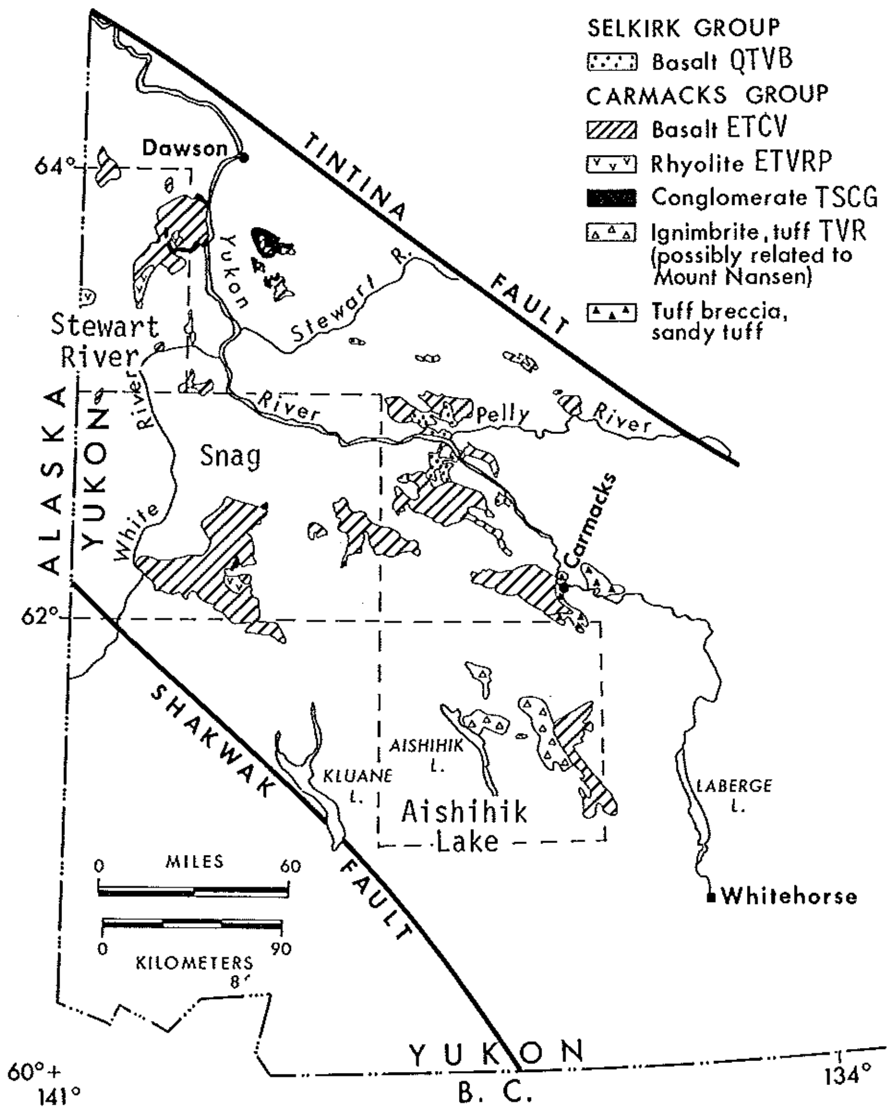
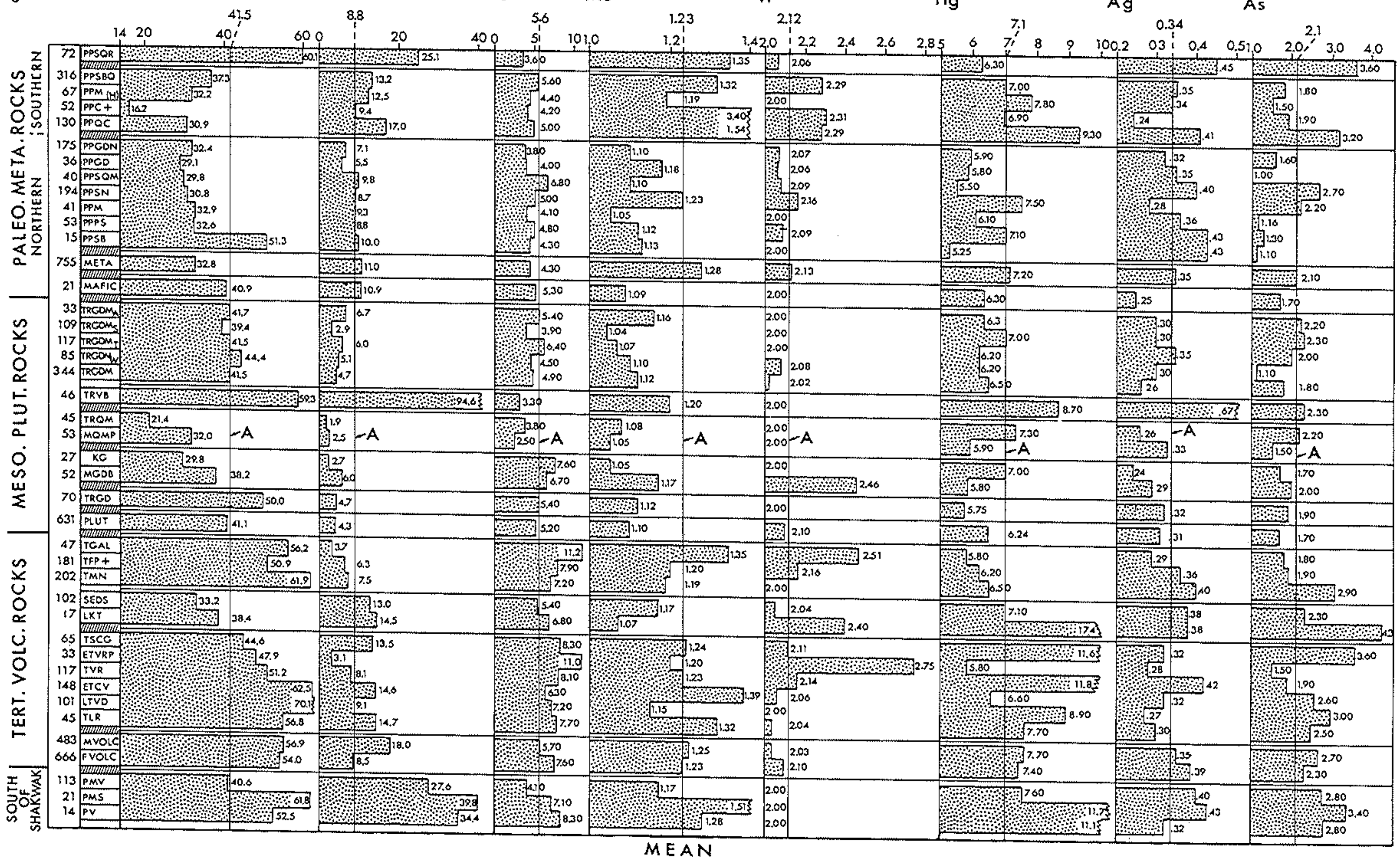


Figure 4. Distribution of Tertiary volcanic rocks of the Carmacks Group (Eocene to Miocene) and of the Selkirk Group (Pleistocene) in the Yukon Crystalline Terrane.

* The mnemonics in brackets are used throughout this report to refer to map-units. They correspond with slight modifications to the symbols used on the geologic maps of this region in Tempelman-Kluit (1974) (see Appendix 2).

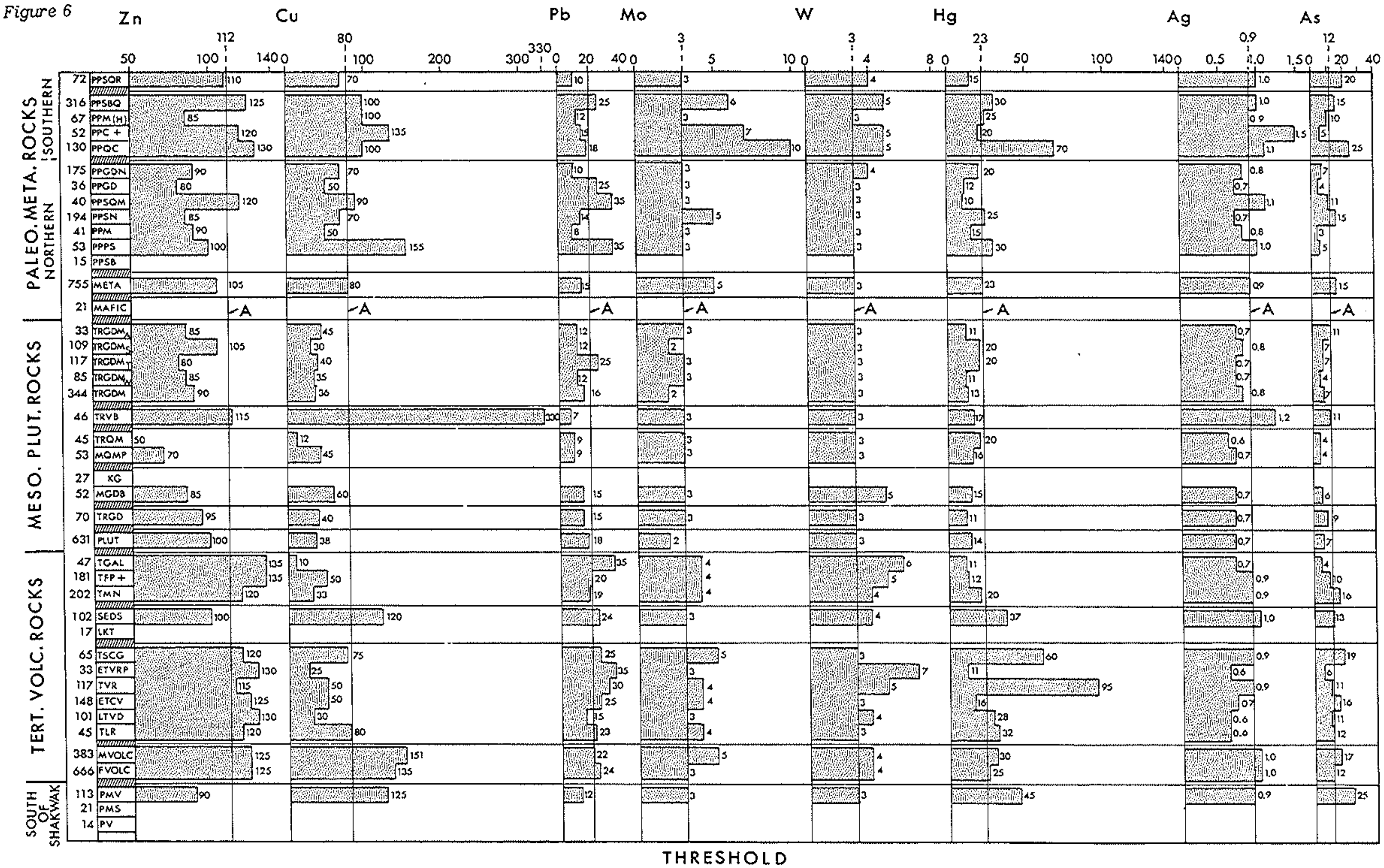
Figure 5



Graphic comparison of the arithmetic mean values of the frequency distributions of the metals studied assuming a log normal distribution. Each bar represents the mean value of one metal among samples from one map-unit or group of rocks (META represents a composite of the metamorphic rocks, PLUT of the plutonic rocks and TRGDM(TOT) of all rocks in the Klotassin suite). Numbers beside the bars indicate mean values in parts per million and the number of samples is indicated beside each mnemonic. Each row of bars compares the log normal mean for one metal. The line labelled "A" running vertically through each row of bars is the mean value for all samples in the project area taken together.

The mean is a measure of central tendency of clustering of a distribution. As such it is an approximation to the background of the metal in the map-unit under consideration and it gives an idea of the normal range of metal values encountered in the unit. Note that there is much more variation in the mean values of certain metals (zinc, copper, arsenic, silver) than in those of others (e.g. lead). Because of limitations in the analytical techniques only the high end of the frequency distributions of mercury, tungsten and molybdenum are accurately reflected by these data and mean values for these metals are misleading. Some map-units have fairly consistently high mean metal contents. For example PPSQR has high values in all metals except tungsten and mercury whereas TRVB has high means in all but lead, molybdenum and tungsten. Similarly samples from the Tantalus Formation (LKT) have high means in all metals except for zinc and lead. Other map-units are consistently metal poor such as the two plutonic rock-units MQMP and TRQM or the Pelly gneiss (PPGDN). More generally the metamorphic rocks of the southern Yukon Crystalline Terrane (PPSBQ, PPM, PPC+, PPQC) tend to have higher metal contents than those of the northern Yukon Crystalline Terrane (PPGDN, PPGD, PPSQMV, PPSN, PPM, PPPS, PPSB). Again generally the plutonic rocks tend to have lower than average metal values while volcanic rocks are more metalliferous. Interestingly, the rocks south of the Shakwak Trench (PMV, PMS, PV) all have higher than average mean metal values and this region is geochemically as distinct from Yukon Crystalline Terrane as it is geologically different.

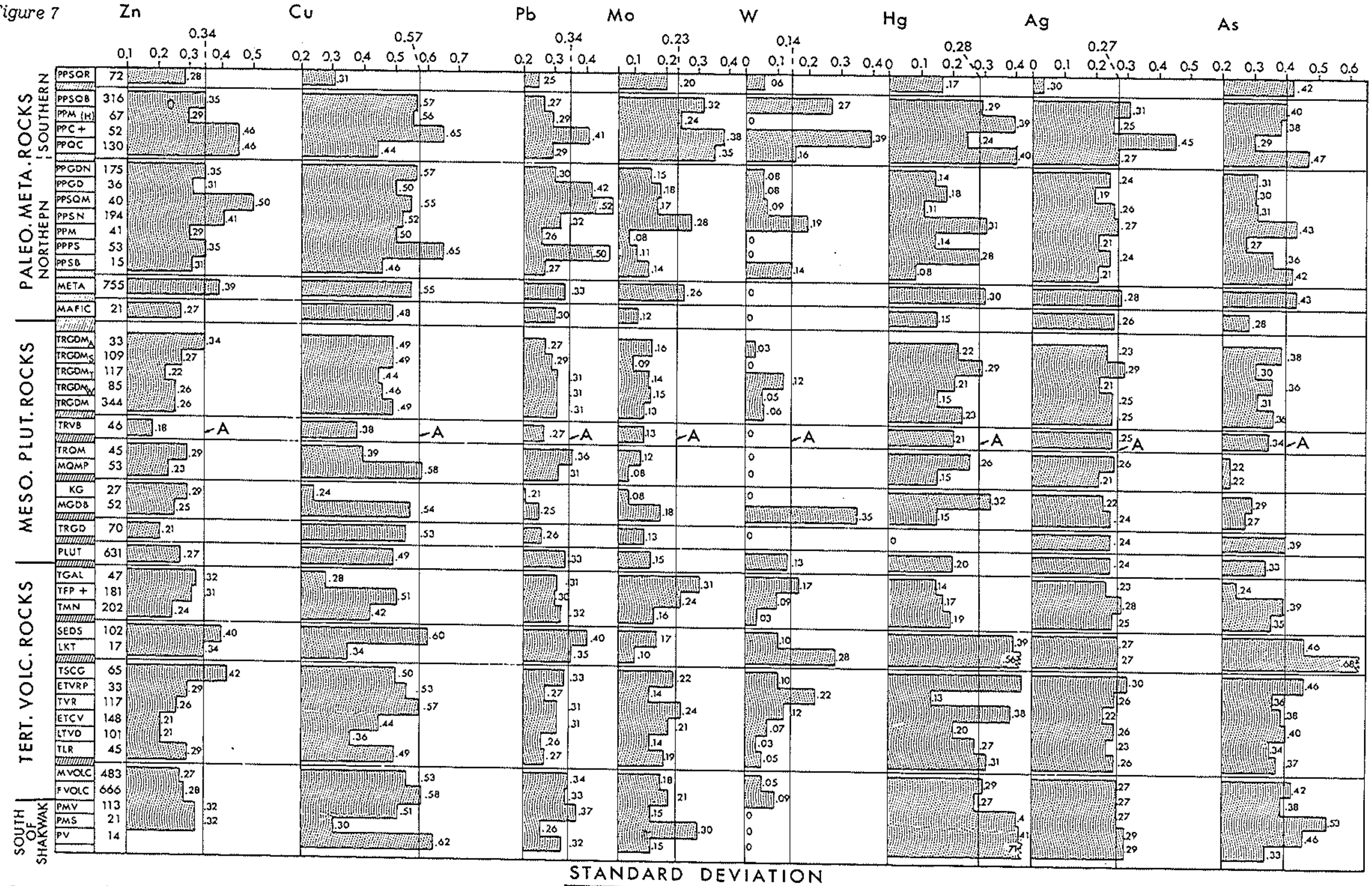
Figure 6



Comparison of the cut-off values or anomaly threshold levels of various metals for different rock-units. Each bar represents the threshold for one map-unit or for a group of map-units. (META represents a composite of all the metamorphic rocks, PLUT of the plutonic rocks and TRGDM(TOT) of all rocks of the Klotassin suite). Numbers beside the bars indicate the threshold in parts per million and the number of samples is shown beside the mnemonic. Rows of bars compare threshold values of different units for the same metal. The line labelled "A" running vertically through each row of bars is the threshold for the total population.

Threshold represents the upper limit of the background or normal metal values. Higher metal values are considered anomalous. Threshold is arbitrarily taken as the 95.5 percentile of the cumulative frequency distribution, because there are no more objective criteria for distinguishing values that are anomalous from those that are not. Note that there is as much variation in the threshold levels as there is in the means (compare this with Figure 5) and that for metals with positively skewed distributions (molybdenum, tungsten, mercury and arsenic) rock units that have higher than average means also have higher than average cutoffs. For zinc, a metal with generally negatively skewed distributions, a crude inverse relationship between cutoff and mean is seen so that a unit with a relatively high mean zinc concentration has comparatively low cutoffs (e.g. TRVB). One rock-unit (PPSQR) has relatively high means but low threshold levels for most metals. This is related to the generally more negatively skewed than average distributions of all metals found in this unit.

Figure 7



Comparison of the standard deviation of the frequency distributions for the metals studied. Each bar represents the standard deviation for a single map-unit or for a group of rocks (META represents a composite of all metamorphic rocks, PLUT of all plutonic rocks and TRGDM(TOT) of all Klotassin suite rocks in the project area). Numbers beside the bars indicate the standard deviation and the number of samples is indicated beside each mnemonic. See Appendix 2 for the meaning of map-unit mnemonics. Each row of bars compares the standard deviation for one metal. The line labelled "A" running through each row of bars is the standard deviation when all samples in the project area are considered together.

Standard deviation is a measure of the dispersion or spread of metal values in the frequency distribution; the higher the standard deviation the greater the dispersion. Note that the standard deviation of the copper distributions is generally highest and that those for arsenic, zinc and lead tend to be successively lower followed by still lower values for mercury, molybdenum and tungsten. The low standard deviations of the last three metals are a reflection of limitation in the analytical methods and are not a real indication of the narrow spread of values of these metals. The range in the standard deviations is reflected in the slope of the cumulative frequency distributions which are progressively flatter for higher standard deviations. Thus the most gently sloping of the cumulative frequency curves is generally that of copper while those of arsenic, lead and silver are progressively steeper (for example compare Fig. 36 with Figs. 39, 37 and 38). Note that the standard deviation of metal distributions in the plutonic rocks is lower than that for other rock types no matter which of the analyzed metals is considered. Also note that the standard deviations of the distributions in the metamorphic and sedimentary rocks is generally higher than for other rocks and that this again holds for all the metals. For the volcanic rocks the standard deviation is not as low as for the plutonic types nor as high as for the metamorphic and sedimentary varieties. This is because the metals analyzed occur in the rocks largely in substitution for the common constituents. In the igneous rocks such substitution is more limited than in the sedimentary and metamorphic types because the major mineralogy of the igneous rocks is more restricted. Thus the range in values of substituted metals (and consequently the standard deviation) is comparatively small in the igneous rocks.

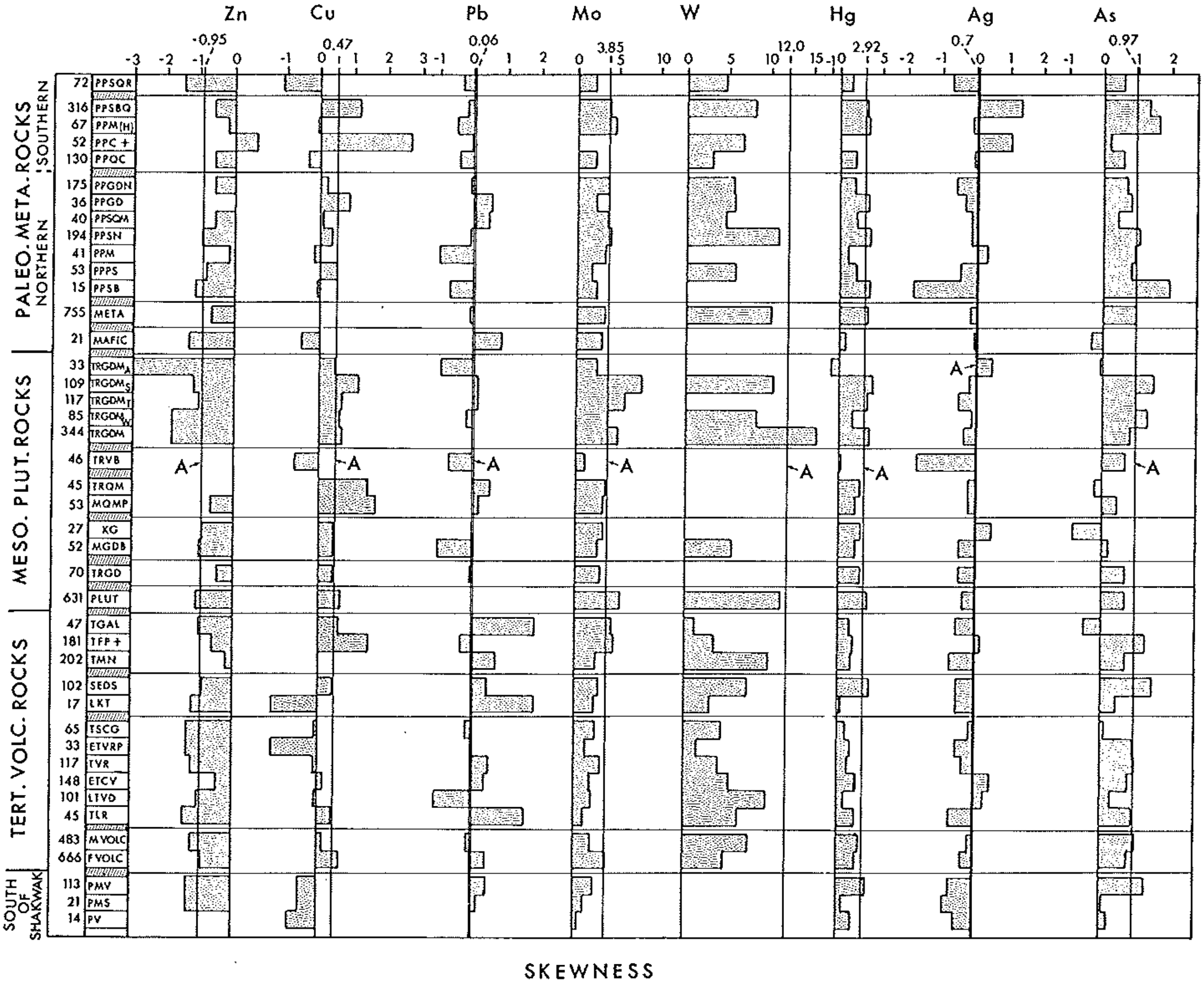
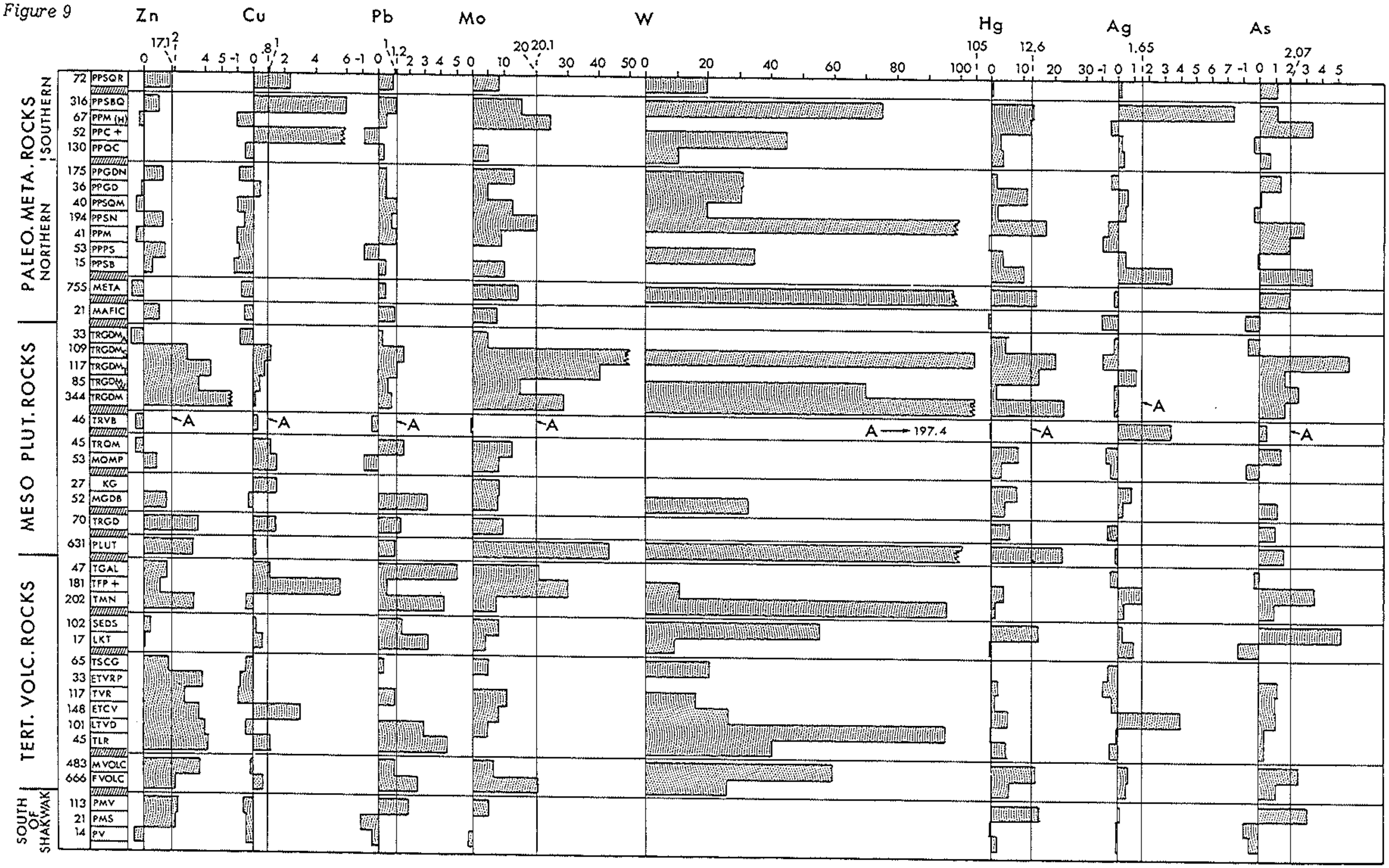


Figure 8

Comparison of the skewness of the frequency distributions for the metals analyzed. Each bar represents the skewness of the frequency distribution of samples from a single map-unit, or for a group of rocks (META represents a comparison of all metamorphic rocks, PLUT of all plutonic rocks and TRGDM(TOT) of all Klotassin Suite rocks in the project area). Numbers beside the bars indicate the skewness and the number of samples is shown beside each map-unit mnemonic. Each row of bars compares the skewnesses for a single metal. The line labelled "A" running through each row of bars is the skewness when all samples of the project area are considered as a single population.

Skewness is a statistical measure of the degree of deviation from symmetry about the central value of a distribution. The higher the number the greater the asymmetry. Negative skewness numbers indicate the relative preponderance of samples with high metal values, whereas positive skew reflects a relative absence of such samples in a given population. The distributions of molybdenum, tungsten and mercury are strongly positively skewed, but this reflects limitations in the analytical techniques for these metals and not their real frequency distribution. Note that the distribution of zinc is generally negatively skewed, whereas that of copper and arsenic is positively skewed. In contrast the distribution of silver and lead tend to be nearly centrally symmetrical and in this aspect are most nearly log normal. The distributions of zinc, copper, lead, molybdenum, mercury and silver for TRVB, the Lewes River Group, all are abnormally skewed. The distributions for PPSQR, the Kluane schist in southern Aishihik Lake map-area, are all more negatively skewed than average. This correlates with the fact that the threshold values for this unit tend to be average although the mean metal contents are above average. Interestingly the distributions of arsenic in two of the granitic suites, the Coffee Creek granite (KG) and Nisling Range alaskite (TGAL), have anomalous negative skew, in contrast to most of the other rock-units and the granodiorites (TRGDM, TRGD) in particular which have positively skewed distributions of arsenic. The underlying cause is unknown.

Figure 9



KURTOSIS

Comparison of the kurtosis of the frequency distributions of the metals in various rock-units and groups of rock-units assuming a log normal distribution. See Appendix 2 for meaning of the mnemonics. Each bar represents the kurtosis of the frequency distribution of one metal in a rock-unit. Numbers beside the bars indicate the kurtosis and the number of samples is indicated beside the mnemonic. Rows of bars compare the kurtosis of the distributions for one metal. The line labelled "A" running vertically through each row of bars represents the kurtosis when all samples of the project area are considered one population.

The kurtosis is a measure of the peakedness of a frequency distribution, that is, the proportion of values clustered around the mean to the total range of values. Distributions with a kurtosis of 0 are log normally distributed, positive values indicate more peaked and negative values flatter than log normal distributions. A distribution with high kurtosis has most of the values clustered close to the mean and also has a large range. Note the range in kurtosis and the general increase in peakedness from copper through lead, silver and zinc to arsenic indicating increasing degrees of deviation from log normality. The high kurtosis values for molybdenum, tungsten and mercury reflect limitations in the analytical technique for these metals and give a false indication of the actual frequency distribution of these metals. Note the relatively high kurtosis of the zinc distribution for Klotassin suite rocks (TRGDM) and the mafic volcanics of the Carmacks Group and related suites (ETCV, LTVD etc.). Similarly the highly peaked silver distribution in the biotite schist unit PPSBQ and the Triassic volcanics (TRVB). The fundamental cause for variation in peakedness is obscure.

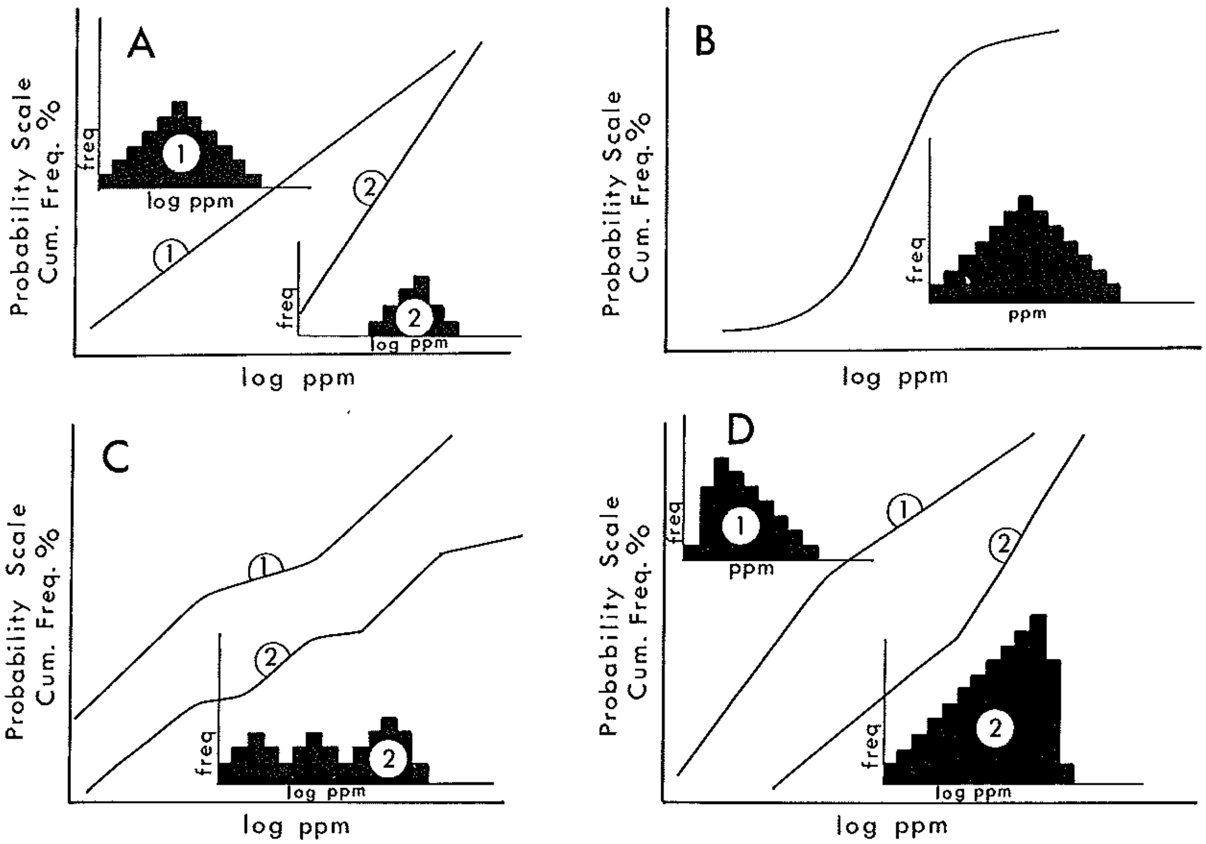


Figure 10

Schematic diagram of cumulative frequency curves to illustrate some of their variability. The straight lines in A mean that the distributions they represent are both log normal; curve 1 has a flatter slope than curve 2 indicating that 1 has a larger standard deviation and that it represents a greater spread in values than 2. The accompanying histograms portray these features in a different manner. The distribution of copper resembles 1 and that of silver is more like 2. The curved tails on plot B indicate that the distribution it portrays is not log normal, but normal; lead commonly shows this feature among metals studied in this project. The broken curves 1 and 2 in C depict bimodal and multimodal distributions respectively; some of the distribution curves for various metals in the sedimentary rocks, display this deviation. Among the various metals studied copper most commonly displays a tendency to be multimodally distributed whereas zinc, lead, silver and arsenic are generally unimodal. Curve 1 in D represents a distribution that is positively skewed whereas curve 2 reflects a negatively skewed distribution; arsenic and zinc show these two different types of distributions among the metals studied.

Four groups of plutonic rocks invade the metamorphic framewrok of the Yukon Crystalline Terrane. The two oldest are the Late Triassic? Klotassin quartz diorite (TRGDM) and the Middle Jurassic pink quartz monzonite and porphyritic quartz monzonite units (TRQM, MQMP). They define the extension of plutonism related to the Intermontane Belt through the Yukon Crystalline Terrane. Mid-Cretaceous intrusions in the northern part of the terrane, the Coffee Creek quartz monzonite (KG) and Nisling Range granodiorite (MGDB) are the continuation of plutons related to the Omineca Crystalline Belt. The youngest plutonic suite, the Eocene Nisling Range alaskite (GAL), is found only in the southern part of the Yukon Crystalline Terrane. It has affiliations with the Coast Plutonic Belt and its presence marks the imprint of that tectonic element on Yukon Crystalline Terrane.

The Mount Nansen Group (TMN) is an assemblage of subaerial acid tuffs, and is the extrusive phase of the Nisling Range alaskite.

The Ruby Range batholith, largely granodiorite (TRGD), lies immediately north of the Denali Fault. It constitutes the northern extension of the Coast Plutonic Complex along with the Kluane schist mentioned above.

Two groups of subaerial basalt, younger than the Eocene Nisling Range alaskite cover parts of the Yukon Crystalline terrane. The older of these, the Carmacks Group (ETCV) may be Eocene and consists of a basal conglomerate (TSCG) rhyolite domes (ETVRP) built on them, and tholeiitic flood basalt covering the whole. The Donjek volcanics (LTVD) and Little Ridge volcanics (TLR) are equivalents of the Carmacks. The youngest volcanic rocks are olivine basalts (QTVBO) which are roughly equivalent to the Selkirk lavas and probably Pleistocene.

ROCK GEOCHEMISTRY

The results of the chemical analyses are summarized in the following pages with maps, histograms and cumulative frequency curves. The maps show the geographic distribution of the analyzed samples in relation to the geology. The same geographic features and a simplified version of the UTM Grid appear on all of the maps. The location of all samples is shown, but only those samples that are considered anomalously high (95.5 and 99 percentiles) are indicated by special symbol. Specific analyses are considered anomalous in terms of the rock-unit to which the sample belongs and not in terms of the total sample population of the map-area. For example a sample with an analyzed copper content of 75 ppm is considered anomalous should it be part of the pink quartz monzonite unit (TRQM); a sample of the same copper content from the Lewes River Group (TRVB) is well below the threshold or cutoff level for that unit and is not considered anomalous nor shown as such.

The maps show the geology in simplified form as adapted and slightly modified from Tempelman-Kluit (1974). Drift has been eliminated and geological contacts are shown by a single symbol. Map-units are indicated by mnemonics that are the same as those used throughout this report and which approximate those used in the earlier report on the geology (see Appendix 2). For each of the areally extensive map-units the maps show a set of numbers. These indicate in consistent order, from top down, the log normal mean in ppm, the median in ppm, the anomaly threshold or cutoff value in ppm, the standard deviation and the number of samples analyzed from the unit.

The log normal mean was selected as the measure of central tendency that best approximates background because it is more consistent than the mode. The modal value is misleading when the distribution is not normal. The threshold or upper limits of background and lower limit of anomalous values for each unit were taken arbitrarily as the 95.5 percentile value from the cumulative frequency distribution.

The frequency distribution of each metal for all rock-units with 20 samples or more was examined and basic statistics computed for them. For each map-unit log normal mean, median, mode, standard deviation, kurtosis and skewness were calculated. Appendix 5 details the methods by which these parameters were derived. The mean, cutoffs, standard deviation, skewness and kurtosis of each of the populations are compared graphically in Figures 5, 6, 7, 8 and 9.

For each metal and map-area, histograms and cumulative curves are used to illustrate the frequency distributions. Although histograms are given for each metal, cumulative curves are not shown for molybdenum, tungsten, and mercury because of their peculiar metal distributions which are strongly biased by analytical limitations for these metals. The histograms and cumulative curves compare the frequency distributions among all samples from selected rock-units with that among all samples from the project. Selection of map-units used for comparison in the histograms and cumulative curves was done subjectively to illustrate as much as possible the range of frequency distributions and to portray also the more extensively sampled units.

Appendix 1 lists the results of the geochemical analyses (on microfiche) and includes other parameters determined for the samples. For most of the plutonic rocks modal counts are given. The density of the majority of the intrusive and extrusive igneous rocks is also indicated. In addition the file lists the magnetic susceptibility of most samples. The modal data for the plutonic rocks was synthesized earlier (Tempelman-Kluit, 1975, 1976), but the susceptibility remains to be studied. R. Currie intends to compile the magnetic susceptibility information, correlate it with rock type and map-unit assemblages and compare this with the aeromagnetic response over the region.

Zinc

Zinc is found in many base metal deposits and is an indicator or pathfinder metal for lead-zinc-silver occurrences in general. No systematic relationship has been noted between lead-zinc occurrences and the lead-zinc contents of plutonic rocks associated with them (Blaxland, 1971). Rock-units with high zinc contents are not necessarily better targets in which to find concentrations of this metal than are rock-units that are depleted. In the project area as elsewhere the volcanic rocks contain more zinc than the metamorphic, igneous, or sedimentary types (see Fig. 35). Of the volcanic rocks the massive green basalts considered the equivalent of the Lewes River Group (TRVB), the Carmacks Group (ETVC), the Donjek Volcanics (LTVD), and the Mount Nansen Group are most zinc-rich with roughly 60 ppm zinc on average. Whereas the Mount Nansen Group consists of intermediate and acid terrestrial explosive volcanic rocks the others are basaltic flows and breccias. The Mount Nansen Group tends to be zinc-rich compared to other acid and intermediate volcanics, whereas the Carmacks, Donjek and Lewes River groups are all zinc-poor mafic volcanics.

Metamorphic rocks are generally zinc-poor compared with other rock types and those in the project area are no exception, tending to have little zinc even by comparison to metamorphic rocks elsewhere. One exceptional assemblage that is therefore doubly intriguing is the Kluane schist (PPSQR) which has anomalously high zinc by comparison to any of the metamorphic rocks. This rock-unit is geochemically unusual among the metamorphic rocks of the project area because it has relatively high copper, molybdenum, silver and arsenic in addition to its high zinc. The Kluane schist is geologically as distinctive among the metamorphic rocks as it is geochemically unique. It is considered the equivalent of the Dezadeash Group and is probably Jura-Cretaceous (Eisbacher, 1976). Its metamorphism, of the Buchan type, is probably Late Cretaceous or Early Tertiary. Other metamorphic rocks of the Yukon Crystalline Terrane are Paleozoic and Late Precambrian and were involved in Permo-Triassic metamorphism of the Barrovian type.

One test of the validity of the correlation of the Kluane schist with the Dezadeash Group is a comparison of the minor element geochemistry and although such a comparison was not a prime aim of this project some of the data bear on this problem. Several samples of the Dezadeash Group were analyzed and are included in map-unit PMS along with older sedimentary rocks. Although the number of samples is small and inadequate for a fair comparison, the similar metal content of the Kluane schist and the Dezadeash Group rocks is striking (see Fig. 5). There is close correspondence not only of the zinc values, but in the concentrations of copper, molybdenum, tungsten, silver and arsenic as well. Mercury and lead contents of the two units differ markedly and it remains to be seen by more careful work whether this difference reflects removal of these elements possibly during the metamorphism that produced the Kluane schist.

It is not known if its high metal content makes the Kluane schist (and Dezadeash Group) attractive to mineral exploration. Neither rock-unit contains important known mineral occurrences.

Plutonic rocks in the project area contain somewhat less zinc than plutonic rocks generally do. Levinson (1974) gave 40 to 60 ppm as the average abundance of zinc in granite and granodiorite respectively whereas granodiorite in the project area has about 40 ppm and granite and quartz monzonite about 30 ppm. Because most of the zinc in these rocks is found in their mafic minerals, the mafic-rich plutonic rocks like the hornblende granodiorite (Klotassin Suite, TRGDM) contain more zinc than the felsic varieties such as the Coffee Creek granite (KG) or the pink quartz monzonite (TRQM).

An interesting exception to this trend is the Nisling Range alaskite (TGAL), a suite essentially without mafic minerals, but which nevertheless has more zinc than any of the plutonic rocks. This alaskite is cogenetic with the acid volcanic rocks of the Mount Nansen Group whose zinc concentration is also relatively high. Although no interesting zinc concentrations are known in either of these related rock-units the alaskite is host to a number of molybdenum-copper occurrences (Casino, Mount Cockfield, Mount Nansen) and the Mount Nansen contains several gold-silver vein deposits (Mount Nansen, Freegold Mountain).

The Denali-Shakwak fault separates the Yukon Crystalline Terrane and Coast Plutonic Complex from the Insular Belt and the pronounced difference between rocks on both sides is reflected in the geochemistry. South of this fault the rocks generally contain more zinc as well as copper, mercury, silver, and arsenic than is found in rocks north of the fault.

The zinc geochemistry points to the cogenetic volcano-plutonic suite, the Mount Nansen-Nisling Range alaskite, as the most interesting group of rocks which warrants careful prospecting for metal concentrations because of its anomalously high zinc content. It also emphasises the uniqueness of the Kluane schist among metamorphic rocks north of the Denali-Shakwak fault, but whether this has significance in directing prospectors to this unit or steering them away is unknown. The Mount Nansen-Nisling Range alaskite has long been recognized as the single most important host rock suite for metal concentrations in this region.

Copper

Copper is a pathfinder element for copper deposits in general and for copper associated base metal and uranium occurrences. It is considered an important element in exploration for such types of showings and samples collected in this study have therefore been analyzed for this metal. In plutonic rocks no general correlation is apparent between the background copper content of the host rocks and the occurrence of copper mineralization (Brabec and White, 1971). The same may be the case for other rock types and this discussion focusses on anomalously high or low copper concentrations without implying economic concentrations specifically.

The abundance of copper in rocks of the project area is considerably lower than that quoted for similar rocks from other areas (e.g. Boyle, 1965; Brabec and White, 1971). This may reflect a real depletion of copper in rocks of this project area or it may mirror different analytical techniques. However the relative differences in copper values between lithological types are similar to those reported in the literature. Thus the mafic volcanic rocks generally contain more copper than the sedimentary and felsic volcanic rocks and these in turn have higher copper concentrations than the plutonic rocks (Fig. 36). The frequency distribution of copper values is more closely normal than that of any other metal studied.

The Lewes River Group (TRVB), which is found in northeastern Aishihik Lake map-area contains far more copper than any other group of rocks in the project area (Figs. 5 and 12d). The Upper Triassic rocks correlate regionally with the Takla and Nicola groups both known to have similarly high copper contents. Not only do these groups of rocks have high copper backgrounds, but regionally they are host to, or closely associated with, many copper occurrences and the Lewes River Group in this region is no exception.

The volcanic rocks (TRVB) are thought to be comagmatic with granodiorite of the Klotassin suite (TRGDM). Interestingly this granodiorite is distinctly copper-poor by comparison with all other rock-units in the region particularly the Lewes River. If the two suites are genetically related their difference reflects very effective partitioning of the copper in this plutonic-volcanic assemblage toward the volcanic phase. A similar concentration of copper in the volcanic part of a cogenetic volcano-plutonic suite is seen in the Nisling Range alaskite (TGAL)-Mount Nansen Group (TMN) and the subvolcanic feldspar-porphyry dykes related to them (TFP). The mean copper content (Fig. 5) varies from 3.7 to 6.3 to 7.5 ppm for the alaskite, dykes and volcanics respectively. Similar partitioning is seen between these three cogenetic groups of rocks for zinc, copper, mercury, silver and arsenic; all are progressively concentrated in the dykes and volcanic parts by comparison with their magmatic equivalants. Lead, molybdenum and tungsten show the reverse relationship and are instead concentrated in the plutonic part relative to the related dykes and volcanic rocks.

The tendency for zinc, copper, mercury, silver and arsenic to be concentrated in the volcanic part of cogenetic volcano-plutonic suites and for lead, molybdenum and tungsten to be preferentially assembled in the plutonic and subvolcanic parts is apparently independent of the chemistry or tectonic setting of the suites. The same trends are seen in the Lewes River-Klotassin, an island arc related group of rocks of basic composition as in the Nisling Range- Mount Nansen, a terrestrial explosive acid suite related to continental extension.

By comparison to the Triassic volcanics and to basaltic rocks in general the tholeiitic basalts of the Carmacks Group (ETCV) and the equivalent Donjek volcanics (LTVD) and the Little Ridge volcanics (TLR) are uniformly copper-poor. No copper occurrences or showings of other metals are known in these rocks and they appear to be poor bets for mineral exploration.

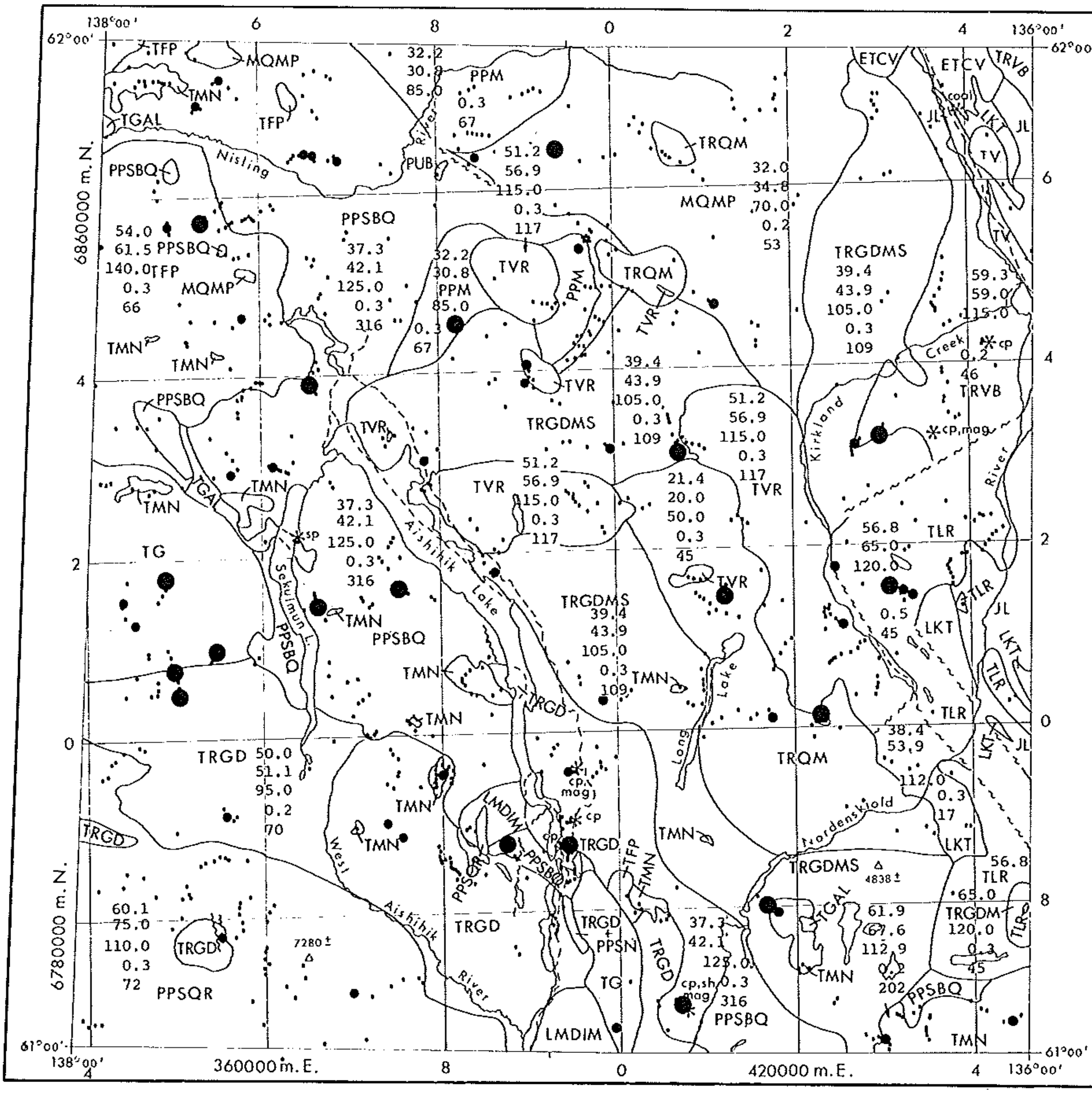
The volcanic rocks south of the Denali fault (PMV and PV) contain interestingly high copper concentrations, but only one or two small copper occurrences are known (see Fig. 20a).

The low background levels of copper in rocks of the Klotassin suite would seem at first glance to rule out the presence of mineralization like that seen at Minto and Williams Creek. There chalcopyrite and bornite occur in schlieren which are conformable with the foliation of the Klotassin. However the concentration of copper in the Klotassin within centimetres of the margins of mineralized zones is the same as the background levels observed in the samples analyzed in the present study (D. Pearson, D. Sinclair, pers. comm. 1976). This implies that the rock geochemistry does not reflect the presence or absence of Minto types of mineralization in the Klotassin suite.

Because copper is low in the plutonic rocks none look like exciting targets for base metal exploration. Even the Nisling Range alaskite, known host to several molybdenum-copper prospects, has little background copper and the copper in this suite of rocks is probably secondary to its molybdenum (see Fig. 5).

Of the metamorphic rocks only the Kluane schist (PPSQR) has high copper. The implications of this, discussed under the heading "zinc", are that this unit has high metal backgrounds, but that it appears unexciting to exploration because no concentrations are known. The carbonate (PPC+) in Aishihik Lake map-area is host to several copper-tungsten occurrences. Because the carbonate itself has copper and tungsten backgrounds similar to those found in carbonate rocks elsewhere, the metals in the deposits apparently originated from outside the carbonate.

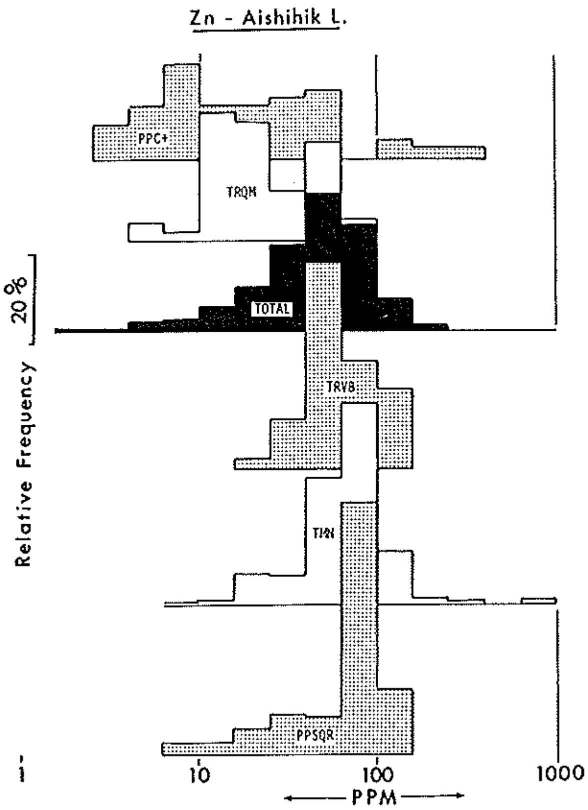
The copper geochemistry points to the basalts (TRVB) correlated with the Lewes River as the one interesting assemblage for copper occurrences. Along with copper those rocks also have anomalously high zinc, mercury and silver.



Zn - AISHIHIK LAKE 115H

0 20km

a



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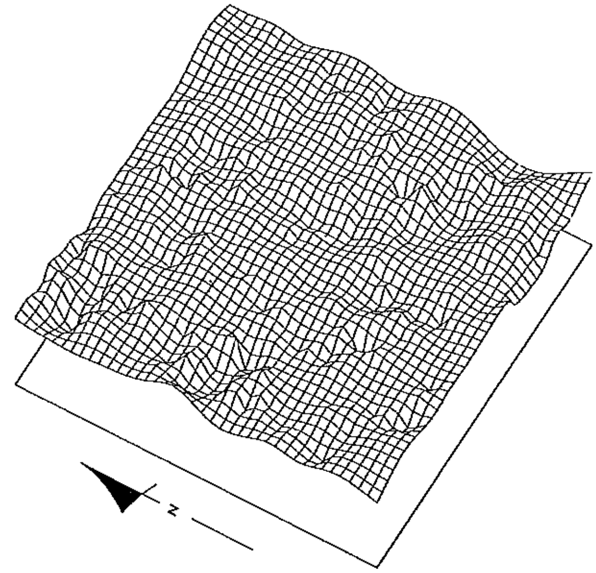

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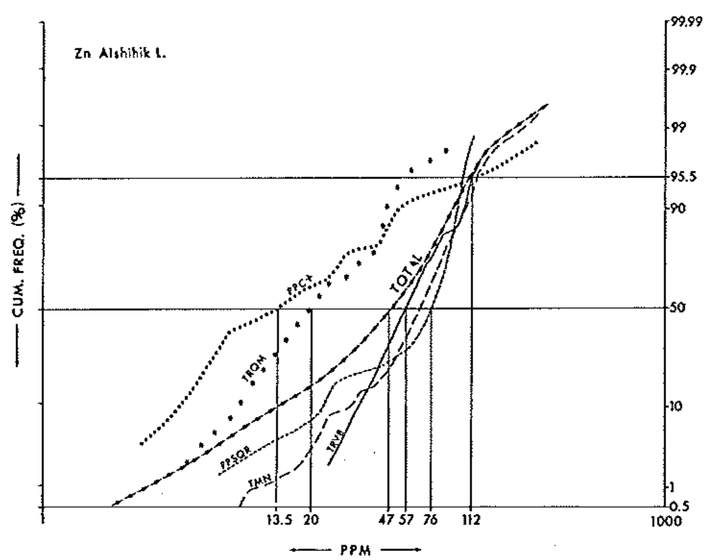


d

Figure 11

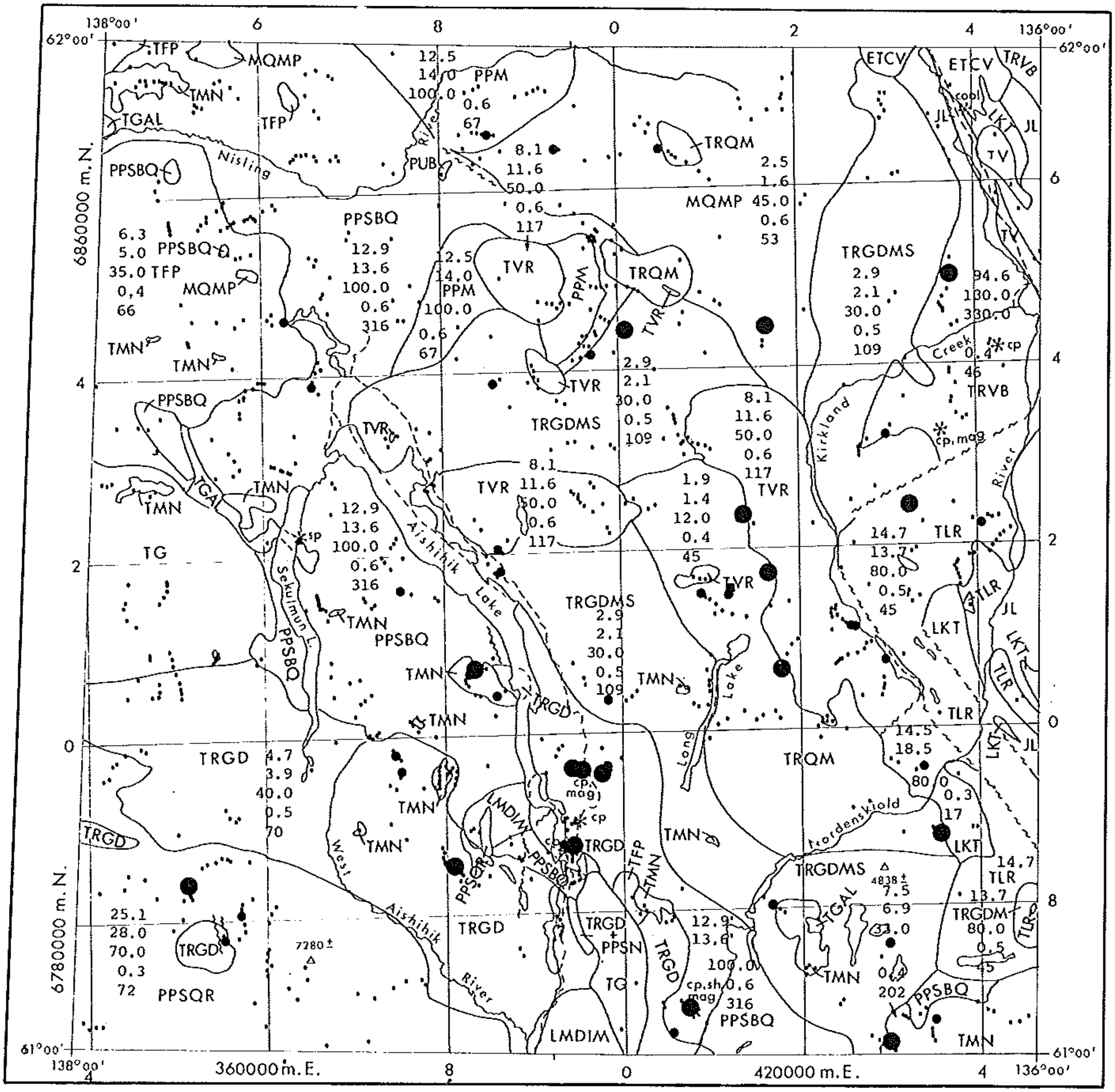
Zinc – Aishihik Lake map-area

Geological sketch map of Aishihik Lake map-area showing statistical parameters related to the geochemistry of zinc for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of zinc were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of zinc in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for zinc during the project and are shown for comparison. The perspective diagram displays the zinc geochemistry as a moving average in the third dimension so it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the zinc concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

The explosive acid volcanic rocks of the Mount Nansen Group (TMN) and the basalt of the Lewes River Group (TRVB) are important as exploration targets in Aishihik Lake map-area because a number of mineral occurrences are known in these rocks. The histograms show that their background zinc is also comparatively high. In addition to their high zinc content the tuffs of the Mount Nansen Group also contain above average amounts of silver and arsenic whereas the Lewes River Group has high concentrations of copper, mercury and silver. The Kluane schist (PPSQR) contains more zinc and other metals than most of the other map-units, but because no mineral occurrences are known in these schists they are thought less important for prospecting. Note the extremely low concentrations of zinc in the pink quartz monzonite (TRQM). The plutonic rocks of Yukon Crystalline Terrane generally have low concentrations of all metals even by comparison to plutonic rocks elsewhere. As a general rule the more felsic plutonic rocks contain less zinc than the more mafic varieties.

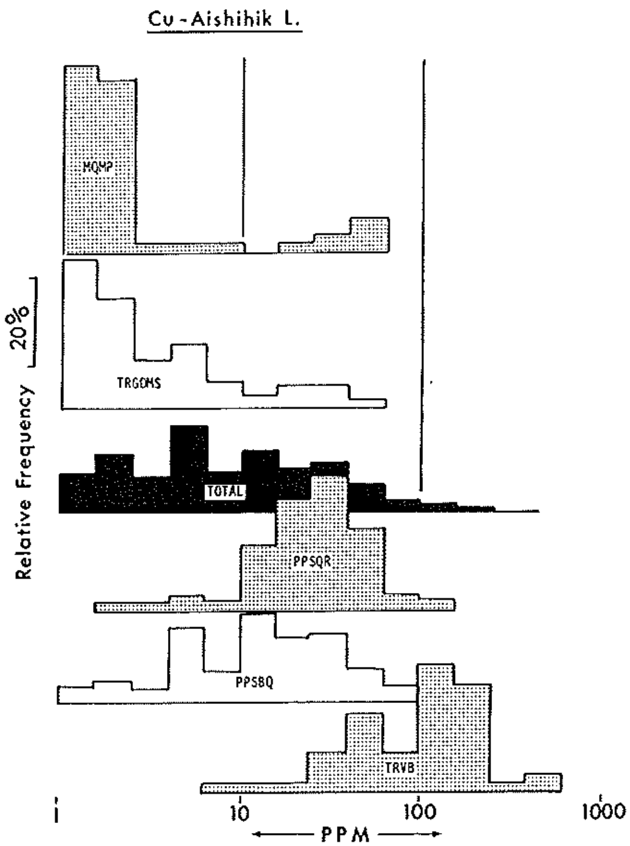
The map (Fig. 11a) and perspective diagram (Fig. 11c) demonstrate the comparative homogeneity of the zinc concentration in Aishihik Lake map-area.



Cu - AISHIHIK LAKE 115H

0 20 km

a



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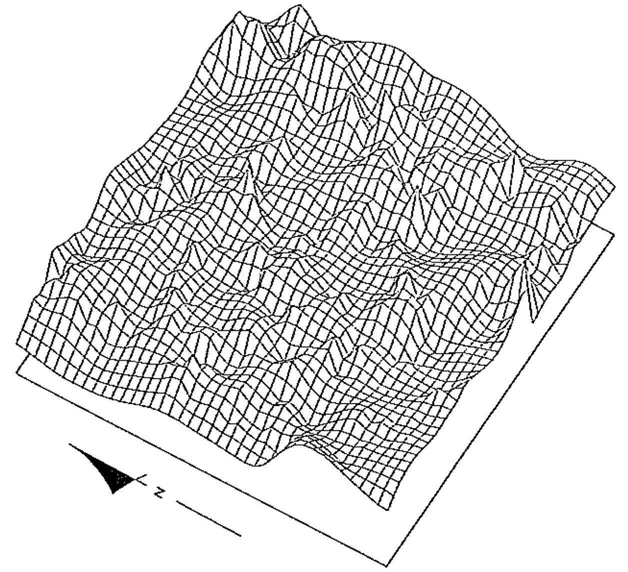

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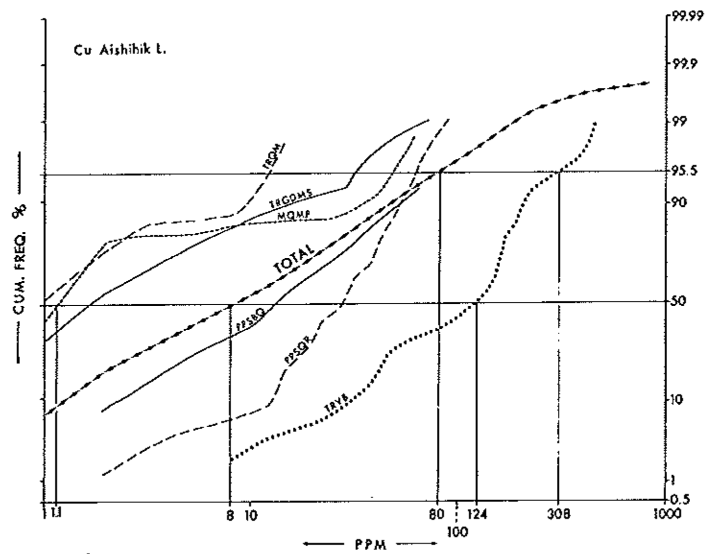

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Figure 12

Copper – Aishihik Lake map-area

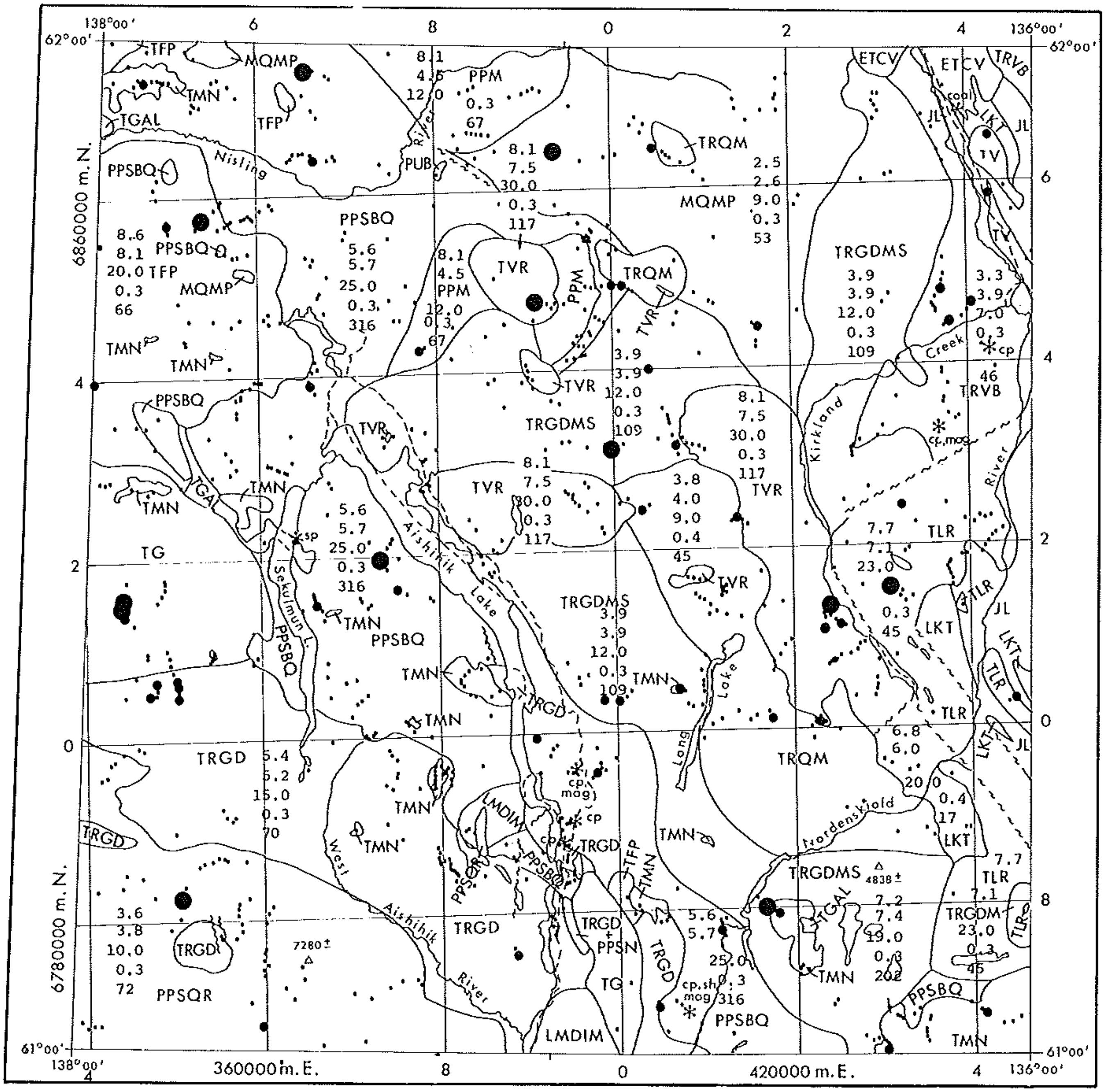
Geological sketch map of Aishihik Lake map-area showing statistical parameters related to the geochemistry of copper for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of copper were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of copper in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for copper during the project and are shown for comparison. The perspective diagram displays the copper geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the copper concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

Note the large differences in the concentration of copper between the various rock-units illustrated. The fifty percentile concentration varies through two orders of magnitude. The cumulative curves and histograms show that the distribution of copper is multimodal in several of the rock-units, particularly MQMP, the pink quartz monzonite and TRVB, the Lewes River Group.

The Lewes River Group (TRVB) and Klotassin quartz diorite (TRDGMS) may be cogenetic. If so this volcano-plutonic pair shows extreme partitioning of the copper into the volcanic phase. Partitioning of copper and other metals is also seen in another volcanic-plutonic suite, the Mount Nansen-Nisling Range alaskite (see for example Fig. 17d, 18d). The plutonic rocks all have extremely low copper concentrations and it is difficult to distinguish between the plutonic suites on the basis of their copper distributions. The high copper background of the Kluane schist (PPSQR) does not relate to the number of mineral occurrences found in this unit. It is thought to reflect sediment dispersal patterns during deposition of these rocks and appears to have been unaltered during their subsequent metamorphism.

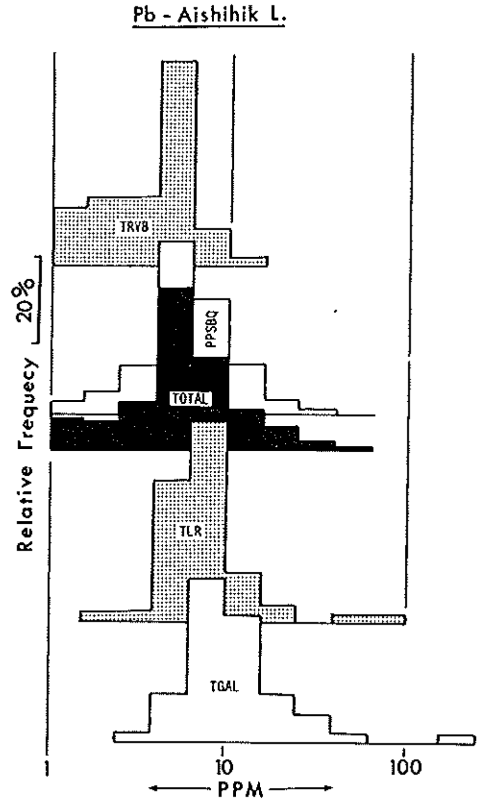
The perspective portrayal of the moving average (Fig. 12c) reflects the high copper concentration of the Lewes River Group (northeast corner) and the Kluane schist (southwest corner) and the generally less abundant copper in the intervening ground. This correlates neatly with the map (Fig. 12a). Contrast the perspective diagrams of zinc and copper (Fig.s 11c and 12c).



Pb–AISHIHIK LAKE 115H

a

0 20 km



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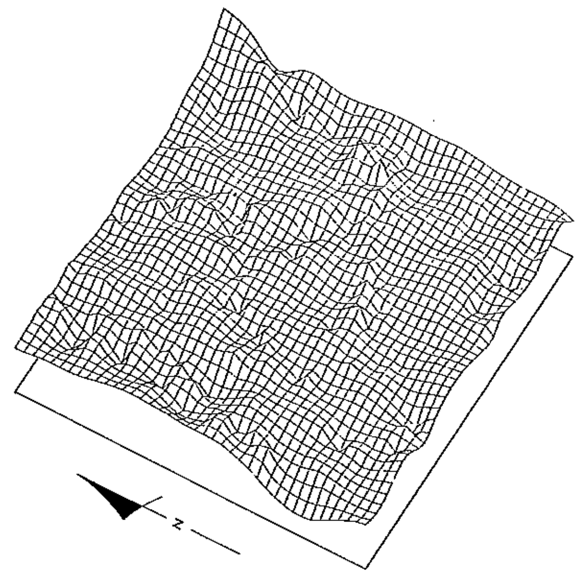

c

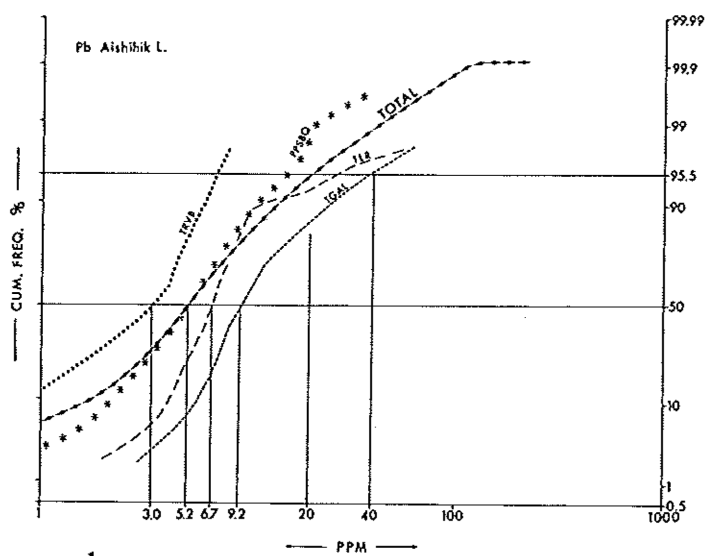

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Figure 13

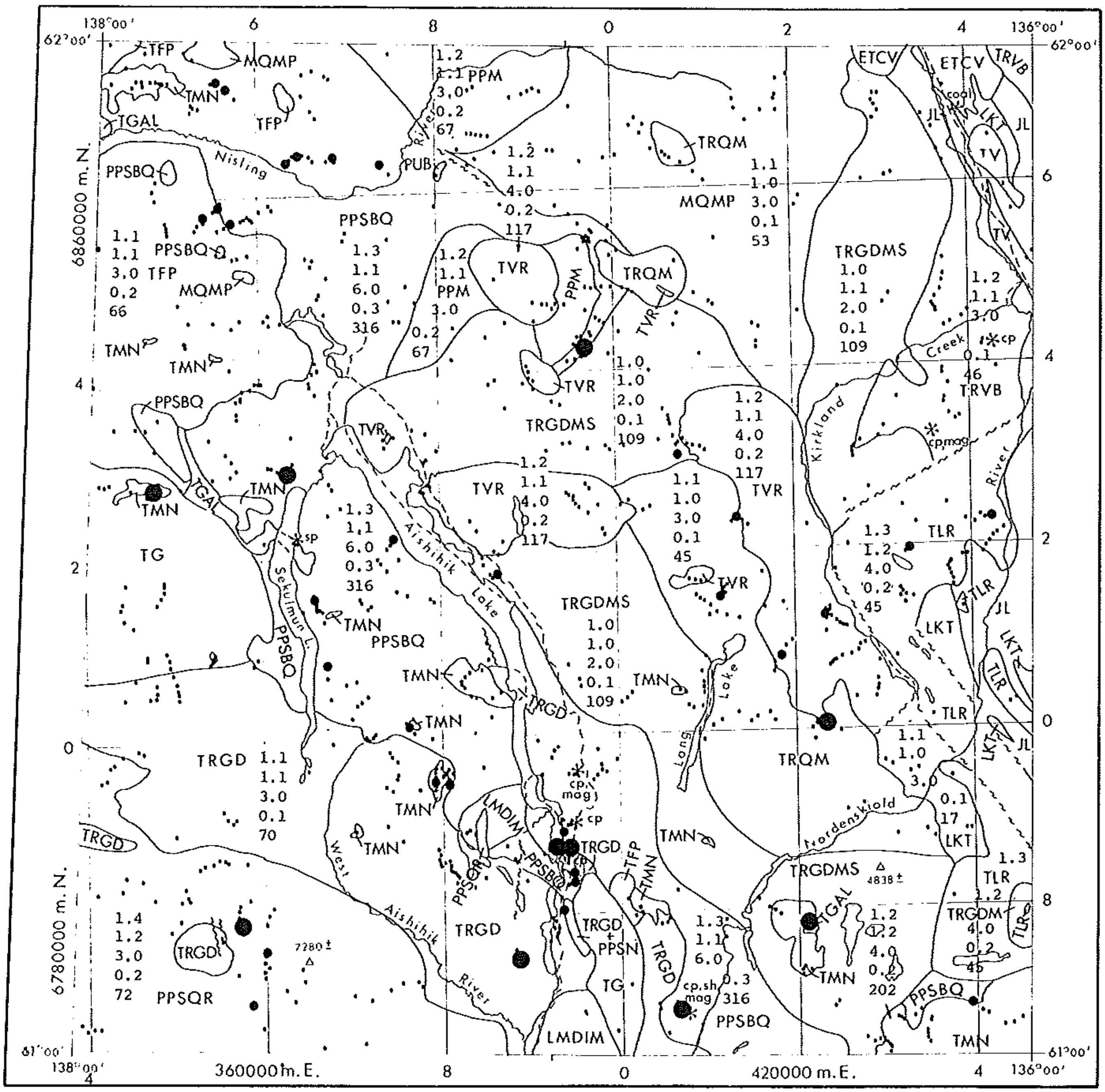
Lead – Aishihik Lake map-area

Geological sketch map of Aishihik Lake map-area showing statistical parameters related to the geochemistry of lead for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of lead were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of lead in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for lead during the project and are shown for comparison. The perspective diagram displays the lead geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the lead concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

The histograms and cumulative curves show the same data for selected rock-units in Aishihik Lake map-area. There is less variation in the lead content of the rocks than in that of zinc or copper. The distributions illustrated were chosen to demonstrate the largest range in lead concentrations. Nisling Range alaskite (TMN) has more lead than any other rocks studied and the Lewes River Group (TRVB) contains the least lead. The lead concentration in the rocks results largely from differentiation or dispersal and is considered least useful as a guide to rock-units likely to contain economic concentrations of this or other metals.

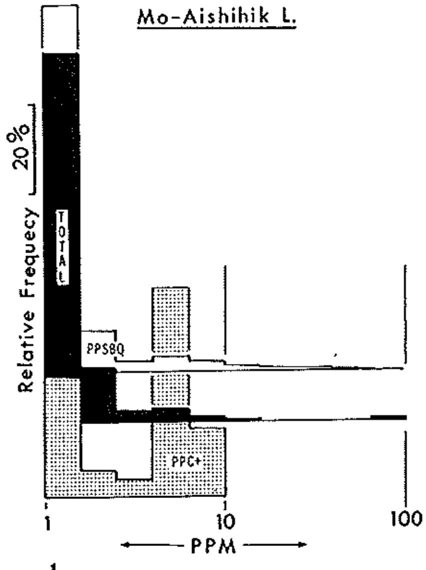
The map (Fig. 13a) and perspective diagram (Fig. 13c) show the comparatively low relief of the lead concentration and both pinpoint individual anomalously high values rather than highs related to rock-units.



Mo-AISHIHIK LAKE 115H

0 20 km

a



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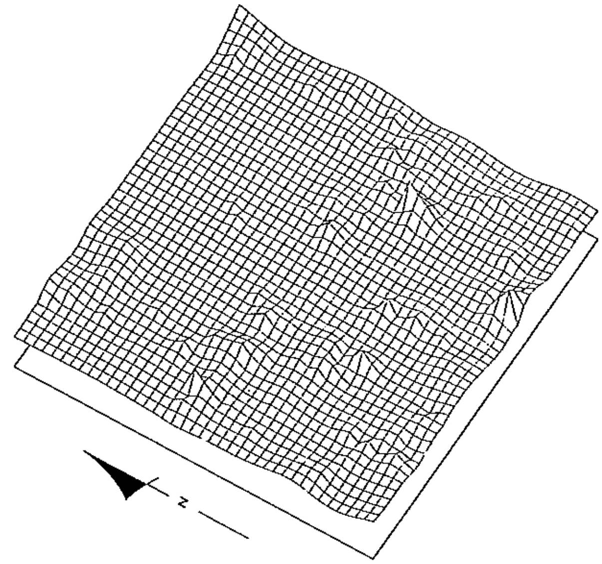

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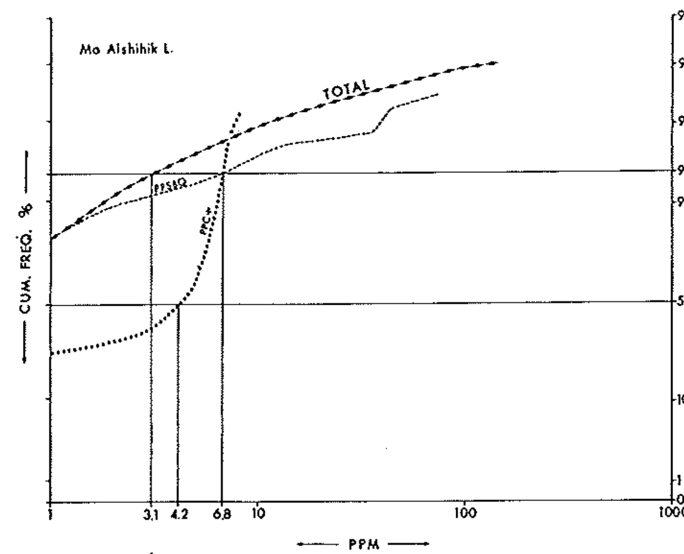

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Figure 14

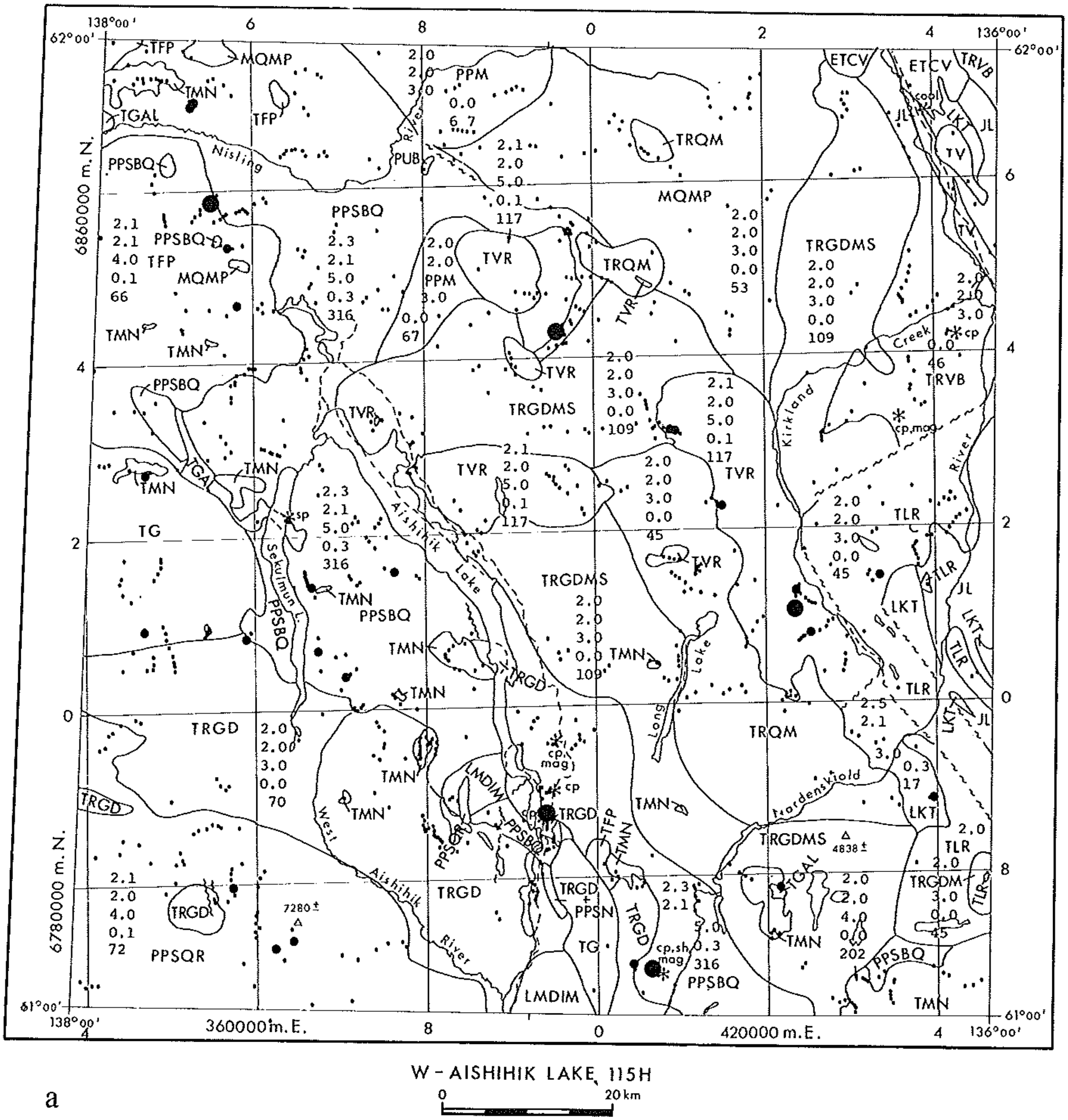
Molybdenum – Aishihik Lake map-area

Geological sketch map of Aishihik Lake map-area showing statistical parameters related to the geochemistry of molybdenum for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. Sampled localities are shown by small dots and samples with anomalously high concentrations of molybdenum are indicated by large dots. Histograms illustrate the frequency distributions of molybdenum in some map-unit assemblages; they are selected to demonstrate the variation between rock-units. The distribution labelled TOTAL represents all samples analyzed for molybdenum during the project; they are shown for comparison. The perspective diagram displays the molybdenum geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For analytical results concerning specific samples the reader is referred to Appendix 1

Note that the scale of molybdenum concentrations in the histograms is logarithmic.

The histograms emphasize the limits imposed by the analytical techniques and do not show the true nature of the molybdenum frequency distributions. Nevertheless the relatively high concentration and bimodal distribution of molybdenum in the marbles (PPC+) of souterh Aishihik Lake map-area is clear. Molybdenum and tungsten are chemically similar and tend to be concentrated in the same rocks. The Nisling Range alaskite (TGAL) and the marbles (PPC+) each have high concentrations of both metals. The Nisling Range alaskite not only has above normal background levels of molybdenum, but is host to concentrations of this metal at several localities within and adjacent to Aishihik Lake map-area. Two such occurrences are at Casino and Mount Cockfield in Snag map-area. The Adanac molybdenum-copper deposit in northern British Columbia is in equivalent rocks.

The map (Fig. 14a) and perspective diagram (Fig. 14c) emphasize spot highs rather than areal highs and lows related to rock-units with outstanding concentrations of molybdenum. The prominent peak southeast of the centre of Aishihik Lake map-area reflects a sample of tuff (TVR) with 30 ppm molybdenum.



a

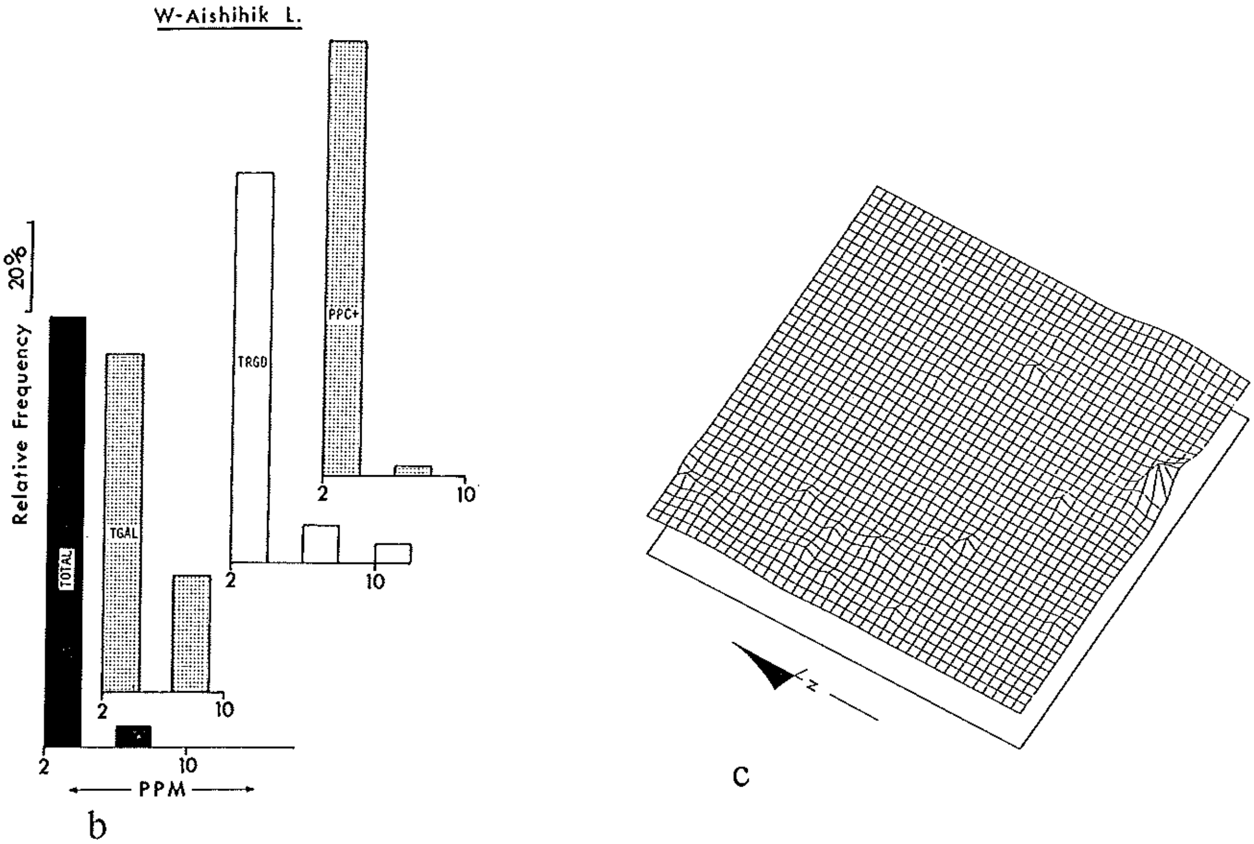


Figure 15

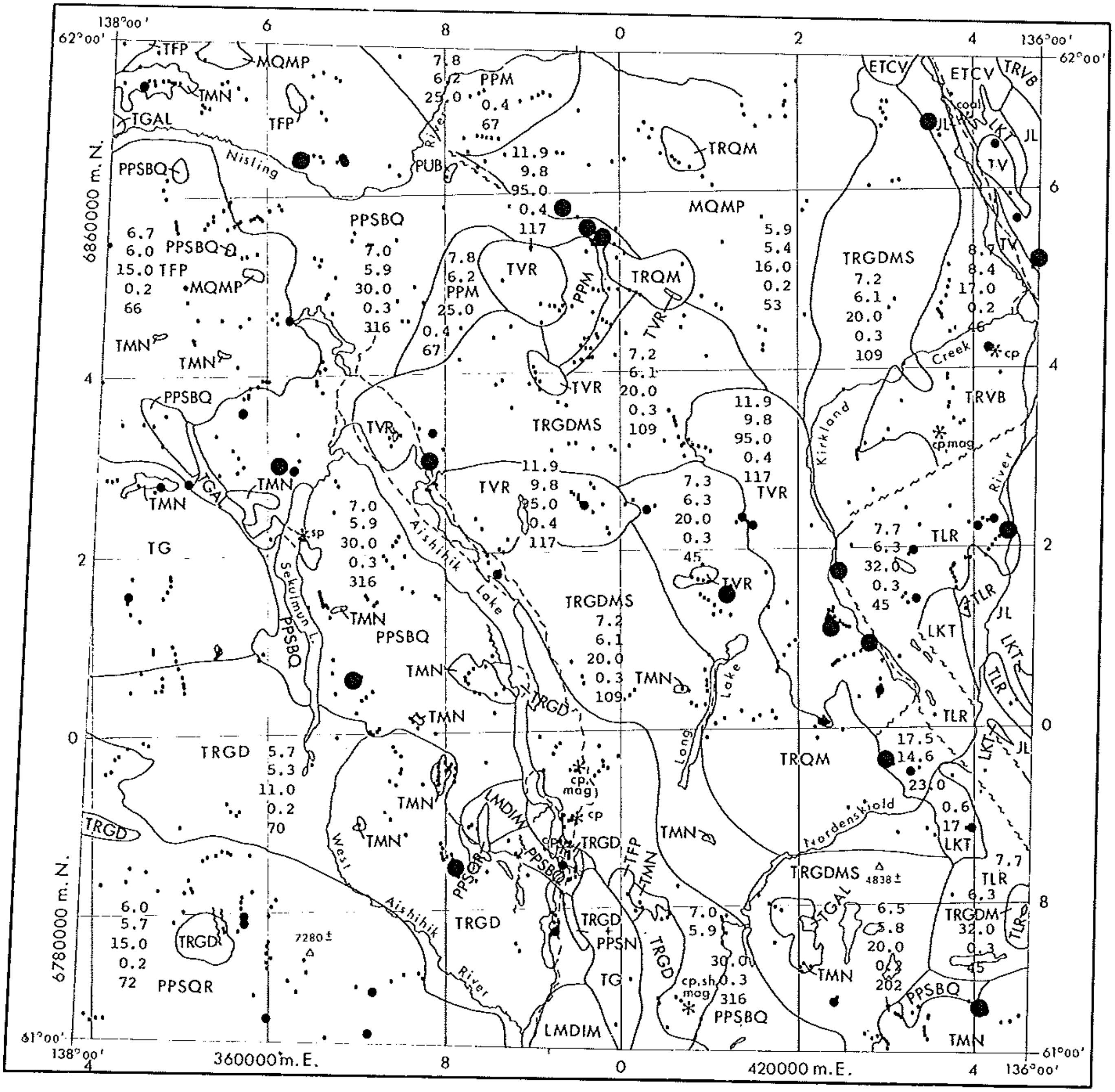
Tungsten – Aishihik Lake map-area

Geological sketch map of Aishihik Lake map-area showing statistical parameters related to the geochemistry of tungsten for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. Sampled localities are shown by small dots and samples with anomalously high concentrations of tungsten are indicated by large dots. Histograms illustrate the frequency distributions of tungsten in some map-unit assemblages; they are selected to demonstrate the variation between rock-units. The distribution labelled TOTAL represents all samples analyzed for tungsten during the project; they are shown for comparison. The perspective diagram displays the tungsten geochemistry as a moving average in the third dimension so it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For analytical results concerning specific samples the reader is referred to Appendix 1.

Note that the scale of tungsten concentrations in the histograms is logarithmic.

The histograms demonstrate that the frequency distribution of tungsten is highly skewed. This is because of analytical limitations and the histograms do not portray the real frequency distribution of this metal. Only the high end of the distribution is shown by the histograms. As noted in Figure 14 the alaskite (TGAL) and marbles (PPC+) have higher tungsten concentrations than other rock-units and both units are host to several small tungsten showings. In addition to its high tungsten and molybdenum content the alaskite has a high zinc content. Together with the genetically related Mount Nansen and feldspar porphyries it is among the most interesting as a target unit for mineral exploration.

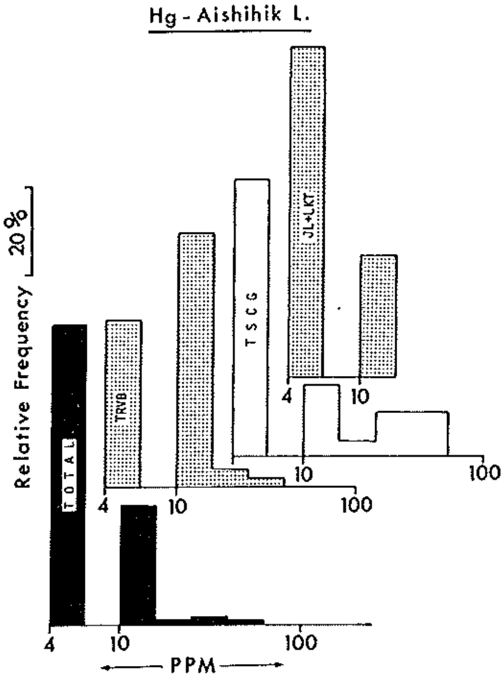
The perspective diagram (Fig. 15c) reflects only the spot high values whereas the map (Fig. 15a) shows the areal distribution of the rock-units with the higher and lower tungsten concentrations. Note the row of spot highs that trends from south-central Aishihik Lake map-area to its northwest corner generally along the northeast edge of the region in which the Nisling Range alaskite occurs. The high peak at the south-central edge is spurious because it results from two samples of a small showing that contained scheelite.



Hg - AISHIHIK LAKE 115H

0 20 km

a



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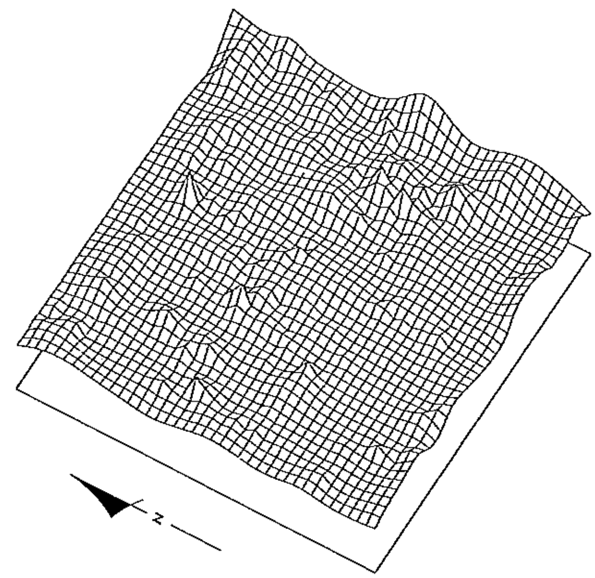


c

Figure 16

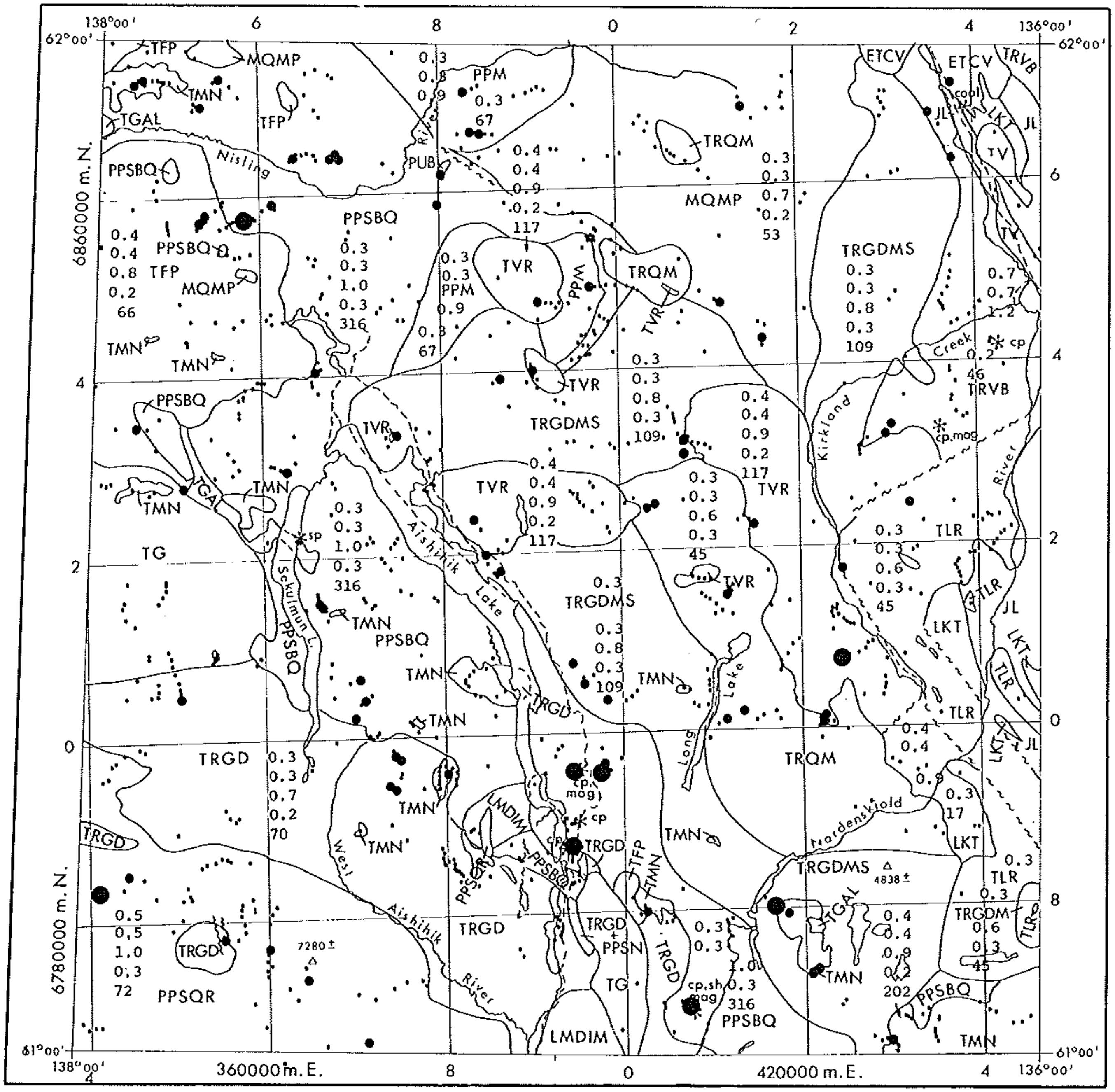
Mercury – Aishihik Lake map-area

Geological sketch map of Aishihik Lake map-area showing statistical parameters related to the geochemistry of mercury for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. Sampled localities are shown by small dots and samples with anomalously high concentrations of mercury are indicated by large dots. Histograms illustrate the frequency distributions of mercury in some map-unit assemblages; they are selected to demonstrate the variation between rock-units. The distribution labelled TOTAL represents all samples analyzed for mercury during the project; they are shown for comparison. The perspective diagram displays the mercury geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For analytical results concerning specific samples the reader is referred to Appendix 1.

Note that the scale of mercury concentrations in the histograms is logarithmic.

The histograms show that mercury is subject to similar analytical limitations as molybdenum and tungsten and again they only illustrate the frequency distribution at the higher mercury abundances. Nevertheless the data show that the sedimentary rocks, including the marine Laberge Group (JL) and nonmarine Tantalus Formation (LKT) as well as the fluvial sandstone and conglomerate in the Carmacks Group (TSCG), have comparatively high concentrations of this metal. The basalt (TRVB) of the Lewes River Group, geochemically high in copper, zinc and silver, also has more mercury than other rock-units. This unit is host to several copper occurrences but no mercury concentrations are known. The varicoloured tuffs (TVR) have relatively high mercury contents but no showings are known. The three samples with high mercury values in these rocks contain 200, 100 and 90 ppm and the area where these are known warrants investigation.

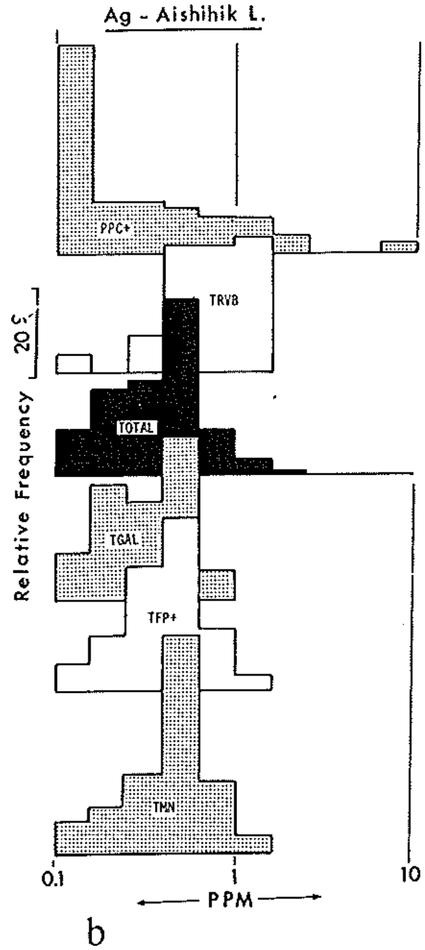
The map (Fig. 16a) shows the areal distribution of these rock-units and their concentration of mercury and the perspective diagram (Fig. 16c) gives a three dimensional portrayal of the data. Along the east side of Aishihik Lake map-area are the rock-units with high mercury background levels mentioned above but in the rest of the map-area only scattered spot highs in low background units are seen. The prominent peak in north-central Aishihik Lake map-area reflects a sample with 750 ppm mercury.

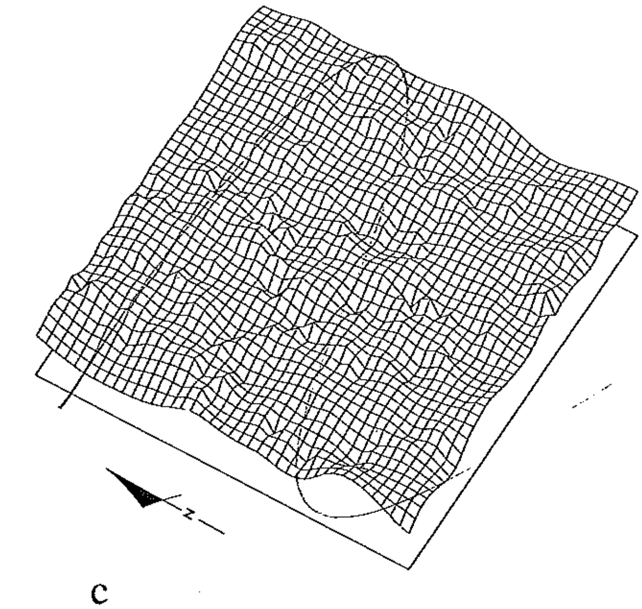


Ag - AISHIHIK LAKE 115H

0 20 km

a





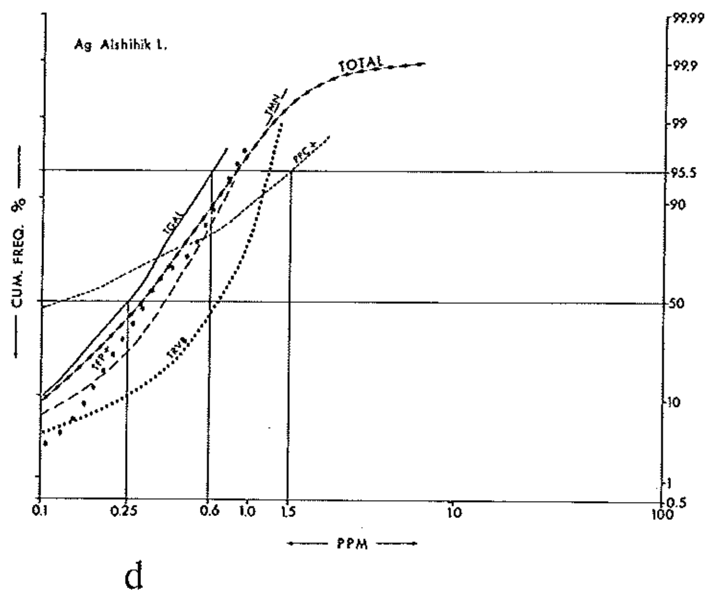


Figure 17

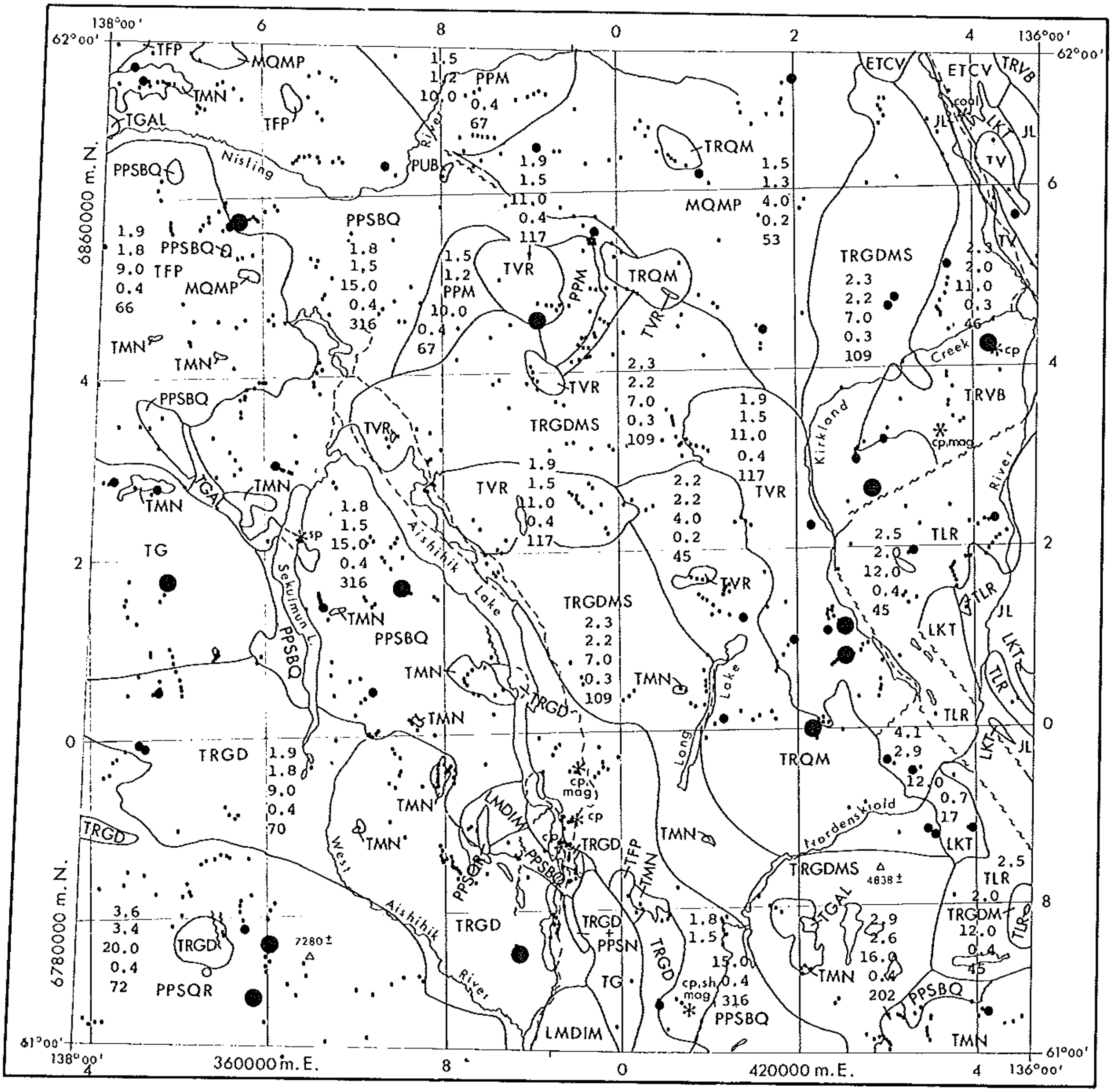
Silver – Aishihik Lake map-area

Geological sketch map of Aishihik Lake map-area showing statistical parameters related to the geochemistry of silver for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of silver were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of silver in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for silver during the project and are shown for comparison. The perspective diagram displays the silver geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the silver concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

The frequency distribution of silver in different rock-units is like that of lead in that it tends to vary little between the majority of the rock-units. The Lewes River Group (TRVB) however has anomalously high concentrations of silver. This probably relates to the higher than average zinc, copper and mercury contents also found in this map-unit. Note the difference in the distribution of silver between the marbles (PPC+) and Lewes River Group (TRVB). The first is positively skewed and the second is negatively skewed. Also note the wider range in silver values (i.e. high standard deviation) in the marbles (PPC+) by comparison to the other rock-units. The histograms and cumulative curves illustrate the partitioning of silver into the volcanic part of the cogenetic suite which includes the Nisling Range alaskite (TGAL), feldspar porphyry dykes (TFP+) and Mount Nansen explosive volcanics (TMN). These three related rock-units also display the same sense of concentration in favour of the volcanic suite for zinc, copper, mercury and arsenic. By contrast lead, molybdenum and tungsten are concentrated towards the plutonic phase (see Fig. 5).

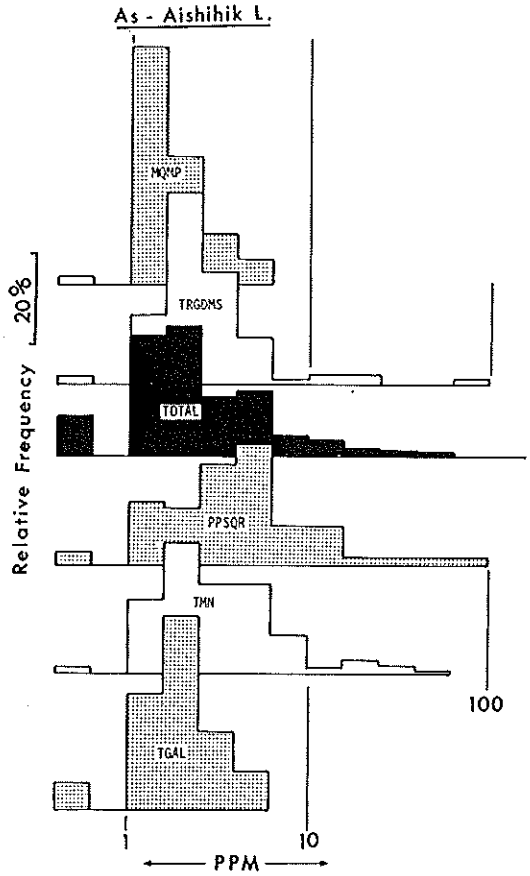
The map (Fig. 17a) and perspective diagram (Fig. 17c) complement one another. The first shows those areas underlain by map-units with higher and lower backgrounds of silver while the second emphasizes that the silver concentration is rather uniform with the exception of the spot highs and that differences in silver concentration between map-units are small.



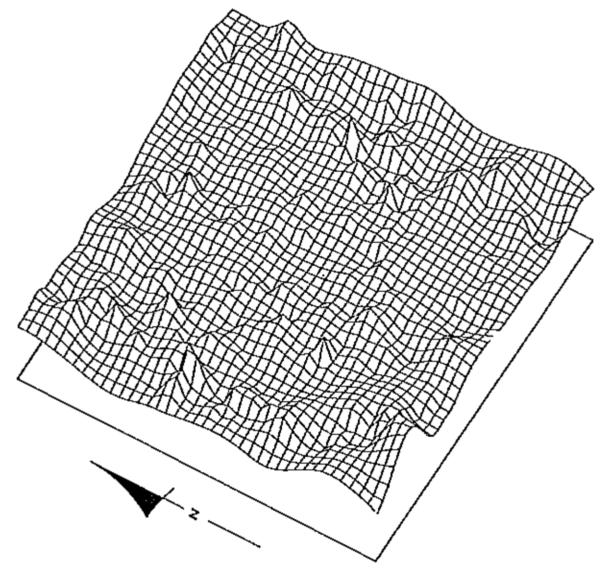
As - AISHIHIK LAKE 115H

a

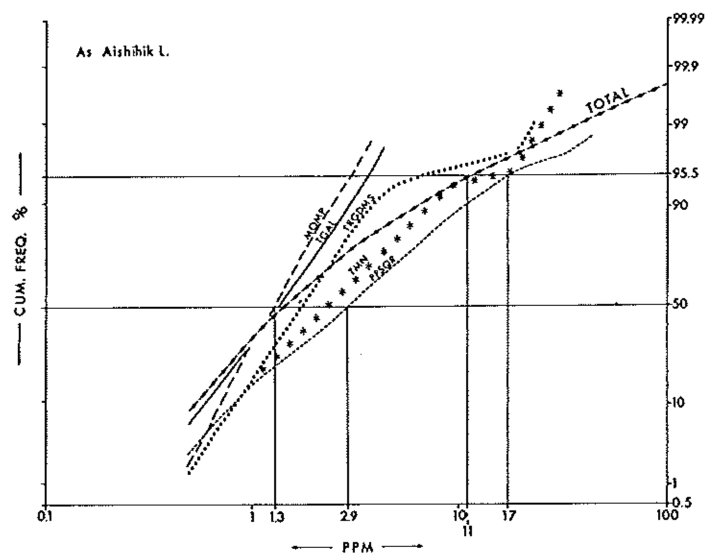
0 20 km



b



c



d

Figure 18

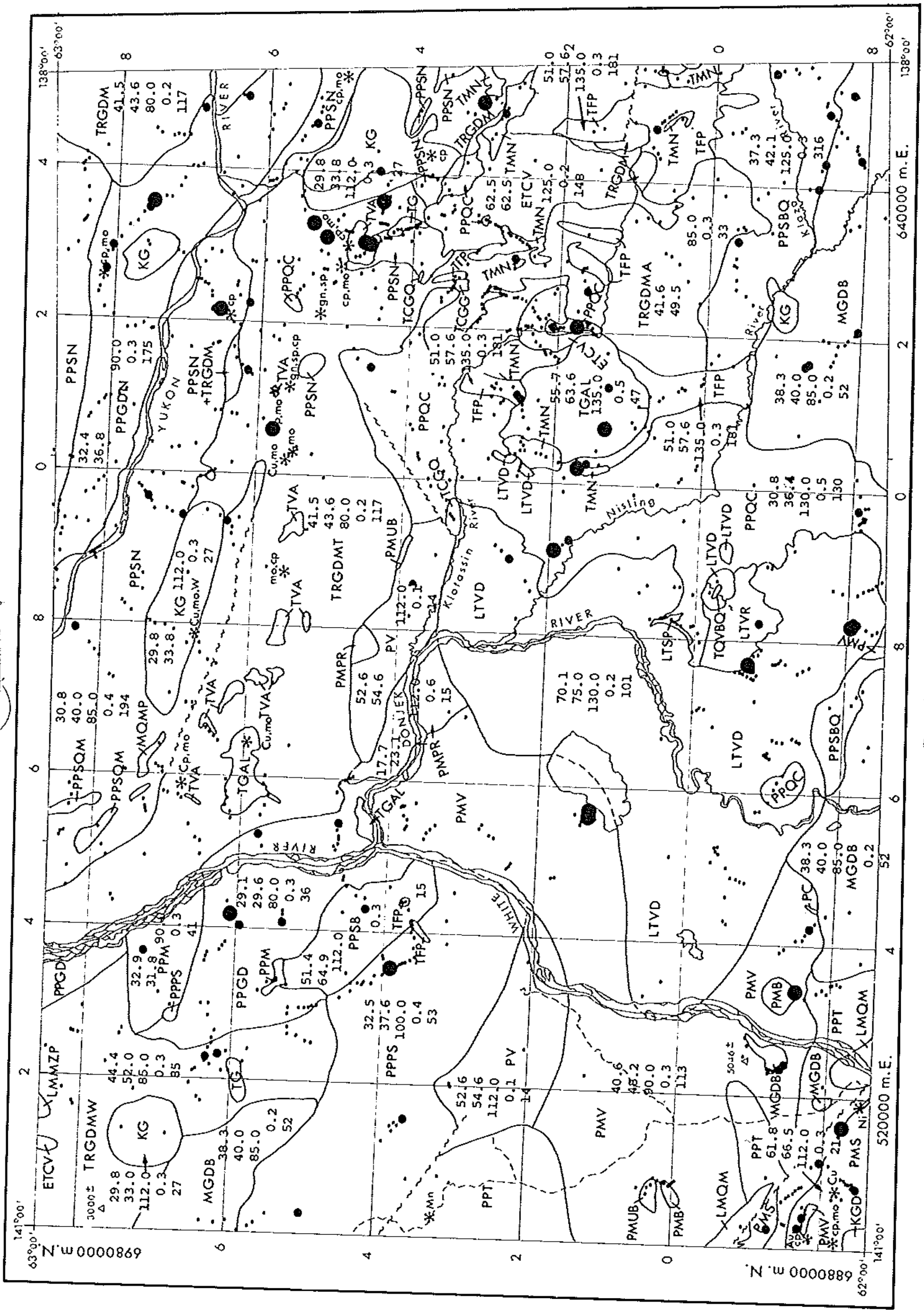
Arsenic – Aishihik Lake map-area

Geological sketch map of Aishihik Lake map-area showing statistical parameters related to the geochemistry of arsenic for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of arsenic were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of arsenic in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for arsenic during the project and are shown for comparison. The perspective diagram displays the arsenic geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the arsenic concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

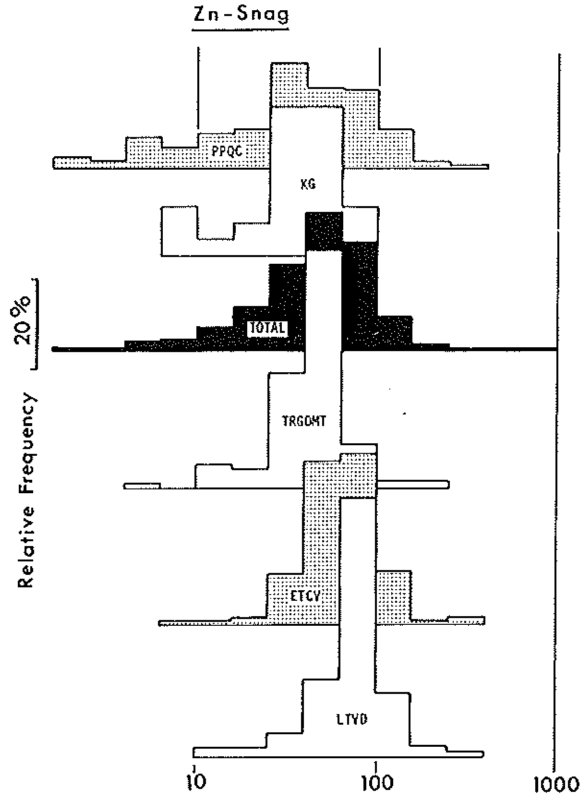
The concentration of arsenic varies considerably among rock-units and in Aishihik Lake map-area the Kluane schist (PPSQR), Mount Nansen Group (TMN) and Tantalus Formation (LKT) have the highest arsenic contents whereas the lowest concentrations are seen in the various plutonic rock-units. The range in arsenic concentrations in the plutonic rocks is also much lower than that in the schist and volcanic rocks (e.g. contrast the slopes of PPSQR and MQMP in Fig. 18d). This implies that substitution of arsenic for other metals in the plutonic rocks is more specific than in the metamorphic and volcanic rocks. These differences are illustrated by the histograms (Fig. 18b) and cumulative curves (Fig. 18d).

The perspective diagram (Fig. 18c) emphasizes the spot highs, but also reflects high and low background areas that correspond to areas underlain by some of the responsive and unresponsive rock-units mentioned above.

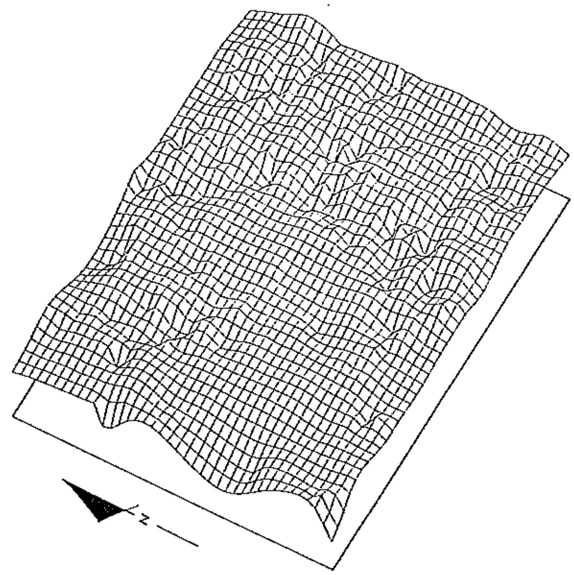


Zn – SNAG 115 J & K

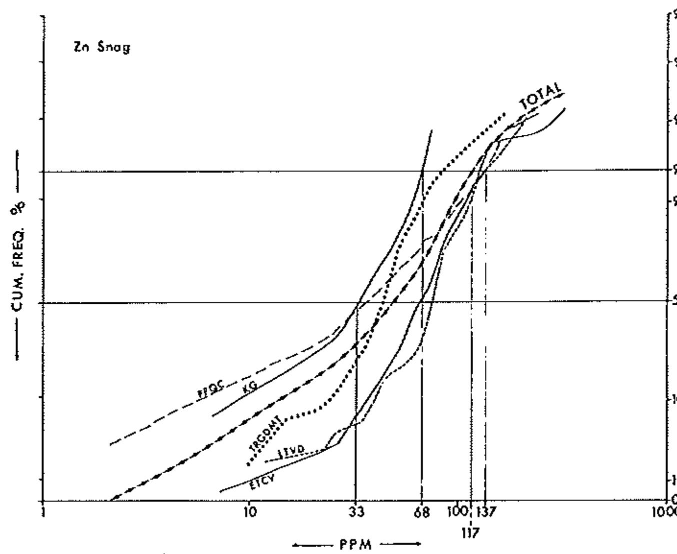
a



b



c



d

Figure 19

Zinc – Snag map-area

Geological sketch map of Snag map-area showing statistical parameters related to the geochemistry of zinc for the areally extensive map-units. From the top down these are the mean and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of zinc were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of zinc in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for zinc during the project and are shown for comparison. The perspective diagram displays the zinc geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the zinc concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

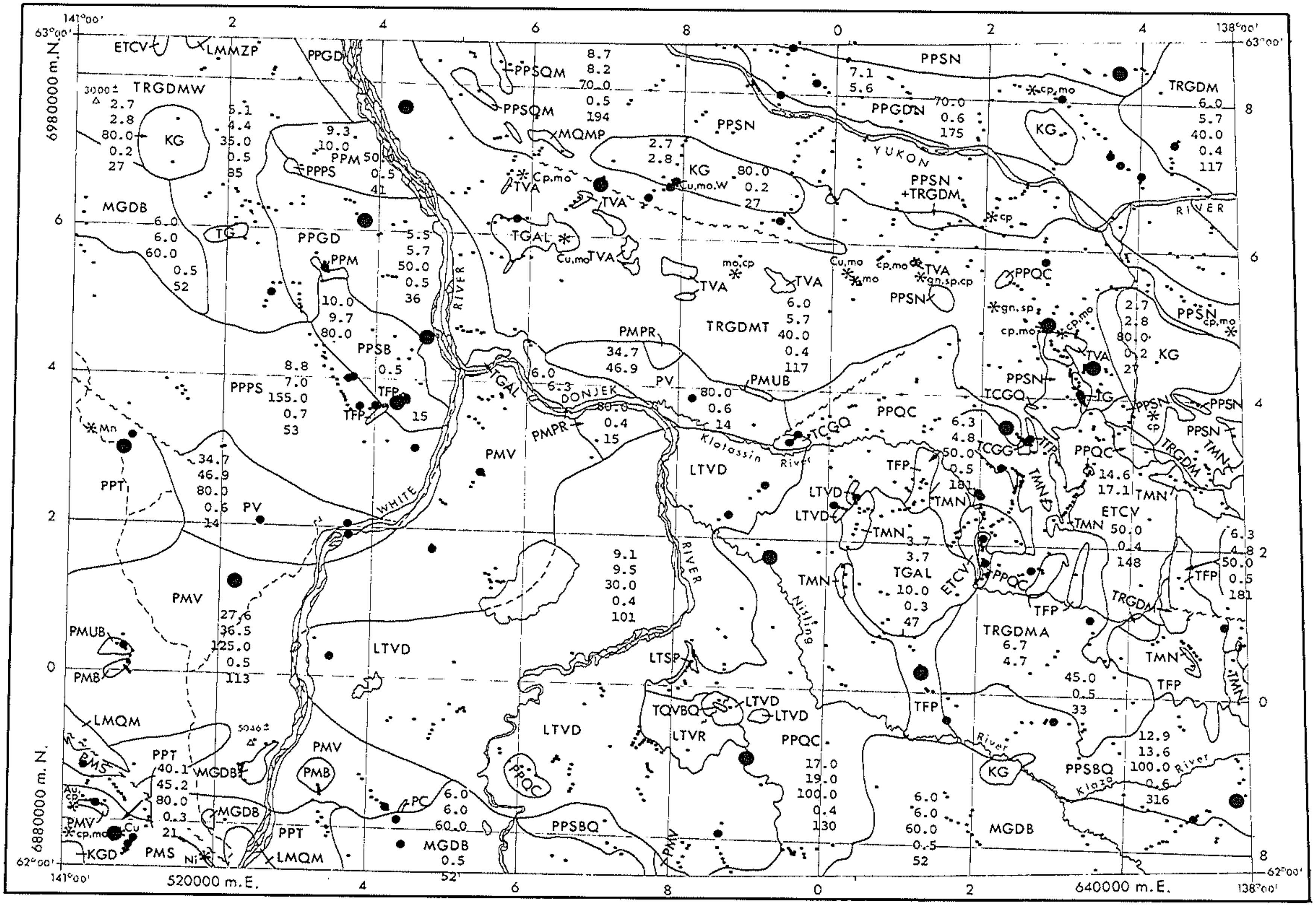
Among all the rocks analyzed the mean and threshold zinc concentrations are 41.5 and 112 ppm respectively. In Snag map-area the zinc values range through three orders of magnitude, but the highest and lowest fifty percentile values differ only by a factor of two. Differences between the populations in terms of standard deviation are therefore more distinctive than differences based on mean metal concentration.

Note that the Donjek volcanics (LTVD) and the equivalent Carmacks Group (ETCV) contain distinctly above average concentrations of zinc as expected for such basaltic suites. Also predictable are the comparatively low levels of zinc in the Klotassin granodiorite (TRGDMT) and Coffee Creek quartz monzonite (KG). Steepness of the cumulative frequency curves LTVD, ETCV and TRGDMT reflects the comparatively small range in values of these distributions which is reflected in the low standard deviations of these distributions. They also have large positive kurtosis (leptokurtic).

Most of the rocks southwest of the Shakwak-Denali fault have high concentrations of all the metals analyzed except tungsten. Their zinc background is high. The area southwest of the Shakwak-Denali fault is geochemically as distinct from the Yukon Crystalline Terrane as it is geologically and the perspective diagram shows this fairly clearly.

The low zinc levels of the Nasina quartzite (PPQC) are a surprise for a metamorphic rock unit made up originally of graphitic shale. Such shales are commonly rich in zinc and other metals (Levinson, 1974). The Nasina quartzite is broadly correlative with the Road River shale of Selwyn Basin.

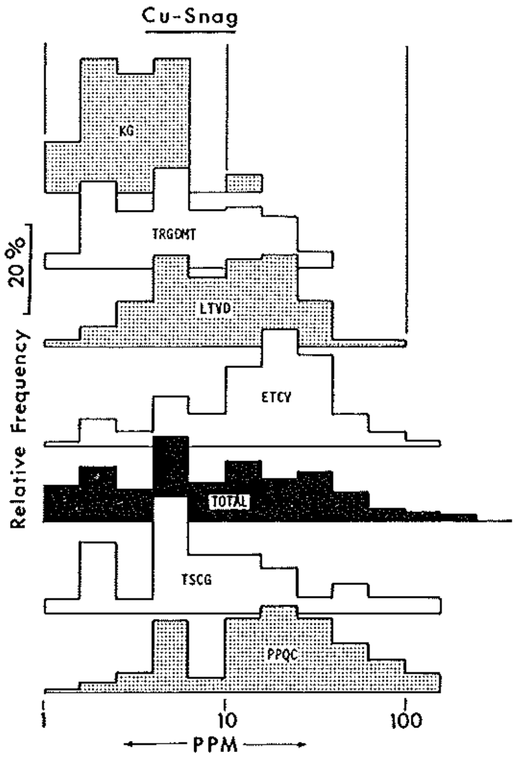
The map and perspective diagram complement each other. The first emphasizes the spot highs and the second points to the active and inactive zinc areas. Much of the region around Wellesley Lake appears uninteresting on the perspective diagram, but this is partly influenced by low sample density in this region and lack of relief in this area is seen in many perspective diagrams for the other metals.



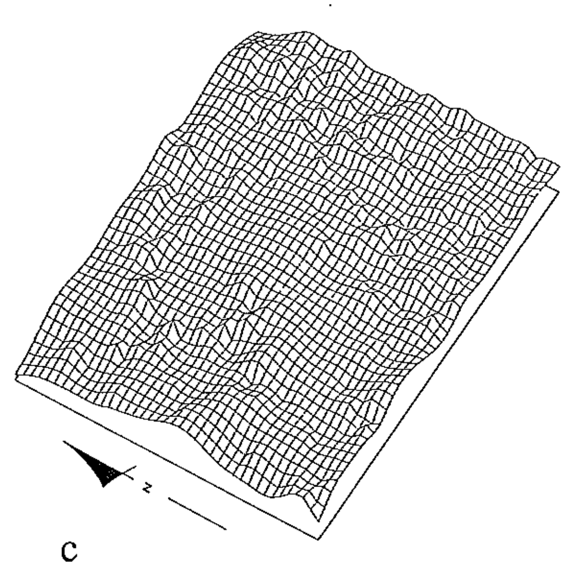
Cu – SNAG 115 J & K

0 20km

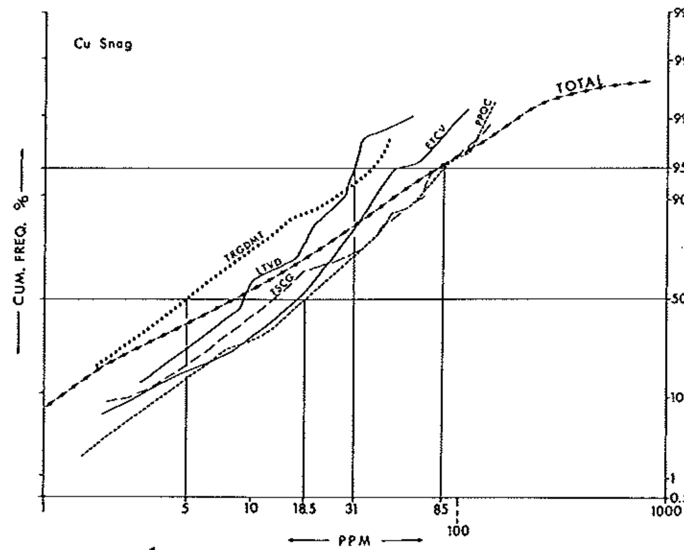
a



b



c



d

Figure 20

Copper – Snag map-area

Geological sketch map of Snag map-area showing statistical parameters related to the geochemistry of copper for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of copper were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of copper in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed from copper during the project and are shown for comparison. The perspective diagram displays the copper geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

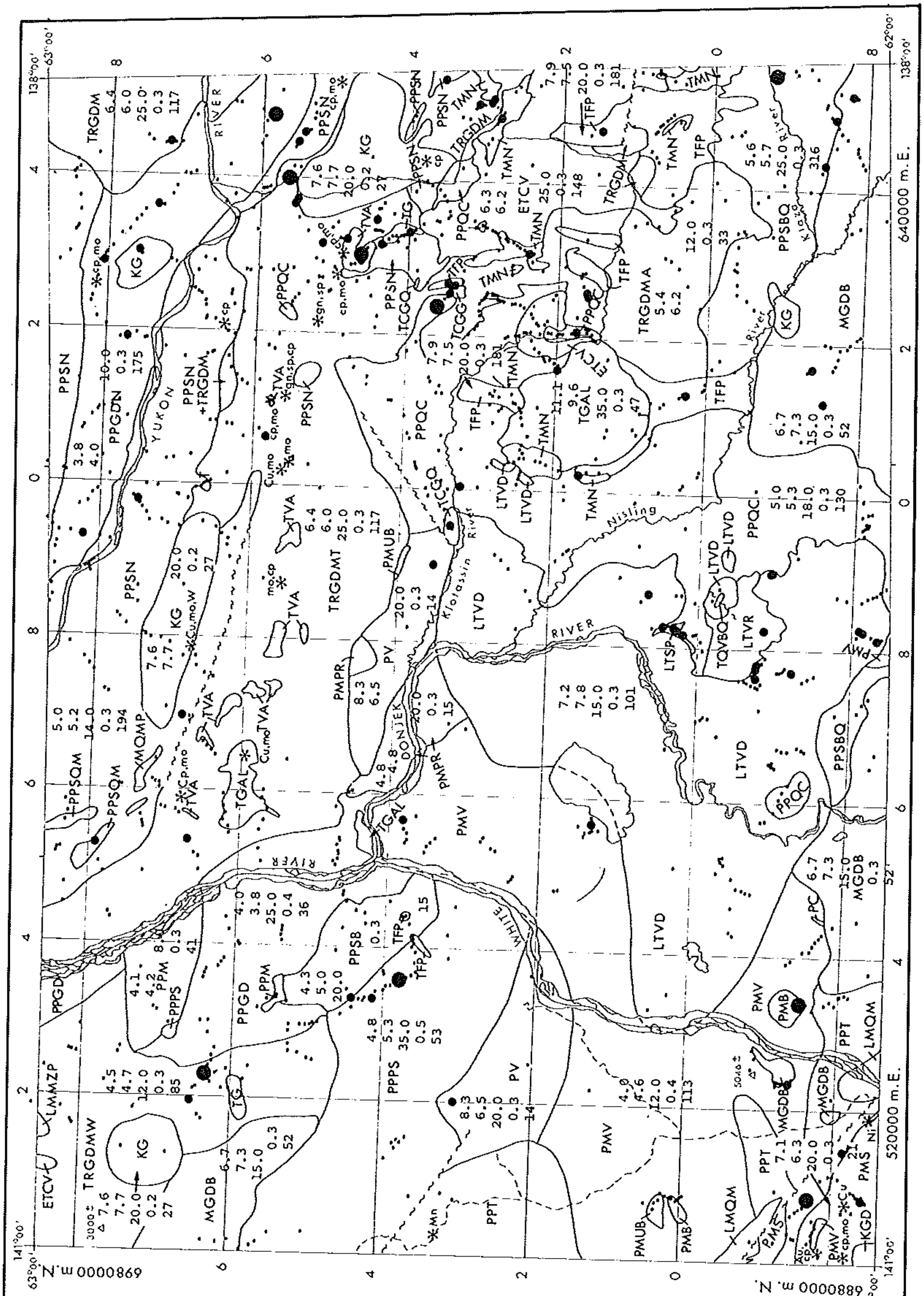
Note that in the histograms and cumulative curves the scale of the copper concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

Of all the rocks analyzed the mean and 95.5 percentile copper concentrations are 8.8 and 80 ppm respectively. Note that the range of fifty percentile values for copper (Fig. 20d) is from 5 to nearly 20 ppm and that the cumulative frequency curves are parallel indicating little variation in the standard deviation. The populations of copper values in individual suites are all multimodal (Fig. 20c), but taken as a whole the copper distribution most closely approximates log normality (Fig. 20d).

The Nasina quartzite (PPQC) has the highest copper backgrounds among the metamorphic rocks, excepting the Kluane schist (PPSQR). This unit also has above average concentrations of Mo, W, Hg, Ag, As. The Nasina of the Yukon Crystalline Terrane is probably time equivalent to Road River strata of Selwyn Basin. Because of this probable correlation and its high metal background the Nasina quartzite may be favourable to metal concentrations. The interesting copper response from part of west-central Snag map-area is from the area underlain by schist (PPSB) and phyllite (PPPS) probably equivalent to the Klondike schist. The Klondike schist has normal copper concentration, but seems to have possibilities for copper concentrations judging by occurrences such as that on Lucky Joe Creek in Stewart River map-area.

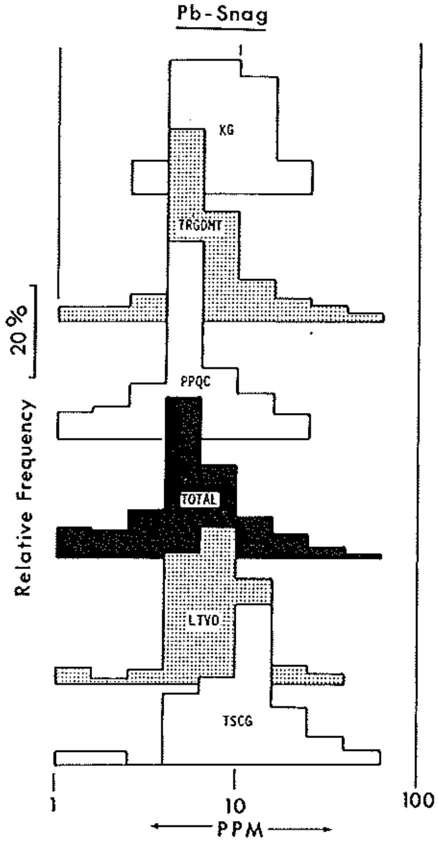
The tholeiites of the Carmacks (ETCV) and Donjek volcanics (LTV) are distinctly copper poor for basalts and appear to be unexciting bets as mineral exploration target units. Similarly the Klotassin suite of hornblende quartz diorite (TRGDMT) is copper poor. The Coffee Creek quartz monzonite (KG) contains even less copper. Together these rocks are among the most metal-poor in the project area.

The perspective diagram (Fig. 20c) does not distinguish the various moderate and high copper units neatly, but it does emphasize the areal low of copper values over the Klotassin Batholith (see Figs. 20a and 20c). The copper-responsive part of Snag map-area is basically its eastern third which is underlain by such copper-rich rock units as the Nasina quartzite, Mount Nansen and Nisling Range alaskite. The Denali-Shakwak fault is not as prominent in the copper perspective as in that of zinc.

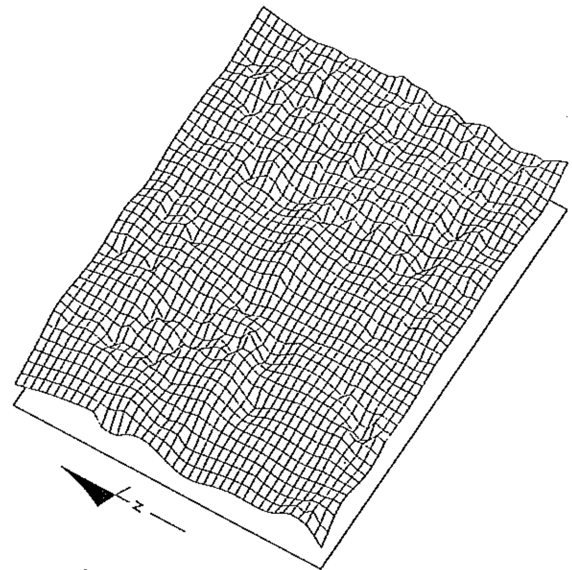


Pb – SNAG 115 J & K

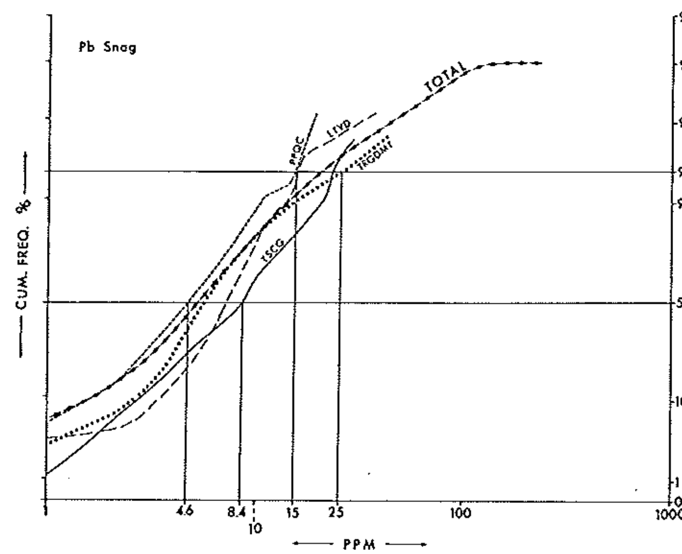
a



b



c



d

Figure 21

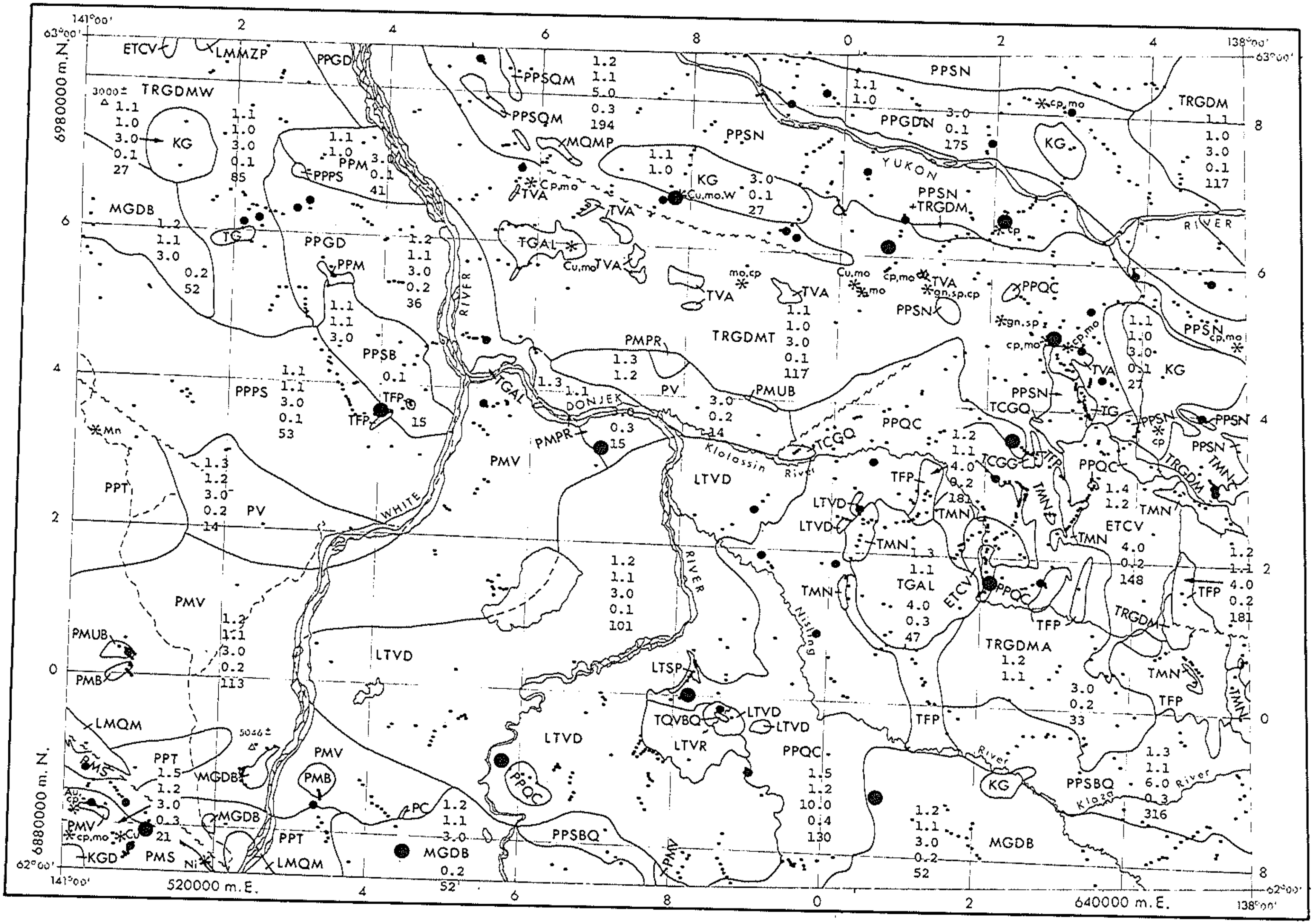
Lead – Snag map-area

Geological sketch map of Snag map-area showing statistical parameters related to the geochemistry of lead for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of lead were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of lead in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for lead during the project and are shown for comparison. The perspective diagram displays the lead geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the lead concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

The mean and 95.5 percentile lead concentrations among all the rocks analyzed in this project are 5.6 and 20 ppm. The range in lead values is small and the lead concentration does not strongly distinguish one map-unit from another. The cumulative frequency curves (Fig. 21d) are parallel indicating that there is also little difference in the standard deviations of the lead populations. The histograms (Fig. 21b) show that the distributions are close to log normal.

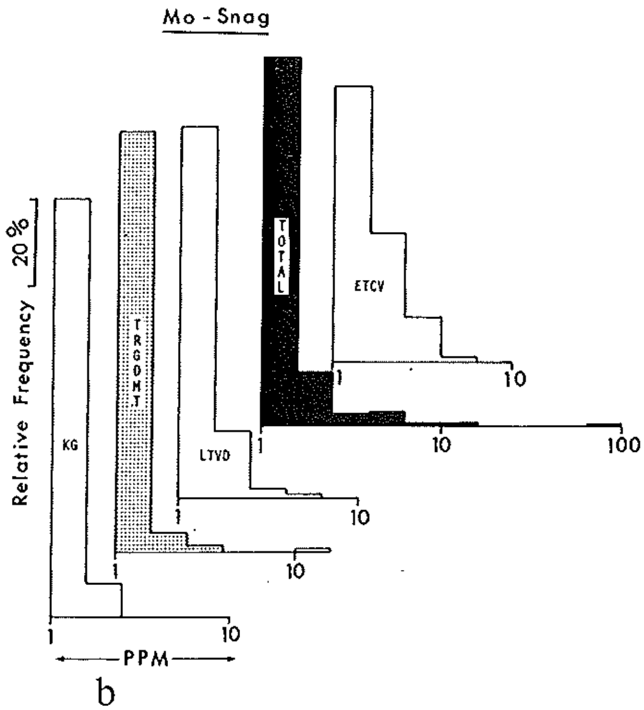
The lead concentration varies so slightly between map-units that the perspective diagram reflects the spot highs rather than high or low background units. One intriguing area that warrants a careful look is in west-central Snag map-area west of White River in the area broadly opposite the mouth of Donjek River. Aside from the high lead values (Figs. 21a, 21c) this area also has anomalous concentrations of zinc, copper and arsenic.



a

Mo-SNAG 115 J & K

0 20km



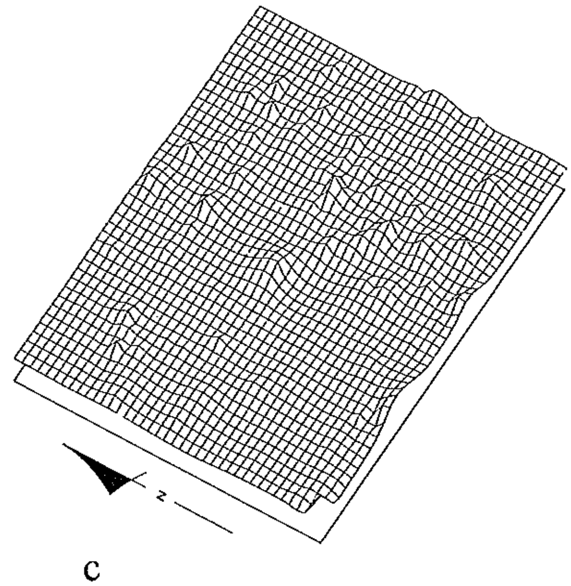


Figure 22

Molybdenum – Snag map-area

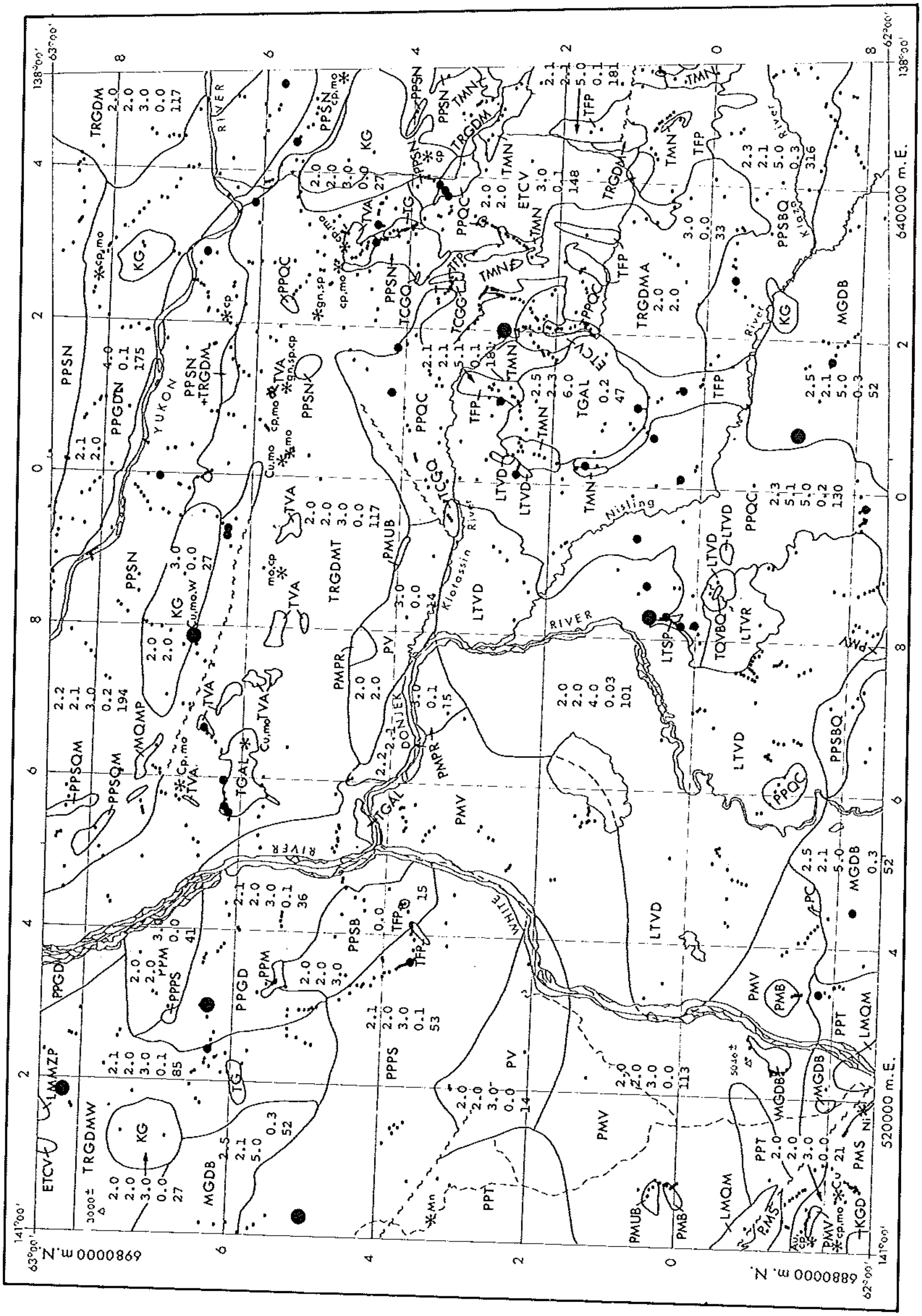
Geological sketch map of Snag map-area showing statistical parameters related to the geochemistry of molybdenum for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. Sampled localities are shown by small dots and samples with anomalously high concentrations of molybdenum are indicated by large dots. Histograms illustrate the frequency distributions of molybdenum in some map-unit assemblages; they are selected to demonstrate the variation between rock units. The distribution labelled TOTAL represents all samples analyzed for molybdenum during the project; they are shown for comparison. The perspective diagram displays the molybdenum geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For analytical results concerning specific samples the reader is referred to Appendix 1.

Note that the scale of molybdenum concentrations in the histograms is logarithmic.

The mean and 95.5 percentile molybdenum concentration among all the rocks analyzed in this project are 1.23 and 3 ppm. The molybdenum distribution in rocks at low levels is incompletely known because of analytical limitations for this metal. Because concentrations below 1 ppm are reported as 1 ppm the frequency distributions of this metal are highly skewed.

Molybdenum is considered a good indicator of its deposits and plutonic rocks with high backgrounds of this metal are likely to contain concentrations of the metal. It is surprising that the Coffee Creek granite (KG) has essentially the same amount of molybdenum as the quartz diorite of the Klotassin (TRGDMT). Felsic granitic rocks generally contain more molybdenum than mafic varieties. The concentration of molybdenum in the basaltic rocks of the Carmacks Group (ETCV) is surprisingly high for such basic volcanics. It is higher than that in the time equivalent Donjek volcanics (LTVD). Both are tholeiitic basalts extruded at different centres. The Carmacks is made up mainly of flows and the Donjek contains more tuffs and breccias. These two correlative units also show differences in the concentration of most other metals studied. The Little Ridge volcanics (TLR) of Aishihik Lake map-area is a third map-unit roughly equivalent to the Donjek and Carmacks but is distinguished in the mapping because it is physically separate. Its geochemistry is different from the other two suites and these three correlative volcanic assemblages are geochemically distinct.

Molybdenum is concentrated in the Nisling Range alaskite (TGAL) as pointed out elsewhere and the stock of these rocks between the Klotassin and Nisling rivers stands out as a molybdenum centre in the perspective diagram (Fig. 22c). The Nasina quartzite also has high molybdenum values. Its threshold level is particularly high (10 ppm).



W - SNAG 115 J & K

0 20km

a

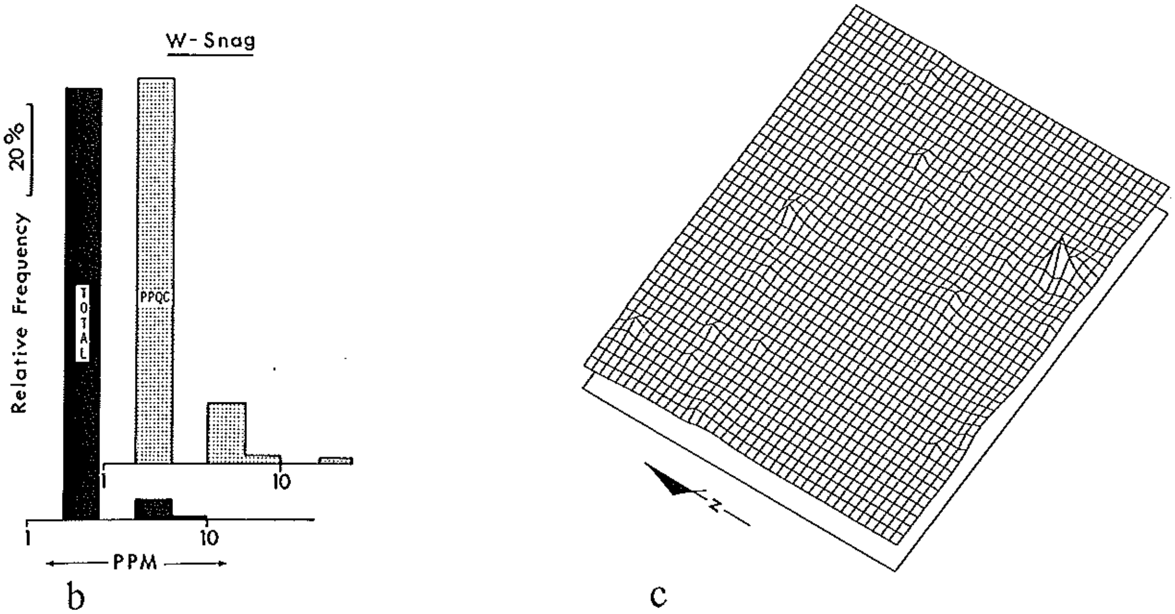


Figure 23

Tungsten – Snag map-area

Geological sketch map of Snag map-area showing statistical parameters related to the geochemistry of tungsten for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. Sampled localities are shown by small dots and samples with anomalously high concentrations of tungsten are indicated by large dots. Histograms illustrate the frequency distributions of tungsten in some map-unit assemblages; they are selected to demonstrate the variation between rock-units. The distribution labelled TOTAL represents all samples analyzed for tungsten during the project; they are shown for comparison. The perspective diagram displays the tungsten geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For analytical results concerning specific samples the reader is referred to Appendix 1.

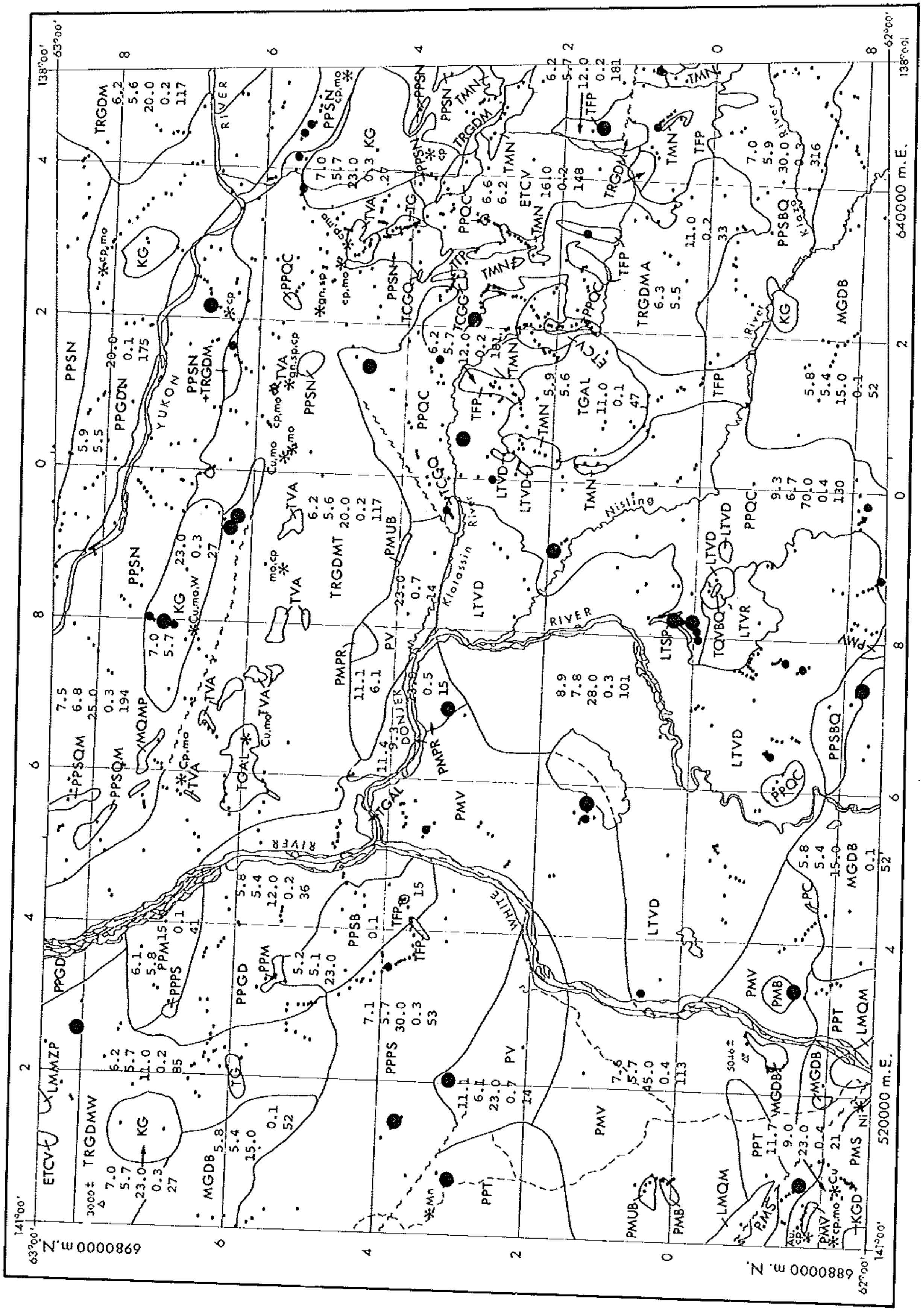
Note that the scale of tungsten concentrations in the histograms is logarithmic.

The mean and 95.5 percentile tungsten concentration in all the rocks analyzed in this project is 2.12 and 3 ppm.

Tungsten is considered a good indicator of its deposits and the Nisling Range alaskite (TGAL) is among the most interesting in this context. The small circular pluton between Klotassin and Nisling rivers warrants a careful look for tungsten concentrations and for molybdenum-copper mineralization. Its highly fractionated acid composition, near surface emplacement and geochemical nature suggest that it also has possibilities for tin occurrences. At Mount Nansen in Carmacks map-area the alaskite is host to porphyry copper-molybdenum mineralization and the spatially and genetically related acid tuffs at Mount Nansen host important gold-silver stockworks. The Casino volcanics are explosive acid volcanic and subvolcanic rocks genetically related to the Mount Nansen Group and Nisling Range alaskite. At two localities in Snag map-area, Casino and Mount Cockfield, they contain important porphyry molybdenum-copper mineralization. The subvolcanic part of the Mount Nansen, or the explosive pipes off the Nisling Range alaskite are targets for this type of occurrence.

The Nasina quartzite has interestingly high tungsten concentrations. This is probably related to the relatively high molybdenum concentration also found in these rocks. Black slate (which the Nasina quartzite was before metamorphism) commonly has high metal backgrounds, which may be associated with economic concentrations.

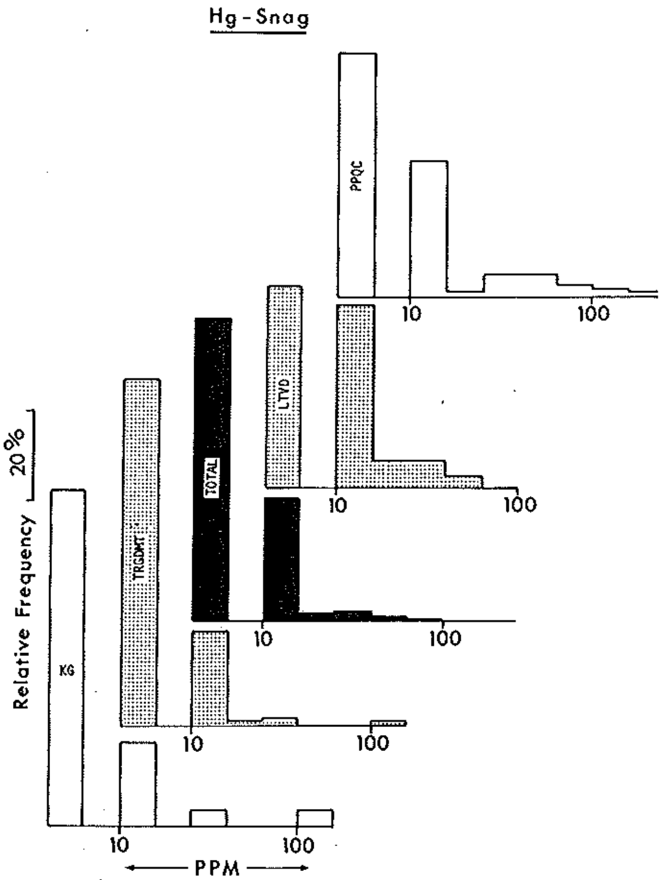
The perspective diagram (Fig. 23c) emphasizes the spot highs and does not express differences related to high or low background units. The single prominent peak near the southeast corner is related to a sample of Nisling Range granodiorite (MGDB) with 450 ppm tungsten.



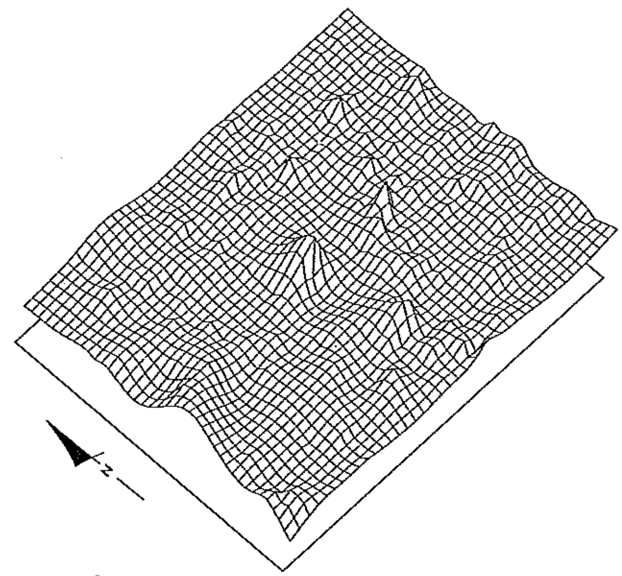
Hg - SNAG 115 J & K

0 20km

a



b



c

Figure 24

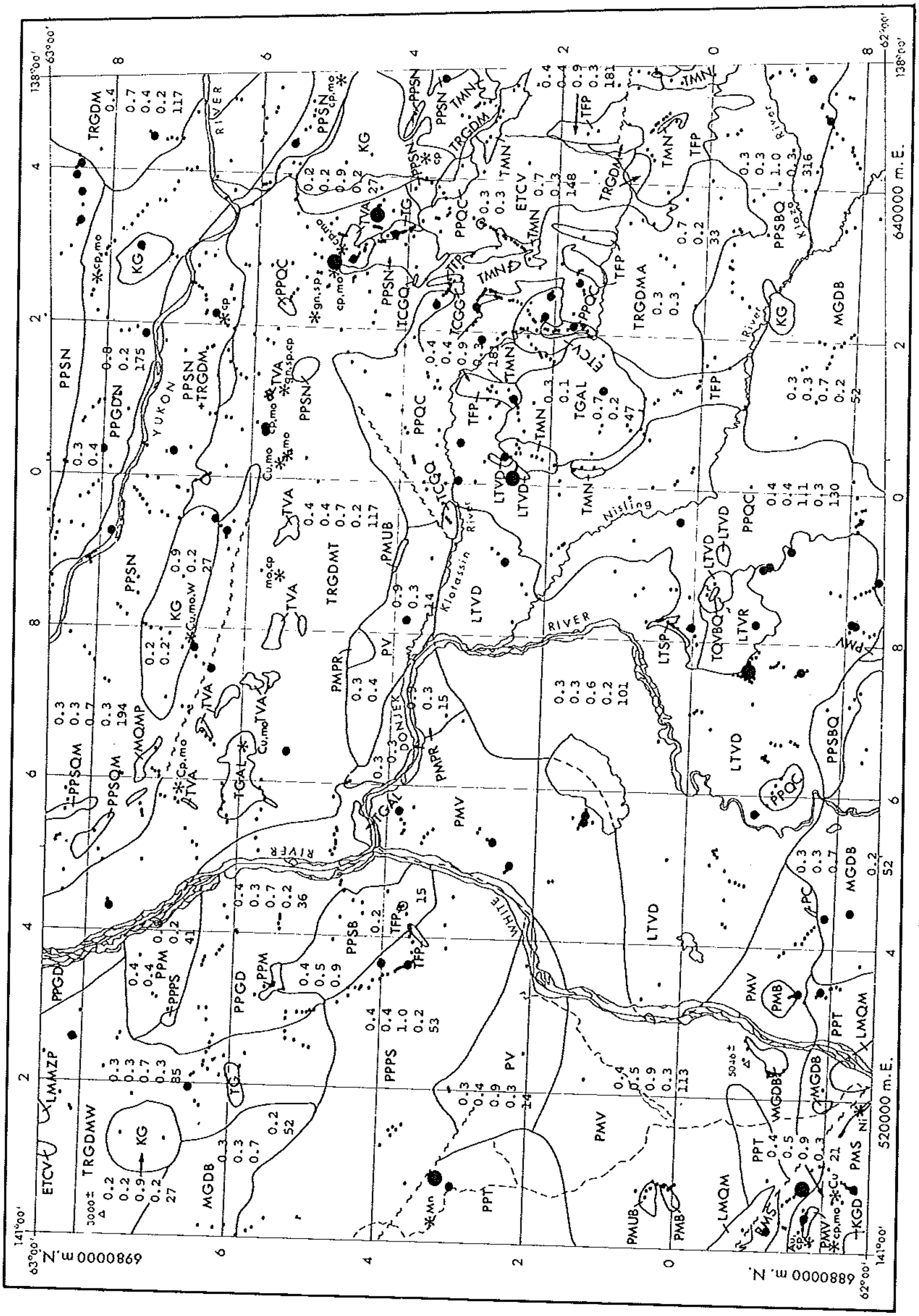
Mercury – Snag map-area

Geological sketch map of Snag map-area showing statistical parameters related to the geochemistry of mercury for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. Sampled localities are shown by small dots and samples with anomalously high concentrations of mercury are indicated by large dots. Histograms illustrate the frequency distributions of mercury in some map-unit assemblages; they are selected to demonstrate the variation between rock-units. The distribution labelled TOTAL represents all samples analyzed for mercury during the project; they are shown for comparison. The perspective diagram displays the mercury geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For analytical results concerning specific samples the reader is referred to Appendix 1.

Note that the scale of mercury concentrations in the histograms is logarithmic.

The mean and 95.5 percentile mercury levels among all the rocks analyzed for this study are 7.1 and 23 ppm. The histograms (Fig. 24c) illustrate that mercury is subject to the same analytical limitations as are tungsten and molybdenum. Nevertheless some rock-units are clearly mercury-rich and others mercury deficient. The Nasina quartzite (PPQC) and Donjek volcanics (LTVD) are among the former whereas quartz diorite of the Klotassin suite (TRGDMT) and Coffee Creek granite (KG) are examples of the latter. The comparatively high concentration of mercury in the Nasina is surprising for although it was originally a black shale, presumably with as much mercury as such rocks commonly carry, this would have been removed during metamorphism.

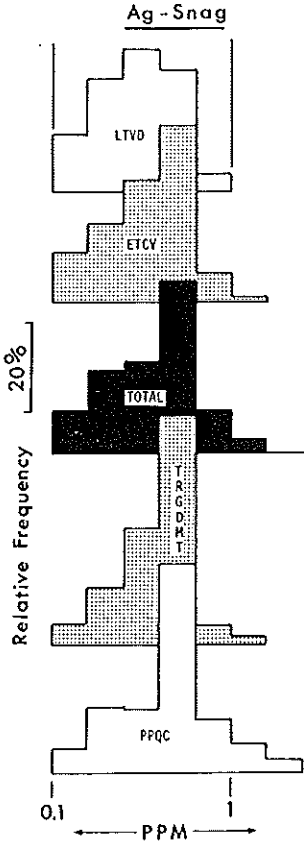
The perspective diagram (Fig. 24c) emphasizes the spot highs on the map rather than high background units. The prominent peak in the centre of the map-area is related to a single sample of ultramafic rocks (PMPR) with a concentration of 770 ppm while the peak due east of it reflects a sample of Nasina quartzite with 185 ppm.



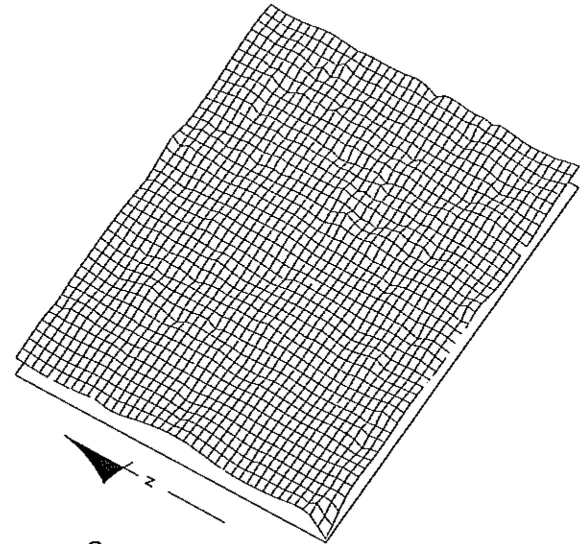
Ag – SNAG 115 J & K

0 20 km

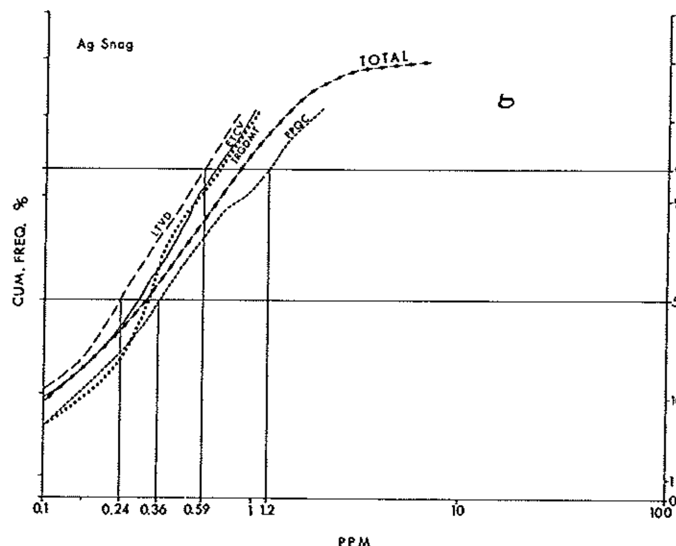
a



b



c



d

Figure 25

Silver – Snag map-area

Geological sketch map of Snag map-area showing statistical parameters related to the geochemistry of silver for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of silver were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of silver in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for silver during the project and are shown for comparison. The perspective diagram displays the silver geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the silver concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

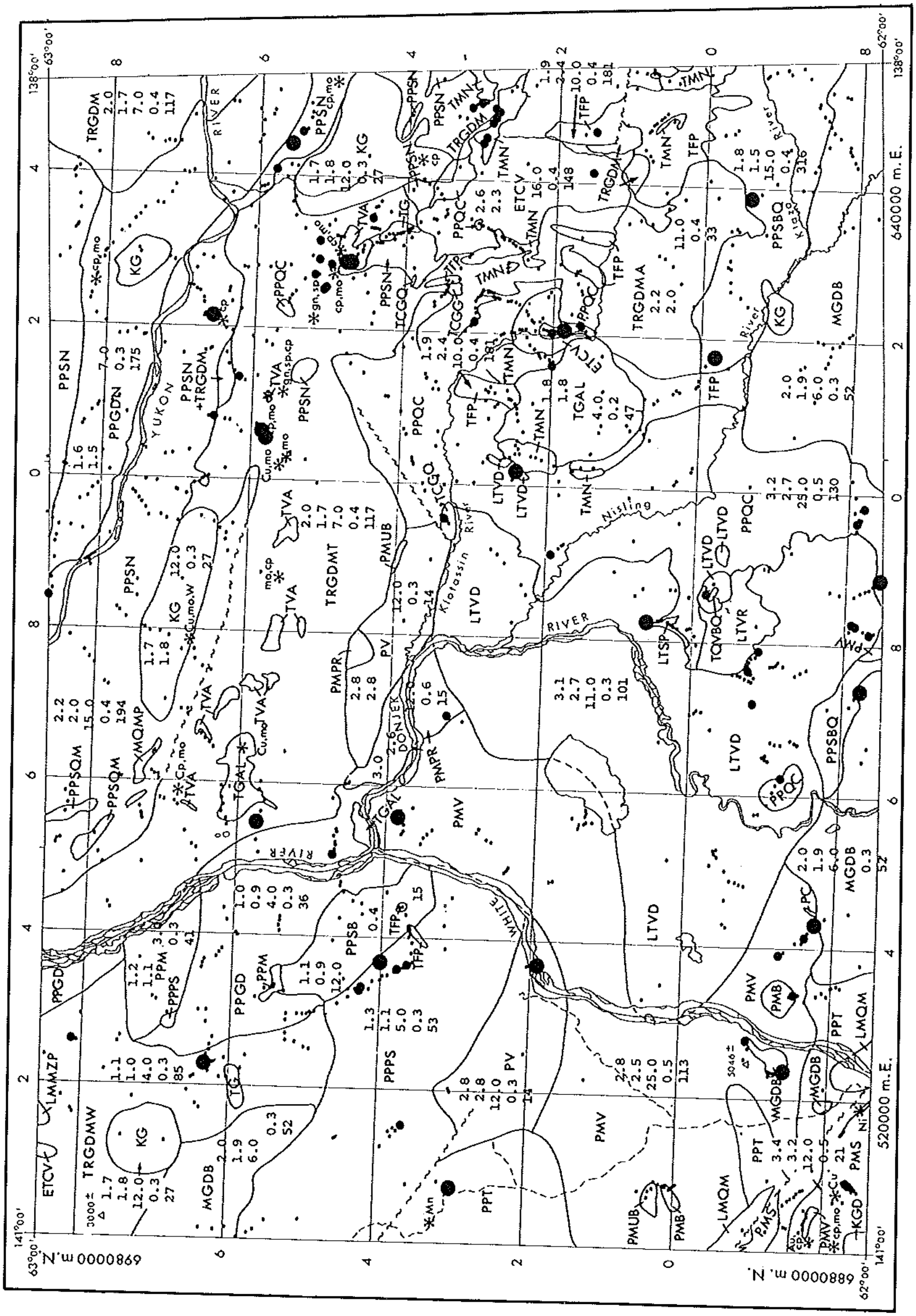
Among rocks analyzed for this study the mean and threshold silver concentrations are 0.34 and 0.9 ppm. The cumulative frequency curves (Fig. 25d) show by the parallelism of the curves and the limited range in fifty percentile values that there is little in the silver geochemistry to distinguish between the populations.

Two rock-units with interestingly high silver are the schist (PPSB) and phyllite (PPS) in western Snag map-area. These map-units are probably equivalents of the Klondike schist which also has higher than average silver. The schist and phyllite also have above average amounts of zinc, copper, lead and arsenic. The geochemically high silver of these rocks points to the possibility that they may, like the Klondike schist, also have high gold. Considering this and the fact that the Tertiary history of this area favoured concentration in placers, streams draining these rocks warrant careful placer prospecting.

The Nasina quartzite (PPQC) is among the most silver rich map-unit in the project area (Figs. 25b, 25d). In addition the Nasina has intriguing copper, molybdenum, mercury and arsenic values and warrants more careful prospecting for concentrations of base metals than it has thus far had.

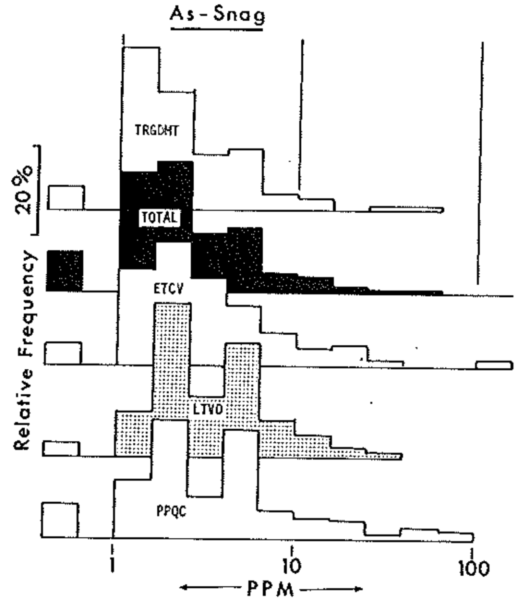
For comparison the frequency distributions of silver in the Carmacks (ETCV) and Donjek volcanics (LTVD) are given in Figure 25d. Surprisingly these basalts have less silver than many of the plutonic rocks which is the reverse of the situation seen commonly. The Mount Nansen Group found near Apex Mountain and Mount Cockfield is comparatively silver-rich. This is commented on elsewhere.

The perspective diagram (Fig. 25c) shows very little relief and weakly reflects a few local highs surrounding the small stock of alaskite (TGAL) between Nisling and Klotassin rivers.

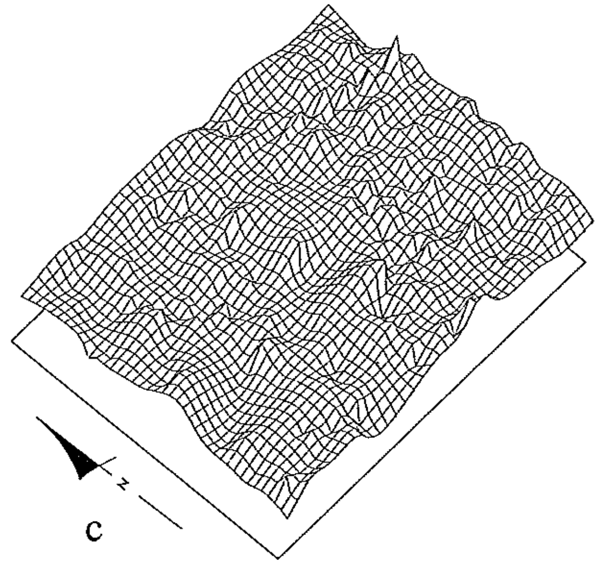


As – SNAG 115 J & K

a



b



c

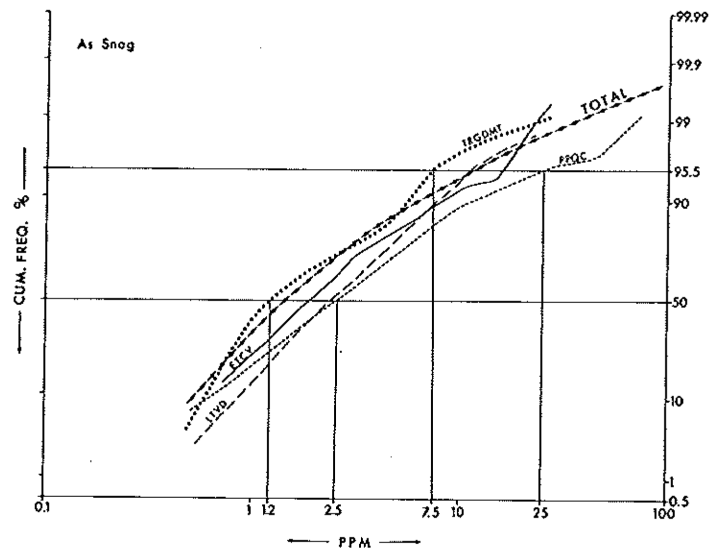
Figure 26

Arsenic – Snag map-area

Geological sketch map of Snag map-area showing statistical parameters related to the geochemistry of arsenic for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of arsenic were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of arsenic in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for arsenic during the project and are shown for comparison. The perspective diagram displays the arsenic geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the arsenic concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

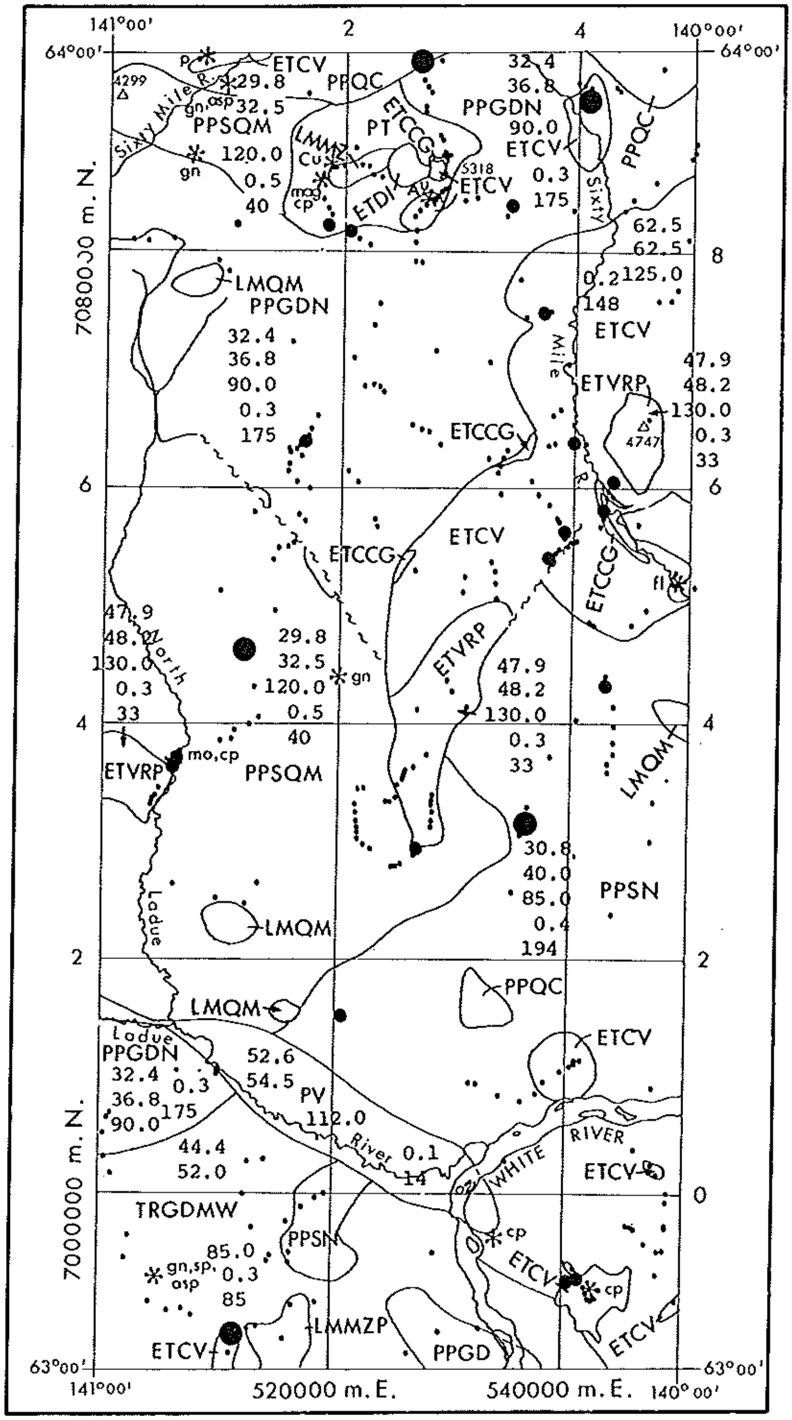
The background and threshold arsenic concentration of all the samples analyzed is 2.1 and 12 ppm. Arsenic geochemistry points to some of the same map-units identified as exciting on the basis of the other metals. In Snag map-area the Nasina quartzite (PPQC) and Mount Nansen (TMN) have more arsenic than other rock suites, while hornblende-quartz diorite of the Klotassin (TRGDMT) has less than most. Arsenic is commonly concentrated in black shales which may account for its abundance in the Nasina quartzite. Nevertheless this unit has high backgrounds of several other metals. Together with the probability that these rocks are time equivalents of the Road River Formation of Selywn Basin this makes the Nasina an important unit largely unexplored for metal concentrations.



d

The histograms emphasize that the Carmacks and Donjek volcanics have fairly high concentrations of arsenic. This is normal for basaltic rocks in general and has no exciting implications. The sandstones and shales in the lower part of the Donjek volcanics on Grayling Creek, distinguished as TSCG on the map, have very high arsenic backgrounds. This is common in organic-rich sediments everywhere and is not thought to be of economic significance. As pointed out elsewhere the area shouthwest of the Shakwak-Denali fault has high metal concentrations in general; the arsenic levels are not exceptional.

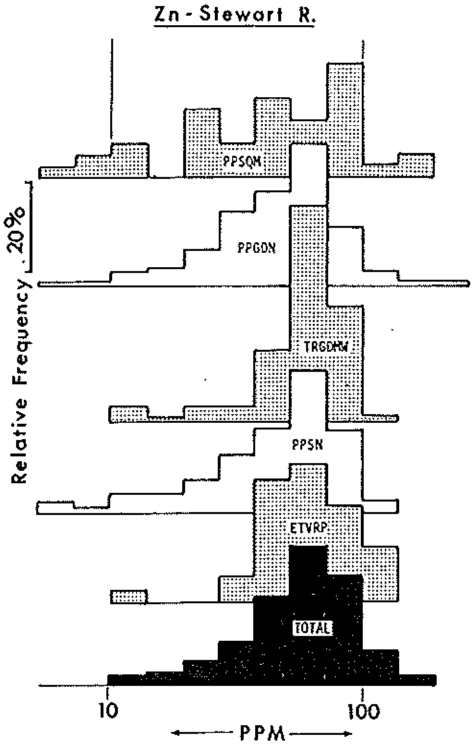
In perspective the relief of the arsenic values is mainly influenced by a few high values such as the row of peaks trending northwest roughly along the northern side of the Klotassin Batholith from the east edge of Snag map-area. Two samples in this area contained 200 and 124 ppm. A high coincides with the area underlain by the sandstones of Grayling Creek (TSCG).



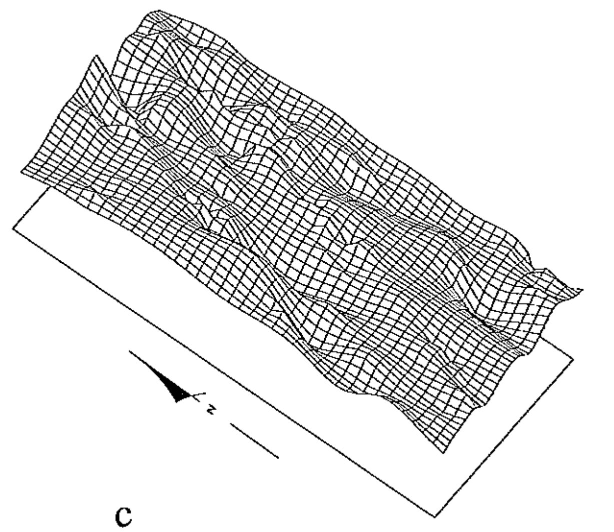
Zn - STEWART RIVER 115N W/2

a

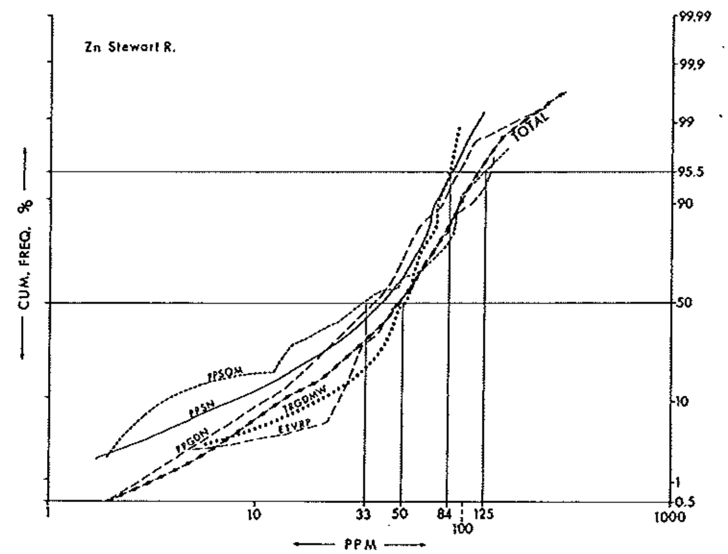
0 20km



b



c



d

Figure 27

Zinc – Stewart River map-area

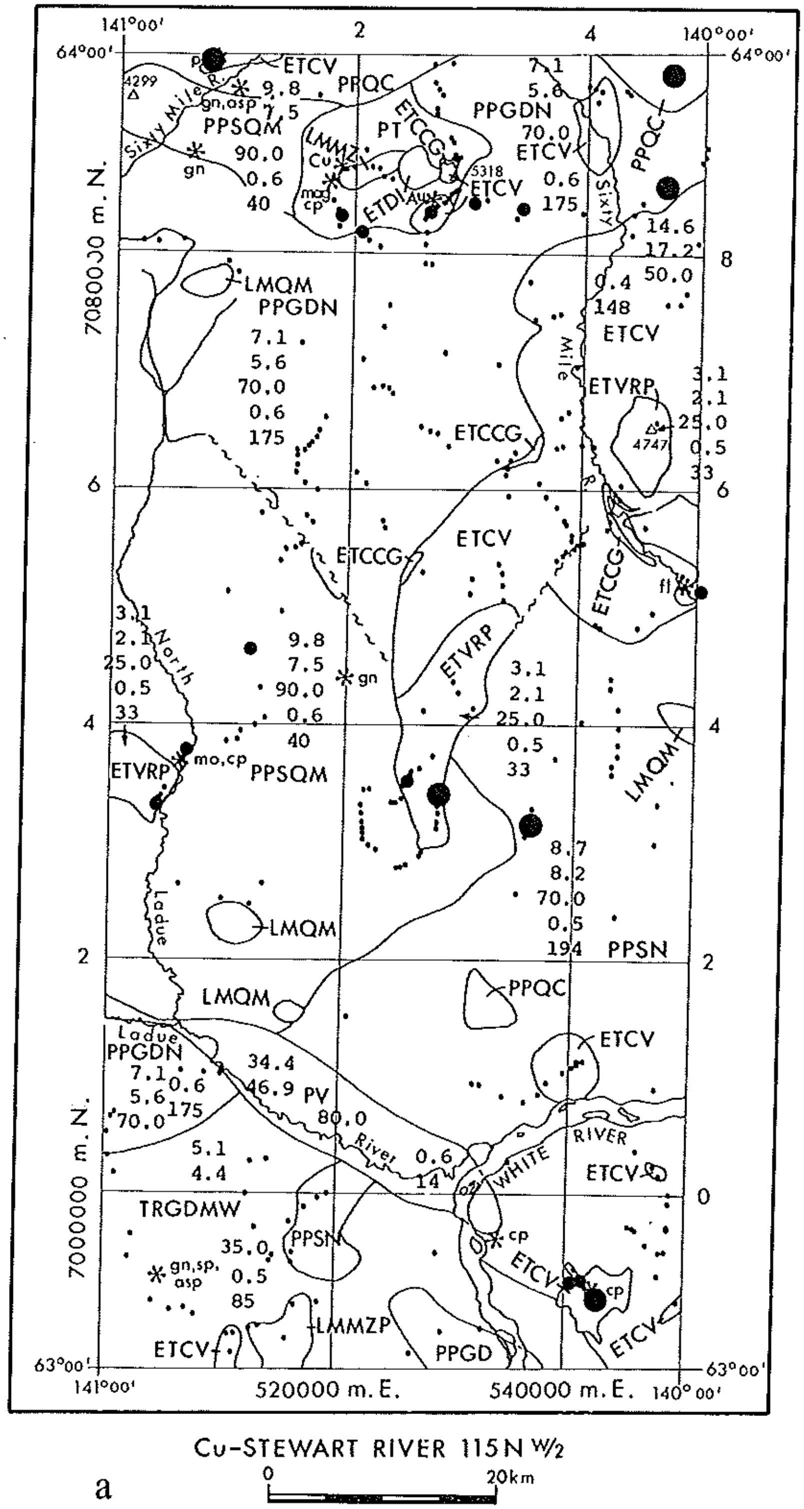
Geological sketch map of Stewart River map-area showing statistical parameters related to the geochemistry of zinc for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations and cumulative curves illustrate the frequency distributions of zinc in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for zinc during the project and are shown for comparison. The perspective diagram displays the zinc geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the zinc concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

In the Stewart River map-area most rocks have below average concentrations of zinc as well as other metals. The cumulative frequency curves (Fig. 27d) illustrate the low zinc in comparison to the total population of analyzed samples. By comparison to Aishihik Lake and Snag map-area, the western third of Stewart River area is generally metal poor.

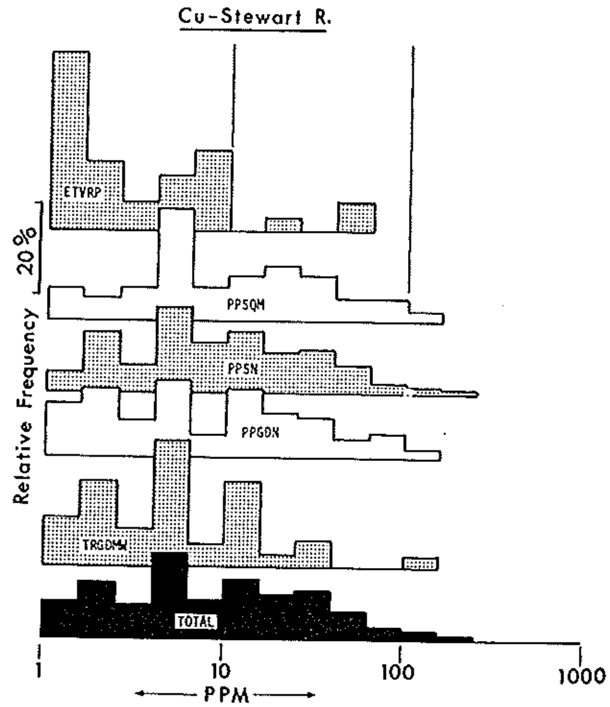
The Pelly gneiss (PPGDN) of Stewart River map-area is a late Precambrian granodiorite gneiss. It is overlain by the schist-gneiss (PPSN), a unit of early Paleozoic schist and gneiss. This is in turn covered by the Nasina quartzite (PPQC) and the Klondike schist (PPSQM) both of Paleozoic age. The rocks have been severely crushed and recrystallized and are blastomylonite. There is nothing in the zinc geochemistry of these various rock-units to distinguish between them. Presumably the crushing which has homogenized these rocks and redistributed their major constituents has also dispersed the minor elements through these rocks so that they now appear geochemically alike. They are not only indistinguishable on the basis of their zinc geochemistry; they show the same lack of individuality in nearly all other metals.

The map (Fig. 27a) shows that only the Carmacks volcanics (ETCV) have above average zinc in the map-area and the perspective diagram (Fig. 27c) reflects only the spot highs indicated on the map.

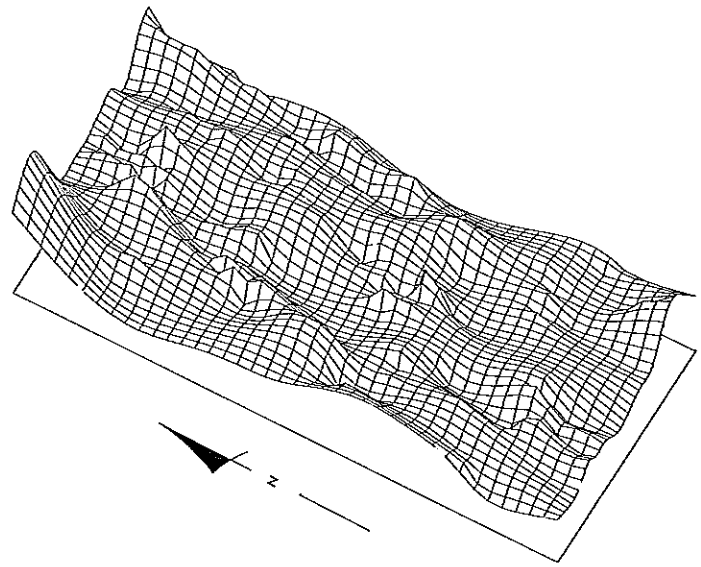


Cu–STEWART RIVER 115N W/2

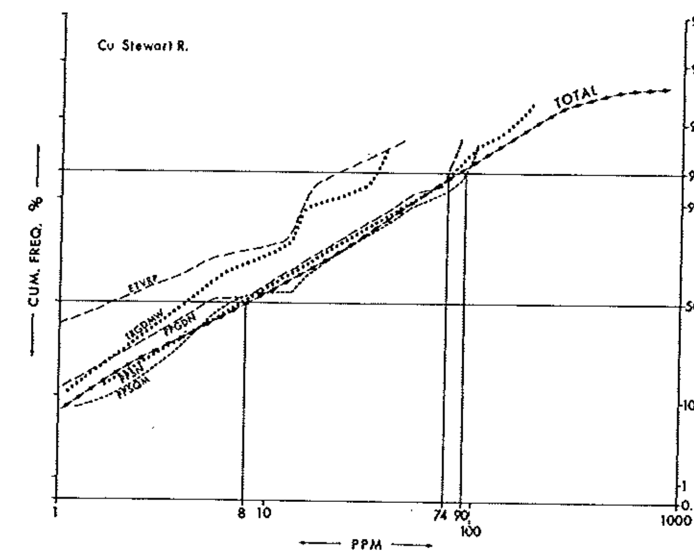
a



b



c



d

Figure 28

Copper – Stewart River map-area

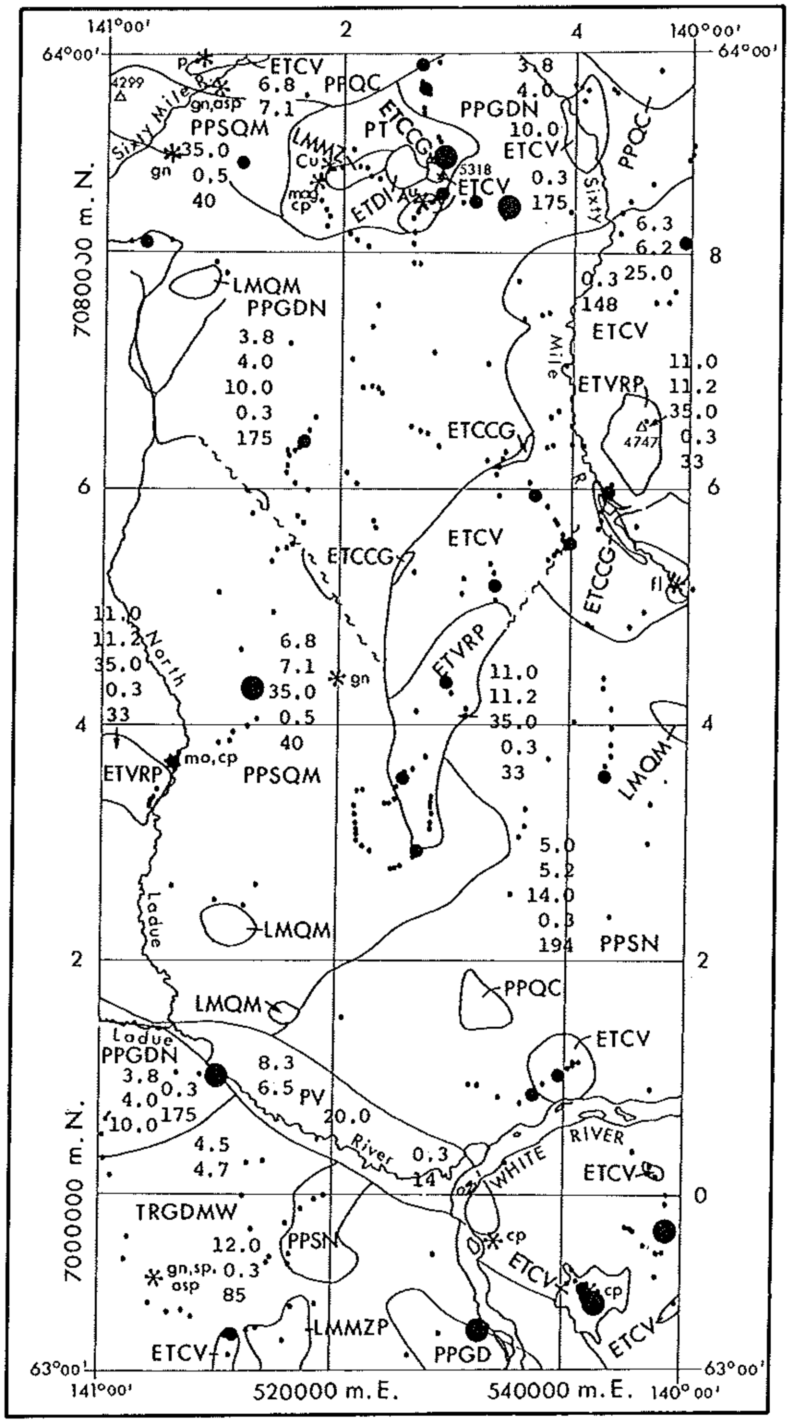
Geological sketch map of Stewart River map-area showing statistical parameters related to the geochemistry of copper for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of copper were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of copper in some of the map-units. They are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for copper during the project and are shown for comparison. The perspective diagram displays the copper geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the copper concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

Note the low concentration of copper in the rocks of this generally metal poor map-area. Also note the similar frequency distributions for the three main units of metamorphic rocks (PPGDN, PPSN, PPSQM). This has been remarked on for zinc also and it was speculated that this might be the result of homogenization of the rocks by granulation.

The Tertiary feldspar porphyries (ETVRP) associated with the Carmacks Group are distinctive in their extremely low copper concentration. Acid volcanic rocks generally contain much less copper than mafic varieties and the low copper in this suite is not unexpected.

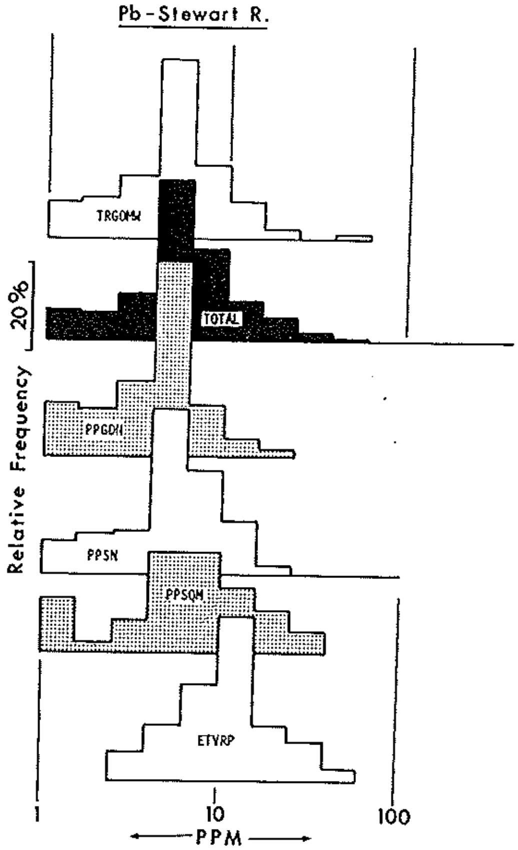
The copper map (Fig. 28a) and perspective diagram (Fig. 28c) hold no surprises; much of the relief is the result of local highs. Mount Hart, where several small prospects are known, is geochemically active for copper and for a variety of other metals also. It may warrant careful prospecting considering this and the number of small intrusive plugs exposed there. The sample in the northwest corner of the map-area with 1500 ppm copper has some visible sulphides. By comparison to Snag (Fig. 20c) and Aishihik Lake (Fig. 12c) map-areas the relief of copper values in Stewart River map-area is moderate.



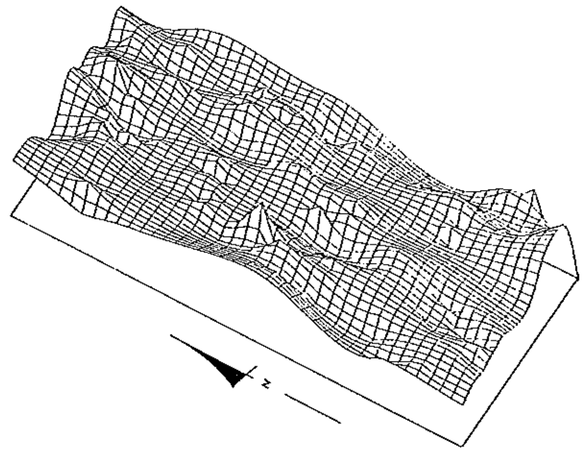
Pb-STEWART RIVER 115N W/2

a

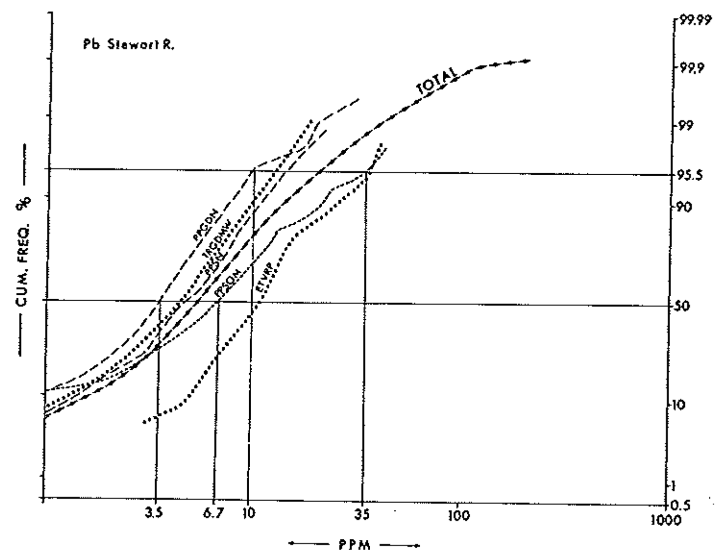
0 20km



b



c



d

Figure 29

Lead – Stewart River map-area

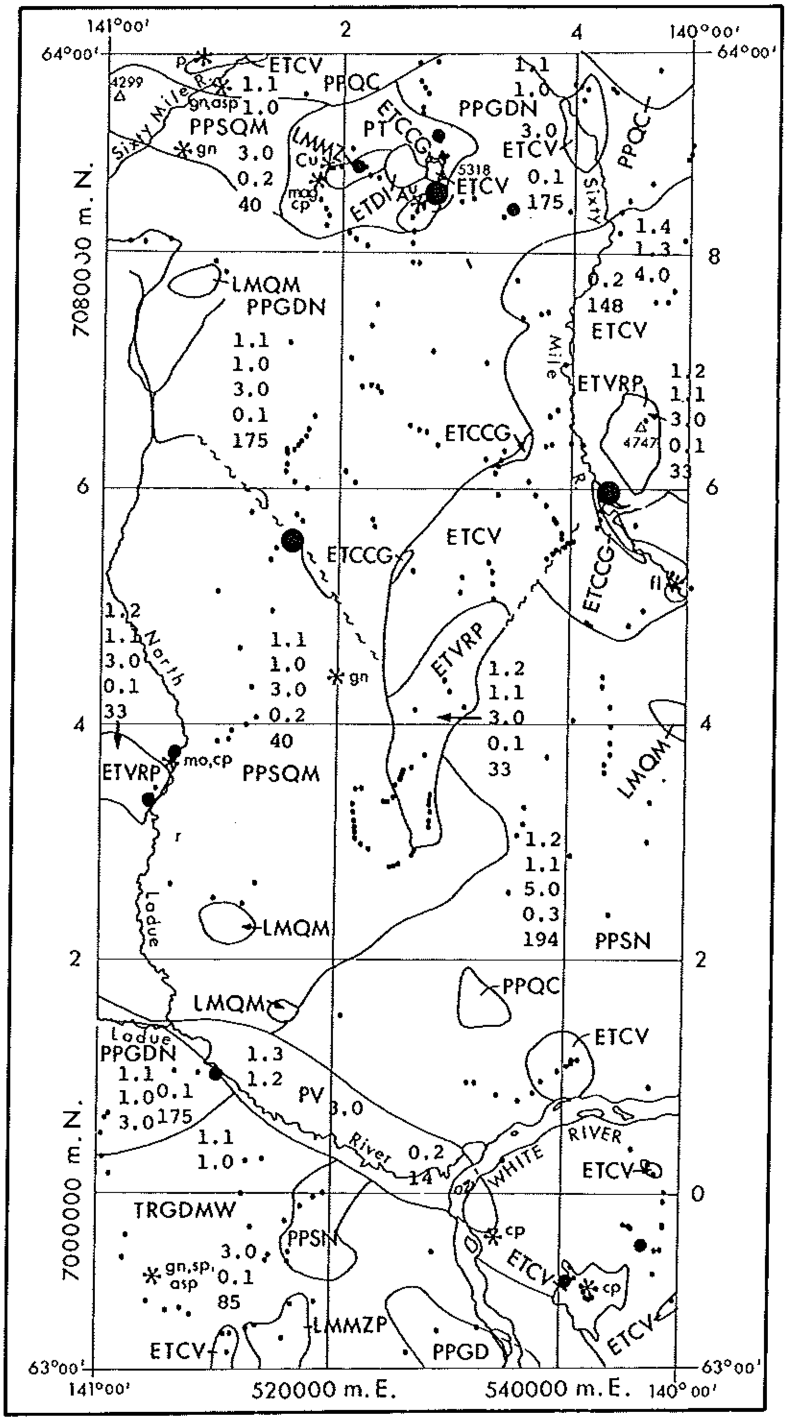
Geological sketch map of Stewart River map-area showing statistical parameters related to the geochemistry of lead for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of lead were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of lead in some of the map-units; they are selected to demonstrate the geochemical variations between rock-units. The distributions labelled TOTAL represent all samples analyzed for lead during the project and are shown for comparison. The perspective diagram displays the lead geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the lead concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

The histograms demonstrate the uniform lead distributions within groups of rocks of widely different age and origin in this map-area. For example the frequency distributions of lead in quartz diorite (TRGDMW), granodiorite gneiss (PPGDN) and biotite-quartz schist (PPSN) are virtually indistinguishable.

Only the quartz-feldspar porphyries (ETVRP) are distinctive in terms of their lead geochemistry. This unit has an extremely high tungsten content and very low copper, mercury, silver and arsenic. The porphyries contain much K-feldspar and their high lead may be related to this and the fact that lead substitutes largely for potassium in that mineral. The lead concentration of the porphyries is about the same as that in the Nisling Range alaskite. In neither unit is the lead inordinately high for the lithology.

Sharp peaks on the perspective diagram (Fig. 29c) are related to single samples with high values. The prominent peak close to the west-central boundary is caused by a 213 ppm sample from the Klondike schist (PPSQM) and the peak close to the southeast corner by another sample with 47 ppm lead.



Mo-STEWART RIVER 115N W/2

0 20km

a

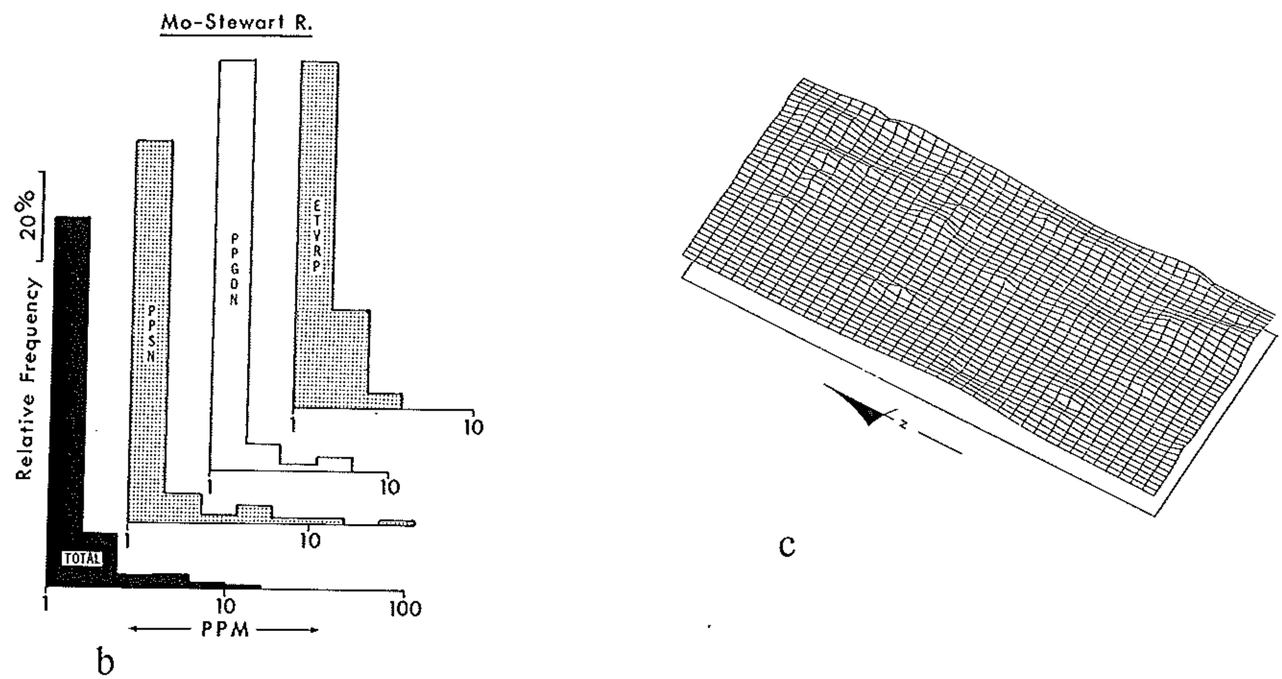


Figure 30

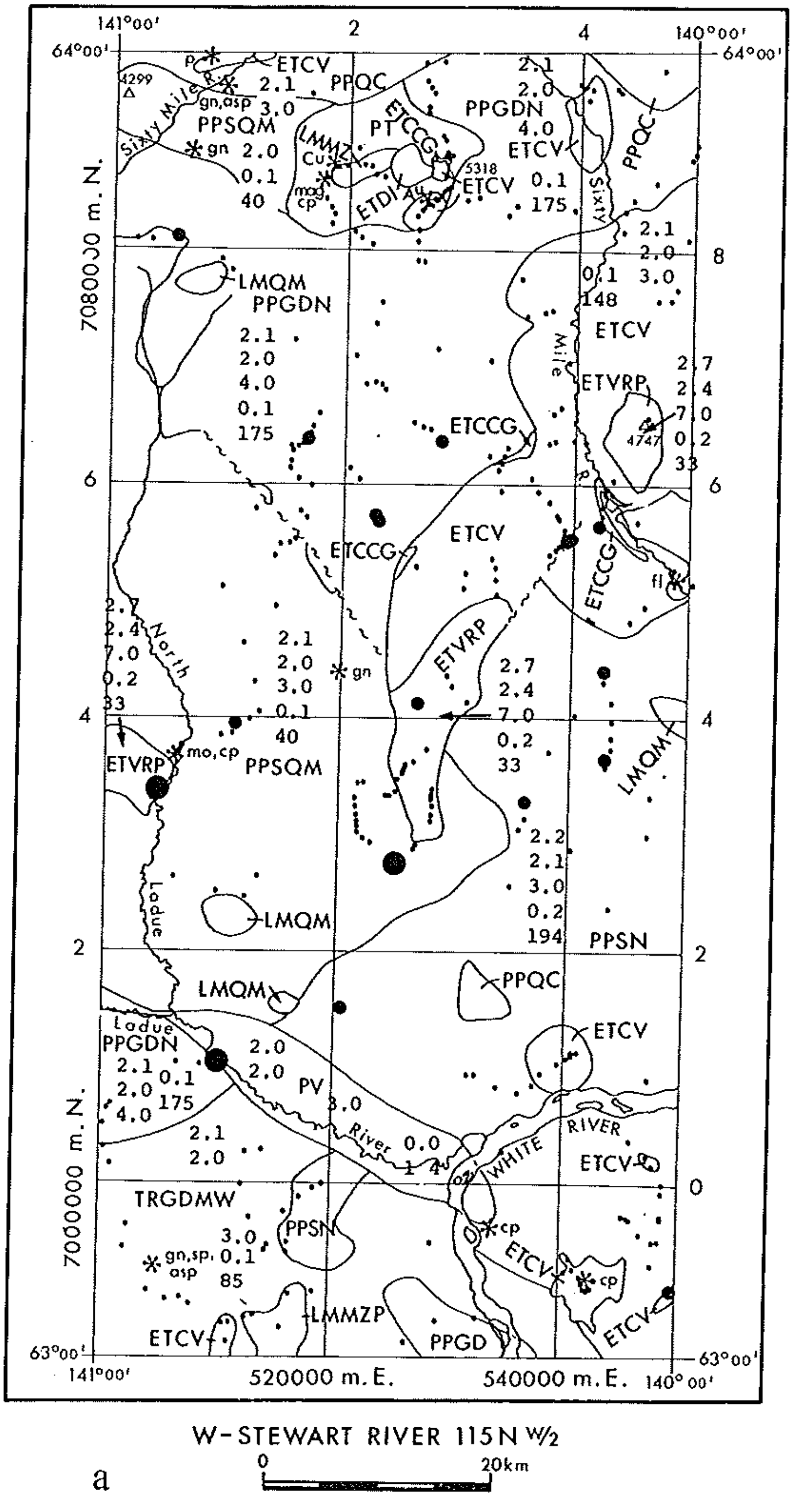
Molybdenum – Stewart River map-area

Geological sketch map of Stewart River map-area showing statistical parameters related to the geochemistry of molybdenum for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. Sampled localities are shown by small dots and samples with anomalously high concentrations of molybdenum are indicated by large dots. Histograms illustrate the frequency distributions of molybdenum in some map-unit assemblages; they are selected to demonstrate the variation between rock-units. The distribution labelled TOTAL represents all samples analyzed for molybdenum during the project; they are shown for comparison. The perspective diagram displays the molybdenum geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For analytical results concerning specific samples the reader is referred to Appendix 1.

Note that the scale of molybdenum concentrations in the histograms is logarithmic.

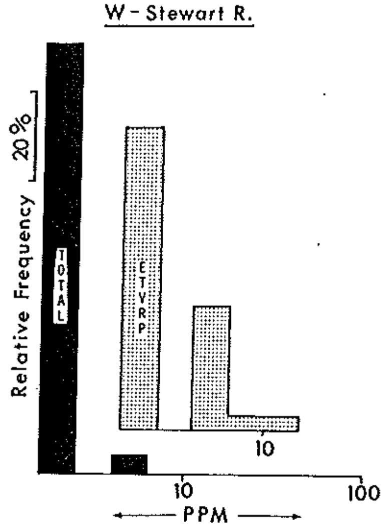
The metamorphic rocks of Stewart River map-area contain much less molybdenum than those of Aishihik Lake map-area in the southern part of the Yukon Crystalline Terrane. This and the fact that the other rocks also have below average amounts of the metal makes the molybdenum map of Stewart River map-area unexciting.

In the perspective diagram (Fig. 30c) most peaks are related to individually anomalous samples rather than to high background units. The area around Mount Hart is slightly positive to molybdenum as it is to several other metals. The broad bulging high near the south corner of the diagram reflects the molybdenum responsive rocks of the Carmacks Group (ETCV). The acid volcanics (ETVRP) have two small anomalous molybdenum concentrations that appear interesting. By comparison with Snag and Aishihik Lake map-areas (Figs. 22c and 14c) the molybdenum relief in Stewart River area is extremely low.

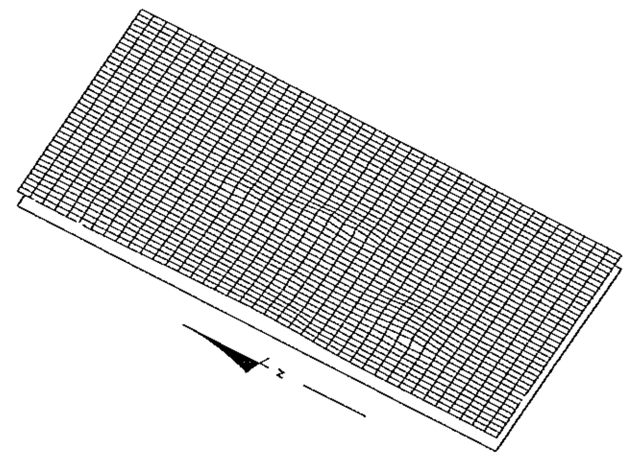


141°00'
64°00'
140°00'
63°00'
7080000 m.N.
7000000 m.N.
520000 m.E.
540000 m.E.
Sixty Mile R.
ETCV
PPQC
PPGDN
PPSQM
LMMZ
ETCCG
ETDI
LMQM
ETVRP
PV
PPSN
TRGDMW
LMMZP
PPGD
North
Lodue
River
WHITE RIVER
W-STEWART RIVER 115N W/2
0
20km

a



b



c

Figure 31

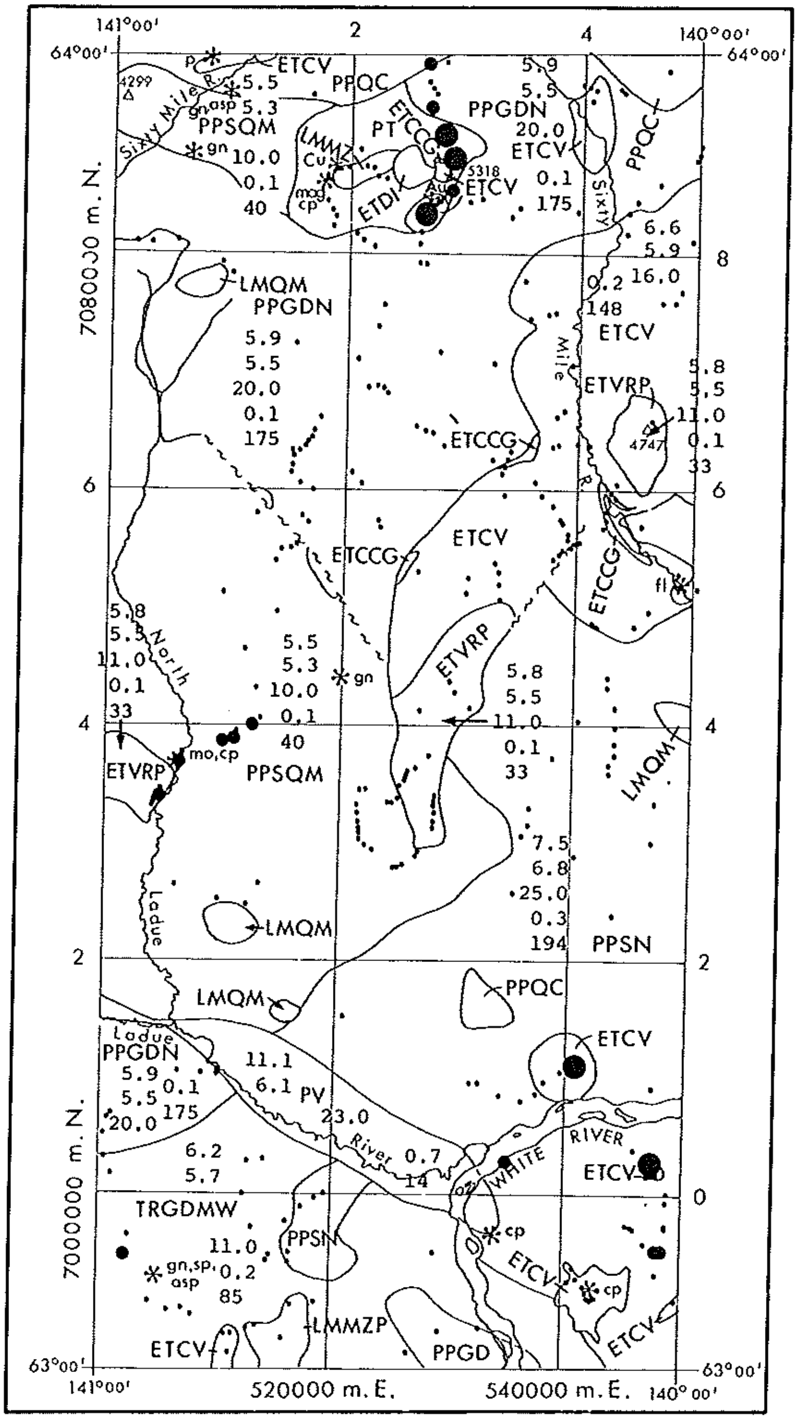
Tungsten – Stewart River map-area

Geological sketch map of Stewart River map-area showing statistical parameters related to the geochemistry of tungsten for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. Sampled localities are shown by small dots and samples with anomalously high concentrations of tungsten are indicated by large dots. Histograms illustrate the frequency distributions of tungsten in some map-unit assemblages; they are selected to demonstrate the variation between rock-units. The distribution labelled TOTAL represents all samples analyzed for tungsten in the project; they are shown for comparison. The perspective diagram displays the tungsten geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For analytical results concerning specific samples the reader is referred to Appendix 1.

Note that the scale of tungsten concentrations in the histograms is logarithmic.

As for the majority of the other metals the concentration of tungsten in most rock-units of Stewart River map-area is much lower than that in rocks elsewhere in the project area. It therefore comes as a surprise to find that the rhyolite and subvolcanic porphyries (ETVRP) are the richest tungsten suite in the entire project area. Several small molybdenum occurrences are known in these porphyries and Mulligan (1975, p. 70) has emphasized a point made earlier by Gleeson (1970, p. 46) that these rocks are the probable source of the wood tin gound in placers of the Klondike. Of the rock-units in Stewart River map-area the porphyries appear most interesting to explore for tin, tungsten or molybdenum-copper mineralization. The mercury, silver and arsenic concentrations in these rocks are all low (lower for example than the Nisling Range alaskite, a lithologically similar, but genetically unrelated older acid subvolcanic suite) which suggest that they are unlikely to have precious metal occurrences.

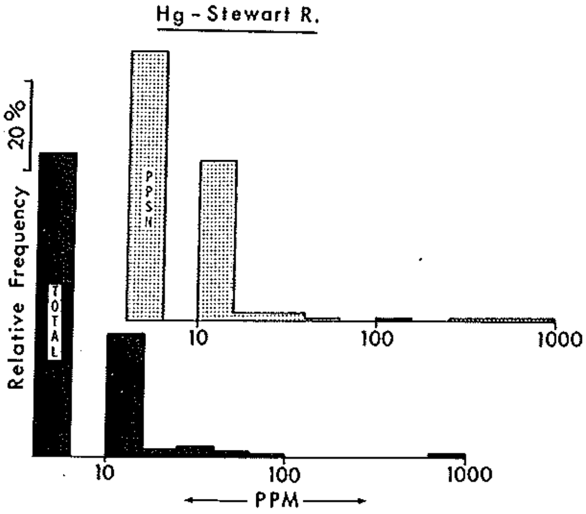
The perspective diagram (Fig. 31c) shows an almost total absence of relief in the tungsten values across the map-area. By comparison to Snag (Fig. 23c) and Aishihik Lake (Fig. 15c) map-areas Stewart River map-area is a low tungsten plateau. The most highly anomalous tungsten concentration in the map-area is 15 ppm from a sample of quartz-feldspar porphyry near the west boundary.



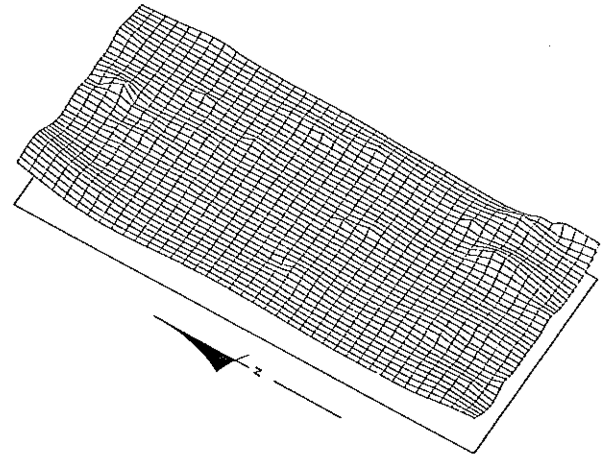
Hg-STEWART RIVER 115N W/2

a

0 20km



b



c

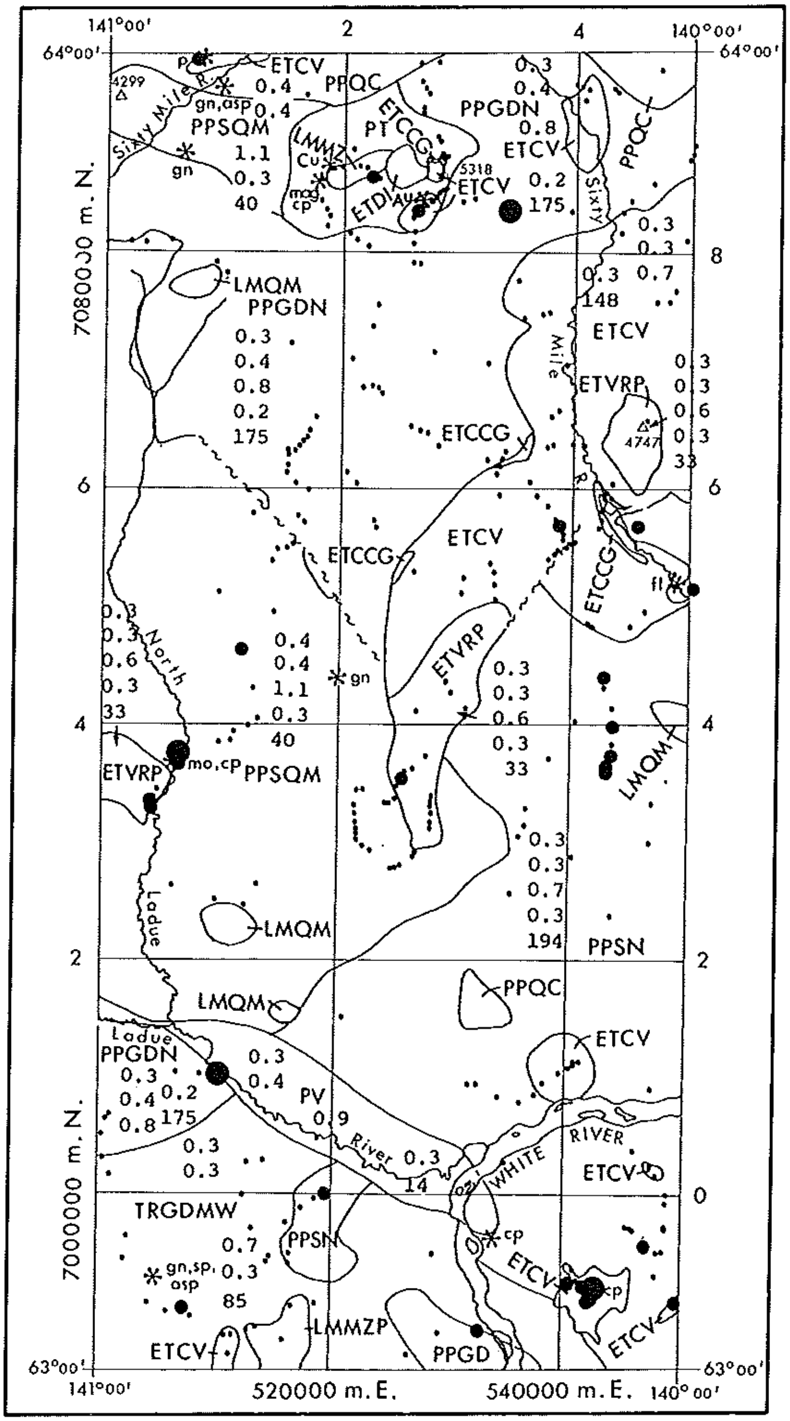
Figure 32

Mercury – Stewart River map-area

Geological sketch map of Stewart River map-area showing statistical parameters related to the geochemistry of mercury for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. Sample localities are shown by small dots and samples with anomalously high concentrations of mercury are indicated by large dots. Histograms illustrate the frequency distributions of mercury in some map-unit assemblages; they are selected to demonstrate the variation between rock-units. The distribution labelled TOTAL represents all samples analyzed for mercury during the project; they are shown for comparison. The perspective diagram displays the mercury geochemistry as a moving average in the third dimension so it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For analytical results concerning specific samples the reader is referred to Appendix 1.

Note that the scale of mercury concentrations in the histograms is logarithmic.

The background and threshold mercury concentration in all rocks analyzed is 7.1 and 23 ppm. The histogram (Fig. 32b) illustrates the frequency distribution of mercury in the schist and gneiss (PPSN), an assemblage with average amounts of this metal. None of the volcanic rocks in Stewart River map-area contain much mercury. Because the metal is reported in placer deposits of the Sixtymile River it was hoped that the geochemistry might help in pinpointing its source. It has been supposed that the mercury might be derived from parts of the Carmacks Group (ETCV), but the data do not bear this out. The map and perspective diagram (Figs. 32a, 32c) show that several samples from Mount Hart in northern Stewart River map-area are anomalous in mercury. The highest level reported there is 145 ppm. This area is a presumed source for the mercury in the Sixty mile River immediately north. Comparison of the perspective diagram for Stewart River area with hose of snag (Fig. 24c) and Aishihik Lake (Fig. 16c) map-areas emphasizes the extremely low relief in mercury values in the first.



Ag–STEWART RIVER 115N W/2

a

0 20km

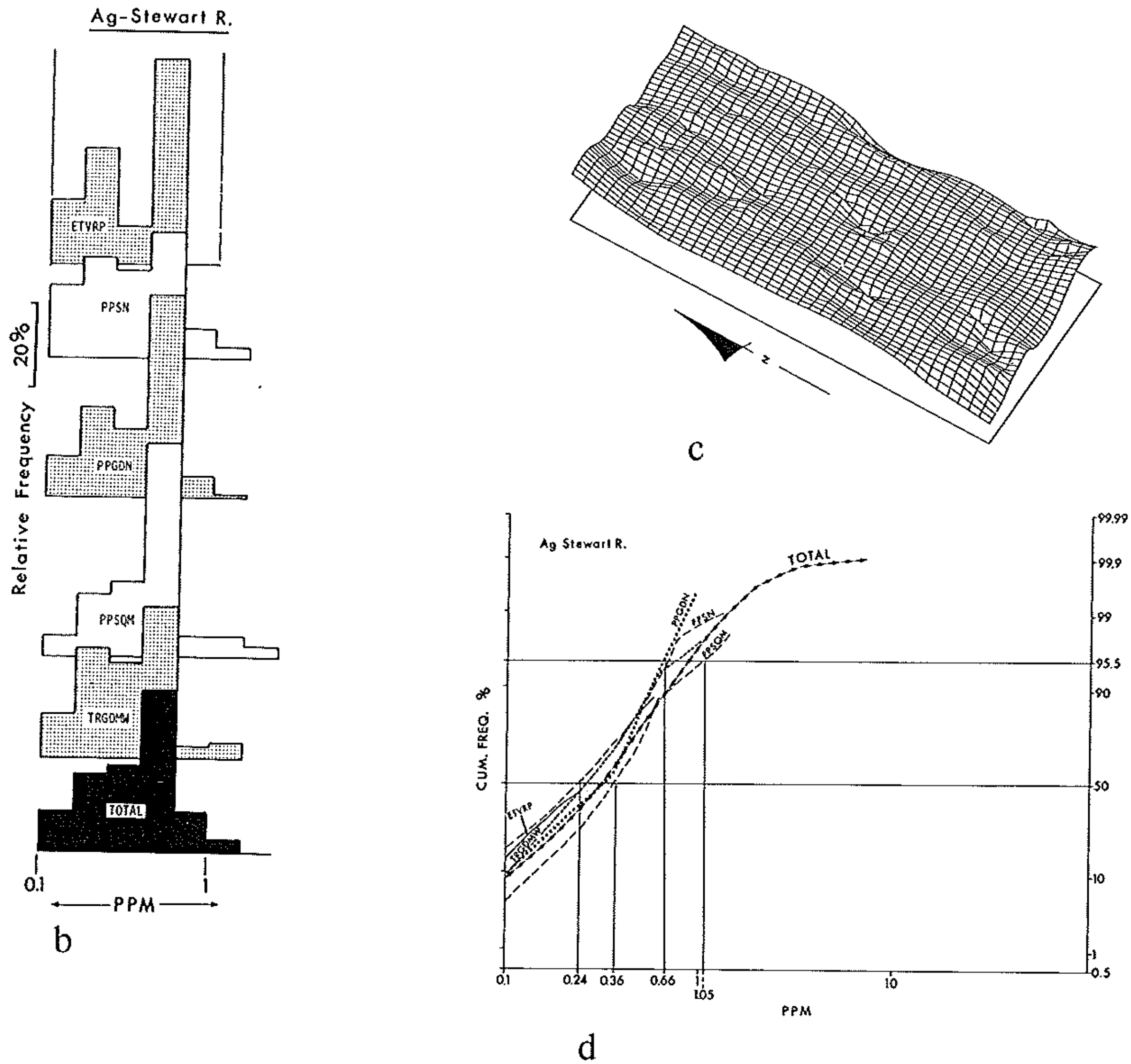


Figure 33

Silver – Stewart River map-area

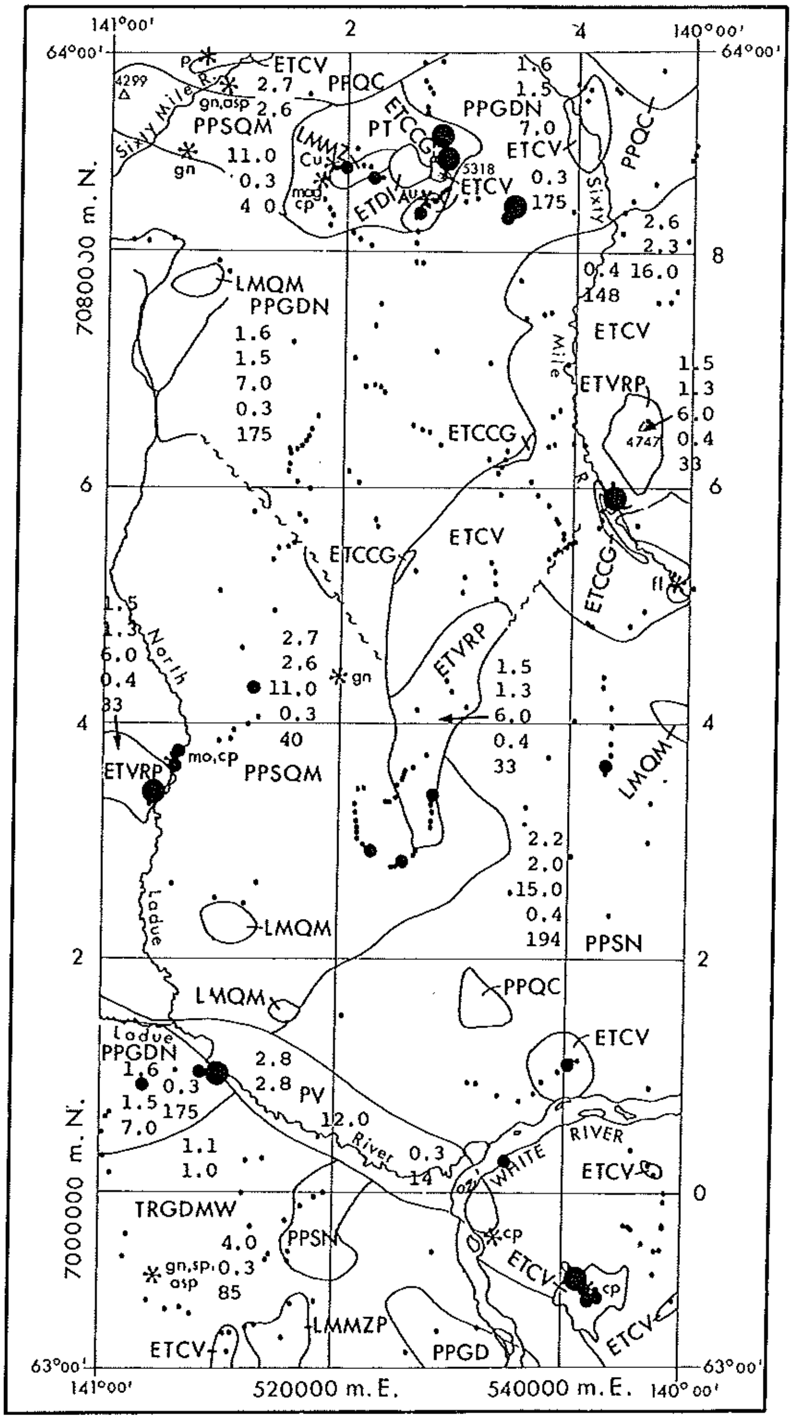
Geological sketch map of Stewart River map-area showing statistical parameters related to the geochemistry of silver for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of silver were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of silver in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for silver during the project and are shown for comparison. The perspective diagram displays the silver geochemistry as a moving average in the third dimension so that it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the silver concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

Differences between the frequency distributions of silver in the various map-units of Stewart River map-area are so slight as to be indistinguishable (Figs. 33b, 33d). Many of the histograms show a tendency for the silver to be bimodally distributed. This is not seen among rock-units in other parts of the project area (compare Fig. 33b with Figs. 25b and 17b).

The Klondike schist (PPSQM) has higher concentrations of silver and arsenic than most of the metamorphic rocks. This unit is probably the ultimate source for the gold concentrated in placers of the Klondike and the comparatively high arsenic and silver values in these rocks support this contention. The placer gold source was probably not the raw rock-unit with its geochemically high gold, but the small lodes derived from this geochemically high unit during its deformation and metamorphism. Locations where both the lode and placer concentrating processes operated are obviously important potential Klondikes of the future and this areally extensive rock-unit warrants a search for these conditions.

The silver perspective diagram for Stewart River map-area (Fig. 33c) shows little relief and is like that of the Snag map-area (Fig. 25c). By comparison the silver relief in Aishihik Lake area is profound.



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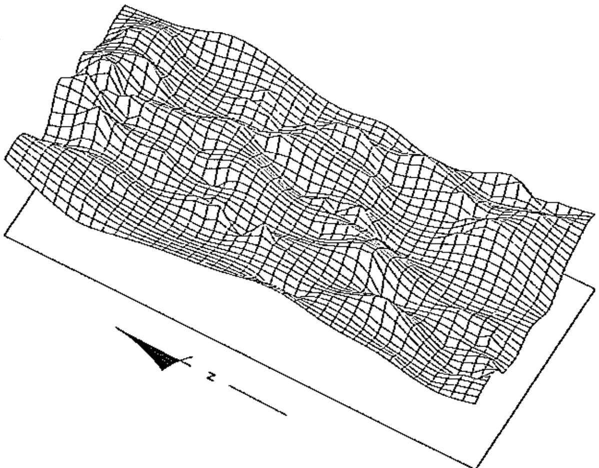
a



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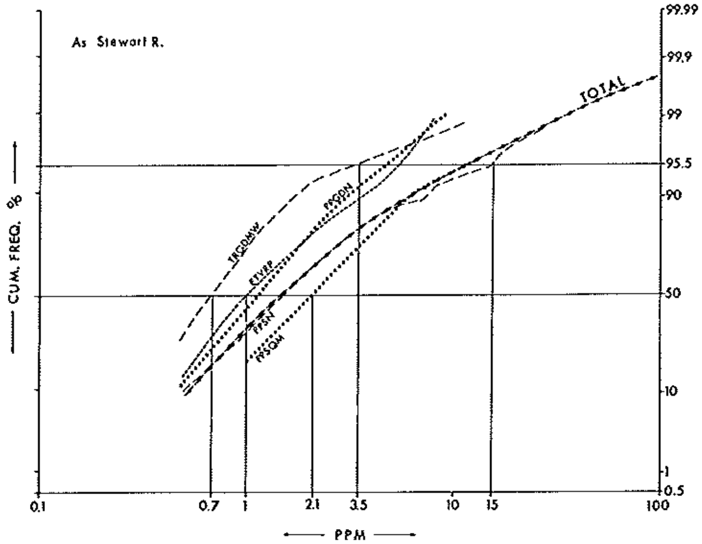

d

Figure 34

Arsenic – Stewart River map-area

Geological sketch map of Stewart River map-area showing statistical parameters related to the geochemistry of arsenic for the areally extensive map-units. From the top down these are the mean, median and threshold levels (all in parts per million) and the log standard deviation and number of samples analyzed from the unit. The sample localities and the locations where anomalously high concentrations of arsenic were analyzed are shown by large dots. The histograms and cumulative curves illustrate the frequency distributions of arsenic in some of the map-units; they are selected to demonstrate the geochemical variation between rock-units. The distributions labelled TOTAL represent all samples analyzed for arsenic during the project and are shown for comparison. The perspective diagram displays the arsenic geochemistry as a moving average in the third dimension so it appears as relief in relation to the map grid. The map and diagrams are intended to give an overview. For the analytical results concerning specific samples the reader is referred to Appendix 1.

Note that in the histograms and cumulative curves the scale of the arsenic concentrations is logarithmic and that the cumulative frequency distribution is on probability scale.

In Stewart River map-area only the Klondike schist (PPSQM) has above average concentrations of arsenic (Fig. 34d) and most other rock units are distinctly arsenic deficient when compared to all rocks of the project area. As noted the high arsenic and silver of the Klondike schist probably relate to the probability that this unit was the ultimate source for much of the Klondike gold. The arsenic content of the Carmacks Group (ETCV) is comparatively high, but normal for such basaltic rocks. The perspective diagram does not bring out the high background Klondike schist and Carmacks Group and instead emphasizes local highs. The spot values near Mount Hart are a standout; one of the samples there runs 100 ppm arsenic. Mount Hart is also geochemically active in silver, copper, lead, molybdenum and mercury and several small mineral occurrences are known on its flanks.

Lead

In general the felsic volcanic rocks contain distinctly more lead than any other rocks analyzed and the metamorphic rocks seem to be particularly lead poor (Fig. 37). However the spread of values is small and there is less basis to distinguish between rock-units on their lead content than on most of the other metals. Lead backgrounds in the plutonic rocks analyzed are low by comparison with those from other areas. The most acid granitic rocks, the Nisling Range alaskite (TGAL), although they do contain more lead on average than granodiorite of the Klotassin (TRDGM), have little better than half the lead generally found in granites.

In contrast to the granitic rocks, the tholeiitic basalts of the Carmacks Group (ETVC) and its correlatives, the Little Ridge volcanics (TLR) and Donjek volcanics (LTVD), are each somewhat richer in lead than general for such rocks (Levinson, 1974), and on average each contains more lead than the plutonic rocks taken together (Fig. 5). The cause for the high lead in this otherwise metal-poor suite of basalts is not known.

Plutonic rocks in the project area have less lead than plutonic rocks elsewhere. The pink quartz monzonite (TRQM) and porphyritic quartz monzonite (MQMP) have distinctly less lead than any of the other intrusive rocks analyzed. This in spite of the fact that they are among the more acid and might therefore be expected to have more lead than most. Not only are these two rock-units deficient in lead, they contain much less zinc, copper, molybdenum and tungsten than other rocks analyzed for this study and are below average in all other metals. These two genetically associated suites appear to offer the poorest prospects for economic concentrations of metals in the project area being geochemically among the least responsive. No mineral occurrences are known in these rocks.

The lead geochemistry is so undemonstrative that it makes rocks in the entire region look uninteresting for concentrations of lead and other metals. Because important metal concentrations (not lead) do exist the conclusion that the distribution of this metal in the region studied reflects magmatic differentiation and primary dispersal patterns but not the metal enrichment scheme is inescapable.

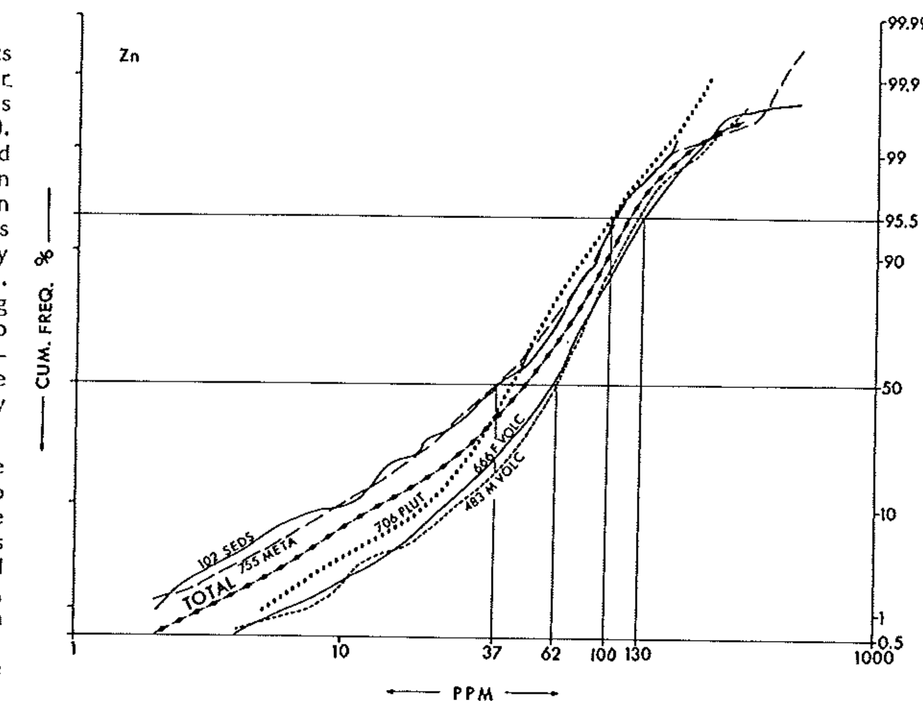

Figure 35

Cumulative curves contrasting the frequency distribution of zinc among composites of the plutonic, metamorphic, sedimentary and volcanic populations. Note that the curves for the plutonic and volcanic rocks are parallel, but that they slope more steeply than the curves for the sedimentary and metamorphic rocks. This difference in slope is reflected by differences in the standard deviations which are .27-PLUT, .27-MVOLC, .28-FVOLC and .39-META, .40-SEDS. The contrast in slope reflects dispersion of metals during sedimentation a feature preserved in the metamorphic rocks. Although parallel the volcanic and plutonic curves are strongly displaced indicating strong partitioning of zinc in the volcanic rocks during magma evolution. This partitioning into the volcanic part of consanguinous magma and away from the plutonic rocks is also seen in the other metals studied. It can be demonstrated on a smaller scale by studying individual plutonic-volcanic suites (the Nisling Range alaskite-Mount Nansen Group and the Klotassin granodiorite – Lewes River Group). Note that as with most other metals the zinc content tends to be lowest in the plutonic rocks and that it is enriched in sedimentary and volcanic rocks. Note that although the metamorphic and sedimentary rocks differ vastly in age, their zinc distributions are identical, implying that the bulk of the metamorphic rocks are metasediments. The negative skewness seen in the zinc distributions of individual rock-units is preserved in the composites as evidenced by the concave-up shape of the curves. Negative skewness can result from bimodality. In the present distributions bimodality due to mixed populations can be ruled out because no matter how the population is broken down the negative skew is preserved. If the biomodality does not reflect limitations in the analytical technique for this element it is presumably caused by a dual control on the zinc substitution in the rocks whereby zinc substitutes for one element or in a certain mineral at low ranges, but for another element or mineral when the zinc content is higher.

Molybdenum and tungsten

Molybdenum and tungsten are geochemically alike and tend to be concentrated or depleted together. Both metals have been analyzed in this study; molybdenum because it is a pathfinder for porphyry copper occurrences in general and molybdenum deposits in particular and tungsten because it pinpoints skarn occurrences in which several metals aside from that element may be concentrated. Although the frequency distributions for both metals are strongly skewed (e.g. Fig. 14b, 15b) because of limitations in the analytical methods the data allow distinction between rock-units on the basis of the abundance of these two metals. In the project area the close correlation between molybdenum and tungsten, which has been noted in other studies, is also evident and rock-units high in molybdenum are similarly high in tungsten while those low in one metal are low in the other (see Fig. 5).

Among the metamorphic rocks those in the northern and southern parts of the Yukon Crystalline Terrane differ markedly in their molybdenum and tungsten backgrounds. Those in the southern part have distinctly higher concentrations of both metals (Fig. 5) than those in the north. The marbles (PPC+) among the metamorphic rocks in the south have the highest concentrations of both metals. This is not surprising because many of the marble lenses are close to

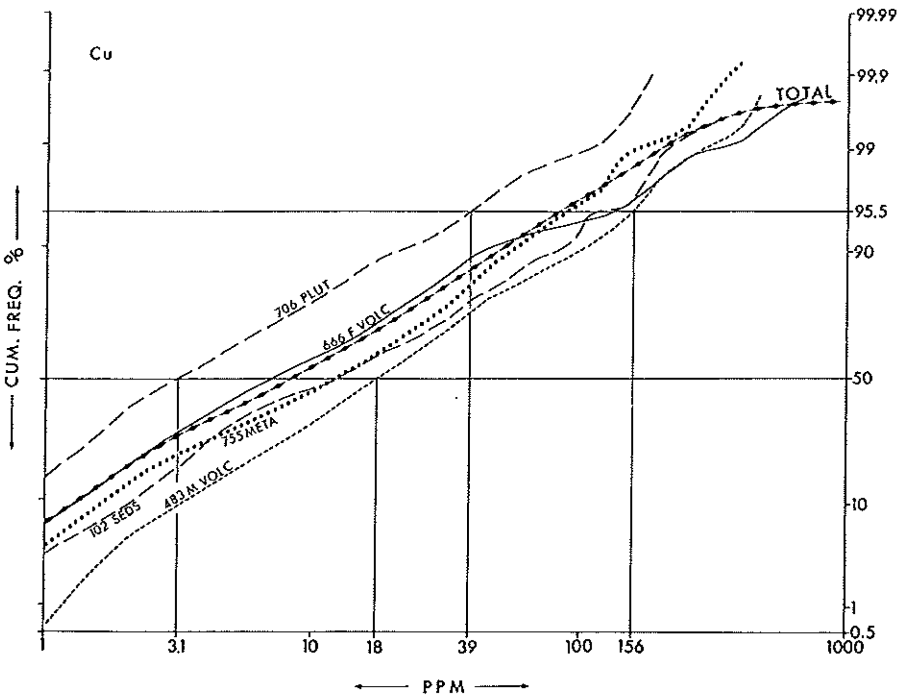

Figure 36

Cumulative curves of the frequency distribution of copper in the plutonic, volcanic, metamorphic and sedimentary rocks of the project area. The comparative straightness of the curves indicates a lack of skewness and an approximation to lognormality in the distribution of copper that is not seen as clearly in the other metals. Although the slopes are closely similar (indicating similar standard deviation) the curves are displaced and there is distinct concentration of copper in the mafic volcanics and depletion in the plutonic rocks. Such concentration of metal in the volcanic rocks relative to the plutonic suites is also noted for some of the other metals (zinc, arsenic silver) and can be demonstrated in individual plutonic-volcanic suites (eg. TRGDM-TRVB, TGAL-TMN) as well. The sedimentary and metamorphic rocks have similar distributions which supports the contention that most of the metamorphic rocks are of sedimentary parentage.

granitic rocks and are skarns in which these metals may be introduced. The cause for the high molybdenum and tungsten backgrounds in the biotite schist (PPSBQ), Nasina quartzite (PPQC) and Kluane schist (PPSQR) is unknown. Though no economic concentrations have been found a number of small skarn occurrences with scheelite are known in Aishihik Lake map-area. The relatively high tungsten and molybdenum backgrounds of the marbles correlates with the indicence of mineral showings of these metals in this map-unit. No occurrences of molybdenum or tungsten are known in the biotite schist, Nasina quartzite or Kluane schist.

The plutonic rocks analyzed are nearly all low in both molybdenum and tungsten by comparison with other rocks in the project area. The Nisling Range alaskite (TGAL) and Nisling Range granodiorite (MGDB), two genetically unrelated plutonic types, are exceptions. The relatively high molybdenum and tungsten backgrounds of the alaskite (TGAL) correspond to the number of occurrences in which molybdenum is concentrated in these rocks. The Casino and Cockfield deposits are examples of porphyry molybdenum-copper deposits in an explosive phase of the Nisling Range alaskite. The Nisling Range alaskite has many of the characteristics seen in granitic rocks that are genetically associated with tin deposits (see Mulligan; 1975 p. 37). These include their strongly discordant high level nature, variable texture, acid composition and abnormal volatile content (fluorite). In addition this suite contains abnormal amounts of tungsten and moybdenum, metals generally found in tin granites. The alaskite would appear favourable to concentrations of tin. Although no molybdenum or tungsten concentrations are known in the Nisling Range granodiorite this suite merits examination for possible occurrences of molybdenite because of its comparatively high tungsten content.

Tungsten is concentrated in the rhyolite porphyries (ETVRP) related to the Carmacks Group which are found in parts of Stewart River map-area. No important mineral showings are known in these rocks, but their anomalously high tungsten (but comparatively low molybdenum) indicates they warrant careful prospecting. Mulligan (1975) has pointed to these rocks as the probable source for wood tin, now concentrated in placer deposits of the Klondike.

Relative to other rock-units in the project area high concentrations of molybdenum are found in the Carmacks Group (ETCV) and Little Ridge volcanics (TLR). Because these are basaltic rocks and because such rocks generally contain less molybdenum than more acid volcanics and plutonic rocks, the high molybdenum in the Carmacks and Little Ridge rocks is interesting. However no known concentrations containing molybdenum or other base metals are known in these rocks and this geochemical concentration may be correlated with the relatively high lead noted in these rocks (see Fig. 5).

The molybdenum and tungsten geochemistry supports the importance of the Nisling Range alaskite-Mount Nansen Group for metal concentrations. The marbles in southern Aishihik Lake map-area merit careful examination for concentrations of tungsten in skarns. Their geochemistry suggests that the Nisling Range granodiorite (MGDB) and rhyolite porphyries (ETVRP) may contain tungsten concentrations.

Most tungsten occurrences in the Canadian Cordillera are associated with biotite-quartz monzonite and related rocks that give 100 m.y. K-Ar ages and which are restricted to the Omineca Crystalline Belt. The plutonic rocks with which the tungsten skarns in Aishihik Lake map-area are associated are the 55 m.y. Nisling Range alaskite and the related Ruby Range granodiorite. Both these plutonic suites are affiliated with the Coast Plutonic Belt. Whereas the Nisling Range alaskite is a molybdenum-tungsten-copper suite the granitic rocks of the Omineca Crystalline Belt are a tungsten bearing plutonic suite per sé without important other base metals.

Silver

The geochemistry of silver and arsenic is similar and because both metals substitute mainly for sulphur they are generally found in pyrite and other sulphides. The silver concentrations in the rocks analyzed for this study vary little so that as a rule there is little in the silver distribution to tell the suites apart. The cumulative curves (Fig. 38) show that of the main groupings only the silver distribution in the plutonic rocks is distinct from the remainder because their silver, like their other metal concentrations is lower than average. The felsic plutonic rocks such as the Coffee Creek granite (KG), pink quartz monzonite (TRQM) and Nisling Range alaskite (TGAL) are each depleted in silver by comparison to mafic igneous rocks like the Klotassin suite (TRGDM) and Ruby Range granodiorite (TRGD). Such relative concentration of silver in mafic plutonic rocks is common in other areas where this has been studied. Arsenic shows the same tendency (see Fig. 5) although it is not as clearly illustrated.

Silver was analyzed in part because it is an indicator metal for hydrothermal vein occurrences of gold and silver. Important gold and silver veins are known in the Mount Nansen Group at Mount Nansen just outside the project area and similar deposits may be associated with this suite of rocks elsewhere. However the background concentration of silver in the Mount Nansen suite (TMN) is only slightly higher than the overall background and therefore gives no indication of the potential importance of this suite of rocks for possible silver occurrences. The varicoloured tuffs (TVR) in Aishihik Lake map-area may be equivalent to the Mount Nansen and also have higher silver contents than most other rocks studied. No mineral occurrences are known in these tuffs.

Although basalts generally contain more silver than most other rock types (Levinson, 1974) only the Lewes River Group (TRVB) of the basic volcanics analyzed for this study fits this rule. Moreover this basalt has a higher silver background than any other suite studied (Fig. 5). The Lewes River also has extremely high copper, zinc and mercury concentrations and its silver reflects the higher total metals in this basalt. The Lewes River Group encloses several important copper deposits, but no occurrences where other metals are concentrated have been discovered.

The Carmacks (ETCV), Donjek (LTVD) and Little Ridge (TLR) volcanics, broadly correlative assemblages of tholeiitic flood basalts, have uniformly and anomalously low silver for such basic volcanic rocks. In addition they are lower in other metals than basalts in general and their silver therefore reflects the low total metal content of these rocks. The Lewes River is a Triassic island-arc-related suite known along much of the Canadian Cordillera whereas the Carmacks is a continental flood basalt roughly correlative with the Plateau Lavas of central British Columbia.

Among the metamorphic rocks the Kluane schist (PPSQR) is a standout for its high silver as it is for zinc, copper, molybdenum and arsenic (Fig. 5). This map-unit has inherently high metal backgrounds, but no mineral occurrences are known. The same is true of the sedimentary and volcanic rocks south of the Denali-Shakawak fault, which also contain much metal, but which host few mineral occurrences. The Kluane schist is probably the metamorphosed equivalent of the Dezadeash Group and the similarities in their geochemistry supports this contention (see also under "Zinc").

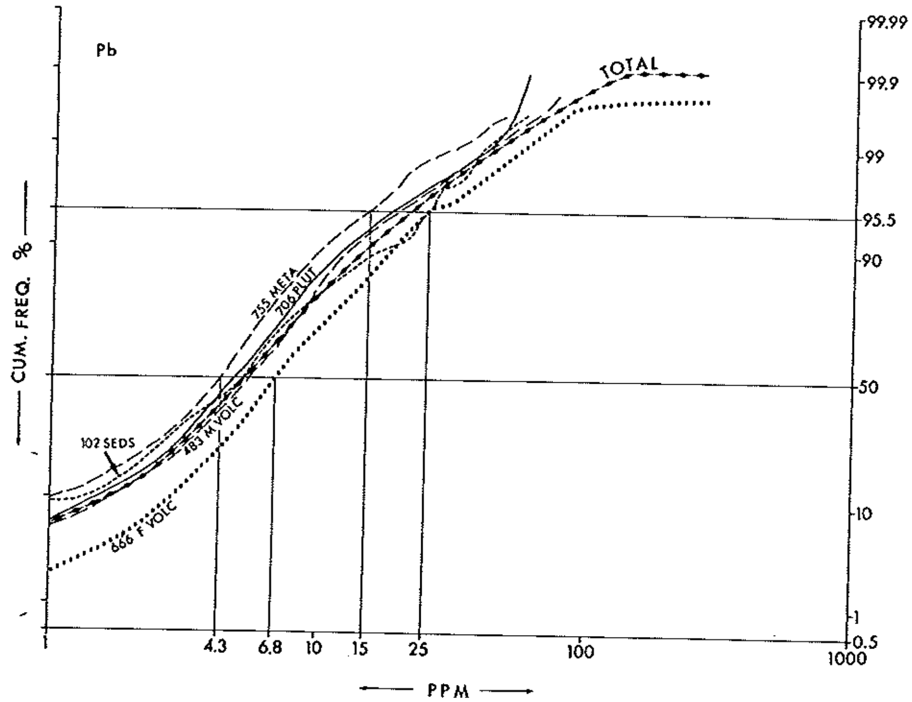

Figure 37

Cumulative curves of the distribution of lead in composites of all the plutonic, metamorphic, volcanic and sedimentary rocks taken together. Parallelism of the curves indicates a similar standard deviation and the relative displacement of the curves reflects variation in metal content. The reverse bend in the curves from concave at the left to convex at right indicates that lead is close to normally distributed. This is characteristic for lead and also for silver (see Fig. 38). Note that the lead content of the metamorphic rocks is distinctly low whereas that of the felsic volcanics is high. The plutonic, sedimentary and mafic volcanic rocks have virtually indistinguishable lead distributions. This is in contrast to the relations seen for copper, zinc, arsenic and silver in which the plutonic rocks tend to be metal poor by comparison to all the other lithologic groupings and the mafic volcanics in particular. Relatively high lead in the felsic volcanic rocks reflects the fact that most of the lead probably substitutes for potassium in potash feldspar, an important constituent of these rocks. Because the metamorphic rocks are lead-poor compared to the sedimentary rocks it appears that lead may have been removed from the metamorphic rocks, which presumably had an initial lead content like that of the sedimentary rocks. Zinc and copper do not reflect this mobility. Such preferential lead removal from the metamorphic rocks may be related to potash metasomatism out of the metamorphic rocks during a metamorphic or plutonic event in the region. (e.g. metasomatism related to emplacement of the pink quartz monzonite?).

The Klondike schist (PPSQM) and its probable correlatives the schist (PPSB) and phyllite (PPPS), though deficient in other metals, all have above average silver concentrations (Fig. 5). These rocks are also the source for the bulk of the gold concentrated as placers in the Klondike district (Gleeson, 1970). The above average silver content correlates neatly with the high gold content of the Klondike schist and is the only indication given by the geochemistry of the gold possibilities of these rocks. Interestingly the Nasina quartzite which also has relatively high silver is not an important source rock for gold in the Klondike (Gleeson, 1970).

The silver geochemistry adds to the picture given by the other metals of overall high (Kluane schist, Lewes River) or low (Carmacks Group) metal background map-units. Although a correlation with mineral occurrences can be inferred with prior knowledge, the silver geochemistry does not by itself have predictive value in pinpointing units of high or low exploration priority.

Arsenic

Arsenic was analyzed for in the samples because it is a pathfinder metal for gold, silver, copper, cobalt and zinc occurrences. Differences in the concentration of arsenic between the main rock types are small (Fig. 39) and only the plutonic rocks are standouts by having distinctly less arsenic than the other groups. The sedimentary, metamorphic and volcanic rocks when grouped together are virutally indistinguishable. Like silver the arsenic concentration in the acid plutonic rocks is lower than that in the more mafic types (contrast the three felsic plutonic suites TGAL, KG and TRQM with the hornblende quartz diorite TRGDM, Fig. 5). The arsenic content of the various rock types is roughly the same as that found in other studies (Boyle and Jonasson, 1973).

Sedimentary rocks of the Tantalus Formation (LKT) and Carmacks Group (TSCG) contain more arsenic than rocks of any of the other map-units (Fig. 5). Because sedimentary rocks generally contain more arsenic than other types this comes as no surprise.

Another rock-unit with above average arsenic is the Mount Mansen Group (TMN). It also has higher than normal silver and zinc. This suite has been discussed in a previous section, but its geochemistry correlates well with the fact that several precious metal vein occurrences are genetically associated with this assemblage. These are gold-silver veins in the vicinity of Mount Nansen, Freegold Mountain and Granite Mountain all in Carmacks map-area. The Mount Nansen in other parts of the region merits exploration for such occurrences.

Among the metamorphic map-units two stand out for their arsenic. One is the Kluane schist (PPSQR) earlier noted because it also has anomalously high background levels in most of the other metals. The other metamorphic suite with high arsenic is the Nasina quartzite (PPQC) (Fig. 5). Interestingly this unit also has above average background concentrations of silver, mercury, tungsten, molybdenum and copper. The Nasina quartzite is roughly equivalent to Ordovician, Silurian and Devonian strata which are largely in shallow marine platform facies to the northeast on the Pelly-Cassiar Platform and in deeper water facies still farther northeast in Selwyn Basin. Thus the Nasina correlates broadly with parts of the Kechika, Sandpile and McDame groups of Gabrielse (1963) and with the Road River in Selwyn Basin (Tempelman-Kluit, 1977).

Its interesting geochemistry and rough equivalence to the Road River, a unit that envelops several large deposits of lead and zinc, suggest that the Nasina warrants a close look for occurrences of base metals. Because it has relatively high concentrations of many metals, but low lead and zinc such base metal occurrences may contain significant copper and their zinc and lead may be of secondary importance. No base metal occurrences have yet been discovered in the Nasina quartzite.

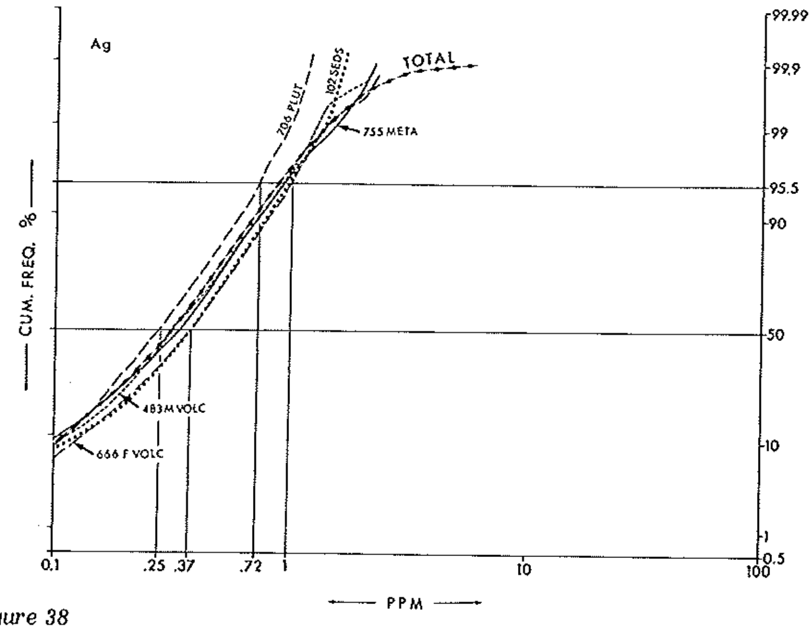

Figure 38

Cumulative curves of the distributions of silver in composites of all plutonic, metamorphic, volcanic and sedimentary rocks together. Note that silver is distinctly low in the plutonic rocks, but that the distributions for the remaining rock assemblages are virtually indistinguishable. This illustrates concentration of silver in volcanic rocks away from the plutonic types, a phenomenon seen also for zinc, copper and arsenic. The curves are parallel and show a slight negative skew (concave upward and left). Although the distribution of silver in all samples together is not skewed (see Fig. 8) slight negative skew is common in many of the subpopulations. The steep slope of the curves reflects the relatively low standard deviation of the silver distribution when compared to the other metals studied.

Note the weak tendency toward reverse curvature (concave up at left, concave down at right) which indicates that silver is normally distributed. Compare this with the curves for lead (Fig. 37) which shows the same tendency and contrast these with the copper distributions (Fig. 36) which are log normal.

COMPARISON OF ROCK GEOCHEMISTRY WITH STREAM SEDIMENT DATA

A summary of a stream sediment geochemical survey covering most of the area examined in this study as well as much adjacent country was published recently by Gleeson and Brummer (1976). It includes regional moving average maps of the concentration of zinc (their Fig. 21), copper (their Fig. 22) and molybdenum (their Fig. 23) in analyzed stream sediment samples. Gleeson and Brummer (1976) also included a correlation of the stream sediment data with the geology.

In general the bedrock geochemistry is in accord with the stream sediment data of Gleeson and Brummer (1976) and the two surveys complement each other. The following paragraphs compare the moving average maps of the stream sediment data with the bedrock chemistry.

The stream sediment maps of zinc, copper and molybdenum reflect a number of metal highs that correspond to areas underlain by Nisling Range alaskite (TGAL) and the related Mount Nansen Group (TMN). As has been shown, both of these rock-units and their related dykes (TFP) have high zinc and molybdenum concentrations. The main areas where these chemically active rocks occur and where there is corresponding stream sediment response in zinc, copper and molybdenum are east of Canyon Lake, along the west side of Aishihik Lake map-area, between the Klotassin and Nisling rivers in Snag map-area and near Casino and Mount Cockfield. Surprising is the fact that there is general copper response from the stream sediments associated with these rocks although the rocks themselves do not contain inordinate concentrations of this metal.

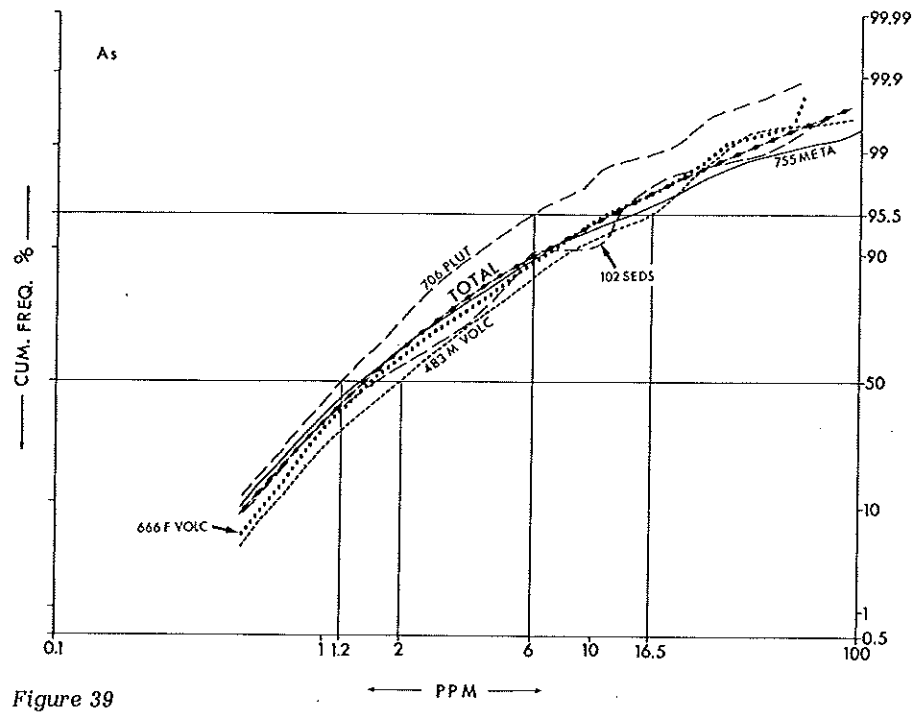

Figure 39

Cumulative curves to describe the frequency distribution of arsenic among composites of all plutonic, metamorphic, volcanic and sedimentary rocks analyzed. The convex shape of the curves reflects the positive skew of the arsenic distributions. Contrast this with the zinc distributions which are negative skewed. Note that the slopes tend to be the same although the plutonic curve is somewhat steeper than the others indicating that it has a smaller standard deviation. The arsenic distribution in the plutonic rocks is lower than that of the other suites and tends to be highest in the mafic volcanic rocks. Concentration of arsenic in the volcanic part of a cogenetic plutonic-volcanic suite is also seen with some individual assemblages as for example the Nisling Range alaskite and its related volcanics the Mount Nansen Group. The arsenic distribution of the plutonic rocks is distinct from that in the volcanic, sedimentary and metamorphic rocks which are too close to allow clear separation between each other.

Unexplained is the absence of stream sediment response over two other areas where the Mount Nansen and the associated feldspar-porphyry dykes occur, one along the east side of Snag map-area about 15 km north of Klaza River, the other at the northeast corner of Aishihik Lake map-area and in adjacent Carmacks map-area. Presumably the Mount Nansen in these two areas has lower metal concentrations than elsewhere or the metals are more readily dispersed in the associated sediments than is generally the case. Sampling of these two areas was not sufficient to discriminate between these possibilities.

Interestingly the high zinc, copper and molybdenum backgrounds of the Kluane schist (PPSQR) are reflected in the stream sediment data by copper, but not by zinc and molybdenum. In the same way the Lewes River basalts (TRVB) in northeast Aishihik Lake map-area, which are geochemically active in zinc and copper, show up in the stream sediments only by their copper. Presumably this is because zinc and molybdenum are more mobile than copper and are therefore more easily dispersed in the sediments derived from these rock-units than copper is. The Carmacks Group (ETCV) and its equivalents (LTVD, TLR) show a similar response. They all have relatively high zinc backgrounds, but the sediments in streams draining them generally do not reflect this high zinc. An exception is the anomalously high zinc in stream sediments over basalt of the Carmacks Group 30 km west of the mouth of Sixtymile River (see Fig. 21 of Gleeson and Brummer, 1976). The low stream sediment response for zinc from the high zinc background Carmacks Group probably results from the high mobility of zinc in the sediments as postulated for the Kluane schist and Lewes River Group.

Just as the high metal background units show good correspondence with the stream sediment data so do those with low concentrations. Plutonic rocks like the porphyritic quartz monzonite in north-central Aishihik Lake map-area (MQMP), which has low concentrations of all metals analyzed, appear as lows on the stream sediment maps also. Similar absence of stream sediment activity is seen for most of the geochemically inactive metamorphic rocks.

Aside from the strong response over areas of Nisling Range alaskite the molybdenum stream sediment map reflects the area of tungsten-bearing skarns east of Canyon Lake and one area 30 km west of the mouth of Sixtymile River underlain by the Carmacks Group, a suite with moderate molybdenum concentrations.

The northwest corner of Stewart River map-area has high zinc concentrations in the stream sediments, but no rock-units which can account for this are exposed there. This anomalous zinc concentration in the stream sediments is therefore probably related to the several mineral occurrences known here. Similar local concentrations in the stream sediments, which cannot be accounted for by the metal backgrounds of surrounding rocks, are likely the reflection of mineral showings

This comparison of the stream sediment and bedrock geochemistry has emphasized the accord between the two types of surveys and has pointed to some differences in response to metal content of the two methods. Zinc and molybdenum tend to be more mobile than copper in the stream sediments. Rock-units with high backgrounds in all three metals therefore yield stream sediments in which the high copper concentrations is retained, but in which the zinc and molybdenum are likely low by comparison to the parent rock.

CONCLUSIONS

The bedrock analyses have given data on the metal concentrations in different map assemblages and lithologic types in west-central Yukon. They show that the metal concentrations in the Yukon Crystalline Terrane are similar to those in like rocks elsewhere and give reasons to focus exploration for certain metals on specific rock-units.

Among the areally extensive map-units of metamorphic rocks the metal concentration in the biotite schist, Pelly gneiss, schist-gneiss, and amphibolite is uniformly below average and these rocks are poor prospects for metal concentrations. The Nasina quartzite has comparatively high copper, molybdenum, tungsten, mercury, silver and arsenic concentrations. Because of this and because the quartzite is roughly the time equivalent of the Road River Formation it is thought an important unit on which to concentrate exploration. The Klondike schist is the probable parent for the bulk of the placer gold concentrated in the Klondike. This is shown by the comparatively high arsenic and silver content of this rock-unit. The Kluane schist includes staurolite-quartz-mica schists whose original composition and metamorphic history are distinct from the other metamorphic rocks. This schist is also geochemically unique because it has much higher than average backgrounds of zinc, copper, molybdenum, silver and arsenic. The Kluane schist is probably the metamorphic equivalent of the Dezdeash Group, a suite, which on the basis of limited sampling, also has high concentrations of the same metals.

As expected most of the plutonic rocks have low metal concentrations. Only the Nisling Range alaskite and its related subvolcanic porphyries and explosive volcanic rocks of the Mount Nansen Group look geochemically exciting. The plutonic phase of this assemblage is relatively rich in lead, molybdenum and tungsten while the extrusive phases have zinc, silver and mercury in higher than average concentrations. Aside from their known association with porphyry occurrences of molybdenum-copper, vein deposits of precious metals and copper-tungsten-bearing skarns (in nearby marbles) these rocks may have associated tin and/or uranium mineralization. Interestingly the geochemistry of this volcano-plutonic suite demonstrates effective partitioning of each of the metals studied between the volcanic and plutonic phases. The Nisling Range granodiorite has a fairly high background in tungsten and this plutonic suite may be important for concentrations of tungsten or molybdenum.

Of the volcanic rocks the Late Triassic island-arc-related basalt of the Lewes River Group has high zinc, copper, mercury and silver and this rock-unit is host to several small, but high grade, copper occurrences. Other basalts include tholeiitic flood basalts of the Carmacks, Donjek and Little Ridge volcanics, which are broadly equivalent. These rocks are all metal-poor yet sufficiently different geochemically to allow distinction between them. The rhyolite porphyries, which are part of the Carmacks Group in Stewart River map-area, contain much tungsten and may have economic occurrences of that metal as well as tin associated with them.

The cumulative frequency curves of the metal distributions have characteristic shapes for each metal studied regardless of how the sample population is broken down. The curve shape and slope therefore identify the metal as clearly as does the concentration. Cumulative curves for zinc are concave whereas those of copper are straight and those of arsenic convex. Lead and silver curves are concave-convex.

Comparison of the bedrock chemistry with regional stream sediment geochemistry demonstrates that, as might be expected, zinc and molybdenum are more mobile than copper. Stream sediments derived from rocks rich in all three metals contain only above average amounts of copper.

When this study was conceived it was hoped that the minor element geochemistry would corroborate some geological prejudices concerning favourable and unfavourable rocks and rock-units and that it would pinpoint strata with unique metal abundances and associations. The geochemical inventory has lived up to these expectations. However this study has not uniquely defined new target areas, target units or detailed targets for mineral exploration, nor has it provided new insights into the genesis of, relations between and history of, the rocks of the region. Geochemical studies such as this are a luxury, considering the expense of time and effort involved. As such they are probably only warranted when the geology is thoroughly understood and when relatively little can be gained by further detailed geological studies. In this sense geochemical study of this region was premature.

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APPENDIX I

The analytical results of this project are listed on the microfiche that accompany this report. The file is ordered alphabetically in terms of the mnemonics, first those of the map-unit and second those representing the lithology. Sample locations are reported by the UTM map-sheet designation and co-ordinates. Sample numbers are those originally assigned in the field; they identify the collector, year the sample was obtained and field note book page where the sample is described.

The file lists the abundances of zinc, copper, lead, molybdenum, tungsten, mercury, arsenic and silver in parts per million. Underlining is used to indicate those metal values that are anomalous in the sample population of each large map-unit. Only those metal values that are anomalous in a given sample are underlined. Single underlining indicates concentrations higher than those found in 95.5 per cent of the samples from the map-unit in question. Double underlining is used when the concentration equals or exceeds that in 99 per cent of the samples from the given map-unit. For map-units that were sparsely sampled the total population of all the samples in the project is used to determine anomalous concentrations. The 95.5 percentile concentrations (threshold levels) are compared graphically in all metals and all map-units in Figure 6.

The sample density is given where determined. Where the density is reported as 0.0 this property was not measured. Magnetic susceptibility is given in units of 10^{-6} emu. A magnetic susceptibility reading of 0 indicates that it was below the detection limit of the instrument, typically 30 to 50 x 10^{-6} emu depending on sample size. A magnetic susceptibility reading of -1 indicates that no measurement of susceptibility was made. Modes, determined from counts of 200 points on stained, sawn slabs of the plutonic rocks are reported under the headings KF-potash feldspar, MA-mafic minerals, PL-plagioclase, QZ-quartz, GM-groundmass in porphyritic rocks with aphanitic groundmass.

To find the analytical results for any sample determine from its location on the sketch maps its approximate UTM co-ordinates and search in the file among samples from the appropriate map-unit and map-sheet for those co-ordinates.

APPENDIX 2

This table lists the map-unit mnemonics used in Appendix 1 and elsewhere in this report and the equivalent map-unit sympols as used in Tempelman-Kluit (1974). The groupings of map-units used to make up the composite files META, SEDS, FVOLC and MVOLC is also listed.

MNEMONIC	MAP-UNIT
PPSQR	Kluane schist, staurolite-quartz-biotite schist (Aishihik L.)
PPSBQ	Biotite schist (Aishihik L., Snag)
PPMH	Amphibolite in Aishihik map-area PLUS amphibolites in PPSBQ
PPC*	Marble (Stewart R., Aishihik L.)
PPC+	PLUS marbles in PPSBQ and PPQC
PPQC	Nasina quartzite, grey graphitic quartzite and slate (Stewart R., Snag)
PPGDN	Pelly gneiss, biotite granodiorite gneiss (Snag, Stewart R.)
PPGD	Foliated biotite granodiorite (Snag, Stewart R.)
PPSQM	Klondike schist, quartz muscovite schist (Snag, Stewart R.)
PPSN	Schist gneiss, biotite-quartz schist and gneiss (Snag, Stewart R.)
PPM	Amphibolite (Snag, Aishihik L.)
PPPS	Phyllite (Snag)
PPSB	Schist (Snag)
PPT*	Argillaceous chert (Snag)
PT*	Chert and metachert (Stewart R.)
PPTI*	Hornfels (Snag)
META	All metamorphic rocks
PMUB*	Dunite (Snag, Stewart R.)
PMB	Gabbro (Snag)
PMPR*	Peridotite (Snag)
MAFIC	Includes all mafic plutonic rocks
TRVB	Lewes River Group, basalt (Aishihik L.)
TRGDMA	Hornblende granodiorite (Klotassin Suite in southeastern Snag)
TRGDMS	Hornblende granodiorite (Klotassin Suite in Aishihik L.)
TRGDMT	Hornblende granodiorite (Klotassin Suite between Donjek and Yukon rivers in Snag)
TRGDMW	Hornblende granodiorite (Klotassin Suite west of White River in snag and Stewart R.)
TRGDM	All rocks of the Klotassin suite together
TRQM	Pink quartz monzonite (Snag, Aishihik L.)
MQMP	Porphyritic quartz monzonite (Snag, Aishihik L.)
KG	Coffee Creek granite (Snag, Aishihik L.)
MGDB	Nisling Range granodiorite (Snag)
PPQMM	Foliated muscovite-quartz monzonite (Stewart R.)
TG	Nisling Range granite (Aishihik L.)
LMMZ*	Hornblende monzonite (Stewart R.)
LMQM*	Quartz monzonite (Snag, Stewart R.)
LMMZP*	Porphyritic monzonite (Snag, Stewart R.)
TGAL	Nisling Range alaskite (Snag, Aishihik L.)
PLUT	all plutonic rocks
TFP	Feldspar porphyry (Aishihik L.)
TFP+	TFP PLUS TFP dykes, TGAL dykes, all dykes and feldspar porphyries in PPSBQ and TRGDMS
TMN	Mount Nansen Group, explosive acid volcanic rocks (Snag, Aishihik L.)
TCGG*	Granite conglomerate (Snag)
JL	Laberge Group, conglomerate, sandstone, shale (Aishihik L.)
TCGQ*	Quartzite conglomerate (Snag)
LTSP*	Sandstone (Snag)
LKT	Tantalus Formation, conglomerate, sandstone, shale, (Aishihik L.)
TSCG	Includes sandstones and conglomerates
ETCCG*	Sandstone and conglomerate (Stewart R.)
SEDS	Includes sedimentary rocks
ETVRP	Rhyolite porphyry (Stewart R.)
TVR	Varicoloured acid tuff (Aishihik L.)
ETCV	Carmacks Group, tholeiitic basalts (Snag, Aishihik, Stewart R.)
LTVD	Donjek volcanics, tholeiitic basalt (Snag)
TLR	Little Ridge volcanics, tholeiitic basalt (Aishihik L.)
TQVBO*	Columnar basalt, olivine basalt (Stewart R.)
QTVBO*	Olivine basalt (Snag)
MVOLC	Includes all mafic volcanics
TVA*	Casino volcanics, acid volcanic breccia and tuff (Snag)
TV*	Undifferentiated volcanics (Aishihik L.)
LTVR	Felsic volcanics (Snag)
FVOLC	Includes all felsic volcanics
PMV	Volcanic rocks (Snag)
PMS	Sedimentary rocks (Snag)
PV	Sheared greenstone (Snag, Stewart R.)

* Map assemblages of small areal extent from which too few samples were collected for statistical averaging. Rocks from these units have been included with those from equivalent map-units as applicable.

APPENDIX 3

Mnemonics used to indicate rock type in the column headed "lithology" of Appendix 1.

ACIV	acid intrusive
ACTF	acid tuff
AEXV	acid extrusive
AGGS	augen gneiss
AGLM	agglomerate
ALSK	alaskite = leucogranite
AMGN	amphibolite gneiss
AMPB	amphibolite
ANDS	andesite
APLT	aplite
ARGL	argillite
BCIV	basic intrusive
BDRT	biotite diorite
BEXV	basic extrusive
BGDR	biotite granodiorite
BGNS	biotite gneiss
BGRT	biotite granite
BHDR	biotite-hornblende diorite
BHPP	biotite-hornblende porphyry
BPPP	biotite porphyry
BQMZ	biotite-quartz monzonite
BQZD	biotite-quartz diorite
BRCC	breccia
BSCS	biotite schist
BSLT	basalt
CGLM	conglomerate
CHRT	chert
CLCT	calcite
DCIT	dacite
DIBS	diabase
DORT	diorite
DRGS	diorite gneiss
DYKE	dyke
EXTV	extrusive volcanic
FBGD	foliated biotite granodiorite
FBPP	feldspar-biotite porphyry
FBQM	foliated-biotite-quartz monzonite
FDRT	foliated diorite
FGDR	foliated granodiorite
FHQM	foliated hornblende-quartz monzonite
FLBC	flow breccia
FLST	felsite
FPPP	feldspar porphyry
FQDR	foliated quartz diorite
FQMZ	foliated quartz monzonite
GASC	garnet schist
GBBR	gabbro
GBDR	gabbro diorite
GDGN	granodiorite gneiss
GNSS	gneiss
GRCK	greywacke
GRDR	granodiorite
GRGN	granite gneiss
GRNS	greenstone
GRNT	granite
GWSS	greywacke sandstone
HBDC	hornblende dacite
HBDR	hornblende diorite
HBFP	hornblende-feldspar porphyry
HBGD	hornblende granodiorite
HBGN	hornblende gneiss
HBGR	hornblende granodiorite
HBLD	hornblendite
HBMZ	hornblende monzonite
HBPP	hornblende porphyry
HBQD	hornblende-quartz diorite
HBQM	hornblende-quartz monzonite
GBSC	hornblende schist
HFLS	hornfels
HSCS	hornfels schist
IEXV	intermediate extrusive
IRFM	iron-formation
JSPR	jasperoid
KFPP	potassium feldspar porphyry
LMST	limestone
MCVS	muscovite schist
MDSN	mudstone
MGMT	migmatite
MGVC	massive green volcanics
MLNT	mylonite
MNZN	monzonite = syenodiorite
MRBL	marble
MSDM	metasediment
ORGS	orthogneiss
PGMT	pegmatite
PLLT	phyllite
PPDC	porphyritic dacite
PPGD	porphyritic granodiorite
PPQM	porphyritic quartz monzonite
PPRY	porphyritic rhyolite

APPENDIX 3 (cont.)

PRDT	periodotite
QFPP	quartz-feldspar porphyry
QRTZ	quartzite
QZDR	quartz diorite
QZFP	quartz-feldspar porphyry
QZMZ	quartz monzonite = adamellite
QZPP	quartz porphyry
RDCT	rhyodacite = quartz latite = dellenite
RYLT	rhyolite
SCST	schist
SDMT	sediment
SHLE	shale
SKRN	skarn
SLSN	siltstone
SLTE	slate
SNDS	sandstone
SRPN	serpentinite
SYNT	syenite
TUFF	tuff
UMFC	ultramafic
VCCB	volcanic breccia
VOLC	volcanics

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APPENDIX 4

Procedures used for metal determination, detection limits and limits of accuracy and precision of the results

Contributed by S. Courville – Geological Survey of Canada

1) Outline of the procedure used for the determination of zinc, copper, lead, silver and molybdenum

Following acid decomposition (HNO_3 and HCl) the sample solution is made up to volume with water containing 1250 ppm Al^{+++}. This solution is used for determination by atomic absorption using appropriate standards. Background corrections are made for silver and lead.

2) Outline of the procedure used for the determination of arsenic

The sample is digested in a nitric-perchloric acid mixture. Arsenic is evolved as arsine gas and complexed using a silver diethyldithiocarbamate-pyridine solution. The intensity of the coloured solution is then compared to standards.

3) Outline of the procedure used to determine mercury

Mercury is determined by the cold vapor method. An atomic absorption spectrophotometer coupled with a closed circulation apparatus is used to measure absorption. Reference: Hatch and Ott (1968) Anal. Chem. v. 20, (14) p. 2085-2086.

4) Outline of the procedure used to determine tungsten

The sample is fused with a basic flux (Na_2CO_3: Na Cl: KNO_3/5:4:1) and leached with hot water. Tungsten is then reduced with stannous chloride, complexed ammonium thiocyanate, extracted into tri-n-butyl phosphate in carbon tetrachloride, and determined by visual colorimetry using standard solution.

5) Magnetic susceptibility was determined from crushed samples with a Geophysical Specialties Company Magnetic Susceptibility Bridge model MS-3. The reproductability of the measurements is ± 2 scale divisions equivalent to between ± 50% and ± 1% with precision increasing with susceptibility.

Detection limits for the elements by the procedures outlined above are

Zinc	2	ppm
Copper	2	ppm
Lead	2	ppm
Molybdenum	2	ppm
Tungsten	4	ppm
Mercury	10	ppm
Silver	0.2	ppm
Arsenic	1	ppm

Accuracy and precision

	Concentration Units	Concentration range ppm 0.1-1.0	1-10	10-100	100-1000	1000-10 000
Zinc	ppm	B.D.*	see below	± 20%	± 15%	± 15%
Copper	ppm	B.D	"	± 20%	± 15%	± 15%
Lead	ppm	B.D	"	± 25%	± 20%	± 20%
Molybdenum	ppm	B.D	"	± 20%	± 15%	± 15%
Tungsten	ppm	B.D.	"	± 40%	± 30%	± 30%
Mercury	ppb	B.D	"	± 30%	± 25%	± 25%
Silver	ppm	see below	± 20%	± 15%	± 15%	± 15%
Arsenic	ppm	B.D	"	± 20%	± 20%	± 20%

	Concentration Range (ppm)	Acceptable ± ppm at: 1	2	3	4	5	6	7	8	9	10
Zinc	2-10	B.D	± 2	± 2	± 2	± 2	± 2	± 2	± 2	± 2	± 3
Copper	2-10	B.D	± 2	± 2	± 2	± 2	± 2	± 2	± 2	± 2	± 3
Lead	2-10	B.D	± 2	± 2	± 2	± 2	± 2	± 2	± 2	± 3	± 3
Molybdenum	2-10	B.D	± 2	± 2	± 2	± 2	± 2	± 2	± 2	± 3	± 3
Tungsten	4-10	B.D	B.D	B.D	± 4	± 4	± 4	± 4	± 4	± 4	± 4
Arsenic	1-10	± 1	± 1	± 1	± 1	± 2	± 2	± 2	± 2	± 3	± 3

Accuracy and precision required for silver in the concentration range 0-1 ppm

Concentration	0.1	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Limits Allowed	B.D	± 0.2	± 0.2	± 0.2	± 0.2	± 0.2	± 0.2	± 0.3	± 0.3

*B.D = Below detection

APPENDIX 5

Methods of caluclating the statistical parameters

Geochemical data generally approximate a log normal frequency distribution more closely than any other distribution (Koch and Link, 1970, p. 213) therefore the analytical results were logarithmically transformed (base 10) before calculating parameters to make the distributions appear "normal".

The statistical parameters were calculated from the following:

Mean
$$x = \frac{\sum_{i=1}^{N} x_i}{N}$$

Standard Deviation
$$= \sqrt{\frac{\sum_{i=1}^{N} (x_i - x)^2}{N-1}}$$

Skewness
$$= \frac{\sum_{i=1}^{N} \frac{(x_i - x)^3}{SN}}{N}$$

Kurtosis
$$= \left[\frac{\sum_{i=1}^{N} \frac{(x_i - x)^4}{SN}}{N} \right] - 3.0$$

x_i = observations

N = number of observations

$$SN^2 = \frac{\sum_{i=1}^{N} (x_i - x)^2}{N}$$