# USING THE REGIONAL GEOCHEMICAL SURVEY DATABASE: EXAMPLES FROM THE 1988 RELEASE*

## (104B, F, G, K)

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*KEYWORDS:* Applied geochemistry, regional geochemical survey, Iskut River, data analysis, anomaly definition, geochemical associations.

## INTRODUCTION

Regional geochemical survey (RGS) results for the Iskut River (104B), Telegraph Creek (104G) and Tulsequah (104K) areas were released in July 1988. The release consists of chemical and physical data for sediment and water samples collected from more than 2700 streams over an area of 35 000 square kilometres underlain by 50 different rock units. For each sample over 40 variables were recorded in the field or determined later in a laboratory. The resulting product is complex and demands a thoroughly systematic approach to analysis if the full value of the survey is to be realised. This paper presents a simple but rigorous method for using the data which relies on the recognition of geochemical subsets appropriate to the scope of the project.

All database manipulations and statistical calculations described can be carried out on a microcomputer using commercially available software. Raw regional geochemical survey data for the entire province are available on floppy diskettes from the Applied Geochemistry Subsection, Ministry of Energy, Mines and Petroleum Resources.

### PROJECT SCALE AND SUB-DATASETS

The RGS data are used in private sector, government and academic studies (*see* Matysek, 1987, for a bibliography) at a variety of scales ranging from comparison of tectonic terranes (McMillan *et al.*, 1988) to selection of exploration targets. Regardless of scale, these investigations demand definition of a baseline model to identify anomalies. The ability to detect significant anomalies is increased by defining a simple model that reflects the scale of the study. In this paper, working models are defined by dividing the data into logical subsets:

- Large scale analytical subsets. The province-wide database has been developed over a 12-year period by several private contractors.
- Environmental units. Major variations in surficial geology, climate, vegetation and topography result in significant differences in the dispersion characteristics of elements in drainage sediments.
- Tectonic terranes. The Cordillera has been divided into tectonic terranes, each with distinctive lithogeochemical characteristics which are reflected in stream sediments (McMillan *et al.*, 1988).
- Geological units. Rock units of different lithologies and ages show well-established variation of elements reflecting their mineralogical composition (Matysek *et al.*, 1982; Johnson, 1984).

Thus, sub-datasets are defined such that anomalies are readily identifiable and can be attributed to a limited number of sources, each of which can be rejected or accepted by examining a relatively small number of physical and chemical variables.

### SOURCES OF GEOCHEMICAL ANOMALIES

Anomalies are defined as departures from a model. In the search for new mineral deposits it is tempting to ascribe all anomalies to the presence of unrecognized mineralization. However, lithological and environmental factors are equally likely to produce high values for elements frequently associated with mineralization. Samples high in organic carbon or iron and manganese oxides may yield high values for base metals (Rose *et al.*, 1979). Likewise, an unmapped mafic intrusion in terrain characterized by felsic intrusions may yield anomalously high values for siderophile elements such as nickel, cobalt and iron. In addition, anomalies may be generated by man-made contamination such as mining or logging activity.

## THE 1988 RELEASE

A description of the area covered by the three RGS Open Files released in 1988 (BC RGS 18, 19 and 20) is provided by Gravel and Matysek (1988). Complete sampling and analytical details are presented in the Open File data booklets and the document files provided with the floppy diskette version of the release (Matysek *et al.*, 1988).

The survey area straddles over 300 kilometres of the boundary between the Intermontane Belt and the Coast plutonic complex. The geology of the region is complex with ultramafic to syenitic intrusions and gneissic complexes varying in age from Mississippian to early Tertiary. Intermontane volcanic and sedimentary rocks include the Triassic Stuhini Group, Jurassic Laberge and Hazelton groups and Jurassic to Cretaceous Bowser Lake Group. Locally, Tertiary and Quaternary volcanism has produced extensive cones and flows.

Much of the region is mountainous, especially adjacent to the Alaskan border. Here, icefields and bare rock are extensive with tills covering the lower valley sides. Areas of extensive thick glacial drift are uncommon in the region though the larger valleys (Iskut, Stikine, Taku) are filled with fluvioglacial deposits. Predominant glacial directions during

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* This project is a contribution to the Canada/British Columbia Mineral Development Agreement.

the final (Wisconsin) glaciation vary from southwestward down the Iskut valley, to eastward away from the Coast Mountains towards the Interior Plateau and northwards parallel to Atlin and Teslin lakes (Holland, 1976).

## DATA ANALYSIS

### SOFTWARE AND HARDWARE

Readily available database management and statistical packages were used throughout the study. dBase III Plus (Ashton-Tate) was used to create data subsets and perform simple statistical calculations. PROBPLOT (Stanley, 1988; distributed by the Association of Exploration Geochemists) was used to produce probability plots. Conventional symbol maps and scatter plots were produced using in-house plotting packages, but similar programs are available commercially.

A microcomputer equipped with a hard disk is essential due to the large databases involved.

### METHODOLOGY

Data analysis methodology is similar to that described by Sinclair and Fletcher (1980). Their method was based on subdivision of data by predominant rock type followed by evaluation of probability plots and multiple regression studies. The importance of other variables such as stream-water pH as a control on concentrations of elements in stream sediments was also considered.

In the current study, initial subdivision of data is on the basis of sampling medium and whether the same laboratory analysed all the samples using the same analytical method (Figure 5-3-1). The data are then subdivided by map sheet and stratigraphic formation in the sediment-sample provenance area. Regional-scale variables such as physiography and stream types are considered so that data from low-lying areas potentially characterised by low-mechanical/high-chemical weathering rates are not mixed with mountainous regions where the opposite conditions prevail. At the same time, important variables characterising the chemical environment in the waters (pH) and sediments (sediment colour, sediment composition, loss-on-ignition, manganese, iron) are investigated for regional variability. The importance of these variables has been demonstrated statistically by Matysek *et al.*(1981).

For the most part, this initial data sorting can be done using the topographic maps and surficial geology maps provided in the release package, combined with the field observations. The four measured chemical indicators (iron, manganese, loss-on-ignition, pH) can be evaluated using probability plots. Screening of regional environmental variability potentially yields a dataset which is as homogeneous as can be expected and is ready for studies of geochemical variations which reflect bedrock geology.

In the second pass, probability plots are used on the assumption that geochemical data distributions can be modeled with mixtures of Gaussian normal or lognormal populations. The plots can be used to determine background and anomalous mean values and a value or range of values that discriminates background and anomalous samples. The selection of a single value as a threshold for an element largely depends on the particular needs of the geochemical program.

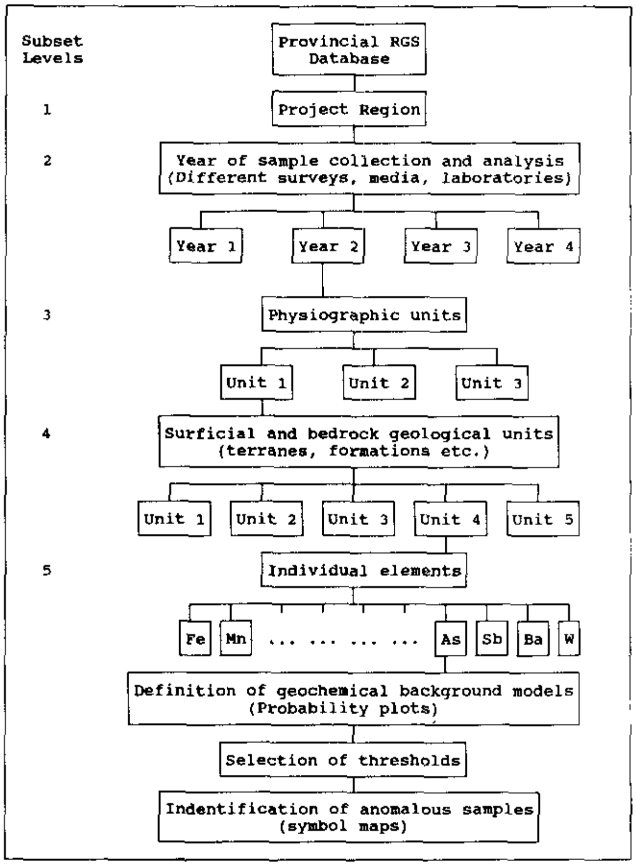


Figure 5-3-1. Flow diagram for data analysis.

Thresholds selected from probability plots were used to prepare simple elemental symbol maps, typically with three concentration intervals, namely background, overlap between background and anomalous, and anomalous. Symbol maps are preferred to contoured maps because elemental concentrations determined at a sediment sampling site are not representative of the site but are a composite of material eroded from the entire drainage basin.

Symbol plots are overlayed on the drainage pattern base map so that clusters of anomalous concentrations can be related to the direction of drainage and size of drainage basin.

### LABORATORY DETAILS

Analytical responsibilities for the 1988 RGS were shared between the British Columbia Geological Survey Branch (104B, 104F, 104K) and the Geological Survey of Canada (104G). As a result, samples were prepared and analysed at two different locations. Identical methods were used for the determination of all elements except gold; in this case fire assay was used with different finishing methods.

Laboratories using the same analytical method may disagree on the absolute concentration of an element in a sample, even though their precision levels are identical and satisfactory. This arises from minor differences in digestion procedures and the model and age of the machine used for the final determination. Analytical results from the two laboratories must be compared, otherwise anomalies determined at a later stage of the data analysis may prove to be analytical artifacts. In the RGS, control reference samples are routinely inserted in each batch of twenty samples to permit a direct comparison of concentrations determined for the same standard material at the two laboratories. Three standards are used which provide a wide range of concentrations for most elements.

Results ($x_i$) for each element can be presented on one diagram (Figure 5-3-2) by calculating the mean ($x_j$) and standard deviation ($s_j$) for each of three control references and determining a standardised concentration ($z_i$) for each of the control samples:

$$z_i = (x_{i,j} - x_j)/s_j.$$

The resulting diagram for each element shows deviations from the standardized mean of each control reference. Ideally, results from the two laboratories should be scattered about the $z = 0$ line as shown by the results for uranium (Figure 5-3-2b). However, for most elements the laboratories consistently produce different results (for example manganese, Figure 5-3-2a). These visual conclusions were quantified with Students t-test to compare two means which shows that only copper, silver, uranium and antimony have indistinguishable results (95 per cent confidence). Although the absolute differences between concentrations determined for the standards might be considered small relative to the range of concentrations encountered in stream sediments, the difference is recognizable and can be eliminated by not mixing results from two laboratories. This example illustrates the importance of monitoring control concentrations in large multi-year multi-laboratory projects of any kind (*see* Day *et al.*, 1988). If data from two surveys are to be considered together, the analysis must be done separately for each component survey. Different absolute geochemical thresholds will be produced permitting subtle anomalous trends between adjacent surveys to be recognized. Undivided data produced by different laboratories may allow recognition of gross trends but the potential for producing misleading false anomalies is increased.

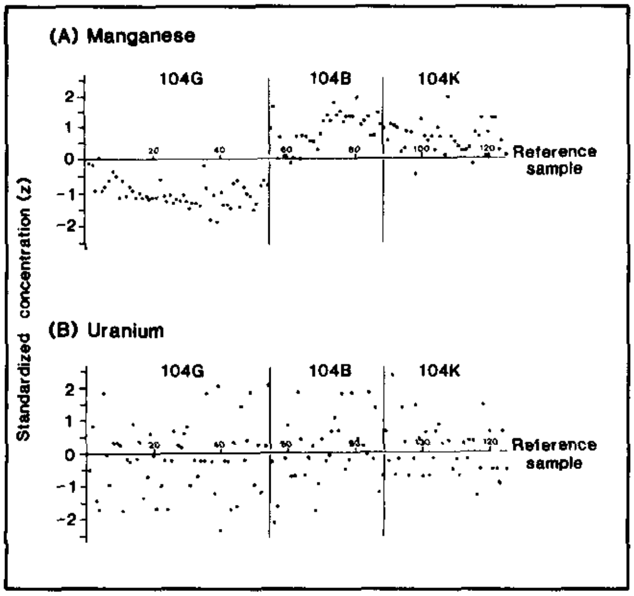


Figure 5-3-2. Standardised concentration ($z_i$) versus batch number for (a) manganese and (b) uranium. Calculation of $z_i$ is described in the text.

## EXAMPLES

### USING THE RGS DATA IN TECTONIC AND METALLOGENIC STUDIES

Two tectonic terranes are represented in the survey area. The Coast plutonic complex in the westerly portion of the area is composed of intrusions ranging in age from Triassic to early Tertiary. In particular, large batholiths of quartz monzonite dated as Cretaceous to Tertiary (coded as "KTqm" in the database) are mapped throughout 104B, 104G and 104K (Figure 5-3-3; Souther, 1970, 1972; Souther *et al.*, 1974) and present an opportunity to study how the trace element composition of intrusions changes within the plutonic belt. Only samples in 104K and 104B were considered because intrusions in these areas are widely separated and the sediment samples were analysed at the same laboratory.

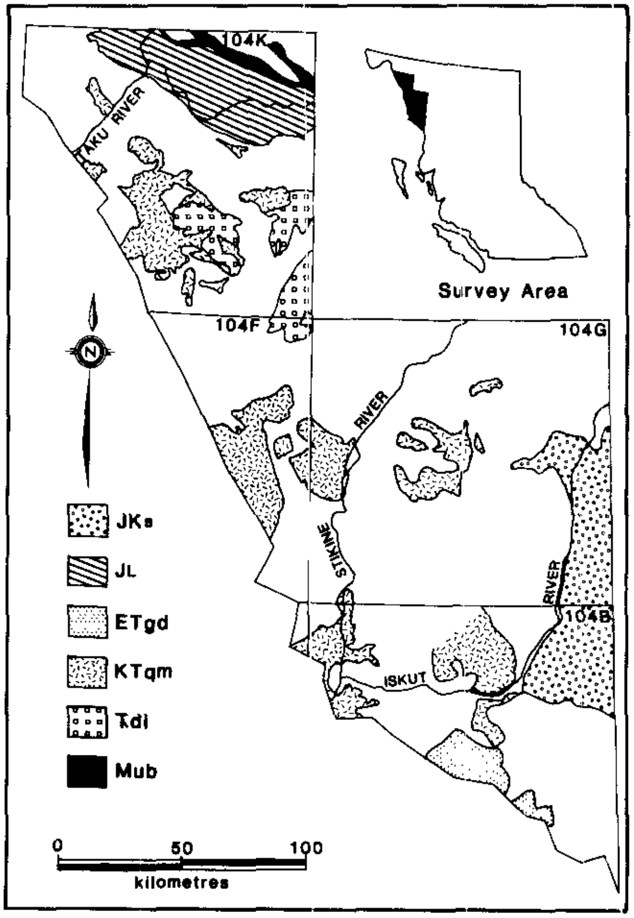


Figure 5-3-3. Distribution of geological units discussed in this paper. JKs = Bowser Lake Group; JL = Laberge Group; ETgd = Early Tertiary granodiorite; KTqm = Cretaceous-Tertiary quartz monzonite; Tdi = Triassic diorite; Mub = Mississippian ultrabasic rocks.

Probability plots for sediment samples, coded as "KTqm", were examined separately for 104B (95 samples) and 104K (145 samples). Usually logarithmic or arithmetic probability plots can be modelled with one normal population (Figure 5-3-4a) or a mixture of two populations that do not overlap (Figure 5-3-4b). In the latter case one population is large (more than 90 per cent of samples) with a lower mean concentration than the smaller population. A few elements cannot be modelled adequately, either because the majority of concentrations are below the detection limit (for example, tungsten, tin) or the plot is not readily interpreted in terms of normal distributions. The large low-concentration population presumably represents background values for the intrusions. Theoretical mean concentrations are summarized in Table 5-3-1.

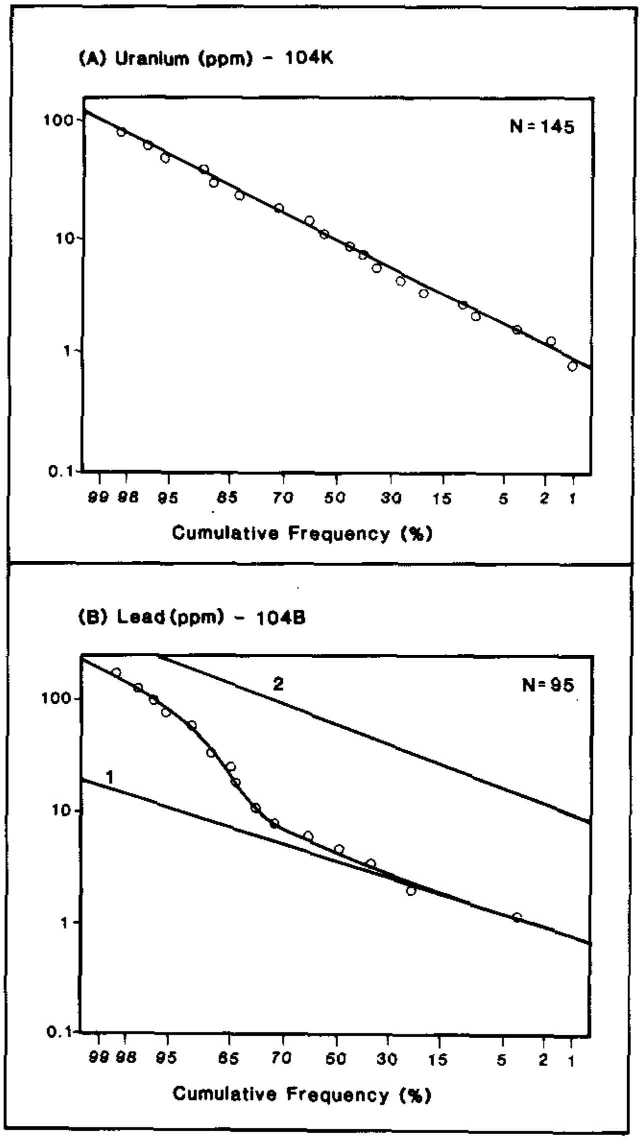


Figure 5-3-4. Probability plots for sediment samples coded as "KTqm". (a) Single population for uranium in 104K. Mean of ideal population is 9.2 ppm, coefficient of variation is 45.8%. (b) Two population fit for lead in 104B. Means of labelled ideal populations 1 and 2 are 3 ppm and 57 ppm, respectively. Coefficients of variation are 53.3% and 10.3%, respectively.

Elements showing similar patterns can be grouped by their associations. Siderophile elements (that is, elements associating with iron) show higher concentrations in samples draining Cretaceous and Tertiary quartz monzonite batholiths in 104B than 104K, though gold is not enriched, perhaps because it shows a stronger chalcophile association in this case. In contrast, the heavy lithophile elements, tungsten and uranium, and the volatile element fluorine, are consistently relatively enriched in the batholiths in 104K. Chalcophile elements show no tendency to be enriched in batholiths in either area.

## Interpretation

Batholiths rising through the crust assimilate material which alters their bulk chemistry. Armstrong (1985), shows that the strontium isotope ratio ($^{87}Sr/^{86}Sr$) has a steep gradient in the survey area. In 104K, Mesozoic intrusions have values of 0.704 to 0.707 for the ratio, whereas further south in 104B, the ratio is 0.703 to 0.704. Likewise a similar relationship is observed for Cenozoic intrusions. Higher values of the ratio in 104K imply assimilation of highly evolved continental crust with its heavy isotopes and elements such as uranium and tungsten. On the other hand, low values imply assimilation of primitive oceanic crust with its high concentrations of lighter isotopes and siderophile elements. McMillan (personal communication, 1988) suggested that deeply buried Precambrian continental crustal rocks underlying 104K and the thick iron-rich volcanic sequences of the Intermontane Belt underlying 104B are responsible for the observed trends.

From a mineral exploration standpoint, "KTqm" batholiths in 104K are clearly better targets for the heavy elements. Tungsten and uranium are clearly enriched in these batholiths, and tin, although occurring in very low concentrations in stream sediments, is also likely to be enriched. Rare-earth elements are also more likely to be associated with these intrusions.

TABLE 5-3-1.

MEAN CONCENTRATIONS FROM PROBABILITY PLOTS FOR STREAMS DRAINING CRETACEOUS-TERTIARY QUARTZ MONZONITES (KTqm) IN 104B AND 104K.

| Association/ Element/Unit | | 104B[1] | 104K[2] | Association/ Element/Unit | | 104B[1] | 104K[2] |
|---|---|---|---|---|---|---|---|
| Siderophile | | | | Chalcophile | | | |
| Co | ppm | 14 | 4 | Cu | ppm | 47 | — |
| Ni | ppm | 11 | 3 | Pb | ppm | 3 | 11 |
| Fe | % | 3.02 | 1.82 | Zn | ppm | 61 | 61 |
| Mn | ppm | 513 | 400 | Ag | ppm | 0.1 | 0.1 |
| Au | ppb | 5 | 5 | Hg | ppb | 10 | 4 |
| | | | | As | ppm | 3 | 6 |
| | | | | Sb | ppm | 0.4 | 0.3 |
| Lithophile | | | | | | | |
| W | ppm | 3[3] | 3 | | | | |
| U | ppm | 1.5 | 9.2 | | | | |
| F | ppm | 345 | 424 | | | | |
| Ba | ppm | 994 | 1031 | | | | |

[1] N = 95 (in the original dataset)
[2] N = 145 (in the original dataset)
[3] $P_{98}$ for W = 6 ppm for 104B and $P_{98}$ = 22 ppm for 104K

## USING THE RGS DATA TO DETERMINE REGIONAL BACKGROUND VALUES

Interpretation of the geochemistry of stream sediments derived from rocks of widely different ages and compositions must begin with the determination of geochemical background levels. As an extension of the previous example, background compositions of stream sediments eroded from early Tertiary granodiorites ("ETgd", 104B), Triassic diorites and gabbros ("Trdi", 104K) and Mississippian ultrabasic rocks ("Mub") (Figure 5-3-3) were determined (Table 5-3-2). Most probability plots for the granodiorites, diorites and gabbros were easily interpreted in terms of single or double normal, or logarithmic normal populations.

Interpretation of the data for samples coded as "Mub" requires further explanation. Two well-defined chemical groups are apparent which cannot be explained by environmental variables such as stream water acidity or organic content of the sediments. Fourteen of the samples are relatively enriched in cobalt and nickel (Figure 5-3-5) whereas the remaining twelve are enriched in copper, lead, zinc, arsenic, antimony and mercury. Spatially the latter group are closer to a northeasterly dipping thrust fault which truncates the rocks to the south. Although one or two of these samples may contain a high proportion of sediments eroded from the Jurassic Laberge group to the south, the smaller group of samples is presumed to represent samples altered by solutions in the fault zone. Thus, Table 5-3-2 reflects the larger sample group which appears to represent relatively unaltered ultrabasic rocks.

Table 5-3-2 shows a sharp contrast between the relatively felsic rocks and the ultrabasic rocks. In particular, concentrations of cobalt, nickel and iron are high in the ultrabasic rocks due to the high proportion of ferromagnesian minerals. The higher content of such minerals as zircon, potassium feldspars and apatite in felsic and intermediate rocks is reflected by the much higher concentrations of uranium, barium and fluorine in the sediments. Although it would normally be expected that lead would show greater concentrations in the more felsic rocks (reflecting the mica and potassium feldspar content), concentrations are very low, preventing determination of reliable background mean concentrations.

TABLE 5-3-2

MEAN CONCENTRATIONS FROM PROBABILITY PLOTS FOR SELECTED ELEMENTS IN STREAM SEDIMENTS ERODED FROM PLUTONIC ROCKS IN 104B AND 104K

| Element/Unit | | ETgd (N = 45)[1] | Trdi (N = 71)[1] | Mub (N = 26)[1] |
|---|---|---|---|---|
| Cu | ppm | 7 | 62 | 22 |
| Pb | ppm | 3? | 5? | 3? |
| Zn | ppm | 43 | 63 | 50 |
| Sb | ppm | <0.3 | 0.4 | 0.1 |
| Hg | ppb | <20 | 14 | 17 |
| U | ppm | 1.4 | 2.7 | 0.8 |
| F | ppm | 386 | 439 | 81 |
| Co | ppm | 8 | 9 | 65 |
| Ni | ppm | 11 | 4 | 1356 |
| V | ppm | 58 | 50 | 46 |
| Ba | ppm | 1119 | 899 | 70 |
| Fe | % | 1.78 | 2.24 | 4.17 |
| LOI | % | 1.2 | 2.2 | — |

[1] N is the number of samples in the original dataset.

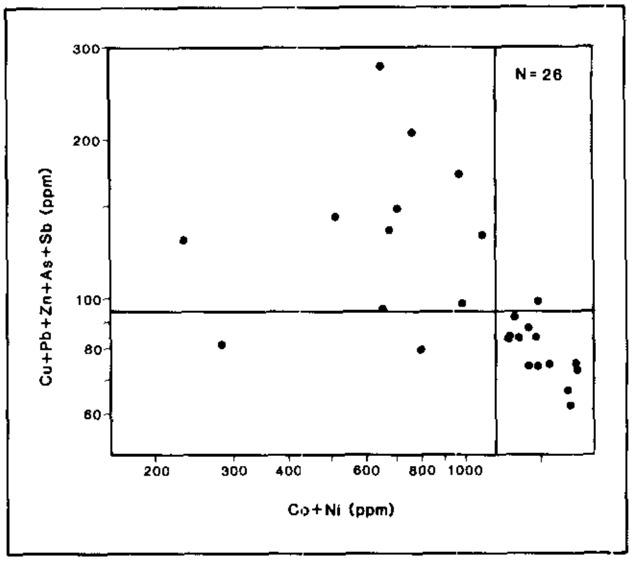


Figure 5-3-5. Co + Ni (siderophile affinity) verses Cu + Pb + Zn + As + Sb (chalcophile affinity) for samples coded as "Mub" in 104K. Dividing lines are thresholds from probability plots.

## EVALUATING GEOCHEMICAL ANOMALIES IN THE RGS DATA

The previous two examples have emphasized the need to subset geochemical data to evaluate background concentration levels. The adequately defined background model with its mean and variance can be used to identify concentrations above or below which samples are labelled anomalous. The following cases show examples of the types of anomalies encountered in the survey area.

### Jurassic Laberge Group ("JL") – Effect of Glaciation(?)

The Laberge Group (Figure 5-3-3), consisting of greywackes and conglomerates, underlies part of the northeastern quadrant of 104K, a dissected upland with moderate relief (1000 metres). Very few intrusions, outliers and inliers are mapped, thus stream sediment geochemistry should be fairly simple, reflecting the relatively homogeneous geology.

Two kinds of elemental distributions are evident on the 1:250 000 maps. Three elements (cobalt, nickel, iron; Figure 5-3-6) show absolute concentrations decreasing toward the southwest, whereas concentrations of other elements appear to vary in a nonsystematic fashion. The three siderophile elements have probability plots that can be modelled with two populations. The proportion of the high concentration population varies from 25 per cent for nickel to 12 per cent for iron. Other elements have a small high-concentration population (proportions less than 6 per cent).

The regional geology map shows that the Laberge Group is bounded to the northeast by Mississippian ultrabasic rocks

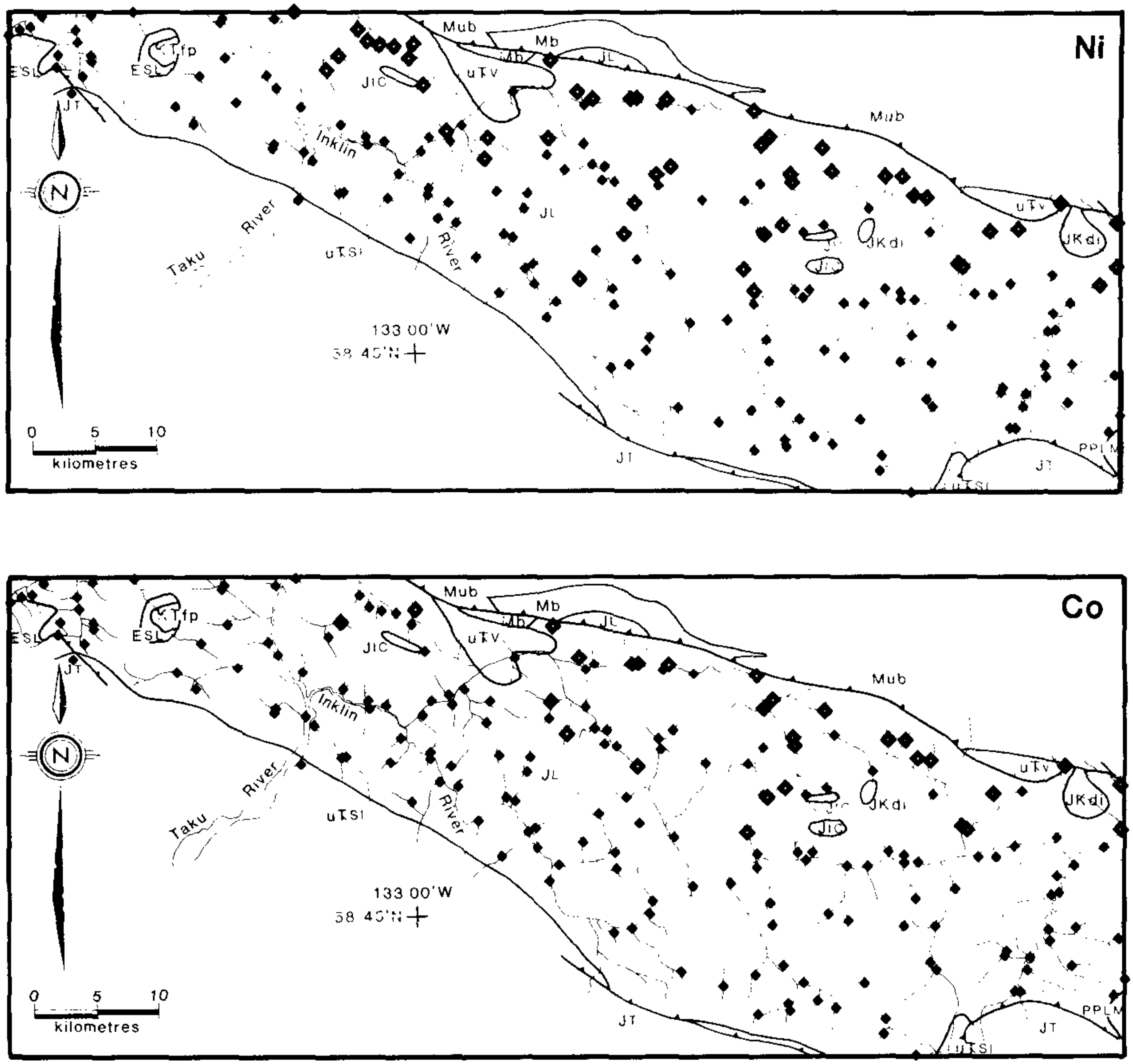


Figure 5-3-6. Element maps for Laberge Group in 104K. Symbol intervals were obtained from probability plots.

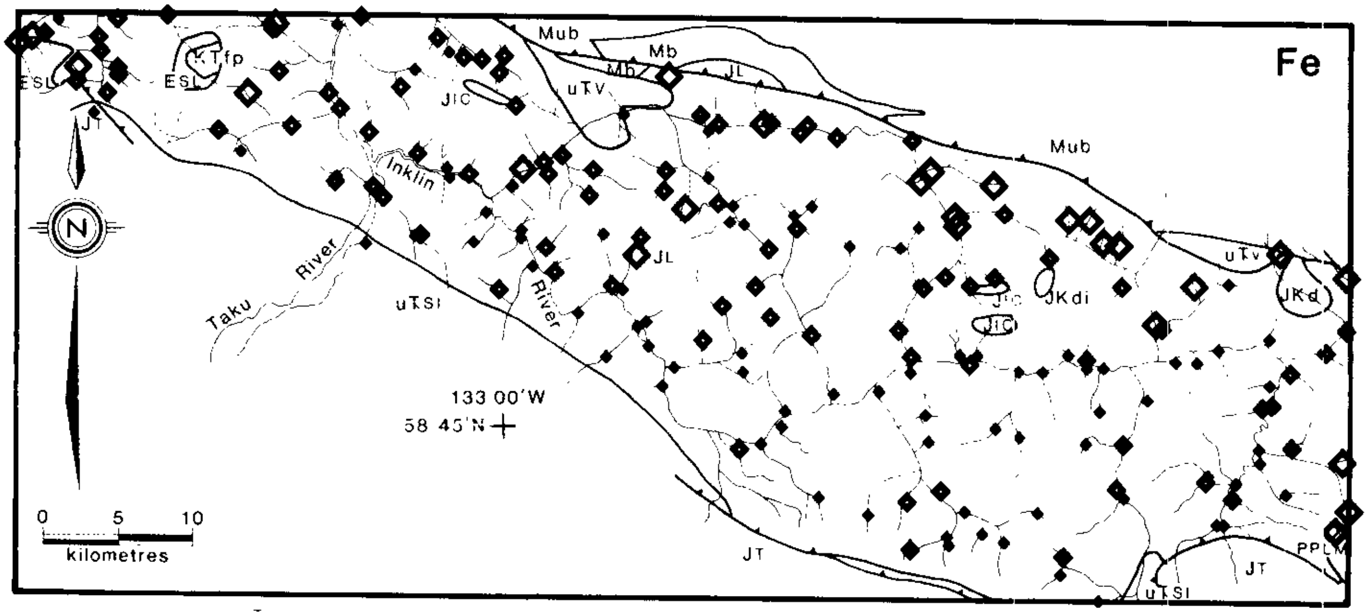


Figure 5-3-6 — *Continued.*

**LEGEND**

| ELEMENTS | ♦ | ◆ | ◇ |
|---|---|---|---|
| Ni (ppm) | 1 - 111 | >111 | |
| Co (ppm) | 1 - 27 | >27 | |
| Fe (%) | 0.01 - 2.31 | 2.32 - 2.47 | >2.48 |

**STRATIFIED ROCKS**

| | |
|---|---|
| PPLM | Pliocene-Pleistocene: basalt |
| ESL | Eocene: rhyolite, trachyte, andesite, basalt |
| JL | Jurassic Laberge Group: greywacke, conglomerate |
| JIC | Jurassic: limestone |
| JT | Jurassic: limestone |
| uTSI | upper Triassic: limestone |
| uTv | upper Triassic: andesite, basalt |

**PLUTONIC ROCKS**

| | |
|---|---|
| KTfp | Cretaceous-Tertiary: felsite, feldspar porphyry |
| JKdi | Jurassic-Cretaceous: diorite |
| Mb | Mississippian: gabbro, diorite |
| Mub | Mississippian: peridotite, serpentinite |

(Mub). As shown in Table 5-3-2, these rocks have high background concentrations of nickel, cobalt and iron. The presence of southerly decreasing values for these elements in the area underlain by the Laberge Group implies southerly transport of sediments derived from the ultrabasic rocks. Although this effect may occur if a stream is coded as "JL" but erodes ultrabasic rocks in its headwaters, the regional scale of the effect suggests southerly glacial transport of sediments. Unfortunately, glaciation directions in this region have not been mapped.

Further analysis of data for the Laberge Group requires that the region be split into two parts. A more southerly area representing minimal "contamination" by sediments eroded from the ultrabasic rocks should be considered separately. Because nickel gives the best indication of the extent of contamination, a threshold value selected from the nickel probability plot shows the geographical dividing line between the two areas.

## Cretaceous-Jurassic Bowser Lake Group ("JKs")

Bowser Lake Group (siltstone, greywacke, conglomerate, shale) crops out in the northeast corner of map sheet 104B over an area of approximately 1200 square kilometres. Relief is moderate (1000 metres), with small areas of alpine glaciation (southwest) and locally chaotic drainage indicated by abundant small lakes (northwest) (Figure 5-3-7). Mineral occurrences have not been reported in this area which is historically considered to have low mineral potential.

Probability plots are relatively simple and provide meaningful threshold values for most elements. As in the previous examples, nickel values may indicate areas where streams are eroding material other than Bowser Lake Group. A small number of samples returned above (nickel greater than 136 ppm) or below (nickel less than 69 ppm) average values. The low values are due to headwater erosion of felsic intrusions at the southern contact of the Bowser Lake Group (Figure 5-3-7). High values occur in a well-defined group in the southeast corner of the area. This may represent lithological variations such as siltstone to shale. Cobalt values are not elevated in this area, precluding the presence of unmapped mafic volcanic rocks.

An association of elevated uranium, fluorine, lead, zinc, barium and antimony concentrations occurs in the southwest corner of the area (Figure 5-3-7). In particular, the association of uranium and fluorine suggests that a felsic stock underlies the fairly extensive cirque glaciers drained by the streams sampled.

Several elements show definable trends and associations but only those for gold will be mentioned here. Despite the notoriety of gold analyses on stream sediments, overlapping thresholds could be selected from a probability plot of the square root of gold concentrations (Hoyle, 1973). The thresholds are very low (4.6 to 6.4 ppb) but the symbol plot defines several coherent areas of anomalous gold concentrations.

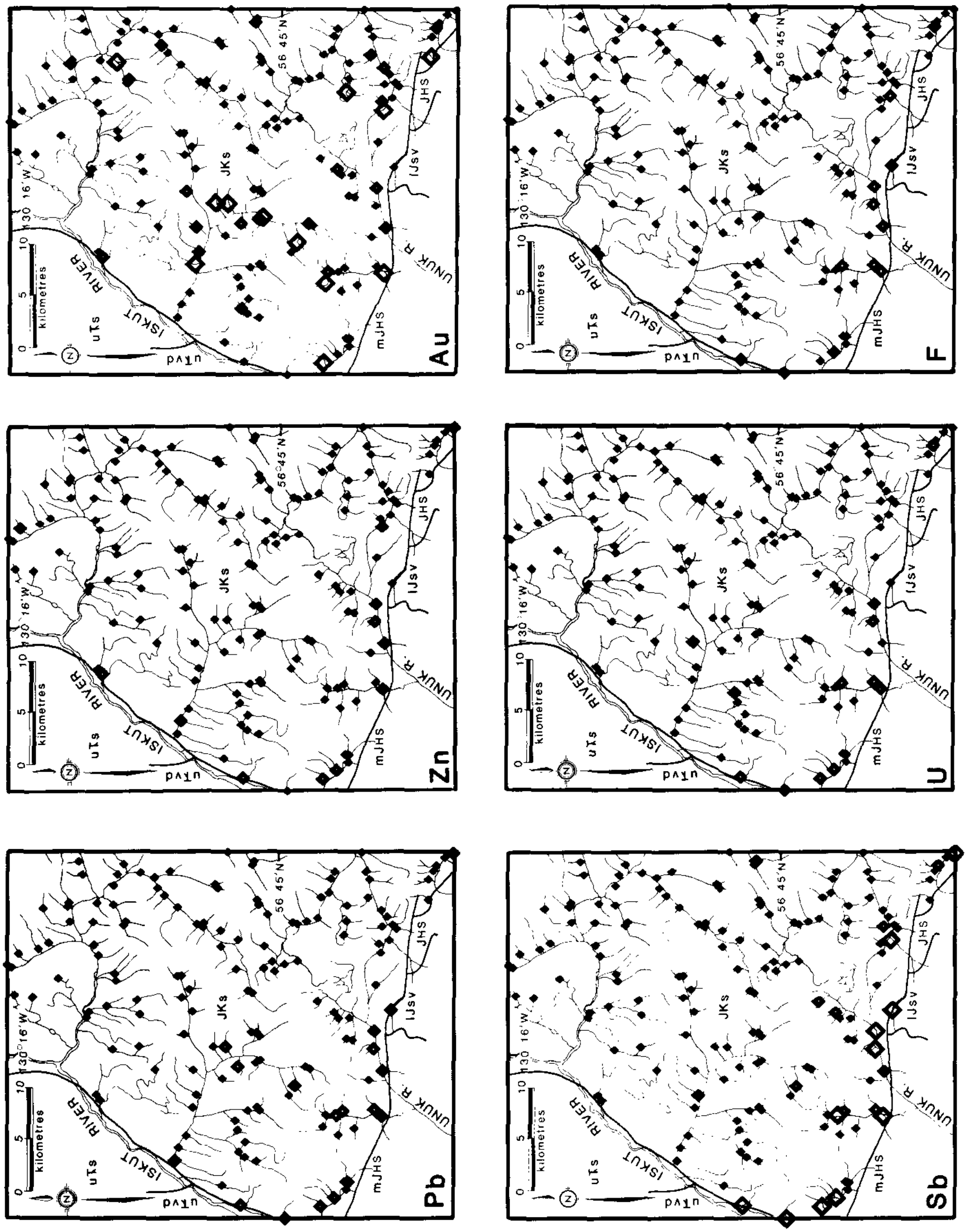
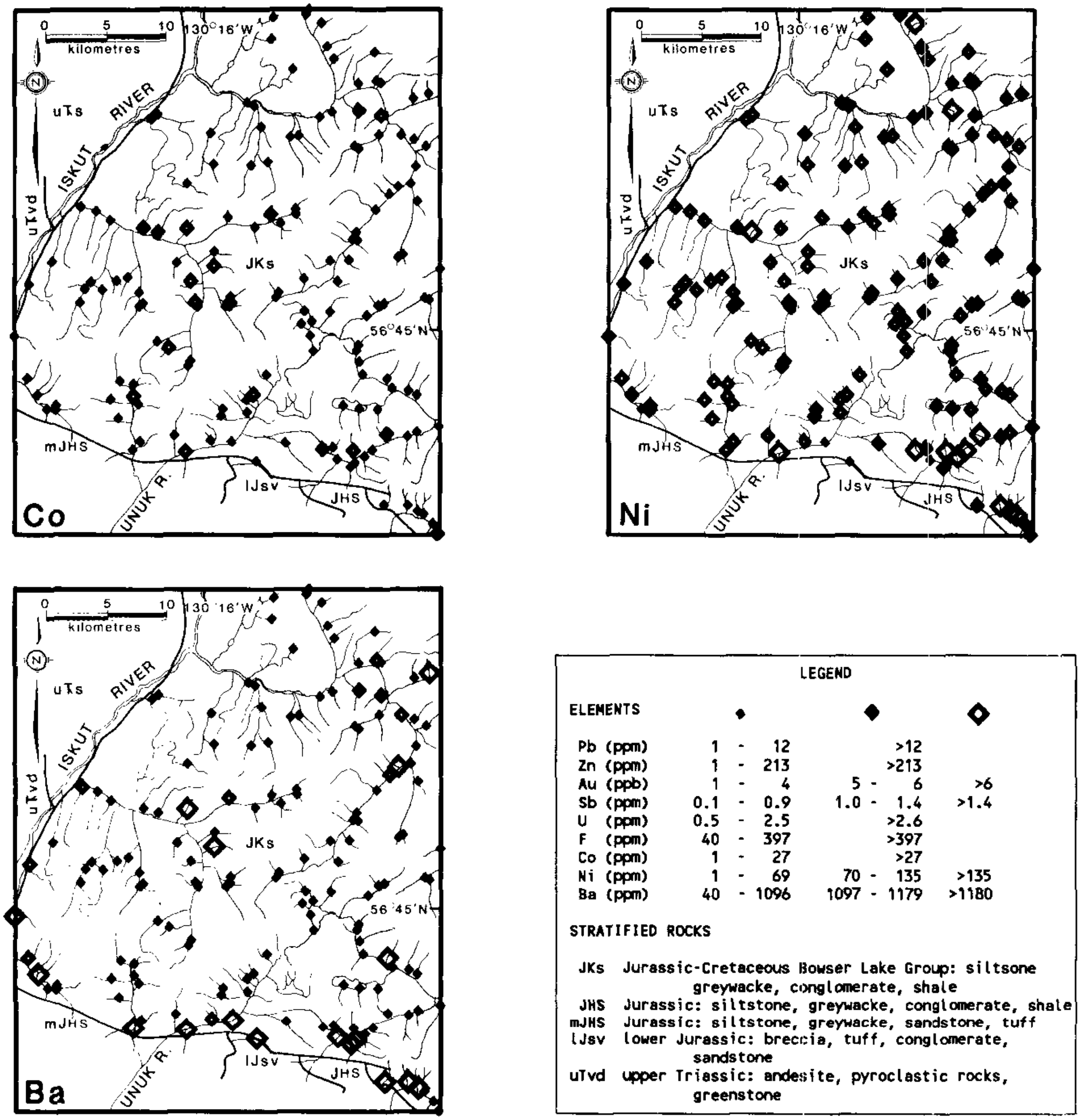


Figure 5-3-7. Element maps for the Bowser Lake Group in 104B. Symbol intervals were obtained from probability plots.



LEGEND

| ELEMENTS | ♦ | ◆ | ◇ |
|---|---|---|---|
| Pb (ppm) | 1 - 12 | >12 | |
| Zn (ppm) | 1 - 213 | >213 | |
| Au (ppb) | 1 - 4 | 5 - 6 | >6 |
| Sb (ppm) | 0.1 - 0.9 | 1.0 - 1.4 | >1.4 |
| U (ppm) | 0.5 - 2.5 | >2.6 | |
| F (ppm) | 40 - 397 | >397 | |
| Co (ppm) | 1 - 27 | >27 | |
| Ni (ppm) | 1 - 69 | 70 - 135 | >135 |
| Ba (ppm) | 40 - 1096 | 1097 - 1179 | >1180 |

STRATIFIED ROCKS

| | |
|---|---|
| JKs | Jurassic-Cretaceous Bowser Lake Group: siltsone greywacke, conglomerate, shale |
| JHS | Jurassic: siltstone, greywacke, conglomerate, shale |
| mJHS | Jurassic: siltstone, greywacke, sandstone, tuff |
| lJsv | lower Jurassic: breccia, tuff, conglomerate, sandstone |
| uTvd | upper Triassic: andesite, pyroclastic rocks, greenstone |

Figure 5-3-7 — *Continued.*

## CONCLUSIONS

The provincial RGS database consists of chemical and physical data for nearly 30 000 stream sediment samples collected since 1976. It provides an excellent tool for private sector, government and academic projects provided that geochemical models are defined which take into account the target and scale of the project.

The method presented here follows the following steps:

(1) Recognition of large-scale subsets such as mapsheets sampled in different years, or elements determined by different analytical methods.

(2) Recognition of smaller scale subsets such as geological terranes, environmental units or stratigraphic units.

(3) Definition of background geochemistry models using probability plots.

(4) Identification of samples that do not fit the background model (anomalies).

The method can be applied to the identification of geochemical variations within a terrane, definition of geochemical background levels for different geological units, recognition of lithological variation within a geological unit and identification of local-scale anomalies. All data manipulation can be carried out on a microcomputer using inexpensive commercially available software.

## ACKNOWLEDGMENTS

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