

**METAL DISPERSION ON THE NORTHWESTERN SEWARD PENINSULA,
ALASKA:
A CAUSE OF NATURAL METAL ENRICHMENTS IN THE ARCTIC**

**By
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A thesis submitted to the faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Science (Geochemistry).

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ABSTRACT

The northwestern Seward Peninsula was targeted for detailed geochemical study after evaluation of data collected during the NURE reconnaissance-level program indicated anomalously high arsenic (60-635 ppm) concentrations in stream sediments. The arsenic is associated with tin skarn, greisen and replacement occurrences in the western Seward Peninsula. Surficial sampling of waters and sediments indicate that arsenic is being transported detritally, but that solution transport is insignificant.

Our new data indicates that sediments downstream from these tin occurrences are characterized by anomalous values of As (70-530 ppm) and Sn (14-44 ppm), as well as consistent anomalies of Ag, Be, Cu, Li, Sb, W, and Zn. Stream sediments collected from drainages underlain by slate, but distal to the exposed tin occurrences, are characterized by background levels of As (10-60 ppm), Li (16-80 ppm), Sn (5-14 ppm), and W (5-10 ppm). These background levels for As and Sn are much higher than concentrations in typical slates and suggest a broad, weak hydrothermal alteration of much of the study area during mineral deposit formation. Stream sediments collected from drainages underlain by carbonates upstream from the tin occurrences at Lost River are characterized by much lower background concentrations of As (<10 ppm) and Sn (< 10 ppm) with similar concentrations for Li and W.

A consistent pattern of $Ca \gg Mg > Na > K$ and generally alkaline pH (7.2-8.3)

characterize waters throughout the study area. Dissolved sulfate concentrations range from 10-40 ppm for waters draining slates and <5 ppm for waters draining carbonates. The waters collected in areas of known tin occurrences in the Potato Mountain area are characterized by increased dissolved sulfate (43-75 ppm) and are generally acidic (pH 4.7-6.5), but most trace metals are at or below detection limits. Dissolved arsenic concentrations in the areas of known tin occurrences at Potato Mountain are at or below 2 ppb. The surface waters downstream from the Lost River occurrences have dissolved As concentrations of 5-9 ppb, but due to the natural buffering from the carbonate host rocks, all other metals related to mineralization remain at or below detection limit.

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Chapter 1. INTRODUCTION

1.1 Purpose

A geochemical study to determine natural background concentrations of metals in surficial materials was carried out on the northwestern Seward Peninsula near the village of Wales, Alaska. Initial interest in this project developed from findings of studies by the United States Fish and Wildlife Service (USFW) and NIST which detected elevated levels of heavy metals, in particular As, Hg, and Cd, in Pacific walrus, beluga and bowhead whales, and seals off the coast of western Alaska. The purpose of this study was to determine potential point sources and pathways of migration for these metals in the nearshore environment.

This part of the Seward Peninsula was targeted for detailed study after assessment of regional element distribution maps of the northwestern Alaska, which I compiled from stream- and lake-sediment geochemical data collected by the Department of Energy during the National Uranium Resource Evaluation (NURE) program (Hoffmann and Buttleman, 1996). Interpretation of the NURE data showed that some stream sediments in drainages feeding Lopp Lagoon (Fig. 1) had anomalously high arsenic [As] (75-63 ppm) and tin [Sn] (60-144 ppm) concentrations, compared to regional background

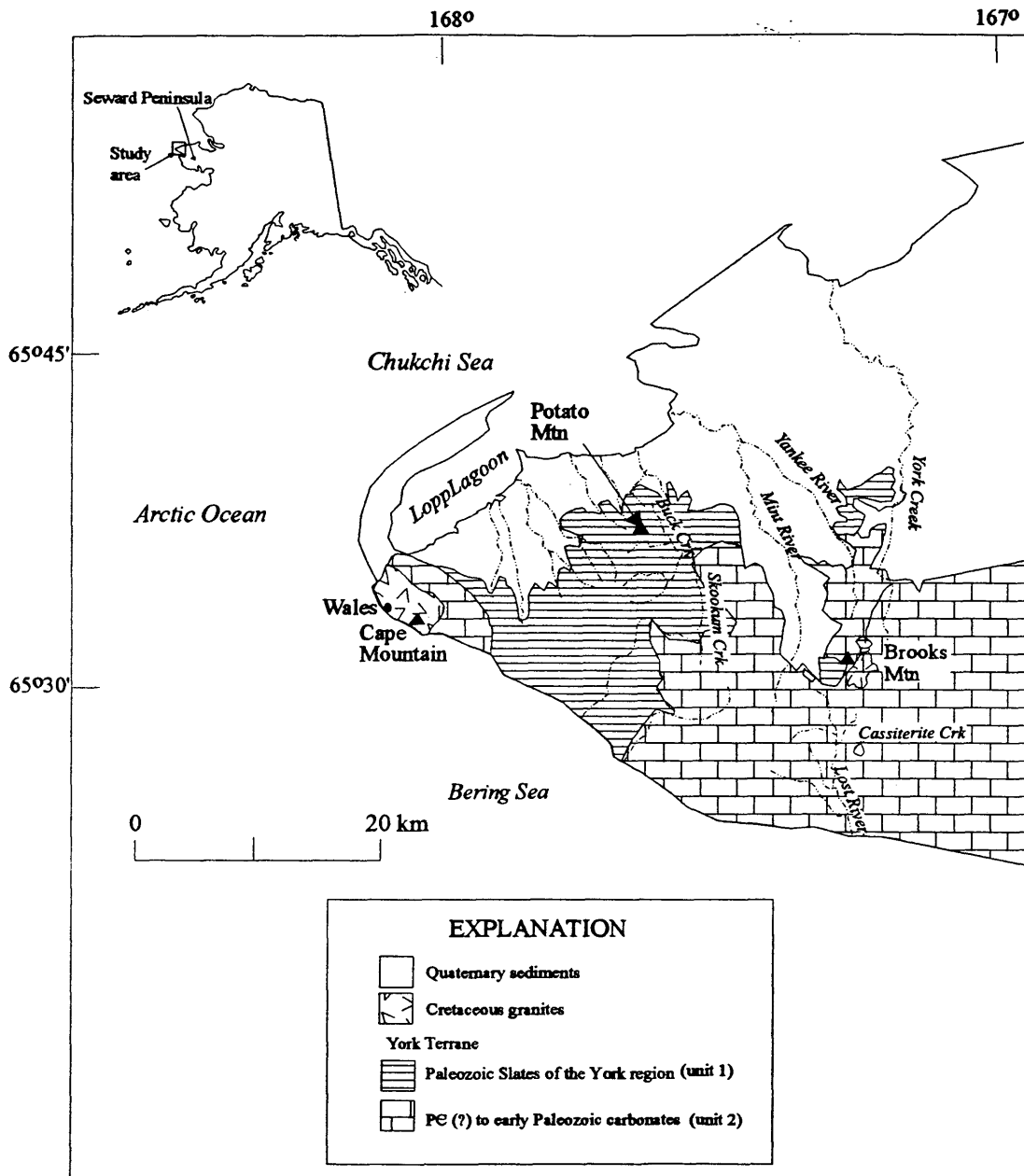


Figure 1. Location of study area and generalized geology
(Geology after Sainsbury, 1972)

concentrations (between 5-36 ppm for As and 7-22 ppm for Sn). Regional mercury and cadmium data were not available from the NURE survey. Further investigation of the western Seward Peninsula indicated that locally anomalous concentrations of trace metals (As, Cu, Sn, W, and Zn) are associated with tin-rich granites and adjacent metasedimentary rocks at scattered locations across the western Seward Peninsula. The anomalous arsenic and tin values observed in the NURE sediments are, at least in part, erosional products from the metalliferous granites and adjacent skarn and replacement bodies.

The presence of relatively metal-rich sediments, soils, or waters in the northwestern Seward Peninsula may be significant for a number of reasons. Biologists from the Biologic Resource Division (BRD) of the United States Geological Survey (USGS) in conjunction with the National Institute of Standards and Technology (NIST) are conducting an ongoing study to monitor heavy metal concentrations and other contaminants in marine mammals. The metal-rich sediments eroded from the tin deposits in the study area are deposited directly into the Lopp Lagoon, which empties into the Chukchi Sea, to the north and the Bering Sea to the south. This may indicate that erosional products from the tin deposits could be a point source for arsenic, tin, and other metals (Be, Cu, Pb, W and Zn) in nearby marine mammals. Furthermore, many of the native Alaskans who live in the village of Wales, located at the western tip of the study area rely heavily on subsistence living. A large part of the native diet consists of marine mammals harvested from the Bering and Chukchi Seas, fish and shellfish from Lopp

Lagoon, and plants harvested from the tundra near areas of known historic mining operations.

1.2 Location

The study area is bounded by latitudes 65°20'-66°00' and longitudes 167°00'-168°10' and encompasses the most western portion of the Teller quadrangle (Fig 1). The study area is divided by the east-west-trending York Mountains which have a maximum elevation of 880 m at Brooks Mountain. Three historic tin mining operations are located in the study area, Cape Mountain and Potato Mountain in the northwest and Lost River in the southeast. North of the York Mountains, the peninsula is a region of low rounded hills that have maximum elevations at Cape Mountain (695 m) and Potato Mountain (425 m). South of the York Mountains is the Lost River Valley, with elevation dropping from approximately 70 m at the headwaters of Lost River to sea level where Lost River empties into the Bering Sea. During the summer months, most of the study area is accessible by foot. Due to time constraints, the fieldwork was done by helicopter in order to sample as many drainage basins as possible.

The region is covered by thick tundra vegetation to approximately 260 m above sea level and thinning upwards an additional hundred meters. The area has no trees, but

many of the low-lying valleys contain sparse groups of willow bushes. The climate is subarctic and is covered by permafrost, which thaws during the summer months, late June through August. Summer temperatures range from 1° to 32° C, and the average annual temperature is -6° C (Mulligan 1966). The average annual rainfall is only 30 centimeters (Mulligan 1966), though there is a persistent wind, commonly accompanied by fog and rain. The average annual snowfall is 152 centimeters. The spring melt can occur in a matter of days, often causing flooding along channels of the intermittent streams draining Potato and Cape Mountains (Lucy Kitchen, personal comm.).

1.2 Previous Studies

Reconnaissance-scale geochemical studies for the Seward Peninsula were conducted during the NURE program in the late nineteen-seventies (Hoffman and Buttleman, 1996). The data collected during the NURE investigation included analyses for major, minor and trace elements in stream and lake waters and sediments. These data were the basis for choosing the field area for this more detailed study. A statistical analysis of these data is included in chapter 4. Numerous studies in the area have been conducted by the USGS, the U.S. Bureau of Mines (USBM), and private mining companies in order to assess the mineral potential of the area (Mulligan, 1965, Sainsbury, 1975; Hudson and Arth, 1983; and Hudson and Reed, 1997). Sainsbury also conducted several regional

geologic investigations (Sainsbury, 1963, 1969, Sainsbury and others, 1968), and published a geologic map of the Teller quadrangle at a scale of 1:250,000 (1972). Sainsbury made significant contributions in describing the geology and geochemistry of the Lost River tin occurrences. Included in these investigations were several papers detailing previously unrecognized beryllium occurrences in the Lost River drainage basin (Sainsbury, 1963). Dobson (1982) also conducted a detailed investigation at the Lost River mine describing the geologic setting, paragenesis, and mineralogy of the deposit. None of these previous studies address the potential of element mobility and/or secondary accumulation distal to the mineral deposits.

Interest in this project was generated in part by studies conducted by the Alaska Fish and Wildlife Service in the late 1980's and early 1990's (Taylor and others, 1986; Warburton and Seagars, 1993). These studies found "elevated" cadmium levels (mean=46.52 ppm wet weight) in the livers and kidneys of the Pacific walrus. Further investigation of heavy metals in marine mammals indicates that this is not an isolated problem. "Elevated" levels of arsenic (0.28-7.9 ppm), cadmium (2.8-125 ppm), and mercury (0.6-92 ppm) are found in the liver tissues of marine mammals worldwide (Yamamoto and others, 1987; Law and others, 1992; Marcovecchio and others, 1994; Wagemann and others, 1995; and Becker and others, 1995). Although the problem of bioaccumulation is beyond the scope of this investigation, it should be noted that only the paper by Wagemann and others (1995) addresses possible sources for heavy metals. One of the principal aims of this study is to assess the levels of arsenic and other metals in

sediments and waters and identify any pathways of migration that could represent potential local point sources to marine life.

1.4 Objectives of Investigation and Presentation

The aim of the present study is threefold: 1) to determine in more detail the distribution of the anomalous As and other metals in stream sediments identified in the NURE survey in order to better understand element dispersion patterns from historic tin mines and to identify any unknown sources of these metals, 2) to use these data to evaluate any possible element enrichments which may present environmental concerns to native Alaskans in the area, and 3) to evaluate the dispersion of metals associated with the tin occurrences in order to evaluate possible point sources for heavy metals in marine mammals. A regional geochemical survey of surface waters, stream sediments and heavy mineral concentrates will aid in accomplishing these goals. Resulting geochemical data will be analyzed using basic statistical analysis, factor analysis and spatial analysis in order to characterize local background geochemistry and anomalies due to mineralization. These techniques have been used successfully with surficial geochemical data in exploration of mineral deposits for several decades. This study will utilize the same methods in order to assess potential environmental concerns.

This report summarizes the design, procedures, results, and conclusions of the geochemical survey. Chapter 2 of this report describes the general geology and historical mining history of the western Seward Peninsula. Chapter 3 outlines the procedures followed in the geochemical survey, including sample design and sample collection procedures, laboratory procedures, data reliability, and data processing. Chapter 4 presents the interpretation of the NURE data. Chapter 5 discusses the results of the present geochemical survey. Anomalous metal concentrations will be identified utilizing statistical analysis and maps to characterize the dispersion of As and Sn associated with the tin occurrences of the western Seward Peninsula. Chapter 6 discusses the conclusions of this study and presents suggestions for future work.

Chapter 2. GENERAL GEOLOGY AND MINING HISTORY OF THE WESTERN SEWARD PENINSULA

2.1 General Geology

Sainsbury (1972) mapped the geology of the western portion of the Seward Peninsula at a scale of 1:250,000. The area consists mainly of Precambrian (?) and early Paleozoic, argillaceous and dolomitic limestones, shales, slates and phyllites (Fig. 1), which are referred to as the York terrane. The age of much of the York terrane mapped by Sainsbury (1972) as Precambrian is questionable, as it is lithologically similar to lower Ordovician rocks found elsewhere on the Seward Peninsula (Till and Dumoulin, 1994). The weakly metamorphosed units were deposited in shallow marine to restricted carbonate platform sedimentary environments. The York terrane may be subdivided into two major units. Unit 1 is the Slate of the York region, an informal name for graphitic, slaty, or phyllitic rocks. Protoliths consisted mainly of carbonaceous siltite, but also contained diverse laminated to thin-bedded mudstone, siltstone, fine-grained sandstone, calcareous sandstone, and carbonaceous limestone (Sainsbury, 1972). Unit 2 is a thick sequence of fossiliferous limestone, dolomitic limestone, and argillaceous limestone.

The York terrane was subsequently intruded by highly evolved tin-rich granites and syenogranites between about 80-70 Ma. Seven tin-enriched granite plutons are exposed

and two others are inferred at depth in the northwestern Seward Peninsula (Hudson and Arth, 1983). Four of these, Cape Mountain, Brooks Mountain, Lost River and an inferred pluton at Potato Mountain, occur within the study area. There is a small exposure of a tin granite stock east of Lost River near Cassiterite Creek (Fig. 1), but the Lost River cupola is encountered only in the underground workings of the mine itself (Hudson and Reed, 1997).

2.2 Geology and Mineralogy of the Tin Lodes and Placers

The tin deposits of the western Seward Peninsula are spatially associated with late stage granites, regardless of the host rock (Hudson and Arth, 1997; Dobson, 1982). The geochemical signature for these tin deposits is, in general, Ag, As, Be, Cu, Li, Pb, W, and Zn (Menzie and Reed, 1986).

All of the tin mined at Potato Mountain was from small placer deposits, although geophysical evidence and a large zone of hornfels suggest a buried pluton, indicative of a lode occurrence much larger than the few small recognized veins and replacement zones (Hudson and Reed, 1997). The cassiterite in the recognized lode and placer deposits at Potato Mountain is often associated with arsenopyrite, pyrite, and scheelite (Mulligan, 1965; Hudson and Reed, 1997). The tin lodes at Lost River occur as skarn, greisen and breccia deposits (Dobson, 1982) hosted in altered carbonate rocks and granite.

The mineralogy of the Lost River deposit is more complex than at Potato Mountain due to the higher reactivity of the carbonate host rocks, and possibly, a more voluminous hydrothermal system. Tin is found as stannite [$\text{Cu}_2\text{FeSnS}_4$] in addition to cassiterite, and the main tungsten-bearing mineral is wolframite. In addition to the tin and tungsten mineralization, Lost River contains significant beryllium resources (Sainsbury, 1963, Sainsbury and others, 1968). Sulfide mineralization is more extensive at Lost River than at Potato Mountain, and accessory minerals in the lodes include chalcopyrite, sphalerite, and galena as well as pyrite and arsenopyrite.

2.3 Historic Mining

Much of the 3,000 t of tin production from the western Seward Peninsula has come from the placer deposits at Cape Mountain and Potato Mountain (Fig. 1). Placer production from the Potato Mountain region was about 1000 t, with the majority of the production (700 t) occurring between 1911-1919 from Buck Creek (Fig.1) using a dredge (Mulligan, 1965). Field investigations in 1997 showed little remaining evidence of the past mining operations in the Potato Mountain area. A few abandoned buildings, some old prospect pits and mounds, and the large dredge in Buck Creek are the only remnants of past mining activity. No reliable grade and tonnage estimations are available for the remaining Potato Mountain tin occurrences.

The Lost River mine operated intermittently between 1904-1955. The majority of the production was from the lode skarn deposit, which yielded more than 300 t of tin from calc-silicate-altered rocks between 1952-1955. Another 85 t of tin was mined from associated placer deposits, which were active into the late 1960's. The workings at the lode mine, located along Cassiterite Creek (Fig.1), consisted of one main adit and three smaller ones, and a small mill. All of these workings have now either collapsed or are flooded. The mineralized zone has also been extensively explored by pits, trenches, diamond drill holes and several collapsed adits, which surround the main workings. Mine waste and tailings that surround the workings are piled along the east bank of Cassiterite Creek, from stream level upward for about 50 m. Small seeps drain parts of these mine waste piles and discharge into Cassiterite Creek. Sainsbury (1969) estimated that there might be as much as 200,000 t of tin remaining in the abandoned lode deposit.

Chapter 3. FIELD AND LABORATORY METHODS

3.1 Sample Design

A total of 62 water samples and 61 stream sediments were analyzed for major, minor and trace elements for the geochemical study of the western Seward Peninsula. Water samples were collected at 49 sites in the drainage basins of Potato Mountain and along and to the west of the Mint, York and Yankee Rivers (Fig. 2) in July 1997. Stream sediment samples were collected from 48 sites; however at one of the sites insufficient material was collected for subsequent analysis. Samples were collected at a sample density of 1 per 1 km² from headwaters of tributaries of Buck Creek, which drains the placer tin operations at Potato Mountain. Buck Creek feeds the Loop Lagoon via Grouse Creek and the Mint River (Fig. 1). The samples were collected at this density in order to assess the dispersion from the historic tin operations at Buck Creek. Drainages on the northern to northwestern side of Potato Mountain which flow directly into the Lopp Lagoon were sampled at a density of 1 per 5 km² to characterize background concentrations of elements in a region underlain by slates distal to any recognized mineralization. The eastern portion of the study area was also sampled at a density of 1 per 5 km² in order to characterize background concentrations of waters and sediments in

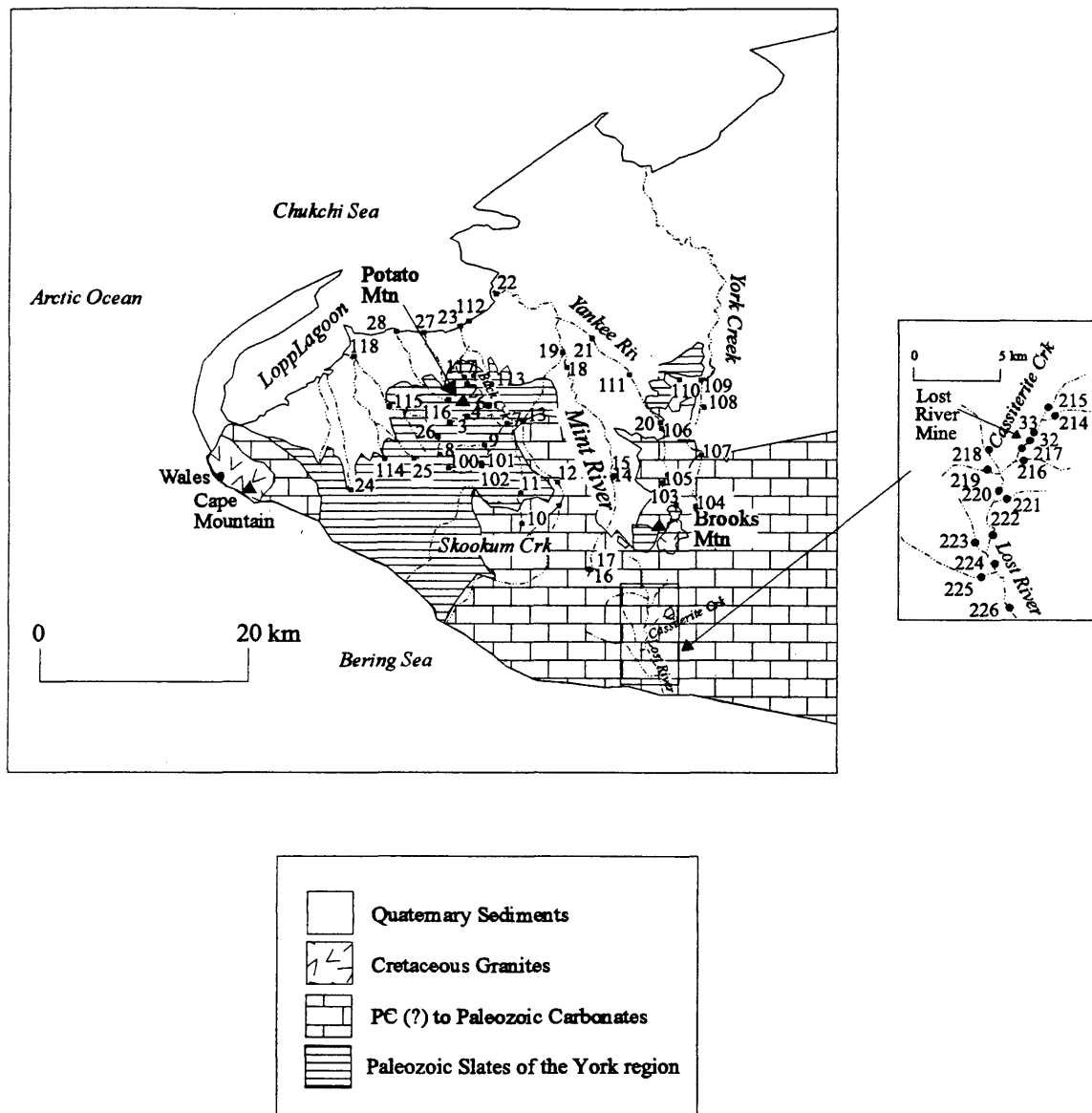


Figure 2. Locations of samples collected in July 1997, 1998
(Geology after Sainsbury, 1972)

an area underlain by carbonates. Two samples were collected near the Lost River mine during the 1997 field season. A follow up survey of the Lost River and its tributaries was conducted in July of 1998 at a sampling density of 1 per 5 km² (Fig. 2) in order to determine the extent of metal dispersion from the tin occurrences in the Lost River area.

3.2 Sample Collection

At each sample site, the pH and conductivity were measured with portable meters. Three 60-mL water samples were collected in high-density polyethylene (HDPE) bottles at each site. Two samples, one filtered and one unfiltered were taken for cation analysis. The unfiltered sample was analyzed for total metals, dissolved plus suspended cations. The second sample was passed through a 0.45-mm-filter to determine the dissolved cation concentrations. Both samples were acidified at the site with 6 drops of concentrated nitric acid to a pH of less than 2. A third filtered, unacidified sample was taken for anion and alkalinity analysis. This sample was packed in ice for shipping and then refrigerated until analyzed.

Stream sediments were collected from the active part of the channel and were sieved in the field to minus-10-mesh (2 mm). Approximately 1 kg of sediment was collected at each site. Panned heavy-mineral-concentrate samples were also collected from the active part of the channel at 29 sites. For each of the panned concentrates

approximately 7 kg of sediment was passed through a minus-10-mesh sieve into a stainless steel pan and flushed with water until most of the visible quartz and feldspars were removed.

3.3 Laboratory Methods

In the laboratory, the stream sediments were dried at room temperature and sieved to minus-80-mesh (1 mm) and then ground into a fine powder using a ceramic mill. A split was taken for each of the samples. One half of the split was archived in case further analysis was necessary, and the remaining split was digested in a total decomposition process using a mixture of hydrochloric, nitric, perchloric and hydrofluoric acids at low temperature (Crock and others, 1983). The samples were then analyzed for 40 elements: Al, Ca, Fe, K, Mg, Na, P, Ti, Ag, As, Au, Ba, Be, Bi, Cd, Ce, Co, Cu, Cr, Eu, Ga, Ho, La, Li, Mn, Mo, Nb, Nd, Ni, Pb, Sc, Sn, Sr, Ta, Th, U, V, Y, Yb, and Zn by ICP-AES. The 1997 samples were analyzed by a USGS contract lab, XRAL, and the 1998 samples were analyzed by Paul Briggs at the USGS in Denver, Colorado. Additionally, a 10-element ICP-AES method which analyzes for Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, and Zn (Motooka, 1996) was applied that utilizes a partial digestion of the sample in a hydrochloric acid-hydrogen peroxide solution. The 10 element data are useful because of lower detection limits for Ag, Cd, Mo and Sb, whose concentrations were below the

detection limit utilizing the 40-element ICP-AES method. A description of the 10-element method is also included in appendix A. In addition, tungsten was analyzed by neutron activation analysis (NAA). A more detailed description of all analytical methods is listed in Appendix A. The stream sediment data for all methods are listed in Appendix B.

The panned concentrates were dried and sieved to minus-18-mesh (<1 mm). The heavy minerals in each sample were then gravity separated using bromoform (specific gravity > 2.86). The heavy mineral concentrates were separated into magnetic, paramagnetic and non-magnetic fractions. The non-magnetic fraction was further separated into two splits. A flow chart (Fig. 3) outlines the procedure followed. One of the splits was analyzed by semi-quantitative emission spectrography (ES) for 33 elements (Ca, Fe, Mg, Na, P, Ti, Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cu, Cr, Ga, La, Mn, Mo, Ni, Pb, Sb, Sc, Sn, Sr, Th, V, W, Y, Zn, Zr) (Grimes and Marranzino, 1968) by Steve Sutley at the USGS in Denver, Colorado. The remaining split was retained for optical mineralogic examination; the results of this examination will be discussed in the chapter 4. A list of the data is included in Appendix B.

The filtered and unfiltered water samples were analyzed for major and minor cations and trace elements by inductively coupled plasma-mass spectrometry (ICP-MS) (Meier and others, 1994). Anion concentrations (F^- , Cl^- , SO_4^{2-}) were determined by the author on the unacidified, filtered water samples using ion chromatography (IC) as described by d'Angelo and Ficklin (1996). Total alkalinity as bicarbonate (HCO_3^-) was

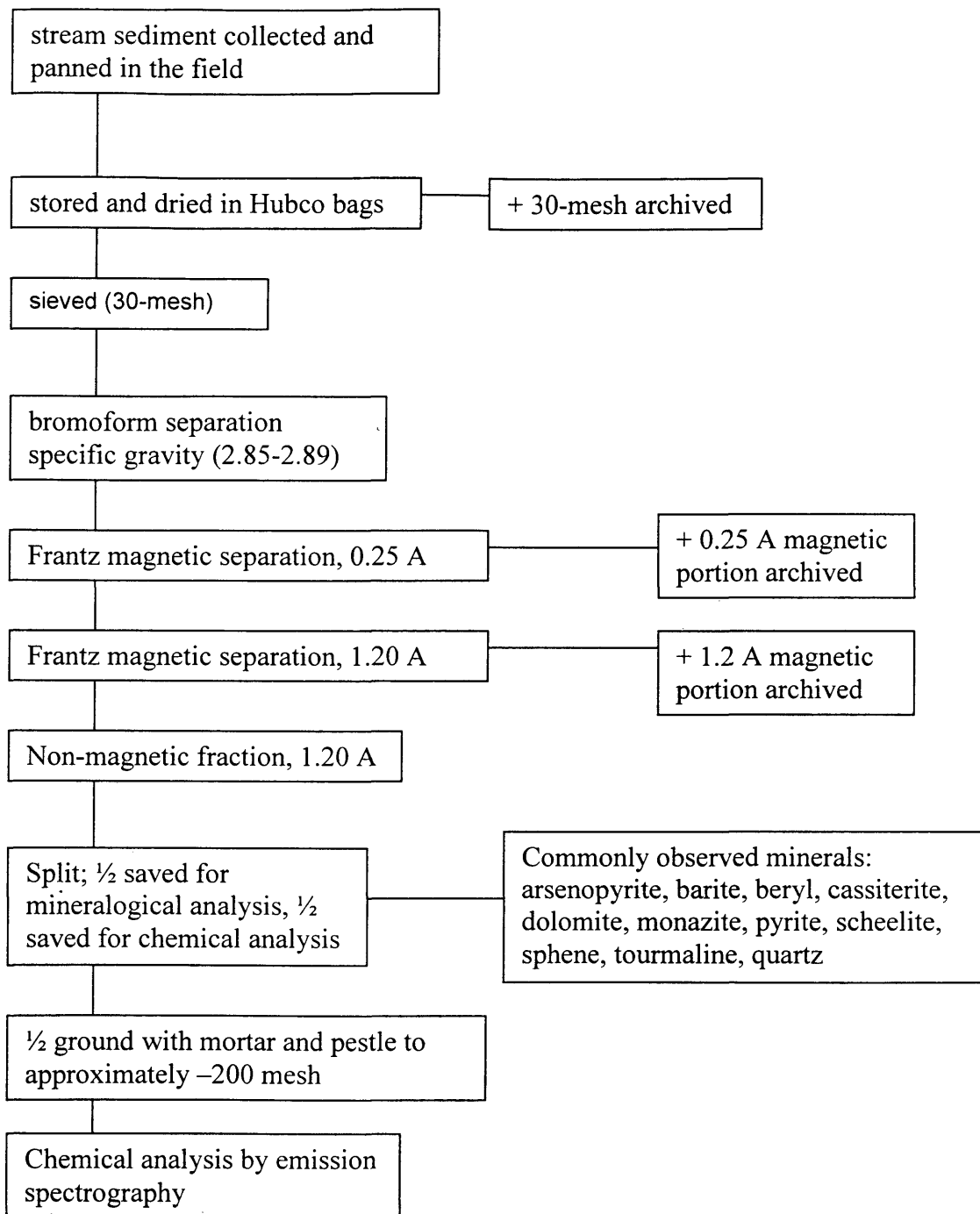


Figure 3. Flow chart of heavy-mineral-concentrate preparation for analysis (after Liebold, 1986)

measured by the author using a titration method. All of these procedures are outlined in detail in Appendix A. A list of all the data is included in Appendix B.

3.4 Data Reliability

Determination of accuracy and precision of geochemical data is important for establishing confidence in the data and to reveal possible errors. The quality of geochemical data may be compromised by three types of error: 1) contamination of the analysis due to instrument error, which can be identified by running blank samples periodically, 2) inaccurate analyses, which can be identified by analyzing standard reference materials, and 3) imprecise analyses, which can be identified by the analysis of duplicate samples.

According to USGS protocol (Arbogast, 1996) the data are within the acceptable accuracy limits for ICP-AES, ICP-MS, IC and alkalinity if the calculated Relative Standard Deviation (RSD) of duplicate samples is no greater than 15%. Acceptable accuracy limits for the semi-quantitative ES are ± 2 steps at the 95% confidence level and ± 1 step at the 83 % confidence level (Motooka and Grimes, 1976). Precision of the ICP-AES, ICP-MS, IC, and alkalinity measurements can be established using the coefficient of variation (CV), which is equal to $100SD/\text{mean}$, where SD is the standard deviation (Rose and others, 1979). For many types of analysis, acceptable precision limits are \pm

10% (Rose and others, 1979). Acceptable precision limits for the heavy-mineral concentrate data, reported on a semi-quantitative scale, were ± 1 step at the 95% confidence level. Within these limits, anomalous concentrations of elements could be distinguished from background concentrations. The results of the quality control for all methods are listed in Appendix A.

The data reliability program followed for this study was dependant on the analysis of reference samples and analytical (sample splits) duplicates. The lack of field duplicates was an oversight in the fieldwork. This does not discount the importance of within-site sampling errors. Only the IC and alkalinity by titration analyses were done by the author, so the only data available for blanks run during analysis are for these methods.

Accuracy of the 40-element ICP-AES data was measured by analyzing five reference-material standards. Accuracy was acceptable for most elements for the 40-element ICP-AES (Appendix A). Arsenic values for the reference samples SARL were $\pm 16\%$ of the RSD, slightly higher than the acceptable accuracy limit. Target values for Sn concentration in the reference samples were not detected in the 40-element ICP-AES method, which may indicate incomplete digestion of the sample. This suggests that the actual values in the samples may be higher than the reported results. For both these elements, background concentrations were distinguishable from anomalous concentrations so these data were considered acceptable. Other elemental concentrations in the reference samples for the 40-element ICP-AES method that did not fall within the acceptable accuracy range were Au, Bi, Eu, Ho, Nb, Ta, and U. These elements were at

or below their respective detection limits in the reference samples for this method. These elements are not critical to the definition of geochemical signatures of the central processes under consideration in this study, and thus these data were not used in the interpretative or statistical analyses. Precision analysis for the 40-element ICP-AES method was acceptable for all elements except Ti, Ba, and Be. These elements are often associated with minerals that are highly insoluble, so it was assumed that there was incomplete digestion of the sample. This did not affect the ability to distinguish background from anomalous concentrations in the stream sediment samples. As such, these data were still acceptable, but absolute concentrations of Ti, Ba, and Be will be held suspect.

The accuracy of the 10-element ICP-AES method was measured by analyzing four standard reference materials. Accuracy results for the 10-element ICP-AES method were unacceptable for As, Au, and Sb. For this reason, and also because 10-element data were only available for the 1997 data set, statistical analyses of As, Cu, Pb and Zn will be conducted using the data from the 40-element method. No precision data were available for 10-element ICP-AES results.

Accuracy of the water analysis (ICP-MS, IC and alkalinity) was measured using reference samples provided by the Water Resources Division (WRD) of the USGS. Accuracy was acceptable for all elements except Al and Fe for the water samples analyzed by ICP-MS. Lack of accuracy for Fe and Al data may be due to instrumentation errors or contamination of the standards. Due to the extremely high error for the Al data,

the results of these data should be considered suspect. No precision analysis was performed for the ICP-MS method due to the lack of unqualified values for most elements.

The IC and alkalinity titrator were calibrated every day prior to running any analyses. Standards and blanks were run after every tenth sample in order to assure calibration of the instrument. Accuracy and precision were within acceptable limits for the anion analysis by IC and alkalinity measurements.

Accuracy of the emission spectrographic (ES) analysis data for heavy-mineral concentrates was measured on three reference-material samples. Accuracy was acceptable for all elements at that 95% confidence limit. Precision analysis was measured for two sample splits. Precision was acceptable for all elements except B and Pb. The heavy mineral concentrate data were used to identify mineralogy in the stream sediments, and to a limited extent to support the stream sediment data. For the purposes of this study, the precision of the ES data was acceptable.

3.5 Data Processing

Four multi-element data sets were available for interpretation in this geochemical investigation: NURE stream sediment data, stream sediment data, heavy-mineral concentrate data, and water data. Due to the different characteristics of each data set,

each data set was evaluated individually. All statistical analyses were performed using the software program STATISTICA 5.1 (StatSoft, 1995) and spatial distribution maps were compiled using MapInfo 4.5.2 (MapInfo Corporation, 1998)

The trace element data compiled from the NURE survey consisted largely of qualified data, i.e. concentrations that are detected, but are below detection limit (L) or undetected, i.e. blank (B). For this reason several methods of data manipulation were employed in order to statistically interpret this data set. All of the qualified data were assigned a value, 0.7 times the lowest detection limit (LDL) for L values, and 0.5 times the LDL for B values (Miesch, 1976). Single element maps and histograms were constructed to evaluate the spatial distribution of elements of interest, namely As, Cu, Li, Sn, W, and Zn. Basic statistics were calculated for the total data set and for a subset of the data from the Teller quadrangle. Results and interpretation of the NURE data are discussed in detail in chapter 4.

Heavy-mineral concentrates were analyzed using a semi-quantitative method. For this reason, and due to the small data set, these data were used only to identify mineralogical assemblages and to better interpret anomalies in corresponding sample sites in the stream sediment data. Basic statistics were performed only for elements containing more than 70% unqualified values. Tin was included in the basic statistics even though its detection ratio was 0.66 (detection ratio equals the number of unqualified values/total number of samples) because of its importance in the overall study.

Water data for this study were also interpreted semi-quantitatively as the majority of the trace element data consisted of qualified data. Before calculating basic statistics for the trace element data, concentrations of elements that were below detection limit were replaced by 0.7 times LDL (Miesch, 1976). Several different methods of evaluating censored data were investigated (Gilbert, 1987; Helsel and Gilliom, 1984; and Miesch, 1976). The replacement method described by Miesch was considered to be the most appropriate. The interpretation of the water data will be discussed in detail in chapter 5.

The interpretation of the stream sediment data was facilitated by the use of basic statistics (mean, standard deviation, range), histograms, single element plots, R-mode factor analysis and factor plots in order to classify the data and to examine the spatial distribution of samples having anomalous concentrations. Duplicate samples and standards were eliminated from the data sets. Before statistical analyses were performed, the data were transformed to log base 10, as most geochemical data sets are not normally distributed (Rose and others, 1979). The log transformation attempts to normalize the distribution so that the statistical analysis is valid. The objective of the analysis was to determine element associations that may reflect geologic processes or features, such as mineralization, lithology, and sources of geochemical dispersion.

The first step in interpreting geochemical data is to be able to recognize differences in data distributions. This process is aided by the use of histograms which show the distributions graphically. Histograms combined with percentile distributions help define background from anomalous populations. Due to the large number of

samples collected from areas of known mineralization and from two distinct lithologies (carbonates vs. slates), the data showed obvious bi- to multi-modal distributions (Fig 4 A-J). Histograms are shown only for elements that characterize the main lithologies (Al, Ca, Fe, and Mg) and for trace elements that characterize the tin mineralization (As, Be, Cu, Pb, Sn, and W). For this reason, subsets of the data were broken out and new populations were calculated in order to discern background from anomalous concentrations.

Areal distribution is also important in characterizing geochemical anomalies. Single element plots were constructed using classes of data for the suite of elements that characterize the tin mineralization (As, Be, Cu, Pb, Sn, W, and Zn). These maps are useful for defining point sources of metals as well as delineating dispersion patterns.

Element associations for stream sediments were determined by factor analysis. R-mode factor analysis with Varimax rotation was used to identify dominant geochemical associations in the sediment data. The purpose of factor analysis is to reduce the number of variables so groups of elements (factors) may be used to define geochemical associations which can be interpreted with respect to underlying geologic or geochemical processes. Resulting factors often delineate suites of elements that are geochemically associated with specific rock types or mineral deposits. Factor analysis is very useful in the definition of geochemical landscapes when trying to interpret data sets with a large number of elements.

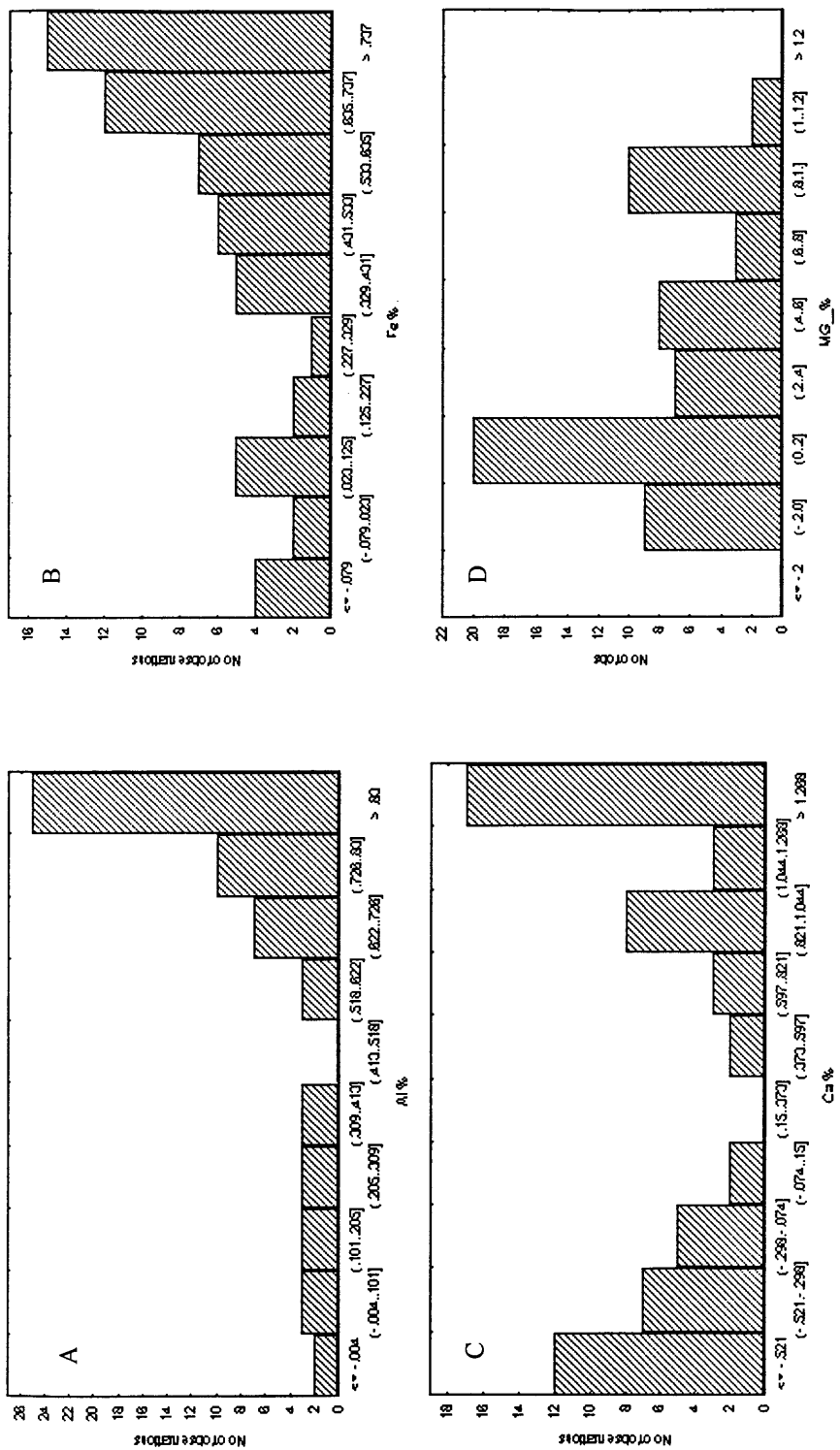


Figure 4. Histograms showing bi- to multi-modal distributions for A) Al, B) Fe, C) Ca, D) Mg, E) As, F) Be G) Cu, H) Pb, I) Sn, and J) W

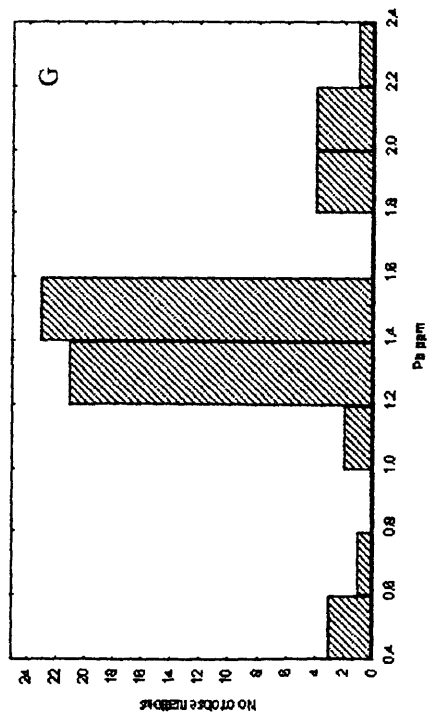
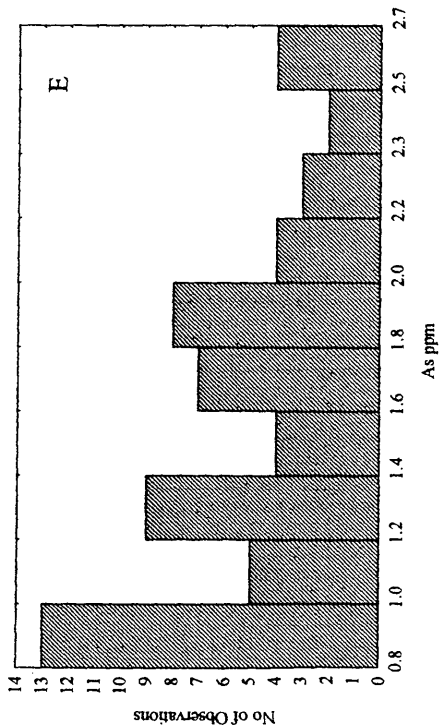
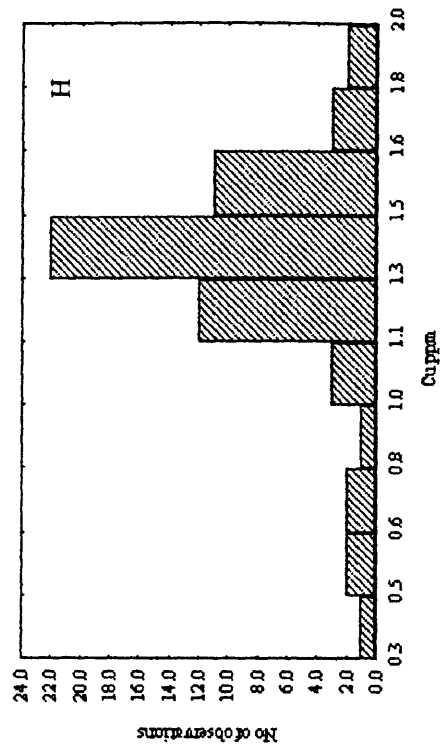
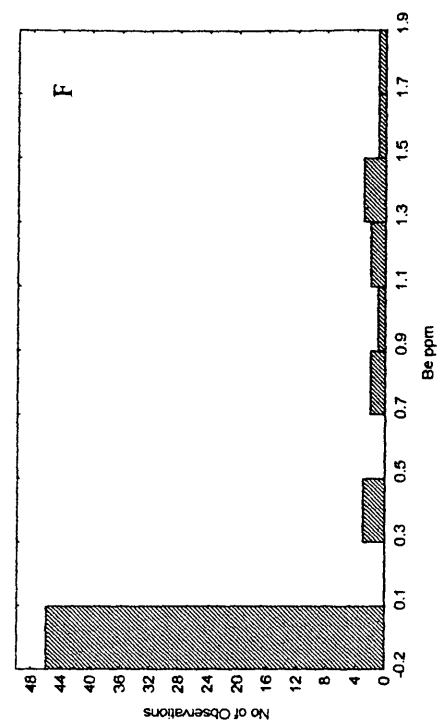


Figure 4. continued

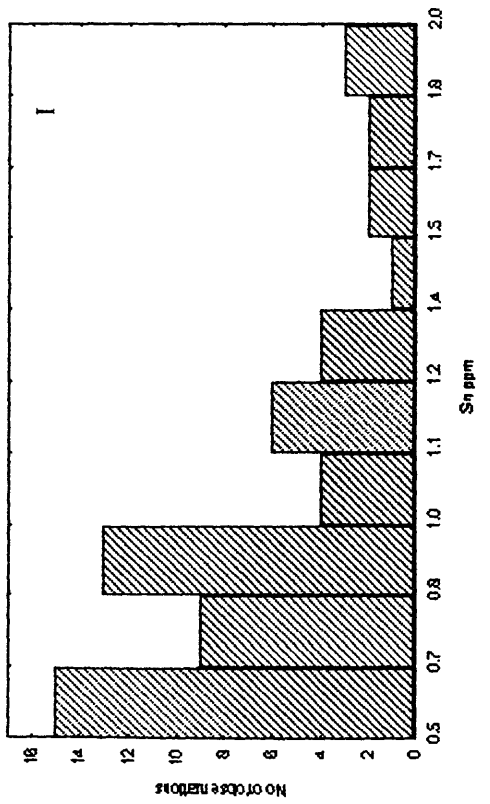
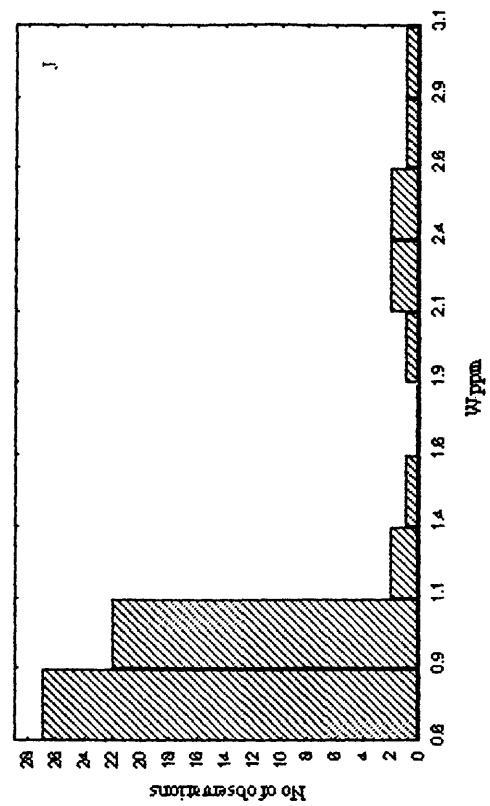


Figure 4. continued

Factor analysis calculates a factor loading for each of the variables (elements) in the data set. A high factor loading indicates a strong association of the particular element with the given factor. Factor loadings may be interpreted in much the same way as correlation coefficients and are mathematically derived from the correlation matrix of the variables. Correlation coefficients for elements used in the factor analysis are listed in table 1. As can be seen, strong correlations exist between many of the elements.

Factor scores are a measure of the intensity of the association at each sample site. The greater the absolute score for a given site, the stronger the association to the element or suite of elements defined by the factor at that site. Maps were constructed for each of the factor scores showing the distribution of scores for each of the significant factors to show the spatial distribution of each factor. The scores were divided into ranges based on a calculation in the MAPINFO program which calculated natural breaks in the data. The breaks were compared to histograms of the scores and were deemed appropriate. These maps were used in the interpretation of the factor analysis to confirm their geologic significance.

It should be noted that interpretations or conclusions for any type of statistical analysis can only be verified using geological and geochemical knowledge. Factor analysis can result in a number of models, some of which may not be applicable to the solution of the problem. The most useful factor model is chosen on the basis of two mathematical criteria: 1) the model should explain a significant portion of the variation within the data

Table 1 Correlation coefficients for stream sediment data

[all values in ppm unless otherwise noted; bolded values significant at the 95% confidence level]

	Al%	Ca %	Fe %	Mg %	Ti %	Mn	As	Ba	Be	Ce	Co	Cu	Cr	La	Li	Ni	Pb	Sn	Sr	V	W	Zn	
Al%	1.0																						
Ca %	-0.8	1.0																					
Fe %	1.0	-0.8	1.0																				
Mg %	-0.9	0.8	-0.9	1.0																			
Ti %	0.9	-0.9	0.9	-0.9	1.0																		
Mn	0.7	-0.6	0.7	-0.7	0.6	1.0																	
As	0.1	-0.3	0.1	-0.1	0.1	0.3	1.0																
Ba	0.7	-0.4	0.7	-0.7	0.6	0.6	-0.1	1.0															
Be	-0.6	0.5	-0.6	0.6	-0.6	-0.2	0.4	-0.5	1.0														
Ce	0.9	-0.8	0.9	-0.8	0.8	0.7	0.2	0.6	-0.5	1.0													
Co	0.9	-0.8	0.9	-0.9	0.9	0.8	0.1	0.7	-0.6	0.8	1.0												
Cu	0.4	-0.2	0.4	-0.3	0.3	0.5	0.6	0.4	0.2	0.4	0.4	1.0											
Cr	1.0	-0.8	0.9	-0.9	0.9	0.6	0.0	0.7	-0.7	0.8	0.9	0.3	1.0										
La	0.8	-0.7	0.8	-0.7	0.8	0.6	0.1	0.5	-0.4	1.0	0.8	0.3	0.8	1.0									
Li	0.4	-0.3	0.4	-0.2	0.3	0.6	0.7	0.1	0.4	0.4	0.3	0.6	0.2	0.4	1.0								
Ni	0.9	-0.7	0.9	-0.8	0.9	0.7	0.0	0.8	-0.6	0.8	1.0	0.4	0.9	0.7	0.3	1.0							
Pb	0.1	0.0	0.0	0.1	0.0	0.4	0.7	-0.1	0.7	0.1	0.0	0.6	-0.1	0.1	0.8	0.0	1.0						
Sn	-0.3	0.1	-0.2	0.3	-0.2	0.0	0.7	-0.5	0.7	-0.1	-0.3	0.3	-0.4	-0.1	0.5	-0.4	0.7	1.0					
Sr	-0.6	0.9	-0.6	0.7	-0.7	-0.4	-0.2	0.5	-0.6	-0.6	0.0	-0.6	-0.6	-0.5	-0.1	-0.5	0.2	0.1	1.0				
V	0.9	-0.7	0.9	-0.8	0.9	0.7	0.0	0.9	-0.7	0.8	0.9	0.3	0.9	0.7	0.3	0.9	-0.1	-0.4	-0.5	1.0			
W	-0.5	0.4	-0.5	0.6	-0.5	-0.2	0.6	-0.5	0.9	-0.4	-0.5	0.2	-0.6	-0.3	0.4	-0.6	0.7	0.4	-0.6	1.0			
Zn	0.2	-0.2	0.2	-0.1	0.1	0.5	0.7	0.1	0.5	0.3	0.2	0.7	0.0	0.2	0.9	0.2	0.9	0.6	0.0	0.1	0.5	1.0	

set (quantified by eigenvalues), and 2) the model should account for most of the variation in each element (quantified by communalities). By far the most important criterion for choosing a factor model is that each of the element associations defined by the factors should be geologically, geochemically and spatially meaningful.

Chapter 4. INTERPRETATION OF THE NURE DATA

The NURE data were evaluated at a scale of 1:1,000,000. This analysis was done in order to delineate nearshore regions of anomalous concentrations of metals, especially As, Cd, and Hg, that were found in the marine mammals studies. The intention was to find localized metal anomalies that had short migration pathways into the waters of the western coast of Alaska. Figure 5 shows the distribution of As in the stream sediments from this study. The NURE survey provided very limited data for Cd, and no Hg data. As can be seen from the distribution map, there are several localized “hot spots” for arsenic (Fig. 5). The anomalous As concentrations near Nome are associated with the gold deposits in the area. The western Seward Peninsula was thus chosen for the thesis study area due to its proximity to the Bering Sea.

Basic statistics from the NURE data for the suite of elements that define the tin occurrences (As, Cu, Li, Pb, Sn, W, and Zn) of the western Seward Peninsula are listed in table 2A. Due to the large number of qualified values for these elements associated with tin deposits in the NURE data set, basic statistics were recalculated using only data collected from the Teller quadrangle (table 2B). The reanalysis of the data was done to discern if there was a significant statistical bias introduced by the use of qualified data.

Commonly the 95th percentile for a given geochemical distribution is chosen as the threshold value in determining anomalous from natural background concentrations for

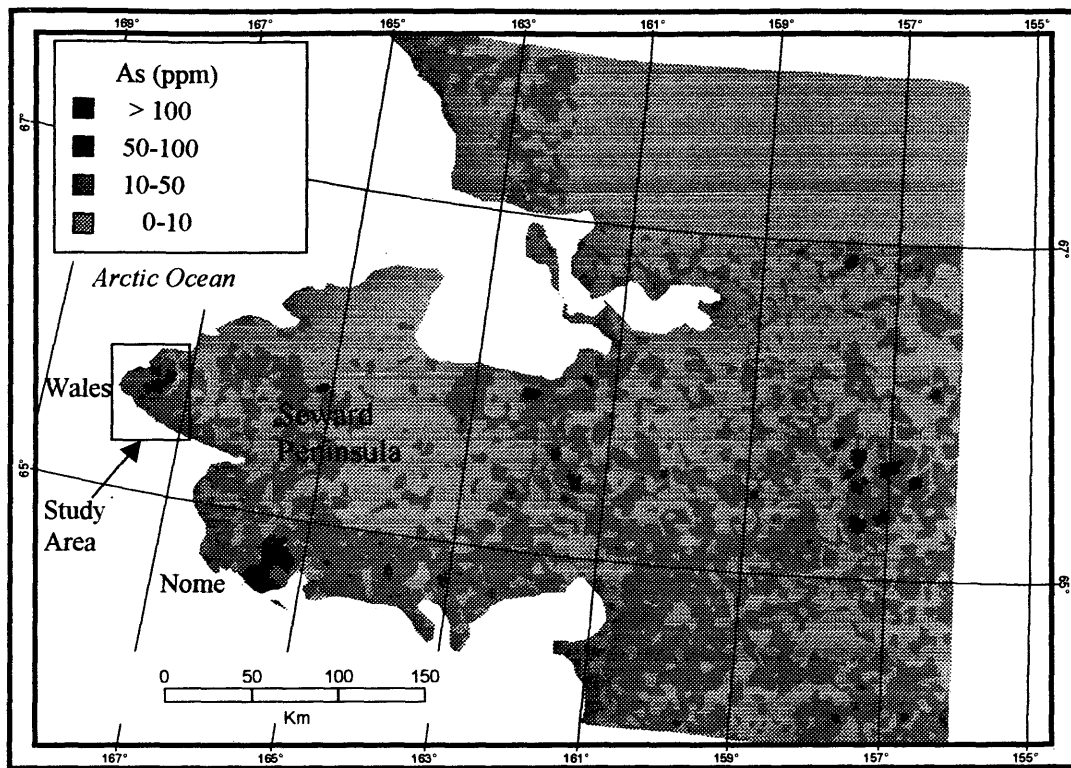


Figure 5. Distribution of arsenic (ppm) in stream and lake sediments from NURE data

Table 2A Basic statistics for selected elements from the NURE survey

[All concentrations in ppm unless; detection ratio is the number of samples with unqualified values divided by the total number of samples; N, total number of samples B, number of samples below detection limit, qualified with "B", (not detected at lower detection limit), L, number of samples detected at lower limit of detection, qualified with "L", (less than lower detection limit); geometric mean calculated using all data—values with "B" were set equal to 0.5 times the lower Detection limit, values of L were set equal to 0.7 times the lower detection limit]

	N	B	L	Detection Ratio	Mean	Standard deviation	Geometric mean	MEDIAN	MIN	MAX	25th percentile	75th percentile	85th percentile	90th percentile	95th percentile
As	9066	3675	713	0.52	10.03	33.24	5.79	5	2.50	1379	3	12	14	17	22.5
Cu	9066	683	263	0.90	28.92	19.82	24.31	28	5.0	1111	19	36	42	46	53
Li	9066	5373	4	0.41	13.51	20.26	3.06	0.70	0.3	258	0.7	25	33	41	50
Pb	9066	682	3036	0.59	8.44	15.86	6.24	6	2.5	950	3.5	10	13	15	19
Sn	9066	682	8255	0.01	7.56	3.86	7.37	7.50	5.0	144	7.5	7.5	7.5	7.5	7.5
W	9066	682	7743	0.07	11.03	3.49	10.72	10.5	7.5	73	10.5	10.5	10.5	10.5	17
Zn	9066	153	4451	0.49	67.7	86.1	32.25	10.5	7.5	3531	10.5	123	149	168	198

Table 2B Basic statistics for the Teller quadrangle for the suite of elements which characterize tin mineralization (from NURE data)

	N	B	L	Detection Ratio	Mean	Standard deviation	Geometric mean	MEDIAN	MIN	MAX	25th percentile	75th percentile	85th percentile	90th percentile	95th percentile
As	515	65	52	0.77	18.32	9.80	2.51	11	2.50	635	5	17	22	27	36
Cu	515	50	22	0.86	24.24	20.65	1.88	24	5	85	17	31	36	38	43
Li	515	50	420	0.09	0.90	3	9.35	1	1	72	1	1	0.7	0.7	24.00
Pb	515	50	183	0.55	6.40	5.46	1.73	5	2.50	28	4	9	10	12	14
Sn	515	50	423	0.08	10.05	7.70	1.67	7	5.00	144	7	7	7	7	22
W	515	50	411	0.10	11.33	10.91	1.28	11	7.50	38	11	11	11	15	20
Zn	515	1	221	0.57	58.83	41.61	2.40	55	11.50	206	16	94	109	120	131

geochemical data (Rose and others, 1986). Using these criteria, a comparison of the elements of interest indicates significant increases in the subset of the Teller quadrangle (table 2B). These increases are in part due to the influence of data collected from the widespread tin occurrences in the western Seward Peninsula. As many of the samples collected during the present study were from areas of known tin occurrences, the large NURE data set was helpful in establishing background metal levels for the region.

Chapter 5. RESULTS AND INTERPRETATION

5.1 Statistical summary of stream sediment geochemistry data

Summary statistics were calculated for 60 stream sediment samples collected in this study (table 3). The data for site 32 (Fig. 2) collected from below the Lost River mine tailings were excluded from the basic statistics as they represent a contaminated site. Inclusion of this sample would bias the mean statistics used to estimate the natural background of the area. Compare the data from site 32 (3 ppm Ag, 1435 ppm As, 106 ppm Bi, 21 ppm Cd, 285 ppm Cu, 768 ppm Li, 766 ppm Pb, 14 ppm Sb, 136 ppm Sn, 210 ppm W, and 5,200 ppm Zn) with that of the other 60 stream sediment samples. Many of these values are several times greater than the maximum concentrations from the remaining data set.

In spite of the exclusion of site 32, mean values for the suit of elements that characterized the tin deposits were abnormally high (As, Be, Cu, Li, Pb, Sn, W, and Zn) compared to average values for the rock types from which the sediments were derived (Table 4; Levinson, 1980).

This is due to the large number of samples collected in areas of known mineralization. As such, the data set was separated into three categories: (1) samples collected from streams underlain by slates, (2) samples collected from streams underlain by carbonates, and (3) samples with metal concentrations indicative of tin mineralization.

Table 3 Basic statistics for selected elements in 60 stream sediments.

Element	valid	N	mean	std.dev.	geometric mean	median	minimum	maximum	25th percentile	75th percentile	85th percentile	90th percentile	95th percentile
Al %	60	5.35	2.46	4.51	6.05	0.78	8.6	3.6	7.30	7.80	7.95	8.40	
Ca %	60	9.61	10.71	2.79	4.75	0.18	31	0.41	20	25	26.5	30	
Fe %	60	3.75	1.87	3.13	4	0.66	6.9	2.2	5.45	5.80	5.90	6.10	
Mg %	60	3.25	3.22	2.18	1.55	0.62	14	1.15	3.9	7.3	8.7	10	
Ti %	60	0.31	0.21	0.22	0.3	0.04	0.95	0.12	0.48	0.53	0.55	0.64	
Mn ppm	60	729	502	618	637	150	3660	472	861	980	1055	1500	
As ppm	60	81	125	36	34	7	530	12	78	140	230	480	
Ba ppm	60	470	512	293	316	30	2510	185	512	854	1003	1620	
Be ppm	60	5.2	13.6	1.3	0.7	0.7	86	0.7	1	5	17.5	32	
Cd ppm	45	2.53	14.86	0.24	0.2	0.05	19	0.1	0.4	0.6	0.8	0.9	
Co ppm	60	16	8	13	16	3	32	7	23	26	27	30	
Cu ppm	60	27	21	21	23	2	130	16	29	41	46	79	
Cr ppm	60	75	41	57	81	7	140	43	110	122	124	132	
La ppm	60	31	20	26	31	4	132	19	42	45	52	56	
Li ppm	60	68	44	55	61	8	260	41	79	103	120	170	
Mo ppm	60	2.0	1.3	1.8	1.4	1.4	7	1.4	2	3	3	5	
Ni ppm	60	41	19	35	45	8	76	25	57	60	62	70	
Pb ppm	60	37	39	27	27	2.8	230	20	30	51	86	130	
Sb ppm	45	5	15	2	1	0.7	100	0.7	4	9	12	16	
Sn ppm	60	15	19	9	8	3.5	90	4	14	23	40	66	
Sr ppm	60	190	134	146	140	42	520	70	316	350	366	470	
V ppm	60	113	64	87	135	13	298	54	149	164	167	225	
W ppm	60	61	204	12	8	4	1400	6	10	15	155	390	
Zn ppm	60	116	92	94	101	15	580	68	119	147	195	310	

Table 4. Average values in host rock for elements characterizing tin occurrences.

Element	Avg. value for shales	Avg. value for limestone	Mean value for all stream sediments
As	15	2.5	81
Be	3	1	5
Cu	50	15	27
Li	60	20	68
Pb	20-70	8	37
Sn	4	4	15
W	2	0.5	61
Zn	100	25	116

Histograms of Ca and Al (Fig. 4A-B) showed two distinct populations, supporting the separation of the data into sediments derived from drainages underlain by slates versus limestones. This is further supported by the spatial distribution maps of Al and Ca (Fig. 6A-B). From visual estimations of histograms (Fig 4 A-L) and comparison with the regional data from the Teller quadrangle collected during the NURE survey, samples with As concentrations greater than 50 ppm and Sn concentrations of greater than 20 ppm were considered anomalous and were interpreted to characterize stream sediments associated with the tin occurrences. Arsenic and tin were chosen as the best elements to characterize sediments associated with tin occurrences because the separation between background and anomalous populations was more distinct than for other elements associated with mineralization (Be, Cu, Li, Pb, W, Zn). Table 5 lists the recalculated statistics for the stream sediments derived from the areas underlain by the A) carbonates and B) slates.

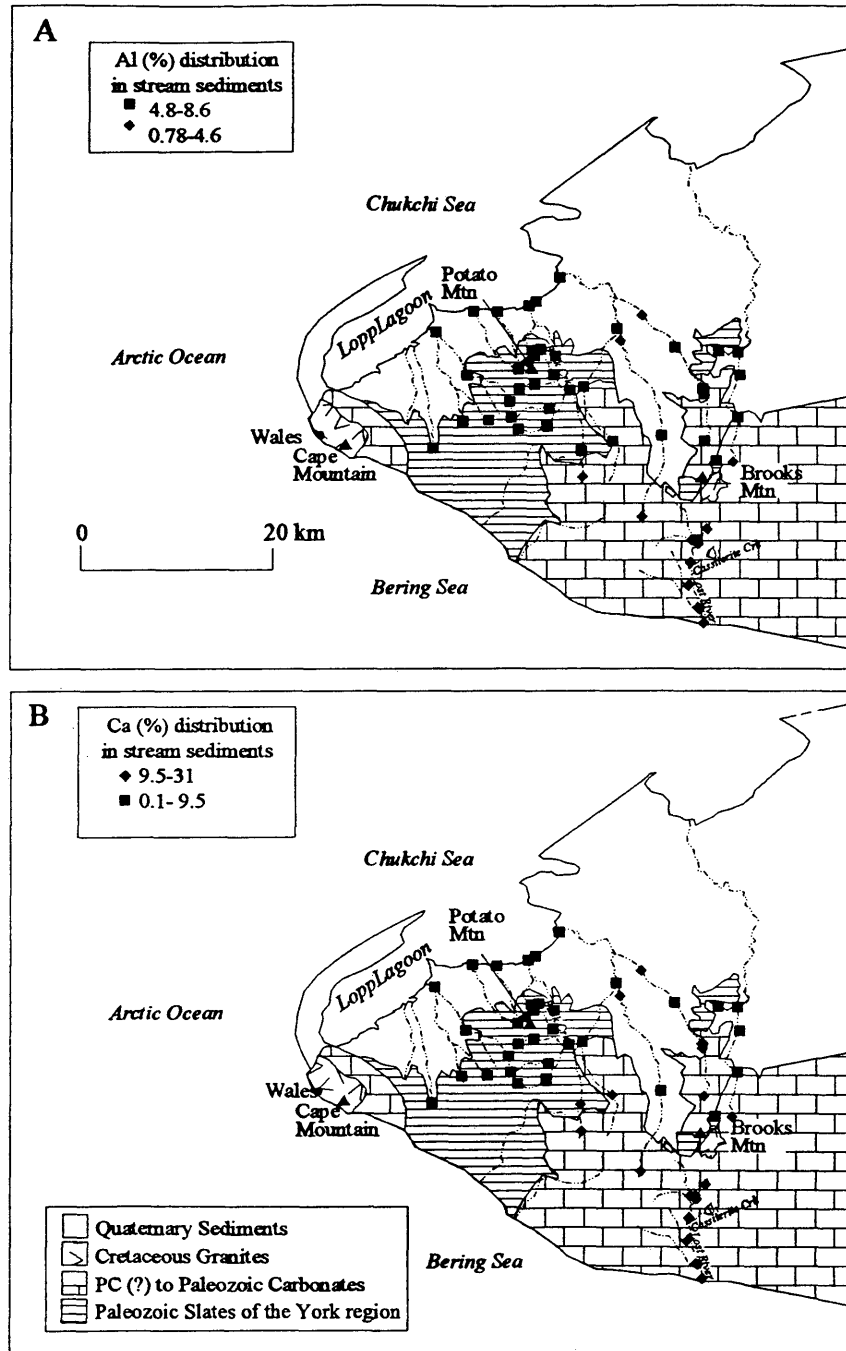


Figure 6. Concentrations of A) Al% and B) Ca% in stream sediments

Table 5A Recalculated statistics for stream sediments collected in drainages underlain by carbonates

Element	valid N	mean	std.dev.	geometric mean	median	minimum	maximum	25th percentile	75th percentile	85th percentile	90th percentile	95th percentile
Al %	14	2.9	1.7	2.4	2.8	0.8	5.2	1.2	4.8	5.1	5.1	5.2
Ca %	14	19.1	7.1	17.8	20.0	10.0	30.0	11.0	25.0	29.0	29.0	30.0
Fe %	14	2.0	1.0	1.7	2.0	0.7	3.2	0.9	3.0	3.2	3.2	3.2
Mg %	14	5.5	3.9	4.2	4.4	0.9	14.0	3.4	7.1	12.0	12.0	14.0
Ti %	14	0.11	0.05	0.10	0.11	0.04	0.20	0.06	0.15	0.18	0.18	0.20
Mn ppm	14	407	257	340	340	150	962	198	540	752	752	962
As ppm	14	10	5	9	7	7	21	7	10	18	18	21
Ba ppm	14	319	337	171	160	30	995	53	629	891	891	995
Be ppm	14	2	2	1	1	1	5	1	2	5	5	5
Co ppm	14	9	5	7	7	3	16	4	15	16	16	16
Cu ppm	14	15	10	11	15	2	30	6	23	27	27	30
Cr ppm	14	37	22	30	41	10	68	13	58	62	62	68
La ppm	14	18	11	14	17	4	42	8	21	35	35	42
Li ppm	14	27	13	23	32	8	42	16	40	42	42	42
Ni ppm	14	26	14	22	25	8	44	12	42	44	44	44
Pb ppm	14	16	9	12	18	3	32	5	20	27	27	32
Sn ppm	14	6	3	5	4	4	11	4	7	9	9	11
Sr ppm	14	291	107	269	316	98	480	216	362	400	400	480
V ppm	14	63	44	47	54	13	138	21	100	134	134	138
W ppm	14	9	7	8	8	4	30	5	10	12	12	30
Zn ppm	14	50	23	44	56	15	82	24	65	80	80	82

Table 5B Recalculated statistics for stream sediments collected in drainages underlain by slates

Element	valid N	mean	std.dev.	geometric mean	median	minimum	maximum	25th percentile	75th percentile	85th percentile	90th percentile	95th percentile
Al %	19	6.95	0.94	6.89	7.00	5.40	8.60	6.00	7.80	8.00	8.20	8.60
Ca %	19	2.68	3.15	1.09	0.47	0.25	9.50	0.28	5.30	7.10	8.10	9.50
Fe %	19	4.89	1.02	4.79	4.60	3.40	6.90	3.90	5.90	6.10	6.10	6.90
Mg %	19	1.40	0.54	1.33	1.20	0.83	3.00	1.10	1.80	2.00	2.10	3.00
Ti %	19	0.41	0.15	0.37	0.47	0.13	0.64	0.28	0.51	0.54	0.61	0.64
Mn ppm	19	840	361	780	773	384	1740	584	855	1490	1500	1740
As ppm	19	24	12	21	24	7	48	15	33	40	43	48
Ba ppm	19	659	598	506	357	270	2510	308	816	1460	1620	2510
Be ppm	19	1	--	1	1	1	1	1	1	1	1	1
Cd ppm	19	0	0	0	0	0	1	0	0	1	1	1
Co ppm	19	21	5	20	19	14	32	16	25	27	28	32
Cu ppm	19	23	7	22	21	13	41	18	27	29	29	41
Cr ppm	19	101	21	98	101	65	132	79	123	125	131	132
La ppm	19	43	25	38	38	21	132	25	51	56	62	132
Li ppm	19	62	15	61	61	36	97	52	71	79	79	97
Ni ppm	19	54	8	54	53	40	76	50	59	61	62	76
Pb ppm	19	24	4	24	24	16	32	21	28	28	29	32
Sn ppm	19	6	3	6	6	4	10	4	9	10	10	10
Sr ppm	19	122	78	103	75	57	301	65	194	209	278	301
V ppm	19	152	23	150	148	123	225	139	162	168	180	225
W ppm	19	7	1	7	6	4	10	6	8	8	10	10
Zn ppm	19	103	13	102	101	79	133	95	113	117	120	133

5.2 Geochemistry distal to known tin occurrences

The sediment samples taken in the area underlain by the slate unit of the York terrane are characterized by background levels of <10-48 ppm As, <5-10 ppm Sn, <1 ppm Be, 13-41 ppm Cu, 36-97 ppm Li, 16-32 ppm Pb, 4-10 ppm W, and 79-133 Zn. The background values for As, Li, and Sn are quite high relative to average values for stream sediments derived from shales and slates (Table 4; Levinson, 1980), reflecting a broad hydrothermal enrichment possibly associated with tin granite alteration haloes. Typical Ca concentrations of 0.2 to 0.5 % characterize sediments derived from the slates, but locally are higher due to calcareous silt and carbonaceous limestone interbedded in the slates. Higher Fe content (3.78%-6.9 %) in the slates relative to the carbonates (0.66%-3.78%) (Fig. 7) possibly indicates the presence of diagenetic pyrite common to shales deposited in marine environments from which the slates are derived (Potter and others, 1980).

The samples collected in the eastern portion of the study area, which is underlain by the limestone unit of the York terrane, had mainly background concentrations of As (<10-21 ppm), Be (1-5ppm), Cu (2-30 ppm), Li (8-44), Pb (2.8-33 ppm), Sn (<10 ppm), W (4-12 ppm) and Zn (15-82 ppm).

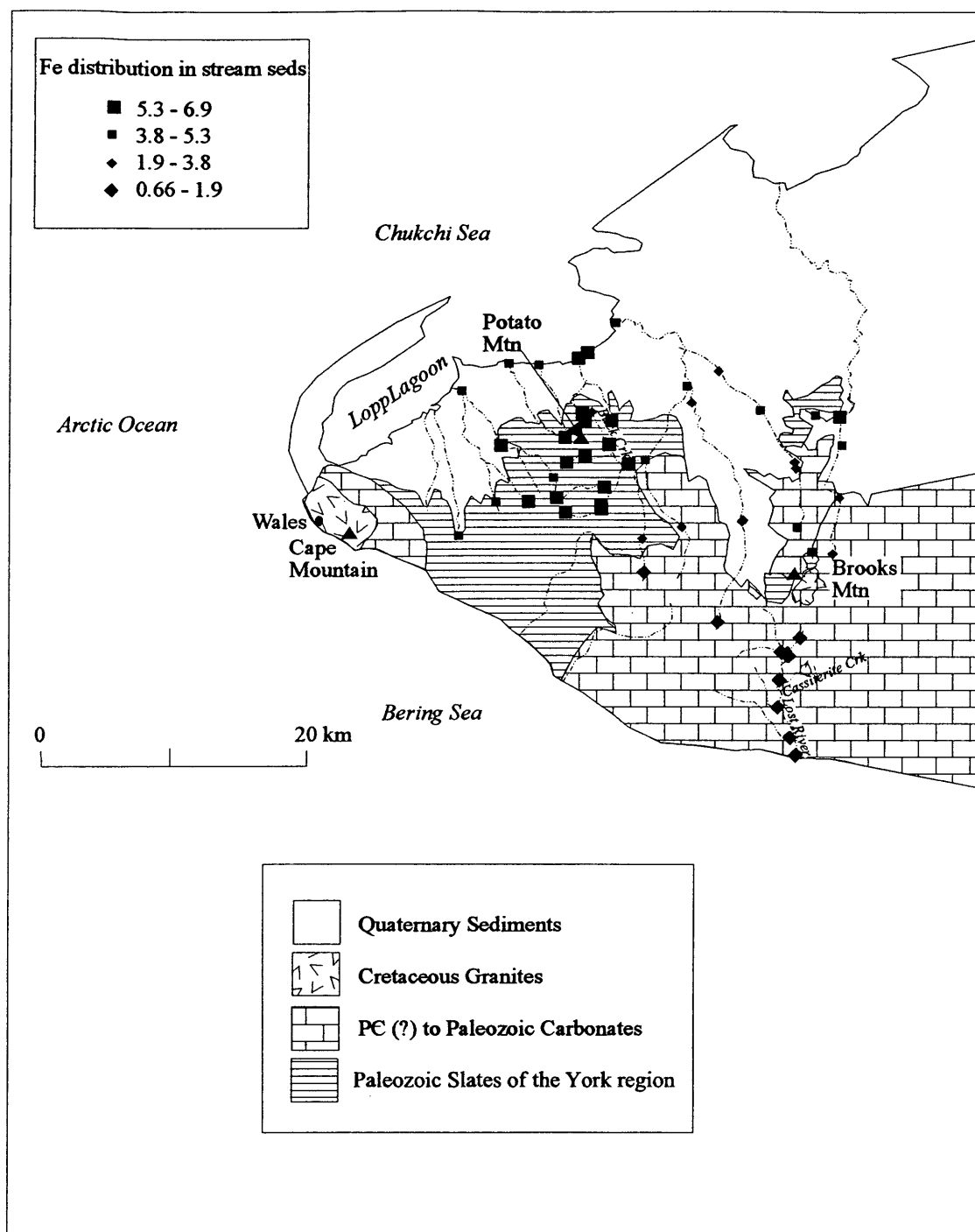


Figure 7. Concentrations of Fe (%) in stream sediments

5.3 Geochemistry of sediments indicating mineralization

Sediment samples taken from the upper reaches of streams draining Potato Mountain, an area of known tin occurrences, are consistently anomalous in As (85-530 ppm; Fig. 8a). Also, they show consistent anomalies for Sn (Fig. 8b), as well as enrichments of Ag, Cu, Ni, Sb, and W. The sediment samples collected in the same drainages, but at lower elevations flowing through the Quaternary sediments directly upstream from Lopp Lagoon (sites 23, 27, 28, 112, and 118) generally contain background Sn and As concentrations. However, two of the five samples (sites 23 and 27, Fig. 2) collected in the lower reaches of the streams contain 78 ppm As. Two samples (sites 109 and 110) collected from a small tributary of York Creek along the eastern border of the study area contained As concentrations of 51 and 72 ppm (Fig. 8a), respectively, suggesting possible hydrothermal mineralization even though there are no known granites in the area. The sample with 72 ppm As also contained detectable Au and Ag, further suggesting hydrothermal mineralization distal to any known granite.

One of the sediment samples collected from York Creek on the northeast side of Brooks Mountain (site 103; Fig. 2) had a tin value of 22 ppm. This sample also had anomalous values for As (99 ppm), Cu (49 ppm), Li (110 ppm), Ni (66 ppm), Pb (86 ppm), and Sb (9 ppm). These enrichments reflect the known tin occurrences upstream and nearer to the peak of Brooks Mountain. This is further supported by a concentration of 26 ppm Sb at an adjacent site (site 104; Fig 2).

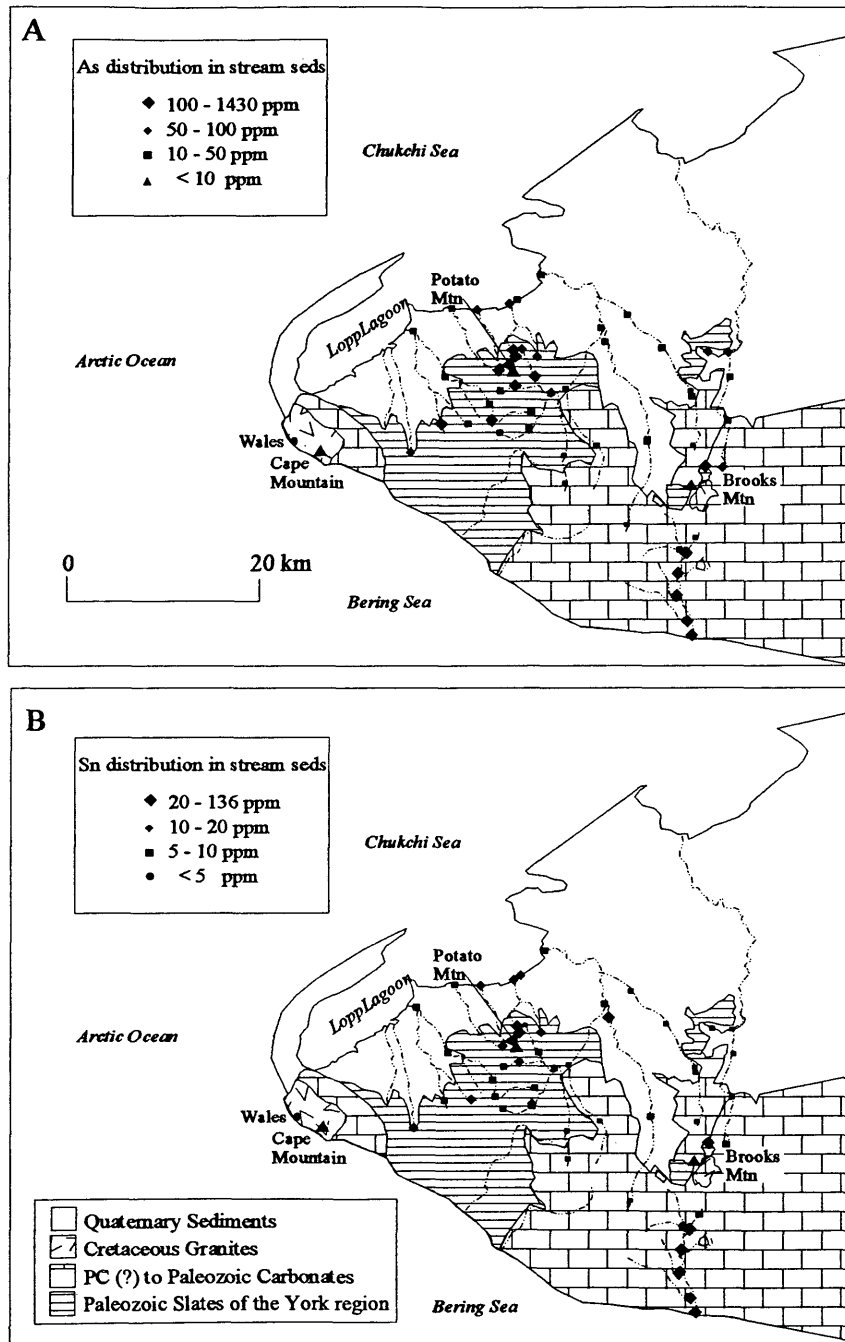


Figure 8. Concentrations of A) As and B) Sn in stream sediments

The sediment samples collected along Lost River contained anomalous concentrations for As (Fig. 8A), Sn (Fig. 8B) and all ore related metals (Be; 15-86 ppm, Cu; 15-90 ppm, Li; 57-260 ppm, Pb; 69-230 ppm, and W; 90-320 ppm) for the entire 8-km-long channel length below the junction with Cassiterite Creek. Beryllium concentrations were highest in tributaries to the Lost River (45 ppm at site 223 and 86 ppm at site 216), possibly reflecting the presence of unmined vein occurrences distal to the main Lost River skarn deposit, as previously mentioned by Sainsbury (1969).

5.4 Factor analysis of stream sediments

Element associations for 60 stream sediments (not including the Lost River tailings sample, site 32; Fig.2) were determined by factor analysis. The Lost River site was eliminated from the factor analysis as the extremely high concentrations of the elements associated with the tin deposits would skew the data set. Elements eliminated from the data set include those with a detection ratio of less than 0.5 (Ag, Au, Eu, Ga, Ho, Nb, Bi, Ta, Th, and U) and those elements which did not significantly change the analysis when deleted (K, Na, P, Ga, Nd, and Y). The ICP-AES 10-element data were not included in the factor analysis because data was only available for the samples collected during 1997.

Factor analysis can provide many different models for a given data set, depending on the quantity of input variables. Seven through three factor models were calculated for the stream sediment data set. Elements with loadings over 0.4 or below -0.4 were used to describe each factor. Figure 9 lists the factor models and the loadings for the elements in each factor. The data generated from the factor analysis are listed in Appendix C.

A 4 factor model which accounts for 91% of the variance in the data set was chosen as the most appropriate to characterize the stream sediment data. All seven of the factor models included the same element associations for factors one through four. The 5, 6 and 7 factor models did not delineate any geologically significant factors that were not already accounted for in the four-factor model. The 4 factor model met the mathematical criteria described in chapter 3, but more importantly, each of the factors and their spatial distribution was geologically and geochemically meaningful. Table 6A lists the communalities for each of the elements used in the factor analysis and table 6B lists the eigen values for each of the factor models. The following section will discuss the interpretation of the factor analysis.

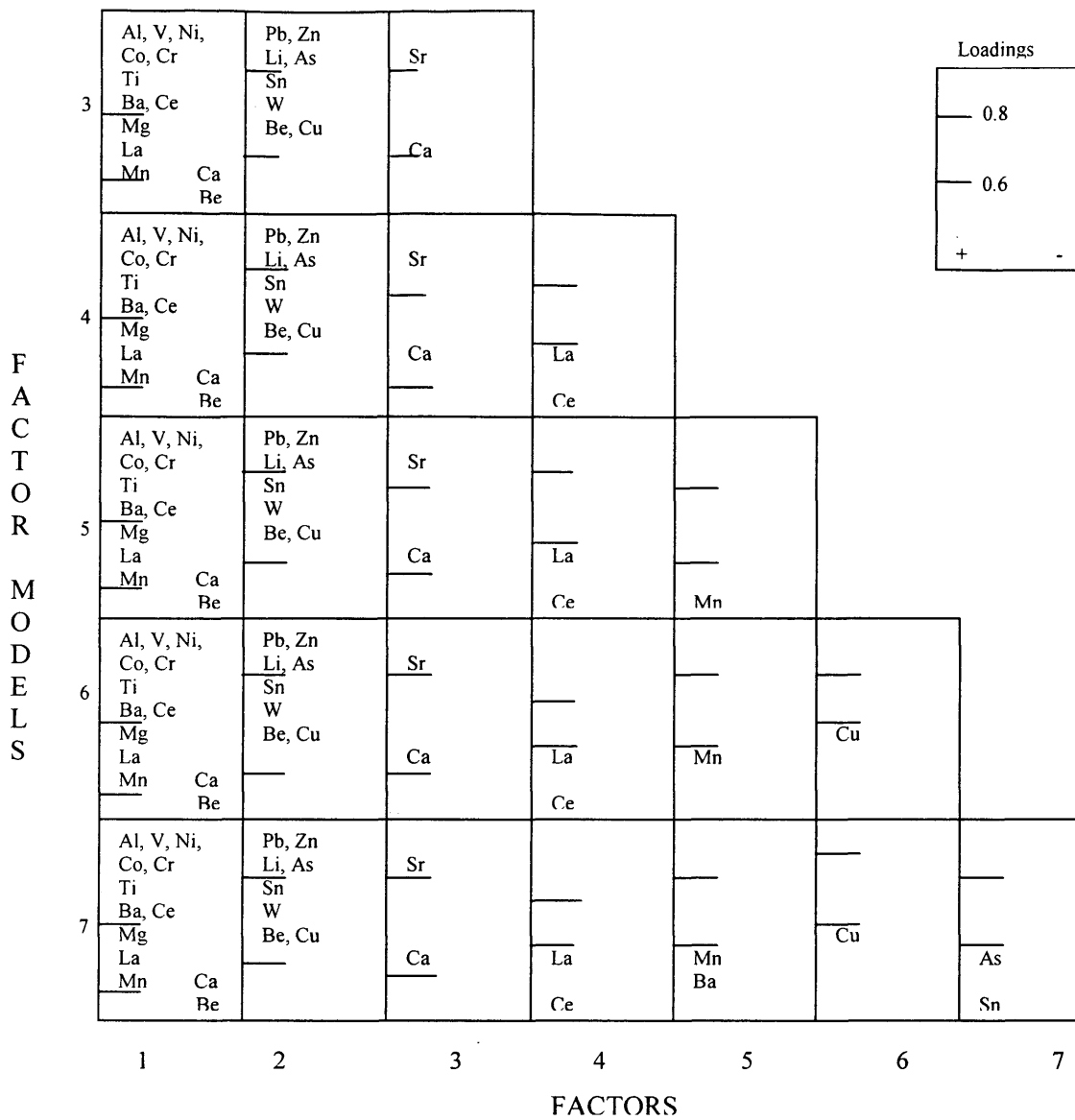


Figure 9. Element associations for the factor model 3 through factor model 7 for the stream sediment geochemical data

Table 6A. Communalities for factor analysis, minus 80-mesh stream-sediment data

Proportion of the variance explained by the 4 factor model

	From 1 Factor	From 2 Factors	From 3 Factors	From 4 Factors	Multiple R-Square
Al %	0.95	0.95	0.96	0.96	0.99
Ca %	0.73	0.73	0.96	0.97	0.98
Fe %	0.96	0.97	0.97	0.97	0.98
Mg %	0.86	0.86	0.87	0.89	0.95
Ti %	0.90	0.90	0.94	0.94	0.97
Mn ppm	0.55	0.70	0.72	0.73	0.87
As ppm	0.01	0.72	0.79	0.84	0.88
Ba ppm	0.58	0.59	0.88	0.89	0.98
Be ppm	0.41	0.87	0.88	0.88	0.92
Ce ppm	0.78	0.79	0.80	0.98	1.00
Co ppm	0.92	0.92	0.93	0.94	0.98
Cu ppm	0.14	0.67	0.84	0.85	0.90
Cr ppm	0.93	0.94	0.94	0.94	0.99
La ppm	0.69	0.71	0.72	0.98	1.00
Li ppm	0.12	0.91	0.91	0.91	0.97
Ni ppm	0.89	0.90	0.94	0.94	0.99
Pb ppm	0.00	0.88	0.90	0.90	0.93
Sn ppm	0.10	0.72	0.83	0.84	0.90
Sr ppm	0.44	0.45	0.88	0.92	0.96
V ppm	0.94	0.95	0.98	0.98	1.00
W ppm	0.33	0.86	0.86	0.87	0.89
Zn ppm	0.04	0.87	0.89	0.89	0.95

Table 6B. Eigenvalues and percent of variance explained by factor models 1-7.

Factor Model	Eigenvalue	% total Variance	Cumul. Eigenvalue	Cumul. %
1	12.26	55.74	12.26	55.74
2	5.59	25.40	17.85	81.14
3	1.52	6.92	19.37	88.06
4	0.62	2.81	19.99	90.87
5	0.47	2.15	20.46	93.02
6	0.34	1.53	20.80	94.54
7	0.27	1.25	21.07	95.79

5.5 Discussion of the 4 factor model

Factors 1 and 3 reflect geochemical signatures of the dominant lithologies in the study area. Factor 1 has high positive loadings for Al, Fe, Ti, Mn, Ba, Ce, Co, Cu, Cr, La, Ni, and V and low negative loadings for Mg, Ca and Sr, indicative of the geochemical signature of the slates. Factor 3 has significant negative loadings for Sr, Ca, and Mg indicative of the geochemical signature for the carbonates. Factor 1 also has a low negative loading for Be, but this is due to the high Be concentrations for many of the samples collected in the Lost River drainage, which is underlain by carbonate rocks.

Maps of the factor scores (Figs. 10A and B) support these interpretations. Sites with positive scores for factor 1 (Fig. 10A) were collected from drainages in the slate dominated lithology. In the Potato Mountain drainage basin there are several sites (1, 2, 4, 26, 27, 28, 114 and 117, and 118) whose factor scores are indicative of interbedded carbonates. The factor score map for factor 3 clearly defines the carbonate lithology (Fig. 10B). Exceptions to this were sites 16 and 214 where low Sr concentrations in the stream sediments caused positive scores for factor 3, but Ca concentrations of 21% in both samples obviously define a carbonate contribution to the sediment. Many of the sites east of the Mint River have mixed signatures for factors 1 and 3 indicating that the sediments are reflecting sediment contributions from both lithologies occurrences in the region.

All of the samples collected from Lost River below the Factor 2 has high positive loadings for As, Be, Cu, Li, Pb, Sn, W, and Zn. This suite of elements defines the

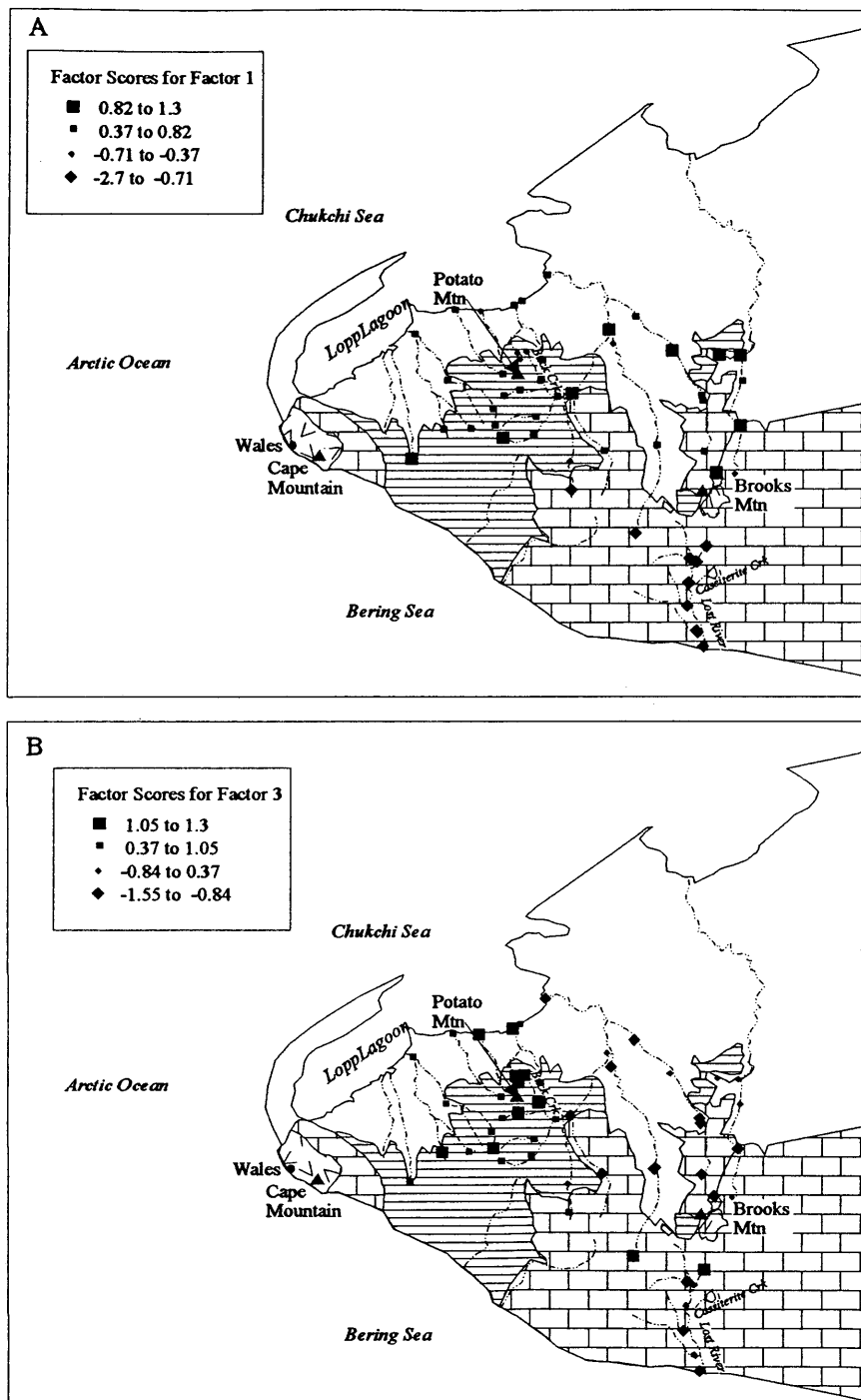


Figure 10. Factor scores for A) factor 1 (positive for Al, Al, Fe, Ti, Mn, Ba, Ce, Co, Cu, Cr, La, Ni, and V and negative for Mg, Ca, Sr) and B) factor 3 (negative for Sr, Ca, Mg)

geochemical signature of stream sediments derived from the tin mine (Fig. 11) had high positive scores for factor 2. Although Be is not part of the geochemical suite characterizing the tin occurrences in the Potato Mountain region, the strength of the correlation between As, Cu, Li, Pb, Sn, W and Zn delineated four locations with high positive scores (>0.4) for factor 2 in the area of known tin occurrences (Fig. 11). Many locations distal to the known tin occurrences at Potato Mountain had positive scores for factor 2. Sites 4, 24, 25, and 113 contained anomalous As and/or Sn in the stream sediments, possibly reflecting small unknown tin occurrences west of Potato Mountain. Site 103, collected from the drainage northeast of Brooks Mountain, had a high score for factor 2 reflecting sediments derived from the exposed granite at Brooks Mountain. Sites 107 and 108, located downstream from site 103, also had positive scores for factor 2, indicative of downstream dispersion from the Brooks Mountain tin occurrence. Other samples with positive scores for factor 2 were collected from a small tributary of York Creek (sites 109 and 110). Although neither sample contained measurable Sn in the stream sediment data, both samples contained greater than 2000 ppm Sn and detectable W (150 ppm) in the heavy mineral concentrate portion of the sample.

Factor four had positive loadings for Ce and La, probably reflecting detrital monazite. This is further supported by the high La concentrations (>2000 ppm) in the heavy mineral concentrates at those sites that had high scores for factor 4. The factor score map (Fig. 12) for factor 4 indicates that monazite is more prevalent in Potato Mountain occurrences than at Lost River.

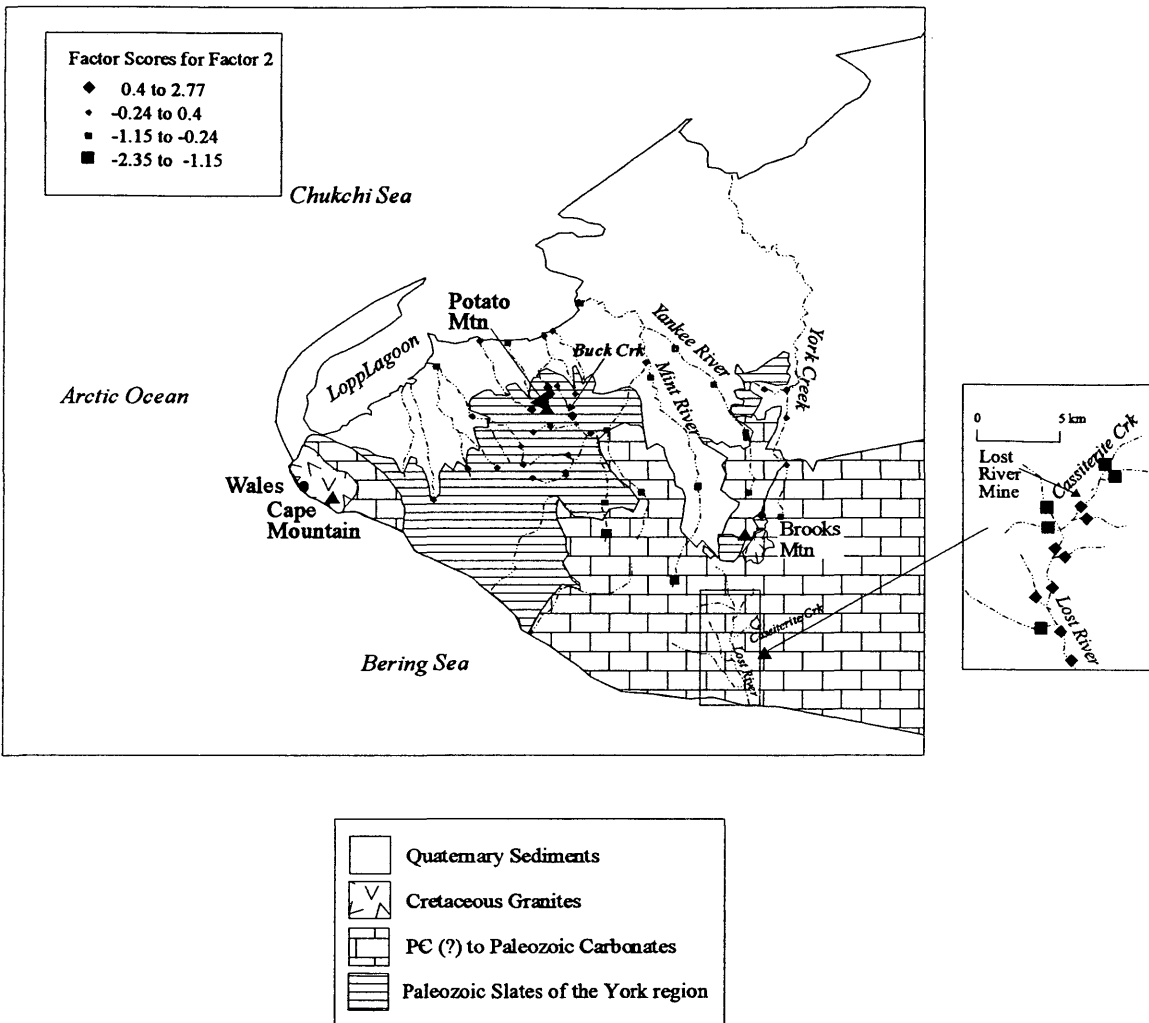


Figure 11. Factor score map for factor 2 (positive loadings for As, Be, Cu, Li, Pb, Sn, W and Zn), for 4 factor model

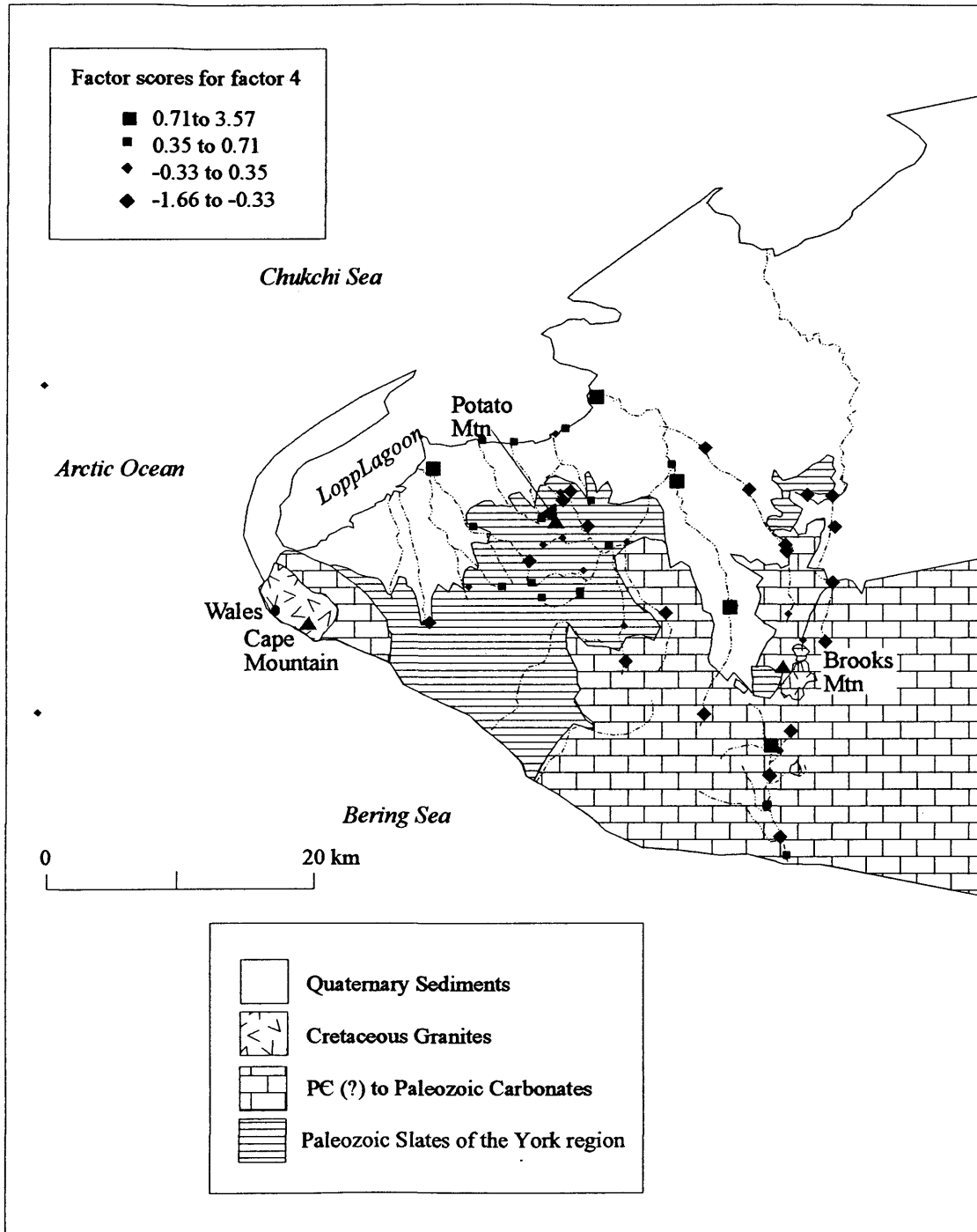


Figure 12. Factor score map for factor 4 (positive loadings Ce and La)

5.6 Geochemistry and mineralogy of heavy mineral concentrate samples

Basic statistics for the heavy mineral concentrates are listed in table 7. Eight of the fourteen samples collected in the drainages of the Potato Mountain area (Fig. 2) contained greater than 2,000 ppm Sn. Three of these samples (sites 4, 116, and 117) contained significant amounts of As (500 ppm), B (1,000-2,000 ppm), Bi (20-2,000 ppm), and Be (2-5 ppm), but similar concentrations of Cu (15-50 ppm), Ni (20-100 ppm), and Pb (20-100 ppm) when compared to the stream sediments. Two of the samples also contained 200-300 ppm W.

The samples that were collected in the eastern portion of the study area, which is underlain by carbonate rocks, and typically had barium concentrations of 3,000 to greater than 10,000 ppm. This is supportive of the presence of detrital barite. But, in addition, the sample collected from the stream northeast of Brooks Mountain (site 103; Fig. 2) contained 500 ppm As and 200 ppm Sn. The two samples from a tributary of York Creek (sites 109 and 110; Fig. 2) contained greater than 2,000 ppm Sn and detectable W (150 ppm). These data are in agreement with the sediment data, and support the existence of exposed tin-bearing occurrences in these drainage basins.

Concentrate samples with anomalous Sn and As values were microscopically examined for identification of associated mineral phases. Because of the highly weathered nature of the grains, it was not possible to optically determine if the dominant sulfide in the concentrates was pyrite or arsenopyrite. Emission spectrographic analyses

Table 7. Basic statistics for 29 heavy mineral concentrate samples collected from the western Seward Peninsula.

[All concentrations in ppm unless otherwise noted; detection ratio is the number of samples with unqualified values divided by the total number of samples; N, number of samples detected at lower detection limit; L, number of samples qualified with "N" (not detected at lower detection limit); L, number of samples qualified with "L" (less than lower detection limit); G, number of samples qualified with "G" (greater than detection limit); geometric mean calculated using all data—values with "N" were set equal to 0.5 times the lower detection limit, values of L were set equal to 0.7 times the lower detection limit, and values of G were set to 1.3 times the upper detection limit]

Element	Detection Ratio	N	L	G	Geometric Mean	Geometric Deviation	Median	Minimum	Maximum	85th Percentile	90th Percentile
Ca %	1	0	0	0	2.39	0.65	2	.1	15	10	10
Fe %	1	0	0	0	0.94	0.30	0	.2	5	2	2
Mg %	1	0	0	0	0.78	0.46	1	.07	7	2	2
P %	.72	3	5	0	0.91	0.34	1	.7	3	2	2
Ti %	.76	0	0	7	0.90	0.45	1	.03	2.6	2.6	2.6
B	.97	1	0	0	295	0.11	700	20	2000	1500	2000
Ba	.97	0	0	1	705	0.72	500	50	13000	5000	7000
Co	.69	2	8	0	21	0.67	20	20	70	30	50
Cr	.93	0	2	0	48	0.21	50	20	200	100	100
Cu	.93	0	2	0	20	0.27	15	15	100	50	50
Ga	.59	5	7	0	9	0.29	10	10	20	15	15
La	.55	2	4	7	357	0.17	200	100	2600	2600	2600
Mn	1	0	0	0	325	0.65	500	50	700	500	700
Ni	.72	2	6	0	22	0.29	20	15	150	70	100
Pb	.45	2	14	0	21	0.35	14	20	100	50	50
Sc	.83	1	4	0	16	0.27	15	10	100	30	50
Sn	.66			10	471	0.77	1000	20	2600	2600	2600
Sr	.83	3	2	0	480	0.33	500	300	1000	1000	1000
V	.97	0	1	0	69	0.20	70	50	200	100	100
Y	.97	0	1	0	61	0.24	70	30	100	100	100
Zr	1	0	0	0	359	0.40	300	50	2000	1000	1500

of the sulfide grains indicate that the samples contained concentrations of greater than 20,000 ppm As. This strongly suggests that arsenopyrite is the dominant sulfide mineral. Metal-rich samples collected at sites in the Potato Mountain area and from streams northeast of Brooks Mountain contained cassiterite, pyrite, monazite, zircon, titanite, tourmaline, and rutile, in addition to arsenopyrite. Two of the samples also contained minor amounts of scheelite. Two samples (109 and 110; Fig 2.) collected in a tributary of the York River contained cassiterite, monazite, rutile, tourmaline, sphene and some pyrite/arsenopyrite.

The samples that were collected in the eastern part of the study area, in the drainages underlain by argillaceous and dolomitic limestone, contained appreciable amounts of barite and zircon, and fragments of limestone and dolomite. One sample (site 012; Fig. 2) collected in the upper reaches of Skookum Creek, at the contact between the slates and the carbonates, contained 2000 ppm Mo which may indicate an upstream molybdenite-bearing occurrence.

5.7 Geochemistry of water samples

Water samples were collected at 62 sites. Table 8 lists the basic summary statistics for the water samples collected during this study. The sample collected from a seep from a tailings pile at the Lost River mine (site 32; Fig. 2) was excluded from the

Table 8. Basic statistics for selected elements for filtered water samples

[Detection ratio is the number of samples with unqualified values divided by the total number of samples; N, total number of samples; B, number of samples below detection limit, qualified with "B" (not detected at lower detection limit); L, number of samples detected at lower limit of detection, qualified with "L" (less than lower detection limit); geometric mean calculated using all data—values with "B" were set equal to 0.5 times the lower detection limit, values of L were set equal to 0.7 times the lower detection limit]

	N	B	L	Detection Ratio	Mean	Standard deviation	Geometric mean	MEDIAN	MIN	MAX	25th percentile	75th percentile	85th percentile	90th percentile	95th percentile
Al ppb	61	0	19	0.69	31.67	148.0	0.659	2.1	0.007	1100	0.007	3.3	4.60	6.7	100.00
Ca ppm	61	0	0	1.00	22.58	14.7	18.651	19	1.8	84	13	27	34	38	48
Fe ppb	61	0	1	0.98	38.44	34.0	28.579	26	7	160	15	48	59	85	110
K ppb	61	0	0	1.00	272.21	158.8	225.606	240	48	830	170	340	420	490	560
Mg ppm	61	0	0	1.00	5.96	4.0	4.583	5.00	0.3	19	2.9	8.30	10	11	13
Mn ppb	61	0	13	0.79	27.51	42.6	1.400	0.74	0.01	120	0.08	47	100	100	100
Na ppm	61	0	0	1.00	2.68	1.5	2.217	2.40	0.6	5.90	1.2	3.8	4.30	4.50	5.6
P ppb	61	0	20	0.67	8.31	10.1	3.493	4	0.7	39	0.7	14	22	26	28
SiO2 ppm	61	0	11	0.82	1.99	1.8	1.357	1	0.35	9.60	0.6	3	3	4.00	5.2
Ag ppb	61	0	29	0.52	0.03	0.041	0.019	0.01	0.007	0.2	0.007	0.05	0.06	0.07	0.1
As ppb	61	0	22	0.64	0.84	1.7	0.294	0.14	0.14	8.9	0.14	0.4	1.8	2.40	4.3
Ba ppb	61	0	0	1.00	9.01	12.8	4.298	4	0.1	66	2	11	16	20	38
Co ppb	61	0	23	0.62	0.30	1.3	0.027	0.014	0.014	8.90	0.014	0.03	0.06	0.08	0.2
Li ppb	61	0	16	0.74	0.98	1.3	0.484	0.7	0.07	9	0.07	1.2	1.8	1.9	2.7
Mo ppb	61	0	14	0.77	0.14	0.2	0.064	0.04	0.014	0.51	0.02	0.2	0.4	0.4	0.47
Ni ppb	61	0	13	0.79	1.04	3.1	0.329	0.4	0.07	20	0.1	0.6	0.9	1	1.2
Sb ppb	61	0	23	0.62	0.08	0.1	0.040	0.03	0.014	0.74	0.014	0.1	0.2	0.2	0.3
Se ppb	61	0	34	0.44	0.20	0.1	0.147	0.14	0.035	0.6	0.14	0.3	0.3	0.3	0.4
Sr ppb	61	0	0	1.00	91.50	67.2	69.950	65	9.20	320	44	120	160	170	230
U ppb	61	0	12	0.80	0.41	1.0	0.058	0.06	0.004	5.80	0.01	0.37	0.89	1.2	1.6
Zn ppb	61	0	40	0.34	1.00	1.7	0.581	0.35	0.35	10	0.35	1	1	2	2
Alk. ppm	61	0	0	1.00	73.42	51.1	50.654	68.41	1.025	259.70	37.99	100.1	110.9	147.6	156.00
F ppm	60	1	0	1.00	0.12	0.1	--	0.0745	0	0.537	0.0515	0.1245	0.1935	0.385	0.5
SO4 ppm	61	0	0	1.00	22.59	22.6	10.745	17	0.5	100	2	36	43	52	58

tabulation because it would strongly skew the data. Field pH measurements (table 9) indicate that most surface waters are neutral to slightly alkaline, with values ranging from 7-8.2. Conductivity, also measured in the field, varied over an order of magnitude, ranging between 51 and 729 μ mhos/s (table 9). The lowest values reflect headwater seeps that have limited flowpaths and thus relatively little water/rock interaction (sites 02, 08, and 103). Analytical results for filtered water samples (Appendix B) indicate a consistent pattern of $\text{Ca} \gg \text{Mg} > \text{Na} > \text{K}$ in both the areas underlain by the slate and the carbonate units of the York terrane. There are no appreciable differences in dissolved calcium and magnesium levels, regardless of whether the samples were collected in streams underlain by slate or limestone. This is indicative of interbedded carbonates within the slates of the York terrane contributing significant amounts of Ca to dissolved loads. This is further supported by the variation of bicarbonate in the area underlain by slate (Fig. 13A). Dissolved sulfate levels for waters collected in streams underlain by slates are typically in the range of 20-30 ppm, and waters collected in the areas underlain by carbonates have sulfate concentrations < 20 ppm (Fig. 13B). Most trace metals were below analytical determination limits for all of the water samples collected, except for the sample collected from the tailings pile at Lost River mine.

Table 9. Field measurements for water samples

FieldNo	pH	Conductivity	FieldNo	pH	Conductivity
1	4.9	145	100	6.7	322
2	5.7	56	101	7.5	243
3	6.1	132	102	7.4	142
4	7.3	282	103	8.7	51
5	6.5	216	104	8.4	165
6	7.0	323	105	8.1	106
7	6.9	258	106	7.5	416
8	6.5	82	107	9.0	321
9	7.0	270	108	7.9	496
10	7.0	137	109	7.5	729
11	7.4	265	110	7.6	635
12	8.2	241	111	7.8	447
13	7.2	277	112	7.3	335
14	8.1	364	113	7.7	190
15	8.0	206	114	7.6	159
16	8.1	165	115	7.4	173
17	8.4	108	116	7.3	234
18	8.2	246	117	4.7	165
19	8.1	260	118	8.0	160
20	8.2	341	214	8.3	129
21	8.0	386	215	8.2	181
22	8.3	257	216	8.3	132
23	7.5	172	217	8.0	138
24	7.9	388	218	8.3	147
25	7.6	231	219	7.8	144
26	7.2	450	220	8.2	132
27	5.5	99	221	8.0	147
28	6.7	145	222	8.2	163
32	8.3	163	223	8.1	167
33	8.0	167	224	8.0	174
			225	8.1	135
			226	8.2	171

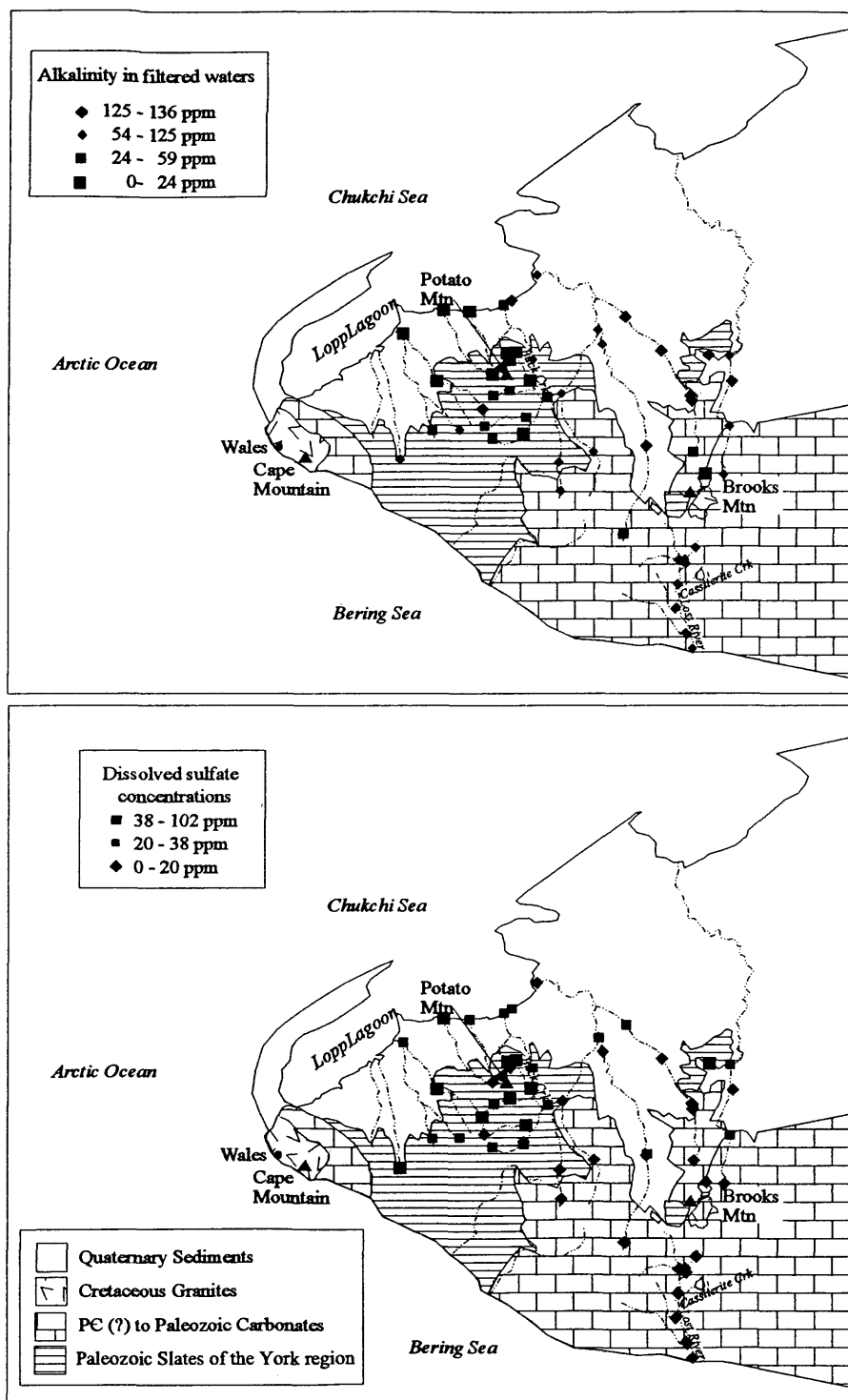


Figure 13. Alkalinity and sulfate concentrations (ppm) in filtered waters

Figure 14 shows the compositions, in terms of sulfate, alkalinity, and iron concentrations of surface waters collected from Potato Mountain and Lost River drainages. Waters collected below the Lost River deposit have little variation in composition, whereas those waters collected from the Potato Mountain area are more variable. Previous work (Mulligan, 1965, Sainsbury, 1969, and Dobson, 1982) indicates that mineralization at the Lost River deposit is more sulfide rich than the Potato Mountain occurrences. But the low concentrations of sulfate and dissolved metals in downstream surface waters along Lost River indicate minimal oxidation of these accessory sulfide minerals and buffering due to the carbonate host rock. Greater variability in the alkalinity and sulfate concentrations in waters from the Potato Mountain area partly reflects the oxidation of diagenetic pyrite within the slates and variable amounts of carbonate units interbedded in the slates.

Most of the water samples collected in the drainages surrounding Potato Mountain contained background concentrations of all metals including the same metals that were anomalous in sediments collected from these sites. However, waters at sites 4-7 and 116-117 (Fig. 2) showed enrichments in As (0.2-0.7 ppb) and Sb (0.2-0.3 ppb) concentrations, both of which are indicator elements for tin deposits. Also, samples collected at sites 1 and 117 (Fig. 2), located just north of Potato Mountain were acidic, (pH 4.85 and 4.73, respectively), and had relatively high concentrations of dissolved Al (1,100 and 360 ppb), Cu (2 and 6 ppb), Mn (120 and 71 ppb), and Ni (20 and 12 ppb). Sites 1 and 117 had very low alkalinity (3.3 and 1.0 ppm) relative to the other samples collected near Potato

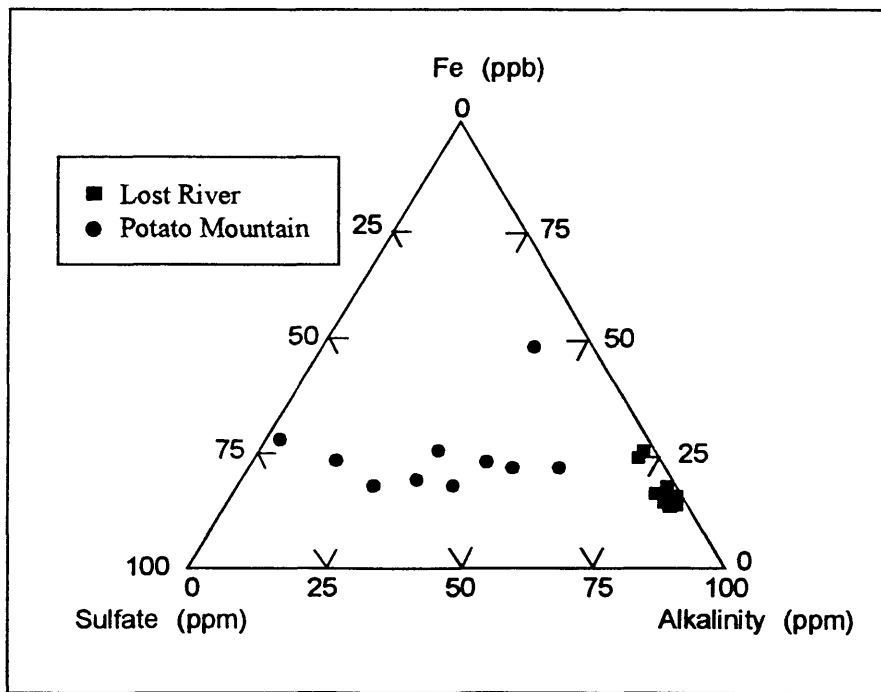


Figure 14. Ternary diagram of Fe, Alkalinity and SO_4 in filtered water samples from River and Potato Mountain.

Mountain, signifying a decrease in the buffering ability of the water. This may be due to weathering of sulfides, which would decrease the pH, but there was no significant increase in dissolved Fe, although sample 117 did have measurable As (0.7 ppb).

Dissolved sulfate concentrations ranged between 40-75 ppm in the waters collected from areas of known tin occurrences, indicating that increased sulfate concentrations may be the best hydrogeochemical indicators of the Potato Mountain tin-bearing occurrences.

The pH of the waters collected in the Lost River drainage basin were alkaline (7.8-8.3) due to the buffering capability of the carbonate host rock, and sulfate concentrations were much lower (2-5.2 ppm) when compared to the waters collected from the Potato Mountain tin occurrences. Water samples collected from the Lost River drainage basin had significant increases in dissolved As (1.5-8.9 ppb) when compared to waters collected in the Potato Mountain area, but other metals related to the tin occurrences (Be, Cu, Li, Pb, Sn, W, and Zn) remained at or below the detection level. The exception to this was the filtered water sample collected from a seep at the base of the main tailings pile (site 33; Fig. 2), which contained 180 ppb As, 0.09 ppb Cd, 0.7 ppb Cu, 8.9 ppb Mo, 1.5 ppb Sb, 0.4 ppb W and 10 ppb Zn. These concentrations are quickly diluted a few meters downstream (sites 32 and 217; Fig. 2). Increased As concentrations may be indicative of a more sulfide-rich style of mineralization at Lost River.

Chapter 6. SUMMARY and CONCLUSIONS

6.1 Summary

The geochemical survey of surficial materials proved helpful in defining the locations of known and possible favorable locations for previously unrecognized tin occurrences in the western Seward Peninsula. Minus-80 mesh stream sediment data collected from areas of known tin occurrences indicated that As, Cu, Li, Sb, Sn, W and Zn define the geochemical suite of elements associated with tin mineralization at Potato Mountain. The host rocks at Potato Mountain are slates interbedded with carbonates. This is indicated by higher Al and Fe concentrations in the stream sediments as compared to sediments collected in areas underlain by carbonates which host the tin occurrences in the Lost River area. The interbedded carbonates are recognized by Ca concentrations which locally are comparable to Ca concentrations in stream sediments collected in areas underlain by carbonates in the study area. Stream sediments collected distal from any known tin occurrences at Potato Mountain indicated that the suite of elements which define the tin mineralization are elevated relative to the average concentrations in slates globally, possibly reflecting a hydrothermal enrichment associated with mineralization. Higher Fe concentrations in stream sediments underlain by slates in the study area

relative to concentrations in sediments collected in areas underlain by carbonates or in areas of known tin occurrences are attributed to diagenetic pyrite.

The same suite of elements (As, Cu, Li, Sb, Sn, W and Zn) in addition to Be define the tin occurrences at Lost River. Mineralization at Lost River has previously been described as being more sulfide-rich than the mineralization at Potato Mountain. This is further supported by higher concentrations of As, Cu, and Zn in the stream sediments in the drainages of the Lost River occurrences as compared to Potato Mountain. Elevated Fe concentrations are noticeably absent in the stream sediments collected in the Lost River region indicating that pyrite is not a dominant sulfide mineral in these deposits. Stream sediments collected in areas underlain by carbonates distal to the mineralization at Lost River were characterized by high Ca and Sr concentrations.

The minus-80 mesh stream sediment data interpretations are further supported by the heavy mineral concentrate data collected in the same drainages. Many of these samples contained As and Sn concentrations which were not recognized as anomalous in the minus-80-mesh stream sediment data. This is attributed to the resistate nature of cassiterite and arsenopyrite, minerals associated with the tin occurrences throughout the Seward Peninsula.

Surface waters collected from both the areas underlain by the slates and the carbonates were neutral to slightly alkaline and contained low levels of metals. The surface waters collected from the Lost River consistently contained higher concentrations of As compared to the waters collected in the Potato Mountain region possibly indicating

a more sulfide rich style of mineralization. Higher sulfate and iron concentrations in the surface water of streams underlain by the slates compared to those underlain by carbonates were interpreted to indicate the oxidation of diagenetic pyrite.

Analysis of geochemical data has become increasingly more complex due to the availability of large multi-element data sets. For this reason, computer aided analyses and graphical display of the data has become indispensable for interpretation. Basic statistical analysis of the data (means, averages and percentiles) indicated abnormally high threshold values for the geochemical suite of elements that characterize the tin deposits. This is due in part to the large number of samples collected in areas of known historic mining, but also to the resistate nature of the minerals associated with the tin deposits (arsenopyrite, beryl, cassiterite, scheelite and wolframite). Comparing the regional data collected during the NURE survey with data collected during the present study helped define local background from anomalous concentrations of elements that characterize the tin deposits.

Spatial distribution of data has long been used in identifying geochemical anomalies and patterns. For this study, combining factor analysis with spatial distribution maps proved very effective in the interpretation of the stream sediment data collected. The factor analysis reduced the data set into recognizable geochemical signatures. Computer generated maps of the factor scores aided in interpretation by quickly compiling the data so different models could be evaluated.

Interpretation of the data was facilitated by the recognition of the geochemical signatures for tin mineralization and major lithologies. This was especially useful in the identification of tin occurrences hosted in the slates of the study area as the abnormally high background concentrations of As, Li, and W made the interpretation of the raw data ambiguous. Spatial distribution maps of the factor analysis also helped identify stream sediment dispersion from the Brooks Mountain occurrence that was not obvious from the data.

6.2 Conclusions

The data indicate significant downstream sediment transport of As, Be, Cu, Li, Pb, Sn, W, and Zn from tin lodes at Lost River and to a lesser extent from those at Potato Mountain. Arsenic concentrations of 260 ppm were found in stream sediments collected at the mouth of Lost River, which flows directly into the Bering Sea. The mouths of streams draining the Potato Mountain occurrences, which flow into the Lopp Lagoon, contained as much as 78 ppm As. This may suggest a significant source for detrital As in the Arctic Ocean. The data also show that solution transport of metals is negligible. The stream sediment and surface water data indicate that physical not chemical dispersion is the dominant mechanism for metal transport in the tin occurrences of the western Seward Peninsula.

This study proves the usefulness of geochemical mapping of surficial data in recognizing dispersion patterns from mineral occurrences. The data indicated a previously unrecognized, more extensive dispersion pattern from the tin occurrences in the Potato Mountain region. Surficial geochemistry is also useful in determining potential environmental concerns due to metal concentrations in areas of historic mining. Metal concentrations in the streams affected by historic mining activities at both Potato Mountain and the Lost River mine were similar to those in the streams unaffected by mining.

In addition, the geochemical survey of surficial materials in the western Seward Peninsula further supports the environmental model for skarn, greisen, replacement and vein tin deposits as proposed by Hammarstrom and others, 1995 and Elliot and others, 1995. The low sulfide mineral content of tin deposits and the low solubility of the ore related minerals (arsenopyrite, beryl, cassiterite, scheelite) contributes to low dissolved metal concentrations (Hammarstrom, et. al, 1995, Elliot, et. al, 1995). Furthermore, low metal values are due to the lack of acidic waters draining the tin deposits of the area, which would increase solution transport of metals. Acidic waters are unlikely in the western Seward Peninsula due to the natural buffering of waters by carbonate units of the York terrane.

6.3 Recommendations for future study

The present study indicates no potentially negative environmental impacts from historic mining operations in the western Seward Peninsula. Anomalous arsenic and tin levels in the stream sediments at the mouths of streams above Lopp Lagoon and at Lost River suggest that metals may be entering the marine environment, but their impact, if any, on marine organisms remains uncertain. Future study should concentrate on the possible dispersion of As and other metals related to tin deposits in the sediments of Lopp Lagoon and the near offshore environment at Lost River both which flow into the Arctic Ocean. Sampling of the vegetation to see if metals are being introduced into the diet of the native Alaskans who live in the area and are known to harvest plants from areas of known tin occurrences would discern if there are certain areas which should be avoided for plant harvesting.

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APPENDIX A

Laboratory Procedures

Stream sediment samples

Stream sediment samples were collected in the field and stored in HUBCO bags to air dry. In the laboratory, the samples were sieved, using an automatic sieve shaker, to obtain the minus 80-mesh fraction for chemical analysis. The samples were subsequently ground to fine powder to insure better dissolution in the acid.

For 40 element ICP-AES, approximately 0.2 grams of sample was placed in a teflon vessel, add 100 μL of Lu (Lutetium internal standard: Lu_2O_3) before adding 2 ml concentrated nitric acid (approximately 70% HNO_3 and 30% H_2O), 3 mL of concentrated hydrochloric acid (approximately 37% HCL and 63% H_2O) and 2mL HF. The solution is then warmed on a hot plate. The solution is then re-dissolved in 1 mL of aqua regia and 9 mL of 1% HNO_3 , and reheated for 1 hour at 95° C. The solution is cooled and then analyzed by a Perkin Elmer ICP-AES.

For 10 element ICP-AES, approximately 1.5 grams of sample was placed in a 50 ml Pyrex beaker before adding 5 mL concentrated hydrochloric acid (approximately 37% HCL and 63% H_2O) followed by 1 mL H_2O_2 . The solution is then placed in a boiling water bath for 20 min. After the solution is cool, add 5 mL C_6HO_6 -KI solution, let stand 20 minutes, then add 3 mL of 10% Aliquat 336-DIBK solution¹. The solution is then centrifuged to separate the organic layer from the acid layer, and analyzed by the Applied Research Laboratories Model 3580 ICP spectrometer.

¹ Aliquat 336, tripropylmethyammonium chloride

Heavy-mineral concentrates

The heavy-mineral concentrates were panned in the field and stored in HUBCO bags to air dry. In the laboratory, the samples were passed through a 30-mesh sieve, and the coarse fraction was archived in cardboard cartons. The minus 30-mesh fraction was processed through bromoform (specific gravity 2.85-2.89) in separatory funnels to eliminate light minerals such as quartz and feldspar. The heavy fraction was processed through a modified Franz Isodynamic Separator to obtain three fractions: (1) magnetic at 0.25 amperes, including magnetite and ilmenite, (2) magnetic at 1.2 amperes, including most of the heavy rock forming minerals such as hornblendes and pyroxenes, and (3) nonmagnetic at 1.2 amperes, including the heavy accessory minerals, sulfides and oxides. The nonmagnetic fraction was split in half; half being retained for mineralogical examination and half was ground by hand using an agate mortar and pestle to about minus 200-mesh. The ground portion was analyzed by emission spectrography for 32 elements.

Filtered water samples

The water samples collected for cation analysis by ICP-MS were filtered with a 0.45 μm filter and acidified in the field to approximately a pH of 2 by adding 3-5 drops of ultra-pure nitric acid (>70% HNO_3). The water samples collected for anion and alkalinity analysis were also filtered in the field with a 0.45 μm filter. All water samples were refrigerated until analysis.

Samples analyzed by IC which had sulfate or nitrate concentrations greater than 50 ppm were diluted approximately 1 to 5 for more accurate analytical results. The samples were analyzed by chemically suppressed IC method.

For alkalinity titration exactly 50 ml of samples was measured into a 100 ml container and the sample was then titrated to just below a pH of 4.5. The automatic titrator software then calculates the excess titrant and the endpoint volume of acid added.

APPENDIX B

Data Reliability Program

Table B 1. Approximate lower limits of detection for stream sediment 40 and 10 element inductively coupled plasma atomic emission spectroscopy (ICP-AES), and heavy mineral concentrate emission spectroscopy data (ES). (-- indicates element not determined)

ELEMENT	ICP-AES		ES
	40	10	
Al %	0.005	--	--
Ca %	0.005	--	0.1
Fe %	0.005	--	0.1
K %	0.005	--	--
Mg %	0.005	--	0.05
Na %	0.005	--	--
P %	0.005	--	0.5
Ti %	0.005	--	0.005
Mn ppm	4	--	10
Ag ppm	2	<0.08	1
As ppm	10	<1	500
Au ppm	8	<0.1	20
B ppm	--	--	20
Ba ppm	1	--	50
Be ppm	1	<1	2
Bi ppm	10	<0.1	50
Cd ppm	2	--	50
Ce ppm	5	--	--
Co ppm	2	<5	20
Cu ppm	2	--	10
Cr ppm	2	--	20
Eu ppm	2	--	--
Ga ppm	4	--	10
Ho ppm	4	--	--
La ppm	2	--	100
Li ppm	2	<0.2	--
Mo ppm	2	--	10
Nb ppm	4	--	50
Nd ppm	9	--	10
Ni ppm	3	<5	20
Pb ppm	4	<1	200
Sb ppm	--	--	--
Sc ppm	2	--	10
Sn ppm	5	--	20
Sr ppm	2	--	200
Ta ppm	40	--	--
Th ppm	6	--	200
U ppm	100	--	--
V ppm	2	--	20
W ppm	2	--	50
Y ppm	2	--	20
Yb ppm	1	--	--
Zn ppm	2	<10	500
Zr ppm	--	--	20

Table B 2a. Detection limits and results of QA/QC for reference samples SAR-L and SAR-M for 40-element ICP-AES

Elem. Id. Det. Lim.	Al % 0.005	Ca % 0.005	Fe % 0.005	K % 0.005	Mg % 0.005	Na % 0.005	P % 0.005	Ti % 0.005	Mn ppm 4	Ag ppm 2
SAR-L	5.75	1.042	2.61	3.02	0.518	1.415	0.085	0.261	2040	2
SAR-L	5.73	1.043	2.62	2.97	0.521	1.378	0.084	0.267	2050	<2
SAR-L	5.93	1.069	2.71	3.06	0.539	1.438	0.084	0.27	2120	2
Mean	5.8	1.1	2.6	3.0	0.5	1.4	0.1	0.3	2070	2.0
%RSD	2%	1%	2%	1%	2%	2%	1%	2%	2%	0%
Target Value	5.79	1.060	2.670	2.980	0.550	1.530	0.090	0.250	2094	2.56
SAR-M	5.97	0.55	3.02	2.96	0.451	1.098	0.074	0.307	5100	2
SAR-M	5.96	0.545	3.06	2.92	0.465	1.075	0.075	0.309	5170	2
Mean	6.0	0.5	3.0	2.9	0.5	1.1	0.1	0.3	5135	2.0
%RSD	0%	1%	1%	1%	2%	1%	1%	0%	1%	0%
Target Value	6.09	0.58	3.22	2.92	0.5	1.19	0.08	0.35	5200	3.1

Table B 2b. Results of QA/QC for 40-element ICP-AES stream sediment duplicate analysis

Sample ID	Al %	Ca %	Fe %	K %	Mg %	Na %	P %	Ti %	Mn ppm	Ag ppm
220-A	1.4	25	0.79	0.55	9.3	0.11	0.01	0.04	470	<2
220-B	1.3	22	0.77	0.52	9.6	0.12	0.01	0.04	480	<2
Mean	1.4	23.5	0.8	0.5	9.5	0.1	0.0	0.0	475.0	
S.D.	0.1	2.1	0.0	0.0	0.2	0.0	0.0	0.0	7.1	
C.V.	5.2	9.0	1.8	4.0	2.2	6.1	0.0	0.0	1.5	
2	7.7	0.79	5.6	1.5	1.7	0.52	0.12	0.48	644	<2
02 split	8.0	0.86	6.0	1.5	1.8	0.56	0.13	0.65	680	<2
Mean	7.9	0.8	5.8	1.5	1.8	0.5	0.1	0.6	662.0	
S.D.	0.2	0.0	0.3	0.0	0.1	0.0	0.0	0.1	25.5	
C.V.	2.7	6.0	4.9	0.0	4.0	5.2	5.7	21.3	3.8	

Elem. Id. Det. Lim.	As ppm 10	Au ppm 8	Ba ppm 1	Be ppm 1	Bi ppm 10	Cd ppm 2	Ce ppm 5	Co ppm 2	Cr ppm 2	Cu ppm 2
SAR-L	20	<8	872	2	<10	<2	164	7	103	389
SAR-L	22	<8	887	3	<10	<2	161	7	104	380
SAR-L	16	<8	910	4	<10	<2	159	7	107	370
Mean	19.3		890	3.0			161	7.0	105	380
%RSD	16%		2%	33%			2%	0%	2%	3%
Target Value	16.5	0.325	879	3.2	1.1	2.5	150	7.5	110	370
SAR-M	42	<8	759	1	<10	4	108	10	95	300
SAR-M	44	<8	782	2	<10	4	116	11	98	323
Mean	43.0		771	1.5		4.0	112	10.5	97	312
%RSD	3%		2%	47%		0%	5%	7%	2%	5%
Target Value	37	0.345	764	2.4	1.33	4.8	120	11	101	320

Sample ID	As ppm	Au ppm	Ba ppm	Be ppm	Bi ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm
220	47	<8	65	20	<10	<2	13	4	7	15
220 split	52	<8	70	14	<10	<2	12	3	6	16
Mean	49.5		67.5	17.0			12.5	3.5	6.5	15.5
S.D.	3.5		3.5	4.2			0.7	0.7	0.7	0.7
C.V.	7.1		5.2	25.0			5.7	20.2	10.9	4.6
Sample ID	AS PPM	AU PPM	BA PPM	BE PPM	BI PPM	CD PPM	CE PPM	CO PPM	CR PPM	CU PPM
2	506	<8	315	1	19	<2	49	17	95	42
02 split	490	<8	400	3	<10	<2	49	16	110	44
Mean	498.0		357.5	2.0			49.0	16.5	102.5	43.0
S.D.	11.3		60.1	1.4			0.0	0.7	10.6	1.4
C.V.	2.3		16.8	70.7			0.0	4.3	10.3	3.3

Elem. Id. Det. Lim.	Eu ppm 2	Ga ppm 4	Ho ppm 4	La ppm 2	Li ppm 2	Mo ppm 2	Nb ppm 4	Nd ppm 9	Ni ppm 3	Pb ppm 4
SAR-L	2	21	<4	74	26	14	21	69	51	605
SAR-L	2	21	<4	70	26	14	22	63	52	600
SAR-L	2	21	<4	69	27	15	30	63	54	615
Mean	2.0	21		71	26	14	24	65	52	607
%RSD	0%	0%		4%	2%	4%	20%	5%	3%	1%
Target Value	1.5	17	1.9	75	28	13	35	66	52	578
SAR-M	<2	25	<4	52	25	14	23	47	40	1020
SAR-M	<2	26	<4	54	26	13	30	50	41	1030
Mean	!	26		53	26	14	27	49	41	1025
%RSD		3%		3%	3%	5%	19%	4%	2%	1%
Target Value	0.67	20	1.7	61	30	12	31	51	41	960

Sample ID	Eu ppm	Ga ppm	Ho ppm	La ppm	Li ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm
220-A	<2	<4	<4	8	57	<2	<4	7	9	85
220-B	<2	<4	<4	8	52	<2	<4	7	9	91
Mean				8.0	54.5			7.0	9.0	88.0
S.D.				0.0	3.5			0.0	0.0	4.2
C.V.				0.0	6.5			0.0	0.0	4.8
2	<2	<4	<4	23	94	<2	<4	26	46	29
02 split	<2	<4	<4	26	100	<2	<4	7	48	25
Mean				24.5	97.0				47.0	27.0
S.D.				2.1	4.2				1.4	2.8
C.V.				8.7	4.4				3.0	10.5

Elem. Id. Det. Lim.	Sc ppm 2	Sn ppm 5	Sr ppm 2	Ta ppm 40	Th ppm 6	U ppm 100	V ppm 2	Y ppm 2	Yb ppm 1	Zn ppm 2
SAR-L	7	<5	144	<40	19	<100	147	40	4	440
SAR-L	8	<5	143	<40	17	<100	148	39	4	441
SAR-L	8	<5	149	<40	21	<100	154	41	5	438
Mean	7.7		145		19		149.7	40.0	4.3	440
%RSD	8%		2%		11%		3%	3%	13%	0%
Target Value	7.8	6	158	2.8	19	5.2	140	44	4.6	420
SAR-M	7	<5	144	<40	15	<100	71	24	3	908
SAR-M	8	<5	141	<40	15	<100	75	25	3	918
Mean	7.5	<5	143		15		73.0	24.5	3.0	913
%RSD	9%		1%		0%		4%	3%	0%	1%
Target Value	8.3	9.4	156	1.3	18	2.6	66	33	3.2	888

Sample ID	Sn ppm 20	Th ppm 6	Sr ppm 220	Ta ppm 40	U ppm 100	V ppm 16	W ppm <20	Y ppm 9	Yb ppm 1	Zn ppm 220
220-A	19	10	210	<40	<100	15	<20	8	1	200
220-B	19.5	8.0	215.0			15.5		8.5	1.0	210.0
Mean	0.7	2.8	7.1			0.7		0.7	0.0	14.1
S.D.	3.6	35.4	3.3			4.6		8.3	0.0	6.7
C.V.	62	<6	105	<40	<100	128	<20	16	1	104
02 split	57	6	110	<40	<100	130	<20	15	1	100
Mean	59.5		107.5			129.0		15.5	1.0	102.0
S.D.	3.5		3.5			1.4		0.7	0.0	2.8
C.V.	5.9		3.3			1.1		4.6	0.0	2.8

Table B 3. Results of accuracy analysis for 10 element ICP-AES method for standards SAR-L and SAR-M

Elem. Id. Det. Lim.	Ag ppm 0.08	As ppm 1	Au ppm 0.1	Bi ppm 1	Cd ppm 0.05	Cu ppm 0.05	Mo ppm 0.1	Pb ppm 1	Sb ppm 1	Zn ppm 0.05
SAR-L	2.7	4	0.2	2	3	396	11.1	623	3	485
SAR-L	2.7	8	0.2	1	3	388	12.3	641	2	465
MEAN	2.7	6	0.2	1.5	3	392	11.7	632	2.5	475
%RSD	0%	47%	0%	47%	0%	1%	7%	2%	28%	3%
Target Value	2.56	16.5	0.325	1.1	2.5	370	13	578	3.2	420
SAR-M	3.4	13	0.6	2	5.7	250	11.9	1080	4	>500
SAR-M	3.3	19	0.3	2	5.6	237	12.1	1050	4	>500
MEAN	3.35	16	0.45	2	5.65	243.5	12	1065	4	>500
%RSD	2%	27%	47%	0%	1%	4%	1%	2%	0%	
Target Value	3.1	6.09	37	0.345	764	2.4	1.33	0.58	4.8	120

A)		(20)	(200)	(10)	(20)	(200)	(200)	(20)	(50)	(20)	(500)	(20)
D. L.	Sample #	Pb	Sb	Sc	Sn	Sr	Th	V	W	Y	Zn	Zr
	116	L	N	20	>2000*	300	N	100	150	70	N	500
		N	N	30	>2000*	500	N	70	200	70	N	500
	5	100	N	50	>2000*	L	L	50	L	70	N	500
		L	N	50	>2000*	200	N	70	70	100	N	700
B)												
	suggested value	50	N	20	N	N	N	50	N	20	L	70
	GXR-6	50	N	20	N	N	N	50	N	20	L	70
	GXR-6	50	N	20	L	N	N	50	N	20	L	100
	GXR-6	50	N	L	N	N	N	50	N	30	L	100

A)		(50)	(20)	(10)	(100)	(10)	(50)	(10)
D. L.	Sample #	Bi	Co	Cu	La	Mn	Nb	Ni
116		L	L	15	200	150	L	20
		20	L	20	200	150	L	10
5		N	50	50	2000	100	N	100
		N	30	50	2000	100	N	100
B)		(50)	(20)	(10)	(100)	(10)	(50)	(10)
suggested value		Cd	Cr	Ga	Mo	Nb	Ni	
GXR-6	L	N	20	50	N	500	N	30
GXR-6	L	N	20	50	N	500	N	30
GXR-6	N	N	20	30	N	700	N	50
GXR-6	L	N	20	30	N	700	L	50

Table B 4. Data reliability for heavy-mineral concentrate data, based on A) two duplicate analyses and B) three standard analysis. (D.L. is detection limit, N not detected, L detected but not quantifiable)

A)		(0.1)	(0.1)	(0.05)	(0.5)	(0.005)	(1)	(500)	(20)	(20)	(20)	(50)	(2)
D. L.	Sample #	Ca%	Fe%	Mg%	P%	Ti%	Ag	As	Au	B	Ba	Be	
	116	1.5	1.5	0.3	1	2	N	L	N	500	300	L	
		1.5	1	0.2	1.5	2	N	500		1000	300	2	
	5	0.15	2	0.3	0.5	0.5	L	N	N	700	200	L	
		L	2	0.3	0.5	0.7	N	N	N	1500	200	L	
B)													
	suggested value	L	2	0.5	N	N	0.3	L	L	N	30	700	
	GXR-6	L	2	0.5	N	N	0.3	L	L	N	30	700	
	GXR-6	L	2	0.7	L	N	0.5	L	L	N	20	700	
	GXR-6	L	3	0.7	L	L	0.5	L	L	N	30	700	

Table B 5. Lower detection limits for inductively coupled plasma-mass spectroscopy (ICP-MS), ion chromatograph (IC), and alkalinity by titration.

Element	Detection limit	Anion	Detection limit
Al ppb	< 0.01	Alkalinity ppm	<1
Ca ppm	<2	Cl ppm	<1
Fe ppb	<10	F ppm	<0.0001
K ppb	<20	SO ₄ ppm	<2
Mg ppm	< 0.2		
Mn ppb	< 0.04		
Na ppm	<0.5		
P ppb	< 1		
SiO ₂ ppm	< 0.5		
Ag ppb	<0.01		
As ppb	< 0.2		
Au ppb	< 0.01		
Ba ppb	<1		
Be ppb	< 0.05		
Cd ppb	< 0.02		
Ce ppb	< 0.01		
Co ppb	< 0.02		
Cr ppb	< 0.5		
Cu ppb	< 0.5		
Li ppb	< 0.1		
Mo ppb	< 0.02		
Ni ppb	< 0.1		
Pb ppb	< 0.05		
Sb ppb	< 0.02		
Se ppb	< 0.2		
Sn ppb	< 0.05		
Sr ppb	<5		
Ti ppb	< 0.1		
U ppb	< 0.005		
W ppb	< 0.02		
Zn ppb	< 0.5		

Table B6. Quality control data for ICP-MS method on filtered water samples

Field No	Al ppb	Ca ppm	Fe ppb	K ppb	Mg ppm	Na ppm	Ag ppb	As ppb	Au ppb	Ba ppb	Be ppb	Bi ppb	Cd ppb	Ce ppb	Co ppb
WRD-T133	130	7.2	41	980	5.8	30	12	29	<0.01	140	34	<0.01	22	0.4	20
MPV	52.1	7.0	31.4	1000	5.8	29.4	7.4	27.1		148	35		23		20
F-psuedosigma	8.1	0.3	6.7	90	0.2	1.2	0.9	3.3		9	2.2		2.1		1.5
WRD-T135	10	11	230	960	2.1	31	7.2	11	<0.01	68	55	<0.01	49	0.03	40
MPV	10.5	10.4	228	960	2.0	30.8	9.8	10		68	59		50.5		40
F-psuedosigma	6.8	0.6	11.0	9	0.09	1.20	1.05	1.1		4	2.6		3.2		2.60
WRD-T137	98	40	110	1300	10	23	9.1	0.4	<0.01	73	5.2	<0.01	7.0	0.05	0.2
MPV	31	38	71	1190	10	22	0.3	0.6		65	5.2		6.8		0.4
F-psuedosigma	7	2	9	130	1	1	1.5	1.0		5	0.5		0.5		0.5
KK021FA	1.1	38	53	270	11	3.2	0.01	<0.2	<0.01	28	<0.05	<0.01	<0.02	<0.01	0.02
KK021FA-D	1.4	38	56	270	11	3.2	<0.01	<0.2	<0.01	28	<0.05	<0.01	<0.02	<0.01	<0.02

Field No	Re ppb	Sb ppb	Sc ppb	Se ppb	Sn ppb	SO4 mg/	Sr ppb	Ti ppb	Tm ppb	U ppb	V ppb	W ppb	Zn ppb	Zr ppb	SiO ₂ ppm
WRD-T133	<0.02	14	0.4	21	1	14	120	0.4	<0.005	0.93	13	<0.02	54	0.3	11
MPV		14.4		21.4			123				13		53		10
F-psuedosigma		2.4		3.7			6				1.7		4.4		0.7
WRD-T135	<0.02	75	0.2	9.8	3	6.8	46	0.2	<0.005	0.30	54	0.04	48	0.2	4
MPV		76.3		10.0			46				52.8		48.2		4.3
F-psuedosigma		8.7		1.4			2.3				3.6		4.7		0.3
WRD-T137	<0.02	17	0.4	0.5	0.5	57	240	0.3	<0.005	13	14	<0.02	51	0.61	7.1
MPV		16		1.3			230				14		50		7.0
F-psuedosigma		3		1.4			14				2		4		0.6
KK021FA	0.02	0.02	0.5	<0.2	<0.05		160	<0.1	<0.005	1.3	<0.1	<0.02	<0.5	<0.05	2
KK021FA-D	0.03	0.02	0.6	<0.2	<0.05		160	<0.1	<0.005	1.3	<0.1	<0.02	0.6	<0.05	2

Field No	Cr ppb	Cs ppb	Cu ppb	In ppb	La ppb	Li ppb	Mn ppb	Mo ppb	Nb ppb	Nd ppb	Ni ppb	P ug/	Pb ppb	Rb ppb
WRD-T133	37	0.2	86	<0.01	0.3	48	120	51	<0.02	0.37	26	52	27	2.4
MPV	38		85.3			51	121	46			27.2		27.8	
F-psuedosigma	3.2		4.5			3.5	7	4.2			3.1		2.7	
WRD-T135	79	<0.01	62	0.01	0.02	68	420	62	<0.02	<0.01	66	170	100	0.68
MPV	79		62			73.70	423	63			65.6		103	
F-psuedosigma	5.5		4.2			5.2	20	5.1			5.0		7	
WRD-T137	20	0.02	2	<0.01	0.04	8.6	100	9.3	<0.02	<0.01	16	490	6.2	1.0
MPV	19		2			8.7	98	8.9			15		6.3	
F-psuedosigma	2		1			1.5	5	1.8			3		1.0	
KK021FA	<0.5	<0.01	<0.5	<0.01	<0.01	0.7	0.20	0.3	<0.02	<0.01	0.4	4	<0.05	0.2
KK021FA-D	<0.5	<0.01	<0.5	<0.01	<0.01	0.6	0.25	0.3	<0.02	<0.01	0.4	4	<0.05	0.2

Table B 7. Data from 40 element ICP-AES for minus 80-mesh stream sediments. All data are in ppm, except where noted. Samples without enough material for subsequent analysis are marked with (-). Limits of detection are listed in Table B 1.

Table B 7. 40 element ICP-AES stream sediment data

Sample ID	Al %	Ca %	Fe %	K %	Mg %	Na %	P %	Ti %	Mn ppm	Ag ppm	As ppm	Au ppm
1	6.2	0.61	2.2	0.66	0.62	0.3	0.1	0.3	530	<9	53	<40
2	7.7	0.79	5.6	1.5	1.7	0.52	0.12	0.48	644	<2	506	<8
3	8	0.25	6.1	2.2	1.2	1.1	0.13	0.47	803	<2	43	<8
4	7.2	0.33	5.3	2	1.5	0.81	0.1	0.4	828	<2	146	<8
5	7.9	0.2	5.7	2.5	1.1	0.4	0.1	0.41	949	<2	133	<8
6	8.6	0.23	5.8	2.4	0.67	0.53	0.12	0.54	882	<2	73	<8
7	7.9	0.25	5.4	2.3	1.2	0.65	0.1	0.46	744	<2	65	<8
8	8.4	0.29	5.9	2.3	1.3	0.94	0.12	0.54	737	<2	85	<8
9	7.8	0.33	5.4	2.2	1.2	0.86	0.1	0.39	852	<2	16	<8
10	1.7	22	1.2	0.54	>5	0.08	0.02	0.08	198	<2	<10	<8
11	5.2	12	3.2	1.6	3.4	0.44	0.04	0.15	434	<2	<10	<8
12	5.1	11	3.2	1.7	3.7	0.54	0.04	0.18	540	<2	10	<8
13	6.1	6.4	4.1	1.9	1.9	0.73	0.06	0.28	712	<2	11	<8
14	5.6	8.1	3.4	1.6	2.1	0.59	0.04	0.13	584	<2	15	<8
15	3.4	19	2.2	1.1	4	0.39	0.03	0.12	473	<2	18	<8
16	1.1	21	0.73	0.34	>5	0.05	0.01	0.05	175	<2	<10	<8
18	3.8	16	2.5	1.2	3	0.46	0.03	0.13	549	<2	11	<8
19	6.5	4.2	4.6	1.9	1.6	0.78	0.07	0.42	815	<2	35	<8
20	4.8	11	3	1.3	1.3	0.33	0.04	0.13	752	<2	<10	<8
21	4.3	10	3	1.2	0.95	0.4	0.05	0.16	962	<2	18	<8
22	5.4	7.1	3.8	1.5	1.8	0.7	0.06	0.32	678	<2	13	<8
23	7.3	0.37	5.6	2.1	1.1	0.65	0.07	0.55	975	<2	78	<8
24	6.6	0.68	5	1.7	1.2	0.83	0.09	0.95	1010	<2	63	<8
25	8.6	0.25	5.9	2.4	1.1	0.95	0.11	0.61	683	<2	33	<8

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	Al %	Ca %	Fe %	K %	Mg %	Na %	P %	Ti %	Mn ppm	Ag ppm	As ppm	Au ppm
26	7.8	0.44	4.4	2.1	0.92	0.84	0.07	0.47	554	<2	40	<8
27	5.7	0.51	4.1	1.5	0.99	0.78	0.06	0.49	489	<2	78	<8
28	7.3	0.27	4.6	2	1.2	0.75	0.06	0.49	526	<2	32	<8
32	5.5	13	3.5	1.8	4.3	0.28	0.06	0.13	2220	3	1430	<8
100	8.2	0.28	6.1	2.3	1.1	0.8	0.12	0.47	1740	<2	18	<8
101	7.1	0.61	6	1.8	1.2	0.85	0.07	0.64	1490	<2	10	<8
102	7	0.44	5.3	1.9	1.3	0.93	0.08	0.54	855	<2	27	<8
103	7.3	6.7	4.6	2.2	3.8	0.73	0.06	0.36	866	<2	99	<8
104	4.3	16	2.5	1.2	3.1	0.27	0.03	0.15	397	<2	58	<8
105	7.2	9.5	3.9	2.3	3	0.48	0.06	0.17	384	<2	<10	<8
106	4.9	11	3	1.4	1.4	0.3	0.05	0.15	720	<2	21	<8
107	6	5.3	3.6	1.9	2	0.38	0.07	0.21	565	<2	24	<8
108	5.9	3.1	3.9	1.7	1.2	0.44	0.07	0.26	773	<2	48	<8
109	6.1	1.1	5.5	1.9	1.2	0.46	0.1	0.3	3660	<2	51	<8
110	7.2	0.86	4.8	2.4	1.4	0.63	0.08	0.39	879	<2	72	<8
111	6	3.3	4.3	1.6	1	0.54	0.08	0.31	1010	<2	17	<8
112	7	0.47	6.9	2.1	0.83	0.62	0.11	0.52	1500	<2	25	<8
113	7	0.57	6.5	1.7	0.72	0.75	0.11	0.66	1180	<2	60	<8
114	7.6	0.18	5.1	2.2	0.8	0.94	0.09	0.44	586	<2	95	<8
115	7.8	0.25	5.7	2.1	1.1	0.93	0.11	0.5	825	<2	23	<8
116	8.3	0.49	5.8	2.1	1.8	0.96	0.12	0.61	985	<2	101	<8
117	6.8	0.3	5.9	1.8	1.4	0.62	0.1	0.53	615	<2	530	<8
118	6.8	0.28	4.9	1.8	0.94	0.86	0.1	0.51	615	<2	24	<8
214	0.78	21	0.66	0.19	14	0.05	0.02	0.04	150	<2	<10	<8

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	Al %	Ca %	Fe %	K %	Mg %	Na %	P %	Ti %	Mn ppm	Ag ppm	As ppm	Au ppm
215	0.98	29	0.70	0.23	12	0.06	0.02	0.06	160	<2	<10	<8
216	2.3	26	1.1	0.92	9.5	0.13	0.02	0.07	1100	<2	150	<8
217	1.2	31	0.95	0.27	10	0.08	0.01	0.05	430	<2	450	<8
218	1.2	27	0.95	0.34	9.2	0.13	0.02	0.06	210	<2	<10	<8
219	3.8	25	2.6	1.2	4.9	0.23	0.04	0.20	420	<2	<10	<8
220	1.4	25	0.79	0.55	9.3	0.11	0.01	0.04	470	<2	42	<8
221	1.7	28	1.1	0.45	8.2	0.13	0.02	0.07	460	<2	200	<8
222	1.7	25	1.3	0.50	7.5	0.12	0.01	0.05	530	<2	280	<8
223	4.2	22	2.5	1.4	3.3	0.19	0.04	0.17	510	<2	70	<8
224	2.3	24	1.5	0.59	6.8	0.13	0.01	0.05	630	<2	480	<8
225	1.4	30	1.9	0.48	5.6	0.09	0.02	0.08	250	<2	<10	<8
226	1.5	30	1.4	0.49	7.5	0.10	0.02	0.06	430	<2	260	<8
227	2.3	19	1.2	0.82	7.1	0.36	0.05	0.11	260	<2	<10	<8

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	Ba ppm	Be ppm	Bi ppm	Cd ppm	Ce ppm	Co ppm	Cu ppm	Cr ppm	Eu ppm	Ga ppm	Ho ppm
1	200	<4	<40	<9	68	20	130	120	<9	<20	<20
2	315	1	19	<2	49	17	42	95	2	22	<4
3	281	<1	<10	<2	91	27	27	118	3	24	<4
4	267	<1	<10	<2	96	26	24	104	3	24	<4
5	333	<1	<10	<2	82	30	29	133	3	26	<4
6	327	<1	<10	<2	89	21	26	140	3	20	<4
7	310	<1	<10	<2	121	23	23	124	3	21	<4
8	289	<1	<10	<2	110	22	26	123	3	24	<4
9	313	<1	<10	<2	82	24	21	123	3	23	<4
10	52	<1	<10	<2	10	4	6	21	<2	19	<4
11	214	<1	<10	<2	39	13	20	68	<2	21	<4
12	891	<1	<10	<2	41	16	30	62	<2	20	<4
13	816	<1	<10	<2	68	19	29	78	2	26	<4
14	938	<1	<10	<2	42	14	21	65	<2	22	<4
15	426	2	<10	<2	79	8	15	36	<2	21	<4
16	38	<1	<10	<2	7	3	3	13	<2	19	<4
18	495	1	<10	<2	87	9	15	40	<2	20	<4
19	518	<1	<10	<2	118	21	29	90	3	19	<4
20	629	<1	<10	<2	42	15	23	58	<2	17	<4
21	995	<1	<10	<2	53	16	22	55	<2	14	<4
22	506	<1	<10	<2	140	16	18	76	3	22	<4
23	399	<1	<10	<2	87	24	16	109	2	27	<4
24	1010	<1	<10	<2	62	30	42	110	2	22	5
25	316	<1	<10	<2	98	24	26	131	3	23	<4

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	Ba ppm	Be ppm	Bi ppm	Cd ppm	Ce ppm	Co ppm	Cu ppm	Cr ppm	Eu ppm	Ga ppm	Ho ppm
26	365	<1	<10	<2	58	18	20	125	2	23	<4
27	326	<1	<10	<2	77	6	9	90	<2	22	<4
28	353	<1	<10	<2	104	14	13	123	3	21	<4
32	191	129	106	21	20	7	285	37	<2	31	<4
100	328	<1	<10	<2	123	32	21	132	3	25	<4
101	270	<1	<10	<2	89	27	18	101	3	20	5
102	295	<1	<10	<2	116	21	19	108	3	23	<4
103	746	1	<10	<2	65	22	49	93	<2	29	<4
104	373	<1	<10	<2	29	10	20	56	<2	21	<4
105	676	<1	<10	<2	48	16	29	90	<2	26	<4
106	650	<1	<10	<2	45	15	24	59	<2	18	<4
107	2510	<1	<10	<2	50	16	41	78	<2	18	<4
108	1460	<1	<10	<2	56	19	27	79	<2	24	<4
109	2350	<1	<10	<2	70	26	27	82	<2	26	<4
110	1510	<1	<10	<2	97	23	40	93	2	22	<4
111	1620	<1	<10	<2	58	19	24	80	<2	15	<4
112	357	<1	<10	<2	89	28	15	103	3	21	<4
113	305	<1	<10	<2	84	24	17	98	3	19	<4
114	329	<1	<10	<2	99	21	23	115	2	18	<4
115	308	<1	<10	<2	111	25	23	110	4	21	<4
116	338	<1	12	<2	115	28	25	119	3	31	<4
117	316	2	11	<2	84	14	59	112	3	19	<4
118	288	<1	<10	<2	361	17	14	100	8	19	<4
214	30	<1	<10	<2	8	3	2	10	<2	<4	<4

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	Ba ppm	Be ppm	Bi ppm	Cd ppm	Ce ppm	Co ppm	Cu ppm	Cr ppm	Eu ppm	Ga ppm	Ho ppm
215	89	<1	<10	<2	10	4	6	11	<2	<4	<4
216	80	86	<10	<2	15	5	13	16	<2	<4	<4
217	60	12	<10	<2	18	4	30	10	<2	<4	<4
218	53	2	<10	<2	56	4	4	13	<2	<4	<4
219	180	1	<10	<2	27	11	15	46	<2	9	<4
220	65	20	<10	<2	13	4	15	7	<2	<4	<4
221	65	24	<10	<2	31	5	39	13	<2	<4	<4
222	74	26	<10	<2	16	5	79	10	<2	9	<4
223	190	45	<10	<2	27	12	19	55	<2	8	<4
224	93	32	<10	2	25	5	90	11	<2	8	<4
225	77	5	<10	<2	14	6	10	18	<2	<4	<4
226	75	15	<10	<2	38	6	51	13	<2	<4	<4
227	140	5	<10	<2	27	5	27	53	<2	<4	<4

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	La ppm	Li ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm	Sr ppm	Ta ppm
1	30	20	<9	<20	48	30	30		<20	42	<200
2	22	94	<2	6	26	46	29	15	62	105	<40
3	38	79	<2	8	47	62	32	19	8	65	<40
4	43	76	<2	4	49	67	26	16	13	69	<40
5	37	80	<2	7	39	75	31	19	7	58	<40
6	41	96	<2	13	45	56	31	20	9	76	<40
7	54	77	<2	12	59	58	27	18	8	63	<40
8	48	74	<2	7	56	57	29	21	8	53	<40
9	37	64	<2	7	38	56	28	18	5	68	<40
10	6	16	2	<4	<9	13	5	4	<5	199	<40
11	18	41	<2	<4	25	36	18	11	<5	218	<40
12	21	42	5	<4	24	44	19	11	<5	216	<40
13	32	48	3	<4	34	50	24	13	<5	209	<40
14	21	54	2	<4	21	48	20	10	<5	278	<40
15	42	40	3	<4	30	24	20	7	9	302	<40
16	4	9	<2	<4	<9	8	4	3	<5	98	<40
18	42	37	<2	<4	31	28	18	7	23	337	<40
19	54	56	<2	5	59	53	25	15	6	147	<40
20	19	36	2	<4	19	42	17	10	<5	362	<40
21	24	30	3	<4	24	42	18	9	<5	335	<40
22	62	45	<2	<4	62	40	20	12	9	197	<40
23	38	79	<2	7	40	46	25	17	14	63	<40
24	28	52	3	8	29	70	28	17	16	111	<40
25	43	79	<2	11	47	58	29	20	10	61	<40

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	La ppm	Li ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm	Sr ppm	Ta ppm
26	25	71	<2	12	27	61	28	18	6	71	<40
27	36	51	<2	7	36	19	20	13	14	75	<40
28	46	70	2	12	52	58	23	16	8	64	<40
32	10	768	5	<4	12	22	766	7	136	236	<40
100	56	97	<2	9	58	76	28	19	8	66	<40
101	38	58	<2	5	41	51	26	17	9	78	<40
102	51	61	<2	9	53	51	25	16	10	65	<40
103	31	110	<2	5	29	66	86	17	22	470	<40
104	15	41	2	<4	10	32	33	9	6	403	<40
105	23	71	3	<4	20	59	16	13	<5	301	<40
106	20	38	2	<4	19	44	18	10	<5	361	<40
107	23	52	5	<4	22	58	23	12	<5	194	<40
108	24	46	4	<4	27	50	21	12	<5	125	<40
109	31	44	7	7	30	57	26	12	<5	97	<40
110	44	64	7	15	41	61	30	17	<5	79	<40
111	26	36	3	7	27	49	21	13	<5	140	<40
112	39	60	<2	10	36	50	24	16	10	75	<40
113	38	132	<2	12	43	43	30	16	13	85	<40
114	43	80	<2	9	48	49	29	17	6	56	<40
115	44	74	<2	11	60	61	28	17	6	61	<40
116	52	78	<2	11	54	56	30	20	15	84	<40
117	38	108	<2	10	41	35	30	15	36	86	<40
118	132	62	<2	9	199	43	21	15	7	57	<40
214	7	8	<2	<4	6	11	<4		9	140	<40

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	La ppm	Li ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm	Sr ppm	Ta ppm
215	8	10	<2	<4	6	11	<4		5	260	<40
216	9	190	<2	<4	7	15	110		31	200	<40
217	10	78	<2	<4	8	10	230		90	290	<40
218	35	18	<2	<4	19	12	20		11	370	<40
219	16	42	<2	<4	14	33	14		6	480	<40
220	8	57	<2	<4	7	9	85		20	220	<40
221	19	120	<2	<4	12	13	140		49	350	<40
222	10	170	2	<4	9	12	120		66	350	<40
223	16	130	<2	<4	14	35	69		20	520	<40
224	14	260	<2	<4	11	13	130		80	350	<40
225	10	18	<2	<4	9	18	32		6	400	<40
226	24	120	<2	<4	14	14	83		44	330	<40
227	16	34	<2	<4	15	26	27		7	330	<40

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	Th ppm	U ppm	V ppm	W ppm	Y ppm	Yb ppm	Zn ppm
1	<20	<400	47	<40	30	<4	71
2	<6	<100	128	5.2	16	1	104
3	9	<100	162	6.1	12	1	117
4	8	<100	130	7.2	16	1	119
5	10	<100	142	17	15	1	118
6	10	<100	166	6.7	14	1	94
7	10	<100	149	6.9	14	1	105
8	11	<100	164	6.8	15	1	116
9	10	<100	139	5.5	13	1	107
10	<6	<100	28	4.7	6	<1	24
11	<6	<100	89	4	12	1	64
12	<6	<100	138	6.2	14	2	82
13	<6	<100	149	6	16	2	95
14	<6	<100	127	4.1	13	1	79
15	<6	<100	76	12	13	1	55
16	<6	<100	17	6.7	4	<1	15
18	<6	<100	85	9.7	14	2	59
19	<6	<100	141	6.1	15	1	102
20	<6	<100	100	4.5	13	1	65
21	<6	<100	134	4.5	16	2	80
22	6	<100	123	6	17	2	79
23	8	<100	147	8	14	1	119
24	7	<100	211	6.6	15	2	154
25	10	<100	168	5.7	14	1	113

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	Th ppm	U ppm	V ppm	W ppm	Y ppm	Yb ppm	Zn ppm
26	8	<100	148	7.9	12	1	91
27	<6	<100	110	8.4	18	2	60
28	9	<100	144	9.6	11	1	101
32	<6	<100	46	210	10	2	5200
100	10	<100	153	7	15	1	133
101	8	<100	158	6.2	16	2	100
102	8	<100	143	5.2	13	1	99
103	<6	<100	141	10	22	2	155
104	<6	<100	88	10	11	1	56
105	<6	<100	136	5.4	12	1	93
106	<6	<100	105	4.9	14	1	65
107	<6	<100	225	10	15	2	110
108	<6	<100	180	7.3	14	1	100
109	8	<100	298	5.3	16	2	133
110	10	<100	235	8.5	20	2	139
111	7	<100	164	7.8	18	2	102
112	7	<100	140	5.5	16	2	113
113	7	<100	154	5.9	14	1	96
114	10	<100	146	12	11	1	105
115	10	<100	149	7.9	12	1	120
116	10	<100	164	8.1	24	2	128
117	8	<100	132	13	20	2	72
118	15	<100	135	7.1	14	1	98
214	<4	<100	13	<20	4	<1	24

Table B 7. 40 element ICP-AES stream sediment data (continued)

Sample ID	Th ppm	U ppm	V ppm	W ppm	Y ppm	Yb ppm	Zn ppm
215	<4	<100	20	<10	5	<1	18
216	<4	<100	22	570	6	1	170
217	4	<100	17	1400	6	1	220
218	11	<100	21	30	6	1	33
219	<4	<100	61	<10	10	1	57
220	6	<100	16	<20	9	1	220
221	7	<100	21	390	7	1	310
222	6	<100	19	350	6	1	450
223	<4	<100	60	90	10	1	110
224	6	<100	21	240	7	2	580
225	<4	<100	27	<20	6	<1	47
226	9	<100	21	220	6	1	250
227	6	<100	47	<20	10	1	65

Table B 8. Data from 10 element ICP-AES for minus 80-mesh stream sediments. All data are in ppm, except where noted. Samples without enough material for subsequent analysis are marked with (-). Limits of detection are listed in Table B 1.

Table B 8a. Ten element ICP-AES data.

Field No	Ag ppm	As ppm	Au ppm	Bi ppm	Cd ppm	Cu ppm	Mo ppm	Pb ppm	Sb ppm	Zn ppm
1	-	-	-	-	-	-	-	-	-	-
2	0.4	<1	<0.1	12	0.2	46.3	0.8	15	12	100
3	<0.08	<1	<0.1	<1	0.06	30.4	0.5	14	2	99
4	<0.08	<1	<0.1	4	0.3	30.1	0.5	13	13	113
5	0.1	<1	<0.1	<1	0.3	34.6	0.6	17	16	117
6	<0.08	11	<0.1	<1	0.07	32.4	0.7	17	4	95.4
7	<0.08	<1	<0.1	<1	0.1	26.3	0.6	17	6	104
8	0.7	<1	1.9	<1	0.09	31.6	0.5	18	<1	118
9	<0.08	<1	<0.1	<1	0.1	26.3	0.5	15	<1	105
10	<0.08	1	<0.1	<1	0.1	9	0.3	6	<1	26.2
11	<0.08	3	<0.1	<1	0.1	22.7	0.7	12	<1	72.3
12	<0.08	<1	<0.1	<1	0.6	32.1	2.8	12	<1	87.6
13	<0.08	<1	<0.1	<1	0.4	33.1	2.5	15	<1	103
14	<0.08	<1	<0.1	<1	0.3	25.5	1.3	13	<1	85.8
15	<0.08	1	<0.1	<1	0.3	17.6	1.4	15	1	58.5
16	<0.08	<1	<0.1	<1	0.07	6.7	0.3	5	<1	18.9
18	<0.08	<1	<0.1	<1	0.3	17.9	1.2	13	1	63.2
19	0.5	<1	0.8	<1	0.3	33.6	1.4	17	2	108
20	<0.08	<1	<0.1	<1	0.3	26.1	1.1	10	<1	72.2
21	<0.08	<1	<0.1	<1	0.5	23.3	2.8	11	<1	80
22	0.4	<1	<0.1	<1	0.2	21.8	1.3	10	<1	83.5
23	<0.08	<1	<0.1	<1	0.3	20.8	1	13	6	121
24	0.1	<1	<0.1	<1	0.8	47.7	1.9	14	1	157
25	<0.08	<1	<0.1	<1	0.1	30.1	0.7	17	<1	114
26	<0.08	<1	<0.1	<1	0.1	22.4	0.4	16	<1	94.4
27	<0.08	<1	<0.1	<1	0.1	10.7	0.5	7	1	55.3
28	<0.08	<1	<0.1	<1	0.2	14.2	0.6	15	3	104
32	3.6	3.0	<0.1	93	18.7	214	3.0	856	14	> 500

Table B 8a. continued

FieldNo	Ag ppm	As ppm	Au ppm	Bi ppm	Cd ppm	Cu ppm	Mo ppm	Pb ppm	Sb ppm	Zn ppm
100	0.1	<1	0.3	<1	0.2	24.2	0.5	14	<1	139
101	<0.08	<1	<0.1	<1	0.1	20.9	0.6	13	<1	108
102	<0.08	<1	<0.1	<1	0.1	21.1	0.6	12	<1	100
103	0.4	<1	<0.1	8	1.6	52.4	1.1	80	9	148
104	0.1	1	<0.1	5	0.3	24	0.9	32	26	60.5
105	<0.08	<1	<0.1	<1	0.1	32	0.5	10	<1	100
106	<0.08	<1	<0.1	<1	0.3	25.4	1.1	12	<1	73.8
107	0.1	<1	<0.1	<1	0.9	39.2	5.4	16	2	114
108	0.1	<1	<0.1	3	0.6	28.2	3.7	13	<1	106
109	<0.08	<1	<0.1	<1	0.6	28.4	8.2	17	1	130
110	0.3	<1	0.2	<1	0.8	42.2	6.8	19	<1	134
111	<0.08	<1	<0.1	<1	0.6	25.4	3.1	13	<1	109
112	<0.08	<1	<0.1	<1	0.08	17.8	0.7	12	<1	127
113	<0.08	<1	<0.1	<1	0.1	20.6	0.7	17	9	116
114	0.3	<1	0.5	<1	0.05	22.4	0.5	16	4	116
115	<0.08	<1	<0.1	<1	0.1	24.2	0.7	16	1	139
116	-	-	-	-	-	-	-	-	-	-
117	0.7	8.0	<0.1	6	0.1	60.1	0.8	16	9	80.2
118	<0.08	<1	<0.1	<1	0.07	16.1	0.5	10	<1	115

Table B 9. Data from emission spectrographic analysis of heavy mineral concentrates. All values are reported in ppm except where noted. Element concentrations are reported on a six step nominal scale in the series 1, 1.5, 2, 3, 5, 7, 10, ect. Samples having element concentrations above upper detection limits were reported with the designation G, *G indicates much greater than upper limit. Detection limits are reported in table B 1.

Table B 9. Heavy mineral concentrate data

Sample #	Ca%	Fe%	Mg%	P%	Ti%	Ag ppm	As ppm	Au ppm	B ppm	Ba ppm	Be ppm	Sample #	Bi ppm	Cd ppm
4	2	0.7	1	1	1	L	500	N	2000	100	2	4	50	N
5	L	2	0.3	0.5	0.5	L	N	N	700	200	L	5	N	N
7	0.2	1	0.7	1.5	1.5	N	N	N	1000	200	L	7	N	N
9	0.2	5	0.3	1	1	N	N	N	70	200	N	9	N	N
10	7	1	7	L	0.03	N	N	N	N	200	N	10	N	N
12	10	2	5	2	0.5	L	N	N	20	7000	N	12	N	N
13	5	2	1.5	2	1	L	N	N	50	2000	L	13	N	N
14	10	1.5	2	L	0.5	N	N	N	1500	1500	5	14	N	N
19	2	0.5	1	1	>2	N	N	N	200	1000	L	19	N	N
20	15	2	1.5	1.5	1	L	N	N	1000	2000	L	20	N	N
24	1.4	0.5	0.07	L	>2	L	N	N	30	2000	N	24	N	N
100	0.1	0.5	0.2	3	2	N	N	N	100	150	N	100	N	N
101	2	0.5	0.5	L	>2	N	N	N	20	300	N	101	N	N
102	0.5	0.5	0.5	1.5	>2	N	N	N	50	2000	N	102	N	N
103	10	1	2	N	0.2	N	500	N	2000	500	L	103	100	N
104	7	0.5	2	N	0.2	N	L	N	1000	100	N	104	50	N
105	7	3	2	0.7	1.5	N	N	N	1000	7000	L	105	N	N
106	10	2	1	2	1	N	N	N	2000	5000	3	106	N	N
107	7	0.5	2	L	0.3	N	N	N	1500	1000	L	107	N	N
108	7	0.7	1.5	1.5	1.5	N	N	N	1000	3000	2	108	L	N
109	10	1	1	2	0.3	1	N	N	700	7000	10	109	20	N
110	10	1	1.5	1	0.5	N	N	N	1000	1500	7	110	100	N
111	7	1	1	1	0.7	N	N	N	500	>10000	3	111	N	N
112	2	0.2	0.3	1.5	>2	L	N	N	100	300	N	112	N	N
113	1.5	0.5	0.3	0.7	>2	L	N	N	70	500	N	113	N	N
115	1.5	1.5	0.2	1.5	2	N	N	N	150	200	L	115	N	N
116	1.5	1	0.2	1	2	N	500	N	1000	300	2	116	20	N
117	0.1	0.5	0.5	N	0.5	2	500	N	1500	50	5	117	2000	N
118	0.5	0.7	0.3	2	>2	L	N	N	150	100	N	118	N	N

Table B 9. Heavy mineral concentrate data (continued)

Sample #	Co ppm	Cr ppm	Cu ppm	Ga ppm	La ppm	Mn ppm	Mo ppm	Nb ppm	Ni ppm	Sample #	Pb ppm	Sb ppm	Sc ppm	Sn ppm
4	30	100	30	10	100	500	N	L	50	4	20	N	20	>2000*
5	50	20	50	N	2000	100	N	N	100	5	100	N	50	>2000*
7	30	30	50	N	>2000	200	N	N	20	7	50	300	50	>2000*
9	70	70	50	15	>2000	300	N	N	100	9	50	N	50	50
10	N	L	15	N	N	50	N	N	15	10	30	N	N	30
12	20	30	30	N	300	150	2000	N	50	12	L	N	10	200
13	20	50	30	10	200	500	N	L	50	13	50	N	10	20
14	L	70	15	10	150	700	N	N	L	14	L	N	10	700
19	20	30	20	L	>2000	500	N	L	L	19	L	N	30	>2000*
20	20	70	50	15	200	300	N	N	50	20	70	N	L	1000
24	20	50	15	N	150	700	N	50	N	24	L	N	20	20
100	20	L	20	15	>2000	500	N	N	30	100	30	N	100	>2000
101	20	30	L	10	200	500	N	L	10	101	L	N	15	30
102	20	20	15	L	>2000	300	L	N	L	102	N	N	20	50
103	L	70	15	15	L	500	N	N	30	103	30	N	10	500
104	N	30	10	10	N	500	N	N	L	104	20	N	L	200
105	50	200	100	20	2000	150	N	N	150	105	50	N	30	100
106	20	50	30	10	500	200	20	L	70	106	L	N	10	1000
107	L	100	10	10	L	500	N	N	50	107	L	N	10	500
108	L	50	10	L	150	500	N	N	20	108	L	N	10	1000
109	20	50	50	L	100	500	N	N	50	109	20	N	L	>2000
110	L	50	10	10	L	700	N	L	10	110	N	N	10	>2000
111	20	50	15	L	100	500	N	N	20	111	L	N	L	1500
112	L	50	L	L	>2000	500	N	N	N	112	L	N	30	500
113	20	70	15	L	1000	200	N	L	L	113	L	N	20	50
115	50	100	15	10	700	500	N	L	70	115	L	N	20	1000
116	L	100	20	15	200	150	N	L	20	116	L	N	20	>2000*
117	L	50	15	10	L	150	N	N	L	117	20	N	15	>2000*
118	30	50	15	10	>2000	300	N	N	15	118	L	N	30	>2000

Table B 9. Heavy mineral concentrate data (continued)

Sample #	Sr ppm	Th ppm	V ppm	W ppm	Y ppm	Zr ppm
4	700	N	100	L	70	300
5	L	L	50	L	70	500
7	1000	N	70	L	100	200
9	1000	N	50	N	100	500
10	N	N	L	N	N	50
12	700	N	50	N	100	700
13	1000	N	70	N	100	300
14	500	N	100	L	50	500
19	500	N	100	N	100	300
20	700	N	70	N	50	1000
24	L	N	200	L	50	150
100	N	200	50	N	70	500
101	500	N	100	N	50	150
102	500	N	70	N	100	300
103	500	N	50	150	50	100
104	300	N	50	L	L	50
105	500	N	100	N	70	1000
106	1000	N	100	L	70	2000
107	500	N	100	N	50	150
108	1000	N	50	N	70	300
109	1000	N	50	100	100	500
110	700	N	70	150	50	200
111	1000	N	70	N	50	200
112	1000	L	70	N	100	1500
113	500	N	100	L	70	1000
115	700	N	70	N	70	500
116	300	N	100	150	70	500
117	N	N	50	300	30	300
118	500	L	70	N	100	1500

Table B 10. Data from filtered water for ICP-MS, IC, and alkalinity by titration. Concentrations are in ppb unless otherwise noted. Detection limits are listed in Table B 5.

Table B 10. Data from filtered water samples

Field ID	pH	Conductivity	Alkalinity	Cl ppm	F ppm	SO ₄ ppm IC	SO ₄ ppm ICP-MS	Al ppb	Ca ppm	Fe ppb	K ppb	Mg ppm	Mn ppb
1	4.9	145	3	8.08	0.138	38.7	39	1100	8.6	16	830	2.8	120
2	5.7	56	4	7.07	0.055	6.8	6.7	71	1.8	<10	430	0.57	2.1
3	6.1	132	27	4.98	0.060	23.4	24	<0.01	11	11	160	4.5	0.14
4	7.3	282	34	7.11	0.094	53.0	52	2.9	18	22	460	6.7	0.08
5	6.5	216	19	7.70	0.126	43.5	45	<0.01	13	14	510	5.9	0.24
6	7.0	323	69	7.79	0.143	49.2	53	<0.01	20	38	300	15	7.0
7	6.9	258	41	6.12	0.086	34.6	43	<0.01	15	19	420	8.2	0.58
8	6.5	82	26	2.25	0.031	5.9	9.0	<0.01	8.6	10	95	2.9	0.06
9	7.0	270	52	7.02	0.089	39.4	38	<0.01	19	21	320	8.0	0.23
10	7.0	137	61	2.64	0.000	1.8	0.9	3.3	20	23	59	1.9	0.06
11	7.4	265	88	3.22	0.060	12.0	12	<0.01	27	30	120	6.1	0.03
12	8.2	241	100	3.81	0.050	12.0	11	2.1	26	36	170	6.2	0.05
13	7.2	277	111	3.15	0.048	13.7	18	<0.01	34	37	280	8.4	0.03
14	8.1	364	135	4.57	0.139	21.0	21	3.2	33	48	320	9.1	0.23
15	8.0	206	90	3.60	0.043	6.7	5.8	2.8	20	29	190	4.8	0.03
16	8.1	165	65	3.08	0.000	2.6	1.7	3.5	16	22	73	2.9	0.05
17	8.4	108	50	1.72	0.000	0.5	0.5	5.0	13	16	57	1.0	0.01
18	8.2	246	105	4.82	0.072	8.3	7.7	3.3	24	35	220	6.1	0.08
19	8.1	260	101	4.61	0.074	21.8	21	2.3	26	36	240	6.7	0.23
20	8.2	341	151	5.32	0.047	17.0	16	0.83	33	46	220	11	0.03
21	8.0	386	174	14.32	0.082	25.5	12	1.1	38	53	270	11	0.20
22	8.3	257	110	7.27	0.070	13.4	14	<0.01	34	37	340	7.7	0.90
23	7.5	172	41	8.86	0.113	25.9	24	1.6	12	68	410	5.0	8.5
24	7.9	388	73	9.35	0.076	101.0	92	3.1	40	59	240	6.4	0.38
25	7.6	231	62	5.44	0.094	34.0	36	<0.01	20	23	190	9.1	0.41
26	7.2	450	148	7.27	0.131	56.5	58	0.91	38	57	120	14	2.4
27	5.5	99	3	9.86	0.072	25.1	25	99	4.3	110	500	1.7	47
28	6.7	145	8	10.77	0.123	42.4	45	4.6	8.3	52	350	4.2	8.4
32	8.3	163	74	3.79	0.500	2.0	2.0	1.7	25	26	490	2.5	0.02
33	8.0	167	80	6.72	1.549	3.4	3.3	<0.01	27	28	100	1.7	0.14
100	6.7	322	44	6.96	0.073	24.5	35	<0.01	33	37	300	10	0.87
101	7.5	243	59	6.15	0.089	27.9	29	<0.01	17	20	320	8.3	0.74

Table B 10. Data from filtered water samples (continued)

Field ID	pH	Conductivity	Alkalinity	Cl ppm	F ppm	SO ₄ ppm IC	SO ₄ ppm ICP-MS	Al ppb	Ca ppm	Fe ppb	K ppb	Mg ppm	Mn ppb
102	7.4	142	15	6.86	0.064	14.4	15	1.6	8.1	12	330	3.9	0.90
103	8.7	51	8	2.26	0.083	2.9	2.2	2.7	6.0	<10	100	0.30	0.03
104	8.4	165	65	3.39	0.053	8.3	8.0	4.1	20	26	560	1.6	0.02
105	8.1	106	24	2.92	0.000	1.9	1.0	2.1	12	14	54	1.6	0.02
106	7.5	416	148	5.19	0.047	16.8	16	1.0	32	46	210	9.7	0.02
107	9.0	321	101	3.34	0.064	19.3	17	1.1	24	31	230	7.0	0.04
108	7.9	496	156	4.50	0.045	17.7	23	<0.01	48	56	380	12	0.64
109	7.5	729	101	5.97	0.083	29.0	38	1.2	59	85	340	13	0.94
110	7.6	635	260	12.69	0.089	47.0	43	<0.01	84	160	280	19	40
111	7.8	447	194	8.15	0.064	17.9	20	<0.01	62	76	410	11	3.1
112	7.3	335	125	11.78	0.070	34.0	36	<0.01	46	150	600	8.8	29
113	7.7	190	93	5.63	0.106	21.2	27	<0.01	23	120	180	13	20
114	7.6	159	38	7.51	0.066	26.9	22	3.4	8.3	18	150	7.0	0.65
115	7.4	173	18	8.22	0.075	40.8	35	2.5	8.4	<10	190	5.9	0.33
116	7.3	234	17	7.45	0.157	49.3	75	6.4	23	30	330	2.8	0.25
117	4.7	165	1	7.30	0.166	54.2	54	360	13	22	600	1.8	71
118	8.0	160	17	9.13	0.066	24.3	28	<0.01	10	55	280	6.2	10
214	8.3	129	66	1.45	0.000	2.8	1	2.4	15	11	260	3.2	<0.04
215	8.2	181	99	1.61	0.000	2.0	<0.8	6.7	27	21	390	1.7	<0.04
216	8.3	132	66	1.12	0.493	2.0	<0.8	2.0	17	15	48	2.0	<0.04
217	8.0	138	71	1.80	0.421	2.8	2	4.3	18	15	290	2.4	<0.04
218	8.3	147	68	1.86	0.000	3.5	2	2.4	16	14	180	3.0	<0.04
219	7.8	144	68	1.72	0.000	3.5	2	<0.5	16	14	81	3.2	<0.04
220	8.2	132	66	1.58	0.221	2.6	<0.8	3.4	15	13	78	3.1	<0.04
221	8.0	147	75	2.19	0.371	3.8	2	3.0	18	15	220	3.4	<0.04
222	8.2	163	75	2.13	0.509	4.2	2	2	18	12	220	3.4	<0.04
223	8.1	167	85	2.16	0.353	5.2	3.0	<0.5	19	15	110	4.9	<0.04
224	8.0	174	77	2.27	0.537	4.1	2	2.5	19	14	210	3.6	<0.04
225	8.1	135	78	1.91	0.095	2.7	0.8	2.8	17	14	100	2.7	<0.04
226	8.2	171	77	3.72	0.399	3.8	2	2	19	13	190	3.6	<0.04

Table B 10. Data from filtered water samples (continued)

Field ID	Na ppm	P ppb	SiO ₂ ppm	Ag ppb	As ppb	Au ppb	Ba ppb	Be ppb	Cd ppb	Ce ppb	Co ppb	Cr ppb	Cu ppb
1	4.6	23	9.6	0.2	<0.2	<0.01	4	0.05	0.3	1.0	8.9	<0.5	2
2	3.8	22	5	0.2	<0.2	<0.01	2	0.05	<0.02	0.04	0.2	<0.5	<0.5
3	3.1	20	3	0.1	<0.2	<0.01	1	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
4	4.2	26	4	0.1	0.6	<0.01	4	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
5	4.4	29	5	0.1	0.2	<0.01	6.0	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
6	4.1	26	3	0.09	0.3	<0.01	5.9	<0.05	<0.02	<0.01	0.05	<0.5	<0.5
7	4.5	31	3	0.07	<0.2	<0.01	5.1	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
8	1.8	15	1	0.06	2	<0.01	0.1	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
9	4.2	17	3	0.06	<0.2	<0.01	4	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
10	1.2	4	<0.5	0.07	<0.2	<0.01	2	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
11	1.6	6	1	0.05	<0.2	<0.01	4	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
12	1.4	7	1	0.07	<0.2	<0.01	17	0.1	<0.02	<0.01	<0.02	1	<0.5
13	2.4	6	2	0.05	<0.2	<0.01	26	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
14	2.2	8	2	0.05	<0.2	<0.01	16	<0.05	<0.02	0.01	0.02	1	<0.5
15	1.3	3	1	0.03	0.2	<0.01	7.1	<0.05	<0.02	<0.01	<0.02	1	<0.5
16	1.0	<1	0.8	0.02	<0.2	<0.01	1	<0.05	<0.02	<0.01	<0.02	0.5	<0.5
17	0.8	1	<0.5	0.02	<0.2	<0.01	0.6	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
18	2.1	1	1	0.02	<0.2	<0.01	14	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
19	2.4	4	1	0.01	<0.2	<0.01	11	0.09	<0.02	<0.01	<0.02	<0.5	<0.5
20	2.2	4	2	0.01	<0.2	<0.01	15	<0.05	<0.02	<0.01	0.02	<0.5	<0.5
21	3.2	4	2	0.01	<0.2	<0.01	28	<0.05	<0.02	<0.01	0.02	<0.5	<0.5
22	3.5	10	2	0.05	<0.2	<0.01	18	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
23	4.3	5	2	<0.01	0.3	<0.01	4	<0.05	<0.02	<0.01	0.07	<0.5	<0.5
24	3.6	5	1	<0.01	<0.2	<0.01	13	<0.05	<0.02	<0.01	0.03	2	<0.5
25	3.0	8	2	0.05	<0.2	<0.01	1	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
26	3.1	4	2	<0.01	<0.2	<0.01	2	<0.05	<0.02	<0.01	0.04	<0.5	<0.5
27	5.8	4	6.0	<0.01	0.3	<0.01	7.4	<0.05	0.1	0.2	3.5	<0.5	0.8
28	5.9	2	3	<0.01	<0.2	<0.01	11	0.05	<0.02	0.01	0.1	0.9	<0.5
32	1.6	4	0.8	0.05	7.6	<0.01	3	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
33	2.3	21	<0.5	0.05	180	<0.01	2	<0.05	0.09	<0.01	<0.02	<0.5	0.7
100	4.2	39	4	0.04	0.4	<0.01	4	<0.05	<0.02	<0.01	0.03	<0.5	<0.5
101	3.5	20	3	0.05	<0.2	<0.01	3	<0.05	<0.02	<0.01	0.03	<0.5	<0.5

Table B 10. Data from filtered water samples (continued)

Field ID	Na ppm	P ppb	SiO ₂ ppm	Ag ppb	As ppb	Au ppb	Ba ppb	Be ppb	Cd ppb	Ce ppb	Co ppb	Cr ppb	Cu ppb
102	3.8	14	3	0.03	<0.2	<0.01	4	<0.05	<0.02	<0.01	0.02	<0.5	0.5
103	0.8	2	0.6	<0.01	1	0.01	0.8	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
104	1.2	<1	1	<0.01	2.0	<0.01	4	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
105	0.9	<1	<0.5	<0.01	<0.2	<0.01	2	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
106	2.2	<1	1	<0.01	<0.2	<0.01	15	0.05	<0.02	<0.01	<0.02	<0.5	<0.5
107	1.2	<1	1	<0.01	<0.2	<0.01	20	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
108	3.1	9	3	0.04	0.3	<0.01	39	<0.05	<0.02	<0.01	0.03	<0.5	<0.5
109	4.2	4	2	<0.01	0.5	<0.01	38	<0.05	<0.02	<0.01	0.03	<0.5	<0.5
110	4.9	24	5.5	0.04	<0.2	<0.01	66	<0.05	<0.02	<0.01	0.09	<0.5	<0.5
111	4.4	20	3	0.04	<0.2	<0.01	53	<0.05	<0.02	<0.01	0.04	<0.5	<0.5
112	5.8	26	4	0.04	<0.2	<0.01	16	<0.05	<0.02	<0.01	0.08	<0.5	<0.5
113	3.6	28	3	0.04	<0.2	<0.01	5	<0.05	<0.02	<0.01	0.06	<0.5	<0.5
114	2.8	5	1	<0.01	<0.2	<0.01	2	0.05	<0.02	<0.01	0.03	<0.5	<0.5
115	3.4	<1	1	<0.01	<0.2	<0.01	3	<0.05	<0.02	<0.01	<0.02	<0.5	<0.5
116	3.3	1	2	<0.01	<0.2	<0.01	7.2	<0.05	<0.02	0.01	0.03	<0.5	<0.5
117	3.2	<1	5.2	<0.01	0.7	<0.01	3	0.2	0.2	0.4	4.4	<0.5	6
118	5.6	2	2	0.03	<0.2	<0.01	5.0	<0.05	<0.02	<0.01	0.06	<0.5	<0.5
214	0.8	<10	<0.5	<0.01	<0.3	<0.01	1	<0.05	<0.03	<0.01	<0.02	<1	<0.5
215	1.1	<10	0.5	<0.01	<0.3	<0.01	5	<0.05	<0.03	<0.01	<0.02	<1	<0.5
216	0.6	<10	<0.5	<0.01	2.9	<0.01	0.4	<0.05	<0.03	<0.01	<0.02	<1	<0.5
217	0.9	<10	<0.5	<0.01	8.9	<0.01	1	<0.05	<0.03	<0.01	<0.02	<1	<0.5
218	1.0	<10	<0.5	<0.01	<0.3	<0.01	2	<0.05	<0.03	<0.01	<0.02	<1	<0.5
219	0.9	<10	<0.5	<0.01	<0.3	<0.01	3	<0.05	<0.03	<0.01	<0.02	<1	<0.5
220	0.8	<10	<0.5	<0.01	1.8	<0.01	0.9	<0.05	<0.03	<0.01	<0.02	<1	<0.5
221	1.2	<10	0.5	<0.01	2.4	<0.01	2	<0.05	<0.03	<0.01	<0.02	<1	<0.5
222	1.2	<10	0.5	<0.01	4.6	<0.01	2	<0.05	<0.03	<0.01	<0.02	<1	<0.5
223	1.3	<10	0.8	<0.01	1.5	<0.01	3	<0.05	<0.03	<0.01	<0.02	<1	<0.5
224	1.3	<10	0.5	<0.01	4.3	<0.01	2	<0.05	<0.03	<0.01	<0.02	<1	<0.5
225	1.1	<10	0.5	<0.01	<0.3	<0.01	2	<0.05	<0.03	<0.01	<0.02	<1	<0.5
226	1.7	<10	0.5	<0.01	2.8	<0.01	2	<0.05	<0.03	<0.01	<0.02	<1	<0.5

Table B 10. Data from filtered water samples (continued)

Field ID	Li ppb	Mo ppb	Ni ppb	Pb ppb	Sb ppb	Se ppb	Sn ppb	Sr ppb	Ti ppb	U ppb	W ppb	Zn ppb
1	9.0	0.05	20	<0.05	0.04	0.3	<0.05	25	<0.1	<0.005	<0.02	10
2	0.5	0.05	1.2	<0.05	0.04	0.4	<0.05	9.2	<0.1	<0.005	<0.02	<0.5
3	1.2	0.02	0.4	<0.05	<0.02	0.2	<0.05	65	<0.1	<0.005	<0.02	<0.5
4	1.6	0.04	0.9	<0.05	0.3	0.3	<0.05	130	<0.1	<0.005	<0.02	<0.5
5	2.7	0.02	1.0	<0.05	0.3	0.3	<0.05	78	<0.1	<0.005	<0.02	<0.5
6	1.2	0.02	0.8	<0.05	0.2	0.4	<0.05	110	0.1	0.02	<0.02	<0.5
7	1.8	0.02	0.4	<0.05	0.08	0.4	<0.05	100	0.1	0.005	<0.02	<0.5
8	0.9	0.03	0.1	<0.05	<0.02	0.3	<0.05	44	<0.1	<0.005	<0.02	<0.5
9	1.9	0.02	0.4	<0.05	<0.02	0.3	<0.05	120	<0.1	0.02	<0.02	<0.5
10	0.2	0.02	0.1	<0.05	<0.02	0.3	<0.05	39	<0.1	0.03	<0.02	<0.5
11	0.9	0.03	0.3	<0.05	<0.02	0.3	<0.05	99	<0.1	0.09	<0.02	<0.5
12	0.7	0.4	0.3	<0.05	0.04	<0.2	<0.05	98	<0.1	0.76	<0.02	<0.5
13	1.2	0.4	0.2	<0.05	<0.02	0.4	<0.05	150	<0.1	0.89	<0.02	<0.5
14	1.0	0.3	0.4	<0.05	0.05	0.2	<0.05	160	0.1	1.2	<0.02	<0.5
15	0.4	0.2	0.2	<0.05	0.04	<0.2	<0.05	69	<0.1	0.39	<0.02	0.7
16	<0.1	0.05	0.2	<0.05	<0.02	<0.2	<0.05	26	<0.1	0.05	<0.02	<0.5
17	<0.1	0.04	0.1	<0.05	<0.02	<0.2	<0.05	21	<0.1	0.02	<0.02	<0.5
18	0.5	0.2	0.3	<0.05	0.03	<0.2	<0.05	100	<0.1	0.42	<0.02	<0.5
19	1.3	0.2	0.4	<0.05	0.04	<0.2	<0.05	120	0.2	0.41	<0.02	1
20	0.6	0.2	0.3	<0.05	<0.02	<0.2	<0.05	140	<0.1	1.1	<0.02	<0.5
21	0.7	0.3	0.4	<0.05	0.02	<0.2	<0.05	160	<0.1	1.3	<0.02	<0.5
22	1.5	0.2	0.4	<0.05	0.03	0.3	<0.05	140	<0.1	0.45	<0.02	<0.5
23	2.0	0.04	0.6	<0.05	0.2	<0.2	<0.05	58	<0.1	0.01	<0.02	<0.5
24	0.8	0.06	1.0	<0.05	0.03	0.3	<0.05	260	0.4	0.29	<0.02	<0.5
25	1.0	0.03	0.3	<0.05	<0.02	0.2	<0.05	110	<0.1	0.01	<0.02	<0.5
26	1.8	0.03	0.9	<0.05	0.02	<0.2	<0.05	190	0.3	0.06	<0.02	<0.5
27	2.8	<0.02	8.3	<0.05	0.07	<0.2	<0.05	22	0.2	0.006	<0.02	8
28	1.4	<0.02	1.2	<0.05	0.1	<0.2	<0.05	62	0.3	<0.005	<0.02	1
32	0.4	0.1	0.2	0.4	0.1	0.2	<0.05	48	<0.1	0.10	0.2	1
33	0.6	8.9	0.6	<0.05	1.5	0.4	<0.05	48	<0.1	0.07	0.4	10
100	1.2	0.2	0.9	<0.05	<0.02	0.3	<0.05	170	<0.1	0.03	<0.02	1
101	1.1	0.04	0.4	<0.05	<0.02	0.3	<0.05	100	<0.1	0.008	<0.02	0.7

Table B 10. Data from filtered water samples (continued)

Field ID	Li ppb	Mo ppb	Ni ppb	Pb ppb	Sb ppb	Se ppb	Sn ppb	Sr ppb	Ti ppb	U ppb	W ppb	Zn ppb
102	0.6	0.03	0.5	<0.05	<0.02	0.3	<0.05	53	<0.1	<0.005	<0.02	<0.5
103	0.3	0.2	0.4	<0.05	0.2	<0.2	<0.05	18	0.1	0.04	<0.02	2
104	0.5	0.4	0.2	<0.05	0.2	<0.2	<0.05	52	<0.1	0.37	<0.02	0.8
105	<0.1	0.03	0.1	<0.05	<0.02	<0.2	<0.05	42	<0.1	0.11	<0.02	<0.5
106	0.6	0.2	0.4	<0.05	<0.02	<0.2	<0.05	140	<0.1	1.1	<0.02	<0.5
107	0.6	0.4	0.3	<0.05	0.1	0.3	<0.05	120	<0.1	1.7	<0.02	<0.5
108	1.2	0.4	0.4	<0.05	0.03	0.6	<0.05	170	<0.1	1.6	<0.02	<0.5
109	1.8	0.50	0.6	0.07	0.03	<0.2	<0.05	230	0.1	4.4	<0.02	<0.5
110	2.1	0.51	1.0	<0.05	0.02	0.5	0.1	320	<0.1	5.8	<0.02	1
111	0.9	0.4	0.6	<0.05	<0.02	0.3	<0.05	210	<0.1	1.3	<0.02	2
112	1.2	0.06	0.6	<0.05	<0.02	0.3	<0.05	240	<0.1	0.18	<0.02	<0.5
113	1.2	<0.02	0.4	<0.05	0.1	0.2	<0.05	98	<0.1	0.05	<0.02	<0.5
114	0.2	0.03	0.7	<0.05	0.06	<0.2	<0.05	64	<0.1	0.01	<0.02	1
115	0.8	<0.02	0.4	<0.05	<0.02	<0.2	<0.05	55	0.1	<0.005	<0.02	<0.5
116	0.2	<0.02	0.8	<0.05	<0.02	<0.2	<0.05	110	0.3	<0.005	<0.02	0.6
117	3.7	<0.02	12	<0.05	0.05	<0.2	<0.05	35	0.2	<0.005	<0.02	6
118	0.6	<0.02	0.4	<0.05	0.02	0.3	<0.05	62	<0.1	<0.005	<0.02	<0.5
214	<1	<0.06	<0.1	<0.05	<0.02	<0.5	<0.6	19	<0.1	0.05	<0.02	<0.5
215	<1	<0.06	<0.1	0.06	0.03	<0.5	<0.6	57	<0.1	0.06	<0.02	2
216	<1	<0.06	<0.1	0.2	0.4	<0.5	<0.6	29	<0.1	0.08	0.07	1
217	<1	0.1	<0.1	0.2	0.2	<0.5	<0.6	34	<0.1	0.09	0.04	2
218	<1	<0.06	<0.1	0.1	<0.02	<0.5	<0.6	44	<0.1	0.05	<0.02	<0.5
219	<1	<0.06	<0.1	<0.05	<0.02	<0.5	<0.6	53	<0.1	0.04	<0.02	<0.5
220	<1	0.51	<0.1	<0.05	0.05	<0.5	<0.6	18	<0.1	0.07	<0.02	2
221	<1	<0.06	<0.1	0.2	0.1	<0.5	<0.6	41	<0.1	0.07	<0.02	<0.5
222	<1	0.47	<0.1	0.1	0.2	<0.5	<0.6	42	<0.1	0.08	<0.02	2
223	<1	0.1	<0.1	0.06	0.74	<0.5	<0.6	67	<0.1	0.06	<0.02	<0.5
224	<1	0.44	<0.1	<0.05	0.2	<0.5	<0.6	45	<0.1	0.07	<0.02	1
225	<1	<0.06	<0.1	0.69	<0.02	<0.5	<0.6	45	<0.1	0.03	<0.02	<0.5
226	<1	0.26	<0.1	0.08	0.2	<0.5	<0.6	45	<0.1	0.06	<0.02	<0.5

APPENDIX C

R-mode Factor Analysis

Table C 1. Communalities for factor analysis, minus 80-mesh stream-sediment data

Proportion of the variance explained by the 4 factor model

	From 1 Factor	From 2 Factors	From 3 Factors	From 4 Factors	Multiple R-Square
Al %	0.95	0.95	0.96	0.96	0.99
Ca %	0.73	0.73	0.96	0.97	0.98
Fe %	0.96	0.97	0.97	0.97	0.98
Mg %	0.86	0.86	0.87	0.89	0.95
Ti %	0.90	0.90	0.94	0.94	0.97
Mn ppm	0.55	0.70	0.72	0.73	0.87
As ppm	0.01	0.72	0.79	0.84	0.88
Ba ppm	0.58	0.59	0.88	0.89	0.98
Be ppm	0.41	0.87	0.88	0.88	0.92
Ce ppm	0.78	0.79	0.80	0.98	1.00
Co ppm	0.92	0.92	0.93	0.94	0.98
Cu ppm	0.14	0.67	0.84	0.85	0.90
Cr ppm	0.93	0.94	0.94	0.94	0.99
La ppm	0.69	0.71	0.72	0.98	1.00
Li ppm	0.12	0.91	0.91	0.91	0.97
Ni ppm	0.89	0.90	0.94	0.94	0.99
Pb ppm	0.00	0.88	0.90	0.90	0.93
Sn ppm	0.10	0.72	0.83	0.84	0.90
Sr ppm	0.44	0.45	0.88	0.92	0.96
V ppm	0.94	0.95	0.98	0.98	1.00
W ppm	0.33	0.86	0.86	0.87	0.89
Zn ppm	0.04	0.87	0.89	0.89	0.95

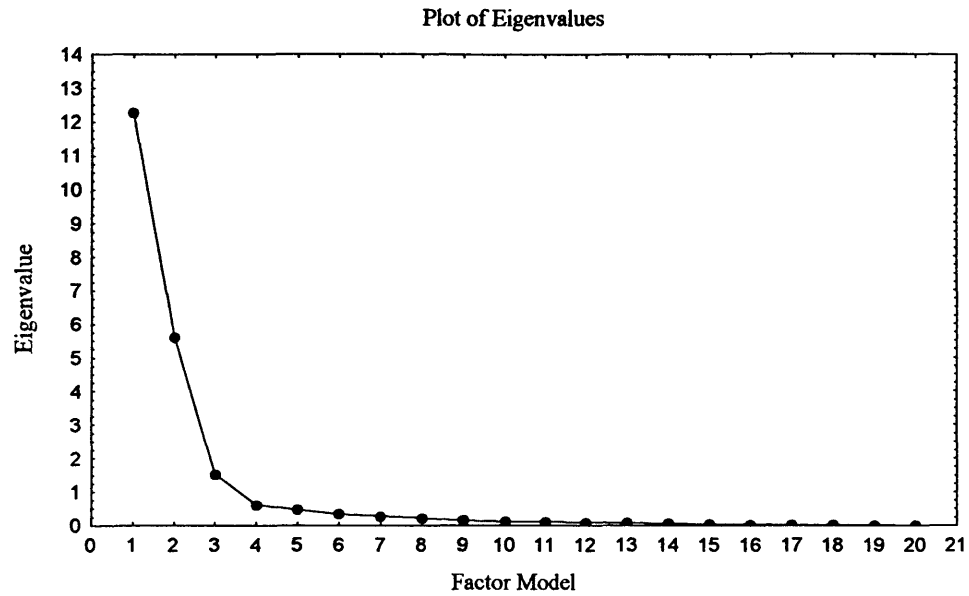


Figure C 1. Eigenvalues vs. factor models, minus 80-mesh stream sediment data

Table C 2. Eigenvalues and percent of variance explained by factor models 1-7

Factor Model	Eigenvalue	% total Variance	Cumul. Eigenvalue	Cumul. %
1	12.26	55.74	12.26	55.74
2	5.59	25.40	17.85	81.14
3	1.52	6.92	19.37	88.06
4	0.62	2.81	19.99	90.87
5	0.47	2.15	20.46	93.02
6	0.34	1.53	20.80	94.54
7	0.27	1.25	21.07	95.79

Table C 3. Factor loadings for 3 factor model, minus 80-mesh stream sediment data

	Factor 1	Factor 2	Factor 3
Al %	0.98	0.08	0.00
Ca %	-0.82	-0.06	0.54
Fe %	0.98	0.07	-0.08
Mg %	-0.92	0.08	0.16
Ti %	0.93	0.01	-0.26
Mn ppm	0.75	0.39	0.09
As ppm	0.08	0.85	-0.25
Ba ppm	0.80	-0.09	0.49
Be ppm	-0.64	0.68	0.09
Ce ppm	0.87	0.12	-0.16
Co ppm	0.96	0.05	0.04
Cu ppm	0.40	0.73	0.39
Cr ppm	0.96	-0.09	-0.07
La ppm	0.82	0.13	-0.19
Li ppm	0.34	0.89	-0.02
Ni ppm	0.96	-0.04	0.13
Pb ppm	-0.01	0.94	0.13
Sn ppm	-0.34	0.79	-0.29
Sr ppm	-0.62	0.05	0.70
V ppm	0.98	-0.09	0.12
W ppm	-0.58	0.72	-0.02
Zn ppm	0.20	0.91	0.13

Table C 4. Factor loadings for 4 factor model, minus 80-mesh stream sediment data

	Factor 1	Factor 2	Factor 3	Factor 4
Al %	0.91	0.09	0.30	0.18
Ca %	-0.59	-0.06	-0.77	-0.20
Fe %	0.88	0.08	0.37	0.20
Mg %	-0.81	0.07	-0.46	-0.12
Ti %	0.78	0.02	0.52	0.25
Mn ppm	0.73	0.41	0.18	0.03
As ppm	-0.02	0.85	0.32	-0.09
Ba ppm	0.92	-0.06	-0.19	-0.03
Be ppm	-0.59	0.67	-0.29	-0.08
Ce ppm	0.71	0.11	0.28	0.62
Co ppm	0.92	0.07	0.27	0.14
Cu ppm	0.50	0.75	-0.20	-0.08
Cr ppm	0.88	-0.08	0.35	0.20
La ppm	0.64	0.11	0.26	0.70
Li ppm	0.29	0.89	0.13	0.12
Ni ppm	0.94	-0.02	0.18	0.14
Pb ppm	0.00	0.94	-0.14	0.08
Sn ppm	-0.45	0.77	0.13	0.15
Sr ppm	-0.36	0.05	-0.88	-0.10
V ppm	0.96	-0.07	0.20	0.13
W ppm	-0.58	0.71	-0.17	-0.01
Zn ppm	0.21	0.92	-0.04	0.02

Table C 5. Factor loadings for 5 factor model, minus 80-mesh stream sediment data

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Al %	0.93	0.11	0.27	0.14	0.00
Ca %	-0.62	-0.07	-0.75	-0.18	0.03
Fe %	0.90	0.10	0.34	0.17	0.01
Mg %	-0.82	0.06	-0.45	-0.09	-0.10
Ti %	0.81	0.03	0.48	0.21	-0.07
Mn ppm	0.67	0.40	0.23	0.04	0.49
As ppm	0.01	0.86	0.29	-0.12	-0.26
Ba ppm	0.91	-0.05	-0.21	-0.05	0.12
Be ppm	-0.63	0.65	-0.25	-0.04	0.15
Ce ppm	0.73	0.12	0.26	0.60	0.02
Co ppm	0.92	0.08	0.26	0.11	0.14
Cu ppm	0.50	0.76	-0.24	-0.11	-0.10
Cr ppm	0.91	-0.06	0.31	0.16	-0.06
La ppm	0.67	0.12	0.25	0.67	0.01
Li ppm	0.28	0.89	0.12	0.11	0.04
Ni ppm	0.95	0.00	0.15	0.10	0.06
Pb ppm	-0.03	0.93	-0.12	0.09	0.16
Sn ppm	-0.42	0.78	0.11	0.14	-0.26
Sr ppm	-0.38	0.05	-0.89	-0.09	-0.05
V ppm	0.97	-0.06	0.17	0.10	0.04
W ppm	-0.60	0.70	-0.14	0.02	0.05
Zn ppm	0.17	0.91	-0.01	0.03	0.23

Table C 6. Factor loadings for 6 factor model, minus 80-mesh stream sediment data

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Al %	0.96	0.11	0.18	0.08	0.02	0.03
Ca %	-0.69	-0.07	-0.68	-0.14	0.03	0.02
Fe %	0.94	0.09	0.25	0.13	0.05	-0.01
Mg %	-0.84	0.07	-0.37	-0.09	-0.18	0.06
Ti %	0.87	0.03	0.40	0.17	-0.05	-0.02
Mn ppm	0.64	0.39	0.20	0.08	0.57	0.05
As ppm	0.01	0.84	0.28	-0.04	-0.07	-0.41
Ba ppm	0.83	-0.07	-0.27	0.02	0.37	-0.24
Be ppm	-0.63	0.67	-0.18	-0.07	0.00	0.22
Ce ppm	0.77	0.12	0.20	0.59	0.06	0.00
Co ppm	0.94	0.07	0.17	0.07	0.16	0.06
Cu ppm	0.46	0.75	-0.29	-0.11	0.03	-0.19
Cr ppm	0.96	-0.06	0.22	0.09	-0.06	0.03
La ppm	0.71	0.11	0.19	0.66	0.03	0.01
Li ppm	0.32	0.90	0.10	0.04	-0.04	0.12
Ni ppm	0.97	0.00	0.06	0.04	0.06	0.07
Pb ppm	-0.03	0.94	-0.11	0.07	0.09	0.13
Sn ppm	-0.39	0.77	0.14	0.17	-0.23	-0.19
Sr ppm	-0.45	0.06	-0.85	-0.09	-0.06	0.02
V ppm	0.97	-0.07	0.08	0.09	0.15	-0.09
W ppm	-0.61	0.70	-0.08	0.04	0.01	0.02
Zn ppm	0.15	0.91	-0.02	0.03	0.23	0.07

Table C 7. Factor loadings for 7 factor model, minus 80-mesh stream sediment data

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Al %	0.96	0.11	0.17	0.09	0.00	0.03	0.04
Ca %	-0.70	-0.06	-0.68	-0.15	0.01	0.05	0.07
Fe %	0.95	0.09	0.23	0.12	0.05	0.02	-0.02
Mg %	-0.84	0.07	-0.36	-0.10	-0.17	-0.09	0.00
Ti %	0.89	0.02	0.35	0.15	0.01	-0.07	-0.12
Mn ppm	0.67	0.39	0.14	0.05	0.59	0.06	0.05
As ppm	0.02	0.80	0.27	-0.07	-0.03	0.16	-0.46
Ba ppm	0.79	-0.05	-0.21	0.06	0.22	0.47	0.10
Be ppm	-0.61	0.67	-0.22	-0.09	0.06	-0.24	0.02
Ce ppm	0.75	0.12	0.21	0.60	0.04	0.03	0.00
Co ppm	0.94	0.09	0.17	0.08	0.13	0.05	0.11
Cu ppm	0.40	0.77	-0.17	-0.04	-0.14	0.38	0.04
Cr ppm	0.96	-0.06	0.20	0.10	-0.06	-0.01	0.02
La ppm	0.70	0.12	0.19	0.67	0.02	0.00	-0.02
Li ppm	0.32	0.90	0.08	0.04	-0.01	-0.13	-0.03
Ni ppm	0.96	0.02	0.07	0.06	0.01	0.07	0.15
Pb ppm	-0.04	0.94	-0.11	0.07	0.09	-0.08	0.02
Sn ppm	-0.34	0.71	0.03	0.09	-0.05	-0.20	-0.53
Sr ppm	-0.45	0.06	-0.87	-0.10	-0.05	0.03	0.02
V ppm	0.96	-0.06	0.10	0.11	0.09	0.20	0.05
W ppm	-0.61	0.69	-0.08	0.03	0.04	-0.08	-0.10
Zn ppm	0.12	0.94	0.06	0.07	0.13	0.12	0.14