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REVIEW OF EXPLORATION GEOCHEMICAL SURVEYS ON SEWARD PENINSULA, WESTERN ALASKA

By

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INTRODUCTION

The Seward Peninsula forms the westernmost extremity of the North American continent and extends to within 90 kilometers of the Eurasian continent across Bering Strait. As such, the peninsula is both geographically and geologically discrete; geographically as a 520,000-square-kilometer appendage of mainland Alaska situated on the vast, submerged Bering-Chukchi Shelf, and geologically in comprising mainly a metamorphic-plutonic igneous terrane which lacks direct ties to mainland geologic elements. In conjunction with these attributes, the peninsula has been one of the major sources of mineral production in Alaska and still possesses significant but undetermined mineral potential.

Geochemical exploration and, before it, mineral prospecting, have been utilized as techniques to search for lode and placer deposits on Seward Peninsula since gold was first found on the Niukluk River in 1865 (Cobb, 1973, p. 64). However, systematic and scientific areal and topical surveys were not undertaken on the peninsula until the 1940's and 1950's. The first of these were done as part of the Strategic Minerals Program before and during World War II, those on the peninsula being concerned mainly with tin and tungsten. Like gold in earlier years, the minerals sought in these surveys were heavy, scheelite in the Nome area and cassiterite and wolframite on the York Peninsula; again, as before, panned stream concentrates were adopted as the principal prospecting medium for these surveys. Thereafter, and for the same reason, the concentrates continued to be used for more numerous and extensive surveys on Seward Peninsula in the late 1940's and early 1950's in conjunction with the Trace Elements Program search for radioactive materials. These surveys yielded many hundreds of panned concentrates which, with a few tens of sluice and dredge concentrates collected in earlier years, were saved; together these became Alaskan placer collection. Chemical analyses were not used in these early mineral surveys except to supplement and refine the mineralogical results; thus, they were not prosecuted as geochemical surveys originally. However, they are covered briefly here because many of the concentrates have been analyzed chemically recently and, if continued to completion, the original heavy mineral surveys could provide the basis ex post facto, for true geochemical surveys. Also cited are several reports covering prospect boring projects done by the U.S. Bureau of Mines; these contain valuable qualitative and quantitative mineral information based on panned concentrates together with the results of chemical analyses and assays obtained from many of them.

Modern geochemical surveys based on chemical data derived from numerous kinds of natural materials only became possible with the development of trace wet, spectrographic and other analytical methods, and semi-quantitative estimating techniques which could be made quickly and accurately on large numbers of samples. The first of this type of survey on Seward Peninsula was done on a small scale, in the Nome area; it was based on analyses of a few tens of total stream sediment samples collected by Hummel in 1958 (Hummel and Chapman, 1960, p. B-30-33). Two years after this, Sainsbury did similar small surveys for beryllium around several of the localities on the York Peninsula which contain known tin lodes. (Sainsbury, 1963). Again, although these were based mainly on total stream sediments, Sainsbury also incorporated slope wash and rock samples. By far the most extensive use of exploration geochemical techniques on Seward Peninsula was made during the recently concluded mineral resources surveys by the U.S. Geological Survey (1967-1971); in most of these, they were generally integrated on an equal basis with geological investigations. About half of these surveys on the peninsula was done by the Alaska State Geological Survey and the remainder by the Federal Geological Survey. All were based mainly on analyses of total stream sediments, but most also included selective rock and ore collections. As an outgrowth of his project in the Heavy Metals Program, Sainsbury initiated chemical analyses of a randomly chosen proportion of samples from the old Alaska concentrate collection. A large number of these came from the Seward Peninsula, many from areas which were covered by later geochemical surveys based on total stream sediments. Studies comprising statistical treatments of analytical data from the concentrates, and comparisons of these results with those obtained from total stream sediments, have recently been published by Overstreet and others. (1974)

<u>Surficial Features of Seward Peninsula and Their Implications for Geochemical Exploration</u> - The configuration and character of the surface and immediate subsurface of Seward Peninsula, like those of any area, largely determine-- and in some instances narrowly limit-- the scope of geochemical surveys which can be prosecuted with success, and the kind or kinds of natural materials on which they can be based. The modern physical character of Seward Peninsula represents the combined effects of the more recent surficial geological and climatic processes and of those which preceded them; in some instances, this involves continuing tectonic events. The older but less prominent geologic features are associated with the metamorphic rocks which form most of the bedrock of the peninsula. For example the major trends of many of the modern trunk drainage systems have developed from the northward-trending, major structures in these rocks. The youngest and most prominent physiographic features are uplifted, fault-bounded mountain ranges; of these, the trend of the Kigluaik and Bendeleben mountain ranges is normal to that of the older structures, whereas that of the Darby Mountains is parallel to them. (Plate 1).

The effects of later geologic events superimposed on these basic bedrock features include widespread effusion of basaltic volcanic lava and ash during the Pliocene (Hopkins, 1963, page 86) throughout lower-lying areas, and extensive glaciations emanating from and spreading away from the Kigluaik, Bendeleben, and Darby mountain ranges; in addition, smaller glaciations arose and spread from Granite Mountain in eastern Seward Peninsula and from York and Cape mountains at the western end of the peninsula. (Plate 1). Intimately associated with the Pleistocene glaciations were concurrent derivation of wind-blown silt from glacial and glaciofluvial deposits produced by them (Hopkins, 1963, Plate 3) and thereafter, erosion and modification of both kinds of deposits, especially along the coast, by intermittent waxing and waning of sea level. Collectively, these geologic events, together with the climate, the vegetation associated with it, and the thermal condition of the subsurface have produced the modern landscape of Seward Peninsula, including much of its micro-relief character. The present terrane of the peninsula can be readily divided into three general classes of topography: (1) low-lying coastal and interior fluvial and lava plains, (2) moderately high rugged mountain ranges, and (3) rolling uplands which lie between these and comprise most of the peninsula. (Pewe', 1975, Plate 1). The nature of these physiographic regions of the peninsula, by themselves, bear strongly on the character of geochemical surveys which can be prosecuted in them and, accordingly, are shown on Plate 1.

<u>Implications for Geochemical Exploration</u> - The geologic processes which have produced, or acted on, the physiographic features of the Seward Peninsula have had considerable bearing on the results of geochemical and mineral surveys done to date; thus they require attention in planning future surveys. They include effects of the Bering-Chukchi Sea shelf, volcanic activity, and the interrelated phenomena of Pleistocene and Holocene glaciations, sea level fluctuations, and climate and vegetation. The manner in which these could play a part in geochemical surveys is reviewed briefly below.

Broadly speaking, geologic processes and features produced by them can have both physical and chemical effects on geochemical surveys. In the first instance, the principal effect of the Bering-Chukchi Sea shelf, a peneplain formed by late Miocene time (Hopkins, p. 453) and thereafter alternately innundated and exposed to the present, is physical. This feature, acted on by geologic processes giving rise to the fluctuations of sea level, led to the formation of the coastal and estuarine-fluvial plains which bound three-fourths of the coastline of Seward Peninsula. Most of the coastal plains, including the largest along the northwest coast, have formed behind off-shore bars, the only exceptions being those which formed locally from glacial drift, such as at Nome, where off-shore bars are lacking. The five largest interior fluvial plains - on the north side of the Kigluaik Mountains, on the Kuzitrin River, at the head of Fish River and along the middle stretches of the Koyuk and Kiwalik Rivers - formed in catchment basins impounded behind natural bedrock barriers. Most of the remaining smaller fluvial plains similarly have formed behind bedrock constrictions including one at the head of the Tubutulik River called Death Valley, which is a perched basin with the highest general elevation (175m) of any on the peninsula. (Plate 1) The principal effect of all these plains on geochemical surveys from the standpoint of exploring bedrock features is physical. That is, all represent various thicknesses of unconsolidated deposits which cover bedrock. Portions of some of these deposits possess intrinsic mineral potential, notably the gold-bearing drift and buried beaches at Nome; however, exploration techniques to determine this potential must be tailored to suit the kinds of deposits sought.

The lava flow plains are like the others in that they obscure large areas of bedrock; however, they differ from them in not being amenable to normal exploration boring methods to detect deposits in or at the surface of the bedrock underlying them. For this reason, although gold-bearing alluvial gravels have been followed for short distances under the perimeter of the flows, no attempts have been made to prospect through them. To this physical effect of the lava fields must be added an adulterating chemical effect which would arise from the composition of the original flows. This, in turn, would be manifested in the results of geochemical surveys through minerals and other materials derived from them, both locally such as on the lava plains around Imuruk Lake, and away from them in the fluvial plain which has formed on the Kuzitrin River below the flows. (Plate 1)

The salient factors about the coastal, estuarine-fluvial, and interior fluvial and lava plains on Seward Peninsula relating to geochemical Surveys can be summarized briefly: These deposits cover bedrock to various depths and, in so doing, effectively preclude direct surface sampling methods to explore it. Consequently, geochemical surveys based on drilling along bedrock trends or on geophysical anomalies must be utilized instead. Portions of these deposits possess intrinsic mineral potential; for data bearing on it, geochemical surveys will have to include both systematic surface and subsurface sampling methods, in conjunction with geophysical surveys.

<u>Effects of Quaternary and Modern Events and Features</u> - Events encompassing both geologic and climatic processes during Quaternary time have determined the present character of the landscape of Seward Peninsula. They include several alpine glaciations, fluctuations of sea level induced by these, and concomitant variations of climate. These, in turn, have produced the present configuration of the topography, widespread glacial drift and loess deposits, the continuous and discontinuous permafrost, and the detailed physiographic character and vegetation on the surface. In both physical and chemical ways, these factors more and less influence the kinds of geochemical surveys which can be done on the peninsula and the results which can be obtained from them.

Glaciations have emanated from several centers on Seward Peninsula, the Kigluaik-Bendeleben-Darby arc, Kiwalik and Granite Mountains in the eastern part, and from Cape and York Mountains at the western end. By far the most extensive of these glaciations took place in Illinoian time or earlier (Nelson and Hopkins, 1972, p. 7); in marked contrast, the most recent glaciations in Wisconsinan time were largely confined within the limits of the more rugged mountain provinces, and so are not shown on Plate 1. The principal effects of glaciations on geochemical exploration arise from transport of materials in two ways: (1) movements of debris on and in front of glaciers from their mountainous source areas and along their routes away from them, and (2) gradual but pervasive transport of wind-blown material from these glaciofluvial deposits and deposition throughout the periglacial areas.

Deposits produced by both means were once widely distributed throughout Seward Peninsula; dissected remnants of these deposits are now scattered throughout much of the upland and mountainous portions of the peninsula while less affected remnants occur in or on the deposits which form the coastal and interior plains. Beyond the general concern for the nonindigenous origin of much of the glaciofluvial and wind-blown deposits is a more specific one which bears directly on the choice of materials to be collected for geochemical surveys: The finest grained materials are preferentially enriched in both types of deposits, the former as rock flour, and the latter derived from it as loess (Hopkins, 1963, p. 37); accordingly, it can be assumed that they are disproportionately present in the standard minus 80 mesh fraction of stream sediment samples normally used for such surveys.

Basis for Review of Geochemical Surveys

All of the geochemical surveys done on Seward Peninsula fall in the general category of applied geochemistry and within the still more specific pursuit of exploration geochemistry as an adjunct in prospecting for economic mineral deposits. The outline used for the case histories of geochemical exploration given in that volume was adopted as the basis for reviewing the geochemical surveys made on Seward Peninsula (Bradshaw and others, 1975, p. 45-46):

Name of deposit or property
Author (Affiliation)
(1) Location
(2) Geology
(3) Mineralization
(4) Physiography; topography, climate, soils, vegetation, permafrost
(5) Sediment data and conclusions
(6) Soil data and conclusions
(7) Other data
Reference(s)

This was done for the surveys on Seward Peninsula for the same reason and with the same inherent limitation as was true for the case histories; that is, "an attempt to present all the data in a common format, and in particular to standardize the presentation of the data. This was not possible in every case by any means, particularly because much of the information presented was collected with no view to standardization". (Bradshaw, 1975, p. 45). The outline finally developed, as modified and elaborated from the one cited above, is given below; it is also annotated to account for factors peculiar to the geochemical surveys on Seward Peninsula and to cite sources of information used to deal with them.

1. Number and name of geochemical survey
   Number is that designated for the survey area and shown on Plate 1; the name is either that assigned by the author, or another of a geographic feature to identify the area.

2. Author(s) and governmental affiliation
   Only geochemical surveys by Federal and Alaska State workers are reviewed; the results of numerous surveys done by private prospecting and mining firms have not been published and so cannot be included.

3. Location and area
   The area given for each geochemical survey is the maximum warranted by the systematic sampling on which it was based. In most cases the area encompasses only that of the drainage basins in which sediment samples were collected and at a density commensurate with the general scale of the survey.

4. Topography, relief, drainage
   The general physiographic divisions depicted on Plate 1 are designated and shown as represented by Pewe. (1975, Plate 1) The principal elements of thes -- topography, relief, drainage -- are described for individual survey areas as defined by Leopold, Wolman, and Miller (1964, p. 131-150), and as required depending on the scale of the survey.

5. Vegetation and other surficial cover
   Tundra, with and without willows and alder, constitutes almost the only vegetation cover throughout most of Seward Peninsula. The only other vegetation consists of white spruce and birch forests, which are restricted to the southeastern and eastern parts of the Seward Peninsula. Both the definition and distribution of these are as shown and described by Hopkins (1959, p. 215-220). The name for one of the principal mass-wastage features of arctic regions, gelifluction lobes, has been adopted and used as defined by Embleton and King (1975, p. 96-125).

6. Geology, bedrock, surficial
   Sainsbury's report, "Geology, Ore Deposits, and Mineral Potential of the Seward Peninsula"(1975), is the principal source used for descriptions of all aspects of the geology of the geochemical survey areas on the main part of the peninsula; for the geology of northeastern Seward Peninsula, Patton's geologic map of the Candle quadrangle (1967) was used. The extent of glaciations on Seward Peninsula, and the distribution of windblown silt, are shown on Plate 1 as represented by Hopkins, as shown first on Plate 3 of his report on Imuruk Lake (1963), then as revised for a later publication (Nelson and Hopkins, 1972, Figures 3 and 4).

7. Mineral deposits, primary, secondary
   The primary and secondary mineral deposits in all geochemical survey areas, mainly lodes and placers, are described for the most part as they were known at the time the surveys were done; the reports by Berg and Cobb (1967), and Cobb (1973) were the principal sources for this information. Exceptions to this consisted of instances in which new deposits or indications of new deposits had been found during preliminary geologic investigations in several areas; in these cases, geochemical surveys were either extended to cover the new areas or done in greater detail in portions of those done previously.

8. Geochemical survey; previous and related work, purpose and scale, sources of natural adulteration or cultural contamination
   All reports which contained information pertinent to either the orientation or applied results of individual geochemical surveys are at least cited. Most belong to two general groups; (1) reports on prospect boring by the Bureau of Mines and (2) those arising from the U.S. Geological Survey's radioactivity investigations. The latter are of particular importance because they were based on systematic collections of panned stream concentrates, many of which have been analyzed chemically in recent years.

The purpose of all of the surveys reviewed was economic exploration geochemistry. Levinson's general classification for scale and sampling density for geochemical surveys based on stream sediments (1974, p. 367-382) was adopted and modified as follows:

Regional Surveys

1st Order - 1 sample per 100 km^2 or more.
2nd Order - 1 sample per 20-100 km^2.
3rd Order - 1 sample per 3-20 km^2.

Detailed Surveys

One or more samples per 3 km^2 or less.

For all surveys, adulteration was judged as the effects of natural materials when mixed with detritus derived from bedrock, the ultimate source of both primary and secondary mineral deposits. Such adulteration, especially of modern stream sediments, comes from three main sources; (1) glaciofluvial debris, (2) wind-blown silt derived from this, and (3) volcanic flow and ash deposits.

In addition to these general matters relating to the geochemical surveys and the areas covered by them, the following specific aspects of the surveys are summarized.

8A. Field procedures; kind and number of samples collected, field preparation and analyses.

8B. Laboratory procedures; sample preparation, chemical analysis.

8C. Data processing and statistical treatments; determination of background, threshold, and anomalous values.

For most surveys, two general methods were utilized; (1) by hand-prepared histograms for selected metals, then determination of anomalous and other values according to the techniques recommended by Hawkes and Webb (1962, p. 25-31), or (2) from computer-generated statistical treatments of chemical data for few to many elements. The U.S. Geological Survey GEOSUM program used for several of the surveys, and the model for a number of others is described as follows by Robert Terrazas (August 30, 1968): The GEOSUM program is designed principally for summarizing and tabulating results of semiquantitative (6-step) spectrographic analyses by the U.S. Geological Survey, but may also be used for other types of geochemical data. One fundamental assumption made in use of the program is that the data are more properly treated on a logarithmic, rather than arithmetic, scale.

The program provides (a) a readable listing of the data, (b) histograms and cumulative frequency distributions, and (c) a statistical summary which includes geometric means and geometric deviations.

Semiquantitative spectrographic analyses by the U.S. Geological Survey are reported as geometric midpoints (1., 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc.) of geometric brackets having the boundaries 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, 0.083, etc. The frequency distributions are computed using these brackets as class intervals.

8D. Results; stream sediments, soil samples, rock, altered rock, and ore samples.

In all of the reports reviewed, geochemical surveys were done concurrently and essentially coordinately with geological and mineral resource investigations; only those results obviously derived largely or entirely from the geochemical surveys, or attributed by the authors to them, are cited here.

8E. Publications

All publications are listed which are cited in reviews of individual geochemical surveys, or which contain data or other information pertinent to them.

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1. NOME AREA

C. L. Hummel, U. S. Geological Survey

Location and Area - Two separate areas located north of Nome; (A) one at head of Nome River and along Snake River drainages (200 km^2) and (B) the other in the Kigluaik Mountains encompassing the head of Grand Central River at the base of Mt. Osborne (200 km^2).

Topography, Relief, and Drainage - Mt. Osborne area: (A) Glaciated alpine topography with serrate knife-edge ridges, U-shaped trunk and tributary valleys, and sparse hanging valleys with modern rock glaciers. Maximum relief in area, 1250 m; general relief throughout most of area, 1100 m. Area is well dissected by well-integrated major and minor drainage except for broad glaciofluvial-filled valley bottom of Grand Central River. (B) Snake-Nome River area: Rolling upland topography with few sharp peaks and ridges. Maximum relief in northern part of area, 850 m; general relief throughout area, 550-800 m. Area is well dissected by north-trending Snake and Nome Rivers and well integrated tributaries to them; valleys of Snake and Nome Rivers have been glaciated and now have broad glacio-fluvial-filled bottoms with braded channels.

Vegetation and Other Surficial Cover - (A) Mt. Osborne area: Glaciofluvial-filled valley bottoms and lower slopes are covered with tundra and willows; sparse patches of alder occur along upper limit of tundra and little or no vegetation is present on middle and upper slopes. Frost-riven talus and glacial moraines occur along most valley walls and in heads of major tributaries of Grand Central River. (B) Snake-Nome River area: Tundra with willows covers all but upper slopes and tops of hills and ridges; latter generally rubble-covered with sparse tundra. Alder patches are moderately abundant along middle slopes; gelifluction lobes are abundant on middle and upper slopes of most hills and ridges.

Geology; Bedrock, Surficial - (A) Mt. Osborne area: Nearly all of bedrock is composed of amphibolite-grade metasedimentary rocks with numerous orthogneiss bodies; small silicic and basaltic dikes and sills are moderately abundant throughout the high-grade metamorphites. Glaciofluvial deposits from the bottom of the Grand Central River; frost-riven talus and glacial moraines occur along the lower valley walls and at the head of most tributaries. (B) Snake-Nome River area: Bedrock consists entirely of greenschist grade metamorphites derived from marine sedimentary and submarine volcaniclastic rocks; northward trends of bedrock structures are manifested by same trends of the Snake and Nome rivers and the ridges between and along them. Glaciofluvial deposits from valley bottoms of both Snake and Nome Rivers; sporadic relics of moraines in some tributaries and sparse glacial erratics on upper slopes and tops of ridges and hills.

Mineral Deposits; Primary, Secondary - (A) Mt. Osborne area: Numerous simple pegmatites with single known occurrence of beryl. (B) Snake-Nome River area: Native gold and scheelite-bearing base metal sulfide vein and replacement deposits clustered at several localities in area. Gold placers, most with some scheelite, in alluvium on many tributaries of the Snake and None Rivers; few bench gold placers derived from reworked glacial drift.

Geochemical Survey - First survey on Seward Peninsula based on chemically analyzed samples; only previous work in same area was mineral survey based on panned concentrates by Coats (1944) to determine distribution of scheelite in stream gravels and gold placers throughout the Snake-Nome River area. Geochemical samples collected by Hummel in 1958; analyses arranged for by Chapman during following two years. Sources of possible natural adulteration and cultural contamination include: (A) Mt. Osborne area; natural-glacial drift, all indigenous to area; cultural - old, disintegrating, iron-band bound siphon and debris left from its construction. (B) Snake-Nome River area: Natural - some glacial drift in tributaries of Snake and Nome Rivers at least some proportion derived from Kigluaik Mountains and other areas north of sample sites; cultural - placer mining and related construction activities including old railroad and modern gravel road; quicksilver used to recover gold in most or all sluice clean-up operations.

Purpose and scale: Mainly orientation to evaluate stream sediments as basis for differentiating drainage basins with known mineral deposits from those not known to contain any; secondary purpose was to obtain data to distinguish between two strongly contrasting bedrock terranes. Samples collected sufficient only for grossest scale of regional geochemical exploration. Survey based on active stream sediments, so chosen and collected as to enhance the content of the finest size and organic material; material obtained from 5 to 10-meter diameter area from each sample site. All sediment samples collected above places where streams crossed by roads, railroad and siphons; samples from streams with gold placer workings collected only to avoid most obvious sources of contamination such as rusted mining equipment and other debris. Thirteen samples collected from Mt. Osborn area and 17 from the Snake-Nome area.

Laboratory and office procedures: All samples screened to minus 80 mesh, pulverized, and analyzed in U.S.G.S. Geochemical Exploration Branch laboratory in Denver. Analyses by visual and spectrophotometric methods for antimony, arsenic, bismuth, copper, lead, molybdenum, tungsten, and zinc; possible interference by organic content of samples.

Data processing and evaluation: Number of samples and analytical data sufficiently limited to permit empirical evaluation and interpretation.

Results: Multiple base metal anomalies from one drainage basin in Mt. Osborn area; general content of molybdenum greater in sediments from higher grade terrane than in those from Snake-Nome River area. Of the metals analyzed, the content of arsenic was greatest in sediments from drainage basins with known mineral deposits in the Snake-Nome River area, and most markedly less in those without deposits.

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2. SINUK RIVER AREA

Gordon Herreid, Alaska Division of Mines and Geology

Location and Area - Located 20 miles northwest of Nome; 400 square kilometers.
Topography, Relief, Drainage - Mainly rolling upland topography with some steep mountains and ridges. Relief ranges from 250 m. to 500 m. with greatest relief and steepest slopes in portions of area underlain by marble. Area generally is moderately to well dissected by well integrated drainage system.
Vegetation and Other Surficial Cover - Most of area is covered with tundra; exceptions are some rubble-topped hills and ridges, and marble mountains and ridges which are nearly devoid of vegetation.
Geology; Bedrock Surficial - All of bedrock is greenschist grade schist and calcitic marble with sparse metamafic bodies; extensive portions of marble have been silicified and dolomitized. Only small proportion of area has been glaciated; glacial drift covers about 10 percent of area.
Mineral Deposits; Primary, Secondary - Barite, fluorite, and base metal sulfides associated with some siliceous-dolomite replacement zones in marble; sparse base metal sulfide veins sporadically present elsewhere in area. Gold placers mined at several localities in area.

Geochemical Survey - Metallized replacement zones deposits in marble, the so-called Sinuk gossans, had been previously sampled, analyzed, and evaluated systematically by Mulligan and Hess (1965). Field work and sample collections by Herreid were done in 1965, 1966, 1968, and 1969. Glacial debris in area almost entirely of foreign origin, mainly from high-grade metamorphic terrane to north in Kigluaik Mountains. Small scale gold placer operations on some streams in area introduced potential contamination from all aspects of mining activities, including use of quicksilver to amalgamate and recover fine gold in sluice boxes. Mainly gravel of glacial origin used in construction of recently built road through area; culverts and bridges across streams, together with construction of them, may have yielded additional sources of potential cultural contamination.
Purpose and scale - Third order regional geochemical stream sediment survey and detailed sampling of soil and rocks in grids and along traverse lines across suspected and known mineral deposits.
Field procedures - Sample collection: Stream sediment samples were taken from mud below water level; soil samples were taken at a depth of 2 to 6 inches. (Herreid, 1970, p.14) 200 stream sediment and 188 soil samples collected in survey. Sample analysis: Field test by Hawkes cold extractable heavy metals method modified by using the ammonium citrate extractant undiluted made in field on 172 stream sediment and 80 soil samples (Herreid, 1966, p.16).
Laboratory and office procedures: All stream sediment and soil samples screened to minus 80 mesh; thereafter, total metal contents of copper, lead, zinc, and molybdenum analyzed by colorimetric and atomic absorption methods by Rocky Mountain Geochemical Laboratories, U.S. Geological Survey, and the Alaska Division of Mines and Geology (Herreid, 1970, p. 51). In addition, emission spectrographic analyses of all soil and sediment samples were made at both the MIRL laboratories at the University of Alaska and in the Anchorage Mobile Laboratory of the U. S. Geological Survey (Herreid, 1970, p. 52, 58).

Data processing and Statistical Treatments: Simple histograms prepared by hand and based on absolute values of copper, lead, and zinc derived from atomic absorption and colorimetric analyses; on basis of these, thresholds were determined intuitively rather than by statistical methods and so indicated on the histograms. Thresholds chosen constituted lowest concentration considered anomalous; anomalies included these and all greater analytical values. (Herreid, 1970, p. 14-15).

Results from stream sediments, soils, and rocks; Stream, sediments generally almost entirely ineffective in locating gossans, the major type of primary lode deposit in the area, even those strongly anomalous in zinc and lead as established by other evidence (Herreid, 1970, p. 14, 18, 39). One sulfide deposit with abundant surficial float discovered during survey yielded a strong sediment anomaly in Aurora Creek, and another previously known stibnite-gold prospect yielded a good sediment anomaly for antimony and arsenic in the creek below it. (Herreid, 1970, p. 14). Similar deposits were inferred from a few anomalies obtained from sediment samples at several other localities in the area (Herreid, 1970, p. 39).
Soil samples collected systematically along lines and in grids over and around known gossans yielded moderately strong to very strong anomalies of zinc and lead generally; for some deposits, other metals including barium, arsenic, boron, and beryllium were present in the soil in anomalous amounts (Herreid, 1970, p. 14-18). So-called rock specimens were, in fact, mainly selected gossan or altered and mineralized material; gossan samples especially contained strongly anomalous amounts of lead, zinc, and other metals (Herreid, 1970, p. 43). Geochemical data from soil and rocks, in conjunction with results of geologic investigations increased the areas of probable mineralization appreciably beyond those underlain by deposits known previously.

Publications:
Herreid, Gordon, 1966, Preliminary geology and geochemistry of the Sinuk River area, Seward Peninsula, Alaska: Alaska Div. Mines and Minerals Geol. Rept. 24, 19 p.
-----1968, Progress report on the geology and geochemistry of the Sinuk area, Seward Peninsula, Alaska: Alaska Div. Mines and Minerals Geol. Rept. 29, 13 p.
-----1970, Geology and geochemistry of the Sinuk area, Seward Peninsula, Alaska: Alaska Div. Mines and Geology Geol. Rept. 36, 63 p.
Mulligan, J.J., and Hess, H.D., 1965, Examination of the Sinuk iron deposits, Seward Peninsula, Alaska: U.S. Bureau of Mines Open File Rept., 34 p.

3. SOLOMON RIVER AREA
R. R. Asher, Alaska Division of Mines and Geology

Location and Area - Portion of lower Solomon River drainage basin comprising 480 square kilometers located 40 kilometers east of Nome.
Topography, Relief, Drainage - Rolling upland topography with a small coastal plain and a few mountains and ridges with steep slopes. Relief ranges from 75 to 500 meters with average about 300 meters. Most of area in drainage basin of Solomon River including its mouth at Norton Sound. Tributaries are well integrated with Solomon River which, together with remaining streams, have produced a well dissected terrane.
Vegetation and Other Surficial Cover - Nearly all of area is tundra covered with rubble and bedrock topped hills and ridges; exceptions are sparse mountains and ridges composed of marble and graphitic quartzite which have little or no vegetation. Gelifluction lobes cover most lower and middle slopes.
Geology; Bedrock, Surficial - Greenschist grade marble and schist with moderately abundant to abundant greenstone bodies form most of bedrock of area; both are cut by a few basalt dikes. Area affected by no more than minor glacial activity; alluvium along streams and modern and older, higher beach and lagoon deposits on coastal plain constitute most of surficial deposits of area.
Mineral Deposits; Primary, Secondary - Copper-bearing, sliceous replacement zones are widely distributed in marble; sparse gold and scheelite-bearing, base metal sulfide deposits present at several localities, including veins and stockwork mined at only lode gold mine ever operated on Seward Peninsula. Gold placers mined along most of Solomon River in area and on many tributaries to it; gold-bearing beach placer mined at one place on coastal plain.

Geochemical Survey; Natural and Cultural Sources of Possible Adulteration and Contamination - Combined geological and geochemical surveys in area with known mineral deposits for purpose of testing exploration methods and to discover new deposits; latter based mainly on stream sediments and secondarily on soil, rock and ore samples. Third order regional stream sediment survey of entire area; soil and rock samples collected in close-spaced grid at one locality.
Glacial drift of foreign origin may have been eroded and incorportated in modern alluvium in small portion of area. Sources of possible cultural contamination include; (1) modern gravel road with numerous culverts and an old, disintegrated railroad along Solomon River and a major tributary of it through the central part of area, (2) extensive dredge and sluice placer gold mining workings with associated repair and housing facilities along the Solomon River and many of its major and minor tributaries throughout the area, and (3) the Big Hurrah lode gold mine located on one of the principal tributaries of the Solomon River. Quicksilver used to recover fine gold in most sluice placer operations and cyanide to recover lode gold.
Field procedures: Stream sediment survey: Samples were collected at one-quarter mile (400 m.) intervals from the active bed of each stream in the upland portion of the quadrangle. Fine sand or silt, rather than coarse material, was collected when possible and stored in plastic bags. Care was taken to exclude organic material from the samples. (Asher, 1969, p. 22). 435 sediment samples collected from 480-square kilometer area.
Soil and rock survey: Samples collected in grid over portion of graphitic schist unit as follows; north-south traverse lines were established at one-quarter mile (400 m.) intervals. Samples were taken at stations approximately 1000 feet (330 m.) apart along the traverse lines. Where possible, a rock chip was taken; if this could not be done a soil sample was substituted. Four soil sample traverses were also made in the same unit; sampling interval was 50 or 100 feet (15-30 m.) (Asher, 1969, p.27).
Field analyses - stream sediment samples were analyzed in camp by dithizone field tests. Field test measured in milliliters of dithizone for cold extractable metals as described by Hawkes (1963) (Asher, 1969, p.22 and 32).
Laboratory and office procedures - Stream sediment and soil samples were dried in the Alaska Division of Mines and Geology laboratory at College, Alaska, then forwarded to the U.S. Geological Survey field laboratory at Anchorage. There samples were screened to minus 80 mesh, pulverized, and analyzed by atomic absorption methods for gold, copper, lead, and zinc. Remaining portions of pulverized samples were then sent to U.S.G.S. Geochemical Exploration Branch laboratory in Denver where 30-element semi-quantitative emission spectrographic analyses were made on all samples (Asher, 1969, p.22).

Data processing and Statistical Treatments - A computer program to tabulate the samples and calculate statistical characteristics of the analytical data was written by L. E. Heiner, Mining Engineer, University of Alaska. The IBM 360 computer at the University of Alaska performed the computations.
Samples were assigned map numbers before they were fed into the computer. The computer tabulated a list of samples and analytical data in numerical order according to map number. For each element the mean and the standard deviation were calculated. From these measures of central tendency, the threshold value, or upper limit of normal background fluctuation and anomalous values were determined for each element. The computer also plotted histograms of frequency distribution for selected elements. As a special project, a zinc trend surface map was plotted and residuals determined.
The threshold and anomalous values for each element were computed by methods described in Hawkes and Webb (1962, p. 30). The threshold value is taken as the mean plus twice the standard deviation; anomalous values are taken as the mean plus three standard deviations.
Frequency distribution histograms for copper and zinc as determined by atomic absorption and lead as determined by spectrograph were prepared by hand.
The concentration of an element in a given sample is either in the background range, between the threshold value and anomalous value, or greater than the anomalous value. Samples are considered possibly anomalous if the concentration is between the threshold value and the anomalous value, and probably anomalous if the concentration of an element is above the anomalous value. Samples containing concentrations of copper, lead, zinc, or gold in the possible anomalous and probably anomalous ranges are indicated. Samples containing anomalous amounts of cobalt, molybdenum, and silver are also shown. (Asher, 1969, p. 22-23).
First through sixth degree trend surface maps and residuals were prepared for zinc. Values as determined by atomic absorption were used. L. E. Heiner of the University of Alaska Mineral Industry Research Laboratory programmed the data for the IBM 360 computer. "The trend surface itself represents the regional component or geochemical trend. This surface, or the value of any point on the surface, represents a threshold value which is variable across the map area" (L. Heiner, Personal commun., 3-25-69). (Asher, 1969, p. 25-26).

Results: Stream sediments - sporadic anomalies of single metals in stream sediment samples from eastern part of area; anomalous contents of single and multiple metals in stream sediments from smaller western portion of area. Copper anomalies point out limestone-schist contacts, verify the presence of a fault, and indicate areas where greenstone crops out. Minor cobalt is also associated with the greenstone.

Lead in stream sediment samples is a reliable indicator element. A number of northwest-trending fractures were outlined by lead anomalies. Zinc, molybdenum, and silver are associated with the lead at places. Further exploration will be required to learn if mineralization is concentrated along the fractures in economic quantities. A zinc trend surface map supports the conclusion that northwest trending fractures are mineralized.

The trend map for zinc indicates a northwest regional trend of the geochemical data. The residuals, which represent anomalies, are also aligned northwest. The trend surface study confirms the conclusion that there are mineralized structures in the quadrangle that trend northwest. The trend surface also indicates that the structures extend across the entire quadrangle.

Because mineralized zones are indicated by geochemical anomalies rather than conventional prospecting techniques, no estimation of the quality or quantity of mineralization is possible. Further investigation of these zones may reveal economic deposits beneath the tundra.

Rock and soil samples - the results of a sampling program across the outcrop area in the graphitic schist unit are still being studied. A preliminary conclusion is that it apparently does not contain disseminated gold in economic amounts.

Publication:

Asher, R. R., 1969, Geologic and geochemical study, Solomon C-5 quadrangle, Seward Peninsula, Alaska: Alaska Div. Mines and Geology Geol. Rept. 33, 64 p.

4. IRON CREEK AREA

R.R.Asher, Alaska Divison of Mines and Geology

Location and Area - 90-square-kilometer area located 60 kilometers northeast of Nome.

Topography, Relief, Drainage - Rolling upland topography with flat-topped hills and ridges, except for prominent, marble ridge with steep slopes. Relief of upland portion of area averages about 150 m.; relief of marble ridge is about 300 m. Most of area lies in drainage basin of Iron Creek; area is generally well dissected by well integrated tributaries of Iron Creek.

Vegetation and Other Surficial Cover - Except for prominent marble ridge, which is almost devoid of vegetation, and outcrop and rubble-topped ridges and hills, area is covered with tundra. Willows occur with most of the tundra and alder patches are present sporadically in higher and better drained parts of the terrane. Gelifluction lobes occur on the lower and middle slopes of most of the hills and ridges of the upland.

Geology; Bedrock, Surficial - Bedrock of entire area is greenschist grade chloritic and graphitic schist and marble with sparse to moderately abundant metamafic bodies. Northern half of area glaciated and contains small areas of drift.

Mineral Deposits; Primary, Secondary - Prominent marble ridge extending northward through the area contains numerous copper-bearing, siliceous replacement zones; base metal sulfide vein present at one locality in area. Placer gold has been mined along most of Iron Creek and on many of its tributaries. (Hummel, 1975)

Geochemical Survey; Sources of Possible Natural Adulteration and Cultural Contamination

Third order economic mineral geochemical survey based on stream sediments. Field work, partly hampered by snow cover, done in five days in June, 1968. Glacial drift reworked into modern alluvium of Iron Creek and extensive cultural contamination possible from sluice and dredge placer mining and associated construction and building activities; quicksilver used to amalgate and recover fine gold in most sluice mining.

Field Procedures: A total of 49 stream sediment geochemical samples were taken from Iron Creek and its tributaries. Samples of fine material were taken from the active stream bed where possible. At some places it was necessary to collect material from the bank because of high water. Ice in many of the streams made geochemical sampling difficult. Samples were transported in plastic bags; they were tested in the field by the dithizone method described by Hawkes (1963, p. 580), (Asher, 1969, p. 1, 8)

Laboratory and Office Procedures: The samples were forwarded to the Alaska Division of Mines and Geology laboratory at College for drying. The dried samples were then sent to the U.S. Geological Survey field geochemical laboratory in Anchorage. There, samples were screened to minus 80 mesh and pulverized, and a portion of each was analyzed for gold, copper, lead, and zinc by atomic absorption techniques. The remainder of each sample was then sent to the USGS Geochemical Research laboratory in Denver where 30-element, semi-quantitative emission spectrographic analyses were made. Raw analytical data were returned to the Alaska Division of Mines and Geology at College.

Data Processing and Statistical Treatment- Lawrence Heiner Mining Engineer, University of Alaska, wrote a program -- to facilitate data processing. The computer tabulated a list of samples and calculated statistical measures of central tendency for each element detected. The mean value and the standard deviation were used to calculate a threshold and anomalous value for each element. Threshold is taken as the mean plus two standard deviations; the anomalous value is taken as the mean plus three standard deviations.

When the concentration of an element in a sample is below the threshold value, the concentration is in the background range of values. A sample is possibly anomalous if the concentration of an element is between the threshold value and the anomalous value. If the concentration of an element in a sample is above the anomalous value, the sample is probably anomalous. All sample locations are shown on a map of the area and samples containing possible and probable concentrations of elements are indicated. (Asher, 1969, p. 8-9)

Results- Stream sediment survey: Sporadic possible and probable anomalous values for several metals in sediment samples from the Iron Creek drainage; possible effects of cultural contamination not evaluated.

Several samples from one locality in the area contained anomalous lead, beryllium, zirconium, lanthanum, niobium, gold, and strontium. This association of elements is indicative of alkaline intrusive rocks, and it is likely that an unexposed dike or other body is in the vicinity. (Asher, 1969, p. 9-10)

Publication:

Asher, R. R., 1969, Geology and geochemistry of part of the Iron Creek area, Solomon D-6 quadrangle, Seward Peninsula, Alaska: Alaska Div. Mines and Geology Geochem. Rept. 18, 19 p.

5. 6. WESTERN BENDELEBEN MOUNTAINS

R. R. Asher, T. K. Bundtzen; Alaska Division of Mines and Geology/ Alaska Division of Geological and Geophysical Survey.

Location and Area - Combined areas of two geochemical surveys comprising an 800-square-kilometer areas in the western Bendeleben Mountain range located 100 km. northeast of Nome and 75 km. north of Solomon.

Topography, Relief, Drainage - Western half of area mainly rolling uplands with general relief of 250 m.; eastern half of area almost entirely rugged mountains with maximum relief of 820 m. near Mt. Bendeleben and average relief of 600 m. Western part of area has moderately well integrated drainage system; eastern part of area is well dissected by well-integrated drainage system, most forming the headwaters of the Niukluk River.

Vegetation and other Surficial Cover - Western half of area is generally tundra-covered with rubble and outcrop-topped ridges and hills. Only bottoms and lower slopes of major valleys covered by tundra in eastern half of area; remaining middle and upper slopes nearly devoid of vegetation.

Geology; Bedrock, Surficial - Amphibolite grade metasedimentary rocks with moderately abundant orthogneiss and granitic igneous bodies predominate throughout most of area; greenschist grade metamorphites make up subordinate proportion of bedrock in western part of area. Dikes varying from silicic to intermediate composition occur at many places. Several glaciatic" nave emanated and spread out from area. As a consequence, glacio-fluvial materials form the bottoms of the major valleys and moraines and frost-riven talus occur along the sides of most streams and rivers.

Mineral Deposits; Primary, Secondary - Several known base metal veins are present at one locality; in addition, simple pegmatites and altered rocks occur sporadically but widely throughout the area.

Geochemical Survey; Sources of Possible Natural Adulteration and Cultural Contamination

Although the results are reported separately, the field collections for both geochemical surveys in the western Bendeleben Mountains were made by the same geologist, T. K. Bundtzen; he was almost entirely responsible for collection of all the samples on which they are based, first as assistant to R. R. Asher in 1969 for the survey of the western part of the area (Asher, 1969, p. 5(, then the following year for the survey of the eastern part of the area, together with other smaller areas around the western area. Accordingly, the fieldwork for both surveys was done in the same fashion, at the same scale, and for the same purpose, namely, a third-order regional geochemical survey for metaliferous mineral desposits based mainly on stream sediments. Multiple alpine glaciations constitute a source of possible adulteration throughout the area. However all of the glacial debris was derived from higher portions of the larger rivers and streams; thus, some glacial material foreign to smaller drainage basins has been reworked into the modern alluvium and, in so-being, constitutes a source of natural adulteration at the scale of the surveys.

Field Procedures; Collections and Analysis of Samples -Stream sediment samples were taken at one-quarter mile (400 meter) intervals from the active bed of each stream in the project area. A composite sample from an area 25 to 50 feet (8-15 meters) long on both sides of the stream was taken at each sample site. Samples of fine silt as free as possible from organic matter were collected in cloth bags. The cloth bag containing the sample was placed in a plastic bag to prevent contamination from other samples during transportation and shipment. 425 sediment samples were collected in 1969 and 639 in 1970.

Each sample collected in 1969 was analyzed in camp by Bundtzen for heavy metals by a dithizone colorimetric technique described by Hawkes (1963); field analyses were not performed on samples collected in 1970. After field analyses were completed the samples were sent to the Division laboratory in College for precise determinations of metal content. The field test results were recorded by the milliliters of dithizone required to reach an end point. A field test of six milliliters was considered significant. Values ranged from zero to 22, but only six samples had a value of six or more. Field data, including information about the sample site, the location and the field test were entered on a specailly prepared form upon which could be entered information obtained later in the laboratory. (Asher, 1970, p. 17-18)

In addition to sediment samples 35 rock specimens were collected and analyzed during the 1969 survey, and 50 in the 1970 survey; in both cases, most of the specimens were pegmatite and other possibly mineralized rocks.

Laboratory and Office Procedures - The minus-80 mesh fraction of all of the stream sediment samples collected for both the 1969 and 1970 surveys were analyzed by atomic absorption for copper, lead, and zinc in the laboratory of the Division of Mines and Geology at College, Alaska. Results of the analyses were entered on the forms that contained the field data.

Thereafter, the samples were analyzed by 30-element semi-quantitative spectrographic methods. The spectrographic work was done by the Mineral Industry Research Laboratory of the University of Alaska under the direction of Lawrence E. Heiner. (Asher, 1970, p.18)

Only emission spectrographic analyses were made on the 1969 rock specimens, and only atomic absorption analyses of those collected in 1970.

Data Processing and Statistical Treatments - Although all field and laboratory procedures leading through analysis of all samples were the same for both the 1969 and 1970 geochemical surveys, the data from them were handled altogether differently; those from the earlier survey were entered, manipulated, and printed by computer whereas all data from the 1970 survey were plotted and tabulated entirely by hand.

For the 1969 survey, all the accumulated data pertaining to each sample were punched on IBM cards then the data were fed into the IBM 360 Computer at the University of Alaska. The computer program was written, managed, and supervised by Lawrence E. Heiner, Mineral Industry Research Laboratory, University of Alaska. The computer print-out tabulated the results of all analyses of each stream sediment sample, plus remarks, sample number and other information pertaining to the sample. The computer determined the average and standard deviation for each element based on the value for every sample. The computer also calculated a threshold and anomalous value for each element by using the average and standard deviation. The threshold and anomalous values for each element were arrived at by methods described in Hawkes and Webb (1962, p. 30). Threshold is taken as the mean plus twice the standard deviation; anomalous values are taken as the mean plus three standard deviations. To learn if the data are normally or lognormally distributed, and thus which value is the most reliable, the computer plotted histograms for copper, lead, and zinc as determined by atomic absorption. Histograms were also plotted using the logarithms of the data for the above elements. By comparing the two histograms for a given element the nature of the population distribution could be determined. The populations for copper, lead, and zinc are more nearly normally distributed than lognormally distributed. Therefore the anomalous and threshold values calculated directly from the data are used in this report. The various histograms are shown in appendix III. Histograms were not plotted for elements determined by emission spectrograph. The detection intervals increase geometrically and histograms are not useful. Element populations determined by emission spectrograph are assumed to be distributed normally. Threshold and anomalous values are taken as the mean plus two and three standard deviations respectively. To verify the threshold and anomalous values for copper, lead, and zinc, cumulative frequency curves were plotted on semi-logarithmic paper. The values obtained are similar to those obtained by assuming the data is normally distributed. (Asher, 1970, p. 18,20)

For the 1970 survey, all chemical and other data were tabulated by hand, then, histograms based on emission spectrographic data were prepared from those for selected elements. Anomalies were located by inspection of; (1) histogram plots (2) continental crustal averages, and (3) the limitations of the analytical technique of that particular element. Only the copper-lead-zinc anomalies analyzed by atomic absorption spectrophotometry were plotted on the location map. (Bundtzen, 1974, p.1)

Results; 1969 Survey, 1970 Survey - Because the results of the 1969 and 1970 geochemical surveys in the western Bendeleben Mountains were based on differing statistical and other treatments of their data, they are reviewed separately.
(A) 1969 Survey, Stream Sediments - Stream sediment samples from the east side of the area contain more copper and zinc than stream sediment samples from the west side of the area. Only two of the samples taken from the west side contain more than background amounts of copper or zinc, but lead is a fairly common anomalous or threshold element. On the east side of the area, copper, lead, and zinc are all fairly common anomalous elements. This indicates that there are two distinct and separate populations in the region and if statistical treatment were carried further they should be treated as such. In addition, on the west side, calcium is concentrated in stream sediment samples to a much higher degree than on the east side of the valley. This probably reflects gross variations in lithology in the two parts of the area and again indicates two separate populations that should be treated separately. (Asher, 197C, p. 20)
Four anomalous zones that may be significant were detected in the area, two each in the western and eastern portions. Follow-up work should be done on these four localities. Soil samples and rock samples would be useful, and if results are favorable. trenching to bedrock should be undertaken.
Because of extensive tundra cover and sparse outcrops, geochemistry is a more effective prospecting technique than visual inspection. Geochemical stream sediment sampling is a useful technique, but laboratory analyses are needed for the detection of subtle anomalies. Colorimetric analyses for cold extractable heavy metals are not sufficiently sensitive to detect anomalous zones in stream sediment samples. (Asher, 1970, p. 25)
Rock Analyses - Analyses of rock samples did not reveal the presence of significant mineralization. (Asher, 1970, p. 25).

(B) 1970 Geochemical Survey, Stream Sediments - Most sediment samples from the central part of the area lying east of Mount Bedeleben contain one to several base metals, Cu, Mo, Pb, Zn, in anomalous amounts; a suite of those from a locality just east of Mount Bendeleben also yielded anomalous contents of tin and tungsten. In addition, two other localities were identified on the perimeter of the 1969 geochemical survey. (Bundtzen, 1974, Plate I).
Rock and Soil Samples - Anomalous contents of base metals were detected in only a few rock and soil samples, one of the former being a copper ore with lead and zinc sulfides and anomalous silver. (Bundtzen, 1974 Plates VI, and VII)

Publications:

Asher, R. R., 1970, Geology and geochemistry of the Belt Creek-Libby River area, Seward Peninsula, Alaska: Alaska Div. Mines and Geology Geochem. Rept. 22, 44 p.

Bundtzen, T. K., 1974, Geochemistry of parts of the Bendeleben A-6, A-5, A-4, B-5, and B-4 quadrangles, Alaska: Alaska Div. Geol. Geophys. Surveys open-file report AOF-39, 0 p.

7. OFFSHORE SOUTHWEST SEWARD PENINSULA
C. H. Nelson and D. M. Hopkins, U.S. Geological Survey

Location and area - Three offshore areas along the southwest coast, one at Nome and two others east and west of Nome having a total area of 850 square kilometers.
Submarine Topography and Relief - All three areas are parallel to the coastline and extend from five to eight kilometers offshore; the sea floor of all areas is featureless with shallow slope from coastline to an average depth of 20 meters along the seaward limits.
Geology; Bedrock, Surficial - All areas are underlain by unconsolidated glacial, marine, and beach deposits up to 150 meters thick. These, in turn, overlie bedrock composed of greenschist grade metamorphites which continue along southward trends from similar rocks which form the bedrock on shore.
Mineral Deposits; Primary, Secondary - Gold-bearing beach deposits are present intermittently along most of the modern coast near Nome.

Geochemical Survey - Survey based on grab samples of bottom sediments collected in grid adequate to constitute third order regional survey; purpose of the survey was to determine distribution of native gold, together with the kind and character of the deposits with which it is associated.
Field Procedures - Grab samples from offshore area at Nome ranged in size from 2 to 12 kilograms; material over 5 mm. screened and discarded, remainder panned and colors counted. Grab samples from areas east and west of Nome averaged 10 to 30 kilograms; gravel screened and discarded, the remaining sample panned and colors counted on board ship (Nelson and Hopkins, 1972, p. 3-4).
Laboratory Procedures - After color counts, all concentrates sent to the laboratory of the U.S.G.S. Marine Geology Branch in Menlo Park where they were analyzed only for gold content by atomic absorption methods. Note: Color count estimate of gold was not confirmed for some samples by AA analyses. Lack of AA confirmation may be due to erroneous color count originally, loss of gold particles during sample transfer between containers or during transport from field to analytical labs in Menlo Park, Calif., or to incomplete solution of gold while processing for AA test (K. Leong, oral commun., 1969, quoted in Nelson and Hopkins, 1972, p. 12).

Data processing and statistical treatment - Nearly all samples were concentrated prior to analysis to avoid particle-sparsity effects. In addition, very large samples were collected from the areas lying east and west of Nome in order to remain within the limits of statistical reliability imposed by the relatively low concentrations and average particle sizes of gold in most samples. For data from the much smaller samples collected near Nome, moving averages were calculated to help alleviate particle-sparsity effects that were particularly apparent in the small-sized samples of gravel (>2 mm.) with very coarse gold (>1 mm.) (Nelson and Hopkins, 1972, p. 3). The samples from the Nome area ranged in weight from less than 2 lb. (1 kg.) to nearly 45 lb. (20 kg.), but most weighed less than 11 lb. (5 kg.). To compensate for inadequate sample weights, moving averages of gold tenor were calculated for groups of samples from similar sedimentary environments.

First, a mean value was calculated from samples from each square-mile (2.59 sq. km.) area in an arbitrary grid. Then, these values were averaged with those in square-mile areas to the east and west, and this average value was plotted in the central grid square. Because the original sample pattern consisted of samples collected on a 1-mile (1.6 km.) grid plus added samples at borehole drilling sites, each mean value was based on at least three samples, and most were based on five or more samples. The average total sample weight upon which moving-average calculations were based was 65 lb. (30 kg.). A comparison of cumulative frequency distribution on curves for individual and for moving-average gold values within a 6-square-mile (15.5 sq. km.) area of relict gravel indicates that particle-sparsity effects are greatly reduced by using moving average data (Nelson and Hopkins, 1972, p. 16).

Results - Nearly all the Nome samples were obtained within the 3-mile limit (5 km.), in areas leased by individuals under prospecting and mining permits; thus, the economic possibilities of specific areas cannot be discussed. However, it can be stated that in some areas where thin relict gravel overlies glacial drift, the gravel may contain enough gold to merit consideration as a minable ore body. Furthermore, although samples from the sea floor surface do not define any minable deposits in the areas of submerged beach ridges, such deposits could exist at depths of less than 10 feet (3 meters) below the sea bottom. Ore deposits in other areas, if present, probably lie at greater depths. Future prospecting for shallow offshore placer deposits in the Nome area should focus primarily upon the "skin deposit" on the drift and upon thicker basal gravel of the now-submerged beaches in areas where the beaches are composed mostly of material reworked from the glacial drift.

Gold is erratically distributed in the main drift area near Nome, but generally all samples contain clearly anomalous amounts of gold, and some are very rich. The variability of gold content per unit volume is partly due to the local thin patches of relatively barren current-deposited sand or mud that cover the richer gravel and partly due to the particle-sparsity effect of samples too small to be representative. Samples from one 6-square-mile (15.5 sq. km.) area have an average value of $1.48 per cubic yard (920 ppb), and the gold consists mostly of No. 3 size flakes (1 mm. diameter) (Nelson and Hopkins, 1972, p. 16). The richest concentrations and coarsest particles (1 mm. or larger) of gold occur in sea-floor relict gravels that mantle glacial drift lobes in the Nome nearshore region and in gravel patches over bedrock in the Sledge Island area; these bodies of relict gravel formed during transgression and regression of the shoreline when eustatic changes of sea level occurred in Pleistocene time.

Relict gravels that overlie outwash fans appear to have no concentrations of gold in their upper surface; however, drilling suggests that buried outwash and alluvial channels that cut into auriferous glacial drift can contain significant concentrations of gold.
The submerged beach gravels of the sea floor, which are identified by their bathymetric locations and by pebble roundness and lithology, contain only low concentrations of gold; however, the gold content may be greater in the buried backbeach deposits.

Trends toward higher median content of pannable particulate gold (>1 ppb) and slightly coarser gold in the bottom sediments near the Seward Peninsula coast point to the Nome-Sledge Island area as a major source for the gold dispersed in the finer sediments of the northern Bering Sea. Local source areas have median gold values about 10 or more times than those of areas without gold concentrations; they also contain gold particles of 1 mm. or larger.

Statistical analysis of values in the richest 6-square-mile (15.5 sq.km.) area of the highly auriferous relict gravels near Nome indicates the following: gold particles about 1 mm. in diameter are common, these particles are randomly distributed, bottom samples are representative, the surface gravel averages 920 ppb in gold, and potentially minable deposits are present.

Although surface samples contain relatively little gold, presence of coarse gold, high background values, and geologic setting suggest that gold may be concentrated in submerged beach sediments. Very closely spaced drilling and vertical sampling increments would be necessary to detect any possible back-beach deposits, which are most likely to occur where inner beaches have been cut into auriferous till.
The coarse gold and high background values in gravel patches over seafloor bedrock of the Sledge Island area indicate a possible offshore gold source; this area as well as the gravel shoal to the northwest are promising for gold exploration. (Nelson and Hopkins, 1972, p. 25).

Publication:
Nelson, C. H., and Hopkings, D. M., 1972, Sedimentary processes and distribution of particulate gold in the southern Bering Sea: U.W. Geol. Survey Prof. Paper 639, 27 p.

8. TELLER AREA

R. Kachadoorian and C. L. Sainsbury, U.S. Geological Survey

Location and Area - An area of 525 square kilometers just south of Teller which includes nearly all of the Teller A3 quadrangle and adjoining parts of the Teller A4 quadrangle.
Topography, Relief, Drainage -Rolling upland topography with flat-topped ridges and hills. Relief averages consistent 150 to 250 m. throughout area. Area is well dissected by well-integrated drainage, most tributary to the Bluestone River.
Vegetation and Other Surficial Cover - Except for rubble and outcrop-topped ridges and hills, entire area is tundra-covered. Gelifluction lobes present on lower and middle slopes of most ridges and hills.
Geology; Bedrock, Surficial - Bedrock composed mainly of greenschist and sub-greenschist grade chloritic schist, marble, slate, quartzite and sparse greenstone; large gabbro bodies cap numerous hills and ridges and limestone is present at one locality. Area generally unglaciated; glacial drift present only in southeast corner.

Mineral Deposits; Primary, Secondary - No primary mineral deposits in area. Gold placers mined along parts of upper Bluestone River, its headwater tributaries, and on two other streams in area (Hummel, 1975); cinnabar, cassiterite, and platinum group metals occur in some gold placers. (Sainsbury, 1969, p. 15)

Geochemical Survey; Previous Work, Possible Natural Adulteration or Cultural Contamination - A heavy mineral survey for radioactive minerals based on panned stream concentrates was made in central part of area in 1946 by White and others (1953); no chemical analyses were made on samples. Third-order regional geochemical survey based on stream sediments for mineral exploration made by Sainsbury and others in 1967. Portion of area covered by glacial drift not covered by survey; some wind-blown silt probably over rest of area. Dredge and sluice gold mining and associated cultural effects and activities, including use of quicksilver in most operations, constitute principal sources of possible contamination in streams of area. Helicopter with mercury clutch used to collect samples cited by authors as possible additional source of mercury contamination.
Field Procedures - 158 samples collected from active stream channels with bias toward sediments with a naturally greater content of heavy minerals. Suite of samples on which survey based sent to U.S.G.S. Geochemical Exploration Branch Laboratory in Denver.
Laboratory Procedures - Representative fraction of total sediment sample analyzed; sample unscreened but hand-picked for coarse particles. All samples analyzed in laboratory of U.S.G.S. Geochemical Exploration Unit Branch in Denver, first in 1968 by atomic absorption, colorimetric, and instrumental methods for arsenic, copper, mercury, nickel, lead, and zinc, and in 1974 for the standard suite of 30 elements determined by the Survey's semi-quantitative emission spectrographic technique.

Data Processing and Statistical Treatment - All analytical data from the survey were entered in the survey computer system, then printed out directly and treated statistically in accordance with the survey's standard GEOSUM program.

Results - Metals judged by Sainsbury to be present in anomalous amounts in the stream sediment samples on the basis of the 1968 analyses were described and reported in 1969 (Sainsbury and others, 1969, p. 15-16, 42-44). The main purpose of the later report (Kachadoorian and others, 1975) was to compile and make available all of the analytical data derived from samples collected during the 1967 survey; in doing so, no attempt was made to interpret them.

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9. YORK PENINSULA

C. L. Sainsbury, U.S. Geological Survey

Location and Area - The westernmost part of Seward Peninsula lying west of the American River, long called the York Peninsula, comprises a total area of more than 8,000 square kilometers. Although it contains some of the best known mineral deposits and greatest mineral potential on the peninsula, geochemical surveys have only been made in three small, isolated areas in the region, one of about 50 km^2 at Ear Mountain, another of about 15 km^2 at Cape Mountain, and the third of 40 km^2 at Brooks Mountain and Lost River.

Topography, Relief, Drainage - The York Mountains in the western part of the region, and the Shishmaref lagoonal coastal plain which forms the northern coast, are the most prominent physiographic features of the York Peninsula, the remainder of the region consisting mostly of flat-topped and rolling upland topography. The North American Continental Divide passes from east to west approximately through the center of the region; the divide ends at Cape Mountain at the western tip and separates drainage systems which flow north to the Chukchi Sea and south to Bering Sea. Except for the coastal plain, the three areas surveyed include the extremes of terrane character in the region: the Ear Mountain area is dominated by an isolated, rounded hill which has produced relief ranging from 300 to 550 meters and produced a system of streams radiating from it. At the other extreme, the Brooks Mountains-Lost River area in the center of the York Mountains is composed mainly of well-dissected steep-sided mountains and ridges with a general relief of 600 to 700 meters and a well-integrated drainage system, most tributary to Lost River. The character of the Cape Mountain area is intermediate between that of the other two; with an average relief of about 400 meters, the area is moderately well dissected by moderately well integrated drainage.

Vegetation and Other Surficial Cover - The three areas also differ markedly in vegetation: Whereas that at Ear Mountain is entirely covered with tundra, only the valley bottoms and lower slopes of the Lost River-Brooks Mountain area have any tundra, such as is present being sporadic even there with the middle and upper slopes almost devoid of vegetation. Again, the Cape Mountain area, with sparse to moderately well developed tundra cover, is intermediate between the extremes represented in the other areas. Finally, gelifluction lobes are abundant on the slopes of Ear Mountain, but largely absent in the Lost River area, where bare outcrops and talus runs form most of the middle and upper slopes of the ridges and mountains.

Geology; Bedrock, Surficial - Carbonate rocks form the preponderant proportion of the bedrock of the York Peninsula, with graphitic slate, siltite, and graywacke in sporadic areas forming a subordinate proportion; these are succeeded to the east and southeast by greenschist grade marble and chloritic schist as the predominant bedrock lithology, with the other types present only in isolated areas in it. Gabbro and metagabbro bodies occur widely throughout the region, and granite plutons together with numerous silicic and mafic dikes are present at a few localities. These latter, together with their associated mineral deposits, have long been the principal targets for mineral exploration and development in the region; the three areas of geochemical surveys covered here include the largest granite bodies exposed in it. In each area, carbonate rock intruded by these form most of the bedrock; at Ear Mountain and Brooks Mountain, graphitic rocks are also present. Both the York Mountains and Cape Mountain have been the source areas for several glaciations, but only small deposits of glacial drift remain in the areas covered by the geochemical surveys; however, Lost River Valley is made up of much reworked glacio-fluvial material, most derived from the Lost River drainage basin. In marked contrast the Ear Mountain area was not glaciated but instead is covered by a thick blanket of wind-blown silt, most of which came from outside it.

Mineral Deposits; Primary, Secondary - Within each of the areas in which geochemical surveys were made, and at several other localities on the York Peninsula, tin and tungsten-bearing lodes, and placer deposits derived from them are closely associated with the granite plutons and silicic and mafic dikes in and around them. The tin-tungsten lodes include skarns, veins, altered zones, and pegmatites; sparse sulfide deposits genetically related to these are also present in all three areas. Gold occurs with some of the cassiterite-wolframite placers; however, no placers have been worked for gold in any of the survey areas; the only such placers in the region which were mined for gold occur in a small area north of Grantley Harbor.

Geochemical Survey, Sources of Possible Adulteration and Contamination - Although Sainsbury's were the first true geochemical surveys made in the Ear Mountain, Cape Mountain, and Brooks Mountain-Lost River areas, and in the region generally, a radioactivity survey based on panned stream concentrates was made at Ear Mountain in 1945 (Killeen and Ordway, 1955), and considerable exploration drilling of and for placer deposits had been done by the U.S. Bureau of Mines (Mulligan, 1959A, 1959B, and Mulligan and Thorne, 1959). The latter work involved quantitative evaluation of alluvial placers in each of the areas and were based on panned concentrates, most of which were also analyzed mineralogically and chemically; accordingly, the reports covering their results are valuable sources of information bearing on geochemical surveys. The specific purpose of the geochemical surveys of all three areas was to locate the bedrock source or sources of beryllium which had been detected in anomalous amounts in some of the Bureau of Mines concentrates (Sainsbury, 1963, p. 1). All were based mainly on total stream sediments collected in 1960; as an out-growth and elaboration of the results from these surveys, Sainsbury later collected and obtained analyses for rocks, minerals, ores, soils, and plants; on the basis of data from these he synthesized the geochemical cycle of beryllium and of several other constituents of the mineral deposits of the region (Sainsbury and others, 1960).
Glacial and periglacial deposits either occur in all of the areas, or have been incorporated in the modern detrital deposits in them.
In both the Cape Mountain and Brooks Mountain-Lost River areas which were glaciated, all of glacial debris was derived from within them; however, in the latter area especially, mineralized material derived from the headward parts of the streams and rivers drainage systems could have constituted a source of natural adulteration of sediments downstream. Similarly, in the Ear Mountain area, much of the non-indigenous wind-blown silt which mantles it has become incorporated in the modern stream sediments.
In addition, considerable exploration for both lode and placer deposits has been done in all of the areas, and placer and lode deposits have been mined at Cape Mountain and Lost River. Together

with their related construction activity, these operations constitute possible sources of large-scale, cultural contamination for many elements but not for beryllium.

Data Processing and Statistical Treatments - All data for beryllium were shown and interpreted empirically according to analyzed values; no computer statistical treatments were utilized.

Field Procedures - For this work, a bulk sample of the fine-grained sediment found in the lee of boulders was collected in most streams. Most of this sediment passed a 40-mesh screen. If it proved impractical to secure such sediment, larger amounts of coarser material were screened to obtain sufficient material. On hillslopes without streams, sediments in rivulets or water-sorted alluvium were sampled (Sainsbury, 1963, p. 17).
Laboratory and Office Procedures - The beryllium content of the stream sediment and slope wash samples was determined by both special quantitative analytical techniques and by the standard U.S.G.S. semi-quantitative emission spectrographic method.

Results - Only the results from the stream sediment surveys of the Ear Mountain, Cape Mountain and Brooks Mountain-Lost River area are summarized here. Although they gave rise to the collection and analysis of a much broader spectrum of materials later, these were selected from throughout the region, more to be representative for the topical study of geochemical cycles than for systematic geochemical surveys; their chief value to the surveys is for orientation to indicate the best materials on which to base them.

Ear Mountain - The beryllium content of stream sediments and alluvium collected by the writer in 1960 show a distinct geochemical anomaly around the granite (Sainsbury, 1963, p. 14-15).
Cape Mountain - Geochemical reconnaissance show anomalous amount of beryllium, which are not, however, as great as those at Ear Mountain and Lost River. The geochemical data are insufficient to prove or disprove the existence of beryllium deposits, but additional prospecting is warranted (Sainsbury, 1963, p. 15).

Brooks Mountain-Lost River -In general, excellent correlation demonstrated between anomalous content of beryllium in stream sediments from known mineralized localities (Sainsbury and others, 1961, p. C16-17 and Sainsbury, 1963, p. 15).
In Camp Creek, and eastern tributary of Lost River, a long and continuous lode system crops out in the small drainage basin. In this small stream the maximum amount of beryllium in total stream sediment was 160 ppm, and in all samples the amount exceeded 100 ppm. Large and small boulders of fluorite-beryllium rock form a significance proportion of the bed load, and these boulders contain beryllium in the range of 0.2-1.75 percent BeO.
In Tin Creek, a larger stream that contains both granite and beryllium-fluorite lodes within its drainage basin, sediments contain beryllium in the range of 10-30 ppm;the highest value was found in sediments downstream from the area of marble that contains numerous veinlets of fluorite-beryllium rock.

In Rapid River valley, where a mineralized belt in limestone crosses the stream, sediments contain as much as 16 ppm beryllium, but values decrease rapidly to less than 3 ppm within a mile downstream.
Stream sediments from the east headwaters of the Mint River, which drains the southwest margin of the granite of Brooks Mountain, consistently contain more than 13 ppm beryllium, yet careful search has failed to find significant fluorite-beryllium lodes. The apparent anomaly is explained by the large amount of granite in the stream sediments and by the fairly large volume of vesuvianite from the contact zone of the granite. The granite contains 15 ppm beryllium, and the vesuvianite as much as 50 ppm beryllium. (Sainsbury and others, 1968, p. 30-31)

York Peninsula, General - From the analyses of the stream sediment samples cited above, and others collected after 1960, it has been determined that the beryllium content of total stream sediments less than 40 mesh in size varies greatly with the rock type within the drainage basin of the streams. In limestone areas, the background content of beryllium probably does not exceed 1.5 ppm and definitely is below 3 ppm. Where granite underlies a substantial part of the drainage basin, the beryllium content of stream sediments may approximate that of the granite (as much as 18 ppm). Hence, a value that definitely is anomalous in one area is not anomalous in another, and these differences should be kept in mind during geochemical prospecting.
In limestone areas a beryllium content in the range of 3-5 ppm might be termed the "threshold" value, and beryllium in the range of 5-10 ppm definitely is anomalous. The maximum values to be expected in sediments will, of course, be a function of the size of the drainage basin, of the amount and richness of ore bodies exposed at the surface within the basin, and of their nearness to the stream. An upper value to be expected in the Seward Peninsula, and probably elsewhere in the Arctic and sub-Arctic, where mechanical disintegration predominates over chemical decay, should approximate the values obtained in Camp Creek, in the Lost River area. (Sainsbury and others, 1968, p. F30-31)

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10, 11. SERPENTINE HOT SPRINGS AND SERPENTINE RIVER AREAS

C. L. Sainsbury, T. Hudson, R. Kachadoorian, T. Richards, W. Marsh, and R. Ewing; U.S. Geological Survey

Location and Area - Two areas, one of about 350 square kilometers centered on Serpentine Hot Springs located 100 kilometers west of Deering (10) on the north coast of Seward Peninsula, and another of about 60 square kilometers at the head of the Serpentine River 25 kilometers west of Serpentine Hot Springs (11).

Topography, Relief, Drainage - Most of both areas consists of rolling uplands with rounded or flat-topped hills and ridges; sparse hills and ridges with steep upper slopes and rubble and rocky tops form small parts of both areas. Maximum relief locally in each area is about 500 meters with the average relief for both ranging from 150 to 450 meters. Both areas moderately to well dissected by moderately to well integrated streams, most of which are headwater tributaries of the Serpentine and Goodhope Rivers.

Vegetation and Other Surficial Cover - Except for rubble and outcrop topped hills and ridges, all of both areas is covered with treeless tundra. Gelifluction lobes are present on the lower and middle slopes of most hills and ridges.

Geology; Bedrock, Surficial - Greenschist and sub-greenschist grade metamorphites including marble, graphitic siltite and schist, and chloritic schist and greenstone make up most of the bedrock of both areas. In addition, orthogneiss forms a small part of the Serpentine Hot Springs area (10); both the orthogneiss and other metamorphic rocks of this area are intruded by a small granite body pluton. Neither area has been glaciated but the lower and middle level hills and ridges in the northern parts of each area are covered with wind-blown silt loess one meter or more thick.

Mineral Deposits; Primary, Secondary - Several copper-bearing silicified replacement zones in marble, together with a more complex base metal sulfide lode occur in the Serpentine River Area (11). Pegmatites together with altered and mineralized felsic and mafic dikes are associated with the granite body in the Serpentine Hot Springs area (10); in addition, metalliferous quartz veins and altered zones has been identified in it during field investigations preceding the geochemical survey there. (Sainsbury and others, 1970, p. 8-10) Gold placers have been worked at the head of Humboldt Creek in the Serpentine Hot Springs area; cassiterite had been identified in the concentrates from these workings. (Sainsbury and others, 1968, p. 1) It had also been reported from the Serpentine River and cassiterite-bearing tactite pebbles had been found in it during previous field investigations by Sainsbury. (Marsh and others, 1972, p. 1)

Geochemical Survey; Previous Work, Possible Sources of Adulteration Contamination - As a result of the determination of high radioactivity from a concentrate from placer workings near the Serpentine Hot Springs, radioactivity surveys based mainly on placer and panned stream concentrates were made around the Hot Springs and the gold mining areas at the head of Kougarok River south of it by Moxham and West in 1946 (Moxham and West, 1946); only radioactivity measurements together with sufficient mineralogy to identify its source, were determined from the concentrates. No significant radioactivity was determined from those collected from the head of the Kougarok River; in marked contrast, all of those from the Serpentine Hot Springs area were more or less radioactive. From these results, in conjunction with bedrock measurements and mineralogic studies, the authors attributed the radioactivity to several accessory minerals disseminated in the granite and pegmatites in the area. (Moxham and West, 1953, p. 7-8).

The geochemical surveys of the Serpentine Hot Springs and Serpentine River areas were based on samples collected during several field seasons. The first were collected in 1967 throughout a much larger area in north central Seward Peninsula aggregating about 2000 square kilometers which included both areas. Thereafter, new collections were made in the Hot Springs area in 1968, and in the Serpentine River area in 1971. Some of the results from the 1967 and 1968 field investigations were released in 1969 (Sainsbury and others, 1969, p. 39-41,45); then, these and others, together with those from the following years, were used as the basis for the two reports covering the geochemical surveys of both areas. (Sainsbury and others; 1970, and Marsh and others 1972). The Serpentine Hot Springs geochemical survey comprised analyzed samples of bedrock and stream sediments and of various fractions of both; the Serpentine River survey was based entirely on panned stream sediment concentrates. Generally,for both areas, sediment sampling was adequate for third-order reconnaissance surveys; however, that done for a portion of the Hot Springs survey was much more detailed. The purpose of both surveys was economic mineral exploration, the emphasis of the one on the Serpentine River being mainly on tin and that of the Hot Springs area on a somewhat broader spectrum of metals.

Varying amounts of foreign wind-blown silt, some one or more meters thick, constitutes a possible source of natural adulteration of bedrock detritus in alluvium in both areas; in addition, emissions from the hot springs for which Serpentine Hot Springs is named and volcanic ash from Devil Mountain north of them may have been other sources of possible natural adulteration there.

Field Procedures - Results from only total stream sediment samples collected by helicopter during 1967 in the Hot Springs area were used for the geochemical survey of that area. All were sent first to the field laboratory of the Survey's Geochemical Exploration Branch in Anchorage, and thereafter to its permanent laboratory in Denver. During the 1968 season, all samples as collected were prepared for analysis in the field as follows: Bedrock samples were crushed to -1/4-inch (6mm.) mesh in a jaw crusher, a split was saved, and the remainder was pulverized in a ceramic-plate pulverizer. A weighed portion of pulverized material was panned, and the panned concentrate was weighed and analyzed as a check against analyses of unpanned mineralized samples. Stream sediments were collected from behind rocks on stream bars, then air dried and screened through a 40-mesh plastic screen; each of the total samples was later pulverized to -200 mesh. To supplement the stream-sediment survey on Humboldt Creeks, numerous samples of concentrates were collected by panning stream gravels as well as alluvium in cutbanks. Concentrates were air dried and weighed, a split was saved for mineralogical work, and the remainder of the concentrates was pulverized and analyzed by the same methods as those used for bedrock and stream-sediment samples. After pulverizing each sample, the pulverizer plates were cleaned by pulverizing a teaspoonful of white quartz, and the resulting powder was added to the sample previously pulverized. This was done to pre-

vent contamination of later samples, because laboratory experiments by J. C. Antweiler (oral commun., 1967) have shown that even small gold particles may smear onto the pulverizer plates and register in the following sample (Sainsbury and others, 1970, p. 1-13).
Only panned stream sediment concentrates were collected for the Serpentine River survey in 1971. Like those from Humboldt Creek cited above, the coarse oversize material was first hand-picked from them and saved, then the remainder was submitted for analysis without further screening.

Laboratory Procedures - All stream sediments samples submitted in 1967 were screened to minus 80 mesh before being analyzed by emission spectrography for all metals determined except gold and mercury, which were detected, respectively, by atomic absorption and instrumental techniques. As described above all samples of both bedrock and stream sediment fractions were prepared for analysis in the field. Later, in the USGS Geochemical Exploration laboratory in Denver, they were analyzed for gold by atomic absorption, for mercury by mercury detector, and for other elements by semiquantitative spectro graphic analyses. Some duplicate splits of samples were analyzed for copper, lead, zinc, tin, and arsenic by wet chemical methods. With the exception of results from gold analyses, which were erratic, analytical results generally were in good agreement (Sainsbury, 1970, p. 3).

Data Processing and Statistical Treatment - Analytical data for the Serpentine Hot Springs area were selected and plotted according to the following method:

1. Background values of elements in various lithologic units were selected according to results of analyses of nine bulk samples of unaltered rock units; "anomalous" values are those that exceed the maximum content found in unaltered rock units.
2. Only elements that are anomalously high in the selected specimens of argentiferous galena, or in samples of altered rock along faults and veins, are considered. These elements include gold, silver, mercury, arsenic, cobalt, copper, molybdenum, nickel, lead, antimony, tin, tungsten, and zinc.
3. Elements present in each sample in amounts above background values were noted, and a numerical value of the anomaly for each metal was determined by dividing the total content for that metal by the background value shown in table 1. This gives a ratio in which the background is represented by the number 1. If the numbers representing the concentration ratios are added and the sum of the backgrounds is subtracted, this gives a figure which represents the magnitude of the total anomaly at that sample site. For instance, a sample that contains 15 ppm (parts per million) Mo, 100 ppm Sn, and 15 ppm Ag would be treated as follows: $15 \div 5 = 3$ (the concentration ratio), $100 \div 5 = 6.6$, $15 \div 1 = 15$, and $3+6.6+15 = 24.6$ (the total concentration ration). The anomaly, however, is 24.6 -3 (the sum of the three backgrounds represented by the number 1 for each element present in more than background concentration), or 21.6. (Sainsbury and others, 1970, p. 3-4, 8).

Results - Total Stream Sediments and Panned Concentrates, Rocks and Ores - Serpentine Hot Springs Area - A reconnaissance geochemical survey in 1967, using only the -80 mesh fraction of stream sediments, did not show anomalous tin on Humboldt Creek, where cassiterite in nuggets as much as 3 inches (8 cm.) in diameter was observed in sluice-box concentrates from placer gold mining. Consequently, alternative methods were applied in 1968 to determine the applicability of different geochemical techniques in this area, where heavy and chemically resistant minerals (gold and cassiterite) were expected to be found in association with base-metal sulfide minerals. In general, both -80 mesh and -40 fractions of stream sediments show only relatively low anomalies with respect to the background values of rock units in the drainage basins of the streams sampled. Anomalies in sediments must be interpreted on the basis of one to three metals in low amounts - generally much lower than five times the failure of stream sediments to point to the lodes found subsequently in the drainages of Humboldt Creek, by sampling and analyses of altered bedrock, is noteworthy. The exploration geologist in search of mineral deposits in this part of Alaska, especially placer deposits, would do well to apply several of the known methods of geochemical exploration, especially panning. (Sainsbury and others, 1970, p. 11-12)

In the detailed geochemical survey on Humboldt Creek, tin was found in panned concentrates of surface stream gravels only in the east fork, where several samples contain the metal in anomalous amounts. In the sluice-box concentrate, tin and several other metals were detected in highly anomalous amounts. The metals that were concentrated in the argentiferous galena sample (gold, silver, lead, arsenic, cobalt, copper, molybdenum, nickel, antimony, tungsten, tin, zinc, and mercury) are commonly associated only in the panned concentrate. If the total concentration of elements, in parts per million, is divided by the concentration ratio (weight of total sample divided by weight of concentrate), most of the anomalies in concentrates disappear; nevertheless, analyses of panned concentrates would lead one directly to the base of the known outcrop of galena from a point far downstream. Analyses of samples of stream sediments, however, would fail to do so, unless the samples were collected very near the lodes.
Of all the metals, mercury shows the most clear-cut, direct correlation with the total metal anomaly, although it seldom accounts for a large share of the total anomaly.

A marked inverse relationship exists between manganese and total trace metals in the altered zones samples. Whether this relationship represents a selective leaching of manganese during supergene alteration of sulfides, or whether it represents leaching of manganese by ore solutions, is not known. In either case, the absence of manganese from mineralized samples is a direct indication of possible mineralized structures. (Sainsbury and others, 1970, p. 12, 18)

Bedrock Geochemical Survey of the Serpentine Hot Springs Area: - Two main areas of mineralized bedrock were samples in detail. One area represented by bedrock samples consists of an altered zone that strikes about N. 55° W. across a saddle southwest of the south headwaters of Humboldt Creek. Float of rusty fracture fillings and rusty quartz lies along the zone, which can be traced at least 2,000 feet. Bulk samples of float quartz and altered graphitic siltite along the zone contain anomalous amounts of many metals, and a grab sample of rusty float contains highly anomalous amounts of gold, silver, mercury, arsenic, copper, molybdenum, lead, antimony, and zinc, amounting to more than 1,000 times the total background value of these metals. Samples that contained only a few metals in anomalous amount yielded panned concentrates that contained, in addition, many related metals in anomalous amount.

In a second area, silver-rich galena crops out on the south side of the southwestern headwaters of Humboldt Creek. Here an altered and stained fault zone can be traced for at least 2,500 feet, and it is probably continuous for an additional 2,000 feet. Numerous samples contain highly anomalous amounts of gold, silver, lead, mercury, arsenic, molybdenum, antimony, tin, copper, and tungsten, all of which are enriched in the hand specimens of argentiferous galena. Float fragments of galena occur only in a small area on the slope break of the drainage. Samples of frost-riven float of altered graphitic slate and stained quartz taken over an area of 1,000 feet by 200 feet (300 x 60 m.) along the altered fault contained highly anomalous amounts of metal. Again, panned concentrates showed a great increase in number of anomalous metals. A sample of stained quartz collected 2,000 feet (600 m.) away along a narrow altered zone that is the probable continuation of the mineralized fault contained 15 ppm Ag, and anomalous gold, copper, and molybdenum. Continuity between these samples localities is assumed only, because talus mantles the slopes between.

Numerous other samples of altered zones contain anomalous amounts of several metals, especially in the highly faulted area on the southeastern side of the granite. Several samples of altered and silicified marble collected above the thrusts east of Humboldt Creek show anomalous amounts of several metals, as did samples of altered schist collected between the klippe of marble. The authors attach more importance to the altered rocks adjacent to the thrust faults near Humboldt Creek because many different metals characteristic of the altered and mineralized rocks near the granite are found in altered rocks along the faults near Humboldt Creek.

Serpentine River Geochemical Survey:- Tin-bearing concentrates all come from the Serpentine River or streams entering from the east. On the other hand, lanthanum and cerium, with very little tin, occur in concentrates from streams entering the Serpentine River from the west. In one concentrate, europium was detected (200 ppm). This suggests that a europium-bearing monazite may occur in the chloritic schists. Obviously, the east drainages should be searched for the lode sources of tin, the west drainages for those of euorpium monazite.
In future prospecting of the general area, it cannot be over-emphasized that panned concentrates are more dependable in searching for buried lodes than are total stream sediments. This was clearly proved by the work in 1968 around the granite of Serpentine Hot Springs (Sainsbury and others, 1970).

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12. INMACHUK AREA

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Location and Area - Area of 450 square kilometers at the head of Inmachuk River, 40 kilometers southwest of Deering.
Topography, Relief, Drainage - Most of area consists of rolling uplands with flat-topped ridges and hills drained by moderately to well integrated streams all headwater tributaries of the Inmachuk River. Relief of uplands ranges from 150 to 350 meters. Small part of area is flat and swampy with little or no relief and sparse, poorly integrated drainage.
Vegetation and Other Surficial Cover - The entire area is covered with tundra; gelifluction lobes are present on the lower and middle slopes of most hills and ridges.
Geology; Bedrock, Surficial - The bedrock of the entire area is composed of greenschist grade chloritic schist, marble, and graphitic schist and quartzite; the metamorphites are intruded by two small granite plutons. Dissected remnants of the Imuruk Lake lava fields occur at several places in the area and underlie the flat, swampy part entirely. Except where eroded along the Inmachuk River, wind-blown silt more than one meter thick covers the entire area.
Mineral Deposits; Primary, Secondary - Gold and silver-bearing, base metal sulfide siliceous-replacement zones occur in marble at two localities. In addition, gossans and dolomitic altered zones in marble are present at several other places in the area. Gold placers have been mined along much of lower Inmachuk River and on parts of several other streams of its tributaries.

Geochemical Survey-Sources of Possible Contamination - As the first geochemical survey in the area, it was designed mainly to extend the known mineral deposits locally, and to attempt to locate others elsewhere in the area. The survey was based mainly on stream sedi-

ments which were collected during two weeks in July, 1965. As completed, the sample density was adequate for a third order regional geochemical survey.
Both the eroded lava and wind-blown silt have been incorporated in the modern stream sediments and so constitute probable natural sources of adulteration of bedrock detritus. Placer mining, lode exploration, and related contruction and other activities comprise sources of possible cultural contamination in the area.

Field Procedures - Stream sediment samples composed of mud or silt, from below the water where possible, were collected at a 158 sites throughout the area; in addition several dozen soil samples were collected near the two known mineral deposits and a few others on and near the gossans and altered zones. (Herreid, 1966, p. 7).
Nearly all of the soil samples, and about half of the stream sediment samples, were analyzed in the field using the cold extractable heavy metals method described by Hawkes (1963) modified for most of the stream sediment samples using ammonium citrate full strength. (Herreid, 1966, p. 5)
Laboratory and Office Procedures - The minus 80 mesh fractions of all samples were later analyzed for total copper, lead, zinc, and molybdenum in the Rocky Mountain Geochemical Laboratories of Salt Lake City, Utah. Tin was analyzed by the U.S. Geological Survey, Branch of Exploration Research. (Herreid, 1966, p. 7-8)

Data processing and statistical treaments - Concentration frequency graphs were prepared by hand for lead, zinc, and tin; these, in turn, were utilized to determine their threshold and anomalous values (Herreid, 1966, p. 8, fig. 4).

Results: Stream Sediments - The Hannum Creek deposit is clearly reflected by the lead content of stream sediments below the deposit. Progressively decreasing anomalous lead values continue down Hannum Creek and the Inmachuk River for 7 miles, as far as samples were taken; zinc drops off to background much more rapidly.
Evidently no deposits as large as the Hannum Creek deposit are cut by streams draining the area between Hannum Creek and the Pinnell River. If the Hannum Creek deposit were undiscovered, geochemical sampling would easily detect it. It is noteworthy that low cold extractable heavy metal analyses of most of these samples indicate that the lead in the anomalous stream sediment samples represents detrital lead minerals and not lead adsorbed on the clays. A mineral deposit located between creeks and not cut by a good drainage would produce a smaller anomaly lacking detrital galena and would be more difficult to detect.

Moderate tin anomalies are associated with the Hannum Creek deposit and are present on American and Perry Creeks. Three samples from near the Hannum Creek deposit which have been analyzed for tin are anomalous. Two taken downstream from the deposit are also anomalous in lead and zinc, but the third taken upstream from the deposit is only anomalous in tin. The anomalous samples elsewhere in the region fall into fairly well defined groups which suggests that they actually reflect areas containing greater than average concentrations of metals. It is doubtful that these areas contain deposits as rich as the Hannum Creek deposit, and any interest in them will probably wait on developments at Hannum Creek. (Herreid, 1966, p. 8-10)

Soil Samples - The pattern of strong lead and zinc anomalies in the vicinity of the quartzite (silicified marble) and gossan areas indicates that soil samples are effective in detecting soil-covered ore deposits in this area. Most samples were taken at shallow depths (6 to 12 inches 15-30 cm.) to duplicate the conditions of sampling in tundra-covered frozen ground. In the side of one trench, samples were taken at depths of one foot (.3m.) and seven feet (2m.) near bedrock to determine the gradient of metals in the soil. The shallow sample contains 60% less zinc than the deep one and both have greater than 1000 ppm. lead. It appears that little advantage would be gained by deep soil sampling in this area. (Herreid, 1966, p. 8)

Rock, Soil, and Stream Sediment Samples Compared - The prominent gossan on Old Glory Creek and the minor gossan above the Fairhaven Ditch, one mile to the east, appear to be fault-controlled replacements of marble with associated silicification and dolomitization - features which are typical of ore deposits. Samples of the ferruginous fines from these gossans were slightly anomalous in gold, silver, and chromium. Soil samples taken at the downhill side of both of these gossans were not anomalous. Moreover there are no stream sediment anomalies associated with either of them (Herreid, 1966, p. 8-11).

Publication

Herreid, Gordon, 1966, The geology and geochemistry of the Inmachuk River map area, Seward Peninsula, Alaska: Alaska Div. Mines and Minerals Geol. Rept. 23, 25 p.

13, 14, 15. BUCKLAND - KIWALIK AREA
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Location and Area - The Buckland-Kiwalik area comprises the northward trending, 1800 square kilometer upland divide lying between the Buckland and Kiwalik Rivers in northeast Seward Peninsula which extends from Haycock on the south to Buckland on the north.
Topography, Relief, Drainage - The topography and relief of the larger, southern part of the Buckland-Kiwalik area differ markedly from those of the northern part. Generally, those of the former comprise steepsided ridges and mountains which rise abruptly from the Buckland and Kiwalik lowlands and have an average relief of about 400 meters and a maximum relief of 550 meters; in contrast, the topography of the northern part consists of rounded and flat-topped ridges and hills with an average relief ranging from 200 to 300 meters. The entire area is moderately to well dissected by moderately to well integrated streams, with the better dissected portions and better integrated drainages located in the southern

part of the region. Nearly all of the streams are tributaries of the Buckland and Kiwalik Rivers.

Vegetation and Other Surficial Cover - Except for rubble and outcrops which form the upper slopes and tops of many of the ridges, hills and mountains - more so in the south than the north - most of the region is covered with treeless tundra. White spruce and birch occur with the tundra along the courses of western tributaries of the Kiwalik River but none are present along the east side of the area.

Geology; Bedrock, Surficial - Andesitic volcanic flows and volcaniclastic rocks make up most of the bedrock of the southern part of the region. These are intruded by one large and several small silicic plutonic bodies of variable character and composition and numerous felsic dikes and sills. The largest body forms most of Granite Mountain, the highest in the region, and so has been named the Granite Mountain pluton. A similar suite of silicic plutonic rocks forms most of the terrane of the northern part of the area; in marked contrast, the volcanic rocks which they intrude there are exposed only in two small areas. The eastern limit of the regionally metamorphosed rocks which form most of the bedrock of Seward Peninsula lies along the Kiwalik River just west of the region.

The entire Buckland-Kiwalik region is surrounded by basaltic lava flows which extend from those around Imuruk Lake to the west and are related to them. Dissected remnants of the flows are present to elevations as high as 600 meters, which indicates that they may once have covered most of the region.

The higher, southern part of the region gave rise to alpine glaciers during Illinoian time, which were largely confined to it. Wind-blown silt from glacial deposits produced by these, and from other nearby mountain ranges, covers the northern part of the area and the lowlands surrounding the entire region.

Mineral Deposits; Primary, Secondary - Only one gold quartz vein and an occurrence of primary and secondary copper minerals were known in the region before the mineral and geochemical surveys reviewed here. However, gold placers had been mined on several streams in the southern part of the area, all heading in the Granite Mountain pluton. Platinum was recovered with some of the gold and concentrates from several placer workings were found to yield strong radioactivity (West and Matzko, 1952).

Geochemical Survey; Previous and Related Investigations; Natural and Cultural Sources of Possible Adulteration and Contamination - Two reconnaissance surveys of nearly all of the Buckland-Kiwalik region have been made. The first, by West and Matzko (1952) was a radioactivity survey based almost entirely on semi-panned stream concentrates; it arose directly from the radioactivity results obtained from the placer concentrates cited above. The second, by Elliott and Miller (1969) was a geochemical survey based mainly on total stream sediments. In addition, detailed geochemical surveys were made in two areas in and around the Granite Mountain pluton, one of the Bear Creek drainage by Herreid in 1964 (Herreid, 1965) and another of the headwaters of Quartz Creek by Miller and Elliott in 1968 (Miller and Elliott, 1969); both surveys were based on analyses of sediment, soil, and bedrock samples.

More recently, at the instigation of C. L. Sainsbury, further work has been done on the concentrates collected by West and Matzko (1952). It comprised a randomized selection of 267 samples from the original collection 356, separation of each into non-magnetic and magnetic fractions, then chemical analysis of all of the non-magnetic and 81 of the magnetic fractions by several techniques (Overstreet and others, 1973; Kuo-Liang Pan and others, 1975). The primary purpose of this work was, first to develop a body of chemical data from them, second, to organize these data statistically, and finally to correlate the statistical results with known mineral deposits together with their associated geological features. Although many of the results are directly or indirectly applicable to mineral exploration, the studies were not intended to be geochemical surveys; however, should analyses of all the samples be completed, they could readily provide adequate basis for them. At their present stage, the chief derivative value of the studies for geochemical exploration is their bearing on orientation aspects to determine the comparative efficacy of various natural materials, or fractions of them, which might be utilized for geochemical surveys.

Volcanic and glacial activity in the region constitute the two principal sources of possible natural adulteration from the standpoint of the bedrock and mineral deposits in it. Lava flows from the former now occur as high as 550 meters and must once have covered most of the region; accordingly, material derived from them must constitute a significant proportion of most detrital debris, especially stream sediments. Because the glacial activity was alpine and emanated from and was largely confined to the southern part of the region, its principal effect would have been such as to erode bedrock and lava from the more headward portions of drainage systems and transport and deposit them in lower portions. Again, much of such glacial material would be reworked and incorporated in modern stream deposits. Conversely, much or most of the windblown silt which covers the northern part of the area would have been derived from sources foreign to the region; its possible effect as an adulterant in modern stream sediments would be significantly enhanced in the finest size fraction.

Placer mining operations and construction activity associated with it and that involved in building the microwave facility on Granite Mountain constitute two sources of possible cultural contamination. However, their effects would be largely confined to streams or portions of them which head in Granite Mountain; as elsewhere on Seward Peninsula, quicksilver was used to clean up fine gold placer concentrates and may have been a particularly pervasive source of mercury contamination in stream sediments.

All of the mineral and geochemical surveys in the Buckland-Kiwalik region were designed and prosecuted for mineral exploration: Of the two regional surveys, that by West and Matzko (1952, Fieldwork-1947) was for radioactive materials and the one by Elliott and Miller (1969, Fieldwork-1967, 1968) was for heavy metals, in particular gold and platinum; of the detailed surveys, Herreid's (1965, Fieldwork-1964) was for gold and base metals while that by Miller and Elliot (1969, Fieldwork-1968) was done during and for the same purpose as their regional survey. Although sample density was variable throughout the regional surveys, for both it was adequate for third-order reconnaissance, geochemical survey, the sample density for the earlier being about twice that for the later one, 1 per 4km^2 vs. 1 per 9km^2. The detailed geochemical surveys of the Bear Creek and Quartz Creek areas were both based mainly on total stream sediments. For these, site density for the former 1 per 3km^2, was near the limit between detailed and third-order regional surveys; whereas that for the latter survey, 1 per 2km^2, supplemented by soil and rock samples, was adequate to qualify as an upper-limit detailed geochemical survey.

Field Procedures - Regional Surveys, West and Matzko (FW-1947)-356 Semi-concentrates were panned from approximately 50 pounds (22 Kg) of sand and gravel collected from depths of 1 to 3 feet (.3-1 meter) from gravel bars and stream beds where natural concentration of heavy minerals would occur. Thereafter, samples were air-dried and tested with counter in the field for radioactivity to determine whether or not further sampling should be done on any given stream. (West and Matzko, 1952, p. 11-12)
Elliott and Miller (FW-1967-1968) - Total active stream sediment samples were collected from 274 sites of which 104 were from the Quartz Creek Granite Mountain area, 30 from the head of Peace River, and the remaining 140 from thoughout the Buckland-Kiwalik region generally. All samples were submitted as collected for physical preparation and chemical analysis.

Detailed Surveys - Herreid's geochemical survey encompassed the Bear Creek drainage basin northeast of Granite Mountain and the heads of other streams draining the west and east sides of Granite Mountain. Sampling was done mainly on stream sediments. Wherever possible, these samples were taken of fine-grained, nonorganic silt and mud from below the water level. In many places such samples were not obtainable, and samples with an appreciable organic content were taken at or above the water table. 72 such samples were collected. (Herreid, 1965, p. 8).

The geochemical survey of the Granite Mountain area by Miller and Elliott was based on total stream sediment samples supplemented by selected samples of soil rocks, and ores from one large area on the west side of Granite Mountain centered on Quartz Creek and another much smaller area at the head of a headwater tributary of Peace River on the southeast side. For the former they collected 135 stream sediment samples and 47 soil and rock samples, and for the latter, 30 stream sediment samples and 22 soil and rock samples. (Miller and Elliott, 1969, p. 8-11, 16-19)

Laboratory Procedures - Regional Surveys - All semi-concentrates from the earlier regional survey were concentrated further in the laboratory by floating off the light-weight minerals and rock fragments with bromoform (S.G.2.8). The equivalent uranium content of the heavier-than-bromoform fractions thus obtained were then determined radiometrically. Selected heavy mineral fractions were then studied to determine the radioactive minerals and their associates. (West and Matzko, 1952, p.12).

For both the regional and detailed geochemical surveys by Miller and Elliott, all stream sediment samples were dried, sifted, and the minus 80 mesh fractions were analyzed by the Survey's six-step, semiquantitative emission spectrographic method, and for gold by atomic absorption. (Elliott and Miller, 1969, p.2). Soil and rock samples were also analyzed by the same methods. (Miller and Elliott, 1969, p.16-19). Stream sediment samples from Herreid's geochemical survey of the Bear Creek area were analyzed in the laboratory by the Division of Mines and Minerals at College Alaska or Rocky Mountain Geochemical Laboratories in Salt Lake City using extraction by bisulfate fusion or hot acid. These methods give total contents of each metal analyzed. (Herreid, 1965, p.8).

Data Processing and Statistical Treatment.
Regional Surveys - The results from the earlier radiometric survey based on semiconcentrates were divided into those with heavy mineral fractions (+2.8 S.G.) which yielded instrument-measured radioactivity greater or less than 0.025 percent equivalent uranium; the principal emphasis of interpretation was then placed on these. (West and Matzko, 1952, p. 15)

Analytical data obtained from all of the stream sediment samples for both the regional and detailed geochemical surveys by Miller and Elliott were entered into the Survey's computer, then processed according to its GEOSUM program. From this, anomalous values were selected largely on the basis of computer-generated histograms. However, the authors emphasized that sediment sampling in these areas is of a reconnaissance nature rather than systematic, and the initial sampling bias strongly influences the apparent frequency distribution as well as other statistical parameters. Thus, the selection of anomalous values remains subjective and interpretive on the part of the writers rather than rigorous. (Elliott and Miller, 1969, p. 5)

For Herreid's geochemical survey of Bear Creek, hand-prepared graphs of frequency vs. concentration were made for copper, lead, and zinc. The graph for each metal shows a single clearly defined peak (or mode) which indicates the concentration of that metal which occurs most frequently. Only a small percentage of the stream sediment samples have a metal concentration of more than twice the mode and most of these are spatially related to known metalliferous deposits. A figure equal to mode was therefore selected as the threshold, and higher values were considered to be anomalous. (Herreid, 1965, p.8)

Results; Stream Sediments, Soil and Rock Samples.
Regional Surveys: The most promising results from the earlier regional survey of the Buckland-Kiwalik region on the basis of radioactivity and mineralogy of stream concentrates were obtained from those collected around the Granite Mountain pluton in the south, Clem Mountain in the north, and another granitic terrane on the western side midway between these. (West and Matzko, 1952, p. 21-26)

Although the results of analyses from all of the total stream sediment samples collected for Elliott and Miller's later survey of the Buckland-Kiwalik region are given in their report (1969), only those from the region generally are discussed. Their reason being that: There was a strong sampling bias in this group of samples because streams draining areas of known or suspected mineralization were sampled at a greater density than other streams. (Elliott and Miller, 1969, p.2) As a consequence, the results from these areas were discussed in another more detailed report which covers only the vicinity including and surrounding Granite Mountain. (Miller and Elliott, 1969); those from the rest of the region are summarized as follows:

Examination of the histograms of the various elements indicates that most of the elements, for which data are available, have either a roughly log-normal frequency distribution or a bi-modal frequency distribution. The bi-modal frequency distribution of some of the elements is probably related to local enrichment of these elements in areas of mineralization, such as the Quartz Creek and upper Peace River areas, which were heavily sample . The lower mode then may represent an approximation of the normal regional mode for the element, and the upper mode may represent the mode of the element within areas of mineralization.

Histograms were replotted for all the samples from the region minus the Quartz Creek and upper Peace River samples, two areas of known mineralization. Histograms were also replotted for 86 samples from the Quartz Creek area. For elements having previously shown a bi-modal distribution, histograms from the first group of samples generally showed a marked reduction of the higher mode and a similar increase of the lower mode. Histograms from the second group of samples showed just the opposite relation.

Anomalous Results:

1. Beryllium was detected in concentrations of 10 and 15 ppm in four sediment samples from small streams on either side of the ridge south of Clem Mountain.
2. One sediment sample from Hunter Creek, just above the Left Fork, contained 50 ppm tungsten and 30 ppm molybdenum.
3. Anomalous amounts of lead were reported in eight sediment samples from a stream on the east side of Granite Mountain (2 samples with 70 ppm, 3 samples with 150 ppm).
4. There are other occurrences of values, for one or more elements, above their designated anomalous concentrations, but these values are neither remarkably high nor is there any particularly significant grouping of elements or sample localities.

Detailed Geochemical Surveys - Anomalous results from Herreid's geochemical survey of the Bear Creek area based on total stream sediments were obtained in only two localities, one on Bear Creek contining gold placers and a base-metal sulfide deposit found during the survey, and the other at the head of Peace River for which evidence had been found earlier. (West in Gault and others, 1953, p. 28-31). On the basis of these results, Herreid concluded that;

Geochemical sampling indicates that the small lead-zinc-gold showing on Bear Creek probably extends westward at least 1/8 mile (200 m.). Detectable geochemical anomalies extend for about one mile (1.6km.) downstream from the known mineral deposits in the area. Analysis of samples by simple field methods that give the readily extractable heavy metal content may require a spacing of samples closer than one mile (1.6km.).

In most of the region, there is little possibility of finding lode deposits exposed at the surface because of the moderate relief and extensive cover of tundra and colluvium. Mafic syenite, diorite, and probably jasper and hematite creek float are considered favorable indications of lode possibilities throughout the greenstone region. Stream sediment geochemical sampling should be effective if sampling is done at intervals of not greater than one mile (1.6km.) on all drainages.

As described above, the geochemical survey of the Granite Mountain area by Miller and Elliott, although done during their regional survey of the Buckland-Kiwalik region, involved a greater density of stream sediment sampling than for it; in addition it was supplemented by analyses of numerous soil and rock samples which, in turn, had been selectively sampled on the basis of geological investigations. Accordingly, their conclusions summarized below represent a synthesis of data from all these sources, and the results from earlier work in the area.

Numerous occurrences of argentiferous galena, sphalerite, pyrite, and arsenopyrite have been found in an altered zone about 18 miles (30 km.) long and 2 to 5 miles (5-13km.) wide west of Granite Mountain. This zone extends N. 15° W. across the drainage basins of the upper Kiwalik River and Quartz Creek and is roughly parallel to prominent lineaments in the area. Conspicuous reddish-orange oxidized areas and large buff carbonate replacement bodies occur in the andesite and in the quartz monzonite that underlies this zone. A striking feature of the mineralized rock in this zone is the association of sulfides with tourmaline.

Semiquantitative spectrographic analyses of sulfide-bearing material from this zone show, in addition to the high lead, zinc, arsenic, and silver contents, consistently high boron contents which indicate the abundance of tourmaline. The manganese and scandium content is also high. Copper and antimony, though present in anomalous amounts in many samples, never exceed 2,000 and 700 ppm, respectively. Gold is low, less than 1 ppm, even though arsenic high. Tin occurs in about 50 percent of the analyzed samples in amounts ranging from just detectable to 500 ppm.

Many stream-sediment samples from this zone contain very anomalous amounts of lead, zinc, copper, and boron. Silver is reported in many of the samples but is never more than 0.7 ppm. Arsenic is reported in some samples, particularly near the southernmost head of Quartz Creek where values as high as 2,000 ppm occur. Sediment samples from streams draining the same area contain as much as 1,000 ppm lead and 1,500 ppm zinc, in addition to anomalous baron and copper. The presence of sulfide-tourmaline-quartz-carbonate float in all the streams draining this tundra-covered area and the location of lode occurrences of sulfide minerals and of anomalous stream-sediment and soil samples outline a strongly mineralized area of about 16 square Kilometers.

Sediment in streams from the west head of Sweepstakes Creek contains anomalous zinc values ranging from 300 to 1,500 ppm. This low area is completely covered with tundra, and no source of the anomaly was found. Anomalous concentrations of lead, zinc, arsenic, silver, and boron were found in soil and rock samples from a locality in the upper Kiwalik River drainage. Stream sediments west of this locality show anomalous lead and zinc.

A copper anomaly occurs in the stream sediments of the northern part of the Quartz Creek drainage basin. The higher copper content generally coincides with lower lead and zinc values and suggests lateral zonation in the major altered zone. The eastern edge of the copper anomaly begins in the North Fork of Quartz Creek near a small body of intensely oxidized rhyolite, and composite grab and soil samples of the rhyolite show anomalous concentrations of copper, antimony, and boron. The copper anomaly persists in the stream sediments of Quartz Creek all the way to the Kiwalik River Valley. Anomalously high concentrations of molybdenum, bismuth, silver, copper, and lead are found in the soils, stream sediments, and outcrops of the upper Peace River drainage basin. These anomalous metal concentrations occur over an area of about 2 square miles (5 km^2) centered around the two main forks of the Peace River. The area is low and tundra covered except for a few scattered out-crops and frost-driven rubble along the cutbanks of the creeks.

Composite grab samples of syenite from the area taken over areas ranging from 10 to 100 square feet (1-10 square meters) contain 15 to 200 ppm molybdenum as well as anomalously high amounts of bismuth, silver, and copper. Rubble of pyrite-quartz material is also abundant along the cutbanks of both forks; composite grab samples of this material contain from a trace to more than 2,000 ppm molybdenum as well as anomalously high bismuth, silver, and copper. In soils from the banks of the northern fork, molybdenum contents reach as high as 70 ppm; and in stream sediments from this fork and its tributaries, as high as 30 ppm. Copper and lead contents are also anomalously high in the stream-sediment samples from this area; however, the highest contents of copper and lead are in the upper parts of southern and northern forks respectively, whereas the highest molybdenum contents are from the lower part of the northern fork.

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16, 17, 18, 19. SOUTHEAST SEWARD PENINSULA

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Location and Area - The southeast part of Seward Peninsula encompasses an area of about 12,000 square kilometers. Approximately 25 percent of the region has been covered by geochemical surveys, mainly in the Darby Mountains which lie in the center of the region.

Topography, Relief, Drainage - The Darby Mountains extend for 100 kilometers north from Cape Darby on the southeast coast of Seward Peninsula where they join with the eastward trending Bendeleben Mountains from the west to form an arcurate range concave toward the southwest. An extensive, nearly flat alluvial plain called McCarthy's Marsh lies within this arc, and is impounded on the southside by a range of low hills; these in turn, are succeeded by the Niukluk-Fish river estuarine-fluvial plain which terminates in Golovnin Lagoon. Toward the north and east, the Bendeleben-Darby arc is bounded by the fluvial plain along the upper Koyuk River and includes a high-level, intermontane fluvial basin called Death Valley in the bend. Toward the east the Darby Mountains are succeeded by rolling uplands, and by an extensive, low-lying, fluvial-estuarine plain along the north side of Norton Sound. The highest peaks and greatest relief are present in the middle part of the Darby Range where the former range from 900 to 1000 meters high and the latter averages from 450 to 600 meters. From here, the general topography decreases toward the north and south. At the north end of the range, the highest peaks are about 1000 meters high and the average relief is about 300 meters. Toward the south, the Darby Range becomes progressively less rugged, giving way in the southern part to rolling uplands. These continue northwestward where they form the divide between McCarthy's Marsh and the fluvial-estuarine plain along the Niukluk and lower Fish rivers. Both the Darby Mountains and the rolling uplands are moderately to well dissected by moderately to well integrated drainage; in marked contrast, the alluvial and fluvial-estuarine plains have poorly integrated drainage systems, sparse throughgoing streams and rivers, and numerous to profuse marshes and thaw lakes.

Vegetation and Other Surficial Cover - Except for the highest and most rugged portions of the Darby Mountains which are devoid of vegetation nearly all of the terrane of southeast Seward Peninsula is covered with tundra. Spruce trees grow along the lower courses of streams and rivers on both sides of the Darby Mountains, to elevations as high as 250 meters on the hills and ridges on the east side, but only sporadically to more than 150 meters on those on the west side. Gelifluction lobes are present and abundant on the lower and middle slopes of most of the ridges and hills; in addition, talus occurs along the lower valley walls in the more rugged portions of the Darby Mountains.

Geology; Bedrock, Surficial - Granitic rocks belonging to several plutons make up the greater part of the Darby Mountain Range, with high grade metamorphic rocks intruded by these making up most of the rest. On the east side of the range, these rocks are flanked by limestone and greenschist grade metamorphites including a subordinate but distinctive schistose marble unit. This same marble unit, intruded by several small granite bodies, makes up most of the bedrock west of the Darby Mountains, including almost all of the divide between McCarthy's Marsh and the Niukluk-lower Fish River fluvial-estuarine plain. The remaining bedrock exposed west of the mountains is composed of limestone and greenschist grade metamorphic rocks like those east of them.
Glaciers formed during at least two alpine glaciations and perhaps several others have emanated in the Bendeleben and Darby Mountain ranges; however all have been largely confined to them. As a result, except for wind-blown silt which is widespread west of the Darby Mountains, glacial deposits occur only around the margins of the mountains. Despite this, it can be safely assumed that glaciofluvial deposits and material re-worked from them form much if not most of the debris filling the McCarthy's Marsh basin, Death Valley, and the Koyuk and Niukluk-lower Fish River alluvial plains.

Mineral Deposits; Primary, Secondary - The silver-bearing base metal deposit mined at Omilak, on the west side of northern Darby Mountains, together with numerous base metal mineral occurrences and gossans surrounding it, mark the most highly mineralized area in southeast Seward Peninsula. (Herreid, 1965, p. 4-6). Beyond this area, only a few base-metal mineral occurrences were known. (Berg and Cobb, 1967, p. 116-117, 119 and Cobb, 1973, p. 62-63, 79-82). In addition, a placer tin deposit had been found on Otter Creek east of the Omilak area, and placer gold had been mined on Aggie Creek on the Fish River divide west of the Darby Mountains.

Geochemical Survey: Previous Work; Purpose and Field Work; Natural Adulteration, Cultural Contamination - Two geochemical surveys have been made in southeast Seward Peninsula, the first a detailed survey by Herreid based mainly on total stream sediments of an area around the Omilak mine in the northern Darby Mountains, and a regional survey by Miller and others, also based mainly on total stream sediments, which covered nearly all of the Darby Mountains and the Fish River divide west of them. The purpose of both surveys was mineral exploration. Sample density of 1-2 per km^2 by Herreid was adequate for a preliminary detailed survey, while that by Miller and others at 1 per 6 km^2 was sufficient for a third-order regional survey. Field work for Herreid's survey was done during July, 1964 and that by Miller and others during the summers of 1969 through 1971.

Prior to these surveys, West made a reconnaissance radioactivity survey in 1948 of southern and eastern portions of the Darby Mountains based on panned stream concentrates. Only the results of radioactivity measurements on these concentrates, supplemented by some minerology, were reported at the time (West, 1953). However, much later during the early 1970's, the same concentrates were divided into non-magnetic and magnetic fractions, then nearly all of the former were analyzed chemically. (Overstreet and others, 1973). Clearly, the data from these concentrates would provide an adequate basis for a regional geochemical survey of the areas from which they were collected, and with appropriate statistical treatment and representation they could be one. However, in their present form, their chief value relates to orientation aspects of geochemical exploration, especially those relating to the comparative efficacy of total stream sediments and concentrates panned from them.

Although the Darby Mountains were glaciated by alpine glaciers during Illinoian and Wisconsinian times, the effects of both were largely confined within and around the mountains. From the standpoint of bedrock sources of mineralization, their principal effect would be to adulterate the alluvium in lower drainage courses with material reworked from glacial debris derived from more headward portions. In addition wind-blown silt winnowed from glaciofluvial deposits and distributed over a large area west of the mountains would constitute material foreign to it, and upon reworking and incorporation in the modern stream alluvium, would introduce a significant source of adulteration, particularly of the finer size fractions.

Cultural contamination in the region was almost entirely confined to two localities, one in and around the Omilak base metal lode mine and the other on Aggie Creek where placer gold was mined. Of these, the old mining operations at Omilak together with more recent prospecting activities in the area around it, probably constituted the more pervasive potential source of contamination in stream sediments in it.

Field Procedures -Regional Surveys - For the survey based on concentrates by West (Fieldwork, 1948), 248 concentrates were collected from 215 sites of stream gravels, 20 sites of beach gravels, and 13 sites in slopewash. Each concentrate from stream and beach gravels was panned from about 50 pounds (25 kg.) of sand and gravel, and each slopewash concentrate was panned from approximately 100 pounds (50 kg.) of disintegrated rock material. Each of these concentrates was tested for radioactivity in the field to determine whether additional concentrates should be taken in any given drainage area. (West, 1953, p.3). The aggregate area represented by the drainages from which the concentrates were collected was approximately 1200 km^2.

The results from a 300-square-kilometer area in the northernmost Darby Mountains was first reported separately by Miller and others (1971), and thereafter included with the results of their regional survey of the entire Darby Range and the Fish River divide west of it. (Miller and others, 1973). The first report was based on analyses of 33 total stream sediments and the latter on 422 sediment samples collected throughout a 2700-square-kilometer area. For both surveys, these were generally collected from the active stream channel; where this was not possible, the samples were collected from stream deposits adjacent to the active channel. (Miller and others, 1971, p. 4, 1973, p. 1). For the detailed geochemical survey by Herreid, 77 total stream sediment samples were collected from a 125 square-kilometer area around Omilak. Wherever possible, these samples were taken of fine-grained, nonorganic silt and mud below water level. In many places such samples were not obtainable, and samples with appreciable organic content were taken at or above water level. (Herreid, 1965, p. 2)

Laboratory Procedures - Regional Surveys - (West, Fieldwork, 1948) - For consistency in expressing the radioactivity of the concentrates, each sample was further concentrated in the laboratory by separating the light-and heavy-mineral fractions with bromoform (specific gravity, 2.89). As preliminary tests showed that essentially all the radioactive mineral occur in the heavy fraction, the equivalent uranium content of each heavier-than-bromoform fraction, was then determined by radiometric analysis. (West, 1953, p. 3)

All of the stream sediment samples collected for the regional geochemical survey by Miller and others, (1971, 1973) were sent to U.S.G.S. laboratories, then prepared and analyzed chemically in the same fashion: The samples were dried, sieved, and the -80 mesh fraction was analyzed for 30 elements by the six-step semiquantitative spectrographic method and for gold by atomic absorption techniques. (Miller and others, 1973, p. 1) Finally, all stream sediment and soil samples collected for Herreid's detailed geochemical survey of the Omilak area were analyzed for copper, lead, and zinc content by the Division of Mines and Minerals at College, Alaska or the Rocky Mountain Geochemical Laboratory in Salt Lake City, using extraction by bisulfate fusion or hot acid. (Herreid, 1965, p. 2)

For the later studies by Overstreet and others based on chemical analyses of these concentrates, a split of the raw concentrate finer than 20 mesh was separated into magnetic and nonmagnetic fractions with a hand-held permanent magnet (SEPOR NO. 903 Automagnet). The magnetic fraction from the first separation was further separated magnetically twice to insure that, insofar as possible in the time allowable for the practicable preparation of samples in the time allowable for the practicable preparation of samples in the context of a feasible exploration technique, the magnetic fraction was reasonable free of nonmagnetic minerals. Both fractions were then analyzed by the standard Survey USGS semiquantitative emission spectrographic technique for 30 elements, and by appropriate atomic absorption methods for elements not determined at all or adequately by this technique (Overstreet and others, 1974, p. 37-38). Further analyses performed on the magnetic fractions included , (1) by an analytical method developed recently in the U.S. Geological Survey to determine the abundances of silver, bismuth, cadmium, copper, cobalt, nickel, lead, and zinc, by atomic absorption techniques on single solutions of iron-rich materials, and (2) equivalent uranium as determined by radiometric counting.

Data Processing and Statistical Treatments; Determination of Anomalous Values - The absolute values of all radioactivity measurements in terms of equivalent uranium contents of the plus 2.89 specific gravity fractions of all concentrates collected by West were sub-divided into <0.01%, 0.01-0.02%, and >0.02% categories, then interpreted and discussed on that basis. (West, 1953, p. 4-6)

Although non-magnetic fractions of nearly all the concentrates by West in the Darby Mountains were later analyzed chemically for the studies of Overstreet and others, (1974), the analytical data presented in their report were treated statistically only to consider the results of the analyses of samples from throughout Alaska as a whole. Division of the data into geographic or geologic regions or geochemical provinces was not attempted. Five methods for the treatment of the data were presented: (1) frequency distribution, (2) histograms, (3) Fisher K-statistics, (4) correlation analyses, and (5) anomaly ratios. The first four of these are derived through the U.S. Geological Survey's standard statistical treatment of chemical data. The anomaly ratio was developed especially for the interpretation of the abundances of minor elements in concentrates (Sainsbury and others, 1970). (Overstreet and others, 1974, p. 170). In contrast, the analytical results obtained from the magnetic fractions of West's concentrates from the Darby Mountains were dealt with separately; however, these were derived from only half the original concentrates, and were strongly biased as to distribution and geologic sources. For these reasons, neither study constitutes a real geochemical survey comparable to the others reviewed here; accordingly, their results are not summarized below.

Chemical data obtained by analyses of all the stream sediment samples collected for the surveys by Miller and others (1971, 1973) were entered in the USGS computer system, then processed in accordance with the Survey's GEOSUM program. From the printout of this program, values were designated as anomalous in their report largely on the basis of the computer-generated histograms. The authors emphasised that the stream sediment sampling was of a reconnaissance nature and the selection of anomalous values was subjective and interpretive. (Miller and others, 1973, p. 2-3). Herreid prepared histogram graphs by hand based on the analytical data obtained from the stream sediment samples collected for his detailed geochemical survey of the Omilak area, then used these to characterize the results values he judged to be anomalous. (Herreid, 1965, p. 2-3, 12)

Results - Regional Surveys - Field studies and the radiometric analysis and mineralogic study of the heavy-mineral fractions of numerous concentrates from placers of the region showed that essentially all the radioactive minerals in the district occur in or were derived from bodies of felsic igneous rocks, chiefly granite.
The most common and widespread radioactive minerals are sphene, allanite,

hematite, and zircon. These minerals, with the possible exception of the hematite, are all believed to be primary accessory minerals in the granite. Locally in the Clear Creek-Vulcan Creek area and near the mouth of McKinley Creek, abnormally high radioactivity of concentrates derived from the granite appears to be due to the presence of a uraniferous titanium niobate mineral. The association of topaz and traces of cassiterite with the uraniferous niobate mineral in the Clear Creek-Vulcan Creek area suggests also that these minerals may be genetically related to lode tin occurrences or pegmatitic phases of the granite. (West, 1953, p. 7)

Later studies by Overstreet and others (1974) based on chemical analyses of the concentrates collected by West confirmed his radiometric anomalies (Overstreet and others, 1975, p. 385-388), and also yielded anomalous niobium in those from the Clear Creek area. (Overstreet and others, 1975, p. 372). In addition, anomalous amounts of numerous other elements were detected in the non-magnetic fractions of the concentrates, and their report should be consulted for specific results and localities. (Overstreet and others, 1975, p. 45-54, 115-119, and 125-149)

The regional geochemical survey by Miller and others (1971, 1973), although based mainly on total stream sediments, was supplemented by analyses of selected samples of soils, rocks, and altered rocks and ores. Of particular note in the general report covering the results of this survey is the authors' development and use of statistical parameters to characterize the geochemical background of individual rock units based on the analytical data obtained from total stream sediments derived from them. (Miller and others, 1973, p. 3, 72-115): the stream sediment sampling program provided geochemical background information which will be useful in future exploration in this and nearby area. As an aid in determining the geochemical background statistical parameters for selected elements have been computed for each of six geologic units or combination of units that underlie most of the survey area. These parameters were determined by considering those samples from streams that drained only one particular geologic unit. In the interpretation of a geochemical result from any particular stream sediment samples, or group of samples, an examination of the geologic map in order to determine the geology of the drainage basin is strongly recommended. (Miller and ohters, 1972)

There is a wide range in background values depending on the bedrock of the drainage basin. These are characterized by the geometric means of sediment analyses from the streams that drain a particular geologic unit or units (p. 72). Copper, for example, shows a range in geometric mean from 5 ppm in streams draining only the Darby pluton to 55 ppm in streams draining the Devonian limestone and dolomite. The geometric mean of lead ranges from 16 ppm in the streams draining schistose marble to 72 ppm in streams draining the composite Kachauik pluton. Other elements show similar ranges and indicate the importance of considering the bedrock geology in interpreting the significance of any particular stream sediment analyses or group of analyses.

Other more specific results reported by the same authors include: (1) The north end of the Darby Mountains is a strongly faulted area with numerous gossans and altered zones. Anomalous amounts of molybdenum, lead, zinc, and silver found in streams draining mineralized areas in and near Windy Creek and Granite Creek have already been reported in Miller and others (1971). Mapping in 1971 resulted in the discovery of galena and sphalerite with minor chalcopyrite and rare fluorite in quartz-aplite breccia fillings in hornfelsed black slate northeast of the area and adjacent to the major fault bounding the south side of the Bendeleben Mountains. Although the examination was brief and much of the area is tundra-covered, mineralization was noted over an area of about 400 feet by 200 feet (125 x 60 meters). Analyses of composite and selected grab samples from the area show anomalous lead, zinc, silver, and copper. Sediment samples from streams draining the west side of the locality contain anomalous amounts of lead (150 ppm) and zinc (200 ppm).
Further east along the major fault mentioned above anomalous amounts of bismuth (more than 10,000 ppm) were reported in a small gossan in high grade metamorphic rocks and from a soil sample collected at a cold spring. This general area at the north end of the Darby Mountains and near the range front fault appears to be a strongly mineralized area.

(2) A placer gold mine is located at Aggie Creek, a west-flowing tributary to Fish River. Aggie Creek drains chiefly a schistose marble unit cut locally by quartz latite porphyry. No obvious altered zones which might constitute a bedrock source for the gold were noted in the schistose marble. East of Aggie Creek and altered quartz latite porphyry contains anomalous amounts of gold and arsenic and such altered intrusive rocks in the Aggie Creek might be the bedrock source. The Aggie Creek drainage also lies along the crest of a northwest-plunging anticline as shown by Miller and others (1972), and mineralization may be related to this structure. A weak-to-moderate copper anomaly also occurs in this area as can be seen from histograms given for this unit. Histograms were computed for 62 samples collected from streams which drain only the schistose marble and the histogram for copper shows a distinct bi-modal distribution. When 22 samples from Aggie Creek and nearby drainages along the crest of the anticline were eliminated, most of the high copper values were eliminated as shown by a histogram of copper distribution without the Aggie Creek and nearby samples. The copper anomaly is distinct but not large as values are not over 100 ppm.

(3) A moderate niobium anomaly also occurs in sediment samples from streams in and around Clear Creek, as indicated by niobium values of 30-70 ppm occur in several streams. The 70 ppm values in two samples from Clear Creek are the highest reported in approximately 2100 stream sediment samples collected from 6 different areas in western Alaska. The samples from the Clear Creek area also contain anomalous amounts of zirconium and lanthanum and weakly anomalous amounts of tin and molybdenum. The bedrock source of the Clear Creek-Vulcan Creek anomaly is not known. The area is underlain by the Darby pluton, which is composed of coarse-grained leucocratic quartz monzonite. (Miller and Grybeck, 1973, p. 4-5)

(4) The Darby pluton also has high background values of uranium and thorium, which is particularly interesting in view of the uraniferous niobate minerals reported by West (1953). Three samples considered to be representative of the range in composition of the pluton showed a range of uranium content of 8.8 to 14.6 ppm and a 48.8 to 64.6 ppm range in thorium, according to gamma-ray spectrometric analysis. The

nearby Bendeleben pluton, in contrast, has a range of 1.8-4.4 ppm U and 16.9-21.4 ppm Th which is similar to published values of 4 ppm U and 18 ppm Th for average granite. (Miller and Grybeck, 1973, p.6)
(5) A small gossan in limestone near the Kwiniuk River contains anomalous amounts of zinc, lead, copper, and barium and anomalous amounts of silver, arsenic, lead, and zinc were found in a highly altered 5-foot wide fault zone in granite on the west side of Cape Darby. (Miller and others, 1973, p. 6)

Detailed Geochemical Survey - The results from Herreid's detailed geochemical survey of the Omilak area based mainly or entirely on analyses of total stream sediment and soil samples are summarized below.
(1) Strong lead-zinc stream sediment anomalies were found for about 1 1/2 miles (2 1/2 km.) below the Omilak mine on Omilak Creek. The lack of anomalies on the North Fork of Omilak Creek indicates a probable lack of deposits as rich as the Omilak mine in that drainage. Strong lead anomalies are present at a sample site about 4 miles (6 1/2 km^2) down Dry Creek from the Foster lead-silver prospect, and in all other stream sediment samples taken from Dry Creek above it. These samples are not anomalous in zinc, although zinc soil anomalies are present adjacent to the ore showings in the area.

(2) Several moderate tin anomalies were detected, mainly in the eastern portion of the map area. On Caribou Creek, two samples, one with 10 ppm tin and another with less than 6 ppm tin were taken from eastern tributaries, while a sample with 62 ppm tin was taken from Caribou Creek itself. These anomalies indicate tin mineralization in the area, possibly associated with the intrusive in the drainage. On Otter Creek, the tin anomalies may be associated with the deposit which is the source of the placer tin at the Foster tin prospect. A sample with less than 6 ppm tin may indicate anomalous concentrations of tin in the stream sediments along Big Creek. More sampling should be done in the area. A sample with 56 ppm tin was taken on the North Fork of Omilak Creek just below the Omilak mine. The lack of tin anomalies in other samples taken along this part of the creek suggests that no significant tin deposit is present in the area.

(3) There is a complete lack of correlation of the contents of tin vs. copper, lead, and zinc in the geochemical samples taken in the map area. None of the anomalous tin samples are anomalous in the other heavy metals. This separation of the two types of mineralization is apparently genetic. (Herreid, 1965, p. 3-4)

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