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MINOR AND TRACE ELEMENT DISTRIBUTION IN THE HEAVY MINERALS OF THE RIVERS AND STREAMS OF THE KENO HILL DISTRICT, YUKON TERRITORY

C.F. GLEESON AND R.W. BOYLE

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MINOR AND TRACE ELEMENT DISTRIBUTION IN THE HEAVY MINERALS OF THE RIVERS AND STREAMS OF THE KENO HILL DISTRICT, YUKON TERRITORY

Abstract

The distribution of selected elements in heavy minerals from the drainage systems of the Keno Hill district, Yukon is described.

Most of the known mineral deposits of the district are reflected by higher than average contents of one or more elements in the heavy mineral fractions, and a number of anomalous sites in streams in the drainage net were found that merit further investigation.

The conclusion is drawn that low density reconnaissance stream sediment surveys involving geochemical analyses of heavy mineral concentrates is an effective way of outlining mineralized areas. In the mountainous regions of Yukon elemental dispersion in the drainage systems is due as much to transport of particulate matter as to hydrologic processes. Traditionally heavy mineral surveys have been used to define areas enriched in metals having a low degree of chemical mobility in the supergene cycle. The present study indicates, however, that analyses of heavy mineral concentrates for the chemically more mobile elements can outline metalliferous areas. In this respect geochemical and mineralogical analyses of heavy mineral concentrates from the drainage net can complement normal stream sediment surveys and provide additional information that can aid in the interpretation of the stream sediment data. Finally, it is notable that particulate dispersion trains of hypogene and supergene minerals may be more extensive than hydromorphic trains especially in carbonate terranes where the chemical mobility of some elements may be restricted due to the high pH.

Résumé

Dans la présente étude, on décrit la distribution de certains éléments que contiennent des minéraux lourds provenant du réseau hydrographique du district de Keno Hill au Yukon.

La plupart des gîtes minéraux connus de la région sont caractérisés par une teneur supérieure à la moyenne d'un ou plusieurs éléments dans les fractions minérales lourdes, et certains cours d'eau du réseau contiennent plusieurs sites remarquables, qu'il serait intéressant d'étudier plus en détail.

On est arrivé à la conclusion que des levés de reconnaissance relativement espacés des sédiments fluviatiles faisant appel à l'analyse géochimique des zones d'enrichissement en minéraux lourds, nous permettent de délimiter efficacement les zones de minéralisation. Dans les régions montagneuses du Yukon, la dispersion des éléments dans le réseau hydrographique résulte dans la même proportion du transport de particules solides, et des processus hydrologiques. Traditionnellement, la prospection des minéraux lourds a servi à reconnaître les zones enrichies en métaux, qui, dans le cycle supergène, sont caractérisés par une faible mobilité chimique. La présente étude indique toutefois qu'en analysant la concentration de minéraux lourds contenant des éléments plus mobiles, on peut aussi délimiter les zones métallifères. A cet égard, l'analyse géochimique et minéralogique des minéraux lourds accumulés dans le réseau hydrographique complète la prospection habituelle des sédiments fluviatiles, et nous apporte d'autres informations pour interpréter les données relatives à ce type de sédiments. Enfin, on a constaté que les couloirs de dispersion des particules de minéraux hypogènes et supergènes peuvent être beaucoup plus vastes que les couloirs hydromorphes, surtout dans les terrains carbonatés, où la mobilité chimique de certains éléments peut être réduite, en raison d'un pH élevé.

INTRODUCTION

During the summer of 1964 the Geological Survey of Canada carried out their first helicopter-supported, integrated, reconnaissance stream and spring sediment, surface and groundwater, heavy mineral, and rock geochemical survey over about 1900 square miles centred on Keno Hill, Yukon. The results of the water and stream sediment analyses have been published (Gleeson et al., 1965, 1966-68), and the hydrogeochemistry and lithogeochemistry of the area has been discussed by Gleeson and Boyle (1976, 1980). Boyle and Gleeson (1972) described gold in the heavy mineral concentrates of the stream sediments.

The present paper deals with the minor and trace elements in the heavy minerals collected in 1964 from the rivers and streams of the area.

Location

The Keno Hill area is in central Yukon, 35 miles northeast of Mayo and about 220 miles due north of Whitehorse. Mayo is served by an all-weather road from Whitehorse and by Northward Airlines scheduled flights from Whitehorse and Dawson. The three villages in the area, Keno Hill, Elsa, and Calumet, can be reached by an all-weather road from Mayo.

Topography, glaciation, permafrost, and climate

The Keno Hill area lies within the northeastern part of the Yukon Plateau, and the terrain is mountainous with elevations ranging from 6852 feet (Mount Patterson) to 2300 feet (Keno Ladue-McQuesten River Valley).

Many of the mountains have steep slopes (Mount Haldane, Mount Hinton) and are traversed by numerous gulches that cut deeply into the rock strata. Keno Hill and Galena Hill, the sites of the principal mineral deposits, have more gentle slopes but here and there are marked by steep gulches and cirques. Below an elevation of 4500 feet the slopes of the mountains and hills are covered with thick deposits of till, soil, rock debris, muck and muskeg, in which conifers, birch, aspen, Arctic black birch and other vegetation grow abundantly. Above this elevation the soil is thin, outcrops are more numerous, the ground is covered with local rock float, the terrain is treeless, and the vegetation is limited to alpine species and grassy meadows.

The lower slopes of the mountains and hills were severely glaciated during Pleistocene time by ice-sheets that spread from the east across the entire area. Glacial till, gravel, and other debris form a series of benches on the slopes of the hills and floor the valleys. The deposits are generally 5 to 20 feet thick, but in some areas as on the southern slopes of Keno Hill facing Lightning Creek and north of Christal Lake, they are 30 to 50 feet thick or more.

The Keno Hill-Galena Hill area is in the region of permanently frozen ground. The permafrost is irregularly distributed and its occurrence is dependent upon the elevation, hillside exposure, depth of overburden, amount of vegetative cover, and presence of flowing underground and surface water. It is generally present at high elevations and on slopes with a northern exposure. Thus, on Keno Hill, mine workings on the top of the hill and on the northern slope encountered permafrost about 400 feet below the surface. On the northern slopes of Sourdough Hill and Galena Hill a similar situation prevails, and frost and ice lenses are present at depths of 250 feet or more in the mine workings. On the lower, southern slope of Keno Hill, however, no evidence of permafrost has been found in the workings of the Onek and Mount Keno mines. In places where surface and underground water are flowing the permafrost has thawed out and frost-free windows and strips (taliks) are present. These provide access and engress for waters that are oxidizing the lodes.

The climate of central Yukon is rigorous. The mean annual temperature at Mayo is 26°F (-3.3°C), the average minimum temperature is 14°F (-10°C) and the average maximum 37°F (2.8°C). Temperatures as low as -80°F (-62°C) and as high as 90°F (32.2°C) have been recorded. The winters are long and cold with only a few hours of daylight each day, and the summers are short and warm with nearly continuous daylight.

The average annual precipitation at Mayo is 11.23 inches (28.1 cm). The rainfall in the Keno Hill area during the spring and summer is moderate with occasional torrential downpours. The snowfall is moderate and usually commences in mid-September or early October. Most of the snow has melted by the end of May, but local patches and small snowfields remain in sheltered places on northern slopes until late August.

GENERAL GEOLOGY AND MINERAL DEPOSITS

The general geology and descriptions of the mineral deposits in the area covered by the heavy mineral survey may be found in reports by Bostock (1947), McTaggart (1960), Kindle (1962), Boyle (1965), Poole (1965), and Green (1971), and only a brief account of the salient features, based mainly on studies by Boyle in the Keno Hill-Galena Hill-Dublin Gulch area, is given here.

The sedimentary rocks underlying the Keno Hill-Galena Hill area belong to the Yukon Group and are probably of Precambrian or Paleozoic age although some geologists consider these rocks to be Jurassic and Lower Cretaceous in age (Tempelman-Kluit, 1970). They consist of graphitic and sericite schists, phyllites, thick and thin bedded quartzites, argillites, and a few limestone lenses.

Conformable lenses and sills of greenstone occur in the schist and quartzite formations, and a few quartz-feldspar porphyry sills are present locally in all rock types. Granitic stocks of Mesozoic age outcrop northwest and southeast of the main mineral belt which is centred on Keno and Galena hills.

The folding pattern of the sedimentary rocks is intricate and cannot be considered in any detail here. On Keno and Galena hills the rocks dip southeast and appear to form the southern limit of a large open anticline whose axis follows the South McQuesten River Valley in the western part of the area; more details are given by Green (1971).

There are two principal fault systems; a northeast-striking system of vein faults which, together with numerous subsidiaries, contains all the ore bodies, and a north-northeast to northwest-trending series of faults which cut the orebodies and are barren of ore minerals.

The most favourable host rocks for the occurrence of lodes and veins are thick bedded quartzites and greenstones. Structurally, the principal lodes are localized in three sites: (1) at the junction of two or more vein faults; (2) at the junction of a vein fault and subsidiary fracture, and (3) in quartzites or greenstones at or near the sites where vein faults pass upward from these rocks into schists or thin-bedded quartzites. In physicochemical terms these three sites were dilatant zones into which the constituents of the ore and gangue minerals were drawn.

Six types of mineral deposits are represented in the area: (1) cassiterite-tourmaline impregnation zones in the Dublin Gulch area; (2) scheelite-bearing skarn lenses and zones near the contact of granitic rocks in the Dublin Gulch area; (3) quartz-wolframite and quartz-scheelite stringers in granites and sediments in the Dublin Gulch area; (4) quartz-pyrite-arsenopyrite-gold lenses in vein faults; (5) siderite-galena-sphalerite-freibergite-pyrite-chalcopyrite lodes in vein faults; and (6) gold and scheelite placers. The siderite lodes and gold placers constitute the economic deposits of the area, yielding silver, lead, zinc, cadmium, and gold.

The siderite and quartz lodes are oxidized to depths ranging from 20 to 600 feet. Much of the oxidation appears to have taken place in late Tertiary time, but oxidation processes are still active in some deposits. In the oxidized zones the primary pyrite and siderite are altered to limonite and wad; arsenopyrite to limonite and scorodite; sphalerite and chalcopyrite to limonite, azurite, and malachite; and freibergite, boulangerite, and jamesonite to bindheimite, beudantite malachite, native silver, and other secondary minerals. Oxidation of the siderite lodes has led to a marked enrichment of lead and silver and a strong depletion of zinc and cadmium.

In some siderite lodes the oxidation zones grade through a zone of reduction ranging from 2 to 20 feet in depth; in others the oxidation zones grade imperceptibly into the hypogene zones. The principal economic minerals formed in the zones of reduction are pyrargyrite and native silver.

The chemistry of the oxidation of the various types of deposits has been discussed in detail by Boyle (1965).

HEAVY MINERALS IN THE RIVERS AND STREAMS

The heavy minerals in rivers and streams of the Keno Hill area have two sources, the country rocks and the various types of mineral deposits mentioned above. Minerals such as the pyroxenes, amphiboles, magnetite, garnet, epidote, and zircon are derived mainly from the country rocks whereas the suite comprising arsenopyrite, barite, cassiterite, scheelite, wolframite, sphalerite, galena, sulphosalts, gold, bismuth, cerussite, anglesite, beudantite, and scorodite originate in the mineral deposits. Minerals such as pyrite, limonite, goethite, and tourmaline are derived from both the country rocks and the mineral deposits. A few of the heavy minerals are exotic, from distant sources. One of these is hematite, described subsequently.

Monazite occurs sparingly in most heavy concentrates, but is particulary abundant in samples from the Granite Creek and Dublin Gulch areas. These are areas marked by granitic intrusions from which much of the monazite presumably was derived.

Magnetite is present in most samples of heavy mineral concentrates, but the quantity of the mineral varies greatly from stream to stream. Much of the magnetite appears to have been derived from the relatively unmetamorphosed sedimentary rocks and basic sills, some magnetite comes from the glacial till and sand, and the remainder probably originated from the skarn and hornfels zones associated with the granitic intrusives of the area. The mineral deposits of the area contain relatively little magnetite.

Native metals identified in the heavy concentrate samples include mainly gold and bismuth. The distribution of gold is widespread occurring particularly in the following streams which from time to time have been the sites of placer operations since 1900: Duncan Creek, Lightning Creek, Thunder Gulch, Edmonton Creek, Field Creek, Haggart Creek, and Dublin Gulch. Boyle and Gleeson (1972) discussed the distribution of gold in heavy concentrates of river and stream sediments of the area.

Bismuth occurs sparingly in the heavy concentrates from Dublin Gulch and Haggart Creek. It is invariably associated with cassiterite, wolframite, and scheelite and probably came from the occurrences containing these minerals. The native bismuth is commonly encrusted with bismutite, $(BiO)_2 CO_3$.

Small particles of native lead (not shot) and native zinc have been identified in the heavy concentrates of some soils and stream sediments on Keno and Galena Hills. The native zinc is a product of the oxidation of sphalerite and other zinc minerals (Boyle, 1961); the native lead may also be a product of the oxidation of various lead minerals, although the mineral has been identified among the hypogene products of ore deposition in various parts of the world and may have such an origin at Keno Hill.

The sulphides most commonly found in the heavy concentrates of the area include pyrite, arsenopyrite, and galena; sphalerite and pyrrhotite are rare. Most of the pyrite derives from the weathering of country rocks such as the pyritic phyllites and schists, but some originates from the pyritiferous deposits of the area. Arsenopyrite occurs most abundantly in the soils and eluvium near the quartz-pyrite-arsenopyrite-sulphosalt-gold veins of the area; in nearby streams the mineral is also present as rounded nodules and small euhedral crystals.

The heavy minerals originate mainly from weathering of the country rocks and minerals deposits. Most of this weathering took place during Tertiary time as noted above, but the accumulation of the heavy minerals has been taking place in the water courses since that time. Initially, the heavy minerals passed into the residual soils of the area and thence into the river and stream sediment. Boyle (1965) investigated the heavy minerals in soils and eluvium of the area.

Selected heavy mineral concentrates from a number of water courses were examined by microscopic and X-ray methods.

Minerals such as pyroxenes, amphiboles, garnet, epidote, rutile, leucoxene, apatite, and zircon are common in most samples and are derived mainly from the county rocks of the area. Limonite, goethite, and wad particles are, likewise, common and nearly ubiquitous in most samples. These minerals, especially wad, tend to have a high frequency of abundance and occurrence in the oxidized parts of the mineralized zones of the area, but it is evident that a large amount of all of these minerals also originates from the weathering of the country rocks. Wad, coating small particles of siderite, invariably derives from the lead-zinc-silver lodes. Allanite, ilmenite, chromite, olivine, and sphene occur sparingly in some samples; their origin is uncertain, but presumably they derive from some of the granitic and basic rocks of the area.

Rounded nodules of hematite-chert (iron formation) ranging in size from that of a large potato to microscopic particles are common in the river and stream sediments. These are exotic and appear to have been glacially transported into the area from the vicinity of Snake River in the northern Mackenzie Mountains, where extensive iron formations are known in the Hadrynian (Late Precambrian) Rapitan Group.

Tourmaline is relatively common in the heavy concentrates of some streams and is especially abundant in the fractions ranging in specific gravity from 3 to 4. In Dublin Gulch and Haggart Creek tourmaline is intimately associated with cassiterite. Elsewhere, the mineral has no particular associates except in some mineral separates from stream sediments on Galena and Keno hills where galena accompanies the borosilicate. Boron, presumably mainly in tourmaline, clearly marks the mineralized zones in the Keno Hill area as can be seen by consulting the geochemical map for boron (Gleeson et al., 1968, Geological Survey of Canada, Map 56-1965). Dublin Gulch and Haggart Creek contain notable amounts of arsenopyrite, derived mainly from the veins that strike northeast through the area south of Dublin Gulch. The mineral is also common in some of the heavy concentrates from the streams of Mount Haldane. In the soils, eluvium, and heavy concentrates from the streams arsenopyrite is commonly accompanied by scorodite one of its alteration products. Galena, as small particles and in rounded, eroded lumps the size of potatoes, occurs in the heavy concentrates of the soils, eluvium, and stream sediments. The mineral derives from the siderite-galena-sphalerite lodes of the area. The particles of galena are invariably encrusted with anglesite and cerussite and occasionally with beudantite. Sphalerite and pyrrhotite, extensively altered to limonite, occur in the heavy mineral concentrates of soils near the lead-zinc-silver veins. Pyrrhotite is also commonly present in mafic dykes and sills; a sample from Philip Gulch, at the head of Scougale Creek contained abundant pyrrhotite in the magnetic fraction of the heavy mineral concentrate. Sphalerite is rare in the heavy mineral suite of the drainage net of the area.

Sulphosalts are rare in the heavy concentrates of the soils and stream sediments. In Dublin Gulch and Haggart Creek boulangerite and jamesonite nodules and particles have been noted. These are commonly coated with oxidation products such as senarmontite and native sulphur. The sulphosalts derive mainly from the early quartz-arsenopyrite-pyrite-sulphosalt-gold veins of the area.

Cassiterite, limonite, goethite, and wad are the principal oxides of interest that are derived from the various deposits of the area. Cassiterite was identified only in the heavy concentrates from Dublin Gulch and Haggart Creek. The mineral occurs as small individual crystals and as intimate intergrowths with tourmaline and chlorite in small pea-sized to rounded lumps several inches in diameter. The cassiterite in Dublin Gulch is derived mainly from the tin lode on the hill north of the Gulch; its dispersion train can be traced by panning the soils from the lode to the Gulch. Most of the limonite and goethite in the heavy concentrates originate through the weathering of the pyrite and other iron minerals in the country rocks. Some limonite and goethite, however, accumulate in the soils near the various deposits and ultimately pass into the eluvium and then into the stream sediments. Limonite and goethite derived from the oxidation of the sulphide-bearing deposits tend to be greatly enriched in arsenic, lead, zinc, cadmium, and antimony compared with that derived from the country rocks. Wad is derived both from the oxidation of manganiferous minerals in the country rocks and from manganiferous siderite and sphalerite in the sulphide deposits. Its surficial history is identical with that mentioned above for limonite and geothite. Wad, derived from the deposits, can generally be identified by the presence of nuclei of siderite and by the fact that the mineral is greatly enriched in elements such as zinc, cadmium, lead, and silver.

Two tungstates, scheelite and wolframite, occur in some of the heavy concentrates of the streams in the area. Both minerals, especially scheelite, are abundant in Dublin Gulch and Haggart Creek, and scheelite is common in the streams draining southward from the Potato Hills into Lynx Creek. The wolframite in the Dublin Gulch area derives from small quartz veinlets in the hornfels, skarn, and granitic body east and southeast of the Gulch. The scheelite originates from small quartz veinlets, thin pegmatites, and skarn lenses associated with the same granitic body.

Of the heavy carbonates only cerussite, $PbCO_3$, occurs in any abundance in the heavy concentrates of soils near the lead-zinc-silver deposits. This mineral is relatively stable and may also occur, although sparingly, in the heavy concentrates of stream sediments in the near vicinity of the lead deposits. Cerussite is commonly associated with galena in the heavy concentrates of the soils and eluvium. Siderite nodules and particles extensively oxidized to limonite and wad occur in some of the soils near the siderite lodes; also in the eluvium and sparingly in the stream sediments.

The sulphates and arsenates observed in the heavy mineral concentrates of the soils, eluvium, and stream sediments include barite, anglesite, beudantite, mimetite, and scorodite.

Barite, accompanied by some witherite, is particularly common in the stream sediments in the northwestern part of the area. Barite is also present in small amounts in some of the soils near the lead-zinc-silver lodes; in these locales the mineral derives from the hypogene mineral assemblage of the lodes. Anglesite, beudantite, and mimetite are particularly common in the soils, eluvium, and stream sediments in the near vicinity of the lead-zinc-silver lodes. Scorodite is relatively rare in the surficial materials but occurs in soils, eluvium, and stream sediments in the vicinity of the quartz-pyrite-arsenopyrite-gold veins. In the heavy concentrates from the streams scorodite is invariably associated with arsenopyrite.

FIELD AND LABORATORY PROCEDURE

A regular 12 inch gold pan full of gravel was panned at each sample site shown on the accompanying figures. To minimize the loss of heavy minerals, and to save time in the field, the samples were panned to a concentrate of about 50 per cent light and 50 per cent heavy minerals weighing about 1 kg. These concentrates were dried and shipped to the Geological Survey in Ottawa for heavy liquid separations and geochemical analyses. A total of 550 sites were sampled in the Keno Hill district (Figure 4).

The heavy minerals were separated from the field concentrate by methylene iodide of specific gravity 3.3. The heavy residue was cleaned, dried, and washed and the magnetic and non-magnetic fractions were separated with a Sepor Automagnet.

An aliquot of the non-magnetic fraction from each sample was anlayzed semi-quantitatively by emission spectograph; another aliquot was analyzed for U and Th using a gamma-ray spectrometer (Horwood 1959). In addition a further aliquot was analyzed for gold using a fire assay-atomic absorption spectroscopy method (Boyle and Gleeson, 1972).

The magnetic fraction was analyzed colorimetrically for Cu, Pb, Zn, Ni, Co, As, Sb, Mo, and W. Only about 300 samples contained sufficient magnetic material for analyses.

RESULTS OF THE INVESTIGATION

The semi-quantitative spectrographic results for Ba, Cu, Pb, Zn, Ni, Co, Cr, Sn, W, Ag, and Bi in the non-magnetic fraction are presented in Figure 1, and the semi-quantitative spectrographic results for Zr, Sc, Y, Ce, La, and Yb, and the gamma-ray spectrographic results for Th and U in the non-magnetic fraction are shown in Figure 2. The colorimetric analysis for Cu, Zn, Pb, Ni, Co, As, Sb, Mo, and W in the magnetic fraction are given in Figure 3.

On the accompanying figures the spectrographic analyses are divided into five groupings as follows:

GROUP	% RANGE
1	100-10
2	10-1
3	1-0.1
4	0.1-0.01
5	0.01-0.001

Si, Fe, Ti, Ca, Al, Mn, and Mg are ubiquitous in all samples, and these elements are not shown on the figures. Those interested in the distribution of these elements can consult Open File 46, Geological Survey of Canada. Sample locations and sample numbers are shown in Figure 4.

Discussion on the distribution of Ba, Cu, Pb, Zn, Ni, Co, Cr, Sn, W, Ag, and Bi in the non-magnetic heavy mineral concentrates (Figure 1)

Barium

Samples containing in excess of 1% barium are numerous in the northwest part of the district particularly in the drainage systems of Eagle Creek and East McQuesten River, an area underlain by an Ordovician-Silurian quartzite-slate-limestone unit (Poole 1965). Barite is abundant in the heavy concentrates from this area, and witherite has been identified in several of them. The source of the barium minerals is not known. However, bedded barite deposits in black shales are common in other parts of the Yukon (Blusson, 1976), and it is possible that similar deposits occur in this area. If the barium minerals are not from bedded barite deposits then their source is probably vein deposits.

Barium is also abundant in the eastern part of the district in the tributaries of Beaver and Rackla rivers where graphitic phyllites, argillites, and quartzites underlie the area (Green, 1972). Samples from streams flowing into Roop Creek and the Keno-Ladue River in the southeastern part of the district contain in excess of 10% barium; graphitic phyllites are also abundant here. Two streams (Basin Creek and Erickson Gulch) draining areas containing lead-zinc-silver lode deposits on Keno Hill contain major quantities of barium.

Copper

Trace amounts of copper (0.01-0.001%) occur in samples throughout the area. Several samples in the upper parts of Eastern McQuesten River and Haggart Creek contain 0.1 to 1% copper. These merit further investigation.

Lead

Most heavy mineral concentrates contain less than 0.001 to 0.01% lead. In the western part of the district samples from creeks draining areas containing quartz-pyrite-arsenopyrite-lead sulphosalt lodes (Secret and Haggart Creeks) and quartz-pyrite-arsenopyrite-gold and tungsten deposits (Dublin Gulch) contain 0.1% to 1% lead. There is also an increase in lead (0.1-1%) in a heavy mineral sample from a stream draining a small lead-zinc occurrence on Mt. Haldane. Lead ranges from 0.1 to 1% in concentrates from some of the creeks draining areas containing lead-zinc-silver lodes on Keno and Rambler hills. In the northeastern part of the district two tributaries of the Beaver River contain 0.1 to 1% lead in their heavy mineral concentrates. Both creeks drain Ordovician-Silurian dolomite and limestone. A sample from Rackla River also contains above normal amounts (0.01-0.1%) of lead. Both these areas merit further investigation.

Zinc

Detectable amounts of zinc in the heavy mineral concentrates are infrequent, due mainly to the lack of sensitivity of the analytical method used.

The highest zinc values (0.1-1%) occur in two samples from a stream draining a small lead-zinc occurrence on Mt. Haldane in the southwestern part of the district and from three tributaries of the Beaver River in the northeast part of the area. Ordovician-Silurian calcareous rocks occur in the latter area, a feature that suggests particular further investigation. Another sample containing 0.1-1% zinc was found near the head of a stream 5 miles north of the east end of McQuesten Lake.

Nickel

Small quantities (< 0.01%) of nickel occur in many samples from the area. Samples from a small tributary on the north side and a larger one on the south side of the East McQuesten River contain 0.01-0.1% nickel. Similar values occur in two samples from a tributary on the north side of the South McQuesten River.

Cobalt

Most of the samples contain non-detectable amounts of cobalt. Where the element is present it does not exceed 0.001 to 0.01%. Several of the creeks (Erickson, Charity, Hope, and McKay gulches) draining the area containing the lead-zinc-silver lodes on Keno Hill have such quantities.

Chromium

Small amounts of chromium (0.001-0.01%) are present in many samples throughout the region. Values of 0.01 to 0.1% occur in several samples from tributaries draining into the East McQuesten River and Corkery Creek. In the southeastern corner of the district one sample from a tributary of Roop Creek, another from a small tributary on the north side of Keno-Ladue River, and several in tributaries of Beaver River contain 0.1 to 1% chromium. The chromium is probably derived from mafic and lamprophyre dykes.

Tin

Most of the heavy mineral concentrates contain non-detectable amounts of tin, but the element is particularly abundant (0.1 to 1%) in samples from Dublin Gulch, Haggart, and Secret Creeks. Alluvial tin is known to occur in these streams, and a small lode source of cassiterite also occurs north of Dublin Gulch (Boyle, 1965). Creeks draining Mt. Haldane, Corkery Creek, and tributaries of Mud Creek in the southwest corner of the area contain values in excess of 0.01% tin. No tin deposits are known in this part of the district, but these results suggest that they may exist. Many of the samples from Duncan Creek and its tributaries contain 0.01 to 1% tin. Placer gold has been mined from this creek, and Boyle (1965) has shown that some of the lead-zinc-silver deposits of the Galena Hill-Keno Hill area contain trace amounts of tin. Some of the tin in Duncan Creek may be derived from such sources, but the relatively high values recorded suggest that tin mineralization in this drainage system may be more widespread than is presently known. On the east boundary of a granite intrusive in the Keno-Ladue River and in several of the tributaries of this river the heavy mineral concentrates contain 0.01 to 1% tin. Single samples containing 0.01 to 1% tin are also present in a stream entering Ladue Lake, in a creek west of the south end of McQuesten Lake, and in two tributaries of Beaver River in the northeastern sector of the district. All of these sites deserve further investigation.

Tungsten

Tungsten is particularly abundant (0.01 to 10%) in samples from Haggart Creek, Dublin Gulch, and the Lynx Creek area. The placer gold deposits of this region are known to contain scheelite, and in the Dublin Gulch area the mineral occurs in lode deposits, in skarn rocks and in granite. Tungsten is also present in anomalous amounts in streams draining Mount Haldane and in a creek west of Halfway Lakes. A small granite stock occurs at the former locality, and the provenance of the tungsten is probably related to this intrusive. In addition, minor amounts of tungsten (0.01-0%) are present in samples from tributaries near the head of Lynx and Skate Creek. All heavy mineral concentrates anomalous in tungsten contain essentially scheelite; minor amounts of wolframite occur in some samples, mainly in Dublin Gulch and Haggart Creek.

Silver

Silver was detected (0.01-0.001%) in several samples from streams draining areas containing the lead-zinc-silver deposits of Keno Hill and in gold-bearing placer creeks (Haggart Creek, Duncan Creek, and Dublin Gulch). The lack of sensitivity of the analytical method used does not allow a true evaluation of silver in the heavy mineral concentrates.

Bismuth

Only one sample from a tributary of Dublin Gulch contains detectable amounts of bismuth (0.1-0.01%). The presence of native bismuth in the placer concentrates from Haggart Creek and Dublin Gulch has been commented on previously in this paper. Bismuth is probably much more common in the heavy mineral concentrates than these results indicate. Failure to record bismuth is due mainly to the poor sensitivity of the analytical method used for the element.

Discussion on the distribution of Zr, Sc, Th, U, Y, Ce, La, and Yb in the non-magnetic heavy mineral concentrates (Figure 2)

Zirconium

Zirconium is present in nearly all samples from the district being present in amounts ranging from 0.001 to 10%. It is bound mainly in zircon. The highest amount of zirconium occurs in the East McQuesten River, South McQuesten River, and Duncan Creek drainage systems. The most prevalent rock types in these areas are gritty quartzites, thin bedded quartzite and schists, and the source of the zirconium is probably in these strata.

Scandium

Detectable amounts of scandium are relatively rare in the non-magnetic fraction of the heavy mineral concentrates. In a tributary of Haldane Creek draining Mount Haldane the element reaches a maximum concentration of 0.01 to 0.1%. In the Dublin Gulch, Secret Creek, and Granite Creek areas the samples generally contain 0.001 to 0.1% scandium. Monazite and ferromagnesian silicates such as pyroxene, amphiboles, and biotites derived from the granitic rocks are the probable source of most of the scandium.

Thorium and uranium

All samples were routinely scanned with a gamma-ray spectrometer, and thorium and uranium analyses were done with the spectrometer on samples that registered above normal amounts of radioactivity. Thorium was found to be more abundant than uranium and the element accounts for most of the radioactivity in the samples. Thorium and uranium occurs in such minerals as zircon, monazite, allanite, and thorite. Of these, monazite and zircon have been identified in the concentrates containing high thorium and uranium contents.

Most of the samples containing measurable amounts of thorium and uranium are confined to areas intruded by granite. In the southeastern part of the district these include: McKim Creek, Keno-Ladue River, Roop Creek, Granite Creek, and several small streams on the north side of Mayo Lake. Samples from Dublin Gulch are anomalous in thorium as are samples from several tributaries of the South McQuesten River. The highest thorium (2144 ppm) and uranium (233 ppm) values are in a small tributary on the north side of East McQuestern River; the area drained by this stream should be further investigated. Other samples containing above normal thorium and uranium contents are scattered along various tributaries of the East McQuesten River and Eagle Creek.

Rare earth elements

Many samples, especially those from granitic terranes contain minor amounts of rare earth elements such as yttrium, cerium, lanthanum, and ytterbium. These elements occur most frequently in heavy minerals such as xenotime, monazite, zircon, sphene, thorite, scheelite, epidote, and apatite.

Samples from streams draining the granitic stock in the southeastern part of the region (McKim Creek and Granite Creek) range in content from 0.1 to 1% yttrium and lanthanum. Concentrates from the Haggart Creek —Dublin Gulch area generally contain detectable amounts of rare earth elements as do also tributaries of the South McQuesten River and Haldane Creek.

Discussion on the distribution of Cu, Zn, Pb, Ni, Co, As, Sb, Mo, and W in the magnetic fraction of the heavy mineral concentrates (Figure 3)

Table 1 is a summary of some basic statistical parameters for the elements determined in the magnetic fraction of the heavy mineral concentrates. Background was taken as the median value (50 percentile); probably anomalous, and anomalous values were determined at the 86 and 97 percentile respectively.

Copper

Anomalous copper values in the magnetic concentrates from streams draining areas known to contain lead-zinc-silver deposits include samples from Mt. Haldane (500 ppm), Duncan Creek (64-760 ppm), Cache Creek (80 ppm), Faro Gulch and Silver Basin Gulch (56 ppm). In addition, the magnetic fraction from Dublin Gulch is also relatively rich in copper (100 ppm). The highest copper value (1800 ppm) is present in a small tributary on the north side of South McQuesten River below the mouth of Christal Creek; this sample also contains 1000 ppm zinc. The anomaly is underlain by the favourable Keno Hill quartzite. Other anomalous values are present in streams draining the Patterson and Davidson ranges, a small tributary of Beaver River in the northeastern part of the area, Allen Creek, Parent Creek, Thunder Gulch, and creeks on the north side of Mayo Lake. The copper anomalies in the Davidson Range occur in streams containing limonite-cemented conglomerate, the limonite having been derived from iron-bearing springs. One probable source of the magnetic minerals in some of these streams is the diorite and gabbro dykes and sills which abound in the area. The economic significance of these anomalous copper values is not known, but they merit further investigation.

Zinc

Magnetic concentrates from some of the streams draining areas containing known lead-zinc-silver deposits are anomalous in zinc. These include Duncan Creek (200-1700 ppm), Faro Gulch (460 ppm), Erickson Gulch (180 ppm), streams on Mt. Haldane (230, 260 ppm), and Cache Creek (280 ppm). A small stream draining into Steamboat Lake in the northwestern part of the district has 200 ppm zinc, and one from Dublin Gulch has 320 ppm zinc in the magnetic fraction of the concentrates. In addition, most of the magnetic concentrates previously mentioned as being anomalous in copper are also high in zinc. All sites anomalous in zinc warrant further investigation.

Lead

In the magnetic fraction of the concentrates lead is anomalous in the following streams draining areas containing known lead-zinc-silver occurrences: Duncan Creek (80 to 140 ppm), Lightning Creek (70 ppm), and Faro Gulch (320 ppm). Lead is anomalous also in Dublin Gulch where placer gold and lode deposits of arsenic, gold, and tungsten occur.

The high lead values in the magnetic fraction of samples from a tributary of Roop Creek (800 ppm), a small tributary of Beaver River (40 ppm) in the northeastern part of

Table 1

Statistical summary for elements in the magnetic fraction of the heavy concentrates

(All values in ppm)

Element	Range	Median	Probably anomalous	Anomalous	Number of samples
Cu	4-1800	13	40-67	>68	308
Zn	20-1700	80	170-199	>200	308
Pb	<5-1400	7	20-59	>60	308
Ni	10-1300	55	140-169	>170	306
Co	<5-180	10	30-49	>50	303
As	<5-1400	5	20-39	>40	238
Sb	<2.5-130	<2.5	5-14	>15	229
Mo	<1-5	<1	3-4	>5	128
W	<4-24	<4		>4	121

the district, Philip Gulch (50 ppm) at the head of Scougale Creek in the Davidson Range, Upper Parent Creek (540 ppm), and Allen Creek (60, 70 ppm) merit further investigation.

Nickel

Higher than normal amounts of nickel occur in the magnetic fractions of samples from Duncan Creek (140-240 ppm), Faro Gulch (160 ppm), Erickson Gulch (140 ppm), and from a gulch draining Mount Haldane (280 ppm). All of these areas contain lead-zinc-silver occurrences. In addition, a sample taken from Dublin Gulch is high in nickel (180 ppm). Anomalous values (140-340 ppm) for nickel in the magnetic fraction also occur in tributaries of the South McQuesten River and Haggart Creek near the western boundary of the district, in tributaries of the East McQuesten River (140-200 ppm), Upper Parent Creek (180-220 ppm), Allen Creek (230-320 ppm), streams draining the Davidson Range (170, 1300 ppm), tributaries of the Keno-Ladue River in the southeastern corner of the area (140-640 ppm) and tributaries of Beaver and Rackla rivers (160-380 ppm). Many of these samples are also high in other metals, and all merit further investigation.

Cobalt

Most of the nickel anomalies described above have associated cobalt anomalies. The highest cobalt value (180 ppm) occurs in Philip Gulch at the head of Scougale Creek along with high contents of nickel (1800 ppm), copper (160 ppm), lead (50 ppm), and zinc (1300 ppm). This area and others with multielement anomalies require further investigation.

Arsenic

Only 238 samples had sufficient magnetic material for arsenic analysis. Arsenic is anomalous in the magnetic fraction of the concentrates from streams draining areas containing some of the lead-zinc-silver lodes of the district. These include the Keno Hill drainage net (25-190 ppm), Duncan Creek (20-1400 ppm), Mount Haldane drainage net, (80-220 ppm), and Cache Creek (120 ppm). Areas known to contain lead-arsenic-sulphosalt occurrences such as Secret Creek are anomalous in arsenic (30 ppm), as are also creeks in the vicinity of gold-arsenopyrite deposits such as the Dublin Gulch, Haggart Creek, and Mount Haldane areas (30-220 ppm).

Arsenic anomalies are also found in the following streams: Fork Creek (110 ppm), Christie Creek (30 ppm), the south side of Mayo Lake (40 ppm), a tributary of Edwards Creek (35 ppm), Allen Creek (80 ppm), a stream entering Beaver River opposite the mouth of Rackla River (60 ppm), and a tributary near the mouth of Scougale Creek (30 ppm). The significance of these high arsenic values is not known, but the sources may be the various lead-zinc-silver, lead-arsenic-sulphosalt, and gold-arsenopyrite veins and lodes. All anomalous arsenic sites should receive careful scrutiny.

Antimony

There was sufficient magnetic material in 228 samples for antimony analysis. The anomalous patterns follow closely those for arsenic. Above average amounts of antimony occur in some of the creeks draining areas containing lead-zinc-silver lodes on Keno Hill (7.5-80 ppm), Duncan Creek (7.5-130 ppm), and Mount Haldane (15 ppm). Other antimony anomalies are in Fork Creek (60 ppm), Allen Creek (110 ppm), Christie Creek (30 ppm), the south side of Mayo Lake (20-30 ppm), a tributary of the Keno-Ladue River opposite the mouth of McKim Creek (15-20 ppm), and a tributary of the Beaver River opposite the mouth of Rackla River (30 ppm).

Molybdenum

Only 127 samples had sufficient magnetic material for molybdenum analysis. Most of the samples (122) contain less than 2 ppm molybdenum. The highest value (5 ppm) was recorded in a sample taken in Erickson Gulch.

Tungsten

Of the 121 samples analyzed for tungsten all but 2 contain less than 4 ppm. The two anomalous samples are located on Haggart Creek; both contain 24 ppm tungsten. Scheelite and minor wolframite are common in the placer gold workings along this creek, the minerals being derived from tungsten deposits in granite, hornfels, and skarn rocks in the Dublin Gulch-Lynx Creek area.

SUMMARY AND CONCLUSIONS

The geochemical distribution of minor and trace elements in the heavy minerals from streams and rivers of the Keno Hill district indicated the following:

1. Streams draining most of the areas containing lead-zinc silver lodes are anomalous in a variety of elements including Cu, Pb, Zn, Co, As, and Sb in the non-magnetic fraction of the heavy mineral concentrates. Although analytical data are not complete for the magnetic fraction, indications are that these deposits are reflected by anomalous values in one or more of the elements: Cu, Pb, Zn, Ni, Co, As, and Sb.
2. Non-magnetic concentrates from streams draining lead-arsenopyrite-sulphosalt veins are anomalous in Pb and Ba, and some of the magnetic fractions contain above normal amounts of Pb and As.
3. Non-magnetic heavy concentrates from areas containing tungsten, tin, arsenic, and gold lode deposits are anomalous in Au (Boyle and Gleeson, 1972), Ba, Pb, Sn, W, Zn, Th, and rare earth elements, especially La. The magnetic heavy concentrates tend to be high in one or more of the following elements: Cu, Pb, Zn, Ni, Co, As, and W.
4. Many non-magnetic heavy concentrates from the northwestern corner of the district contain in excess of 1% barium; from this it follows that possible bedded or vein barite deposits in Ordovician-Silurian sedimentary rocks may occur there. The heavy concentrates from other streams draining graphitic phyllites in the Patterson Range are also high in barium.
5. Anomalous Pb, Zn, and Sn values in the non-magnetic fraction of the heavy concentrates from tributaries of the Beaver River in the northeastern portion of the area should be investigated. Other areas anomalous in tin include streams in the southwestern corner of the area, Duncan Creek, and the Keno-Ladue River.
6. The non-magnetic fraction of the heavy concentrates from streams draining granitic rocks in the southeastern part of the area are marked by high values in Zr, Th, U, Y, Ce, La, and Yb.
7. There are a number of unexplained multi-element anomalies in the magnetic heavy concentrates in streams from the Davidson and Patterson Ranges. These are anomalous in one or more of the following elements: Cu, Zn, Pb, Ni, and Co. In Cache Creek and in a stream opposite the mouth of Rakla River As and Sb anomalies are also present.
8. There are a number of streams whose heavy minerals contain higher than normal contents of several of the elements investigated. These merit further work.
9. Low density reconnaissance stream sediment surveys involving geochemical analyses of heavy mineral concentrates can be effective in outlining mineralized areas. In the mountainous regions of Yukon Territory elemental dispersion trains in the stream and river systems are caused as much by transport of particulate matter as by hydrologic processes. Traditionally heavy mineral surveys have been used to define areas enriched in metals having a low degree of chemical mobility in the supergene cycle. The present study indicates, however, that analyses of heavy mineral concentrates for the chemically more mobile elements can outline metalliferous areas. In this respect geochemical and mineralogical analyses of heavy mineral concentrates from the drainage net can complement normal stream sediment surveys and provide additional information that can aid in the interpretation of stream sediment data.

Particulate dispersion trains of hypogene and supergene minerals may be more extensive than hydromorphic trains especially in carbonate terranes where chemical mobility of a number of elements may be restricted due to the high pH.

In Canada much more research needs to be done on the applications of trace element analyses of regional heavy mineral stream concentrates in defining metalliferous districts. The presence of mineral deposits containing magnetic minerals is generally indicated by low density reconnaissance surveys utilizing analyses of the magnetic fraction of the heavy mineral stream concentrates.

REFERENCES

Blusson, S.L.
1976: Selwyn Basin; Yukon and District of Mackenzie; in Report of Activities Part A, Geol. Surv. Can., Paper 76-1A, p. 131-132.

Bostock, H.S.
1947: Mayo, Yukon Territory; Geol. Surv. Can., Map 890.

Boyle, R.W.
1961: Native zinc at Keno Hill; Can. Mineral., v. 6, pt. 5, p. 692-694.

1965: Geology, geochemistry, and origin of the lead-zinc-silver deposits of the Keno Hill-Galena Hill area, Yukon Territory; Geol. Surv. Can., Bull. 111, 302 p.

Boyle, R.W. and Gleeson, C.F.
1972: Gold in the heavy mineral concentrates of stream sediments, Keno Hill area, Yukon Territory; Geol. Surv. Can., Paper 71-51, 8 p.

Gleeson, C.F.
1967: The distribution and behaviour of metals in stream sediments and waters of the Keno Hill area, Yukon Territory; Proceed. Symp. Geochem. Prospecting, Ottawa, April 1966, Editor E.M. Cameron; Geol. Surv. Can., Paper 66-54, p. 134-144.

Gleeson, C.F. (compiler)
1965: Heavy metal content of stream and spring waters, Mayo Lake, Yukon Territory; Geol. Surv. Can., Map 18-1964.

1965: Heavy metal content of stream and spring sediments, Mayo Lake, Yukon Territory; Geol. Surv. Can., Map 19-1964.

1965: Heavy metal content of stream and spring waters, Keno Hill, Yukon Territory; Geol. Surv. Can., Map 20-1964.

1965: Heavy metal content of stream and spring sediments, Keno Hill, Yukon Territory; Geol. Surv. Can., Map 21-1964.

1965: Heavy metal content of stream and spring waters, Mount Haldane, Yukon Territory; Geol. Surv. Can., Map 22-1964.

1965: Heavy metal content of stream and spring sediments Mount Haldane, Yukon Territory; Geol. Surv. Can., Map 23-1964.

1965: Heavy metal content of stream and spring waters, Rackla River, Yukon Territory; Geol. Surv. Can., Map 24-1964.

1965: Heavy metal content of stream and spring sediments, Rackla River, Yukon Territory; Geol. Surv. Can., Map 25-1964.

Gleeson, C.F. (compiler) cont.

1965: Heavy metal content of stream and spring waters, Scougale Creek, Yukon Territory; Geol. Surv. Can., Map 26-1964.

1965: Heavy metal content of stream and spring sediments, Scougale Creek, Yukon Territory; Geol. Surv. Can., Map 27-1964.

1965: Heavy metal content of stream and spring waters, McQuesten Lake, Yukon Territory; Geol. Surv. Can., Map 28-1964.

1965: Heavy metal content of stream and spring sediments, McQuesten Lake, Yukon Territory; Geol. Surv. Can., Map 29-1964.

1965: Heavy metal content of stream and spring waters, Dublin Gulch, Yukon Territory; Geol. Surv. Can., Map 30-1964.

1965: Heavy metal content of stream and spring sediments, Dublin Gulch, Yukon Territory; Geol. Surv. Can., Map 31-1964.

1966: Lead content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 45-1965.

1966: Silver content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 46-1965.

1966: Zinc content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 47-1965.

1966: Arsenic content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 48-1965.

1967: Antimony content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 49-1965.

1968: Copper content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 50-1965.

1967: Molybdenum content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 51-1965.

1967: Tungsten and tin content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 52-1965.

1967: Nickel content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 53-1965.

Gleeson, C.F. (compiler) cont.

1968: Cobalt content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 54-1965.

1968: Manganese content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 55-1965.

1968: Boron content of stream and spring sediments; Keno Hill area, Yukon Territory; Geol. Surv. Can., Map 56-1965.

Gleeson, C.F. and Boyle, R.W.

1976: The hydrogeochemistry of the Keno Hill area, Yukon Territory; Geol. Surv. Can., Paper 75-14, 22 p.

1980: The lithogeochemistry of the Keno Hill district, Yukon Territory; Geol. Surv. Can., Paper 77-31, 19 p.

Green, L.H.

1971: Geology of Mayo Lake, Scougale Creek and McQuesten Lake map-areas, Yukon Territory; Geol. Surv. Can., Mem. 357, 72 p.

1972: Geology of Nash Creek, Larsen Creek, and Dawson map-areas, Yukon Territory; Geol. Surv. Can., Mem. 364, 157 p.

Horwood, J.S.

1959: A graphical determination of uranium and thorium in ores from their gamma-ray spectra: Dept. Mines Tech, Surv., Ottawa, Mines Branch Research Report R 46, 24 p.

Kindle, E.D.

1962: Keno Hill, Yukon Territory; Geol. Surv. Can., Map 1105A.

McTaggart, K.D.

1960: The geology of Keno and Galena Hills, Yukon Territory; Geol. Surv. Can., Bull. 58, 37 p.

Poole, W.H.

1965: Mount Haldane (105M/13) and Dublin Gulch (106D/4) map-areas; in Report of Activities: Field, 1964; Geol. Surv. Can., Paper 65-1, p. 32-35.

Tempelman-Kluit, D.J.

1970: Stratigraphy and structure of the "Keno Hill Quartzite" in Tombstone River-Upper Klondike River map-areas, Yukon Territory; Geol. Surv. Can., Bull. 180, 102 p.