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**THE HYDROGEOCHEMISTRY OF
THE KENO HILL AREA, YUKON TERRITORY**

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1976

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Abstract

The hydrogeochemistry of the Keno Hill area, Yukon is discussed in terms of the statistical treatment of analytical data obtained on 739 stream and 172 spring water samples.

The surface and spring waters are $\text{SO}_4\text{-HCO}_3$ waters dominated mainly by the presence of Ca and Mg with small amounts of Fe, Na, K, and Mn. Some surface and spring waters are characterized by relatively high contents of Zn.

Moving average – residual element maps show that high values for SO_4 , CXM (cold extractable metal), and SO_4/Cl in the waters from the area outline the zones containing Pb-Zn-Ag deposits and pyritiferous rocks. The distribution of Cl in the waters exhibits no relationship to the known mineral deposits. Relatively high Cl contents correlate mainly with the presence of limestone and dolomite units.

Spring waters that leach the known siderite-sulphide lodes exhibit appreciably higher geometric means for various constituents including HCO_3 , SO_4 , SiO_2 , F, and various cations, particularly Zn, compared with the spring waters in the region as a whole. They also have a higher pH but lower Cu contents.

Springs exhibiting relatively high values in their anionic and cationic content may be reflecting hidden mineral deposits, and their source areas should be thoroughly prospected.

Résumé

Ce rapport est une étude de l'hydrogéochimie de la région de Keno Hill, au Yukon, d'après le traitement statistique de données d'analyse portant sur 739 échantillons d'eaux courantes et 172 échantillons d'eaux de source.

Les eaux de surface et de source sont des eaux contenant des ions SO_4 et HCO_3 , où dominant le Ca et le Mg, accompagnés de petites quantités de Fe, Na, K et Mn. Certains échantillons d'eaux de surface sont caractérisés par une teneur en Zn relativement élevée.

Les cartes donnant les moyennes mobiles des éléments-traces indiquent que, dans cette région, des valeurs élevées de la teneur en SO_4 et en métaux extractibles à froid, ainsi que du rapport SO_4/Cl caractérisent les zones où l'on trouve des gisements de Pb, Zn et Ag ainsi que des roches pyriteuses. La distribution des teneurs en Cl de ces eaux ne montre aucune corrélation avec les gisements minéraux connus. Des teneurs en Cl relativement élevées correspondent essentiellement à la présence de formations calcaires et dolomitiques.

Comparativement à l'ensemble des eaux souterraines de la région, les eaux de source qui ont lessivé des filons connus de sidérite et de sulfures présentent une augmentation appréciable des moyennes géométriques de divers ions constituants comme HCO_3 , SO_4 , SiO_2 , le F et de divers cations, notamment le Zn. Elles ont aussi un pH plus élevé mais des teneurs plus faibles.

Il est possible que des sources qui exhibent des teneurs relativement élevées en anions et en cations correspondent à des gisements minéraux cachés; les régions d'où proviennent leurs eaux doivent donc faire l'objet d'une prospection sérieuse.

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 some 1900 square miles centred on Keno Hill, Yukon.) The results of the water and stream sediment analyses have been published (Gleeson *et al.*, 1965, 1966-67), and the heavy mineral analyses for a number of elements, including gold have been placed on open file by the Geological Survey of Canada (Open file report 46). A paper on gold in the heavy mineral concentrates of the stream sediments has also been issued (Boyle and Gleeson, 1972). Early hydro-geochemical work in the area has been published by Boyle *et al.*, 1955, 1956.

The present paper deals with the geochemistry of the surface and groundwaters collected for analysis in 1964.

Location

The Keno Hill area is in central Yukon, 35 miles northeast of Mayo and some 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 cut 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 of 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 some 400 feet below the surface. On the northern slopes of Sourdough Hill and Galena Hill a similar situation prevails, and frost and ice lenses have been found at depths of 250 feet or more in the mine workings. On the lower, southern slope of Keno Hill, however, the workings of the Onek and Mount Keno mines show little evidence of permafrost. In places where surface and underground water are flowing the permafrost has been thawed out and frost-free windows and strips are present. These provide access and egress 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. 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 hydrogeochemical 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 age¹. They consist of graphitic and sericite schists, phyllites, thick- and thin-bedded quartzites, argillites, and a few limestone lenses.

¹ Some geologists consider these rocks to be Jurassic and Lower Cretaceous in age (Tempelman-Kluit, D. J., Geol. Surv. Can., Bull. 180).

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 types of rocks. 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. Further 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 orebodies, and a north-northeast to northwest-trending series of faults which cut the orebodies and are barren.

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 physiochemical 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 is discussed in detail by Boyle (1965).

GENERAL CHARACTERISTICS OF THE SURFACE AND GROUNDWATERS OF THE KENO HILL AREA

The surface waters of the area comprise creeks, rivers, and a number of lakes, the largest of which is Mayo Lake in the southern part of the area. Most of these bodies of water are virgin and uncontaminated by human habitation or mine workings. Exceptions are some of the creeks that drain Keno, Sourdough, and Galena hills, the sites of the principal mines and villages.

The creek and river pattern is exceptionally well developed, there being practically no part of the area more than a few thousand feet from a creek or river. The irregular dendritic pattern is common in uplifted mountainous regions.

The creeks that feed the rivers and lakes rise high in the gulches deriving their water from small snow-fields in the spring and early summer and from a myriad of springs in flat-lying, grassy and boggy areas at the heads of the gulches. The water in these springs is derived mainly from the thawing of the active layer of the permafrost. Where windows appear in the permafrost some of the springs receive contributions from the groundwater system as noted below. During the spring breakup and the early summer the creeks are commonly raging torrents; as summer progresses and passes into autumn many of the creeks, not fed by underground water, decline in their flow and some become only a trickle or dry up completely.

Most of the creek, river and lake waters are relatively clear and contain only small amounts of organic matter (humic matter). In the wide valleys some of the creeks and rivers are sluggish, and they and the small ponds and lakes contain relatively large amounts of humic matter. Some of the lakes in the McQuesten River Valley have marl bottoms. Near the orifices of springs receiving water from the groundwater system, the water of the creeks is generally greatly modified as discussed in more detail below. The waters of the lakes and the larger rivers and creeks support abundant aquatic vegetation, various low-order organisms, and several species of fish, especially grayling and lake trout.

The pH of the surface waters as measured in the field varies between 3.7 and 8.9. The lower pH's are recorded mainly in waters in boggy areas and in certain waters at the orifices of springs that derive their water from the groundwater system; the higher pH's are characteristic of some groundwaters and of most creek, river, and lake waters. The average pH of the surface waters is probably about 6.5.

The temperature of the surface waters ranges from 0°C for meltwater derived from snowfields and the active layer of the permafrost, to 15°C for stagnant pools in bogs, creeks, and rivers. Probably the average temperature of most surface waters is near 8°C.

Surface waters, devoid of contributions from the groundwater system, are essentially weakly mineralized sulphate-bicarbonate waters.

The groundwaters evidently derive their water from meteoric sources through windows in the permafrost at higher elevations. Passing downward these waters circulate below the permafrost, following bedding planes in the sediments, faults, and linear crush zones. In places, again through windows in the permafrost, the groundwaters emerge in springs commonly along the surface traces of faults or bedding planes.

All of the groundwaters are clear and contain relatively little organic matter. On emerging at the surface some become murky and begin to precipitate various iron oxides and other components as discussed below. Their temperature ranges from 0°C to 4°C, and their pH as measured in the field ranges between 3.4 and 8.6. Where the waters are actively leaching sulphides in the vein faults their pH may be as low as 4.4, but as they come into contact with the carbonate gangue their pH rises to values near 7.5.

The groundwaters are essentially highly mineralized sulphate-bicarbonate waters with traces of silica, chloride, fluoride, and nitrate. Their cationic content varies widely as shown in Table 4 (Appendix) the most abundant cations being calcium, magnesium, iron, manganese, and aluminum. One characteristic feature of the presence of groundwater springs is the precipitation for distances of 1000 feet or more of black, light brownish to yellowish, or chocolate to reddish coloured precipitates at the spring orifices and along the creeks into which they flow. In places the precipitates, which originally comprise hydrous aluminum, iron, and manganese oxides, sulphates, silica, etc., have congealed, hardened, and cemented particles of rock, soil, muskeg, and decayed vegetation into a limonitic conglomerate.

FIELD PROCEDURE

Two water samples were taken at different places from each creek, one sample from the upper part and the second from the lower course. These were tested in the field for pH and cold extractable heavy metals (CXM) using a method described by Boyle *et al.* (1955), (Table 4, Appendix). These stream waters were subsequently analyzed in the laboratory for SO₄ and Cl anions as described below.

In addition, 1 litre samples of water were taken from springs throughout the area and within the mine workings. Complete laboratory analyses for anions and cations were done on these waters (Table 5, Appendix).

Altogether some 739 stream waters and 172 spring water samples were analyzed from the 1900-square-mile area.

LABORATORY PROCEDURE

The stream, spring, and mine waters were analyzed in the laboratories of the Industrial Waters Section, CANMET, Ottawa according to the procedures listed below:

<u>PARAMETER</u>	<u>METHOD</u>
Total hardness	Calculated from Ca and Mg results
Calcium	Sodium ethylenediaminetetraacetic acid (EDTA) titration with Eriochrome Blue SE as indicator
Magnesium	Sodium ethylenediaminetetraacetic acid (EDTA) titration with Eriochrome Black T as indicator
Iron	Colorimetric with, αα -dipyridyl
Manganese	Colorimetric utilizing periodate
Zinc	Colorimetric utilizing dithizone
Sodium	Flame photometer
Potassium	Flame photometer
Chloride	Potentiometric titration with standard mercuric nitrate solution
Fluoride	Colorimetric with SPADNS reagent
Total inorganic PO ₄	Boiled with sulphuric acid (H ₂ SO ₄); colorimetric with ammonium molybdate 1-amino-2-naphthol-4 sulphonic acid (ANSA) and bismuth nitrate (Bi(NO ₃) ₃)
NO ₃ +NO ₂	Spectrophotometric by ultraviolet absorption
SiO ₂	Colorimetric with ammonium molybdate (NH ₄) ₆ Mo ₇ O ₂₄ ·4H ₂ O 1-amino-2-naphthol-4 sulphonic acid (ANSA), - sodium sulphite (Na ₂ SO ₃) - sodium bisulphate (NaHSO ₃) solution.
pH	pH meter
Colour	Visual comparison using Hellige colour comparator
Turbidity	Hach turbidimeter
Alkalinity	Potentiometric titration with standard sulphuric acid (H ₂ SO ₄)
Conductivity	Wheatstone bridge and pipette type conductivity cell
Sulphate	Titration with barium chloride (BaCl ₂) using thordin as a visual endpoint detector
Copper	Colorimetric with zinc dibenzyl-dithiocarbamate.
Non-carbonate	Calculated from total hardness and alkalinity
HCO ₃ , CO ₃	Calculated from alkalinity and pH
CO ₂	Calculated from alkalinity and pH

Table 1

Statistical summary for CXM, Cl, SO₄, and SO₄/Cl in surface and spring waters,
Keno Hill area, Yukon Territory

Element	Range	Means		Standard deviations	Correlation Coefficient			
		Arith.	Geom.		CXM	Cl	SO ₄	SO ₄ /Cl
CXM ppb	<0.5 - 2500	25.8	2.6	69.8		.07	.02	.00
Cl ppm	<0.05 - 9.9	0.3	0.2	0.3			.04	.00
SO ₄ ppm	<0.1 - 3840	32.9	20.9	32.4				.00
SO ₄ /Cl	0.5 - 153,600	282.8	107.7	390.7				

PLOTTING OF RESULTS AND COMPUTER PROCESSING

Initially all sample sites were plotted manually and the SO₄, Cl and SO₄/Cl ratios were entered at the appropriate sites. Data such as vein systems, faults, mines, etc. were added for visual correlative purposes (Fig. 1).

All analytical and field data were then entered on punched cards and routine statistical parameters such as means, standard deviations, histograms, and correlation coefficients were computed (Tables 1, 2, and 3; and Figs. 2 and 3).

The location of each sample was digitized and automated maps for CXM, Cl, SO₄, and SO₄/Cl were drawn and contoured showing moving average and residual values (Figs. 4-7 inclusive). A window radius of 2 inches was used for the moving average map with an overlap of 75 per cent. The residual values were determined by calculating the difference between the moving average and the original values.

A full listing of all computer data is on file at the Geological Survey of Canada, Ottawa.

DISCUSSION OF RESULTS

Various statistical parameters and correlations for surface and spring waters are discussed first followed by a discussion of similar and additional statistical parameters and correlations for spring waters and underground waters in the mines.

Surface and Spring Waters

The range of values, arithmetic means, geometric means, and standard deviations for CXM, Cl, SO₄, and SO₄/Cl in surface and spring waters are shown in Table 1. Histograms for each of these parameters are shown in Figure 1. All show a positive skewness, and all are polymodal. The latter feature is to be expected because the waters have a variety of sources in different geological terrains.

No significant correlations are apparent between the elements shown in Table 1.

To obtain a more adequate idea of the regional distribution of CXM, Cl, SO₄, and SO₄/Cl, computer plotted moving average-residual values maps were constructed for these elements. These indicate the following:

Cold extractable heavy metal (CXM)

The geometric mean for CXM in the Keno Hill area waters is 2.6 ppb (Table 1). Regional highs in excess of 80 ppb (Fig. 4) over Keno and Galena hills and the Gustavus, Davidson, and Patterson ranges tend to follow the geological trends of the underlying quartzites and phyllites.

Regional highs in excess of 100 ppb are present in the vicinity of the mineral deposits on Galena Hill and the Davidson Range. Extensive regional highs in the Patterson Range, and more locally in the Gustavus Range, are probably due to undiscovered mineral deposits and/or pyrite-rich phyllites. Multi-element anomalies in the stream sediments (Gleeson, 1966-67) are also present in those areas.

A regional increase in CXM to 40 ppb is centred over Mount Haldane where mineralized vein faults, similar to those on Galena and Keno hills occur (Boyle, 1965). Stream sediments from this area are also high in Zn, Pb, Cu, Ni, B, Mo, Mn, As, W, Ag, and Sn.

Table 2
 Statistical summary of analytical data obtained for surface and
 underground mine spring waters (172 samples)

Element	Range of values	Means		Standard deviation
		Arith.	Geom.	
CO ₂ (ppm)	<0.1 - 30	4.2	3.2	3.2
pH	2.5 - 8.4	6.44	6.24	1.43
Sp. Cond. (Mho at 25°C)	4.4 - 4938.0	260.5	141.8	292.9
Ca ppm	<0.1 - 500.0	35.3	15.5	49.7
Mg ppm	<0.1 - 630.0	9.4	5.0	10.3
Fe ppm	<0.01 - 500.0	4.41	0.69	9.5
Mn ppm	0.002- 146.0	0.40	0.03	0.79
Cu ppb	<1 - 2450	9.9	2.3	25.3
Zn ppb	<1 -27 000	99.4	13.2	183.0
Na ppm	0.1 - 8.4	0.8	0.6	0.6
K ppm	<0.1 - 5.1	0.3	0.2	0.3
HCO ₃ ppm	<0.1 - 372.0	61.3	7.5	78.1
SO ₄ ppm	<0.1 - 3840.0	83.3	26.1	143.1
Cl ppm	<0.05 - 3.2	0.3	0.2	0.3
F ppm	<0.03 - 1.28	0.21	0.18	0.11
NO ₃ ppm	<0.01 - 34.0	0.3	0.1	0.4
SiO ₂ ppm	0.4 - 33.0	5.4	4.3	3.1
Sum of Constituents	4.6 - 3019.0	149.8	82.8	173.9

Another regional increase in CXM is apparent in the northeast part of the area straddling and north of Beaver River. This appears to be associated with Ordovician and Silurian dolomite and black shale units. The stream sediments in this area are also high in Zn, Pb, Ni, Mo, Cu, and As (Gleeson, 1966-67), suggesting that the black shale unit is probably the source of the metal.

In addition there is a regional increase in CXM in the northwest corner of the area north of Eagle Creek. A northwest trending thrust fault marks the contact of a grit unit on the south and the Keno Hill quartzite, at the headwaters of the creek, on the north. Metal anomalies in Zn, Cu, Ni, B, Mo, Mn, and Ag are,

likewise, present in the stream sediments from this region (Gleeson, 1966-67).

The mineralized area (Au, W, Pb, As, and Sb) around the Potato Hills granitic stock is marked by low CXM regional values. Similar low values are also present around the granitic stocks northwest of Hanson Lakes and in the Roop Lakes area. However, stream sediments in the Potato Hills area are anomalous in Pb, As, W, Sb, and Mn. The paucity of zinc in the mineral deposits of this area is the cause of the relatively low CXM values in the waters.

Specific locations showing positive residual anomalies in CXM are located, for the most part, in areas of regionally high CXM values.

Table 3
Statistical summary of analytical data obtained for spring waters and underground discharge waters from mine workings (20 samples)

Element	Range of values	Means		Standard deviation
		Arith.	Geom.	
CO ₂ ppm	3 - 26	9.4	8.2	5.2
pH	6.8 - 8.2	7.53	7.52	0.30
Sp. Cond. (Mho at 25°C)	157 - 2210	707.7	618.3	351.4
Ca ppm	19.9 - 500	123.5	104.3	69.2
Mg ppm	6.8 - 72.9	20.7	17.4	11.7
Fe ppm	0.01 - 23.00	3.78	1.47	3.62
Mn ppm	0.24 - 10.80	1.57	1.06	1.38
Cu ppb	1 - 4	1.1	0.9	0.6
Zn ppb	4 - 1280	174.3	81.8	192.4
Na ppm	0.9 - 3.8	1.4	1.3	0.5
K ppm	0.2 - 1.4	0.5	0.5	0.3
HCO ₃ ppm	56.1 - 372.0	207.8	195.7	59.4
SO ₄ ppm	4.5 - 1295.0	340.9	185.1	308.4
Cl ppm	<0.05 - 3.2	0.2	0.1	0.5
F ppm	<0.03 - 1.28	0.44	0.40	0.18
NO ₃ ppm	<0.1 - 0.20	0.09	0.08	0.02
SiO ₂ ppm	3.7 - 15.0	6.9	6.5	2.3
Sum of Constituents	95.0 - 1989.0	399.6	352.0	187.6

In summary, regional CXM anomalies are related to areas containing Pb-Zn-Ag deposits and pyrite-rich sedimentary rocks. The Pb-Ag-Sb and Au-W deposits in the Potato Hills area are associated with relatively low regional CXM values.

Chloride (Cl):

The chloride content (Fig. 1) of the surface and groundwaters is low, the geometric mean being 0.2 ppm (Table 1).

Regionally, there appears to be little correlation between the known ore deposits of the area and the chloride content of the waters (Fig. 5).

However, in the northeast part of the map-area there is an increase in the Cl content in areas underlain by limestones and dolomites. Moving average highs there are more or less parallel to the trend of the underlying calcareous rocks. Stream sediments from these areas are also high in Zn and Pb (Gleeson, 1966-67).

Another regional high trends northwest from the central part of the Davidson Range to Steamboat Lake. The core of this zone (>0.7 ppm) is underlain by phyllites and quartzites, and the northwestern part of the anomalously high area is underlain by a grit unit containing lenses of limestone. The regional increase in chloride probably reflects the presence of these limestones. Similarly, the high moving average in the

southwest portion of the map-area on the north side of the South McQuesten River probably is related to limestone lenses in the grit unit.

A regional increase in chloride occurs between Roop Lakes and McKim Creek in an area intruded by a granitic stock. High residual values in chloride appear to occur on the periphery of the granite. In addition similar high residual values are present near the granite stock at the head of Lynx Creek.

In summary, regionally high chloride values in the water appear to outline areas underlain by limy rocks. Phyllitic rocks on Rambler Hill, southeast of McQuesten Lake, are also marked by regionally high chloride values. There are indications that increases in the chloride content of the waters occur on the periphery of some granite stocks.

Sulphate (SO₄):

The geometric mean of the sulphate content of the waters of the Keno Hill area is 20.9 ppm (Table 1).

The moving average map for sulphate (Fig. 6) shows a regional northeast trending high over the Pb-Zn-Ag veins cutting the quartzites on Galena Hill. This trend more or less continues northeastward to include Keno Hill and its mineral deposits. This regional high may also be partially related to the pyritic, graphitic phyllites and schist which underlie the Keno Hill quartzites.

North of Keno Hill the regional trend changes abruptly to a northwesterly direction. This corresponds to the regional strike of the phyllites and quartzites which underlie the Davidson Range. The moving average highs appear closely related to the graphitic phyllites and the source of the sulphate could be pyrite which is common in these rocks. Pb-Zn-Ag-Cu deposits also occur in this area, and they also probably contribute to the high regional sulphate content of the waters.

High regional sulphate contents in the waters also occur in the Patterson Range which is underlain by phyllites and quartzites. The sulphate is probably mainly derived from pyrite which is common in the phyllites. However, the anomaly over the quartzite unit could also be related to metallic deposits, especially as the stream sediments of this area contain poly-element anomalies in Zn, Cu, Pb, Ni, Co, As, Mn and Ag (Gleeson, 1966-67).

Southeast of Rackla River a northeast trending regional high marks a grit unit in contact with graphitic phyllites, phyllites, and phyllitic quartzite. The sulphate here probably has the same origins as those mentioned for the Patterson Range.

A moving average high in sulphate occurs in the northwest corner of the map-area which is underlain by a grit unit. As with all regional sulphate anomalies discussed so far, this one also corresponds to a regional increase in CXM in the waters. Stream sediments from this area contain multi-element anomalies in Cu, Zn, Ni, Mo, B, and Mn (Gleeson, 1966-67). In addition heavy mineral concentrates from this area contain appreciable amounts of barite. Hence, the sulphate in

this area is probably derived from varied geological provenances, and additional work would be required to delineate these sources.

Another circular regional high in sulphate is associated with the grit unit in the southwest part of the area on the north side of South McQuesten River. The cause of this high is not known.

The areas underlain by granitic rocks (Hanson and Roop lakes) are marked by low moving average sulphate values in the waters.

In summary, except in the northeast, where dolomitic rocks are present, there is little correlation between the high regional sulphate and chloride contents of the waters. Hence, for the most part, the origin of chloride in the waters is independent of the source of the sulphate. However, most areas high in sulphate are correspondingly high in CXM. Undoubtedly much of the sulphate in the waters is derived from sulphide occurrences in the rocks of the map-area. Some of these occurrences are mineral deposits, and others are pyrite-rich sediments containing above normal amounts of trace metals. Finally there are indications in the northwest part of the area that minerals such as barite may contribute some sulphate to the waters.

Sulphate-chloride ratio:

The regional distribution pattern of the sulphate-chloride ratio (Fig. 7) is markedly similar to the sulphate trends. The geometric mean (Table 1) for SO₄/Cl is 107.7.

The SO₄/Cl values are maximal over the ore deposits on Galena Hill and in areas underlain by phyllites and quartzites. The reason for this is the presence of pyrite-rich rocks and poly-metallic (Pb-Zn-Ag-Cu) deposits such as those that occur at Keno, Beauvette, Cobalt, and Forbes hills.

The Au-W-As and Pb-As-Sb occurrences west of Potato Hills area are generally marked by low SO₄/Cl regional-residual values. An exception to this appears to be the north side of Lynx Creek where several residual values greater than 1200 occur.

The moving average values for SO₄/Cl are also high in the northwest part of the map-area underlain by a grit unit. The high SO₄/Cl ratios there are due to sulphate derived from pyrite-rich sediments and possibly in part from barite-bearing rocks. No metallic deposits are known to occur in this area which is also characterized by unexplained multi-element stream-sediment anomalies (Gleeson, 1966-67).

In summary, the regional distribution of SO₄/Cl is markedly similar to the sulphate moving average pattern. The high sulphate regional-residual values are related to poly-metallic deposits in the Keno Hill quartzite and pyrite-rich phyllites. Sulphate-bearing minerals such as barite are present in the northwest part of the area and may also contribute to high SO₄/Cl ratios. The area containing the Pb-As-Sb and W-As-Au veins west of Potato Hills is marked by relatively low SO₄/Cl ratios.

	CO ₂	pH	SpCd	Ca	Mg	Fe	Mn	Cu	Zn	Na	K	HCO ₃	SO ₄	Cl	F	NO ₃	SiO ₂	Sum*
CO ₂		0.12	0.40	0.57	0.14	0.05	0.05	0.01	0.02	0.44	0.48	0.48	0.32	0.13	0.20	0.42	0.08	0.45
pH	•		0.22	0.32	0.09	0.04	0.02	0.02	0.01	0.24	0.21	0.59	0.13	0.23	0.14	0.07	0.08	0.23
SpCd	●	•		0.59	0.15	0.02	0.04	0.00	0.02	0.28	0.26	0.50	0.33	0.07	0.17	0.07	0.11	0.46
Ca	●	•	●		0.19	0.03	0.05	0.00	0.02	0.34	0.32	0.70	0.47	0.09	0.20	0.07	0.14	0.67
Mg	•	•	•	•		0.01	0.02	0.01	0.01	0.14	0.12	0.19	0.11	0.04	0.06	0.05	0.05	0.16
Fe	•	•	•	•	•		0.02	0.04	0.01	0.03	0.10	0.05	0.02	0.05	0.02	0.03	0.02	0.03
Mn	•	•	•	•	•	•		0.01	0.01	0.03	0.04	0.04	0.03	0.02	0.03	0.02	0.02	0.04
Cu	•	•	•	•	•	•	•		0.01	0.02	0.05	0.01	0.01	0.02	0.02	0.02	0.01	0.00
Zn	•	•	•	•	•	•	•	•		0.01	0.02	0.02	0.01	0.01	0.04	0.01	0.01	0.02
Na	●	•	•	•	•	•	•	•	•		0.62	0.44	0.16	0.29	0.17	0.56	0.23	0.18
K	●	•	•	•	•	•	•	•	•	●		0.34	0.17	0.21	0.14	0.63	0.15	0.18
HCO ₃	●	●	●	●	•	•	•	•	•	•	•		0.30	0.23	0.29	0.14	0.20	0.27
SO ₄	•	•	•	•	•	•	•	•	•	•	•	•		0.03	0.08	0.03	0.08	0.28
Cl	•	•	•	•	•	•	•	•	•	•	•	•	•		0.09	0.24	0.10	0.02
F	•	•	•	•	•	•	•	•	•	•	•	•	•	•		0.07	0.12	0.00
NO ₃	●	•	•	•	•	•	•	•	•	●	●	•	•	•	•		0.06	0.00
SiO ₂	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		0.00
Sum*	●	•	●	●	•	•	•	•	•	•	•	•	•	•	•	•	•	

Range: ● > 0.50 ● 0.40-0.49 ● 0.30-0.39 ● 0.20-0.29 ● 0.10-0.19 ● 0.00-0.09

* Sum of constituents

Correlation: Black,+ ; white,-

Figure 2. Correlation coefficients of spring waters, Keno Hill, Yukon Territory.

	CO ₂	pH	SpCd	Ca	Mg	Fe	Mn	Cu	Zn	Na	K	HCO ₃	SO ₄	Cl	F	NO ₃	SiO ₂	Sum*
CO ₂		-0.70	0.65	0.63	0.62	0.53	0.39	-0.06	0.26	-0.19	0.39	0.05	0.68	-0.09	-0.11	0.21	-0.24	0.65
pH	○		-0.13	-0.10	-0.29	-0.43	-0.51	0.17	-0.30	0.28	-0.21	0.58	-0.21	0.33	0.33	-0.13	0.21	-0.14
SpCd	●	○		0.99	0.85	0.58	0.33	0.22	0.19	-0.18	0.54	0.49	0.99	0.07	0.06	0.25	-0.25	0.99
Ca	●	○	●		0.81	0.55	0.32	0.20	0.20	-0.19	0.49	0.50	0.99	0.07	0.08	0.24	-0.21	1.00
Mg	●	○	●	●		0.58	0.30	0.30	0.11	-0.04	0.71	0.27	0.87	0.03	-0.07	0.32	-0.28	0.85
Fe	●	○	●	●	●		0.80	0.20	0.55	-0.11	0.47	-0.07	0.59	0.06	0.18	0.30	-0.24	0.58
Mn	•	○	•	•	•	●		0.12	0.80	-0.20	0.17	-0.26	0.36	0.09	0.26	0.01	-0.21	0.34
Cu	•	•	•	•	•	•	•		0.14	0.43	0.51	0.08	0.20	0.20	0.26	0.24	-0.07	0.14
Zn	•	○	•	•	•	●	●	•		-0.04	0.06	-0.01	0.19	0.11	0.36	0.01	-0.07	0.18
Na	○	•	○	○	○	○	○	●	○		0.11	0.24	-0.22	0.64	-0.20	0.28	0.61	-0.20
K	•	○	●	•	●	•	•	●	•	•		0.02	0.55	-0.11	0.16	0.66	-0.32	0.49
HCO ₃	•	●	•	●	•	○	•	○	•	•	•		0.39	0.40	0.15	-0.05	0.07	0.19
SO ₄	●	○	●	●	●	●	•	•	•	○	●	•		0.01	0.03	0.26	-0.26	0.84
Cl	•	•	•	•	•	•	•	•	•	●	○	●	•		0.05	-0.10	0.26	0.00
F	○	•	•	•	•	•	•	•	•	○	•	•	•	•		-0.10	-0.27	0.00
NO ₃	•	○	•	•	•	•	•	•	•	•	●	•	•	○	○		0.22	0.00
SiO ₂	○	•	○	○	○	○	○	○	○	●	○	○	•	○	○	•		0.00
Sum*	●	○	●	●	●	●	•	•	•	○	●	•	●	•	•	•	•	

Range: ● > 0.50 ● 0.40-0.49 ● 0.30-0.39 ● 0.20-0.29 ● 0.10-0.19 ● 0.00-0.09

* Sum of constituents

Correlation: Black,+ ; white,-

Figure 3. Correlation coefficients of spring waters in mines, Keno Hill-Galena Hill area, Yukon Territory.

Spring Waters

A total of 152 water samples were taken from surface springs along the drainage systems of the area. In addition 20 samples were obtained from springs and groundwater discharges in the mine workings of Keno and Galena hills. The locations of all samples are shown on Figure 1. The spring and underground mine waters¹ were analyzed for major and minor inorganic components (Table 5, Appendix).

The values for 18 of the parameters including CO₂, pH, specific conductance, Ca, Mg, Fe, Mn, Cu, Zn, Na, K, HCO₃, SO₄, Cl, F, NO₃, SiO₂ and sum of constituents were rendered computer processible, and the basic statistical parameters such as means, standard deviations, and correlation coefficients were calculated. A complete listing of data including histograms and individual ratings of each sample is on file at the Geological Survey of Canada, Ottawa.

The range of values, arithmetic mean, geometric mean, and standard deviation for all surface and underground mine spring waters are listed in Table 2.

The ranges of values are considerable for most elements with the maxima being many fold greater than the means.

Correlation coefficients for the spring waters are shown in Figure 2.

Good positive correlations exist between the following:

1. CO₂ vs. Ca-Na-K-HCO₃-NO₃- Specific Conductance and Sum of Constituents
2. pH vs. HCO₃
3. Specific Conductance vs. Ca-HCO₃-CO₂ and Sum of Constituents
4. Ca vs. HCO₃-CO₂-Specific Conductance-Sum of Constituents and SO₄
5. Na vs. K-NO₃-CO₂ and HCO₃
6. K vs. Na-NO₃ and CO₂
7. HCO₃ vs. Ca-pH-Specific Conductance-CO₂ and Na
8. NO₃ vs. K-Na and CO₂
9. SO₄ vs. Ca
10. Sum of Constituents vs. Ca-CO₂ and Specific Conductance

In addition less marked but possibly significant correlations exist between the following:

1. CO₂ vs. SO₄
2. pH vs. Ca
3. Specific Conductance vs. SO₄
4. Ca vs. pH-Na and K
5. Na vs. Ca-Cl and Specific Conductance
6. K vs. Ca and HCO₃
7. HCO₃ vs. K-SO₄ and F
8. SO₄ vs. Specific Conductance-CO₂ and HCO₃

Most of the above relationships are what one would expect from the normal processes of weathering,

¹The underground spring and discharge waters in the various mines were virgin waters circulating along faults and through the mineralized veins. They were taken in places that avoided contamination by waters used in mining operations.

involving hydrolysis of silicates, oxidation of sulphides, and solution of carbonates.

The various ions, including Fe, Mn, Cu, and Zn, show no correlation with the other parameters listed for the statistics of all the spring samples.

For comparative purposes the analytical results of the 20 samples from the spring and groundwater discharges in the various mines were separated from the 172 spring waters and subjected to the same statistical treatment as the total population.

The range of values, means and standard deviation for the spring waters from the mines are listed in Table 3. Comparing these results with Table 2 it is obvious that the geometric means for CO₂, pH, Specific Conductance, Ca, Mg, Fe, Mn, Zn, Na, K, HCO₃, SO₄, F, SiO₂, and Sum of Constituents in the springs from mine workings all show significantly higher values when compared with the spring waters from the region. The geometric means for Cu and Cl are lower in the spring waters from the mine workings than for the springs throughout the region.

In the waters circulating through the veins and lodes the principal anions are bicarbonate, sulphate, and to a lesser extent silica. Although fluoride is present only in small amounts its geometric mean (0.40 ppm) in the underground waters in the mines is more than twice that in the whole region (0.18 ppm). Small amounts of chloride and nitrate are also present in the underground mine springs, but they are not diagnostic constituents. Cations such as Fe, Mn, Zn, Ca, and Mg are present in significant amounts in the underground waters in the mines.

Correlation coefficients for the various constituents of the underground waters from the mines are presented in Figure 3. The following marked positive correlations are apparent between:

1. CO₂ vs. Specific Conductance-Ca-Mg-Fe-SO₄ and Sum of Constituents
2. pH vs. HCO₃
3. Specific Conductance vs. CO₂-Ca-Mg-Fe-K-SO₄ and Sum of Constituents
4. Ca vs. CO₂-Specific Conductance-Mg-Fe-HCO₃-SO₄ and Sum of Constituents
5. Mg vs. CO₂-Specific Conductance-Ca-Fe-K-SO₄ and Sum of Constituents
6. Fe vs. CO₂-Specific Conductance-Ca-Mg-Mn-Zn-SO₄ and Sum of Constituents
7. Mn vs. Fe and Zn
8. Cu vs. K
9. Zn vs. Mn and Fe
10. Na vs. Cl and SiO₂
11. K vs. Specific Conductance-Mg-Cu-SO₄ and NO₃
12. HCO₃ vs. pH and Ca
13. SO₄ vs. CO₂-Specific Conductance-Ca-Mg-Fe-K and Sum of Constituents
14. Cl vs. Na
15. NO₃ vs. K
16. SiO₂ vs. Na
17. Sum of Constituents vs. CO₂-Specific Conductance-Ca-Mg-Fe-K and SO₄

Good negative correlations are present between:

1. CO₂ vs. pH
2. pH vs. CO₂ and Mn
3. Mn vs. pH

Most of the above relationships are understandable when the chemistry of the oxidation phenomena affecting the primary mineral veins is considered. The veins contain essentially manganiferous siderite, quartz, galena, sphalerite, pyrite, and freibergite. Boyle (1965) has explained that as the various sulphides in the veins are attacked by oxygen-bearing waters soluble sulphates are produced, and some free sulphuric acid is liberated during the reactions. The latter attacks the siderite producing sulphates of Fe, Mn, Mg, and Ca plus H₂CO₃. The carbonic acid produced during the acid attack on siderite augmented by atmospheric carbon dioxide dissolved in percolating waters is responsible for the solution and transport of some Fe, Mn, Mg, and Ca by forming soluble hydrogen carbonates. The presence of H₂SO₄ and H₂CO₃ in the underground waters also facilitates the chemical breakdown of the numerous silicate minerals in the wall rocks and gouge of the faults and veins. Na, K, and Al are thus taken into solution and transported as either sulphates or carbonates. The silica entering solution evidently migrates as the monomer Si(OH)₄.

SUMMARY AND CONCLUSIONS

Moving average-residual element maps show that high values for SO₄, CXM and SO₄/Cl in the waters from the Keno Hill area outline zones containing Pb-Zn-Ag deposits and pyritiferous rock-units. In the northwest part of the map-area barite in the rocks may also contribute to high SO₄ values.

The distribution of Cl in the waters exhibits no relationship with the known mineral deposits in the map-area. Relatively high Cl contents correlate mainly with the presence of limestone and dolomite units.

The spring waters in the map-areas have an average pH value of 6.24 and a mean CO₂ content of 3.2 ppm. The dominant anions are SO₄ and HCO₃; these average 26.1 and 7.5 ppm respectively. SiO₂ has a mean of 4.3 ppm and Cl, F, and NO₃ all average less than 0.2 ppm. All means mentioned are geometric.

Ca and Mg are the dominant cations with geometric means of 15.5 and 5.0 ppm respectively; next in abundance is Fe which has a geometric mean of 0.69 ppm. Geometric means for Na, K, and Mn are 0.6, 0.2, and 0.03 ppm respectively. The geometric mean value for Zn is 13.2 ppb, and for Cu it is 2.3 ppb.

By contrast the waters leaching the siderite-sulphide veins and lodes are more alkaline, their geometric mean pH being 7.52; they also contain on the average more CO₂ (8.2 ppm). These waters in addition contain higher geometric mean values for HCO₃ (195.7 ppm), SO₄ (185.1 ppm), SiO₂ (6.5 ppm), and F (0.40 ppm) than the springs in the whole region. Furthermore, the geometric means for most of the cations in the waters leaching the lodes are appreciably

higher when compared to the spring waters from the whole region. In the underground waters in the mines Ca has a mean of 104.3 ppm; Mg, 17.4 ppm; Fe, 1.47 ppm; Mn, 1.06 ppm; and Zn, 81.8 ppb. However, the mean for Cu is less in the waters leaching the lodes (0.9 ppb) compared with the springs from the whole region (2.3 ppb).

Analyses for all spring samples are listed in Table 5 in the Appendix. Those exhibiting relatively high values in their anionic and cationic content may be reflecting hidden mineral deposits, and their source areas should be thoroughly prospected.

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APPENDIX

Tables 4 and 5

INDEX OF ABBREVIATED FORMS

ALK PHEN	Alkalinity titrated to pH 8.3	SAT INDEX	Saturation index at test temperature
CaCO ₃ NON-CARB	Non-carbonate hardness expressed as ppm CaCO ₃	SP COND	Specific conductance, micromhos at 25°C
CaCO ₃ TOTAL	Alkalinity expressed as ppm CaCO ₃	STAB INDEX	Stability index at test temperature
COLOUR	Colour (Hazen units)	SUM CONSTS	Sum of constituents
CO ₂	Carbon dioxide (CO ₂) calculated	TOTAL ACID	Total acidity
DISS	Dissolved	% Na	Per cent sodium
HARDNESS TOTAL	Hardness expressed as ppm CaCO ₃	**	Aluminum probably present but not determined
MIN ACID	Mineral acidity	*	Indicates value in mineral acidity and total acidity columns
NA ABS RATIO	Sodium absorption ratio (SAR)		
PPTE	Precipitate	#	Indicates value equal to one half detection limit e. g. 0.05# = < 0.10

Analyses by: Industrial Waters Section, Mines Branch (now CANMET), Ottawa, 1964-1965.

TABLE 4

FIELD MEASUREMENTS ON SPRINGS, KENO HILL AREA, YUKON

SAMPLE	TEMP C	PH	HEAVY METAL TOTAL (PPH)	DESCRIPTION
KS 101	2.2	7.8	0.000	
KS 102	2.2	5.7	.032	
KS 103	0.6	4.5	.000	
KS 104	1.7	7.5	.0015	SPRING IN SWAMP.
KS 105	1.7	5.6	.055	
KS 106	2.2	7.9	.003	
KS 107	4.4	7.3	.002	PARTLY CONTAMINATED WITH CREEK WATER.
KS 108	2.2	7.6	.025	
KS 109	11.1	7.2	.01	LIMONITE PPT. STAIN CONSPICUOUS.
KS 110	0.6		.035	
KS 111	3.9		.14	
KS 112	1.7		.005	
KS 113	4.4	6.8	.002	FE SPRING. PPT. ON SNOW AND ICE LEDGE, CONTINUES DOWNSTREAM
KS 114	2.2	7.9	.000	
KS 115			.0025	50 FT. FROM STREAM
KS 116	2.2		.000	SPRING ISSUING FROM LIMSTONE.
KS 117	1.1		.000	SPRING ISSUING FROM LIMSTONE.
KS 118		7.5	.000	20 FT. FROM QUARTZITE OUTCROP.
KS 119		5.5	.50	FE SPRING.
KS 120		5.5	.006	
KS 121		6.0	.010	
KS 122		5.0	.115	FE SPRING.
KS 123	3.3	5.0	.050	FE SPRING.
KS 124	3.9	5.5	.050	IN SWAMP, RUSTY PPT. QUARTZITE OUTCROP.
KS 125	6.7	5.5	.000	FE PPT. GELATINOUS.
KS 126	0.0	5.0	1.500	FE PPTES. IN AREA.
KS 127	1.1	4.8	1.4	FE SPRING.
KS 128	1.7	4.9	.015	FE SPRING.
KS 160	3.9	5.0	.8	STREAM WATER.
KS 201	0.6	8.0	.000	SMALL SPRING.
KS 202	0.6		.000	
KS 203	0.6	7.3	.0025	LARGE SPRING LOCATED BETWEEN TWO HUSKEG STREAMS.
KS 204	2.8	7.8	.0025	PEBBLES OF BLACK SCHIST PRESENT.
KS 205	1.7		.00	HIGH IN MOUNTAIN BELOW SNOW PATCH.
KS 206	1.1	5.0	.002	
KS 207	2.2	5.5	.005	WESTERN SLOPE OF SOURDOUGH HILL, SEVERAL SPRINGS NEARBY.
KS 208	12.2		.175	FE SPRING, ABUNDANT LIMONITE CONGLOMERATE.
KS 210	4.4	5.0	.075	SLIGHTLY TURBID.
KS 211	2.2	5.0	3.0	FE SPRING, PEBBLY QUARTZITE.
KS 212	2.2	5.5	.000	SPRING 500 FT. FROM CREEK.
KS 213	2.8	5.5	.000	SPRING 200 FT. UP FROM STREAM.
KS 214	4.4	5.5	.040	SPRING 200 FT. UPHILL FROM RANKIN STREAM.
KS 215	2.8	5.5	.020	NEAR HEAD OF STREAM, BUBBLING FROM QUARTZITE.
KS 216	1.7	5.5	.750	FE SPRING AT HEAD OF VALLEY. LIMONITE CONE, 30 X 30 FT. AT BASE, 10 FT. HIGH.

TABLE 4 (CONT'D)

FIELD MEASUREMENTS ON SPRINGS, KENO HILL AREA, YUKON

SAMPLE	TEMP C	PH	HEAVY METAL TOTAL (PPH)	DESCRIPTION
KS 217		5.0	.000	MINOR IRON STAIN.
KS 301	0.8		.000	APPROXIMATELY 20 FT. EAST OF CREEK.
KS 302	2.8		.000	HIGH SILT CONTENT. 10 FT. FROM KENO-LADUE RIVER.
KS 303	0.6	7.8	.001	10 FT. UP RIGHT BANK OF CREEK.
KS 304	0.6	4.8	.004	SPRING FEED POOL SEEPING DOWN FROM NORTH-WEST SLOPES.
KS 305	0.6	5.4	.005	SEEPAGE FROM HILLSIDE APPROXIMATELY 350 FT. FROM SPRING KS 304
KS 306	2.2		.005	SPRING FEED STREAM. ELEV. 3060 FT.
KS 309	1.1	7.3	.000	ON ROAD.
KS 310	2.8	7.4	.000	
KS 311			.015	
KS 312		1.2		WHITE, BROWN AND RED PPTES.
KS 313		5.0	.010	BOGGY ZONE.
KS 314		5.0	.000	LIMESTONE AND PHYLLITE OXIDIZED TO RED-BROWN COLOUR.
KS 315		5.5	1.0	SMALL SPRING. 10 FT. WEST OF MAIN CREEK.
KS 316		4.8	.080	SEEPS FROM HILLSIDE. PYTE. IS YELLOW, BUFF AND WHITE.
KS 317		4.8	.008	FE SPRING, SEEPS THROUGH MOSSY HILLSIDE. FE PYTE IN BANK.
KS 318		4.8	.2	SOUTH SIDE OF STREAM. FE PYTE.
KS 319	1.1	5.0	.060	FE PYTE.
KS 320	0.6	4.9	.3	SPRING ON SOUTH SIDE OF RANKIN CREEK. WHITE PYTE.
KS 321	0.6		.100	FE SPRING.
KS 401	1.1	7.0	.000	FE STAIN, SMALL SPRING.
KS 402	0.6		.000	SMALL SPRING FLOWS FROM SOUTH.
KS 403	0.6		.000	SPRING FLOWING FROM SOUTH.
KS 404	1.7	8.1	.000	FLOWS IN FROM EAST
KS 405	1.1	6.8	.020	LARGE SPRING FLOWING IN FROM EAST.
KS 406	0.6		.5	WHITE AND YELLOW PYTE.
KS 407	1.1	6.5	.7	FE SPRING. HEAVY FE PYTE. ABOVE TREE LINE. VERY EVIDENT FROM AIR (IE.HELICOPTER).
KS 408	2.2	7.2	.630	
KS 409	1.7	6.0	.380	FE SPRING, RED PYTE. SEVERAL SPRINGS WITHIN 150 YD. RADIUS.
KS 410	1.1		.010	FE SPRING.
KS 411	1.1	5.2	1.000	SPRING FLOWING FROM TILL ON BARNEY CREEK.
KS 412	0.6	4.8	.630	RED PYTE. EMERGES HALF WAY UP HILL WHICH DRAINS HEAVILY RUST STAINED AREA APPROXIMATELY 110x20 FT. SILICEOUS SERICITE SCHIST.
KS 413	3.3	7.8	.000	CHRISTIE CREEK DRAINAGE SYSTEM.
KS 414	3.3	5.4	.825	FE SPRING, RICH RED PYTE. FE CONGLOMERATE DEVELOPED OVER AN AREA 250 X 50 FT.
KS 415	1.1	7.0	.090	FE SPRING 200 FT. EAST OF MAIN STREAM.
KS 416	3.9	4.4	.600	FE SPRING FLOWING FROM SCHISTOSE SLATE.
KS 417	4.4	3.4	2.500	RED-ORANGE-WHITE PYTE.
KS 418	1.1	7.0	.500	FE PYTE. AND LIMONITE CONGLOMERATE. SMALL STREAMLET.
KS 501			.001	SPRING FROM RIGHT LIMIT, CLEAR RUNNING WATER.
KS 502			.004	SERICITE-CHLORITE-SCHIST, CLEAR SPRING 10 FT. ABOVE CREEK. SPRING ISSUING FROM GLACIAL GRAVEL.
KS 503	1.1	7.8	.800	SPRING BUBBLING THROUGH GLACIAL TILL. MUCH SILT IN SUSPENSION. WATER MUDDY BROWN.
KS 504	1.1	7.5	.005	CLEAR SPRING IN MOSS. ANOTHER SPRING 100 FT. DOWNSTREAM.
KS 505	1.1	6.4	.2	WATER FROM FE-MN GOSSAN AREA.
KS 506	1.1	4.6	.2	CLEAR SPRING AREA ON LIMIT OF CACHE CREEK.

TABLE 4 (CONF, D)

FIELD MEASUREMENTS ON SPRINGS, KENO HILL AREA, YUKON

SAMPLE	TEMP C	PH	HEAVY METAL TOTAL (PPM)	DESCRIPTION
KS 507	0.0	4.8	.045	CHLORITIC-GRAPHITIC-PHYLLITE, SMALL, CLEAR SPRING. ELEVATION 4250 FT.
KS 508	0.0	7.2	.0025	CLEAR SPRING ON RIGHT LIMIT OF CACHE CREEK.
KS 509	0.0	6.8	.000	ELEV. 4500 FT. FAST FLOWING CLEAR SPRING ISSUING FROM GREENSTONES, RUSTY OXIDE IN PLACES.
KS 510	0.0		.200	LAKE (0.5 X 0.25 MILES) AT HEAD OF ALLEN CREEK.
KS 511		6.0	.007	SEEP AT BASE OF CLIFF. FE PPT. OVER AN AREA 50 X 100 FT.
KS 512		5.8	.160	SPRING FROM UNITED KENO HILL MINE. TRENCH NO. 2, BREWIS LAKE PROPERTY.
KS 513	8.9	6.0	.010	POND 6 IN. DEEP WITH 6 FT. BANKS, IN GRANITE, COLLAPSED PINGO.
KS 514	6.1	5.0	.075	LARGE IRON SPRING, RIGHT SIDE OF CHRISTIE CREEK. POND WITH 15 FT. DIAM. AND 3 FT. DEEP, CLEAR WATER SEEP AREA 100 FT. X 30 FT. AT BASE OF TALUS SLOPE. LARGE LIMONITE DEPOSIT AROUND SPRING.
KS 515	0.6	5.5	.130	SPRING ISSUING FROM BASE OF SLOPE ON LEFT SIDE OF CREEK.
KS 516		6.2	.005	SPRING FROM MT. HALDANE NEAR FAULT.
KS 517	1.1	5.5	1.550	ELEV. 4250 FT. ON RIGHT SIDE OF CREEK.
KS 518	1.1	5.5	1.600	ELEV. 4225 FT. RATE OF FLOW APPROXIMATELY 0.5 GAL. PER MIN.
KS 519	2.2	6.0	.000	ELEV. 4975 FT. RATE OF FLOW APPROXIMATELY 5 GAL. PER MIN. SLIGHT FE STAIN.
KS 520	3.3	6.0	.000	SPRING ISSUING FROM QUARTZITE, ABOUT 1 GAL. PER MIN.
KS 521	2.2	6.0	.001	LEFT FORK OF SMALL GULCH, 100 FT. BELOW TAILINGS FROM REX VEIN. RATE APPROXIMATELY 1 GAL. PER MIN. NO CONTAMINATION.
KS 548	13.9	6.0	.250	SHALLOW, SHALMY POND, GREENSTONE AND THIN BEDDED QUARTZITE.
KS 550		3.7	1.250	STREAM WATER, MASSIVE QUARTZITE AND GREENSTONE.
KS 574	2.2	5.5	.120	ELEV. 4275 FT.
KS 583	3.3	5.5	.200	LEFT FORK, PARENT CREEK.
KS 594	3.9	7.7	.100	STREAM WATER, CACHE CREEK.
KS 601	2.2	6.0	.001	
KS 602	8.9	5.5	.0025	100 FT. SOUTH OF TRACTOR TRAIL AT HEAD OF RAY GULCH.
KS 603	1.1	6.5	.000	SOUTH OF LYNX CREEK.
KS 604	1.1	5.5	.0025	ON HILL SOUTH OF EAST MCQUESTEN LAKE.
KS 605	1.1	6.0	.006	
KS 606	1.7	6.0	.004	RUNS NORTH-WEST NEAR EAST MCQUESTEN RIVER.
KS 607	1.1	6.0	.010	NORTH OF ALDIS CREEK.
KS 608	12.2	6.0	.000	SHALMY SPRING. RED PPT. IN WATER.
KS 609	2.2	6.0	.000	DUNCAN CREEK RD.
KS 610	3.3	6.0	.050	SCARLET PPT. 3 SPRINGS WITHIN 100 FT. SOME PHYLLITE RUBBLE, EAST SIDE STEAMBOAT MOUNTAIN.
KS 611	0.6	5.5	.750	SOME RUST, MUCH FINE GREY SEDIMENT. ANOMALOUS SPRING NORTH SIDE OF DAVISON RANGE.
KS 612	0.6	5.5	.040	FE SPRING, WEST SLOPE.
KS 613	2.2	4.8	.750	SEEPS FROM PHYLLITE AND GRAPHITIC PHYLLITE, GREEN SLIME, LIMONITE DEPOSIT.
KS 614	1.7		.350	SPRING FROM GROUND.
KS 615	0.6	7.2	.000	6 FT. FROM DRY CREEK.
KS 616	1.1	5.5	.125	FE SPRING. SOME LIMONITE CEMENTED MATERIAL IN AREA.
KS 617	1.1	5.6	.000	
KS 618	1.1	6.2	.025	ON WEST SIDE OF STREAM.
KS 619	6.7	6.6	.000	SEEP, FE STAIN.
KS 620	10.0	7.4	2.25	SHAL STREAM IN SWAMP, ORANGE ORGANIC MATTER, MARSH GAS
KS 621	1.1	5.8	.960	FE SPRING 3000 FT. SOUTH OF MAIN STREAM.
KS 622	0.6	7.5	.000	MOSSY.
KS 623	3.3	7.5	.625	FE STAIN. MINOR CEMENTATION OF SOIL BY LIMONITE. REDDISH-WHITE PPT. IN STREAM.
KS 624	2.2	7.3	.700	FE STREAM AT BASE OF FRACTURED GREENSTONE OVICROP.

TABLE 4 (CONT'D)

FIELD MEASUREMENTS ON SPRINGS, KENO HILL AREA, YUKON

SAMPLE	TEMP C	PH	HEAVY METAL TOTAL (PPH)	DESCRIPTION
KS 625	1.7	7.2	5.0	FE SPRING. RED-YELLOW-BLACK PPTC.
KS 702	1.1	7.0	.000	WATER COMES FROM REDDISH SOIL.
KS 703	1.1	7.8	.000	RISES IN MOSSY AREA RUNS OVER MOSS TO BROOK.
KS 704	1.7	8.0	.000	RISES IN MOSSY AREA.
KS 705	2.8	7.7	.000	MOSSY, SHAMPY. JUNCTION OF TWO MAIN TRIBUTARIES OF WILLIAMS CREEK. NUMEROUS SPRINGS ISSUE FROM 1 MOSS.
KS 706	3.3	8.0	.000	TAKEN ALONG FAULT ZONE.
KS 707	5.0	6.4	.003	IN SPHAGNUM BOG TERRAIN.
KS 708	1.1	8.2	.0025	SMALL SPRING.
KS 709	2.2	8.6	.000	
KS 710	1.7	7.8	.000	
KS 711	1.7	7.6	.000	INTERBEDDED QUARTZITE AND SCHIST.
KS 712	4.4	7.8	.000	FROM SHAMP.
KS 713	5.6	7.2	.000	
KS 714		4.3	.020	FE SPRING.
KS 715		7.6	.005	
KS 716			.0025	
KS 717		5.3	.040	LARGE FE SPRING, RED PPTC. IN SERICITE-QUARTZ-SCHIST.
KS 718	1.7	7.8	.120	FE SPRING.
KS 719		7.6	.000	SPRING.
KS 771		7.5	.500	STREAM WATER 50 FT. FROM CLAY BANKS. ORANGE COLOUR WITH DITHIZONE.
KMH 01				CALUMET MINE. DDH 6-606, 6-4S DRIFT.
KMH 02				CALUMET MINE. DDH 11, 11-18N DRIFT.
KMH 03				CALUMET MINE. DDH 11-778.
KMH 04				CALUMET MINE. DDH 11-812.
KMH 05				CALUMET MINE. DDH 11-814.
KMH 06				CALUMET MINE. DDH 4-781, 4-23N DRIFT.
KMH 07				ELSA MINE. 6-4N DRIFT.
KMH 08				ELSA MINE. DDH E6-232.
KMH 09				ELSA MINE. DDH 4-302.
KMH 10				ELSA MINE. DDH 6-294.
KMH 11				ELSA MINE. VERTICAL DDH, 6-2N DRIFT.
KMH 12				ELSA MINE. 7-17 VEIN.
KMH 13				ONEK MINE.
KMH 14				NO CASH MINE.
KMH 15				KENO MINE. 8-9S DRIFT.
KMH 16				KENO MINE. 700 ADIT.
KMH 17				GALKENO MINE. 900 ADIT.
KMH 18				GALKENO MINE. DDH 3-24, 380 ADIT.
KMH 19				SILVER KING MINE. DDH 3-19, 3-2N DRIFT.
KMH 20				SILVER KING MINE. DDH 3-34, 3-1S DRIFT.

TABLE 5 (CONT'D)

SAMPLE	STAB INDEX	NA ABS RATIO	S04/CL
KS 505	16.	0.03	161.3
KS 506		0.03	86.0
KS 507	17.	0.02	183.0
KS 508	7.4	0.02	70.0
KS 509	13.9	0.05	14.5
KS 510	14.2	0.02	83.3
KS 511	16.	0.01	138.0
KS 512	14.	0.14	3.3
KS 513	12.9	0.06	9.3
KS 514		0.05	105.3
KS 515	15.0	0.10	39.0
KS 516	9.9	0.03	19.5
KS 517		0.008	565.0
KS 518		0.01	550.0
KS 519	11.3	0.03	3.4
KS 520	12.9	0.07	6.0
KS 521	7.6	0.19	120.0
KS 548		0.97	
KS 550		0.03	260.0
KS 574	16.	0.02	43.3
KS 583		0.02	99.3
KS 594	10.5	0.03	139.0
KS 601	9.7	0.03	
KS 602	17.	0.09	
KS 603	9.2	0.02	
KS 604	17.5	0.08	3.3
KS 605	11.9	0.02	51.0
KS 606	10.9	0.02	22.0
KS 607	11.2	0.06	141.5
KS 608	8.3	0.02	
KS 609	7.1	0.05	73.8
KS 610	9.5	0.02	68.8
KS 611	6.7	0.07	147.0
KS 612	10.6	0.07	282.5
KS 613		0.02	106.8
KS 614	6.7	0.01	133.0
KS 615	7.5	0.01	4.8
KS 616		0.03	87.0
KS 617	14.	0.18	6.0
KS 618	10.6	0.02	160.8
KS 619	7.2	0.01	3.2
KS 620	6.9	0.03	22.9
KS 621	9.7	0.02	217.5
KS 622	7.6	0.05	15.8
KS 623		0.04	196.3
KS 624		0.97	220.0
KS 625	8.2	0.03	
KS 702	14.8	0.08	
KS 703	11.	0.03	
KS 704	9.9	0.04	30.5
KS 705	10.	0.03	
KS 706	8.2	0.06	
KS 707	14.3	0.05	
KS 708	10.5	0.04	
KS 709	8.8	0.02	
KS 710	7.9	0.03	
KS 711	9.8	0.02	8.0
KS 712	8.6	0.02	22.8
KS 713	7.3	0.03	111.8
KS 714		0.05	117.4
KS 715	8.7	0.10	20.0
KS 716	11.	0.02	62.5
KS 717		0.06	117.8
KS 718	9.0	0.01	655.0
KS 771	7.5	0.03	194.7
KMH 1	7.5	0.04	1348.0
KMH 2	6.2	0.04	1055.0
KMH 3	6.8	0.05	728.0
KMH 4	7.2	0.04	247.0
KMH 5	7.4	0.04	1410.0
KMH 6	9.0	0.09	
KMH 7	6.5	0.02	6990.0
KMH 8	6.2	0.02	674.0
KMH 9	6.4	0.01	
KMH 10	5.9	0.01	
KMH 11	8.8	0.03	2680.0
KMH 12	6.0	0.01	
KMH 13	5.1	0.02	
KMH 14	5.7	0.02	
KMH 15	6.2	0.09	33.1
KMH 16	6.9	0.05	158.8
KMH 17	6.0	0.03	
KMH 18	5.7	0.02	198.6
KMH 19	6.7	0.05	1580.0
KMH 20	7.0	0.03	

TABLE 5 (CONT'D)
VARIABLES 34-36

SAMPLE	STAB INDEX	NA ABS RATIO	S04/CL
KS 101	10.7	0.02	114.0
KS 102	14.2	0.008	128.0
KS 103	7.6	0.02	
KS 104	9.7	0.01	18.8
KS 105	5.6	0.02	1720.0
KS 106	9.5	0.03	21.6
KS 107	11.	0.03	46.5
KS 108	6.3	0.03	191.4
KS 109	6.2	0.03	107.0
KS 110	11.5	0.04	38.0
KS 111	11.	0.05	12.4
KS 112		0.11	
KS 113	14.2	0.02	7.2
KS 114	7.0	0.04	374.
KS 115	10.9	0.01	71.8
KS 116	8.6	0.02	57.3
KS 117	8.4	0.05	77.6
KS 118	10.	0.02	47.7
KS 119		0.06	
KS 120	17.	0.04	
KS 121	8.3	0.03	480.
KS 122		0.07	235.0
KS 123	14.	0.06	420.0
KS 124	15.5	0.05	5.8
KS 125	10.	0.08	53.0
KS 126		0.03	
KS 127		0.02	
KS 128		0.07	177.7
KS 160		0.02	317.5
KS 201	8.1	0.01	218.0
KS 202	12.	0.008	35.0
KS 203	16.	0.04	34.0
KS 204	9.5	0.03	6.6
KS 205	8.3	0.02	57.0
KS 206	16.	0.03	8.5
KS 207	17.	0.03	32.0
KS 208	12.7	0.05	
KS 210		0.07	404.0
KS 211		0.03	
KS 212	6.9	0.03	
KS 213	9.0	0.02	
KS 214	14.	0.13	
KS 215		0.18	16.8
KS 216		0.19	365.0
KS 217	5.9	0.05	1326.0
KS 301	9.8	0.001	36.5
KS 302	10.	0.02	61.8
KS 303	11.	0.01	6.2
KS 304	18.	0.07	5.3
KS 305	18.	0.09	7.3
KS 306	17.	0.05	6.0
KS 309	9.4	0.01	29.0
KS 310	14.1	0.11	13.0
KS 311	12.3	0.06	7.8
KS 312	14.0	0.02	202.5
KS 313	15.3	0.12	48.0
KS 314	8.4	0.02	235.0
KS 315	5.8	0.05	3680.0
KS 316	9.3	0.04	735.0
KS 317	6.1	0.03	720.0
KS 318	8.7	0.15	595.0
KS 319	7.5	0.05	600.0
KS 320	13.	0.03	53.5
KS 321	9.1	0.04	353.0
KS 401	8.6	0.01	7.9
KS 402	8.5	0.03	23.4
KS 403	17.	0.08	16.7
KS 404	9.6	0.02	9.0
KS 405	12.2	0.06	55.3
KS 406	12.4	0.06	433.3
KS 407	9.1	0.03	56.1
KS 408	14.4	0.02	858.0
KS 409	12.8	0.03	25.9
KS 410		0.02	47.2
KS 411		0.02	443.3
KS 412		0.01	595.0
KS 413	7.1	0.03	
KS 414		0.03	52.8
KS 415	9.2	0.02	279.0
KS 416		0.05	
KS 417		0.02	
KS 418		0.02	
KS 501	16.	0.04	12.0
KS 502	17.	0.02	7.7
KS 503	7.5	0.02	11.8
KS 504	7.7	0.05	