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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
BULLETIN 36

GEOCHEMICAL INVESTIGATION OF HEAVY METAL CONTENT OF STREAMS AND SPRINGS IN THE GALENA HILL-MOUNT HALDANE AREA, YUKON TERRITORY

BY
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EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
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PREFACE

In areas that have been extensively prospected most orebodies that outcrop have beeen found and new techniques must be adopted to find orebodies that are not so exposed. Hydrogeochemical prospecting is one of these new techniques, and this report presents the results of an investigation by this method.

The authors have outlined in the report and in the maps the methods used, the encouraging results obtained, and some of the pitfalls to be avoided. Furthermore, some of their general conclusions can be applied to other areas where similar mineralization occurs under approximately the same conditions.

GEORGE HANSON,
Director, Geological Survey of Canada

Ottawa, December 19, 1955

GEOCHEMICAL INVESTIGATION OF HEAVY METAL CONTENT OF STREAMS AND SPRINGS IN THE GALENA HILL-MOUNT HALDANE AREA, YUKON TERRITORY

Introduction

The investigation described in this paper completes a hydrogeochemical study of the streams and springs in the region containing the rich lead-zinc-silver deposits of Keno Hill and Galena Hill. A previous report (1)* described a similar investigation of the Keno Hill–Galena Hill area. The present report extends the investigation to the southwest along the favourable quartzites that contain the large lead-zinc-silver deposits on Galena Hill.

The investigation covers an area some 20 miles wide centred on Galena Hill and Mount Haldane. The results obtained from the investigation of this area indicate that the heavy metal (Zn, Cu, Pb) anomalies in the streams and springs are centred principally on the favourable belt of quartzites that underlies parts of Galena Hill and Mount Haldane and contains the principal lead-zinc-silver lodes. North and south of this favourable belt only scattered anomalies are present. The results suggest that detailed prospecting for lead-zinc-silver deposits should be concentrated along this favourable belt of quartzites, particularly on Mount Haldane and in the drift-covered area between Mount Haldane and Galena Hill. A few significant anomalies occur north of Mount Haldane across the McQuesten River, and this area also merits some investigation.

Acknowledgments

The investigation was done entirely in the field in 1955. E. Pekar and P. Patterson did the stream analyses, and the senior author was responsible for the spring analyses and the general geochemical and geological correlations. J. Nykoluk and B. Kieller assisted in the field work, drafting, and correlation of the results.

The authors wish to thank C. E. White, General Manager of United Keno Hill Mines Limited for his many courtesies, especially for the loan of the buildings in which to maintain a field laboratory, and many others who contributed information and discussion, including McLeod White, Exploration Manager of United Keno Hill Mines Limited, A. Pike, Manager of the Hector-Calumet Mine, and A. D. Carmichael, Chief Geologist of United Keno Hill Mines Limited. Thanks are also due G. Campbell and W. R. McQuarrie, Manager and Geologist respectively, of Mackeno Mines Limited.

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* Numbers in parentheses refer to references at the end of the report.

Topographic, Climatic, and Geological Conditions of the Area

The Galena Hill-Mount Haldane area is in central Yukon, 35 miles northeast of Mayo and some 220 miles due north of Whitehorse. The area is served by an all-weather road from Mayo which connects with an all-weather road from Whitehorse. Canadian Pacific Airlines maintain an air transport and passenger service from Whitehorse to Mayo.

The present economic interest in the area centres chiefly about the lead-zinc-silver deposits which have been worked since 1915 and have produced more than $75 million in silver, lead, zinc, and cadmium. The present producing mines are the Hector-Calumet Mine operated by United Keno Hill Mines Limited, and the Mackeno Mine. Former producing mines were the Elsa, Silver King, and Bermingham. Numerous other prospects occur throughout the area, but none has proved of economic value to date.

The topography of the area is dominated by Mount Haldane which rises from an elevation of 2,500 feet at its base in the McQuesten River valley to an elevation of 6,023 feet at its summit. Galena Hill, having an elevation of 4,740 feet, forms the other prominent topographic feature of the area. Mount Haldane is characterized by many steep-walled gulches that terminate in a series of narrow ridges. Galena Hill has moderately steep north, northeast, and northwest slopes, gentle east and south slopes, and a flat rolling topography above 4,200 feet. Other parts of the area, particularly those north of the McQuesten River and south of Galena Hill, are relatively low; elevations rarely exceed 4,000 feet, and the topography is undulating and hilly.

The climate of the area is rigorous. The mean annual temperature at the Mayo Meteorological Station is 26°F., the average minimum temperature is 14°F., and the average maximum 37°F. Temperatures as low as —80°F., and as high as 90°F. 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 Galena Hill-Mount Haldane area is greater than that at Mayo owing to the influence of the high mountains to the north and northwest. 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.

The areas below 3,500 feet were severely glaciated during Pleistocene time and glacial gravel and till fill the principal valleys and cover the lower slopes of Mount Haldane, Galena Hill, and the terrain southwest of Galena Hill and north of the McQuesten River. The gravel and till deposits in most places are 10 to 20 feet thick, but some may exceed 50 feet in thickness.

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* Data, courtesy Dominion Meteorological Service, Department of Transport, Ottawa, Canada.

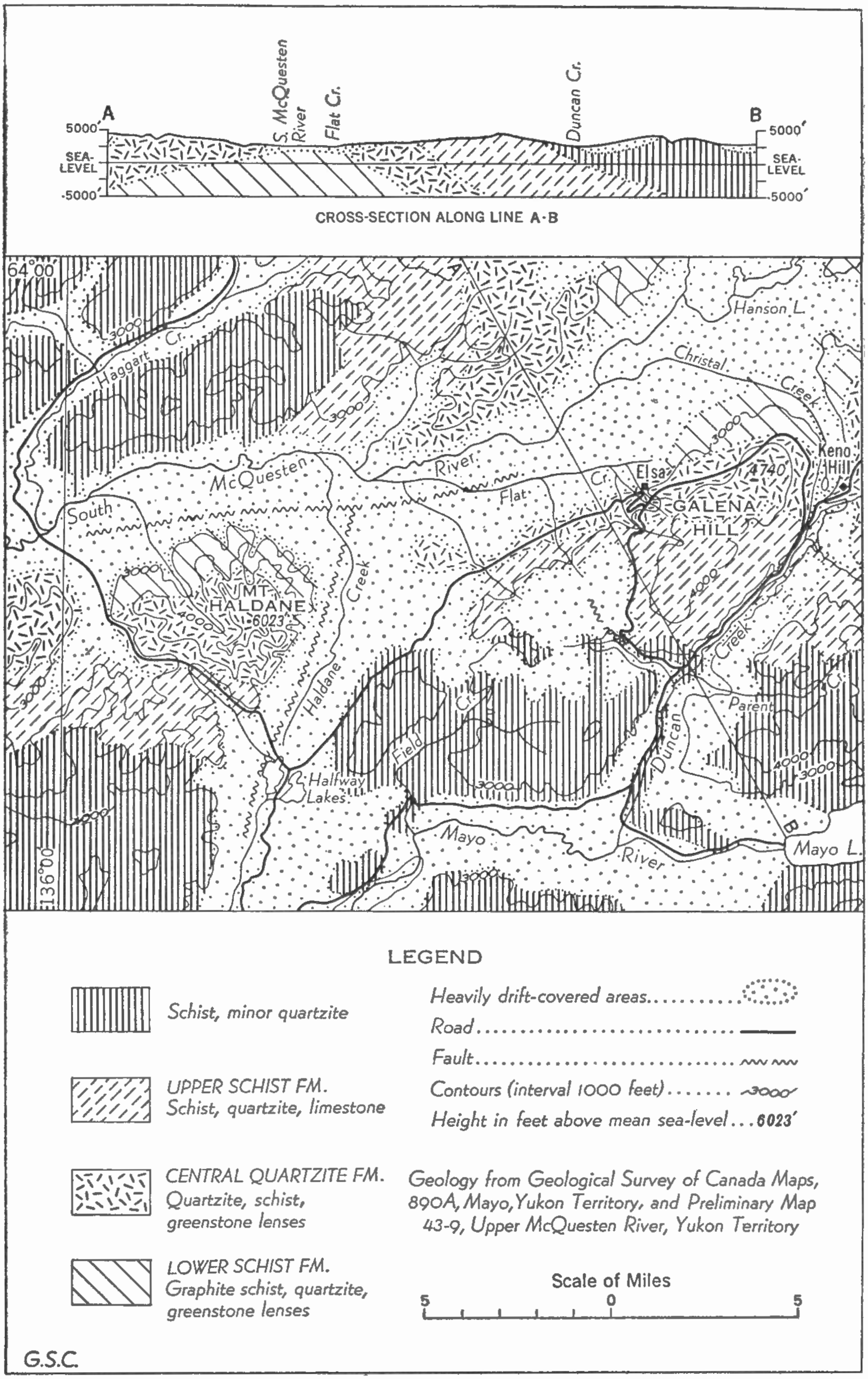

Figure 1—Geological map and cross-section of the Galena Hill-Mount Haldane area, Yukon Territory

The area is in the region of permanently frozen ground, but the distribution of the permafrost is patchy. The principal factors promoting the presence of permafrost are: a northern hillside exposure, high elevation, and the presence of a thick insulating layer of moss, decayed vegetation, and muskeg. Flowing underground and surface waters in some areas have produced windows in the permafrost zone by thawing out the ground near the channels, and in all mine openings below the permafrost underground waters are flowing freely along fractures and faults.

The consolidated rocks underlying the area belong to the Yukon group and may be Precambrian or Palæozoic in age. They consist of sericitic, chloritic, and graphitic schists, thick- and thin-bedded quartzites, greenstone lenses and sills, and a few beds and lenses of limestone.

Four principal formations are present in the area (*see* Figure 1). The lowest formation in the stratigraphic sequence consists of a thick series of graphitic schists and thin-bedded quartzites, both interbedded with many greenstone lenses. A few lead-zinc-silver deposits occur in this formation, principally in faults cutting greenstone lenses. The graphitic schists are overlain by a quartzite formation composed of thick- and thin-bedded quartzites, some graphitic schist, and a few greenstone lenses. The principal lead-zinc-silver deposits of the area occur in faults cutting the thick-bedded quartzites of this formation. The quartzites in turn are overlain by a formation composed mainly of graphitic schists, thin-bedded quartzites, and a few beds of limestone. The uppermost formation consists predominantly of interbedded brownish to greenish quartz-mica schist and schistose quartzite with a few lenses and beds of crystalline limestone at scattered points. No lead-zinc-silver deposits are known to occur in the upper two formations despite the presence of numerous faults.

The rocks on Galena Hill and Mount Haldane and in the area to the south have an average southern dip of 25 degrees. Those immediately north of the McQuesten River valley dip north with an average dip of 20 degrees. These dips suggest that the structure of the area investigated is an anticline with an axis roughly along the McQuesten River valley.

The lead-zinc-silver lodes of Galena Hill and the surrounding area occur in brecciated fault zones where they cut thick-bedded quartzites and greenstones. Two general types of lodes are recognized: an early type containing quartz, pyrite and/or arsenopyrite with minor amounts of galena and sphalerite, and a late type mineralized with siderite, galena, sphalerite, and freibergite (grey copper). Each type may occur separately, but most deposits contain minerals characteristic of the early lode type which have been fractured and are now cemented by minerals of the late lode type.

The lodes are highly oxidized from the surface to depths varying from 50 to 750 feet. The minerals resulting from the oxidation of hypogene pyrite, siderite, sphalerite, galena, and freibergite are limonite, hydrous manganese oxides, gypsum, anglesite, smithsonite, cerussite, copper carbonates, and oxides of arsenic and antimony. It is apparent that much of the oxidation in the lodes took place prior to the formation of the present permafrost because ice veins occupy the solution channels that must have been the courses followed by the oxidizing meteoric waters during an early period of oxidation. In most lodes, however, meteoric waters that have gained access to the vein structures in areas where permafrost is absent are circulating freely below areas sealed by permafrost. In these lodes oxidation of the hypogene minerals is proceeding at present.

The metallic content of the ore varies with depth in a deposit depending upon the extent of oxidation. Unoxidized ore averages about 40 ounces of silver per ton and contains from 6 to 10 per cent lead, 5 to 9 per cent zinc, and 0·01 to 0·1 per cent copper. Oxidized ore is lower in zinc and generally higher in silver and lead. The silver values in oxidized ore range from 60 to 250 ounces or more per ton The lead content may rise to 25 per cent or more in extremely highly oxidized, near-surface parts of the lodes, and the zinc content may drop to 1 per cent or less. In most lodes the copper content of the oxidized parts remains relatively unchanged from that of the hypogene ores.

Character of the Streams and Springs

The area investigated is drained by McQuesten and Mayo Rivers and a well developed pattern of dendritic streams tributary to these rivers. The principal streams are Duncan and Field Creeks draining into Mayo River, and Ross, Bighorn, Haldane, Flat, Christal, Shanghai, and Haggart Creeks draining into McQuesten River. All other creeks in the area form tributaries of the two main rivers or the principal streams.

The volume of water flowing in the streams is dependent upon the amount of rainfall, the rate of thawing of the active layer of the permafrost, the rate of melting of snowfields, and the abundance of underground springs. The principal streams such as Duncan and Field Creeks have large flows of water of the order of 20,000 gallons per minute and maintain this rate of flow throughout the summer months. The smaller streams such as Galena Creek and the streams draining the north slope of Mount Haldane have relatively small flows of water of the order of 2,500 gallons per minute. Some of the smaller streams are intermittent and dry up during spells of dry weather.

The streams draining Galena Hill rise below the flat area topping the hill and are fed by numerous springs at their sources and along their courses. The upper reaches of some streams such as Galena and Porcupine Creeks follow deeply incised gulches in the quartzite and schist formations on Galena Hill and flow through an extensive area of glacial till, gravel, and muskeg along their lower courses. Other streams, such as those draining the area northeast of Elsa, rise in an area covered by glacial gravels and muskeg and flow through a similar terrain along their lower courses. These streams, however, derive much of their water from numerous springs that issue from the bases of large rock float areas above the limit of glacial gravels and from many small discontinuous streams that occur at many places below the flat topped part of Galena Hill.

The streams draining Mount Haldane and the area to the south rise high up in steep-walled gulches. Some, such as Bighorn Creek and Ross Creek, are continuous along their courses; others are discontinuous in nature disappearing below accumulations of rock float in the gulches and reappearing again at lower elevations at the bases of these accumulations. During the spring months much of the water in these streams is derived from small snowfields situated at the heads of gulches. Some of the snowfields persist well into mid-summer and provide a fairly regular supply of water during this period. Other sources of water are provided by the numerous springs issuing from faults and fractures in the headwalls and steep lateral walls of the gulches.

Field, Williams, and Corkery Creeks and other streams draining the terrain southwest of Galena Hill rise in a rolling hilly area covered by glacial gravel, till, and muskeg. Corkery Creek and Williams Creek flow through glacial material along much of their courses but cut through the upper schist and schistose quartzite formation at some places. Field Creek has cut deeply into the upper schist formation and flows between steep schist walls along the southern part of its course.

The streams draining the area north of McQuesten River rise principally in terrain covered with glacial material and muskeg and flow through this type of terrain along a part of their courses. Some have cut deeply into the schists and quartzites and flow between walls of these rocks. The source of much of the water in these streams is the water soaked muskeg areas which serve as reservoirs. A few underground springs provide an additional source of water.

The springs in the area can be classified into two general types: springs that derive their water from run-off and near-surface sources, and springs that derive water from deep underground sources. Springs of the first type are generally situated in wet muskeg and drift areas and consist of small pools of water fed by seepage from the water-soaked muskeg and the melting of the active layer of the surrounding permafrost. Similar springs issue from the bases of accumulations of rock float on the slopes of the hills and in the gulches. The water issuing from the latter variety of spring generally percolates through several hundred feet of rock float that may contain mineralized lode material. Springs having a near-surface source of water, tend to be intermittent in habit and may dry up in late summer or during dry weather. Springs of the second type issue from fractures, faults, and bedding planes in the rocks and have been observed in the headwalls of gulches, along rock bluffs, and in all underground mine workings below the permafrost level. The flow of water from this type of spring is relatively constant in most occurrences and does not appear to change markedly with climatic conditions. These springs are the outlets of underground channels along which water from the surface has gained access to the deeper parts of the rocks through areas not sealed by permafrost.

The chemical features of the streams and springs and the chemistry of the oxidation processes in the lodes have been described in two previous reports, (1) (2), and the interested reader is referred to these for details. Chemical work has shown that the streams carry Fe, Mn, Ca, and Zn as the principal cations and SO_4^{2-}, SiO_3^{2-}, and some CO_3^{2-} as the main anions. For purposes of this investigation the presence of Zn in the stream water is the most important consideration and the field work has been principally devoted to the determination of the concentration of this cation.

The springs differ in the concentration of their dissolved salts. Springs deriving water from run-off and melting of snowfields or permafrost generally contain low concentrations of dissolved salts except in the vicinity of mineralized zones. On the other hand, springs that issue from faults and fractures in the rocks are highly charged with salts of iron, manganese, calcium, and other elements. Many contain high concentrations of zinc salts especially where the water in the underground channels has had access to lode deposits or mineralized fault zones. Some springs issuing from the lodes contain dissolved lead salts and others contain copper. One characteristic chemical feature of these springs is the precipitation of black and chocolate or reddish coloured iron and manganese compounds at their orifices or along the bottoms of the streams into which they flow for distances of 1,000 feet or more. In places the precipitates have hardened and cemented particles of rock, muskeg, and other vegetation into a limonitic conglomerate.

Method of Analysis

The concentration of the heavy metals zinc, lead, and copper in the stream and spring water was estimated by means of the dithizone method as described in a previous publication (1). Zinc was the only heavy metal detectable in the stream waters. In a few springs some lead and small amounts of copper were found.

The majority of stream analyses were done in the field by means of small portable field kits. Control analyses were carried out in a well equipped field laboratory. Surface springs were analysed in the field, and the water from underground springs was collected in polyethylene bottles and analysed in the field laboratory. Special dilution methods were necessary for some spring water owing to the high heavy metal content.

The pH of the stream and spring waters was taken in the field by pH paper. An investigation of the pH of the waters by a portable pH meter was also carried out. The results of this investigation indicated that the pH papers tend to give lower pH values than those recorded by the pH meter. Most stream and spring water ranges in pH from 5 to 8. There appears to be no apparent relationship between the metal content of the water and the pH as recorded by pH meter.

The temperature of the stream water varied from ·5 to 10 degrees centigrade. The temperature of most spring water varied from ·5 to 3 degrees centigrade.

The water in some streams contains an abundance of organic matter which seriously interferes with the dithizone reactions. In these reactions the dithizone is generally completely oxidized giving a yellow product thus preventing its reaction with heavy metals that may be present in the water. The water in some springs, especially that leaching large accumulations of rock float and muskeg areas, likewise contains organic matter that interferes with the dithizone. In other springs, especially those emanating from underground channels, ferric iron and manganese, where plentiful, may oxidize the dithizone and prevent or reduce its reaction with heavy metals.

In the field highly aereated water may also oxidize the dithizone. If this effect is suspected the samples should be brought back to a field laboratory and boiled gently for a few minutes before carrying out the metal tests.

Some experiments were carried out using reducing and precipitating reagents in an effort to eliminate the effects of oxidation. The results were not very successful but are quoted here as a possible aid to those doing work of this kind. A few drops of concentrated hydroxylamine hydrochloride were found to reduce the oxidation effect of certain types of organic compounds, but this reagent is not effective where large amounts of most organic compounds are present in the water. Heating the sample of water after addition of hydroxylamine hydrochloride is also recommended in certain cases. Iron in spring and stream waters can be removed by precipitation as the hydroxide by the addition of ammonium hydroxide followed by filtration. The filtrate must then be neutralized and the pH brought down to 7 by the addition of a few drops of hydrochloric acid before addition of the acetate buffer. The precipitation of iron, however, may cause other difficulties owing to the adsorption of metal cations, such as zinc, on the gelatinous iron hydroxide. A complicated procedure, not adapted to field work, is necessary to extract the adsorbed ions.

In some cases chloroform as a solvent for dithizone appears to be more suitable than carbon tetrachloride where oxidation is a problem. The organic layer after reaction is usually clearer when chloroform is used and, where large amounts of organic matter are present, the effects of oxidation are somewhat minimized.

Results of the Investigation

The results of the stream analyses are shown on Map 1, and those of a detailed investigation of the springs are plotted on Map 2. The following table gives the results of analyses of some characteristic underground springs on Galena Hill.

The chemical results show that zinc is the principal heavy metal in the stream water detected by the dithizone reaction. The concentration of lead and copper in all stream water is too low to be detected by routine methods. In spring water zinc is also the principal heavy metal reacting with dithizone, but some lead and copper are present in underground springs issuing from the vicinity of ore shoots containing the primary sulphides, galena, sphalerite, and freibergite.

Analyses of Underground Springs

Sample No.	Zn (ppm)	Cu (ppm)	Pb (ppm)	pH	T°C
1	78·3	0·65	1·00	6·4	3°C
2	50	N.F	N.F	4·4	3°C
3	0·75	N.F	N.F	7·2	3°C
4	0·006	N.F	N.F	7·4	2°C
5	1·66	N.F	N.F	6·7	2°C
6	0·11	N.F	N.F	7·3	2°C
7	1·33	N.F	N.F	6·8	3°C
8	80	N.F	0·01	6·4	4°C
9	66	N.F	0·10	7·2	3°C
10	0·01	N.F	N.F	7·5	3°C
11	46	N.F	N.F	7·0	3°C
12	0·03	N.F	N.F	7·4	—
13	0·31	N.F	N.F	7·8	—
14	3	N.F	N.F	7·7	—

N.F = not found.

Sample No.

1 100 foot level (1-2 N drift) Hector-Calumet mine. Water leaching mineralized zone. No iron precipitates.

2 100 foot level (1-11 S drift) Hector-Calumet mine. Water issuing from Jock fault (post ore fault). Iron and manganese precipitates.

3 300 foot level (3-4 drift) Hector-Calumet mine. Water issuing from diamond drill-hole in hanging-wall of vein fault. Iron and manganese precipitates.

4 300 foot level (3-4-1 S drift) Hector-Calumet mine. Water issuing from diamond drill-hole in hanging-wall of vein fault. No iron or manganese precipitates.

5 300 foot level (3-4-1 S drift) Hector-Calumet mine. Same location as No. 4. Water issuing from diamond drill-hole in foot-wall of vein fault. This drill-hole cuts the Jock fault (post ore fault). Abundant iron and manganese precipitates.

6 300 foot level (3-4 480 x-cut) Hector-Calumet mine. Water issuing from fractures. Abundant iron and manganese precipitates.

7 300 foot level (3-4 drift) Hector-Calumet mine. Water issuing from fractures in Jock fault zone. Abundant reddish iron and black manganese precipitates.

8 300 foot level (x-cut to 3-2 N drift) Hector-Calumet mine. Water issuing from fracture in Hector fault zone. Iron precipitates.

9 300 foot level (3-2 N drift) Hector-Calumet mine. Water issuing from ore shoot. Bluish-white precipitate on walls.

10 400 foot level (4-4 S drift) Hector-Calumet mine. Water issuing from diamond drill-hole in hanging-wall of vein fault. Iron precipitates.

11 400 foot level (4-4 S drift) Hector-Calumet mine. Water issuing from brecciated vein fault.

12 650 foot level (6-4 S drift) Hector-Calumet mine. Water issuing from drill-hole in hanging-wall of vein fault.

13 650 foot level (6-4 S drift) Hector-Calumet mine. Water issuing from drill-hole in hanging-wall of vein fault.

14 650 foot level (6-4 SN drift) Hector-Calumet mine. Water issuing from vein fault.

Most of the heavy metal anomalies in the streams of the area occur in those streams draining the northwest slope of Galena Hill and the north and east slopes of Mount Haldane. A few anomalies occur in the streams draining southward into the McQuesten River. Other streams in the area contain relatively little heavy metal. The anomalies, therefore, are centred on the areas underlain by the favourable quartzite formation that underlies Galena Hill and Mount Haldane and which contains the majority of the lead-zinc-silver lodes.

The springs on the north and northwest slopes of Galena Hill (Map 2) contain large amounts of heavy metal (principally zinc) derived from the oxidation of the lode deposits on this hill. Much of the water in these springs is derived from mine water draining from adits, but some issues from underground fractures and faults.

The results on Map 2 are instructive in tracing the dispersion and precipitation of zinc where extensive areas of muskeg are present. For instance, the map shows a series of anomalous heavy metal values in near-surface springs northwest of the Hector-Calumet and Bermingham adits. The metal in all these springs is zinc and originates principally from mine water that seeps through rock accumulations and muskeg and appears as springs at intervals down slope. At the Hector-Calumet adit, 40 ppm zinc are present in the water. Down slope some 2,000 feet the springs carry from 0·01 to 2 ppm, and along the Elsa-Keno Hill road the streams draining the flat muskeg area contain no detectable zinc. A similar decrease in the zinc concentration in the water and springs originating from the Bermingham adit is apparent. These observations show that zinc is strongly absorbed by muskeg and possibly by glacial deposits in the area concerned. The absorption of zinc by muskeg is further indicated by the fact that analyses of the muskeg material show it to contain significant concentrations of zinc (200 ppm or greater).

Discussion and Conclusions

The present investigation and that carried out in 1954 (1) have given much data on the dispersion of several elements from the lead-zinc-silver deposits of the Keno Hill-Galena Hill area. In the following paragraphs the various factors bearing on the dispersion of zinc, lead, copper, iron, and manganese are discussed and the problems involved in using the dispersion of these elements in geochemical prospecting outlined.

The dispersion of zinc is the highest of the three elements, detected by the dithizone reaction. Zinc can be detected in many streams miles from its source. The reason for the high dispersion of zinc is the high solubility of its sulphate, and as it is ubiquitous and abundant in most lode deposits in the area it is a good indicator element for tracing mineralization by hydrogeochemical prospecting methods.

Lead is relatively immobile and has a limited dispersion. In a few springs lead can be detected in the water, but the concentration is generally low despite the fact that the waters leach large masses of galena that are undergoing oxidation. Lead was not detected in any of the streams of the area and it is clear that the element does not migrate far. The reason for this is the low solubility of its sulphate. The low dispersion of lead from the deposits indicates that the nearby soils should be relatively enriched, a feature that suggests the use of the element as an indicator in geochemical prospecting techniques utilizing soil analyses. Other work, to be published soon, shows that lead is indeed an ideal indicator, and it has been possible to trace many vein faults by determining the lead content of the soils along selected grid lines. On the other hand zinc which is highly mobile has not proved to be very useful for this purpose.

Copper is rarely detected in the water, but this is not surprising because the deposits contain only small amounts of the element, and the amount of copper entering the water would be below the normal detection limit of the dithizone reaction. Another factor appears to be the relative immobility of the copper ion during the oxidation of the deposits. The copper content of the lodes is reduced only slightly during oxidation. In most lodes the oxidation of freibergite yields copper to the solutions, but this copper is soon precipitated by vein siderite and calcite with the formation of malachite and azurite. In general the content of copper in the water is too low to use this element as an indicator. Similarly the copper content of soils over lodes and vein faults is also too low to give anomalies with a strong contrast.

Iron springs are widespread throughout the area. These springs are marked by an abundance of iron and manganese precipitates at their orifices and on rocks and gravel in the stream bottoms. In some places they form characteristic limonitic conglomerates. When iron springs are found in an area the prospector should look upon them as favourable indicators of possible ore deposits. As has been shown in this and the previous investigation the iron springs are closely related to some lodes. This is true for many other parts of the Yukon and indeed in many famous mining camps of the world. In many places throughout the world the presence of iron springs carrying copper or zinc has drawn attention to an area in which deposits have been found.

When the geochemical prospector finds iron springs in an area he should carefully consider the topographic location of the spring and the possible sources of the metals in the spring. In some places iron springs are closely related to lodes and are therefore good indicators. In other places the springs may be located some distance, always downhill, from the lodes. In the latter case the prospector must bear in mind the fact that the water carrying the metal has entered mineralized zones and lodes at higher elevations and has migrated downhill along underground fractures and faults. Also, the underground fractures and faults from which the springs issue may not be the ones containing the lodes but may be post-ore in origin. As regards the sources of zinc and other heavy metals in the springs there are two possibilities. Either the metal has been derived from oxidation of lodes or from the oxidation of scattered sulphides in the country rock or along sparsely mineralized faults and fractures. There is no way to tell which source is the main contributer. From the research carried out to date on iron springs in the Keno Hill-Galena Hill area it would appear that springs carrying a high manganese content and a concentration of zinc in excess of 0·05 ppm derive their zinc and manganese mainly from siderite-galena-sphalerite lodes or mineralized zones. There may, however, be exceptions to this, and the prospector should examine any area carefully when he finds iron springs or conglomerates, especially if they contain detectable amounts of zinc or copper.

The hydrogeochemical investigations of the Keno Hill-Galena Hill area indicate that all heavy metal anomalies in the stream systems with the exception of one significant case (Parent Creek) are restricted to a belt centred on the areas underlain by the favourable quartzite formation in which most of the important lead-zinc-silver deposits occur. This shows that hydrogeochemical prospecting is suitable for outlining the extent of mineralized belts and hence should isolate the area in which the geochemical prospector can concentrate his efforts to find deposits by means of ordinary prospecting techniques or utilizing biogeochemical methods and soil analyses.

The presence of permafrost conditions in the area does not seriously affect the application of hydrogeochemical methods because there are sufficient windows in the permafrost to allow ingress and egress of oxidizing waters. Some lodes, however, are sealed by permafrost and do not contribute heavy metals to springs and streams. Where this is the case the water leaching surface accumulations of float may still pick up sufficient metal to give a clue to the presence of mineralization.

In geochemical prospecting in settled and mining areas one must consider the contribution of man-made works such as mines, etc., to the dispersion pattern of the indicator elements. It is undoubtedly true that oxidation of the sulphides on mine and prospect dumps and the presence of working mines in which oxidation is proceeding rapidly has added much zinc to the streams and springs of the Galena Hill-Mount Haldane area, but the research was carried into areas where mines and prospects are absent, and significant anomalies have been found. In view of this the authors feel assured that the mineralized parts of the Keno Hill-Galena Hill area could have been outlined by hydrogeochemical methods before any of the deposits were disturbed.

From an exploration viewpoint the results of the investigation described in this report suggest that detailed prospecting for lead-zinc-silver deposits should be concentrated on Mount Haldane and in the drift-covered area between this mountain and Galena Hill. A few significant anomalies occur north of Mount Haldane across the McQuesten River. This area is probably underlain by quartzites and merits investigation.

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