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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
BULLETIN 39

SOIL ANALYSES AS A METHOD OF
GEOCHEMICAL PROSPECTING IN
KENO HILL-GALENA HILL AREA,
YUKON TERRITORY

By
Robert W. Boyle and C. Brian Cragg

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
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CONTENTS

| | PAGE |
|--|------|
| Preface..... | v |
| Introduction..... | 1 |
| Acknowledgments..... | 2 |
| Topographic and geological conditions..... | 2 |
| Character and composition of the soils and glacial deposits..... | 5 |
| Procedure for the determination of heavy metals in soils..... | 6 |
| Field sampling method..... | 7 |
| Laboratory procedure..... | 8 |
| Procedure in brief..... | 8 |
| Reagents..... | 8 |
| Apparatus..... | 12 |
| Detailed chemical procedure..... | 13 |
| Results of the investigation..... | 17 |
| Discussion and conclusions..... | 23 |
| References..... | 26 |
| Bibliography..... | 27 |

Illustrations

| | |
|--|------------------|
| Figure 1. Geological map and cross-section of the Keno Hill-Galena Hill area, Yukon Territory..... | 4 |
| “ 2. Index map showing main geological features and principal mines and prospects, Keno Hill-Galena Hill area..... | <i>In pocket</i> |
| “ 3. Heavy metal content of soil, No. 6 vein fault, Keno Hill..... | “ |
| “ 4. Heavy metal content of soil over Bellekeno and Kinman veins..... | 21 |
| “ 5. Heavy metal content of soil over Hogan vein..... | 22 |
| “ 6. Heavy metal content of glacial till and gravel over Silver King veins..... | 23 |

PREFACE

The detection of areas containing lead and zinc orebodies in the Keno Hill-Galena Hill area by the analyses of spring and stream waters has been described in previous reports by the senior author. In the present report the process is carried a step further and a method of detecting the approximate position of individual orebodies by the analysis of the overlying drift is described. Both methods appear to be powerful prospecting tools if intelligently used under suitable conditions.

The detection of lead and zinc orebodies by soil analyses presents many problems, especially in areas of permafrost. Some of these problems are described, and precautions necessary to ensure reliable results are outlined.

GEORGE HANSON,
Director, Geological Survey of Canada

OTTAWA, June 21, 1956

Soil Analyses as a Method of Geochemical Prospecting in Keno Hill-Galena Hill Area, Yukon Territory

INTRODUCTION

This bulletin describes the results of field research carried out during the summer of 1955 in the Keno Hill-Galena Hill area, to determine the following:

1. The dispersion characteristics of lead, zinc, and copper from the lead-zinc-silver lodes.
2. The applicability of soil analyses as a method of geochemical prospecting for the lead-zinc-silver lodes.

The results of the research show that zinc from the deposits is widely dispersed by ground water and streams, and is therefore not suitable as an indicator element in geochemical methods using soil analyses. Copper likewise, due to its erratic dispersion habit and its general scarcity in the deposits, is not a suitable indicator in the soils. Lead on the other hand has a limited dispersion and is enriched in soils near the lode deposits, making it an excellent indicator.

The results of analyses of partly residual soil along traverses across known mineralized vein faults indicate that in the vicinity of vein faults, the lead content of the soil rises several times above the background and gives a strongly contrasting anomaly. Where lead deposits are present the anomaly is particularly marked and values tens, and in places hundreds of times greater than background were obtained.

A method using the total heavy metals content of residual soils was equally effective in determining the location of vein faults and deposits and is recommended because of its simplicity. The contrast of some anomalies obtained by the total heavy metal method is not as marked as that given by the lead test, but the operator can easily check any anomaly for a high content of lead by a modification of the total heavy metal test.

Analyses of near-surface glacial materials, muck, and peat along traverses across known vein faults were generally ineffective in determining the presence of the vein faults or deposits. Samples of the glacial material taken close to bedrock, however, give good anomalies with strong contrast over some vein faults and deposits.

The methods and problems of field sampling and the preparation of samples for analysis are discussed. Geological and chemical factors that influence the dispersion patterns of the elements and the bearing these factors have on geochemical prospecting techniques in the area are outlined.

The analytical methods used in the field are given in sufficient detail to guide those wishing to do similar work.

ACKNOWLEDGMENTS

All work was done in the field. C. B. Cragg did the soil analyses in the field laboratory, and the senior author was responsible for the field sampling and geological correlations. E. L. Pekar and P. Patterson assisted in the analyses and pH determinations, and J. Nykoluk and B. J. Kieller did the draughting and assisted in the field work.

The authors wish to thank Mr. C. E. White, general manager of United Keno Hill Mines for the loan of buildings for a field laboratory; and McLeod White, exploration manager for the same company, who rendered much assistance with a bulldozer, and also supplied geobotanical data and surface geological maps.

TOPOGRAPHIC AND GEOLOGICAL CONDITIONS

The Keno Hill-Galena Hill area is in central Yukon, 35 miles northeast of Mayo and some 220 miles due north of Whitehorse. The present economic interest in the area centres about the rich silver deposits, which have been worked since 1915 and which have produced more than \$75 million in silver, lead, zinc and cadmium. The principal operating mines are the Hector-Calumet and Mackeno, both situated on Galena Hill. Former producing mines were the Silver King, Elsa, and Birmingham on Galena Hill, the Onek, Ladue-Sadie-Friendship, Lucky Queen, Shamrock, and No. 9 on Keno Hill, and the Bellekeno on Sourdough Hill.

The topography of the area investigated is mountainous with elevations ranging from 2,500 feet (McQuesten River Valley) to 6,065 feet (Monument Hill). Areas above 4,200 feet are flat topped with a rolling hilly topography. South-facing slopes are gentle, whereas north-facing slopes, especially on Keno Hill, are steep to precipitous.

The area was severely glaciated during Pleistocene time, and areas below 3,500 feet are covered by a mantle of glacial tills and gravels. In most areas where glacial tills and gravels are present they are 10 to 20 feet thick, but in some areas thicknesses of 50 feet or more have been observed.

The area is in the region of permanently frozen ground, but the permafrost is patchy in its distribution. The main factor promoting permafrost appears to be the hillside exposure. Thus north-facing slopes are generally underlain by permafrost, whereas on south-facing slopes at lower elevations

it may be local or completely absent. Other factors include elevation, the absence of flowing water in near-surface and underground channels, and the presence of a thick insulating layer of moss and muskeg. The presence of permafrost in the area makes soil sampling difficult, and in most places where it occurs deep sampling is impossible by hand auger methods.

Frost action, soil creep, and slope wash effects are marked on both hills. Frost action is responsible for features such as stone rings and stone rivers, and has produced a general "boiling action" which brings rock float, mineralized float, and soil from deeper layers to the surface. Soil creep and slope wash effects have produced a marked downhill mechanical dispersion of primary and secondary ore minerals and mineralized lode material on steep slopes. These effects and the problems they cause in pedogeochemical prospecting techniques are discussed in the sections to follow.

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, and greenstone sills and lenses. On Keno and Galena Hills the rocks have an average dip of 25 degrees to the south and appear to form the southern limb of a large anticline (Figure 1).

The silver-lead-zinc lodes of the area (Figure 2) are localized in brecciated fault zones where these zones intersect thick-bedded quartzites and greenstones. Two types of lodes are recognized; an early type containing quartz, pyrite, arsenopyrite and small amounts of galena and sphalerite, and a late type mineralized with siderite, galena, sphalerite, and freibergite (grey copper). Each type may occur separately, but it is general to find hybrid lodes consisting of the early type fractured and mineralized with the minerals characteristic of the late type.

Most lodes near the surface are highly oxidized, and minerals resulting from oxidation are present down to depths of 750 feet in some lodes. The minerals developed in the oxidized zones include limonite, hydrous manganese oxides, calcite, gypsum, anglesite, smithsonite, cerussite, jarosite, quartz, malachite, and azurite.

The metallic content of the ores varies with depth in the lodes depending upon the extent of oxidation. Unoxidized ores average 40 ounces of silver per ton and contain from 6 to 10 per cent lead, 5 to 9 per cent zinc, and 0.01 to 0.1 per cent copper. Oxidized ores are lower in zinc and generally higher in lead and silver. The silver values range from 60 to 250 ounces or more per ton, the lead content may increase to 25 per cent or more, 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 unoxidized ores.

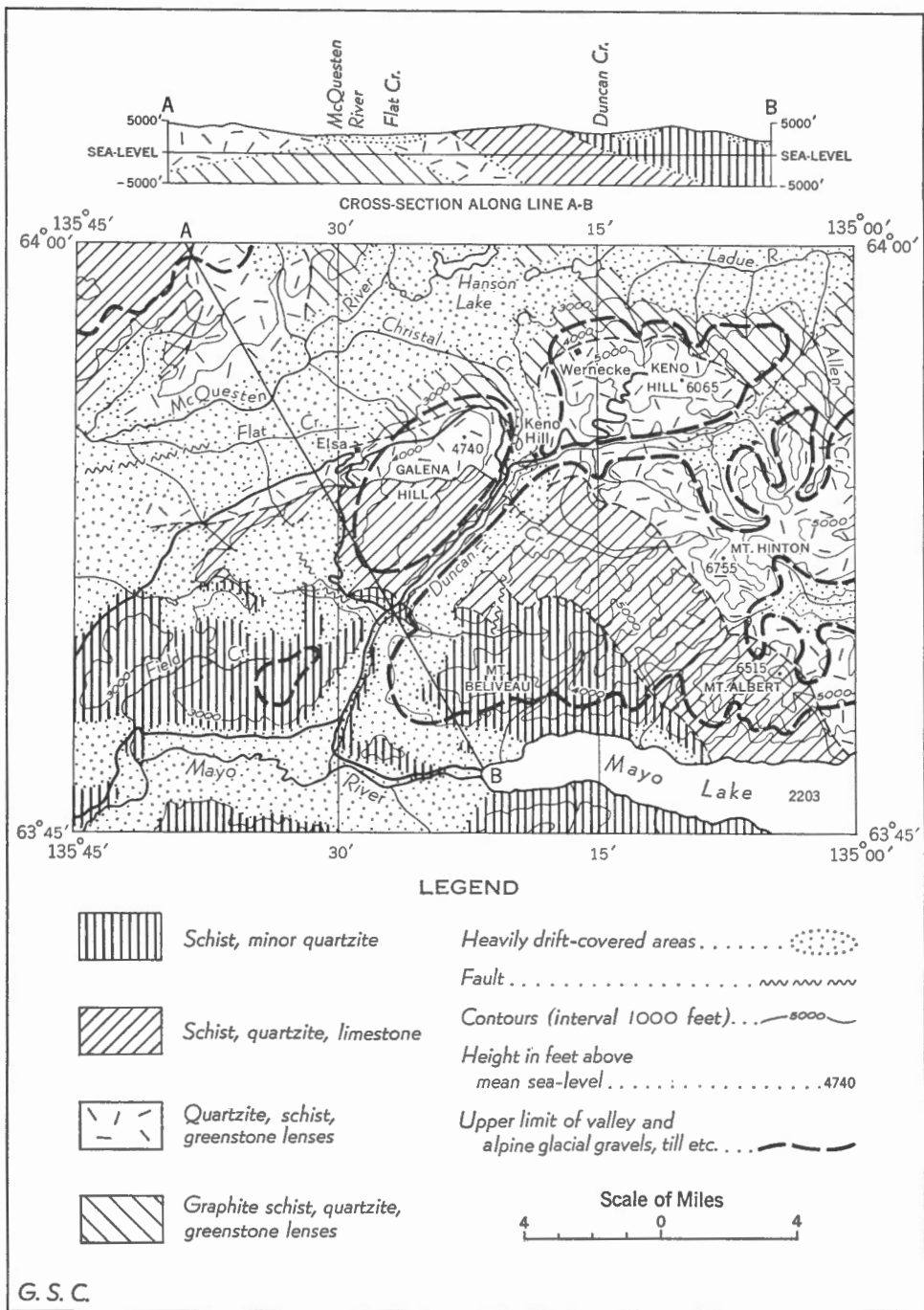


Figure 1. Geological map and cross-section of the Keno Hill-Galena Hill area, Yukon Territory.

CHARACTER AND COMPOSITION OF THE SOILS AND GLACIAL DEPOSITS

Soils in the Keno Hill-Galena Hill area can be divided into two general types as follows (1) soils developed on the bedrock schists, greenstones, and quartzites, (2) soils developed on glacial deposits. These two types of soils, together with glacial deposits such as gravel, sand, and till, form the three types of unconsolidated material with which this geochemical investigation is concerned.

Glacial deposits, as shown on Figure 1, floor the principal valleys and form benches on the lower slopes of Keno and Galena Hills. In thickness the deposits vary from a few feet to 50 feet or more. In many places on the lower slopes of both hills and in some of the valleys, outcrops of resistant rocks, such as greenstones, project through the glacial deposits. Tills, glacio-fluvial deposits, glacio-lacustrine gravel, sand, and silt, and peat layers are the chief constituents of the glacial deposits. The tills are rarely more than a few feet thick and are absent in places. They consist of a heterogeneous mixture of fine sand, clay, and variously sized boulders. Lenses of gravel and sand are common in some tills, and thin peat layers are present locally. The glacio-fluvial deposits are up to 50 feet or more thick and are mainly composed of poorly sorted gravels that occur in kames, eskers, and glacial benches. The glacio-lacustrine deposits vary from a few feet to tens of feet in thickness and are stratified in some places. In other places these deposits consist of unsorted, washed gravels containing sand lenses. In most places the glacial deposits are permanently frozen.

The soils developed on the glacial deposits are characterized by their organic content. In most occurrences the profile shows the following sequence from the surface downwards.

Surface—Trees, grass, Labrador tea, moss, leaves, etc.

Muskeg composed of undecomposed organic matter consisting of roots, moss, etc.—3 to 6 inches thick—unfrozen during the summer months.

Muskeg composed of black decomposed organic matter, clay, sand, etc.—6 to 10 inches thick. Generally permanently frozen below top few inches.

Till and/or gravel—frozen. Thickness varies.

Bedrock—graphitic schist, quartzite, greenstone.

The soils and organic debris formed on the glacial tills and gravels are very poorly drained, and are water-saturated throughout the summer months. The pH of these soils varies from 6.5 to 7.0.

The soils developed on the bedrocks are predominantly residual in origin, but some intermixed loess and decomposed till representing an old glaciation is present in places. Their thickness is variable depending upon the slope of the hills. Thus, on the tops of the hills the soils are rarely more than 3 feet thick and are entirely absent in places. Lower down on the slopes the soils are thickened by slope wash and land creep and may exceed 10 feet in thickness. In most areas the following poorly developed profile is present from the surface downwards.

Surface—Trees, grass, Labrador tea, moss, leaves, etc.

Undecomposed organic layer consisting of roots, moss, etc.—3 to 6 inches thick—unfrozen during the summer months.

Decomposed organic layer consisting of clay, sand, decomposed roots, moss, etc.—3 to 6 inches thick—generally unfrozen during the summer months. This layer is very thin or absent in places.

Residual soil, loess, decomposed till, etc.—1 foot to 10 feet thick. The soil overlying quartzite and greenstone rocks is light reddish and yellowish brown and contains much fine sand, clay and iron oxides. Many angular blocks of greenstone and quartzite are admixed with the soil in all areas. The soil overlying schists is grey or black depending upon the type of schist. Over graphitic schists the soil is black and contains much graphitic material. Constituents of the soil are clay, quartz fragments, and iron oxides. Small fragments and plates of schist are universally present. The distribution of permafrost in the residual soils is erratic.

Bedrock—quartzite, greenstone, and schist.

Most residual soils are moderately well drained on the lower slopes of the hills, but on the tops of the hills most areas are poorly drained and the soil is water-saturated during the summer months.

The pH of most residual type soils varies from 5.5 to 6.5.

PROCEDURE FOR THE DETERMINATION OF HEAVY METALS IN SOILS

The following field laboratory methods were found suitable for the determination of total heavy metals (Pb, Cu, Zn) and for individual determinations of lead, zinc, and copper in soil samples and glacial material. The analytical error involved in the methods is of the order of ± 25 per cent of the actual amount of metal present. The methods use dithizone (diphenylthiocarbazone). This reagent is a highly sensitive and specific

organic reagent and the utmost precautions must be taken to reduce the effects of contamination to a minimum. This necessitates purification of reagents, the scrupulous cleaning of glassware, running blanks, and doing frequent check analyses.

The methods described in this report are only a few of many methods suggested for the determination of the metal content of soils and rocks. For further reading the interested investigator is referred to the bibliography at the end of this report.

Field Sampling Method

In the field several methods of soil sampling were tried, all with about the same success. The one described was found to give reliable results and is the most suitable for the types of soils and glacial material found in the area.

Before outlining the method of soil sampling it is appropriate to state the difficulties encountered during field sampling. Two features of the area combine to make sampling difficult—the presence of permafrost and the occurrence in most soils of blocks of quartzite and/or greenstone.

The permafrost makes sampling very difficult by any hand method. The auger cannot be used effectively and the pick and shovel are likewise of little use; even the bulldozer fails in permafrost. The only answer to the problem appears to be a mechanical drill, such as a churn drill or some similar device. This drill would allow the operator to obtain a sample of the soil at depth, a practice which is necessary in those areas covered with glacial deposits. During this investigation a sharp steel bar and hand auger were used, but the sampling was laborious, and few samples could be obtained below a depth of 5 feet.

The occurrence of large blocks of quartzite and greenstone in the residual soils also makes hand sampling difficult. In some areas the soils contain up to 50 per cent of these blocks and hand methods of sampling to depths of a few feet or more are often impossible. Again, a mechanical drill seems to be the answer. In areas where permafrost is absent the bulldozer is effective in making cuts deep enough for effective soil sampling.

During this investigation the samples of soil and glacial material were collected along traverse lines at right angles to known or suspected vein faults. The length of these traverses and their spacing depend upon the geological situation. Many cross faults offset the vein faults throughout the area, and traverse lines run to follow vein faults should be long enough to pick up their faulted extensions. The spacing of traverse lines again depends upon the geological picture. Lodes in the vein faults are commonly short, rarely over 200 feet in length, and traverse lines should probably be spaced 25 to 50 feet apart in detailed work.

In the field soil samples were collected on 5-foot centres along the traverse lines. In some cases each 5-foot sample was analysed, but as the investigation proceeded it was found that four 5-foot samples could be combined into one sample for analysis. This speeded the work and gave satisfactory results. About $\frac{1}{2}$ pound of soil or glacial material was collected from each 5-foot centre and the four $\frac{1}{2}$ -pound samples were placed in a paper bag and labelled with the number of the traverse line and the distance covered by the sample, e.g., Traverse line 1, 20-30 feet. In some cases continuous samples along a trench or cut were taken. In this procedure the sample was collected along 10- or 20-foot lengths depending upon the type of soil and the ease of obtaining the sample. Every effort was made to obtain samples of the same type of soil and if possible to obtain samples from the same depth. Where cuts were available series of samples were taken along the same traverse line at different depths. This was done to see how the metal content varied with depth above bedrock (*see* Figure 5).

Laboratory Procedure

PROCEDURE IN BRIEF

A weighed sample of finely ground soil is digested in dilute nitric acid for 1 hour and filtered. Aliquots of the filtrate are then diluted with metal-free water and certain buffering and sequestering reagents are added for the determination of the total metal content or for the specific determinations of lead, zinc, or copper. The aliquots as prepared above are then shaken with a solution of dithizone in carbon tetrachloride and the colour of the organic layer is compared with standards.

REAGENTS

Dithizone (diphenylthiocarbazone) stock solution, 0.016 per cent (weight/volume), prepared by dissolving 0.080 gms. of dithizone in 500 ml. of reagent-grade carbon tetrachloride. This solution is stable if kept in amber-coloured, glass-stoppered pyrex bottles in a cold, dark place.

Dithizone working solution, 0.0016 per cent (weight/volume), prepared as needed from the stock solution by diluting 10 ml. of 0.016 per cent dithizone solution to 100 ml. with reagent-grade carbon tetrachloride.

Carbon tetrachloride CCl_4 —reagent-grade

Metal-free water prepared by distillation and final removal of all traces of metals by passing through a small hand resin demineralizer (Deeminac, Model 16-4 obtainable from any chemical supply house).

Concentrated nitric acid (HNO_3), reagent-grade, approximately 69 per cent (constant boiling).

Dilute nitric acid, prepared by mixing one volume of concentrated HNO_3 and seven volumes of metal-free water.

5 per cent sodium acetate—1 per cent ammonium fluoride buffer solution (pH 7) prepared as follows:

1. Dissolve 100 gms. anhydrous sodium acetate ($\text{NaC}_2\text{H}_3\text{O}_2$) or 166 gms. sodium acetate trihydrate ($\text{NaC}_2\text{H}_3\text{O}_2 \cdot 3\text{H}_2\text{O}$) in 500 mls. metal-free water.
2. Dissolve 20 gms. ammonium fluoride (NH_4F) in 50 ml. of metal-free water.
3. Mix solutions 1 and 2 and remove traces of reacting heavy metals as in 4 below.
4. To the solution contained in a separatory funnel add about 5 ml. of 0.016 per cent dithizone solution followed by 5 ml. of carbon tetrachloride. Shake vigorously for two minutes. If the organic layer is red, draw it off and repeat the treatment using another 5 ml. of dithizone solution and carbon tetrachloride. This procedure must be repeated until the organic layer remains green. At this stage the aqueous layer will have a light orange colour. The organic layer is then drawn off and small volumes of carbon tetrachloride are added, the solution is shaken, and the green carbon tetrachloride remaining after settling is drawn off. This procedure is repeated until the carbon tetrachloride layer remains colourless after shaking and settling. At this point the acetate-fluoride solution should be colourless.
5. Transfer the extracted acetate-fluoride buffer solution to a large polyethylene bottle scrupulously cleaned with metal-free water and a few drops of dithizone. Make the volume up to 2 litres by adding metal-free water.

Sodium acetate-acetic acid buffer solution (pH 6) prepared as follows:

1. Prepare a 2 N solution of acetic acid by diluting 120 ml. of glacial acetic acid to 1 litre with metal-free water.
2. Prepare a 2 N solution of sodium acetate by dissolving 164 gms. $\text{NaC}_2\text{H}_3\text{O}_2$ in metal-free water and diluting to 1 litre.
3. As required mix 9 volumes of 2 N sodium acetate solution and 1 volume 2 N acetic acid solution and remove traces of heavy metals with dithizone as described above for the acetate-fluoride buffer.

Ammonium hydroxide (NH_4OH), 28 per cent NH_3 , reagent-grade.

Ammonium hydroxide, 2 N, prepared by diluting 30 ml. of the 28 per cent solution to 250 ml. with metal-free water.

Thymol blue solution, 0.04 per cent

Ammonium citrate solution—prepared by dissolving 50 gms. ammonium citrate, $(\text{NH}_4)_2\text{HC}_6\text{H}_5\text{O}_7$ in 100 ml. of metal-free water. Extract traces of reacting heavy metals with dithizone as described above for the acetate-fluoride buffer.

Hydroxylamine hydrochloride solution—prepared by dissolving approximately 80 gms. of the crystalline reagent in about 100 ml. of water and adding 28 per cent ammonium hydroxide to bring the solution to pH 7. This solution should be shaken with dithizone to extract reacting heavy metals as described for the acetate-fluoride buffer.

Potassium cyanide (KCN), 2 per cent, prepared by dissolving 10 gms. KCN in 20 ml. of metal-free water and extracting the heavy metals with dithizone. The solution is then made ammoniacal by addition of 30 ml. 28 per cent ammonium hydroxide and diluted with metal-free water to a volume of 500 ml.

Hydrochloric acid (HCl), concentrated redistilled reagent-grade.

Sodium thiosulphate, 1 N, prepared by dissolving 124 gms. $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ in metal-free water and diluting to 500 ml. Traces of heavy metals must be removed by shaking with dithizone as described above.

Zinc standard, 0.01 per cent in 0.1 N HCl, prepared by dissolving 0.1 gm. reagent-grade 30-mesh zinc in 10 ml. concentrated HCl and diluting to 1 litre with metal-free water. One millilitre of this solution contains 100 micrograms of zinc (100 γ)*.

Copper standard, 0.01 per cent, prepared by dissolving 0.2 gm. of C.P. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in metal-free water, adding a few drops of H_2SO_4 and diluting to 500 ml. with metal-free water. One millilitre of this solution contains 100 micrograms of copper.

Lead standard, 0.01 per cent, prepared by dissolving 0.016 gm. dry C.P. $\text{Pb}(\text{NO}_3)_2$ in 100 ml. of metal-free water, containing one drop of concentrated HNO_3 . This solution contains 100 micrograms of lead per millilitre.

The amounts of reagents required for 1,000 determinations by each method described is given below. These figures provide for the minimum quantity of reagents required with some extra to take care of losses and repeat determinations.

* The γ is equivalent to 1 microgram, and one γ per millilitre equals one part per million (ppm).

REAGENTS REQUIRED FOR 1,000 DETERMINATIONS

Total heavy metals in soils—

| | |
|---------------------------------|-------------------|
| Ammonium fluoride..... | 1 lb. |
| Sodium acetate (anhydrous)..... | 8 lb. |
| Dithizone..... | 2 gm. |
| Nitric acid, conc..... | 20 lb. |
| Hydrochloric acid..... | 1 lb. |
| Carbon tetrachloride..... | 2 gallons |
| Zinc metal..... | $\frac{1}{4}$ lb. |

Lead in soils—

| | |
|--|-------------------|
| Thymol blue (as 0.04 per cent solution)..... | 400 ml. |
| Ammonium citrate..... | 1 lb. |
| Ammonium hydroxide..... | 4 lb. |
| Potassium cyanide..... | 2 lb. |
| Carbon tetrachloride..... | 2 gallons |
| Dithizone..... | 2 gm. |
| Lead nitrate..... | $\frac{1}{4}$ lb. |
| Nitric acid, conc..... | 20 lb. |
| Hydroxylamine hydrochloride..... | 1 lb. |

Zinc in soils—

| | |
|---|-------------------|
| Ammonium citrate..... | 1 lb. |
| Ammonium hydroxide..... | 4 lb. |
| Sodium acetate (anhydrous)..... | 8 lb. |
| Acetic acid (glacial)..... | 1 lb. |
| Sodium thiosulphate $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ | 6 lb. |
| Nitric acid..... | 20 lb. |
| Carbon tetrachloride..... | 2 gallons |
| Dithizone..... | 2 gm. |
| Hydrochloric acid..... | 1 lb. |
| Zinc metal..... | $\frac{1}{4}$ lb. |
| Thymol blue (as 0.04 per cent solution)..... | 400 ml. |

Copper in soils—

| | |
|--|-------------------|
| Ammonium citrate..... | 1 lb. |
| Ammonium hydroxide..... | 4 lb. |
| Hydrochloric acid..... | 2 lb. |
| Nitric acid..... | 20 lb. |
| Carbon tetrachloride..... | 2 gallons |
| Dithizone..... | 2 gm. |
| Hydroxylamine hydrochloride..... | 1 lb. |
| Copper sulphate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ | $\frac{1}{4}$ lb. |

In addition to the above chemicals a supply of potassium dichromate and sulphuric acid should be on hand for making dichromate cleaner for glassware. Acetone is valuable for removing organic chemicals, and a supply of methyl alcohol is necessary as a fuel for small alcohol burners.

APPARATUS

The following apparatus is required for each operator. Extra apparatus is included to cover breakage.

- 3—100 ml. glass-stoppered pyrex graduated cylinders
- 2—10 ml. graduated cylinders
- 2—250 ml. glass-stoppered pyrex erlenmeyer flasks
- 2—5 ml. serological pipettes, pyrex, graduated to 0.1 ml.
- 2—1 ml. serological pipettes, pyrex, graduated to 0.1 ml.
- 3—100 ml. pyrex glass-stoppered volumetric flasks
- 2—pyrex long-stemmed fluted funnels 100 mm. diameter
- 20—Griffin beakers, pyrex, 100 ml.
- 20—cover glasses, pyrex, 65 mm. diameter
- 1—small alcohol burner
- 2—250 ml. reagent bottles, amber, pyrex, glass-stoppered
- 8—125 ml. reagent bottles, clear, pyrex, glass-stoppered
- 1—agate 75 mm. diameter, mortar and pestle
- 1—aluminum sieve, 2 mm. mesh
- 10—polyethylene dropping bottles, 75 ml.
- 2—Deeminac resin demineralizers Model 16-4
- 2—replacement resin cartridges for demineralizer
- 5—rolls of pH paper (pHydrion)
- 1—burette stand and burette holder
- 2—25 ml. burettes
- 1—tripod
- 1—filtering stand

Assortment of clamps, rings, clamp holders, rubber and cork stoppers, etc.

In addition the field laboratory should contain:

- 2—100 ml. pyrex glass-stoppered graduated cylinders
- 2—10 ml. volumetric pipettes
- 1—500 ml. pyrex volumetric flask
- 1—rubber bulb
- 7—250 ml. pyrex reagent bottles
- 2—500 ml. pyrex reagent bottles
- Assortment of test tubes
- 2—hot plates*
- 1—drying oven**
- 5—asbestos mats
- 2—500 ml. separatory funnels
- 2—125 ml. separatory funnels
- Miscellaneous assortment of beakers (20 ml. to 1,000 ml. capacity)
- Miscellaneous assortment of erlenmeyer flasks (50 ml. to 500 ml. capacity)
- Stirring rods, funnels, etc.
- Filter paper—Whatman No. 41 (1 sheet per determination)
- 2—polyethylene wash bottles
- 2—large polyethylene bottles 2 litre capacity
- 1—Nessler tube rack
- 12—colorimetric tubes, Nessler, short type with glass caps
- Watch glasses, spatulas, forceps, scoops, brushes, pinchcocks, etc.
- Supply of rubber and glass tubing
- 1—analytical balance
- 1—rolling pin
- 2—aluminum sieves, 10 and 80 mesh
- 1—horn spoon
- Paper bags
- Kleenex
- Sample bottles, 2 oz.—wide mouth

* NOTE—Hot plates can be made by placing a sheet of iron $\frac{1}{2}$ inch thick over a small Coleman gasoline stove.

** Drying ovens can be made by taking an ordinary square gasoline tin or biscuit tin, cutting one end out and placing drying shelves in the can. This oven is then placed on a Coleman stove.

DETAILED CHEMICAL PROCEDURE

Sampling:

1. Allow the field sample to dry in paper bags in a hot dry place.
2. After preliminary drying, place sample on a large piece of wrapping paper and crush lumps with a wooden rolling pin.
3. Pass sample through a 2 mm. aluminum sieve to remove stones, etc.
4. Mix thoroughly and quarter sample; discard opposite quarters; repeat the mixing and quartering until a sample of 5 to 10 grams remains. Place sample in glass sample bottle and discard sheet of wrapping paper. Clean rolling pin.
5. Dry the 5- to 10-gram sample in an oven for at least 1 hour.
6. Grind sample in an agate mortar to pass 80 mesh.
7. Weigh out a 0.5-gram sample from the ground sample and place in a 100 ml. pyrex beaker.

NOTE: Many modifications of sampling procedure are described in the literature. Some of these use a weighed sample as described above; others use a small sampling scoop made by drilling a small hole with a volume of 0.25 cubic centimetres in a plastic (lucite) bar. The sampling method used depends upon equipment available and speed required.

Digestion:

1. To the 0.5-gram sample in the 100 ml. beaker add 30 ml. 1:7 dilute nitric acid. Place a cover glass over the beaker and boil gently for 1 hour.
2. After cooling filter the solution into a 100 ml. volumetric flask, through a Whatman No. 41 filter paper, transfer the residue in the beaker to the paper and wash with a few millilitres of metal-free water. Discard the residue.
3. Dilute the solution to 100 ml. with metal-free water. Aliquots of this solution are taken for the various tests.

Total heavy metals test:

1. Prepare standards containing a known amount of zinc (1 γ to 4 γ in 50 ml. metal-free water). To these add 30 ml. of ammonium fluoride-sodium acetate buffer and react as described below with 0.0016 per cent dithizone solution. Transfer the standards to 50 ml. Nessler tubes.
2. To an aliquot of the sample solution in a glass-stoppered 100 ml. pyrex graduate add 30 ml. of ammonium fluoride-sodium acetate

buffer followed by 5 ml. of the 0.0016 per cent dithizone solution. Shake for 30 seconds, transfer to a 50 ml. Nessler tube, allow the organic layer to settle, and compare with the organic layers of the zinc standards prepared in 1 above.

3. Estimate and express the total heavy metals present as zinc in parts per million.

NOTES: The operator must familiarize himself with the range of colours obtained by reacting the dithizone solution with known concentrations of zinc, copper, and lead.

The aliquot of sample should be chosen to give a mixed colour (corresponding to a concentration of 1 γ to 4 γ of zinc in 50 ml. of metal-free water), and for most soils will be from 0.5 to 5 ml. of solution.

An alternative procedure may be used in the estimation. In this procedure a zinc standard containing 2 micrograms (γ) Zn in 50 ml. of metal-free water is reacted to give a blue-grey colour to 5 ml. of 0.0016 per cent dithizone solution. This is the most sensitive transition colour and is easy to remember once seen. Successive aliquots of the sample solution are then taken until one is found which after reaction with the dithizone matches this grey colour.

The calculation to express the metal present in the soil sample in parts per million is carried out as follows:

Let weight of soil sample = 0.5 gm.

Let aliquot of sample solution taken = 1.5 ml.

Suppose this matched the zinc standard containing 2 γ Zn.

Therefore the 1.5 ml. of sample contains 2 γ total heavy metals as zinc, and 100 ml. contains 133 γ .

This amount of metal is contained in 0.5 gms. of soil, and hence 1 gm. of soil contains 266 γ .

Therefore the soil sample contains 266 ppm. total heavy metal expressed as zinc (1 γ per gram = 1 ppm.)

Zinc test:

1. Prepare a series of zinc standards, add the reagents for this test described below, and shake with 5 ml. 0.0016 per cent dithizone solution, or prepare a zinc standard that upon reaction with dithizone gives the blue-grey transition colour. Transfer the standards to 50 ml. Nessler tubes.
2. To an aliquot of the sample solution in a glass-stoppered 100 ml. pyrex graduate add 20 ml. metal-free water, one drop ammonium citrate, and three drops of thymol blue.
3. Add 2 N ammonium hydroxide until the solution is a clear yellow.

4. Add ten drops sodium acetate-acetic acid buffer, 5 ml. of 1 N sodium thiosulphate, and 5 ml. 0·0016 per cent dithizone solution.
5. Shake for one minute, transfer to a 50 ml. Nessler tube, allow the organic layer to settle, and compare with the standards prepared in 1.

Lead test:

1. Prepare a series of lead standards, add the reagents described for this test, and shake with 5 ml. 0·0016 per cent dithizone solution. Transfer standards to 50 ml. Nessler tubes.
2. Transfer an aliquot of the sample solution to a 250 ml. erlenmeyer flask, add 3 drops thymol blue, 1 drop ammonium citrate, 5 to 10 drops hydroxylamine hydrochloride, and enough metal-free water to make the volume to 20 ml. Add 2 N ammonium hydroxide to make the solution just basic (1st blue colour).
3. Heat the solution just to the boiling point and cool to room temperature in a cold water bath.
4. Transfer the solution to a 100 ml. glass-stoppered pyrex graduate, add 5 ml. ammoniacal potassium cyanide solution, followed by 5 ml. 0·0016 per cent dithizone solution, and shake for 30 seconds.
5. Transfer solution to a 50 ml. Nessler tube, allow the organic layer to settle and compare with standards prepared in 1.
6. If the organic layer has a yellowish colour the test should be repeated using more hydroxylamine hydrochloride.

Copper test:

1. Prepare a series of copper standards in pyrex graduates, add the reagents for this test, and shake with 5 ml. 0·0016 per cent dithizone solution, or prepare a copper standard which upon reaction with the dithizone gives the blue-grey transition colour. Transfer the standards to 50 ml. Nessler tubes.
2. To an aliquot of the sample solution in a 100 ml. glass-stoppered graduate add 1 drop of ammonium citrate and make the volume to 20 ml. with metal-free water.
3. Add 2 N ammonium hydroxide, a drop at a time, until the pH is 5 or 6 as indicated by pH test paper.
4. Add 5 ml. 0·0016 per cent dithizone solution and shake the mixture for 1 minute.
5. Add hydrochloric acid, a drop at a time shaking after each drop, until the pH is 1 or 2. Shake for 1 minute.
6. Transfer the mixture to a 50 ml. Nessler tube and compare with the copper standards.

7. If oxidizing agents are present as indicated by the presence of a murky yellow organic layer proceed as follows:

To an aliquot of the sample solution in a 250 ml. erlenmeyer flask add one drop of ammonium citrate, 10 drops of hydroxylamine hydrochloride solution and metal-free water to make the volume to 20 ml. Heat to boiling as in the lead test and after cooling transfer the solution to a 100 ml. pyrex glass-stoppered graduate. Proceed with the test from stage 3 above.

NOTE: Copper is slow to react with the dithizone solution at pH 1 or 2 obtained by adding hydrochloric acid. To speed the procedure it was found best to bring the pH of the test solution to 5 or 6 and shake with dithizone. After a preliminary shaking the pH can then be brought to 1 or 2 by adding hydrochloric acid.

Note on Standards:

The colours of both unreacted dithizone solution and metal dithizonates fade upon exposure to light and are unreliable after 30 minutes. This necessitates the preparation of fresh standards frequently, and in accurate work this procedure is necessary.

If the work is of a general routine nature some method of reproducing the colours in a more permanent form is desirable. Several methods have been tried successfully and give fairly reliable results. One of these consisted of making up a series of zinc and copper standards and noting the mixed colours obtained. The colours were then reproduced as nearly as possible by colouring circles with coloured pencils on a piece of white paper. Each coloured circle represented the colour of the organic layer corresponding to a known concentration of metal, e.g., 1 γ , 2 γ , 3 γ Zn. A verbal description for each concentration supplemented the visual aid. This procedure of a colour with verbal description provides an effective memory aid for the operator who has prepared the standards himself.

The lead test, being a monocolour test, requires a different procedure. An adequate comparison of the intensities of the colours (faintly pink to red) requires that the unknown and standards be viewed under as similar conditions as possible. Hence, the colour standards should be prepared in Nessler tubes identical to those holding the unknown solution. In this investigation a commercial red vegetable dye obtainable at any grocery store was found to be satisfactory in making permanent standards for the lead test. These dyes do not fade and retain their colour for long periods of time. The preparation of the permanent standards was done by preparing lead standards of known concentration, reacting them with dithizone, and matching the colours obtained by diluting a drop of the red vegetable dye with water.

RESULTS OF THE INVESTIGATION

This section presents tables and figures showing the distribution of lead, zinc, and copper in the lodes, typical soils, peat, muskeg, glacial material, and vegetation. A discussion of the significance to geochemical prospecting of the dispersion patterns of the metals from the lode deposits follows in the next section.

Table I gives data on the distribution of lead, zinc, copper, and silver in the principal lode deposits of the area. The percentage values of the

TABLE I

Metallic Content of Hypogene and Oxidized Lodes

| Location | Description | Pb% | Zn% | Cu% | Ag oz/ton |
|------------------|---|-------|------|------|--------------|
| Bellekeno Mine | Average assay of highly oxidized ore..... | 7.25 | 1.51 | 0.08 | 59.26 |
| Sourdough Hill | Average assay of highly oxidized ore..... | 58.9 | 1.5 | 0.25 | 203.0 |
| No. 9 Vein | Average assay of unoxidized ore..... | 4.4 | 5.6 | — | 42.4 |
| Keno Hill | Average assay of unoxidized ore..... | 7.8 | 4.7 | — | 55.3 |
| Ladue Mine | Average assay of oxidized ore above 50-foot level..... | 42.0 | 4.5 | — | 485.3 |
| Keno Hill | Average assay of unoxidized ore on 200-foot level..... | 6.0 | — | — | 133.8 |
| Sadie Mine | Average assay of moderately oxidized ore... | 7.29 | 5.05 | 0.04 | 37.03 |
| Keno Hill | Average assay of unoxidized ore..... | 9.2 | 8.4 | — | 38.4 |
| Lucky Queen Mine | Average assay of near-surface oxidized ore... | 25.39 | 0.5 | 0.4 | 467.4 |
| Keno Hill | Average assay of oxidized ore on 160-foot level..... | 11.8 | — | — | 173.6 |
| “ | Sample across 2 feet, 40 feet from collar of No. 2 shaft. Oxidized ore.. | 61.4 | 1.7 | — | 374.2 |
| “ | Sample across 5 feet, 60 feet from collar of No. 2 shaft. Oxidized ore.. | 23.1 | 15.6 | — | 152.8 |
| “ | Sample across 7 feet, 80 feet from collar of No. 2 shaft. Unoxidized ore | 22.3 | 6.8 | — | 156.8 |
| “ | Sample across 7 feet, 90 feet from collar of No. 2 shaft. Unoxidized ore | 4.3 | 5.6 | — | 57.8 |
| “ | Sample across 4 feet, 100 feet from collar of No. 2 shaft. Unoxidized ore | 3.9 | 8.7 | — | 38.5 |

NOTES: 1. All analyses in Table I from various mining reports and company assay plans.
2. Dashes indicate no data available.

elements show fairly conclusively that the near-surface parts of the lodes are enriched in silver and lead and depleted in zinc. The assay results for the Silver King mine are especially significant in this respect. The data on copper distribution are not extensive enough to draw conclusions, but preliminary work now in progress suggests that the copper content of the oxidized parts of lodes is not very different from that of the unoxidized parts.

Table II shows the distribution of lead, zinc, and copper in typical soils and glacial materials. The values for lead indicate that soils and glacial material distant from lodes are relatively low in this element. In the vicinity of and over vein faults and lodes, however, the content of lead increases and may exceed the normal background values in typical soils by a factor of several hundred. The content of zinc in typical soils is generally erratic even in the vicinity of lode deposits and vein faults. Some gossans, especially those over sphalerite lodes, retain much zinc, but other

TABLE II
Heavy Metal Content of Soils, Glacial Gravels, Peat, etc.

| Description | Pb (ppm) | Zn (ppm) | Cu (ppm) | pH |
|--|-------------|-------------|-------------|-----|
| Muck overlying glacial gravels, Christal Creek valley..... | 50 | 250 | <50 | 6.8 |
| Black muck with much decomposed organic material overlying glacial gravels, Christal Creek valley..... | 50 | 65 | <60 | 6.7 |
| Peaty layer in glacial tills and gravels, Christal Creek valley..... | <30 | 110 | 140 | 6.3 |
| Red muck overlying glacial tills and gravels, Christal Creek valley. Muck may represent ash from old forest fire..... | <30 | 800 | 70 | 6.5 |
| Black muck near surface, Christal Creek valley... | <30 | 200 | <60 | 7.2 |
| Black muck near surface, northwest slope of Galena Hill..... | 145 | 180 | 70 | — |
| Glacial gravel, Sourdough Hill..... | <40 | 90 | 30 | 6.2 |
| Glacial till 2 feet below surface, Silver King area..... | <40 | 40 | 30 | 6.5 |
| Glacial till and gravel, 1 foot above Silver King vein..... | 18,000 | 100 | 90 | 6.9 |
| Residual soil. Soil has been transported by slope wash. Onek mine area. Normal background value of samples over quartzite rocks..... | 140 | 200 | <40 | 5.5 |
| Surface residual soil No. 6 vein area. Normal background value of surface samples over greenstone rocks..... | 120 | 100 | 160 | 5.7 |
| Surface residual soil, vicinity No. 6 vein..... | 1,100 | 200 | 310 | 5.6 |
| Surface residual soil, normal background value of samples over schists..... | 160 | 40 | <80 | 5.5 |
| Surface residual soil over schists, Kinman vein area..... | 670 | 70 | 50 | 5.2 |
| Red soil and rusty gossan over sphalerite lode in No. 6 vein..... | 100 | 5,000 | 1,300 | 6.3 |
| Red soil and rusty gossan over Hogan vein..... | 4,500 | 140 | <80 | 6.1 |
| Soil and gouge in post-ore fault cutting Hogan vein.. | <40 | 50 | <80 | — |

gossans and soils over deposits contain only a little zinc. One significant fact appears in the distribution of lead and zinc in muck, peat, and most glacial material, namely, that the zinc content is generally much higher than the lead content. The copper content of most soil samples is low except in the vicinity of some vein faults and lodes where it may rise a few parts per million over the background values. In general the copper content of soils overlying greenstones is greater than that overlying schists and quartzites.

Most soil over post-ore faults and the gouge and crushed rock in these faults is relatively low in heavy metals. Exceptions can, however, be expected where much drag ore is present in post-ore faults or where underground waters containing much heavy metal have circulated for a long time.

TABLE III
Metal Content of Vegetation

| Description | Average ppm Cu of twigs | Average % Cu in ash | Average ppm Zn of twigs | Average % Zn in ash | Average ppm Pb of twigs |
|--|-------------------------------|---------------------------|-------------------------------|---------------------------|-------------------------------|
| Labrador tea (<i>Ledum</i> sp.) growing in muck overlying glacial till and gravel, Silver King mine area..... | 8.7 | .036 | 160.6 | .685 | .43 |
| Black Spruce (<i>Picea mariana</i>) growing in muck overlying glacial till and gravel, Silver King mine area..... | 10.5 | .040 | 330.7 | 1.26 | .40 |
| Dwarf birch (<i>Betula glandulosa</i>) growing in muck overlying glacial till and gravel, Silver King mine area..... | 9.1 | .045 | 449.0 | 2.24 | .63 |

NOTE—Average values in Table III calculated from data supplied by McLeod White, Exploration Manager, United Keno Hill Mines. Analyst C. H. Gross, Biogeochemistry Laboratory, University of British Columbia, Vancouver, B.C.

Average values for the lead, zinc, and copper content of two species of shrub and one species of tree are given in Table III. It will be noticed that the copper and lead contents are relatively low and fairly uniform, the copper content generally exceeding the lead content by a large margin. The zinc content differs with the species but is greater by a large factor than either the lead or copper content.

Figure 3 shows the distribution of heavy metals in residual soil along traverses that crossed No. 6 vein fault and intersecting faults. Traverses A and B show the lead content across the veins and C and D the total content of heavy metal (Pb, Zn, Cu). The variation in contents of lead, zinc, and copper along traverse B are also plotted. The main points of interest are the marked anomalies in the content of lead on traverses A and B and

in the content of heavy metals on C and D. On traverse A the anomalies lie directly over the veins, whereas on traverses B, C, and D they are offset. The contrast of the anomalies is generally good, and most are broad, covering a distance of 50 feet or more. This breadth of anomaly appears to be general over vein faults and lodes 3 feet or more in width. This is fortunate as most veins in the area average about 3 feet in width and might be missed by soil analyses if the dispersion of the heavy metals were not as broad as it is. The graphs of the lead, zinc, and copper contents along traverse B are typical of most residual soils in the area. The lead content is high in the vicinity of veins, zinc is erratic, and copper is generally low and fairly uniform.

Figure 4 shows the results of analyses of residual soil on traverses across a known vein fault (Bellekeno) and a suspected extension of the Porcupine vein fault (Kinman vein). Both veins dip southeast and average 5 feet in width. The soil in the vicinity of the Bellekeno vein overlies thick- and thin-bedded quartzites, and in the case of the Kinman vein the soils are developed on graphitic and sericitic schists. In both cases the soil is permanently frozen and frost boiling is common. Soil samples were taken 1 foot to 2 feet from the surface. The results show clearly that the total heavy metal content rises significantly in the immediate vicinity of the veins. Lead is the element principally responsible for the anomalies in both cases. The anomalies are slightly offset and are 60 to 100 feet or more in breadth. The results obtained on traverses over these two veins are representative of areas where the residual soil cover is light (1 foot to 5 feet) and where slope wash and other effects of soil transportation are limited.

Plots of the analyses on traverses across the Hogan vein (*see* Figure 5) illustrate the results obtained in an area where the soil has been partly transported by slope wash and creep. Soil samples taken 1 foot below the surface give no hint of a vein in the area, but samples taken 3 feet below the surface and 1 foot above bedrock give a high anomaly over the vein fault. These results are typical in terrain where permafrost is generally absent and where slope wash or creep is marked. Soil profiles over the Onek vein on Keno Hill and those over the Hector-Calumet on Galena Hill gave similar results.

The results of analyses over vein faults covered by deposits of glacial material 10 to 30 feet thick are typified by those obtained over the two veins at the Silver King mine (*see* Figure 6). As can be seen from this figure the heavy metal content of near-surface glacial material is fairly uniform and anomalous values indicating the presence of veins beneath is certainly not marked. The metal content does rise slightly above the background value over vein B but this slight anomaly should not be considered significant. Systematic sampling of glacial material at depth along traverses could not

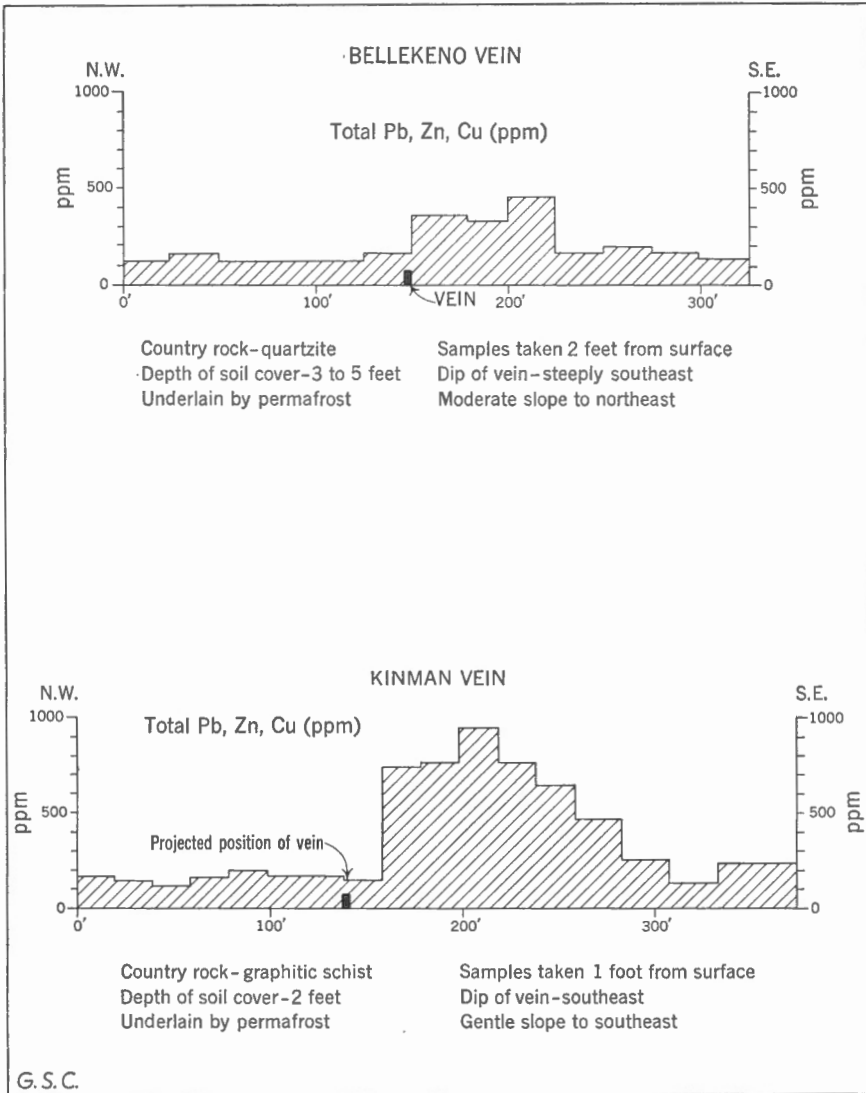


Figure 4. Heavy metal content of soil over Bellekeno and Kinman veins.

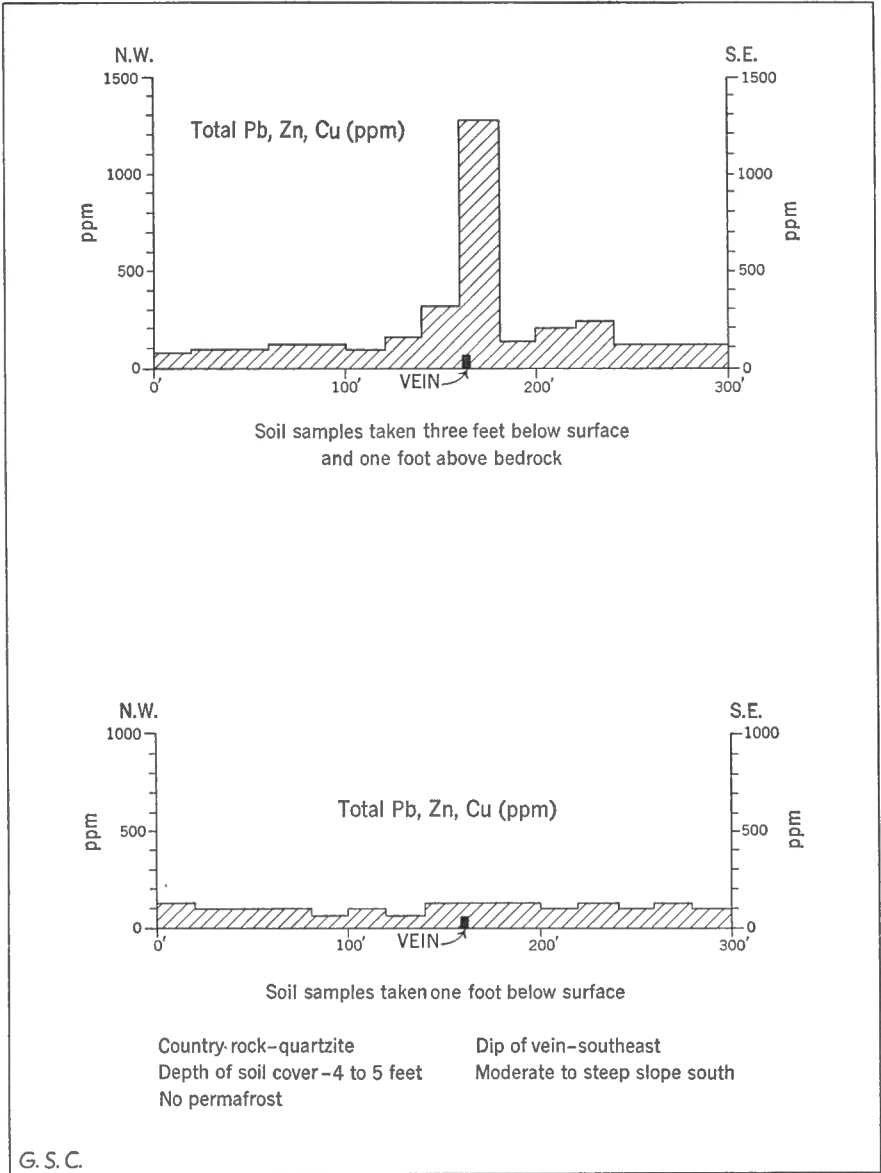


Figure 5. Heavy metal content of soil over Hogan vein.

be done with the equipment available, but some spot samples taken a foot or so above bedrock in cuts across veins show high values in heavy metals. One such gravel and till sample 2 feet above vein B at the Silver King mine gave 18,000 ppm. Pb. These data suggest that the heavy metal content of the glacial material near bedrock rises significantly in the vicinity of vein faults and especially where lodes are present.

DISCUSSION AND CONCLUSIONS

The results of this investigation and of two previous investigations (1) (2)* of the heavy metal content of spring and stream waters have given much information on the dispersion of lead, zinc, and copper from the lode deposits. The features of the dispersion patterns of these elements are discussed below and the bearing that these patterns have on geochemical prospecting using soil analyses is outlined.

The distribution of lead, zinc, and copper in oxidized and unoxidized lodes, soils, glacial deposits, vegetation, and spring and stream water shows clearly that zinc is the most strongly dispersed of the three elements. Lead does not show any marked dispersion and remains relatively close to its primary source. Copper, likewise, appears to have only a very limited dispersion.

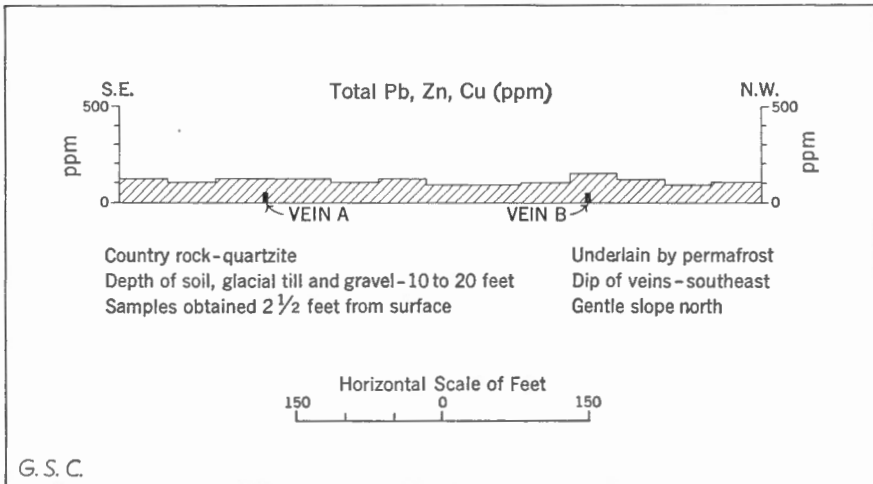


Figure 6. Heavy metal content of glacial till and gravel over Silver King veins.

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

The facts supporting the statement that zinc is strongly dispersed from the lodes are numerous. They include the facts that the sulphate is highly soluble, that zinc shows a marked loss in the oxidized parts of lodes, and that zinc is a persistent element in stream and spring water, especially in springs in or near lode deposits. Zinc is also readily taken up by vegetation and is present in shrubs and trees in much greater amounts than either copper or lead. In muskeg, peat, and muck, zinc is present in the highest concentration of the three elements. In these materials it is enriched by the decay of zinc-bearing vegetable matter and by the adsorption of the element from surface waters that percolate slowly through them.

The concentration of zinc in certain areas of muskeg, peat and muck that form settling basins or have absorbed zinc may give geobotanical and pedogeochemical anomalies that have no direct relationship to vein faults or lodes. Such anomalies are rarely of much direct use in geochemical prospecting and, in fact, may give false leads if the problem is not fully understood and recognized. In the Keno Hill-Galena Hill area this type of anomaly can generally be recognized by the low lead content of the soil, muck, muskeg, etc. In certain cases, however, especially in residual soils, anomalies having a high zinc content may occur and the investigator should examine the anomaly carefully and ascertain if possible whether the zinc is due to adsorption or some other process or whether it reflects the presence of a high zinc lode in the vicinity.

The general results bearing on the dispersion of zinc from the lodes of Keno and Galena Hills show that this element is very useful for isolating mineralized areas by hydrogeochemical prospecting and may be used as an indicator element in geobotanical prospecting where the soils are residual, if due consideration is given to its erratic dispersion. Because of this general erratic dispersion in residual soils zinc has only a restricted use as an indicator in pedogeochemical prospecting, and for reasons given above its use as an indicator element in geobotanical prospecting in muskeg areas appears to be limited.

Only small amounts of lead are chemically dispersed from the lode deposits. In some places, however, mechanical dispersion may be pronounced as on the sides of steep gulches and hills. The effects of mechanical dispersion will be considered in the sections to follow. The general low chemical dispersion of lead is a consequence of its low solubility as a sulphate. The data for the oxidized and hypogene lodes show conclusively that lead is enriched in the oxidized zones, and soil analyses in the immediate vicinity of lodes show that lead is the principal heavy metal present. Furthermore, lead is not detected in the water of streams and only occurs in the water of springs issuing from lodes containing high concentrations of lead minerals. Even in these springs only insignificant amounts of lead are transported.

The content of lead is relatively low in muskeg, peat, and glacial material, and in the vegetation growing in the terrain underlain by glacial deposits lead is present in much lower concentrations than zinc or copper.

The general low chemical dispersion of lead and its accumulation in soils in the vicinity of and over vein faults and lodes make this element an excellent indicator for geochemical prospecting by soil analyses. If significant and consistent anomalies with a high lead content are found the investigator may be certain that a vein fault or lode lies close by. In geobotanical prospecting and hydrogeochemical prospecting lead is of little use as an indicator, due to its consistently low concentration in both vegetation and water.

The dispersion of copper from the deposits is difficult to assess on account of the general low content in the lodes, in soils and glacial materials, and in the vegetation. The copper content of oxidized parts of lodes is not markedly different from the unoxidized parts. In residual soils the copper content over greenstones is a little higher than over schists and quartzites. In the vicinity of veins and over lode deposits there is rarely any marked change in the copper content of soils, and in the vegetation the element is present in only small amounts. Copper is rarely detected in stream and spring water, indicating that relatively little copper is migrating. The sulphate of copper is soluble, but the content of copper in the deposits is too low to produce any marked anomalies in the streams and springs and hence the element is not a suitable indicator in hydrogeochemical prospecting.

The results of the present investigation show that near-surface soil analyses are an effective method of locating vein faults and lodes in areas with a light cover of residual soils. In areas with a thick cover of residual soils, especially where slope wash effects are notable, sampling near bedrock is effective. Analyses of near-surface samples of glacial material have not proved effective for locating vein faults or lodes, but deep sampling of glacial material near the bedrock may produce results.

A close grid system is recommended to locate lodes, but a widespread grid system will give valuable information on the location of vein faults. Anomalies of total heavy metal content must always be checked for a corresponding high lead content otherwise the investigator may be dealing with an anomaly caused by adsorption of zinc in soil or muskeg. In certain cases high zinc lodes may give anomalies in which zinc is the principal heavy metal and the investigator will have to judge accordingly and rely on his geological and geochemical knowledge.

Many factors influence the migration of the elements and their dispersion pattern; some are chemical, others are physical. The prospector must assess both of these factors when he finds a heavy metal anomaly in

soils. First he must decide what chemical factors have operated to produce the anomaly, and then he must decide how far the anomaly is displaced by purely mechanical agencies. The most important physical factors contributing to the displacement of anomalies are soil creep, slope wash, and frost boiling. On the tops of the hills these effects displace the anomalies only short distances as shown by the accompanying figures. On steep slopes and in the gulches the mechanical dispersion may be so great that a distinct anomaly showing a strong contrasting peak is not present, but a dispersion fan or train may be present. This fan or train may be dealt with by a grid of samples taken up hill. The termination of the high values of lead or zinc marks the approximate site of the metal source. This procedure is identical to the old and well-established prospecting technique of tracing trains or fans of vein float.

In all work pertaining to pedogeochemical prospecting a representative soil sample must be obtained. Experience has shown that a sample taken every 5 feet gives satisfactory results. The samples should be taken as close to the bedrock as practicable. To do this in some areas a drilling technique will be necessary as hand methods are slow, laborious, and virtually impossible in permafrost.

Aside from making sampling difficult the presence of permafrost in the area does not appear to affect the applicability of pedogeochemical prospecting. In fact, in some areas especially on the hilltops, frost boiling has brought small bits of vein float and soil from near bedrock to the surface. This feature actually aids the sampling procedure because only near-surface samples need be taken.

In conclusion, the investigation shows that it is possible to detect lodes and vein faults in the Keno Hill-Galena Hill area by a grid of soil analyses. Due care and caution must be taken in the work, and all the geological and geochemical knowledge of the investigator must be brought to bear on the problem. The work must be done in detail, and the chemical and physical features that disperse or concentrate the three indicator elements must be carefully evaluated.

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