

NATIONAL **ADVISORY** COMMITTEE ON RESEARCH IN THE GEOLOGICAL SCIENCES

Abstracts and Program Symposium on Geochemical Prospecting

Ottawa, April 20, 21, 22, 1966



Host, Geological Survey of Canada **Department of Mines and Technical Surveys**

GEOCHEMICAL PROSPECTING SYMPOSIUM

OTTAWA, APRIL 20, 21, 22, 1966

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All sessions will be held in the Bruce MacDonald Motor Hotel, 1400 Carling Avenue, Ottawa.

DETAILED PROGRAM SCHEDULE

Wednesday Morning, April 20

Registration:

8:00-10:00 A.M.

Opening Session:

10:00 A.M.

Chairman: Dr. Y.O. FORTIER, Director, Geological Survey of Canada, Department of Mines and Technical Surveys.

Welcoming Remarks:

The Honourable JEAN-LUC PÉPIN, Minister of Mines and Technical Surveys.

Opening Remarks:

Dr. J.M. HARRISON, Assistant Deputy Minister (Research), Department of Mines and Technical Surveys.

COFFEE BREAK

R.W. BOYLE:

Geochemical Prospecting -Retrospect and Prospect. 11:00 A.M.

LUNCH

Wednesday Afternoon, April 20

- Cochairmen: S.C. ROBINSON, Chief, Economic Geology Division, Geological Survey of Canada, and J. HANSULD, American Metal Climax, Inc.
- F.C. CANNEY AND R.L. ERICKSON: Geochemical 1:30-1:50 Prospecting Research by the United States Geological Survey.
- O. BROTZEN: Recent Geochemical Prospecting by the 2:00-2:20 Geological Survey of Sweden.
- H. BLOOM: The Education of the Applied Geochemist: 2:30-2:50 Will the University Meet his Need?

COFFEE BREAK

D.R.	CLEWS: Geochemical Prospecting Procedures, Theory and Practice.	3:30-3:50
н.v.	WARREN, R.E. DELAVAULT, AND C.H. CROSS: Some Problems in Applied Geochemistry.	4:00-4:20
P.L.	SIEMS: Geochemistry in the Selway-Bitterroot Wilderness Area, Central Idaho.	4:30-4:40
W.A.	SIMS: Heavy Minerals as Prospecting Guides, Gaspé, P.Q.	4:50-5:00
J.A.0	C. FORTESCUE: Geochemical Prospecting, Case Histories and Exploration Architecture.	5:10-5:30

Concluding Remarks: J. HANSULD

Thursday Morning, April 21

Cochairmen: J. RIDDELL, Consulting Geochemist, and J.R. ASSAD, Quebec Department of Natural Resources.

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I. NICHOL, R.G. GARRETT, AND J.S. WEBB: 9:00-9:20 Studies in Regional Geochemistry. R. VAN INGEN: Granite Studies Related to Ore Formation 9:30-9:45 in the Eastern Townships, Quebec. A. GRIMBERT: Contribution à l'Etude de la Dispersion 9:55-10:15 Superficielle de l'Uranium par Déversement de Solutions Uranifères dan des Cours d'Eaux du Massif Central Français. COFFEE BREAK J.R. SMITH: Detection of Anomalous Concentrations of 10:40-11:00 Ore Metals in Precambrian Country Rock. 11:10-11:25 J.L. WALKER: Primary Geochemical Dispersion and its Application to Exploration and Mining Programmes.

J.A.C. FORTESCUE, AND E.H.W. HORNBROOK: 11:35-11:50 A Progress Report on Biogeochemical Prospecting Research at the Geological Survey of Canada, 1962-1965.

LUNCH

Thursday Afternoon, April 21

	Cochairmen:	J.A.C. FORTESCUE,	
		Geological Survey of Canada, and I. NICHOL,	
		Imperial College of Science and	
		Technology, London, England.	
C.F.	GLEESON, A	ND J.A. COOPE: Some Observations	1:30-2:00
	on the Distrib	oution of Metals in Swamps in	

Eastern Canada. F.C. CANNEY: Hydrous Manganese-Iron Oxide 2:10-2:20 Scavenging: Its Effect on Stream Sediment

Surveys.

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G.E. PAJARI, AND L.T. TREMBATH: Geochemical Control of Copper Deposition on Grand Manan Island, Bay of Fundy, New Brunswick.	2:30-2:45
COFFEE BREAK	
J.A. HANSULD: Eh and pH in Geochemical Exploration.	3:25-3:45
E. DIMROTH: Stream Sediment Sampling During Traverse Mapping.	3:55-4:10
L.M. ANTHONY: The Discovery of the Keystone Gold Mine, Cleary Hill District, Alaska: A Geochemical Prospecting Case History.	4:20-4:40
C.F. GLEESON: Distribution and Behaviour of Metals in Stream Sediments and Waters of the Keno Hill Area, Yukon Territory.	4:50-5:20
Concluding Remarks: J.A.C. FORTESCUE	
Friday Morning, April 22	
Cochairmen: D. RICHARD CLEWS, Barringer Research Limited, and C.F. GLEESON, Société Quebecoise d'Exploration Minière.	
J. MOGENSEN: The Analysis of Large Numbers of Geochemical Samples.	9:00-9:15
A.H. DEBNAM: The Atomic Absorption Spectrometer in the Geochemical Laboratory.	9:20-9:40
L.M. AZZARIA, AND J.M. BRYAN: A Method of Determining Traces of Mercury in Natural Materials.	9:45-10:05
COFFEE BREAK	
C.F. GLEESON, AND W.M. TUPPER: Coding System and Field Card for Geochemical Surveys of Streams.	10:30-10:50

J.J. LYNCH, AND C.C. DURHAM: Field Laboratories	10:55-11:15
for Operation Bathurst - A Combined Chemical	
and Spectrographic Analytical Program.	
E.W. PRESANT: A Trace Element Study of Podzol Soils,	11:20-11:40
Bathurst District, New Brunswick.	

J.C.G. MOORE: A Copper Soil Anomaly Near Sunnybrae, 11:45-11:55 Pictou County, Nova Scotia.

LUNCH

Friday Afternoon, April 22

Cochairmen:	W.M. TUPPER,
	Department of Geology,
	Carleton University, and
	R.L. ERICKSON,
	U.S. Geological Survey.

J.E. RIDDELL: Geochemical Patterns at Mount Pleasant Mines, Limited.	1:30-1:45
G.H. FRIEDRICH, AND H.E. HAWKES: Mercury Dispersion Haloes as Prospecting Indicators at the Base-Metal Deposits, West Shasta District, California.	1:55-2:10
A.S. BROWN: Some Mercury Profiles in British Columbia Soils.	2:20-2:35
N.H. BRUNDIN: Study of Heavy Minerals in Glacial Soils.	2:45-3:00
COFFEE BREAK	
P.R. DONOVAN, AND C.H. JAMES: Geochemical Dispersion in Glacial Overburden Over the Tynagh (Northgate) Base Metal Deposit, West-Central Eire.	3:30-3:45
R.W. KELLY, AND R. ASSAD: Geochemical Prospecting for Molybdenum - A Case History in the Mount Ste. Cécile Area, Frontenac County, Quebec.	3:55-4:10

O.H.	ROSTAD: Geochemical Case History at the Little Falls Molybdenite Prospect, Boise County, Idaho.	4:20-4:35
R.V.	OJA: Investigations of the Thunder Bay Silver Area.	4:45-5:00
н.с.	MORRIS: Some Geochemical Exploration Case Histories from Eastern Canada.	5:10-5:30

Concluding Remarks: W.M. TUPPER

Coffee courtesy of Technical Service Laboratories, Toronto.

ABSTRACTS OF PAPERS

SUBMITTED FOR THE GEOCHEMICAL PROSPECTING SYMPOSIUM, OTTAWA APRIL 20, 21, 22, 1966

The Discovery of the Keystone Gold Mine, Cleary Hill District, Alaska-A Geochemical Prospecting Case History

ANTHONY, L.M., School of Mines, University of Alaska, College, Alaska

Geochemical prospecting played a major role in the discovery of the Keystone Gold Mine, Cleary Hill District, Alaska. Three prospectors, using the University of Alaska's general geochemical exploration technique for copper, lead, and zinc in soil, discovered a strong anomaly between two formerly productive but presently inactive gold properties.

Subsequent trenching of the geochemical anomaly revealed a highgrade gold-quartz vein, averaging two feet in width and more than two thousand feet in length. It contains from one to five per cent antimony and lead and traces of copper and zinc.

Soils overlying the area are of the residual sub-arctic brown forest type. Rock types underlying the area belong to the Yukon Group of Precambrian or early Palaeozoic age.

A Method of Determining Traces of Mercury in Natural Materials

AZZARIA, L.M., Department of Geological Sciences, McGill University, Montreal, and BRYAN, J.M., Technical Research Center, The Consolidated Mining and Smelting Company of Canada Limited, Trail, British Columbia

The mercury halo method of mineral exploration is presently receiving a great deal of attention. Successful use of this method requires reliable determination of nanogram quantities of mercury in natural materials. Most methods used for this purpose depend on the absorption of ultraviolet light by mercury vapour. In these methods when a single beam technique and, in some cases, a double beam technique is used, serious interference is encountered in analyzing some materials. The interference is due to the presence of organic matter, sulphides, and water in the samples. A method is described for determining nanogram quantities of mercury in natural materials containing interfering substances. The method is based on collecting the mercury on gold wool while exhausting interfering substances. This is followed by heating the gold to vaporise the mercury. The resulting mercury vapour may be measured with a suitable detector. In the present work a low cost single-beam and a Williston twin-beam ultraviolet absorption instrument were used. The properties of gold wool, as a collector and emitter of mercury, are given. Changes in these properties as a result of the continuous use of the gold wool are also detailed. The materials analyzed consisted of soils of different organic and water content, stream sediments, sulphides, and rocks.

The Education of the Applied Geochemist: Will the University Meet his Need?

BLOOM, H., Department of Chemistry, Colorado School of Mines, Golden, Colorado, U.S.A.

The evergrowing application of geochemical exploration methods throughout the world has long since exhausted the manpower supply of trained geochemists. While their need continues to increase, no new supply is readily forthcoming until the universities begin to recognize this demand. The Geological Surveys of both the United States and Canada, while committed to research in geochemistry, are often forced into the role of educators. Until very recently, the U.S. Geological Survey conducted regular classes in geochemical exploration techniques. In spite of the fact that both Canada and the United States are today scenes of intensive exploration activity, these countries have to look abroad for university trained graduates in applied geochemistry.

The task of ensuring the sound future of applied geochemistry begins with the training by universities of graduate students. Graduate programs must permit adequate course work as well as thesis opportunities in geochemical exploration problems. Close cooperation with progressive mining companies is also necessary in making such plans.

Geochemical exploration has come of age in the mining industry and is waiting impatiently for the universities to grant it recognition. Will the two meet?

Geochemical Prospecting-Retrospect and Prospect

BOYLE, R.W., Geological Survey of Canada, Ottawa, Ontario

The concept of using chemical methods in prospecting is an old one dating back at least to the middle of the 16th century. At this time crude

methods of discovering veins by hydrogeochemical and biogeochemical methods were described by Agricola. Even before his time botanical associations with ores were noticed and used in prospecting by the Chinese in the 8th or 9th centuries.

Modern methods of geochemical prospecting based on secondary halos and utilizing trace element techniques were first practised in U.S.S.R. and Scandinavian countries in the 1930's. After 1945 the methods based on soils, stream sediments, and vegetation were rapidly developed in U.S.A., the United Kingdom, Canada, France, and other countries.

The modern methods of geochemical prospecting owe their rapid development in the 20th century to the following:

1. Recognition of primary and secondary dispersion halos and trains that are associated with all mineral deposits.

2. Development of accurate and rapid analytical methods utilizing the spectrograph and the various specific sensitive colorimetric reagents, especially dithizone.

3. Development of polyethylene laboratory ware of all types and the development of resins. These permitted greater freedom of field analyses and reduced the incidence of contamination.

4. Development of gas chromatography. This permitted the rapid and accurate determination of hydrocarbons in methods for petroleum prospecting.

Future research in geochemical prospecting should be focused on the following tasks:

- Definition of geochemical provinces and their relation to mineral deposits.
- 2. Development of methods for discovering large low grade deposits.
- 3. Development of methods for discovering deeply buried deposits.
- 4. Further development of methods to outline primary halos.
- 5. Elucidation and formulation of techniques to relate the size and intensity of anomalies to grade of deposits.
- Development and refinement of biogeochemical methods, especially those based on indicator plants, chlorotic or toxic effects, and microbiological techniques.
- Definition of types of primary and secondary halos associated with accumulations of oil and gas.

Recent Geochemical Prospecting by the Geological Survey of Sweden

BROTZEN, O., Chief, Geochemical Department, Geological Survey of Sweden, Stockholm 50, Sweden

The lay-out of geochemical prospecting programs, their supervision, and the recording of the results and their interpretation (including mineralogical work) is done by three geochemists and two assistants at the Survey. In this work close contact is maintained with geologists, geophysicists, and chemists. The sample preparation and analytical work is done by the laboratory staff of the Survey. In routine work, analysis is made by the tape method and quantometer (25 elements). Soils are sieved to minus 100 microns, stream sediments are finely ground, and rocks are ground and buffered. In the field, use is made of semiquantitative spot tests for Cu, Ni, and Zn.

In 1965 approximately 15,000 sediment samples and 3,000 soil samples were collected, as well as some biomaterials. About 1,000 rock samples from drill-holes will also be analyzed in connection with primary dispersion studies.

As examples of recent work, the conditions near a known Cu-Zn orebody (with little effects on the trace-content of moraine at shallow depths) will be illustrated, as well as primary dispersion patterns of two flat-lying pyritic ores, and a study of stream sediments from the Swedish mountains. This study indicates that the contents of Cu, Zn, and Pb in the samples are rather insensitive to variations in pH, in grain sizes smaller than 0.6 mm, in the content of organic matter, and in the proportion of ferric to ferrous iron. By contrast covariation with the content of total iron is marked, notably for Zn.

Some Mercury Profiles in British Columbia Soils

BROWN, A.S., Geologist, British Columbia Department of Mines and Petroleum Resources, Victoria, British Columbia

Significant reproducible results can be achieved by analyzing the mercury content of soils with a Lemaire S-1 detector if certain precautions are observed. These include: collection of non-organic samples from the top of the unmodified soil, air drying at room temperature, sieving, charging retorts with iron filings in sulphide-rich areas, and exercising great care to avoid contamination.

Profiles were run over ten ore deposits in north central British Columbia: three mercury, five molybdenum, one lead-zinc, and one copper. All deposits had anomalous mercury values associated with them, and all except one had well-developed halos significantly broader than the ore zones. Anomaly peaks over the mercury deposits ranged from 1 to 200 ppm with backgrounds from 0.02 to 0.08 ppm-rarely to 0.2 ppm. Anomalies over the molybdenum deposits were of a different order, although the backgrounds were similar; peaks ranged from 0.085 to 0.175 ppm and backgrounds from 0.01 to 0.025 or rarely 0.04 ppm. Anomalies over the lead-zinc and copper deposits ranged between these extremes.

Study of Heavy Minerals in Glacial Soils

BRUNDIN, N.H., Chief Geochemist, Grängesbergsbolaget, Box 28, Lindesberg, Sweden

The distribution of heavy minerals in till near twelve Swedish ore deposits is under active investigation.

Pits were laid out "downstream" from the deposits, i.e. in the direction of glacial transport, and in profiles approximately perpendicular to this direction. The heavy minerals were concentrated on a shaking table and further investigated.

Some preliminary results regarding the occurrence of ore minerals in till have been obtained, and some general conclusions will be presented. The content of heavy minerals increases with depth even in apparently unsorted till deposits. The presence of ore in a number of the investigated cases is clearly indicated by the distribution of heavy minerals. As a specific example, the significance in prospecting of the occurrence of manganese minerals in till will be cited.

Hydrous Manganese-Iron Oxide Scavenging: Its Effect on Stream Sediment Surveys

CANNEY, F.C., United States Geological Survey, Federal Center, Denver, Colorado, U.S.A.

Appraisal of a large body of data based on the analyses of several thousand active stream sediment samples from Maine has revealed a strong positive correlation between the cold-extractable heavy metal (cxHM) and manganese contents of stream sediments from unmineralized terrane. The relationship is exponential with the formula ppm cxHM = a (ppm Mn)^b where a and b are constants. This correlation reflects the preferential scavenging and accumulation of significant amounts of zinc by hydrous manganese-iron oxides, commonly occurring as coatings and crusts on bed material in many

stream courses in glaciated areas. In such areas, calculation and use of a single threshold value in the conventional way will produce many anomalies unrelated to mineral deposits. Samples from streams draining mineralized areas, however, generally have ratios higher than predicted by the above equation, often considerably so. On this basis the HM-Mn ratio offers promise as a yardstick by which the significance of heavy-metal streamsediment anomalies in glaciated terranes can be evaluated.

Geochemical Prospecting Research by the United States Geological Survey

CANNEY, F.C., and ERICKSON, R.L., United States Geological Survey, Federal Center, Denver, Colorado, U.S.A.

Geochemical prospecting research by the U.S. Geological Survey, both in field and laboratory programs, is devoted to the examination of principles of geochemistry that may have potential for mineral exploration. The program consists of applied research projects aimed at developing new methods, instruments, and techniques to help find concealed mineral resources, with considerable emphasis on development of analytical methods that can be taken to the field to directly guide geochemical sampling and make results immediately available. A few projects are geochemical reconnaissance surveys for ground favourable for the occurrence of minable ore. And still others (geochemistry of gold; geochemistry of mercury) have the objective of accumulating basic geochemical background data to provide a sound theoretical and experimental basis for the applied research programs.

The principal applied geochemical studies include, 1) projects aimed at the difficult task of prospecting in the Basin and Range Province of the Western United States where much ground favourable for the occurrence of minerals is concealed by a relatively thin (less than 200 feet) cover of pediment gravels; 2) the development and study of techniques of geochemical reconnaissance in glaciated areas based on water and stream sediments where considerable emphasis is now being given to techniques of anomaly appraisal; 3) the determination of accessory-sulphide distribution patterns in relation to vein deposits in some intrusive rocks in the Front Range of Colorado; 4) studies on the distribution of minor elements in barren and productive stocks of the Western United States; and 5) research on the preparation and interpretation of geochemical maps based on analysis of stream-sediment samples.

Chemical research has recently yielded very sensitive wet methods for determining gold, silver, and mercury that can be performed relatively easily in mobile laboratories operating close to the field areas. And currently plans are well advanced to study the integration of atomic absorption instrumentation for collecting data in applied geochemical prospecting programs.

Geochemical Prospecting Procedures, Theory and Practice

CLEWS, D.R., Vice President, Barringer Research Limited, 304 Carlingview Drive, Rexdale, Toronto, Ontario

The dispersion patterns and mechanisms as well as the mode of occurrence of metals in the geochemical cycle are described. These include the clastic agencies of wind, rain, gravity, etc. as well as saline agencies. The solubility of metals in natural waters is considered as well as transport and precipitation in this medium. Dispersion patterns related to drainages and soils are described.

Geochemical prospecting methods and analytical techniques for regional appraisals as well as detailed investigations are listed.

Examples of the mechanism by which false anomalies are formed in soils are detailed. Some of the major types of false anomalies are listed and examples of the criteria used for differentiating between false and true anomalies are given.

Geochemical prospecting techniques in Canada are discussed. These include those designed for residual or partly residual soil covered areas as well as the totally transported soil covered Shield areas.

The Atomic Absorption Spectrometer in the Geochemical Laboratory

DEBNAM, A.H., Consulting Geochemist, 1266 Grosvenor Street, Oakville, Ontario

The geochemist now has at his disposal analytical instrumentation which is ideally suited for the routine analysis of all the metals commonly sought in geochemical prospecting. The recently available atomic absorption spectrometer is based on the principle that the atoms of every element absorb radiation at specific wavelengths which are different for each element. The source of radiation is a hollow-cathode lamp, with the cathode made of the element to be determined and emitting light of the required wavelength. The beam from the cathode is directed through a flame into which a sample solution is aspirated. The amount of absorbed radiation is measured on a photodetector and is proportional to the amount of metal in the solution. Atomic absorption is versatile, rapid, sensitive, accurate and free from many of the interferences found in other instrumental methods of analysis. As many as 1,500 metal determinations can be made with one instrument in an 8-hour day. Only one solution per sample is required for such multi-element determinations as Cu, Pb, Zn, Ni, Co, and Ag, all with sensitivities of 1 ppm.

Several commercial atomic absorption spectrometers are presently available for routine geochemical analysis. However, multichannel instruments programmed for up to 12 elements hold exciting prospects for the future. Coupled with the computer for data processing and interpretation, such instrumentation will make it economically feasible to carry out extensive multi-element geochemical surveys covering large areas with perhaps hundreds of thousands of samples.

Stream Sediment Sampling During Traverse Mapping*

DIMROTH, E., Geological Exploration Service, Quebec Department of Natural Resources, Quebec, P.Q.

Stream sediments were sampled during traverse mapping on a scale of 1 inch = 1/2 mile by most field parties of the Geological Exploration Service, Department of Natural Resources, Quebec. Sediment samples were taken from all streams intersected by traverses. In this way an irregular sampling grid with an average density between 1 and 2 samples per square mile was obtained. The samples were analyzed for Cu, Zn, Pb, Mo, and in certain cases, for Ni by the Laboratories Service.

The relatively small number of samples (between 150 and 350 per map-area) does not allow an exact analysis of the frequency distribution of the trace element contents. Background values can be interpreted as lognormally distributed. Anomalous populations can be interpreted as lognormally distributed and partly overlapping the background population. Anomalous values occur in certain cases in tectonically defined zones, coinciding with known or presumed zones of mineralization. Procedures and results are demonstrated by an example from the Labrador Trough.

*Presented with the permission of the Deputy Minister, Department of Natural Resources, Quebec

Geochemical Dispersion in Glacial Overburden Over the Tynagh (Northgate) Base Metal Deposit, West-Central Eire

DONOVAN, P.R., Applied Geochemistry Research Group, Imperial College of Science and Technology, London, England (now Geochemist, McPhar Geophysics, 139 Bond Avenue, Don Mills, Ontario) and JAMES, C.H., University of Leicester, England

Secondary dispersion of metals was investigated in an area of calcareous drift around the Tynagh Pb-Zn-Ag-Cu deposit in west-central Eire.

In the high pH environment there is little or no evidence of present day dispersion of Pb, Zn, Cu, or Hg from the deposit into the overlying 5-50 feet of limestone till. Dispersion was predominantly mechanical, and syngenetic with the till. In hilly areas cryoturbation and solifluction in intraand post-glacial times may have caused some modification to the form of the initial anomalies, while strictly limited redistribution due to groundwater movement may have occurred locally.

The metal contents of freely-drained soils in the calcareous terrain, although enriched up to twofold, closely reflect those in the underlying drift. They show little variation with depth in rendzinas and brown earths, but in grey-brown podzolics they are enriched in the B horizon in the order $Hg \ge Zn \ge Cu \ge Pb$.

Compared with freely-drained soils, peat near metal sources shows locally high enrichment of Cu, Zn, and Hg but not of Pb. In background areas the Cu, Zn, and Pb contents of peats are comparable with those of freely-drained soils, but Hg may be somewhat enriched due to atmospheric precipitation and chelation by organic matter.

Well developed geochemical indicator trains of Pb, Zn, Cu, and Hg in the soil and till were found to be associated with the compound boulder train from the deposit.

Cu, Zn, Pb, and Hg dispersion trains are readily detectable in the stream sediments, and are related to the soil-till anomalies rather than to the bedrock source.

Geochemical Prospecting, Case Histories and Exploration Architecture

FORTESCUE, J.A.C., Geological Survey of Canada, Ottawa, Ontario

The application of geochemical prospecting methods in Canada has frequently been criticised because results obtained by a given method in one

area are considerably more reliable than results obtained by the application of the same method in a second area. In this paper the role that case histories can play in recording the scope and limitations of geochemical methods in Canada is discussed. The need for a simple, but generally accepted, terminology for the description of geological, geophysical and geochemical components of an exploration program is stressed and one set of terminology for this purpose is described under the heading of "Exploration Architecture".

A Progress Report on Biogeochemical Prospecting Research at the Geological Survey of Canada, 1962-65

FORTESCUE, J.A.C., and HORNBROOK, E.H.W., Geological Survey of Canada, Ottawa

During the past three years, the foundations have been laid for a long term biogeochemical prospecting research program at the Geological Survey of Canada. A review of the literature on biogeochemical prospecting methods tried in Canada prior to 1962 revealed that the method was in the <u>experimental</u> stage of development, and that there was a need for systematic studies of the morphology and geochemistry of vegetation near mineral deposits, in order to determine the scope of biogeochemical and geobotanical prospecting methods under Canadian conditions. It was considered advantageous to carry out research in the vicinity of known but undisturbed mineral deposits, so that the results of biogeochemical and geobotanical investigations could be interpreted in terms of parallel geological and geophysical studies carried out at the same level of intensity (the <u>followup</u> level).

The practical aspects of the biogeochemical prospecting research program have involved setting up a moveable biogeochemical laboratory unit housed in two specially designed trailers. Besides having drying and sample preparation facilities, the laboratory is equipped with an optical spectrograph and ancillary equipment and will include an atomic absorption spectrophotometer in the near future. The unit was specifically designed to carry out research on biogeochemical and geobotanical investigations at the followup level of detail which involves large numbers of chemical determinations on large numbers of samples of different materials. In order to achieve this a systematic approach was adopted to the organization of planning, sample collection, chemical analysis, and the mechanical processing and plotting of results.

In addition to the setting up of the laboratory, progress has been made in the setting up of greenhouse experiments in biogeochemistry. Preliminary experiments have shown that it is feasible to grow small trees and cuttings under controlled conditions in the greenhouse on the roof of the Geological Survey building in Ottawa. Feasibility experiments have already been made using known amounts of minor elements, a radioactive tracer, and artificial mixtures of common isotopes.

Much attention has been given to the selection of field areas for systematic biogeochemical and geobotanical studies as well as to the details of laying out line and plot types of sampling programs. These methods have been developed in the course of four field investigations—two near mineral deposits, and two away from such deposits. The control experiments were carried out in a peat bog near Ottawa and in the Moose River area of northern Ontario. The experimental investigations near mineral deposits were carried out at a property near Silvermine, Cape Breton Island, and in the vicinity of the Texas Gulf Sulphur deposit near Timmins.

The experience gained in all these aspects of the biogeochemical prospecting research program will be referred to in this brief paper; a more detailed account will appear in a progress report which should be published before the end of 1966.

Mercury Dispersion Haloes as Prospecting Indicators at the Base-Metal Deposits, West Shasta District, California

FRIEDRICH, G.H., Institute of Mineralogy, Technische Hochschule Aachen, 51 Aachen, Germany, and HAWKES, H.E., Department of Geology, Imperial College of Science and Technology, University of London, London S.W. 7, England

Geochemical work in the West Shasta district, California, has demonstrated that mercury anomalies occur in soils over blind but known orebodies of the Early Bird Mine, the Keystone Mine, and the Mammoth Mine. The lenticular and flat-lying orebodies, consisting of massive pyrite, smaller amounts of chalcopyrite and sphalerite, and minor amounts of galena, tetrahedrite, pyrrhotite, and magnetite, are overlain by unmineralized rhyolite and tuff horizons. The ore occurs at a depth of about 200 feet. The mercury content of the soil samples taken above the orebodies is far above the background value. They contain up to 340 ppb (parts per billion) mercury. The background range is from 20 to 60 ppb Hg. Distribution and Behaviour of Metals in Stream Sediments and Waters of the Keno Hill Area, Yukon Territory

GLEESON, C.F., Geological Survey of Canada, Ottawa (now at Société Québecoise d'Exploration Minière, 2383 Chemin Ste. Foy, Ste. Foy, P.Q.)

In 1964, the Geological Survey of Canada completed a reconnaissance helicopter supported geochemical-heavy mineral survey of the Keno Hill area, Yukon Territory. The project was called "Operation Keno" and covered about 1,900 square miles.

The study was undertaken to determine the applicability of stream sediment, water, and heavy mineral analyses as methods of prospecting for ore deposits in the area, to stimulate interest in mineral exploration and development of the district, to outline metallogenic districts, and to study the effects of various rock types on the distribution of metals in the stream sediments and waters.

The field party consisted of 7 two men crews, a cook and a helper, 2 helicopter pilots and an engineer. Two Bell Super G 2 A helicopters were used to set out and pick up the traverse teams. They traversed the creeks on foot, took samples of the stream sediments, and tested the waters and sediments for cold extractable heavy metals at intervals of 1,500 feet. Approximately 5,900 stream and spring sediments, 5,700 stream waters, and 150 spring waters were tested at the sample site for cold extractable heavy metal. In addition, several samples of water were taken from each creek and submitted to the water testing laboratories in Ottawa for sulphate and chloride analyses. In addition 150 large water samples (1 litre) were obtained from the springs for complete anion and cation analyses. The stream sediments were dried at about 60 °C and sieved to minus 80 mesh in the field. Subsequently, they were sent to the geochemical laboratories in Ottawa where colorimetric analyses for Cu, Pb, Zn, As, Sb, W, and Mo, and spectrographic analyses for Ni, Co, Ag, Sn, Mn, Bi, B, and Au were done. The heavy mineral samples were obtained by panning the creek gravels; these concentrates were sent to Ottawa for heavy liquid separations and semiquantitative spectrographic analyses.

To date, a series of 14 maps has been published at a scale of one mile to the inch showing the distribution of cold extractable heavy metals in the waters and stream sediments. Laboratory analyses have been completed on all samples and presently this information is being compiled for publication.

Observations on the character of the environment and the composition of the sediments and rock types were entered on field cards in

coded form. This information, in addition to the laboratory analyses, has been punched on cards for electronic data processing. In addition, X and Y coordinates based on the universal transverse mercator grid were assigned each sample point. A computer program has been devised so that in the future mechanical plotting of analytical information will be possible.

Field expenditures for Operation Keno were approximately \$75,000.00; of this \$40,000.00 was spent on the helicopter charter. The field cost of this survey per square mile was about \$40.00. This figure does not include the cost of laboratory analyses.

The results of the cold extractable field tests showed that reconnaissance stream sediment and hydrochemical surveys are practical and useful exploration tools for this area. With these methods, it was possible to detect most of the known lead-zinc-silver deposits in the area. In addition, numerous anomalies were found in areas that to date have been little prospected. Anomalous trains varied from less than a mile to over 10 miles in length.

The water and stream sediment anomalies were generally coincident, but certain exceptions did occur in the vicinity of some of the metal-rich acid springs, where the cut off of the sediment anomalies was displaced several thousand feet below the cut off of the water anomalies. The reason for this displacement is thought to be related to the physico-chemical conditions of the environment, especially the pH. Dilution from heavy rains or spring run-off did not seem to be an interfering factor.

The anomalies found with the field tests were mainly due to zinc. In addition, many of the samples contained above background amounts of Cu, Pb, Ag, As, Sb, and W. Little can be said at this time about the distribution of individual metals in the stream sediments and heavy minerals until the maps for these metals are published. However, the following general statements can be made. Tungsten was commonly found in stream sediments from creeks draining areas of granitic rocks. Arsenic was high in creeks draining gold-arsenopyrite-pyrite veins and Pb-Sb-As-Ag veins. Some of the greenstone bodies in the area contribute copper and, in some places, nickel and cobalt to the stream sediments. Zinc, copper, lead, manganese, and silver anomalies were found in areas underlain by quartzites and phyllites, especially where these rocks were faulted. Lead was anomalous in some areas underlain by dolomitic limestones. Analyses of the heavy mineral concentrates outlined several areas high in tin.

It is concluded that reconnaissance geochemical stream sediment, water, and heavy mineral surveys in the Keno Hill area can be used to detect areas of Zn, Cu, Pb, As, Sb, Ag, Ni, Co, Mn, Mo, W, and Sn mineralization. The methods are relatively cheap and can supply much additional information on boundaries of metallogenic districts both old and new.

Some Observations on the Distribution of Metals in Swamps in Eastern Canada

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The results obtained from geochemical investigations in poorlydrained areas of the Canadian Shield and in Palaeozoic districts of Newfoundland are described.

The studies were made in swampy environments located 70 miles southeast of Kenora, Ontario, 35 miles north of Amos, Quebec, and near Daniel's Harbour on the west coast of the island of Newfoundland. Precambrian rocks underlying the Quebec and Ontario field areas are partially obscured by lacustrine sands and gravels of Pleistocene age and are barren of base metal mineralization. The Daniel's Harbour district has also been heavily glaciated, but the Ordovician dolomites in the area contain irregularly distributed concentrations of sphalerite.

Swamp profiles in all three areas are essentially similar, and consist of a zone up to 28 feet in thickness composed of living and decomposing organic matter overlying heavy, compact clayey sediments. Careful sampling and analysis of these profiles has indicated that, in background areas, the zinc, copper, and nickel content in the organic horizons increases gradually with depth, and maximum values are present in the upper layer of clay beneath the peats. Below the upper clay layer the metal content decreases.

A similar pattern of zinc distribution is present in anomalous swamp profiles sampled close to areas of mineralized bedrock in western Newfoundland. The zinc content of the upper clay layer increased in the vicinity of known mineralization, and the contrast between the metal content of surface organic samples, the upper clay layer, and lower clay layers is more marked than in background profiles.

The geochemical investigations in Ontario, Quebec, and Newfoundland indicate that there is a tendency for certain trace metals to become regularly distributed in swamp profiles in poorly-drained, heavily glaciated regions. The increase in zinc content in the vicinity of known mineralization indicates that, in selected areas, careful sampling of specific horizons in the swamp profiles can be used as a geochemical tool when prospecting for unknown ore deposits. Such an exploration technique may be of particular value in the Canadian Shield.

Coding System and Field Card for Geochemical Surveys of Streams

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The card, consisting of two sheets separated by a thin carbon, was used to record data for four samples or stations. One copy is retained in the field, the other sent to the computer centre where the coded data are punched on IBM computer cards. The card, parts of which are colour toned for easy reference, was designed for an 80 digit system.

Some data, such as stream width and depth, sediment composition, pH, temperature and metal content is recorded on the card in its exact form. A mnemonic system (letters) is used for rock names. The remainder of the data are coded, using numbers; thus, the flow rate of water was coded as 0 = not flowing, 1 = slow, 2 = moderate, and 3 = fast.

Coding of the field data and the field cards offers several advantages; all data and observations are reduced to a "common denominator", no observations are omitted or forgotten, and note-taking time is considerably reduced over conventional methods. Greater advantages accrue when the coded data can be mechanically processed.

Contribution à l'Etude de la Dispersion Superficielle de l'Uranium par Déversement de Solutions Uranifères dans des Cours d'Eaux du Massif Central Français.

GRIMBERT, A., Section de Géochimie, Department des Prospections et Recherches Minières, Centre d'Etudes Nucleaires, Fontenay-aux-Roses, Seine, France

The paper outlines a study of the dispersion of uranium in the natural waters of the French Central Massif.

Eh and pH in Geochemical Exploration

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The terms Eh (oxidation potential) and pH (acidity) are defined and the method of measurement described. The theory of construction of Eh-pH diagrams is briefly shown and a number of typical geochemical environments plotted in terms of Eh and pH.

The use of Eh and pH in describing and interpreting geochemical data is demonstrated with the aid of several simple Eh-pH diagrams. In general, two aspects are considered—1) the oxidation of certain primary sulphides in the outcrop or suboutcrop environment, and 2) the movement of metals in some typical secondary dispersion media. Practical applications of each are illustrated with exploration case histories representing environmental conditions in the Canadian Shield, the southwestern United States, and the Caribbean.

Geochemical Prospecting for Molybdenum-A Case History in the Mount Ste-Cécile Area, Frontenac County, Québec

KELLY, R.W., Graduate Student, Department of Geology, Laval University, Québec, P.Q., and ASSAD, R., Geological Exploration Service, Quebec Department of Natural Resources, Québec, P.Q.

Two zones of vein type molybdenum mineralization are known in the area.

Soil, vegetation, and stream sediment samples were analysed for molybdenum. This element is distributed in the samples as two near lognormal populations of which the one with the highest modal value is considered as anomalous.

One of the mineralized zones was not revealed by the stream sediment survey. The other zone gave anomalous results and would have been found with a greater sampling internal than the 500 foot spacing used. The soil and vegetation survey revealed the molybdenite bearing veins, but a close spacing sampling pattern is required.

Humus rich samples collected in swamp areas were enriched in molybdenum. Winter sampling gave results similar to those obtained during the course of the summer sampling. Samples collected during periods of heavy rain, did not show marked differences in their molybdenum content. LYNCH, J.J., and DURHAM, C.C., Geological Survey of Canada, Ottawa, Ontario

The supporting analytical facilities of a geochemical stream sediment program in the Bathurst area of New Brunswick are described. The sample preparation, chemical, and spectrographic laboratories employed in this program were all assembled in the immediate area.

Stream sediment samples collected by six sampling teams were dried, sieved, ground, and split in the sample preparation laboratory. The splits were then distributed to the two analytical laboratories. Using hot extraction methods and colorimetric techniques, zinc, copper, lead, arsenic, antimony, molybdenum, and tungsten were determined in the chemical laboratory which operated in one of the local high schools. By employing a rapid semiquantitative spectrochemical method, manganese, barium, chromium, nickel, cobalt, tin and silver were determined on a 1.5 metre grating spectrograph mounted in a trailer. The results from both laboratories were then forwarded to the field geologists for plotting, usually within seven to fourteen days after the date of sample collection. During the months of June, July and August, a total of 3,550 samples was processed in these laboratories.

The Analysis of Large Numbers of Geochemical Samples

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The proper way of bagging, drying, and sieving the samples is discussed, showing two slides to describe the mechanics involved in the absorption of metal ions, as well as the cementation caused by the drying procedure.

The "cold" and "hot" results on the same sample are discussed, using one slide to illustrate the two types of digestion and their effect on the sample material.

Special equipment used in handling large numbers of samples per day (1,000) is shown on five slides. Its use is described, and instructions are given on how to make and where to buy the equipment. The importance of certain minimum standards in the manufacture of geochemical solutions for field or laboratory use is demonstrated, using three slides.

Finally, a short summary of one of the most important geochemical field tests, the THM (total heavy metals) test, and the different ways it can be handled safely in the field, is given.

A Copper Soil Anomaly Near Sunnybrae (lat.45°24'N, long. 62°30'W), Pictou County, Nova Scotia

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Sediment sampling of streams, at intervals of 500 feet, in an area of about three by eight miles, centred near the village of Sunnybrae, Nova Scotia, established the following background: copper, nil to 20 ppm; lead, nil to 35 ppm; and zinc 60 to 100 ppm. The only part of this area found to be anomalous confirmed the presence of the copper anomaly (15 to 112 ppm) shown on Geological Survey of Canada Geochemistry Map 27-1959.

Soil sampling of the drainage area of the anomalous streams, at 100-foot intervals on a 400-foot grid, led to delineation of soil anomalies (ranging from 40 to 1,000 ppm) along a zone of about 2,400 feet in length. The anomalous zone overlies Ordovician argillitic rocks, and is downslope, between 50 and 800 feet, from their contact with Silurian intermediate to mafic volcanic rocks.

Electromagnetic and self-potential surveys over the grid revealed no geophysical anomaly. An induced polarization survey outlined (1) a weak anomaly, roughly coincident with a geochemical soil anomaly, and (2) a resistivity change, in part at least, along the contact of volcanic and sedimentary rocks.

Even though two of the three trenches that reached bedrock, in areas of geochemical "highs", uncovered traces of chalcopyrite, the writer does not believe that the amount of chalcopyrite exposed, is adequate to explain the extent and magnitude of the copper anomaly.

Studies in Regional Geochemistry

NICHOL, I., GARRETT, R.G., and WEBB, J.S., Applied Geochemistry Research Group, Imperial College of Science and Technology, University of London, London S.W. 7, England Research carried out to date in regional geochemistry has demonstrated the applicability of the comprehensive analysis of stream sediments to delineating areas of potential economic significance and providing information relating to the geology of the area as a whole.

Hitherto, data handling and plotting have been carried out by laborious manual methods, with the data being presented as a series of single element maps, and interpretation has been based on a subjective interpretation of these patterns. Due to the difficulty of assimilating more than a few variables simultaneously, it is probable that only the more obvious features have been recognized to date and subtle though significant features have remained undetected.

Preliminary studies of the application of mechanical methods of data plotting using the Stromberg Carlson 4020 have permitted considerable savings in time. The geochemical data are presented to the S-C 4020 on magnetic tape and converted into characters according to the content of the element present which is projected on the face of the cathode ray tube. The image on the face of the tube is photographed by a 35 mm camera and simultaneously recorded on 8" x 8" photosensitive paper. Jobs normally taking three hours to complete can be carried out in a matter of seconds.

Investigations to date into the application of mathematical and statistical methods to the interpretation of geochemical data have included a limited study of over 15,000 square miles of the basement complex in Sierra Leone. Surface trend analysis has been applied to separate the regional geochemical background over the area from sites that contain metal contents outside the limits imposed by sampling and analytical error and which can be regarded as anomalous. The general correspondence between the trend surfaces of metal contents in rocks, soils, and stream sediments over the area provides further confirmation of the relationship between the metal contents of associated rock, soils, and sediments, and the adequacy of stream sediment analyses as a measure of the geochemistry of relatively large tracts of country.

Currently, investigations are in progress into the application of factor analysis to the interpretation of geochemical data. This method of data analysis is envisaged as providing a means for the identification of the relation of geochemical patterns to controlling factors such as bedrock geochemistry, discrete mineralization, or secondary environment. In most cases it is expected that the geochemical patterns may be related to a combination of causal factors, and the potential of factor analysis lies in its possible use in determining the extent to which different factors are affecting the observed geochemical patterns. Subsequently, it is hoped that the production of factor maps relating to several elements might aid in providing a more meaningful interpretation of the data.

Investigations of the Thunder Bay Silver Area

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The Thunder Bay silver area was divided into two belts and designated by N.L. Bowen in 1911 as the "gray argillites" and "black slates" belts. The "gray argillites" belt strikes northeastward through a series of diabasic islands lying about 25 miles southeast of the Lakehead in Lake Superior and includes McKellar Point, Victoria, and Spar Islands, as well as the famous Silver Islet. The "black slates" belt extends some 80 miles from the region 10 miles northeast of Port Arthur, southwestward through the city, the Rabbit and Silver Mountains, to Whitefish and Arrow Lakes.

Until recent years, virtually no research or exploration had been devoted to the Thunder Bay silver area since the publication of the Geological Survey of Canada Memoir 167 by T.L. Tanton in 1933. During the past several years, however, a variety of detailed and reconnaissance magnetometer, self potential, electromagnetic, and geochemical surveys coupled with photogeologic investigation and limited diamond drilling have been conducted over several portions of the "black slates" belt. This report is a short case-history of the geochemical investigation of two silver properties, and indicates that silver mineralization can be detected by simple geochemical techniques.

Geochemical Control of Copper Deposition on Grand Manan Island, Bay of Fundy, New Brunswick

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The west half of Grand Manan Island consists of a series of tholeitic volcanics and related sills overlying flat lying red Triassic sandstones and siltstones. The maximum thickness of the igneous series is approximately 500 feet.

The sediments immediately underlying the volcanics contain a higher concentration of copper than the sediments lower in the section. A simple model of copper precipitation from groundwater moving from the volcanics into the sediments is proposed by the writers. The physicochemical conditions of this process are described and interpreted.

A Trace Element Study of Podzol Soils, Bathurst District, New Brunswick

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In all horizons of these acid, Podzol soils, total amounts of iron, manganese, copper, lead, zinc, arsenic, antimony, silver, and tin were higher above sulphide deposits than above the surrounding country rocks. Lead and silver were the elements most enriched in the surface humus horizons. Total amounts of most elements were depleted in the leached Ae horizons, relative to the overlying humus and underlying B horizons; tin was an exception. Concentrations of arsenic, lead, copper, and antimony in the B horizons were apparently related to higher free iron oxide contents. In soils above non-mineralized rocks total copper, zinc, and manganese contents were usually highest in the parent materials of the C horizons.

Geochemical Patterns at Mount Pleasant Mines Limited

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A reconnaissance geochemical survey of the stream sediments in 1954 identified Mount Pleasant in southern New Brunswick as an area of potential base metal mineralization. Geochemical soil surveys outlined large and complex patterns of copper, lead, and zinc dispersion in the B soil horizon of the area. In 1959 reanalyses of these original samples showed anomalously high concentrations of tin and molybdenum. Tin showed a large and irregular dispersion pattern strongly modified by glaciation. The molybdenum pattern was more restricted and coherent. Subsequent diamond drilling, surface stripping, and underground development have confirmed the presence of widespread polymetallic metallization in bedrock with numerous shoots of ore grade. The mineralization is related to mid-Carboniferous volcanism and is known to a minimum depth of 1,000 feet below surface.

Each metallic element has developed its own distinctive pattern of dispersion and concentration in both the endogenic and the exogenic geochemical cycles. The exogenic patterns show modification by the processes of degradation and glaciation.

Geochemical Case History at the Little Falls Molybdenite Prospect, Boise County, Idaho

ROSTAD, O.H., American Metal Climax, Inc., 1485 Sherman Street, Denver 3, Colorado 80203, U.S.A. During 1962, Amax geologists used geochemical methods to help evaluate a molybdenum prospect in an intrusive igneous terrane situated in a semi-arid area of rugged, mature topography.

Soil samples taken on a grid defined an anomalous area about 600 feet wide by 2,400 feet long in which the soils are generally acid and contain 160 to 1,400 ppm Mo. Local background is 20 ppm Mo.

Samples of the minus 35 mesh soil contain approximately 2.5 times the amount of molybdenum present in the immediately underlying oxidized bedrock, which in turn contains about half again as much molybdenum as the drill core from the sulphide zone.

Recognizably anomalous values were not obtained from either water or stream sediments taken from two streams which cut through the anomalous area.

Geochemistry in the Selway-Bitterroot Wilderness Area, Central Idaho

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A geological, geochemical, and geophysical survey of an area of 2,400 square miles within the Idaho batholith and surrounding metamorphic rocks was commenced in 1965. The primary objective of the 9-year program is to evaluate the mineral potential of the wilderness area.

Knowledge of geology and possible mineral deposits of the area is limited because of difficult accessibility. Deposits outside the wilderness, but still spatially related to the margins of the Idaho batholith, have collectively produced tungsten, cobalt, antimony, mercury, gold, and monazite.

Geochemical reconnaissance is based on stream sediment, soil, water, and rock sampling. Colorimetric analytical procedures for molybdenum, beryllium, cobalt, tungsten, and cold-extractable and total copper and zinc are planned.

Low background values of 0.5 ppm heavy metals by Bloom's citrate-extractable procedure, and less than 1 ppm cxCu by Canney and Hawkins' procedure, are indicated for active sediment collected from granite and schist terrains. Slightly higher background values of 1 ppm heavy metals and 2 ppm cxCu represent a quartzite, hornblendite, and metamorphosed calc-silicate rock terrane.

Detection of Anomalous Concentrations of Ore Metals in Precambrian Country Rock

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In numerous areas in which Precambrian country-rock in Saskatchewan has been sampled on a reconnaissance basis (4 to 20 specimens per square mile), concentrations of Ni, Cu, and Zn exceeding 200 parts per million are rare, ranging from less than one out of one hundred specimens to about one out of fifteen specimens in different areas. Although contouring of the metal concentrations in some cases reveals trends on which the high concentrations lie, their significance is not immediately apparent. The purpose of this paper is to illustrate the nature and possible significance of some anomalously high ore-metal concentrations found by reconnaissance sampling of bedrock.

From an area underlain by granodioritic intrusive complexes surrounded by Amisk-type basic volcanic rocks where 16 specimens per square mile were taken, 100 out of some 1,600 specimens (or one out of 16) contain more than 200 ppm of copper. In the basic volcanic rocks themselves, the ratio is one out of nine, and it is highest in units which are closest to the granodioritic intrusions. The highest ratio of all (one out of five specimens containing more than 200 ppm of copper) is in a relatively small unit which is the host of three known copper orebodies. The ratio is the same among 370 specimens per square mile collected near the Coronation mine, and the specimens with more than 200 ppm of copper are concentrated along a belt on strike with the orebody.

The same reconnaissance sampling detected many high concentrations of nickel in meta-gabbro sills, and suggested a zonal distribution of nickel in some of them. Detailed sampling of one sill disclosed a marked increase in nickel concentrations toward the contact with ultrabasic rocks, and chemical analyses demonstrate that the sill itself is ultrabasic gabbro,

Reconnaissance sampling (20 specimens per square mile) of a second area near Hanson Lake, Saskatchewan, suggested clustering of high concentrations of copper near the contact of a granitic body and of nickel and zinc in metasomatized volcanic and sedimentary rocks. Detailed mapping and sampling (400 specimens per square mile) disclosed many well-defined anomalies in the distributions of all three metals, the most marked of which surrounds the only known showing of copper-zinc sulphides in the area. Most of the few scattered high concentrations of nickel, copper, and zinc found by the reconnaissance sampling are neighboured by many specimens containing as much as several tenths of one per cent of the ore-metals. Preliminary mineralogical studies suggest that concentrations greater than 200 ppm of copper and zinc signify the presence of chalcopyrite and sphalerite in the specimens, but that much or all of the nickel may be in silicate minerals.

It is concluded that reconnaissance sampling of Precambrian country-rock for geochemical studies can reveal information of geologic and economic value, even though no well-defined "anomalies" are obvious. Detailed sampling of bedrock discloses many well-defined anomalies, some of which delineate zones of disseminated ore-sulphides which normally escape detection by detailed geological mapping and by geophysical surveys.

Granite Studies Related to Ore Formation in the Eastern Townships, Quebec

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Three Devonian granite masses were mapped and samples collected by stratified random sampling methods.

No ore deposits are associated with the mesozonal Winslow granodiorite mass, outer portions of which are basified.

Molybdenite-quartz stockworks, occurring in hornfelsic siltstones of Silurian age, are spatially related to biotite leuco-quartz monzonite at both ends of the epizonal St. Cécile quartz-monzonite-granodiorite stock.

Stratabound Cu-Zn sulphide deposits, occurring in sheared Ordovician volcanics, are spatially related to muscovite-biotite leuco-quartz monzonite which crops out in a crescent shaped area that makes up the western part of the epizonal Weedon granodiorite.

Both the epizonal masses are characterized by bimodal distributions of SiO₂ values and significant differences in chemical and mineralogical compositions, probably related to differences in the composition of crustal rocks that were fused.

The molybdenum contents of all three granite masses is probably normal. For example, 55 samples of granite and 6 of dykes from St. Cécile contained from 1 to 3 ppm Mo, with a mean of 1.7 ppm Mo. Mo is inversely proportional to SiO₂.

The base metal contents of the granites are somewhat lower than comparable data from Sandell and Goldich, 1943.

	Mean	Median	Range	Std. Er. Mean	No. Specimens
Winslow	64.3	65.0	51.3-74.2	1.8	14
Weedon	71.9	73.8	66.7-75.0	0.8	17
St. Cécile	72.0	71.0	68.2-76.3		53
			Cu ppm		
Winslow	6.6	6	2-26	0.8	33
Weedon	6.4	3	1-28	1.0	41
St. Cécile	7.4	5	2-45		53
			Zn ppm		
Winslow	46.1	50	9-82	3.0	33
Weedon	38.5	33	9-63	2.8	41
St. Cécile	30.0	28	10-60		53
			Pb ppm		
Winslow	2.2	1	1- 8	0.3	33
Weedon	7.3	7	1-15	0.7	41
St. Cécile	8.7	6	2-25		53

The St. Cécile leuco-quartz monzonite phase has a mean Cu content of 5.9 ppm, excluding anomalous values of 170 and 190 ppm Cu, which is significantly higher than the 1.6 ppm Cu content of the leuco-quartz monzonite phase of the Weedon granite. However, anomalously high Cu and Zn values come from this phase where it has assimilated host rocks of the Weedon deposit which terminates at depth in granite.

If the ore deposits are cogenetic with the granite, as inferred from evidence that sulphides replace granite and contact metasomatic minerals, the deuteric alteration hypothesis postulated by Earl Ingerson may account for their origin. But both the Cu-Zn and Mo deposits are cut by dykes having compositions that can be correlated with those of the granite phases, and the Weedon deposit may be a "contact metamorphosed" deposit.

Primary Geochemical Dispersion and its Application to Exploration and Mining Programs

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Primary geochemical dispersion involves the distribution of elements in igneous and metamorphic rocks at relatively high temperatures

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SiO2

and pressures characteristic of deep-seated conditions. The resultant distribution patterns of elements permit an examination of the chemical variations in the rock which have resulted from primary dispersion processes. These patterns can be studied today in rocks below the zone of weathering and provide valuable additional data as to the geological history of the area. In particular, however, trace element distribution patterns can be an invaluable guide to mineral deposits.

In the U.S.S.R. primary dispersion studies have played an important role in exploration for blind orebodies of hydrothermal and/or metamorphic origin for some time. Research investigations have been undertaken in other parts of the world by both Universities and Mining Companies. Much of this research, however, has been confined to certain aspects of the overall concept. Nevertheless, these investigations have proved the applicability of "rock" geochemistry as an aid to geological mapping, and as an ancillary guide to mineral deposits. As a result of these investigations, primary dispersion studies are becoming an integral part of geological exploration and development programs.

Primary dispersion studies in certain forms have been fundamental to the study of geology. Initially, mineral assemblages and mineral distribution patterns were the only parameters used. As chemical analyses have advanced, the chemical composition of the major element constituents of rocks and minerals has become a common means of elucidating geological processes. In mineral exploration also, the chemical composition of major constituents is used in the assaying of rocks for their ore metal content.

By the examination of the trace element constituents of rocks and minerals, "rock" geochemistry has broadened the concept of primary dispersion in providing measurements of parameters which are submicroscopic. This has been possible with the development of geochemical analytical techniques, which have provided rapid and quantitative analyses of trace quantities of metals.

Four of the principal aspects of investigation in which primary dispersion studies have been undertaken are as follows:

(a) delimiting geochemical provinces by comparing the abundance of trace elements in igneous rocks, and to a lesser extent in sedimentary rocks, in a particular area to their average concentration in the earth's crust as a whole;

(b) aiding geological mapping of folded strata by establishing marker horizons based on their characteristic trace element assemblages, ratios, and/or absolute values;

(c) discovering blind orebodies by detecting anomalous concentrations of metal in rocks overlying the deposit;

(d) determining hydrothermal and/or metamorphic patterns around orebodies by measuring the trace element content of rocks and minerals in order to establish chemical gradients in depth, along strike, and around the deposit, whereby prospect drilling and/or mine development can be directed towards the maximum concentration of ore metals.

Primary dispersion studies are proving to be a valuable ancillary guide to the discovery of ore deposits. The applicability of this approach to exploration in North America as well as in other parts of the world has already been proven. Just as in the surface environment, where geochemical techniques have provided additional and often primary data in the discovery of mineral deposits, so, in the prospect drilling and development stages of exploration, primary geochemical dispersion can provide invaluable and at times unique data concerning the nature of the mineralization and the direction in which to go in search of ore.

Some Problems in Applied Geochemistry

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Geochemistry is being used more and more in exploration and development work. Nevertheless, there are many problems of technique that need to be appreciated if full use is to be made of this exploration tool.

The authors provide examples to illustrate geochemical techniques which can easily involve mistakes being made by the unwary.

Selecting appropriate extractants and horizons in pedogeochemistry, and the most appropriate organs and species of trees and plants in biogeochemistry, are among the techniques that are discussed.

Heavy Minerals as Prospecting Guides, Gaspé, P.Q.

SIMS, W.A., Mount Allison University, Sackville, New Brunswick

During the summers of 1964 and 1965, the heavy minerals from Recent stream sediments were collected in the region of Gaspé Copper Mines, Gaspé, Quebec.

Chemical and mineralogical analyses of these samples may provide useful prospecting data for copper deposits associated with skarn.

This applied research project is being sponsored by the Ministère des Richesses Naturelles, of the Province of Quebec.

