

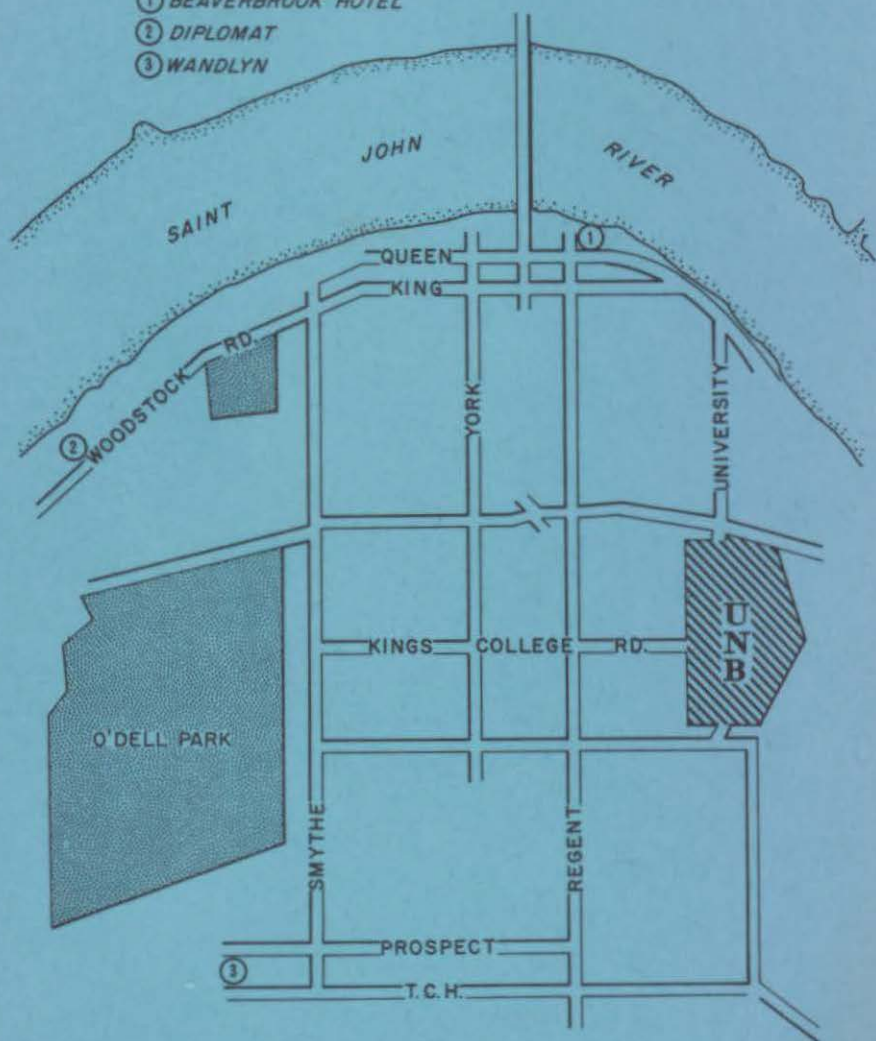


EXPLORATION GEOCHEMISTRY IN THE APPALACHIANS

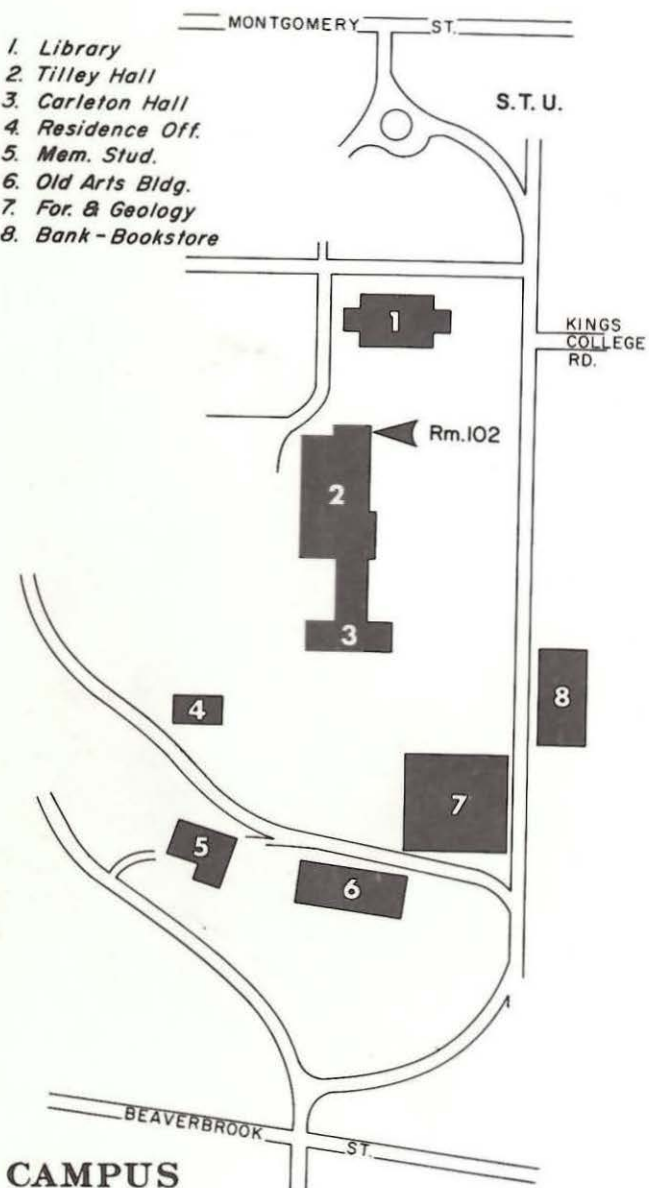
Abstracts & Programme

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THE ASSOCIATION OF EXPLORATION
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J.L. Wahl, Tourism, Displays, & Field
Excursion Guidebook

Ladies Programme

Mrs. A.L. McAllister
Mrs. J. Moore

GENERAL INFORMATION

All technical sessions will take place in Sir Leonard Tilley Hall, University of New Brunswick. The Lord Beaverbrook Hotel is designated the official hotel of the symposium.

REGISTRATION

Registration will take place as follows:

Wednesday, 21 April. 2:00-6:30 pm. Lord
Beaverbrook Hotel

Thursday, 22 April. 8:30-12:00 am. Sir
Leonard Tilley Hall
Room 204.

Registration kits for pre-registrants will be available during these hours.

TECHNICAL SESSIONS

All technical sessions will take in the auditorium (ground floor) Room 102, Sir Leonard Tilley Hall. Delegates should be seated five minutes before the sessions begin. Contributors to the discussions should use the nearest microphone and clearly preface their remarks with their name and affiliation. Papers are strictly limited to 20 minutes duration; discussion of 10 minutes is allocated to each paper.

AUTHORS CORNER

Authors will be available for one-half hour after each session to discuss their papers. "Authors Corners" are scheduled near the cash-bar before lunch following the morning session and in Sir Leonard Tilley Hall Room 204 after the afternoon session (coffee provided).

FACILITIES FOR AUTHORS

Breakfast for the authors and chairmen of the day will be provided in the Restigouche Room of the Lord Beaverbrook Hotel at 7:45; transport for those at other hotels will be available at 7:30. Slide viewing facilities are available in Room 205, Sir Leonard Tilley Hall.

DISPLAYS

There will be displays which outline work in exploration geochemistry which has been done or is underway in New Brunswick on the ground floor and in Room 204, Sir Leonard Tilley Hall.

OFFICE

A desk for inquiries (and a telephone) will be manned on 22 and 23 April in Room 204, Sir Leonard Tilley Hall during the technical sessions.

TRANSPORTATION

Transport between hotels and the campus will be available by chartered bus in the morning at 8:30 and in the afternoon at 5:30 on 22 and 23 April.

COFFEE

Coffee will be served between technical sessions on the first floor of Sir Leonard Tilley Hall.

LUNCH

Lunch on campus will be available with pre-paid tickets on 22 and 23 April; there will be a cash-bar between 12:00 and 2:00 pm. Lunch tickets will be found in the Registration Kit.

SOCIAL PROGRAMME

Wednesday, 21 April. 6:30-8:00 pm

Reception, courtesy of the President of the University of New Brunswick, Dr. J.M. Anderson for all registrants and their wives.

Thursday, 22 April.

Reception and dinner, courtesy of the Provincial Government of New Brunswick.

LADIES PROGRAMME

A ladies programme will be announced at the meeting. Details will be available at registration.

FIELD TRIPS

The following field trips have been arranged:

Heath Steele Mines and Anaconda Caribou deposit.

Brunswick Mining and Smelting and Anaconda Caribou deposit.

Mt. Pleasant.

Lake George antimony mine.

Details of these trips are available in the Field Guide which will be issued free to all registered for the field trips.

PUBLICATIONS

The papers presented at the meeting will be published as a Special Issue of the *Journal of Geochemical Exploration*; this issue may be purchased separately; details of price will be announced at registration. A limited number of copies of the Field Guide (issued free to participants in the field trips) are available at a cost of \$1.00. Orders (with appropriate remittance) should be placed at the meeting.

ANNUAL GENERAL MEETING

The Annual General Meeting of the Association of Exploration Geochemists will be held at 4:00 pm in the Auditorium (Room 102) Sir Leonard Tilley Hall on 23 April 1976.

ACKNOWLEDGEMENTS

The Organizing Committee is extremely grateful for the assistance it has received from many people not formally part of the committee and wishes to especially thank the wives of the members of the Exploration Geochemistry Group of the University of New Brunswick, the staff of the New Brunswick Department of Natural Resources, and Dr. A.L. McAllister of the University of New Brunswick. The Committee would also like to express its gratitude to the following people and organizations: the President of the University of New Brunswick, Dr. J.M. Anderson, and the administrative staff of the University for their hospitality and the use of University facilities; the Province of New Brunswick for its cooperation and for the hos-

pitality offered; the Tourism Departments of the Provincial Government and the City of Fredericton; the Director of the Mineral Resources Branch of the New Brunswick Department of Natural Resources, Dr. R.R. Potter, and Atlantic Analytical Services Ltd. of St. John, N.B. The following mining companies are thanked for arranging field trips to their operations: Anaconda Canada Ltd., Brunswick Tin Mines Ltd., Brunswick Mining and Smelting Corp. Ltd., Consolidated Durham Mines and Resources Ltd., and Heath Steele Mines Ltd.

At the time this Handbook went to press, contributions towards the printing costs have been received from the following companies and consultants whose contributions are gratefully acknowledged:

Amoco Canada Petroleum Co. Ltd.
John P. Anderle
Consolidated Durham Mines and Resources Ltd.
Heath Steele Mines Ltd.
International Nickel Co. of Canada Ltd.
Newmont Mining Corp. of Canada
Nigadoo River Mines Ltd.
Noranda Exploration Ltd.
The Price Co. Ltd.
Shell Canada, Ltd.
Texasgulf Inc.

TECHNICAL PROGRAMME

22 April

Morning Session

Chairmen - G.J.S. Govett and J.A. Coope

- 9:00 Dr. D.C. Brewer, Acting Dean of Science, University of New Brunswick and The Hon. R.C. Boudreau, Minister of Natural Resources, New Brunswick.

H.E. Hawkes. Keynote Address, "New Brunswick: Where it All Began"

10:00 *Coffee*

- 10:30 W.S. Fyfe and R.W. Kerrich. Geochemical Prospecting: Extensive vs. Intensive Factors.

- 11:00 W.D. Goodfellow and J.L. Wahl. Water-extracts of Volcanic Rocks -- Detection of Anomalous Halos at Brunswick No. 12 and Heath Steele B-zone Massive Sulphide Deposits.

- 11:30 A.W. Lockhart. Geochemical Prospecting of an Appalachian Porphyry Copper Deposit at Woodstock, New Brunswick.

12:00 *Lunch*

Afternoon Session

Chairmen - R.R. Potter and F.K. Theobald

- 2:00 G.J. Dickie and C.J. Sampson. Exploration for Zinc and Lead in Western Newfoundland Based on Geochemical Surveys.

- 2:30 A. Harris. Definition and Priority Rating of Exploration Targets in the Coldspring Pond Area, Central Newfoundland.
- 3:00 *Coffee*
- 3:30 R.B. Ferguson and V. Price. National Uranium Resource Evaluation Program (NURE) Hydrogeochemical and Stream Sediment Reconnaissance.
- 4:00 A.W. Rose, M.L. Keith, and N.H. Suhr. Tests of Geochemical Techniques for Detection of Uranium Occurrences in Sedimentary Rocks of Eastern Pennsylvania.
- 4:30 W. Dyck, A.K. Chatterjee, D.E. Gemmell, and K. Murrice. Well Water Trace Element Reconnaissance in Eastern Maritime Canada.

23 April

Morning Session

Chairmen - E.V. Post and P.M.D. Bradshaw

- 9:00 S.C. Adams and W.C. Hood. Biogeochemical prospecting for Copper and Zinc Using *Juniperus virginiana* L.
- 9:30 J.E. Callahan. A Geochemical Survey Based on Stream Sediments in Watauga County, North Carolina, U.S.A.
- 10:00 *Coffee*
- 10:30 G.A. Nowlan. Concretionary Manganese-Iron Oxides in Streams and Their Usefulness as a Sample Medium for Geochemical Prospecting.
- 11:00 V. Austria and C.Y. Chork. A Study of the Application of Regression Analysis for Trace

Element Data from Stream Sediments in New Brunswick.

11:30 J.O. Larsson. Organic Stream Sediments in Regional Geochemical Prospecting, Precambrian Pajala District, North Sweden.

12:00 *Lunch*

Afternoon Session

Chairman - F.C. Canney

2:00 J.B. Gustavson. Use of Mercury in Geochemical Exploration for Mississippi Valley Type of Deposits in Tennessee.

2:30 J.E. Worthington. Techniques of Geochemical Exploration in the Southeast Piedmont.

3:00 Address by the President of the Association of Exploration Geochemists, R.W. Boyle.

3:30 *Coffee*

4:00 ANNUAL GENERAL MEETING, Association of Exploration Geochemists.

ABSTRACTS

(In order of appearance on the programme)

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GEOCHEMICAL PROSPECTING: EXTENSIVE VS. INTENSIVE FACTORS

W.S. Fyfe and R.W. Kerrich
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London, Ontario, Canada

To most workers geochemical prospecting involves the study of some features of the distribution of selected elements. The weakness of such techniques lies in the inability to distinguish an "ore body" from a region of slight concentration. While we do not discount the value of such "classic" approaches, it is suggested that geochemical and geological features which evaluate mass relations are also of importance.

The formation of an ore involves chemical transport, and this implies:

- (a) an appropriate transport medium of large mass;
- (b) an energy source of large capacity;
- (c) permeability at source and sink over large volumes;
- (d) a structure to promote flow over large volumes;
- (e) and a thermal gradient to promote focused deposition;
- (f) or a structure to promote mixing of transport fluid and precipitating fluid.

It will be shown that stable isotope and fluid inclusion studies can bear on quantitative aspects of (a), as can other factors such as oxidation-reduction processes, leaching processes, and volume of gangue minerals.

Energy sources are either gravitational (laterites) or thermal, and in the latter case are commonly caused by igneous intrusions or evapor-

ite-hydrocarbon reactions.

Permeability is related to porosity or fractures frequently caused by hydraulic fracturing or igneous events (e.g., intrusion and crystallization shrinkage).

Steep thermal gradients can be assessed from metamorphic patterns and are necessary for focussed deposition; they are often created by proximity to the hydrosphere.

The general thesis is developed with particular reference to sea floor magmatism, high-level plutonism, and stratabound lead-zinc deposits, and we illustrate with reference to analyzed examples how extensive indicators may be used to answer the old question "to drill or not to drill?".

WATER-EXTRACTS OF VOLCANIC ROCKS -- DETECTION
OF ANOMALOUS HALOS AT BRUNSWICK NO. 12 AND
HEATH STEELE B-ZONE MASSIVE SULPHIDE DEPOSITS

W.D. Goodfellow and J.L. Wahl
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Approximately 200 rock samples from the surface outcrops and diamond drill holes passing through acid and mafic volcanic rocks at Brunswick No. 12 and through acid volcanic rocks at the Heath Steele B-zone massive sulphide deposits in northern New Brunswick were collected. These samples were located near to, lateral to, and stratigraphically remote from the ore zones.

The rock samples were crushed and ground to minus 200-mesh and were analyzed for water-extractable Na, K, Mg, Ca, Cl^- , F^- , and H^+ and for total S, Rb, and Sr; the conductivity and the pH of a water slurry of the rock powders were also measured. The interpretation of the data shows that there are significant variations in element concentrations which can be spatially related to the sulphide zones of the deposits.

The Brunswick No. 12 and the Heath Steele B-zone deposits are located in the Cambro-Ordovician sequence of volcanic and sedimentary rocks, all of which have been subjected to lower greenschist regional metamorphism. The Brunswick No. 12 deposit has at least 82×10^6 tons of massive sulphide containing approximately 10 per cent Zn, 4 per cent Pb, less than one per cent Cu, and 2.46 ounces of Ag per ton; the main sulphide minerals are pyrite, sphalerite, galena, pyrrhotite, chalcopyrite, tetrahedrite, and bornite.

The hanging wall rocks are iron formations, chlorite, and sericitic siliceous sedimentary rocks and mafic volcanic rocks; the footwall rocks are chloritic and sericitic siliceous sedimentary rocks and pyroclastic acid volcanic rocks. The Heath Steele B-zone has at least 25×10^6 tons of massive sulphides containing approximately 5 per cent Zn, 3 per cent Pb, and less than one per cent Cu; the main sulphide minerals are pyrite, pyrrhotite, sphalerite, galena, and chalcopyrite. The hanging wall rocks are iron formations, acid pyroclastic volcanic rocks, and minor chloritic and sericitic sedimentary rocks; the footwall rocks are acid pyroclastic rocks, chloritic and sericitic sedimentary rocks, and rhyolites.

The acid volcanic rocks stratigraphically below Brunswick No. 12 deposit show the following element distribution trends towards the deposit:

- water-extractable F^- , Cl^- , Na, pH, and total Sr decrease;
- water-extractable K, Mg, Ca, conductivity, and total S increase;
- total Rb shows no obvious trend.

The basaltic volcanic rocks stratigraphically above the Brunswick No. 12 deposit show the following element distribution trends towards the deposit:

- water-extractable F^- , Cl^- , Na, K, total S, and conductivity increase;
- water-extractable Ca, Mg, and total Sr decrease;
- total Rb remains generally constant.

The acid volcanic rocks stratigraphically above the Heath Steele B-zone show the follow-

ing element distribution trends towards the deposit:

- water-extractable F^- , Cl^- , K, and total Rb decrease;
- water-extractable Na, Ca, total K, total Sr, and pH and conductivity increase;
- water-extractable Mg remains constant.

The acid volcanic rocks stratigraphically above the Heath Steele B-zone show the following element distribution trends towards the deposit:

- water-extractable F^- , Cl^- , K, Ca, total S, total Rb, pH, and conductivity decrease;
- water-extractable Na and total S increase;
- water-extractable Mg remains constant.

Single elements and combinations of elements successfully outline halos with a radius of up to 1,200 feet in the rocks stratigraphically above both the Brunswick No. 12 deposit and the Heath Steele B-zone; a hemispherical alteration zone with a radius of up to 1,500 feet is outlined below the Brunswick No. 12 deposit. The size and intensity of these anomalous zones associated with both deposits, as well as the rapidity of water-extractable analyses, has great significance in rock geochemical exploration for buried massive sulphide deposits.

GEOCHEMICAL PROSPECTING OF AN APPALACHIAN PORPHYRY COPPER DEPOSIT AT WOODSTOCK, NEW BRUNSWICK

A.W. Lockhart
Lockhart Exploration Services Ltd.,
Fredericton, N.B. Canada

A project to discover a porphyry copper deposit in New Brunswick commenced in 1965. In 1970, after five years of outcrop and boulder prospecting assisted by a major soil sampling survey, the discovery of ore grade porphyry copper mineralization was made. The discovery area is mantled with two to 15 feet of soil. The mineralization occurs as chalcopryrite disseminations and fracture fillings within a Devonian age quartz diorite stock. The host Cambro-Ordovician quartzites and argillites have been sericitized and contain chalcopryrite disseminations and fracture fillings. Non-magnetic pyrrhotite and pyrite occur in amounts up to 10 per cent by volume. Trace amounts of magnetite and molybdenite are present.

More than a dozen significant soil copper anomalies have been discovered within an area of eight square miles; nine of these have been trenched by eight miles of bulldozer trenches. Each anomaly was found to be underlain by copper mineralization in bedrock. Various amounts of drilling, induced polarization surveys, and magnetometer surveys tested three major anomalies. Significant areas containing 0.3 to 1.0 per cent copper were discovered, but no orebody has been outlined to date.

This paper describes exploration work done at Woodstock since 1965. Emphasis is on the

geochemical exploration done. It will be shown that regional stream geochemistry, done in sufficient detail, would locate similar occurrences in Northern Appalachia. With the possible exception of traditional prospecting of boulders and outcrops, stream and soil geochemistry over well selected geological targets are the best methods for discovering porphyry copper mineralization in this region.

In describing the sequence of exploration on this porphyry copper deposit, it will be demonstrated that detailed soil sampling over initial reconnaissance soil copper anomalies is necessary to avoid drilling localized areas of low copper content lying within a broad highly anomalous area. An example of incorrect laboratory results is presented. A large, highly anomalous area of copper mineralization was undetected by the initial reconnaissance soil sampling survey. Poorly executed wet chemical laboratory procedures provided incorrect results; this "laboratory anomaly" can be recognized with reasonable ease from the pattern of the reported results. The desirability of peripheral reconnaissance soil sampling on geologically selected target areas lying at considerable distances from the known anomalous areas is shown.

The existence of porphyry copper mineralization of economic interest in Northern Appalachia has been proven. The use of geochemistry in the discovery of such mineralization has been demonstrated.

EXPLORATION FOR ZINC AND LEAD IN WESTERN NEWFOUNDLAND BASED ON GEOCHEMICAL SURVEYS

G.J. Dickie and C.J. Sampson
British Newfoundland Exploration Ltd.
Montreal, Quebec, Canada

A belt of Cambro-Ordovician carbonate rocks occurring along the western edge of Newfoundland from the Port-au-Port Peninsula in the south down the Great Northern Peninsula contains zinc mineralization, notably at Daniel's Harbour. Exploration for similar deposits in the carbonates to the west of Deer Lake has been based on geochemical surveys which have proved sensitive to small accumulations of zinc and lead.

A regional survey of lake sediments in the area outlined broad areas where the sediments were anomalously high in zinc and lead. Where these results were not downgraded by earlier scattered stream and soil surveys a widely spaced soils sampling programme was carried out. Analysis of these results further narrowed down the area of interest, and in 1974 detailed grids were cut and sampled on a 200 foot (60m) spacing.

Inspection of the glacial deposits in the area indicated that the bedrock cover was composed of a basal, strongly weathered till which was probably locally derived, and gravel-silt slope wash material of recent origin. Accordingly, prospecting was concentrated in areas around the uphill from the sample locations with anomalously high zinc and lead content. Threshold values were calculated from cumulative frequency plots on probability paper.

Mineralization in the order of 0.5 to 1.0 per cent zinc was discovered in the dolostone bedrock underlying the areas of geochemically anomalous soils.

DEFINITION AND PRIORITY RATING OF EXPLORATION TARGETS IN THE COLDSRING POND AREA, CENTRAL NEWFOUNDLAND

Alex Harris
Dept. of Geology
University of Western Ontario
London, Ontario , Canada

The Coldspring Pond area is underlain by a sequence of mafic to felsic volcanic and argillaceous sedimentary rocks which have been assigned an Ordovician age. These rocks are intruded by gabbroic and ultrabasic plugs and Devonian granitic batholiths. Within the area, metamorphic grade increases from lower greenschist facies in the southeast to upper amphibolite facies in the northwest over a distance of about two miles.

The 1967 Asarco discovery of a massive sulphide deposit containing one million tons of 3 per cent Cu within meta-volcanic rocks near Great Burnt Lake about five miles along strike to the north of the Coldspring Pond area indicated a potential for other deposits of this type within the same volcanic belt. This discovery is a success story for exploration geochemistry and consequently, extensive geochemical work has been done in the Coldspring Pond area.

Approximately 1,700 stream sediment samples were collected during 1968 and 1969 within an area of approximately 30 sq. mi. as part of an initial exploration programme. Only Cu and Zn were determined, and follow-up work was limited to areas of strikingly obvious copper anomalies. Subsequently, a more comprehensive exploration programme,

involving a re-evaluation of this geochemical data, was begun early in 1975. Means (\bar{x}) and standard deviations (s) were calculated for each metal. Values greater than $\bar{x}+s$ were considered anomalous, and anomalous values were classified into five orders, each having a range of 15, with fifth order being extended to include all values greater than or equal to $\bar{x}+5s$.

Helicopter-borne electromagnetic and magnetic surveys had also been completed in 1969. Therefore, in addition to the geochemical targets, all electromagnetic conductors and unexplained magnetic anomalies were considered to be exploration targets.

Because the economic potential of the area was clearly for discovery of volcanogenic massive sulphide deposits, any or all of the following characteristics of exploration targets were considered to be favourable. (1) Electromagnetic conductors of short strike length (200 to 2,000 feet) or distinct "thickening" of long "formational conductors". (2) Geochemical anomalies. (3) association with volcanic rocks, preferably felsic.

All targets defined by these criteria were numbered, and priority ratings were assigned on an arbitrary scale of 1 to 10, taking the most favourable targets as first priority and the least favourable as tenth priority. Although these priority ratings have no quantitative significance, they do relate qualitatively to the probability of discovering a massive sulphide deposit at any particular target.

Field work during the 1975 field season consisted mainly of geological mapping with a limited amount of detailed geochemical

soil sampling. A surface discovery of interesting copper mineralization (1.3 per cent copper over 6.2 feet) in altered acid volcanic rocks was made on a target previously rated as second priority. This target was defined by a third order copper anomaly, a second order zinc anomaly, and a short, weak electromagnetic conductor. It had not been considered as a target of interest in the initial 1969 exploration programme.

NATIONAL URANIUM RESOURCE EVALUATION PROGRAM
(NURE) HYDROGEOCHEMICAL AND STREAM SEDIMENT
RECONNAISSANCE *

R.B. Ferguson and V. Price

Savannah River Laboratory, E.I. du Pont de
Nemours and Company, Aiken, South Carolina,
U.S.A.

The NURE Program was initiated by the United States Atomic Energy Commission (AEC) in the spring of 1973 and continues under the sponsorship of the United States Energy Research and Development Administration (ERDA). The NURE Program is a comprehensive effort to evaluate domestic (U.S.A.) uranium resources and to identify areas favourable for uranium exploration. There are seven major areas within the NURE Program:

- National aerial radiometric reconnaissance.
- National hydrogeochemical and stream sediment reconnaissance.
- Surface geologic investigation projects.
- Geologic drilling projects.
- Remote sensing projects.
- Geophysical technology development.
- Low-grade (< 500 ppm U) study projects.

The Savannah River Laboratory (SRL), Oak Ridge Gaseous Diffusion Plant (ORGD), Los Alamos Scientific Laboratory (LASL), and Lawrence Livermore Laboratory (LLL) have accepted responsibility for the hydrogeochemical and stream sediment reconnaissance of the United States.

The objective of the initial portion of

* The information contained in this paper was developed during the course of work under Contract No. AT(07-2)-1 with the U.S. Energy Research and Development Administration.

the NURE Program is to accomplish for the first time a systematic determination of the distribution of uranium and associated trace elements in surface and underground waters and in stream sediments in the continental United States and Alaska as guides for uranium search. The physical and chemical parameters controlling the distribution of uranium in these waters will be investigated.

As a prelude to wide area sampling scheduled to begin in 1976, SRL personnel designed and conducted orientation studies in the Appalachian region of the eastern United States. The goals of these orientation studies are to develop models for the behaviour of uranium and associated elements in subsurface and fluvial environments and to develop techniques to maximize the useful information that can be generated in the wide area survey on a cost-effective basis. Our strategy has been to select known uranium occurrences for detailed sampling and analysis.

Field equipment has been designed to collect, wet-sieve, and package stream sediments. The field samplers are designed to collect sediment samples under a wide range of conditions without contamination or loss of fines. The sediment samplers are transported in a backpack together with a commercial water quality analyzer. A second backpack was modified to form a field laboratory table for filtration of water. The field filtration system consists of a two-litre aluminium reservoir lined with polytetrafluoroethylene. The reservoir may be pressurized up to 40 psig with fluorocarbon gas in small cans. In general, one litre of filtered water can be obtained in one to five minutes, and a second litre can be recovered

in an additional 10 to 30 minutes.

The stream water is analyzed directly with the portable water quality analyzer to determine pH, Eh, conductivity, dissolved oxygen, and temperature. Detailed colourimetric procedures were developed to measure phosphate, nitrate, ammonia, and sulphate concentrations with a field spectrophotometer. Total alkalinity is measured by a field titration. The entire sampling and field analysis procedure for the orientation studies requires only 35 minutes.

A neutron activation analysis facility was established at SRL. This facility has a sensitivity for uranium of 0.6 ppb in water and a U/Th discrimination ratio of about 600:1. With field ion-exchange concentration techniques, also developed at SRL, uranium can be analyzed at 0.006 ppb in water. Uranium and approximately 35 other elements can be determined in sediments.

Approximately 1,600 sites have been sampled, and 8,000 samples have been collected for analysis. Complete multi-element analyses of these samples will be available early in 1976.

One study area in the Georgia piedmont contains a uraninite-bearing pegmatite deposit. Monazite appears to be disseminated in the country rocks. Uranium analyses of sediments range from crustal abundance levels (1 to 5 ppm) up to nearly 900 ppm. A confirmation analysis on one high uranium sample indicates high concentrations of zirconium, thorium, and rare earths, suggesting that the sample represents a zircon or monazite concentrate. Preliminary data from this area suggest the following conclusions:

- (1) Multielement or mineralogical analyses are required before a given uranium analysis can be attributed to a source with commercial potential.
- (2) The -40 +100 mesh sediment size gives a clear definition of the uraninite source for over one-half mile downstream (second-order stream basin; two square miles in area).
- (3) Finer sediment sizes yield longer downstream dispersion trains, but define a given deposit poorly.
- (4) The Georgia study area is readily distinguished from non-uraniferous areas.

Additional data from the Georgia orientation study and results and conclusions from other study areas are presented.

TESTS OF GEOCHEMICAL TECHNIQUES FOR DETECTION OF URANIUM OCCURRENCES IN SEDIMENTARY ROCKS OF EASTERN PENNSYLVANIA

A.W. Rose, M.L. Keith, and N.H. Suhr
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About 45 occurrences of uranium in sandstone and shale are now known in the Catskill and Mauch Chunk Formations of northeastern and northern Pennsylvania, and a small amount of test mining has been done at one occurrence. One group of occurrences (type A) along the Lehigh River near Jim Thorpe contains mainly uranium and extends for distances up to 2,000 ft (610 m) approximately along the bedding of the sandstones. A second more widespread group of occurrences in north-central and northeastern Pennsylvania (type B) is primarily red-bed copper occurrences with minor uranium localized in carbonaceous deposits in the base of channel-filling sandstones. At least one deposit of type A has a roll-shape and is localized at an oxidizing-reducing interface.

In order to develop optimum geochemical techniques for detecting deposits in this region, samples of stream sediments, waters, and rocks from the vicinity of the deposits have been studied.

Stream waters have been analyzed by fluorimetry (detection limit about 0.3 ppb) and by delayed neutron activation (detection limit about 1 ppb). Ion exchange resins in conjunction with neutron activation have also been utilized to improve detection limits. Normal waters of the region contain less than 0.5 ppb U (mostly less than 0.2 ppb) and most have

low to very low total dissolved solids, as indicated by conductances of 8-25 micromhos for waters near type A occurrences and 50-100 near type B occurrences. Anomalous values of 2-15 ppb U were found in streams near some of the known occurrences in samples collected in fall and early winter of 1974-75, but during the spring and early summer, U cannot be detected in these stream waters at a level of 0.5 ppb. A very large seasonal effect therefore exists. The low conductivity did not change appreciably with time, indicating that the seasonal effect is probably due primarily to changes in the rate of oxidation rather than to dilution.

In stream sediments, a cold acetic acid-hydrogen peroxide leach has been used to selectively extract adsorbed and recently precipitated uranium and to reject uranium in accessory minerals and silicate lattices. Background values are 0.1 to 0.5 ppm by this method. Streams draining uranium occurrences contained 1.5 to 3 ppm extractable U in fall and early winter, decreasing to 0.6 to 1.0 ppm in early spring, and recovering to the original values in late spring. Seasonal effects in the stream sediments are smaller and of shorter duration than in water and appear to result from the lower U values in the waters, plus washing out of fines from the sediment. No correlations of U with organic matter or Fe-Mn oxides are recognized. Sediments near type A occurrences are also anomalous in Cu. Based on these results, stream sediments collected during periods of relatively low rainfall and runoff appear to be the most satisfactory medium for reconnaissance detection of U districts and occurrences in temperate climates of moderate rainfall and relief.

WELL WATER TRACE ELEMENT RECONNAISSANCE IN EASTERN MARITIME CANADA

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To test the feasibility of using well waters as a means of tracing mineral occurrences in the Carboniferous basin of the Maritimes, a survey of parts of the basin was carried out during the summer of 1975. This survey was conducted under the auspices of the newly established Federal-Provincial Uranium Reconnaissance Programme with provinces of Prince Edward Island, Nova Scotia, and New Brunswick providing background information, student manpower, and assistance in interpretation of results, and with Energy, Mines and Resources funds and facilities for field and analytical work. The Geology Department of Mount Allison University provided laboratory space and services for the "field" laboratory.

Approximately 2,000 wells were sampled from an area comprising all of P.E.I. and roughly 7,000 mi² (18,000 km²) of coastal mainland Nova Scotia and New Brunswick from Miramichi Bay to New Glasgow. An overall sampling density of one sample:5 mi² (13 km²) was aimed for, but in swampy and mountainous areas this density could not be achieved. In addition to the above

samples, approximately 120 well water samples and 100 stream water and 100 stream sediment samples were taken from the Triassic region of the northern Annapolis valley over an area of about 500 mi² (1,300 km²). Also in two areas within the sampled region the wells and streams were sampled in greater detail. One area of 260 mi² (665 km²) situated between Sackville and Moncton was sampled at a density of one sample:2.4 mi² (6.2 km²). In the other area of about 150 mi² (390 km²) near Pugwash, N.S., one sample:1.1 mi² (2.5 km²) was collected.

In the field laboratory an unacidified water sample was analyzed for U, Rn, O₂, F, Eh, pH, alkalinity, and conductivity. A second unacidified sample was sent to the Federal Department of the Environment Laboratory in Moncton for NO₃⁻, SO₄⁻, Cl, Ca, and K analysis, and an acidified sample was sent to the Geological Survey of Canada Laboratories for He, CH₄, H₂, Cu, Zn, Pb, Fe, and Mn analysis.

Well water U and Rn anomalies occur along the northern coast of Nova Scotia and New Brunswick between New Glasgow and Cape Tormentine. There are known Cu-U occurrences in this area, but the extent and frequency of these well water anomalies suggest other similar, not as yet known occurrences of U. Uranium and Rn values of up to 60 ppb and 5,700 pc/l, respectively, were encountered in this region, with the highest values in the vicinity of the following: Baie Verte; Pugwash, where a Cu-U occurrence near Chisolm Brook has been known for some time; near Fox Harbour; Tatamagouche; and River John. Element concentrations generally decrease from the coast inland.

Small U highs were encountered in a band between Sussex and Moncton (\leq 18 ppb U and

≤ 3,600 pc/l Rn). In the lowlands around Sackville, Amherst, and Truro, U levels of up to 6 ppb and Rn levels up to 5,000 pc/l were encountered.

On Prince Edward Island the U-Rn levels did not exceed 7 ppb and 2,700 pc/l, respectively, with the higher values occurring mainly in the northern third of the island. Regionally the U-Rn coincidence is clearly visible, although individual sites did not always show positive correlation.

By comparison 277 spring and well water samples in the U districts of Wyoming and South Dakota were found to contain up to 200 ppb U and a mean of 25 ppb U; Rn levels of up to 200,000 pc/l were encountered in Wyoming (as reported by other workers).

The abundance of U in well waters in the sedimentary rocks of the sampled area relative to surface waters suggests an active, oxidizing water regime which effectively leaches U from the rocks and/or the numerous weak U occurrences in the area. The relatively low Rn levels encountered suggest weak U mineralization, although the wide sample spacing could make this conclusion invalid because of the relatively short range of Rn compared to that of U.

The analytical results for the other trace and minor elements mentioned above will be available by the end of 1975. He, CH₄, and H₂ results are available for all the samples. No significant H₂ results have been obtained. However, a prominent CH₄ anomaly, with samples containing up to .60 standard cc of CH₄/l water was encountered between Sackville and Moncton along the east bank of the Peticodiac River and both banks of the Memramcook River. The proximity of the Stony Creek gas and oil field on the west

bank of the Peticodiac River suggests itself immediately as the source of this CH_4 . The second highest He value was also found in this area, but its significance is unknown at present.

Although the great majority of samples analyzed so far contain background or equilibrium amounts of He, isolated anomalous values of up to $n \times 1,000 \times 10^{-5}$ std cc/l H_2O , as well as two broader anomalous areas, have shown up so far. One rather weak anomalous area coincides roughly with the E-W trending faults and the Egmont Bay anticline on Prince Edward Island where the basement rocks come to within 4,000 ft (1,200 m) of the surface. The second area is just west of Cape Tormentine. It also appears to be centred on an anticline with basement rocks within 3,000 ft to 5,000 ft (900 m to 1,500 m) of the surface. The highest He value encountered in the survey comes from the southern edge of this anomaly on the southern shore of Baie Verte where the sediment cover has reached a thickness of 10,000 ft (3,000 m); however, it is still too early to draw conclusions on the value of He in exploration. The evidence so far suggests that it may be useful in elucidating geologic structure. There is as yet no evidence that the He is related to the U or the Rn in the well waters.

The well water reconnaissance orientation survey has shown that U and Rn are useful tracers in outlining U mineralization in the Carboniferous basin of the Maritimes. As results for other trace elements, such as Cu and Zn, become available and the U and Rn results are studied in more detail, other aspects of the hydrogeochemistry of the Carboniferous of the region will become evident.

BIOGEOCHEMICAL PROSPECTING FOR COPPER AND ZINC
USING *Juniperus virginiana* L.

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Red cedar (*Juniperus virginiana* L.) is a common, widely occurring species in eastern North America. It is highly adaptative to elevation, soil type, climate, and hydrologic conditions. This paper presents the results of a study conducted to assess the potential use of this species as a copper and zinc exploration sampling medium. A test site was selected over a small area at Zell, Missouri, known to have copper mineralization with grades of up to 25 per cent. Zinc mineralization in the area was suspected because of known occurrences nearby. The mineralization is composed of sulphides and secondary carbonates in the Ordovician dolomites of the Powell Formation. At the selected site there were few potential contamination problems due to very limited mining. Soil sampling in the area is impractical, due to a cobbly, dense chert residuum 1.5 to 3.0 metres thick.

Red cedar twigs were collected on intersecting traverses covering parts of a 5 km² area. Dried plant material was ashed, dissolved, and analyzed by atomic absorption methods. Copper, Zn, Fe, Co, Ni, Mn, and Pb were measured in the ash of 121 samples of red cedar. Copper, Pb, and Zn were measured in an additional 14 samples of red cedar and also in a number of oak bark samples from several

species of oak.

The analytical results were examined using statistical methods on an IBM 360 computer to determine elemental correlation coefficients, means, standard deviations, variance, R and Q mode factor analysis, and histograms. A cumulative frequency curve gave a linear plot with copper in red cedar ash on a log scale and cumulative frequency on an arithmetic scale. Following techniques used by others, a strong break in slope on the linear plot was taken as the cut-off for anomalous values. This value corresponded to positive one standard deviation.

Correlation coefficients indicated a strong relationship between pairs of the elements Cu, Zn, Fe, and Co. Correlations were also present between Fe and Pb, Pb and Zn, and Mn and Ni. Q mode factor analysis was unsuccessful for interpreting the influence of variables, such as soil type or bedrock lithology. Apparently the plant muted differences in soil chemistry or such differences were quite gradational.

Map plots were made of anomalous sample sites. Because results were erratic, an averaging technique was used to group anomalous sample sites. The resulting averaged Cu and Zn anomalies were coincident with areas of known mineralization. In addition, broad anomalies extend about 300 metres up slope and up dip from the known mineralization. Cobalt appeared to form an aureole around the Cu and Zn anomalies. An additional small but intense Cu-Co-Zn anomaly was located 600 metres up slope and up dip from known mineralization. Surface inspection located several cobbles of pyrite within this small area. From these data, a broad area of mineralization and a smaller, intense area

are inferred to be present up slope from the outcropping mineralization.

The iron anomalies appear to be of little value in prospecting in this area, probably due to the high content of iron oxides in the residual soils. Iron and Pb appear to be more closely related to the distribution of thick residual soils than to areas of mineralization. Some areas of high Zn content also appear to be related to thick residual soil.

A very curious relationship was demonstrated for red cedar and red oak (*Quercus rubra* L.) sampled at the same site. Zinc content in the bark of red oak was inversely proportional to that in red cedar twigs. A similar relationship of Zn content in red oak to availability has been recorded by another worker.

Sampling of red cedar for copper and zinc exploration purposes in eastern North America is a useable technique, but some restrictions are necessary due to limited contrast between anomalous and background areas. Sampling during even seasonal periods is recommended on the basis of standard biogeochemical techniques. A combination of elemental correlation coefficients and map plots of the data is recommended for interpretation of the results.

A GEOCHEMICAL SURVEY BASED ON STREAM SEDIMENTS IN WATAUGA COUNTY, NORTH CAROLINA, U.S.A.

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Stream sediment samples were collected from streams at 90 localities in the 320 square mile area of Watauga County, North Carolina. The minus 80-mesh fractions of the samples were analyzed for Cu, Pb, Zn, Ni, Ag, Mo, U, and Mn. The specific conductance of the water was also determined at each locality. In addition, coarse fraction samples were obtained at ten sample sites by two different techniques, panning and sieving, to evaluate the feasibility of rapidly collecting a heavy mineral concentrate through sieving.

The results suggest that the concentration levels of several of the elements are influenced by the associated bedrock lithologies. Samples taken from streams draining the Ashe formation have high Cu values; samples from the Blowing Rock gneiss have high Ag and Pb values. All of the known Cu, Pb, and Zn prospects in the county were outlined by this low-density survey. There are additional samples with high trace element concentrations not related to known mineral occurrences that may be significant. The higher copper values in the Ashe formation are of particular interest since there are several known copper deposits in the Ashe that have been worked in the past. The survey indicates that the Ashe formation, and therefore its equivalents to the north and south, may be favourable for further exploration for copper. High specific conductance readings, with the exception of those near populated areas, do not appear to be related to high trace element levels. However, there

appears to be a trend of high conductance values associated with a portion of one of the major transportation corridors that might be attributed to run-off from the roadbed.

A minus 60-mesh heavy mineral concentrate suitable for analysis was obtained for each site by both the panning and the sieving technique. With the exception of a few higher Cu and Zn values in the panned fraction, the techniques appear to provide concentrates that yield similar analytical results. Since it is faster to obtain heavy minerals by the sieving technique, and since similar results are obtained (with the possible exception of Cu), the panning technique may be replaced by the sieving technique in order to save time, and therefore, money.

CONCRETIONARY MANGANESE-IRON OXIDES IN STREAMS AND THEIR USEFULNESS AS A SAMPLE MEDIUM FOR GEOCHEMICAL PROSPECTING

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The scavenging of many trace elements by hydrous manganese-iron oxides in stream sediments complicates the interpretation of stream sediment data from many areas in Maine. But the scavenging ability also provides a potentially useful prospecting tool.

Other studies have concentrated on the solution of oxide coatings from alluvial material and the subsequent analysis of the solutions. This study concentrates on the analysis of discrete nodules and of concretionary coatings which can readily be scraped from cobbles and rocks at the sample site.

The analysis of 725 samples of nodules, coatings, and stream sediments from Maine confirmed the conclusions of others that the anomaly-to-background contrast for some elements is increased when the oxides are used as a sample medium. Also, the geochemical distribution of some of the rarer elements such as Cd and Tl can be studied more readily because they are scavenged by the oxides to such an extent that routine methods of analysis can readily detect background amounts in the oxides.

The relation of more than 30 elements to manganese and iron content of the 725 samples was studied by statistical methods. Correlation analyses resulted in the division of the elements into those scavenged by manganese-

iron oxides and those not scavenged. Included in those scavenged by the oxides are As, Cd, Co, Cu, Mo, Ni, Pb, Tl, and Zn.

The work of others suggests that the use of element:Mn ratios refines the interpretation of analyses of oxide coatings. In this study the absolute content of the scavenged elements in oxide samples was found to be just as definitive as ratios in either the oxides or routine stream sediments.

Other than those discrete concretions that are obviously transported, concretionary deposits in Maine are characteristically found wherever there is an interface between reduced and oxidized waters coupled with the presence of a suitable nucleus for deposition, usually inorganic material of some kind; concretionary deposits are seldom found with organic muck, for example. In looking for concretionary deposits, one first looks for areas of any size where waterlogging exists and then looks for inorganic material. The inorganic material may range in size from clay or silt containing nodular concretions to boulders with concretionary coatings. The heaviest coatings commonly occur on the underside or other protected areas of a rock, and so coatings may not be apparent until the rock is turned over.

A strong recommendation is made that oxides be collected routinely along with stream sediments in any sampling programme in Maine or in similar areas.

A STUDY OF THE APPLICATION OF REGRESSION
ANALYSIS FOR TRACE ELEMENT DATA FROM
STREAM SEDIMENTS IN NEW BRUNSWICK

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Positive correlation of Cu, Pb, Zn, and Mo with Fe and Mn in stream sediments has long been recognized in New Brunswick, but remains unresolved as to the significance in the interpretation of geochemical data. Sorption of trace elements by Fe and Mn oxides in the sediments is indicated, and the present study is an attempt to apply correlation and regression analysis to eliminate the trace element variations that may be due to Fe and Mn.

Data for Cu, Pb, Zn, Mo, Fe, and Mn from 1,200 samples of stream sediments were used in the regression analysis. The samples were collected in 1972 from an area underlain mainly by Ordovician and Silurian slate, argillite, and greywacke which have been intruded by mafic and granitic rocks. Known mineral occurrences of Cu, Pb, and Zn are present in the Ordovician rocks. Anomalous concentrations of trace elements, Fe, and Mn are found in many places, notably in Ordovician terrane.

The regression equation used is of the form

$$y = b_0 + b_1 X_1 + b_2 X_2 \dots b_n X_n$$

where y is the dependent variable; $b_0, b_1, b_2 \dots b_n$ the coefficients of variations; and X_1, X_2

... X_n the independent variables. The log-transformed data were used because they showed higher correlation coefficients than the arithmetic data. Zinc showed the highest correlation with Fe and Mn; Mo showed the least correlation.

The residual values were calculated from the differences between the raw data and the predicted values. High positive residual values may indicate sources of metals other than those tied up with Fe and Mn.

Comparison of the original maps and the residual maps disclosed no significant changes in the disposition of the original anomalies, suggesting that these anomalies are related to some unaccounted for sources other than Fe and Mn. It is difficult to explain, however, the fact that all the trace element anomalies are characterized by high concentrations of Fe and Mn. The coincidence of trace element anomalies and high Fe and Mn content can be interpreted as a manifestation of the presence of ferruginous and manganiferous strata that may contain higher than normal concentrations of trace elements, or the presence of high Fe and Mn concentrations accompanying the Cu-Pb-Zn mineralization. In any case, regression analysis may prove ineffective since it tends to invalidate all types of anomalies because of their high Fe and Mn content.

The results of the study in the present context are inconclusive, although they do not in any way preclude the use of regression techniques in stream surveys. Rather the study has demonstrated the complexity of the role of Fe and Mn in geochemical surveys and the inherent limitations of regression techniques in solving the problems.

ORGANIC STREAM SEDIMENTS IN REGIONAL GEO-CHEMICAL PROSPECTING, PRECAMBRIAN PAJALA DISTRICT, NORTH SWEDEN

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As part of a large integrated prospecting programme of the Pajala district in the north-east of Sweden, a regional geochemical survey was carried out during the 1973-1974 seasons. Subsequent to the initial fundamental studies, this is the first large-scale programme by the Geological Survey of Sweden where the technique of using organic stream sediments instead of inorganic stream sediments as a sampling medium has been fully applied.

The surveyed area totals about 8,000 km². Mires and low productive forestland are predominant in this flat lying area (at the Arctic Circle) of the Baltic Shield. More than 10,000 samples of organic stream sediments were collected along all minor drainage channels at intervals of about 300 m. Metal contents for 25 elements were determined by X-ray and optic spectrographs on the ashed samples. The influence of the organic and the Fe and Mn contents on the total metal content of each sample were corrected for by stepwise regression analysis. Geochemical maps were presented on the same scale as those of regional geology and aeromagnetism.

Regionally the anomalous patterns indicate a general association of base metals with areas of predominantly greenstone rock-types relative to surrounding granite and gneisses. Uranium and Mo enhancements are all located in areas underlain by formations of the Lina granite type. However, only one of the many

gabbro intrusives within the area is distinguished by relatively high Cr, Ni, and Co contents.

In detail, all of the previously known base metal occurrences have been outlined. However, as a direct result of the present survey, increased prospecting attention will be focused on several new areas where detailed follow-up studies are now planned. Of particular interest are certain graphite-bearing sections of the greenstones which display strong correlations to Cu and Ni enhancements in the organic stream sediments.

USE OF MERCURY IN GEOCHEMICAL EXPLORATION FOR MISSISSIPPI VALLEY TYPE OF DEPOSITS IN TENNESSEE

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The carbonate basin west of the Southern Appalachians has been the setting for intense exploration activities for zinc by major companies after the discovery of the Elmwood deposit. The new zinc district is of the typical Mississippi Valley type: limestones and brecciated dolomites as host rock for sphalerite mineralization. An exploration effort was undertaken by the Metals Division of International Oil and Gas, Inc. in 1973, and continued over the next two years in joint venture with International Mogul Mines, Ltd., Toronto, and later with Bear Creek Mining Company, a subsidiary of Kennecott Copper Corporation.

From the onset of the programme it was recognized that any additional ore deposits would present unusual exploration problems due to their deep-lying, disseminated nature. The ore-carrying Mascot formation lies an average of 1,500 ft (457 m) below surface level. Geochemical prospecting was chosen as the prime reconnaissance method towards identifying drilling targets as well as towards gaining knowledge of the basement structure, if possible, at basin depths reaching 5,000 ft (1,524 m). It was considered possible that significant basement structures in form of major relief as well as faulting might have had sufficient effect on the overlying carbonates to increase their permeability, provide for vertical dispersion passages, and influence the trace element distribution in the typically thin soil cover in carbonate terrains.

A 3,000-sample stream sediment survey was first conducted along a 5 mi (8 km) wide strip over a distance of 75 mi (120 km). This survey was run during the late fall months of 1973 because the streams in Tennessee are generally low through the fall and well into the early winter months. During this time of year the water in the streams is predominantly deep ground water which, after percolating through potentially mineralized sections of the Mascot formations, might bring with it a higher zinc concentration. Although a number of anomalous locations were identified, none of these could be qualified as drilling targets during subsequent detailed soil surveys. Stream sediment sampling is therefore considered a less efficient method in this particular situation.

Reconnaissance soil sampling was conducted in a number of areas which were selected primarily for reasons of known mineralization from oil well cuttings, major structural features, geophysical indications such as magnetic highs, and for other reasons. Orientation surveys were laid out over the known deposit at Elmwood, Tennessee. Soil samples were taken from the upper-B horizon, which generally lies from 12-14 inches (30-36 cm) below the surface. Experienced samplers were used, and care was taken in protecting the soil samples from extreme heat. Soil was stored in kraft paper bags for about five days on the floor in a well-ventilated room and subsequently sieved and analyzed by XRAL in Toronto. Standard atomic absorption techniques were used to determine Zn concentration, while a Hg spectograph unit was used to determine Hg to a detection level of 10 ppb.

Zinc anomalies were found in several locations, but they frequently were found to relate to "veins" or "caps" of the typical uneconomic

leakage deposits of Middle Tennessee. Other times the increase in soil Zn content could be directly related to a down-slope location from outcrops or subcrops of Chattanooga shale, which acts as a scavenger and subsequent releasing agent during weathering.

Mercury, on the other hand, showed an unusual distribution which may be significant in exploration in this terrain. From several thousand samples a background value for Hg has been determined. It averages about 25 ppb, with very slight regional variations. There is thus an 8-10 ppb increase in the background value of Hg in the soil from the northern part of the exploration area to the southern part, a distance of about 75 mi (120 km). The individual samples show a remarkably low standard deviation. As with Zn, the Chattanooga shale can occasionally create local Hg anomalies; therefore, careful mapping was made in areas where the shale may be present. In general, the shale is absent on the Nashville Dome where this Devonian/Mississippian black marine shale has been eroded away to expose the lower lying Middle Ordovician formations.

From orientation surveys run at the Elmwood deposit and several other areas of positively proven mineralization, it was noted that anomalous halos of Hg were detectable in the soil. The average Hg value in the soil is from 2.2 to 2.5 times higher than the regional background and with low standard deviation. Thus, while the regional average is about 25 ppb, the soil above the Elmwood deposit is about 60 ppb.

Two possible explanations are forwarded for this enrichment. For one, the middle Tennessee type of sphalerite contains Hg in the sphalerite lattice; therefore, Hg could be expected to be released during diagenesis of

deposits at depths. Upon liberation, the Hg in free or complexed form, as atomic Hg or as Hg ions may have dispersed through the carbonate rock and become sorbed in the B-horizon of the soil. Alternatively, the enrichment of soil Hg may be due to the location of the Elmwood deposit, as well as a number of the other anomalies, on crustal weaknesses or possible faults which may be supplying Hg to the carbonate basin.

To test these hypotheses a number of drill cores were tested in both mineralized and non-mineralized areas. Both Zn and Hg were determined in the cores to a depth of several thousand feet (hundreds of metres). The Hg content in the carbonate rock averages about 15 ppb, which corresponds well with the internationally recognized Clarke for carbonate rocks. Standard deviation was reasonably low. Interestingly, no increase was found in Hg content in the rock above mineralized zones of core, although the mineralized zone itself, with high percentages of sphalerite, naturally showed an increase to several thousand ppb. Anomalous Hg levels were found in one instance below a mineralized zone in otherwise barren dolomite rock, but the sample population is too limited to select the one over the other hypothesis.

It is concluded, however, that the soil over the Elmwood deposit, as well as over a couple of other known deposits in middle Tennessee is enriched in Hg by a factor of between 2-2.5. Soil sampling has therefore been used on a reconnaissance basis to identify a number of areas of similar anomalously high Hg content, several of which show distinct halo formation. These areas are now the subject of additional exploration, including deep water well geochemical analyses and conventional core drilling of detailed targets.

TECHNIQUES OF GEOCHEMICAL EXPLORATION IN THE SOUTHEAST PIEDMONT

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The Piedmont of the southeastern United States is a region that is peculiarly well suited to applications of geochemical prospecting techniques, although skill and care are required in interpretation of results. The Piedmont is a region of low to moderate relief and sluggish drainage covered by a thick blanket of residual soil that effectively obscures conventional geologic observations. Bedrock consists of igneous and metamorphic sequences that are derived from late Precambrian-early Paleozoic eugeosynclinal volcanics and sediments. Contained ore deposits include a variety of types typical of such an environment, and while past production has not been large, the geologic potential of the region is promising for discovery of hidden deposits. Geochemical prospecting techniques have proven to be valuable in this environment.

The techniques described are the result of about 40 man-years of exploration in the Piedmont, spanning about 18 years of elapsed time. Techniques were initially developed by trial and error and were then considerably improved by study of the physiographic and geochemical conditions prevalent in the region. Stream sediment techniques have not proven to be universally effective because of the well leached character of the residual soils, shallow water table, and ever present problems of contamination due to population density. Geochemical sampling by analysis for total metal of residual soils, when properly interpreted, has

proven to be an effective and valuable prospecting aid. Soil prospecting techniques have been used successfully for evaluation of a variety of geologic types of exploration targets.

Soil sampling has been used in evaluating base metal-bearing massive sulphide targets. Several prospects are known in the Piedmont of massive sulphide deposits in eugeosynclinal volcano-sedimentary strata that are similar to other Appalachian deposits. Geochemical sampling has effectively delineated known target areas at such prospects, although no new deposits have been found. Soil sampling has also been effective in delineating and evaluating disseminated copper-molybdenum or "porphyry" targets. Several such occurrences in mid-Paleozoic quartz monzonite intrusives have been discovered by geochemical prospecting, although none have proved to be commercial. Gold deposits have also been explored and evaluated by soil sampling. Problems of behaviour of gold in the residual soils have not been entirely solved, but direct analysis of such soils for gold appears to effectively delineate auriferous areas. Disseminated or "no-see-um" gold deposits, if they exist in the Piedmont, should be readily detected by soil analyses. Soil sampling has also been proved effective in evaluating nickeliferous areas for both sulphide and laterite ore potential in areas of ultramafic rocks.

