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The United States Geological Survey

INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM

Program and Abstracts



April 17-20, 1968
Colorado School of Mines
Golden, Colorado 80401

**INTERNATIONAL
GEOCHEMICAL
EXPLORATION
SYMPOSIUM**

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Hosts: Colorado School of Mines
U. S. Geological Survey

Symposium Committee:

Harold Bloom: Colorado School of Mines
Frank C. Canney: U. S. Geological Survey
John A. Hansuld: American Metal Climax, Inc.
(Mrs.) Rachel Coleman: Symposium Secretary

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GENERAL INFORMATION

1. All technical sessions will be held in the Gymnasium building, Colorado School of Mines, located at Illinois and 14th Streets, Golden.
2. The proceedings of this symposium will be published as an issue of the Quarterly of the Colorado School of Mines not later than January 1969. The registration fee includes a bound copy of the proceedings.
3. Free bus service will be provided to the campus in the morning and return after the last session from the following motels:
 - Holiday Inn West
 - Mosko Holiday Manor
 - Ramada Inn MotelCheck motel desks for schedules.
4. Due to the limited restaurant facilities in Golden special arrangements have been made to serve a lunch on campus at the College Union Building from 12:45 to 1:30.
5. Bar coupons for the no-host cocktail party will be on sale at the registration desk.
6. A courtesy phone—(303) 279-3930—for incoming calls will be located at the registration desk. A message board will also be located in the lobby.
7. Coffee courtesy of American Metal Climax, Inc.

WEDNESDAY AFTERNOON, 12:30-4:30

Registration 12:30
Laboratory tours of U.S.G.S. Geochemical Laboratories 1:30
Tour leaders: F. N. Ward, D. J. Grimes, and G. H. Van Sickle
U. S. Geological Survey

Free bus service will be provided to the following motels after the tours:

Holiday Inn West
Mosko Holiday Manor
Ramada Inn Motel

THURSDAY MORNING

Registration 8:30-10:00
Opening Session 10:00
Chairman: Harold Bloom, Colorado School of Mines
Opening Remarks: Harold Bloom
Welcoming Talks: O. E. Childs, *President of the Colorado School of Mines*
W. T. Pecora, *Director of the U. S. Geological Survey*
U.S.G.S. Program in Geochemical Exploration—R. L. Erickson, *U. S. Geological Survey*

THURSDAY AFTERNOON, 2:00-5:30

Cochairmen: F. C. Canney, U. S. Geol. Survey, Denver
J. S. Webb, Imperial College, London

(A five-minute discussion may follow each paper)

1. W. T. Meyer: *Uranium in lake water from the Kaipokak region, Labrador* 2:00
2. J. A. Macdonald: *An orientation study of the uranium distribution in lake waters, Beaverlodge District, Saskatchewan* 2:20
3. S. S. M. Chan: *Suggested guides for exploration from geochemical investigation of ore veins at the Galena Mine deposits, Shoshone County, Idaho* 2:40
4. G. M. Crosby: *A preliminary examination of trace mercury in rocks, Coeur d'Alene District, Wallace, Idaho* 3:00
Coffee Break
5. R. L. Akright*, A. S. Radtke, and D. J. Grimes: *Comments on minor elements in gold ores and associated rocks as exploration guides, Carlin gold mine, Eureka County, Nevada* 3:50
6. B. E. Kilpatrick: *Nickel-chromium-cobalt enrichment in tropical soils over serpentinites, Wanamu - Blue Mountains area, Northwest District, Guyana* 4:10

*Speaker

7. H. E. Hawkes: *A geochemical case history from New Zealand* 4:30
8. J. B. Borucki*, and C. Ratsimbazafy: *The geochemical mapping of the Horombe Plateau (Southern Madagascar)* 4:50
9. L. C. Huff: *Accumulation of ore metals by mesquite plants* 5:10

FRIDAY MORNING, 9:00-12:30

Cochairmen: R. S. Young, Univ. of Virginia, Charlottesville
 R. G. Garrett, Geol. Survey of Canada, Ottawa
 (A five-minute discussion may follow each paper)

1. P. G. Gregory† and J. S. Tooms: *Geochemical prospecting for kimberlites* 9:00
2. A. P. Ruotsala*, S. C. Nordeng, and R. J. Weege: *Trace elements in accessory calcite — a potential exploration tool in the Michigan Copper District* 9:20
3. W. Dyck* and A. Y. Smith: *The use of radon-222 in surface waters in geochemical prospecting for uranium* 9:35
4. R. E. Van Tassell: *Exploration by overburden drilling at United Keno Hill Mines Limited* 9:50
5. N. H. Brundin: *Heavy mineral prospecting in Sweden* 10:10
 Coffee Break *1/2 hr*
6. A. S. Ritchie: *Recent advances in the chromatographic analysis of geologic materials* 11:00
7. A. H. Debnam: *The modern geochemical laboratory* 11:25
8. C. N. MacIver, D. McDonald, D. Sampey*, and J. V. Sullivan: *Multi-element analysis in geochemistry: a six channel atomic absorption spectrophotometer for simultaneous determinations* 11:45
9. F. N. Ward* and H. M. Nakagawa: *Atomic absorption techniques in geochemical exploration — problem or progress* 12:05

FRIDAY AFTERNOON, 2:00-5:30

Panel Discussions

Each panel member will present a short prepared statement. Open discussion will be deferred until all members have delivered their remarks at which time questions or comments will be solicited from the floor.

*Speaker

†Paper will be presented by P. M. D. Bradshaw

1. Education of the Exploration Geochemist 2:00-3:30
 Moderator: Harold Bloom, *Colorado School of Mines*
 Panelists: R. W. Boyle, *Geological Survey of Canada, Ottawa*
 T. S. Lovering, *Univ. of Utah, Salt Lake City*
 R. A. Barker, *Amax Exploration Inc., Vancouver*
 J. A. Coope, *Newmont Mining Company, Vancouver*
 H. E. Hawkes, *Consultant, Washington, D. C.*
 A. Beus, *Tech. Advisor, United Nations, N. Y.*
 J. S. Webb, *Imperial College, London*
 W. M. Tupper, *Carleton Univ., Ottawa*

Coffee Break

2. What is a Geochemical Analysis? 4:00-5:30
 Moderator: J. A. Hansuld, *American Metal Climax, Toronto*
 Panelists: G. W. Mannard, *Texas-Gulf Sulfur Co., Toronto*
 H. W. Lakin, *U. S. Geological Survey, Denver*
 F. C. Canney, *U. S. Geological Survey, Denver*
 M. Salmon, *Fluo-X-Spec. Company, Denver*
 G. R. Weber, *McGill University, Montreal*
 D. B. Roberts, *Kennecott Copper Corp., Salt Lake City*
 W. F. Bondar, *Bondar-Clegg & Company, Ottawa*

SATURDAY MORNING, 9:00-12:30

Cochairmen: W. R. Griffiths: U. S. Geol. Survey, Denver
 C. F. Gleason: SoQuem, Quebec City

(A five-minute discussion may follow each paper)

1. A. A. Beus: *The geochemical criteria for assessment of the mineral potential of the igneous rock series during reconnaissance exploration* 9:00
2. F. Cachau-Herreillat: *Geochemical prospecting for lead zinc stratiform deposits; non-linear correlation between the content of these metals in soils and their use in separating stratiform and hydrothermal deposits* 9:20
3. O. H. Rostad: *Use of geochemistry at the Bald Butte molybdenite prospect, Lewis and Clark Co., Montana* 9:40
4. D. N. Stevens*, D. N. Bloom and R. E. Bisque: *Evaluation of mercury vapor anomalies at Colorado Central Mines, Clear Creek County, Colorado* 10:10

Coffee Break

5. A. T. Miesch: *Experimental design in geochemical exploration* 11:05
6. R. G. Garrett* and I. Nichol: *Factor analysis as an aid in the interpretation of regional geochemical stream sediment data* 11:25

*Speaker

7. E. C. Dahlberg: *Use of a model for relating geochemical prospecting data to geologic attributes of a region; South Mountain, Pennsylvania* 11:45
8. R. F. Horsnail*, I. Nichol, and J. S. Webb: *Influence of variations in the surface environment on metal distribution in drainage sediments* 12:05

SATURDAY AFTERNOON, 2:00-4:00

Cochairmen: T. S. Lovering, Univ. of Utah, Salt Lake City
 J. A. Hansuld, American Metal Climax, Toronto

(A five-minute discussion may follow each paper)

1. N. Varlamoff: *Bearing of tin minerals and ores in the weathering zone and the possibility of geochemical exploration for tin* 2:00
 2. J. J. Barakso: *Soil and plant relationships to bedrock at some mineralized areas in British Columbia* 2:25
 3. H. Ling Ong* and V. E. Swanson: *Natural organic acids in the mobilization of gold* 2:50
 4. M. Koksoy and P. M. D. Bradshaw*: *Dispersion of mercury from cinnabar and stibnite deposits, West Turkey* 3:10
 5. A. K. Chakrabarti: *Geochemical exploration of the ore bearing horizons at Zawar Mines, India and its possible bearing on metallogenesis* 3:30
- Concluding remarks — J. A. Hansuld

*Speaker

ABSTRACTS

COMMENTS ON MINOR ELEMENTS IN GOLD ORES AND ASSOCIATED ROCKS AS EXPLORATION GUIDES, CARLIN GOLD MINE, EUREKA COUNTY, NEVADA

AKRIGHT, ROBERT L., *Newmont Exploration Ltd., Box 672, Elko, Nevada*; RADTKE, ARTHUR S., *U. S. Geol. Survey, 345 Middlefield Rd., Menlo Park, Calif.*; and GRIMES, DAVID J., *U. S. Geol. Survey, Denver Federal Center, Denver, Colo.*

Hydrothermally altered, mineralized gold-bearing zones near the top of the Roberts Mountain formation show significant concentrations of other elements in addition to gold. Total abundance range and median values for 18 elements are compared between normal unaltered barren rocks and altered mineralized gold-bearing ores. Elements studied in order of decreasing average content in gold ores are barium (900 ppm), arsenic (600 ppm), manganese (170 ppm), antimony (150 ppm), strontium (100 ppm), zinc (100 ppm?), boron (70 ppm), nickel (50 ppm), copper (38 ppm), mercury (31 ppm), lanthanum (30 ppm), lead (30 ppm), tungsten (18 ppm?), gallium (10 ppm), scandium (10 ppm), cobalt (9 ppm), molybdenum (6 ppm), and silver (0.3 ppm?).

All elements except strontium show higher average or median values in mineralized areas than in fresh unmineralized Roberts Mountain formation. With zinc and tungsten relatively poor sensitivity by normal spectographic techniques combined with apparent low abundances in fresh rock preclude definite statement as to degree of concentration with mineralization.

In general the total abundance range for any given element is much greater in mineralized areas compared to unmineralized fresh rock. Erratic element distribution is apparently characteristic for disseminated type gold deposits and itself may be a clue to mineralization in areas of the Roberts Mountain formation showing characteristic argillic alteration.

SOIL AND PLANT RELATIONSHIPS TO BEDROCK AT SOME MINERALIZED AREAS IN BRITISH COLUMBIA

BARAKSO, JOHN J., *Chief Chemist, Kennco Explorations (Western) Ltd., 1405 Pemberton Ave., North Vancouver, B. C., Canada*

The distribution of trace elements in bedrock, soils and plants, was studied in twelve areas of British Columbia where mineralization was known to occur below different kinds and depths of overburden. Samples were taken from the horizons of two soil profiles and the bedrock at each location, and second and third year twigs

of the principal vegetation found within a radius of fifty feet of each profile were also collected. The bedrock, soil and plant samples were analysed. The soil samples were used for the determination of pH, organic matter content, percentage of material less than 80 mesh, cation exchange capacity, exchangeable heavy metals, and content of Cu, Mo, Zn, Pb, As, Co, Ni, Fe and Hg. The same elements were determined in the bedrock and vegetation samples.

The results were examined graphically for relationship between elemental contents of the bedrock, soil horizons and vegetation. The data were then statistically analysed by computer.

- (a) soil horizons and plant relationship with bedrock
- (b) inter-elemental relationship of individual horizons of soils and of plants, as well as all horizon relationships
- (c) multiple correlation study of cation exchange capacity, percentage of organic material, and < 80 mesh content of individual and all soil horizons.

These studies showed that, although most of the soil horizons were developed from transported materials, (glacial alluvial, etc.), there was a highly significant correlation with B and C horizons and bedrock that confirmed the value of soil sampling in prospecting, since horizon development includes the upwards migration of the elements from bedrock.

The secondary dispersion of the halo elements (Mo, Zn, Pb, As, Co, Ni, Hg) proved useful as pathfinders where major economic elements may have been masked during the upward migration process. Secondary dispersion may also be, in some degree, helpful in identifying the origin of soils and plants.

A great divergence in the affinity of various plants for different elements, and of the same species at different locations, was noted. It was also observed that plants have a closer relationship to the soils than to the bedrock itself, but even so, indicate mineralization.

The important relationships between elemental distributions in soil horizons and in plants with bedrock, indicated a logarithmic relationship.

The multiple correlation study indicated that some of the major factors of influence in the level of element content in soils developed on transported material-covered areas, are the size of the soil particles and frequently the pH of the soil.

In general, the study indicated that the distribution of trace elements is highly complex and that bedrock, soils, and plants, should all be combined into one study; since the study of one of these alone would be incomplete without the others.

THE GEOCHEMICAL CRITERIA FOR ASSESSMENT OF THE MINERAL POTENTIAL OF THE IGNEOUS ROCKS SERIES DURING RECONNAISSANCE EXPLORATION

BEUS, ALEXEI A., *Moscow, U.S.S.R. and United Nations, Box 20, Grand Central Sta., New York, N. Y. 10017.*

1. The geochemical criteria which permit us to judge the possible mineral potential of igneous rock series are essential during reconnaissance exploration. The peculiarities of so-called geochemical specialization of the igneous rock series can successfully be used as the criteria for such purpose.

2. The geochemical specialization of each rock series can be mathematically described by statistical parameters of distribution of some indicatory elements in the rocks. From this point of view it is reasonable to distinguish global, regional and local parameters in regard to the distribution of chemical elements in the rocks.

3. Depending on the statistical distribution law of element contents in rocks the main parameters of its distribution include the following values: arithmetical mean, dispersion and standard deviation of contents (in case of normal distribution), or the same, but for logarithms of the contents (in case of lognormal distribution). The probability of appearance of some indicatory element contents in the rock samples in the promising and unpromising rock series calculated on the basis of the statistical parameters of these elements distribution, can serve as objective criteria during exploration.

4. On the basis of our work in the USSR such criteria were established for tin, tungsten, tantalum and other rare metal deposits related to granites. On the basis of indicatory elements distribution, it is possible also to distinguish copper and nickel-bearing basic and ultrabasic rocks and basic volcanics which are promising for copper-pyrite deposits.

5. For example, tin contents in granites 10 ppm and more and 5 ppm and less, were selected as criteria in order to distinguish the promising granite series during tin exploration. The probability of appearance of these indicatory values in the sample populations from the promising granites with whom tin deposits are connected are 0.82 (and more) and 0.03 (and less) respectively. In the sample populations from bare granites this probability is 0.02 (and less) and 0.90 (and more) respectively.

6. The above mentioned geochemical criteria enable us to assess the mineral potential of the igneous rock series during geochemical reconnaissance on the basis of a limited number of samples (10-30 samples) and to select the area for further detailed prospecting for hidden ore deposits.

THE GEOCHEMICAL MAPPING OF THE HOROMBE PLATEAU (SOUTHERN MADAGASCAR)

BORUCKI, JERZY, *United Nations Development Program, Tananarive, Madagascar*; and RATSIMBAZAFY, CYRIL, *Geological Survey of Madagascar, Tananarive, Madagascar*

Geochemical mapping at the 1/200,000 scale was performed on the surface of some 3500 sq. km of the Horombe Plateau in the semi-arid zone of Southern Madagascar. The rocks' complex of Horombe, composed of plagioclase gneiss, cordierite gneiss, quartzites and marbles, is attributed to the Precambrian Androyen System. The lateritic soils with ferruginous crust cover practically all the surface of the Plateau. The streams' sediments — the object of the sampling — are composed of the redeposited soils with organic matter or arenaceous material.

Any important deposits or mineralization have been reported.

The precise previous planning of the sampling permitted to reduce the number of points to one per 4 sq. km. The fine fraction (<0.2 mm) of the stream sediments samples was analyzed by the semi-quantitative spectographic method. Statistical method of interpretation have been applied.

The presence of a positive correlation was established between yttrium and thorium as well as between copper and nickel, but no correlation was found between cobalt and copper or nickel.

The following means were obtained (in parts per million) Cu : 226 ; Ni : 76 ; Co : 39 ; Sn : 54 ; Th : 340 ; Y : 13, as well as the following coefficients of variance (in per cent) : Cu : 4.7 ; Ni : 11 ; Co : 13.6 ; Sn : 47.2 ; Th : 16 and Y : 66.8.

A long belt of rather low tin anomalies (to 40 ppm) as well as a high thorium-uranium anomaly (Th to one per cent and U to 80 per million) and a strong yttrium anomaly (to 2000 per million) have been revealed.

HEAVY MINERAL PROSPECTING IN SWEDEN

BRUNDIN, NILS H., *Grängesberg Mining Co., Sweden*

Organized heavy mineral prospecting has in the past never been carried out in Sweden. Therefore, adequate knowledge is lacking about Sweden's potential resources of certain ores, which are difficult to locate by geophysical methods, such as ores containing wolframite, scheelite, cassiterite, pyrochlore, chromite etc.

As was reported at the Symposium for Geochemical Prospecting in Ottawa, 1966, tests carried out at some known ore deposits in Sweden have shown possibilities to trace ores of different types by study of the heavy minerals in glacial soil.

This work has been continued, still sponsored by The Swedish Ore Foundation for General Scientific Research and Industrial Development and The Grängesberg Company.

It has been found economic to replace primary concentration of heavy minerals in the field, using water as a concentrating medium (panning, use of sluice boxes etc.) by treatment of small, easily transportable samples (1-5 hg) in a permanent or mobile laboratory.

It was found suitable to use low cost tetrabromoethane (TBE, sp. gravity 2.95) for the primary separation of the samples into a light and a heavy fraction. The heavy fraction was analyzed by spectrographic methods.

Different flow sheets for the treatment are discussed as well as cost factors.

The most suitable process has been applied on stream sediments collected during last summer over an area of 700 sq. km in Central Sweden. Also moraine samples have been collected in some interesting areas and treated in the same way.

The results will be discussed in comparison with conventional geochemical prospecting, carried in the same regions.

GEOCHEMICAL PROSPECTING FOR LEAD ZINC STRATIFORM DEPOSITS: NON-LINEAR CORRELATION BETWEEN THE CONTENT OF THESE METALS IN SOILS AND THEIR USE IN SEPARATING STRATIFORM AND HYDROTHERMAL DEPOSITS

CACHAU-HERREILLAT, F., *Bureau de Recherches Géologiques et Minières, B. P. 818 Orleans 45, France.*

The present paper deals with the drastic problem of the difference between syngenetic and epigenetic deposits. In the area of Gatuzières (Lozère-FRANCE), the two ore types are supposed to coexist: syngenetic deposits of sphalerite in dolomitic strata of liasic age, and quartz sulphide veins with galena, sphalerite, and copper sulphides.

A campaign of geochemical prospecting was undertaken with the purpose of selecting major areas of interest. The results of soil sampling show two types of anomalous areas:

—A first type, correlated with tectonic features, (fault, quartz vein, anticline) is mainly a lead anomaly.

—A second type, correlated with stratigraphic features (strata) is a zinc anomaly with minor lead.

The zone of interference between the two areas is particularly rich in zinc and lead.

Pb-Zn correlation diagrams (logarithmic scale) were built up. Two types appear:

—In the first case of "tectonic" anomaly the correlation coefficient is low, and Pb seems to be just superimposed to a Pb-Zn background.

—In the second case of "stratiform" anomaly the correlation

coefficient is higher, and the ratio: $\frac{\log \text{Zn}}{\log \text{Pb}}$ is about 2. This suggests a statistical correlation between lead and zinc in the stratiform deposit: $\frac{\text{Pb}^2}{\text{Zn}}$ = K. The regional variations of the K ratio were studied and plotted on the map.

Previous work on "Kupferschiefer" deposits in Permian red beds had shown a syngenetic origin and a similar type of correlation: $\frac{\text{Zn}^2}{\text{Cu}}$ = m. Such a type of correlation appears to be characteristic of syngenetic deposits.

GEOCHEMICAL EXPLORATION OF THE ORE BEARING HORIZONS AT ZAWAR MINES, INDIA AND ITS POSSIBLE BEARING ON METALLOGENESIS

CHAKRABARTI, A. K., *Dept. of Mineral Resources, Precambrian Geology Div., Gov't Admin. Bldg., Regina, Saskatchewan, Canada.*

Geochemical exploration was carried out on the galena-blende - pyrite bearing horizons at Zawar Mines, Rajasthan, India. The ore is essentially confined in the Precambrian dolomites and the deposit is a typical two-dimensional, stratiform one in nature.

Geochemical analysis of trace elements near the ore body suggests a progressive enrichment in chalcophile elements and a corresponding impoverishment in lithophile elements as the sulphide mineralization increases.

Analytical experiments were carried out using 15% HNO₃ digestion and potassium bisulphate fusion techniques on galena and sphalerite, in order to find out the weakest acid which would extract all the Pb and Zn from these minerals. A comparative study of the results obtained from these techniques were made with the results obtained through the spectrographic analysis.

Along the strike length of the deposit high Sr- and Rb-contents accompany Pb-high and Zn-poor zones. The dispersion patterns of trace elements indicate a wall-rock aureole of approximately 20 ft. in dolomite. Since the petrographic work reveals complete lack of wall-rock alteration, two possibilities are considered as alternatives to primary wall-rock alteration: (1) primary dispersion in sediments (2) secondary dispersion through pore fluids during metamorphism.

Trace element studies in sulphides favour an epigenetic hydrothermal origin of the deposit.

To compromise between pure epigenetic and syngenetic hypotheses, a theory of submarine-hydrothermal (exhalative-sedimentary) origin for galena-blende and pyrite has been postulated.

SUGGESTED GUIDES FOR EXPLORATION FROM GEO-CHEMICAL INVESTIGATION OF ORE VEINS AT THE GALENA MINE DEPOSITS, SHOSHONE COUNTY, IDAHO

CHAN, SAMUEL S. M., *College of Mines, University of Idaho, Moscow, Idaho 83843*

This paper presents the preliminary phase of a continuous long-term geochemical exploration project which is conducted by the Northwestern Mining Department of the American Smelting and Refining Company in the Galena Mine of northern Idaho.

The Galena Mine is located in Lake Gulch, near Wallace, Idaho, and is one of the major silver-producing mines in the United States. The deposits are recognized as vein type, hydrothermal replacements and fracture fillings. The main ore from this mine is silver-bearing tetrahedrite. Siderite and quartz are the gangue of the veins. Galena, chalcopyrite, pyrite, and arsenopyrite also occur in the veins. Dissemination of siderite and the above mentioned sulfides in wall rocks near the main veins is one of the main features of the deposits. There are also various types of hydrothermal alteration near the zones of mineralization.

The geochemical exploration program consists of both underground rock and surface soil analysis. The main purpose is to find out the background contents and the general patterns of distribution of the metallic elements in their primary and secondary dispersion states, and the probable anomalous zones around the ore veins. This information may then be used to guide exploration. The present paper deals with the underground portion of the program, especially the areas in and near ore veins.

Some data have been accumulated concerning ratios among the elements: Ag, Cu, Fe, Pb, Zn, Sb, and As in some ore veins. Certain correlations between major and minor elements suggest the possibilities of indication of mineralization.

Mercury occurs in veins as well as in wall rocks. Its content increases steadily as the mineralized veins are approached, in many instances. This shows the existence of "indicative envelopes" around some of the Galena Mine deposits and suggests the usefulness of this technique in ore finding.

A PRELIMINARY EXAMINATION OF TRACE MERCURY IN ROCKS, COEUR D'ALENE DISTRICT, WALLACE, IDA.

CROSBY, GARTH M., *Chief Geol., Day Mines, Inc., Box 1010, Wallace, Idaho*

Rocks have been sampled in several underground openings in the east-half of the district to study the relationships of trace-mercury distribution to Precambrian rocks, major ore occurrences and mineral belts. Traverses were determined chiefly by the locations of major adit crosscuts, and sample intervals vary with the traverse from 150 feet to 500 feet. Mercury content was determined

in the laboratory of Cordero Mining Company, Winnemucca, Nev.

With the exception of Striped Peak Formation which was not sampled, all Precambrian formations contain anomalous mercury. St. Regis and Revett formations demonstrate the sharpest contrast between in-belt and out-of-belt anomalies. Rocks adjacent to one or both walls of all major veins contain anomalous mercury ranging from less than 100 ppb to several hundred or a few thousand ppb. Profiles of vein anomalies rise abruptly above broad plateaus of less-anomalous mercury which in some cases match surprisingly well with mineral belt limits adopted from an interpretation of geologic structure. Within mineral belts anomalies range from 600 ppb to 3000 ppb, while outside mineral belts anomalies highs are less than 500 ppb. A large zinc orebody displays a prominent anomaly in the shape of a closely-hung drape over and around the upper half of the mine, generally broadening and weakening in depth.

USE OF A MODEL FOR RELATING GEOCHEMICAL PROSPECTING DATA TO GEOLOGIC ATTRIBUTES OF A REGION; SOUTH MOUNTAIN, PENNSYLVANIA

DAHLBERG, ERIC C., *Dept. of Geochemistry and Mineralogy, The Pennsylvania State University, University Park, Pa., 16802.*

The ideal correspondence of local "highs" in the geochemical landscape of a region to locations of mineral deposits is usually confounded by effects of additional influences. Recognition of meaningful anomalies is improved when these effects are estimated, isolated, and, if necessary, removed.

For explaining variation in stream sediment trace metal data as a function of some regional properties, a model expressed by the general equation

$$T = f(L, H, G, C, V, M, e)$$

has been utilized. "T" denotes element concentration, "L" represents lithological influences, "H" denotes drainage system effects, "G" represents geological features, "C" denotes cultural (man-made) influences and "V" stands for types of natural cover. "M" represents the effects of mineral bodies and "e" denotes error plus effects of additional factors not explicitly defined in the model.

Application of the model in an area of native copper occurrences near South Mountain, Pennsylvania, utilizing a multiple regression technique discloses that:

(1) The individual trace metal concentrations (T) are highly intercorrelated indicating that the geochemical information which they supply is to some extent redundant.

(2) Chromium content of the stream sediment is perhaps the most effective "tracer" for copper-rich zones in this area since

it is most strongly associated with variables related to existing copper prospects.

(3) Correlations between elements (T) and lithologic units (L) reflect the influence of local bedrock geology.

(4) Associations between trace metals (T) and geologic features (G) related to the length of local basalt contacts are noted.

(5) Few correlations of trace metals (T) with variables representing man-made influences (C) or drainage properties (H) are observed.

When combined with factor analysis for evaluation of the efficiency of the geologic and geochemical measurements the effectiveness of the model as a basis for prediction is enhanced.

Use of such a model thus aids in exposing not-so-obvious relationships among geochemical and regional properties, provides objective ranking criteria for eliminating less useful information, and is general enough to be applied to any similar type of prospecting problem.

THE MODERN GEOCHEMICAL LABORATORY

DEBNAM, ADRIAN H., *Technical Service Laboratories, 355 King St., West, Toronto 2B, Ontario, Canada*

During the last few years we have observed a revolution in geochemical prospecting analysis. The colorimetric analytical methods initially developed specifically for geochemical exploration have been largely replaced by atomic absorption analyses which have the advantages of simplicity, rapidity and accuracy, particularly for metals which require complicated colorimetric procedures.

The demand for multi-metal analyses on geochemical samples will probably increase rapidly in the future. Some government surveys already require 15- to 30-metal analyses and stationary or mobile spectrographs have been successfully used for this purpose. The main disadvantage of emission spectrography is that the operators, particularly those who interpret the spectograms, must be well trained specialists.

Automation appears to be the best solution to multi-metal geochemical analyses and we now have available a small direct reading emission spectrometer which can be programmed to determine up to 30 elements. This instrument is approximately 48 inches high, 40 inches long and 20 inches deep and is ideal for use in mobile laboratories. The price of the unit is as low as \$20,000 if programmed for 10 elements with meter read-out. Greater flexibility is achieved by adding more slits or replacing the meter with more sophisticated read-out systems. A total mobile system built into a trailer or a truck to handle 250 samples per day with 25-metal analyses should cost less than \$50,000.

An emission spectrograph with similar dimensions to those of the spectrometer is also available at a lower price.

THE USE OF RADON-222 IN SURFACE WATERS IN GEOCHEMICAL PROSPECTING FOR URANIUM

DYCK, WILLY, and SMITH, ARTHUR Y., *Geol. Survey of Canada, Ottawa, Canada.*

During a geochemical prospecting study of uranium in the Bancroft district of Ontario, a feasibility study on the use of radon in surface waters was carried out. Fifty-nine samples of surface waters (lakes, ponds, and streams) were collected over an area of approximately one hundred square miles during a two-week period in late August. In addition, seventy-eight water samples were collected near Hull, Quebec and surrounding district for comparison studies. Radon was measured by degassing the waters, collecting the gas and measuring its alpha activity in a ZnS cell. At the same time, the uranium content of the waters was measured by a fluorometric technique.

The radon content of surface waters varied from 0 to 2200 pc/l (pico curies per litre) while uranium content varied from 0 to 47 ppb (parts per billion). A difference was noted between the radon content of lakes and ponds (0 to 262 pc/l), some of the higher values being related to known uranium mines; and that of creeks and streams (1 to 2200 pc/l). No such variation was noted in the case of uranium. No correlation between radon and uranium contents of surface waters was observed.

The results successfully indicated gross areal variation in radon content of surface waters between uraniferous and non-uraniferous areas. Its cheapness and simplicity suggest considerable potential as a preliminary reconnaissance geochemical prospecting method. Further tests over much larger areas are indicated.

U.S.G.S. PROGRAM IN GEOCHEMICAL EXPLORATION RESEARCH

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Research by the U. S. Geological Survey in geochemical exploration is carried on chiefly in the Branch of Exploration Research. The principal objectives of this Branch is the development and appraisal of geochemical methods, both in the field and in the laboratory, that will aid in the search for concealed ore deposits. The Branch program is fourfold: (1) basic research in geochemistry in the zone of weathering, (2) research in analytical methods, (3) research in field methods, and (4) analytical support, both in-house and field, of the Wilderness mapping program and the Heavy Metals program.

The geochemistry of mercury and geochemistry of silver and gold, particularly in the zone of weathering, the role of microorganisms in the solubilization of gold, and the solution, transport,

deposition, and distribution of metals in the zone of weathering in various geologic environments are part of the basic research program.

The current emphasis in analytical research is on the development of methods for the determination of rare metals, including gold, silver, platinum, and palladium, in near-background concentrations and under mobile laboratory conditions. The measurement of mercury vapor in the atmosphere, application of the laser probe to analytical problems, determination of halogens and sulfide ion content, and development of a neutron activation technique for gold analysis of large (10,000-gram) samples are also being investigated.

Much of the research in field geochemical exploration methods is done in the western U.S. where metal deposits are concealed by extensive surficial cover, barren bedrock, and post-mineral volcanic rocks. Caliche, phreatophytes, water, soil gas sampling on gravel-covered pediments, and fracture-joint sampling in bedrock offer promise as exploration approaches in the Basin and Range province. Humus (mull) sampling in forested areas in the Rocky Mountain region looks useful. Determination of patterns of distribution of metals around porphyry copper deposits, "Carlin-type" gold deposits, and silver deposits, and studies in reconnaissance methods are also being carried on.

A major effort in the Branch has been the development of analytical services on a scale adequate to meet the geochemical exploration needs of the Heavy Metals and Wilderness programs. These services are provided by our Field Service Section, which includes about 45 chemists and technicians, 14 mobile chemical or "camper" labs, 4 instrument vans, 4 mobile spectrographic labs, and 4 mobile sample preparation units as well as extensive fixed laboratory facilities. About 75,000 samples per year are being analyzed by atomic absorption, colorimetric, and spectrographic techniques.

FACTOR ANALYSIS AS AN AID IN THE INTERPRETATION OF REGIONAL GEOCHEMICAL STREAM SEDIMENT DATA

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In a preliminary study, certain methods of statistical analysis indicated their usefulness as means of affecting a more significant interpretation of regional geochemical reconnaissance data. In areas of complex geology, the different lithologies frequently display widely differing metal contents. In so far as the minor element content of the stream sediments is largely related to admixtures

of material derived from the various lithologies, limited geological information often precludes an adequate assessment of the extent to which samples are related to different lithologies. Factor analysis proved useful as a method for identifying the factors affecting the metal distribution and expressing the minor element distributions of the samples as various admixtures of these factors. Restrictions of the method in that only 100 samples could be treated simultaneously, have now been eliminated with the development of computer programs to handle large volumes of data. The application of this modified technique is illustrated with reference to a drainage reconnaissance survey carried out over a mineralised schist belt of geochemically contrasting lithologies in Sierra Leone. The multi-element data of some 1000 samples was expressed as components of factors with distinctive geochemical characteristics i.e. bedrock or secondary environment. Furthermore, certain factors would appear to be associated with distinct types of element assemblages of possible economic interest. Although it has not been possible to investigate the significance of anomalies detected by this data analysis in the field, their association with areas of mineralisation as well as hitherto unknown mineralisation may indicate the existence of further mineralised areas. Whereas conventional interpretational procedures require prior geological knowledge of the area in order to classify data according to bedrock type, factor analysis establishes the geochemical association within the data which are then interpreted in terms of available geological information.

GEOCHEMICAL PROSPECTING FOR KIMBERLITES

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The possibility has been investigated of using geochemical methods for prospecting for kimberlite. Such methods would complement the established and highly successful mineralogical techniques, particularly in those areas where diagnostic minerals, eg. pyrope garnet, chrome diopside, are absent or scarce.

The research study was undertaken on kimberlites in south west Arkansas, with very limited comparative studies on kimberlitic rocks elsewhere in the U.S.A.

Kimberlites are ultrabasic rocks and therefore contain high concentrations of elements such as Mg, Fe, Mn, Ni, Co, Cr, and Ti. However they differ from other ultrabasics in that there is an enrichment of Ba, Sr, Rb, P, Nb, Zr, and certain Rare Earths.

During soil formation there is a redistribution of the elements with a marked tendency for many of them to be concentrated in iron-manganese nodules and/or mineral aggregates. Anomalous haloes have been detected in surface soils for several hundred feet downslope from kimberlite outcrops. Abnormal concentrations of

selected characteristic elements were also observed in drainage components for several thousand feet downstream from such outcrops.

Whilst basic and ultrabasic rocks, including kimberlite, can be detected by nickel analyses of stream sediments and soils, kimberlites can normally be differentiated by analysis of anomalies for niobium and other characteristic elements.

A GEOCHEMICAL CASE HISTORY FROM NEW ZEALAND

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The discovery of the Eliot Creek molybdenum prospect on the South Island of New Zealand in March, 1967, was the product of a low-cost geochemical reconnaissance survey of a kind that could easily be carried out by independent prospectors in many parts of the world today. The sequence of decisions that led to this discovery consisted of: (1) the decision to investigate a relatively unexplored part of the circum-Pacific Circle of Fire; (2) selection of New Zealand as the least explored country of this belt that afforded adequate economic and political stability and at the same time favorable working conditions for an independent prospector; (3) selection of the pre-Tertiary terrain of the northwest corner of the South Island as offering the most favorable geologic environment for large low-grade deposits; and (4) decision to collect samples on all passable roads and principal bush tracks, and to determine total copper, molybdenum, and heavy metal colorimetrically in a local laboratory. A total of 404 stream sites were sampled, resulting in four anomalies deserving follow-up. A molybdenum anomaly at Eliot Creek, 80 miles northwest of Nelson, was by far the strongest, showing at the discovery site 75 ppm Mo in sediments of a stream draining about 6 square miles. Follow-up of the anomaly led to a section of stream containing abundant boulders of vein quartz and silicified quartz porphyry showing strong pyrite-molybdenite mineralization. At the present writing, the full extent and grade of mineralization in the bedrock has not been determined. Excepting the cost of air fares to New Zealand, the overall investment in the program was four man-months of time and about \$2000 for expenses.

INFLUENCE OF VARIATIONS IN THE SURFACE ENVIRONMENT ON METAL DISTRIBUTION IN DRAINAGE SEDIMENTS

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Multi element regional geochemical drainage sediment surveys in selected areas of the U.K. have revealed patterns of metal distri-

bution variously related to geology, mineralisation and secondary environment. Regarding geochemical patterns related to secondary environment the drainage sediments of an area of poorly drained peaty gleys and podzols have variously enhanced contents of Mn, Co, As, Fe, Ni and Zn relative to adjacent areas of freely drained brown earths. Metal contents of rocks and soils in the two zones are essentially similar apart from slightly lower mean Mn and Co content in poorly drained soils. The operation of a concentration mechanism is thus indicated in the surface drainage system of areas of poorly drained soils. Mn and Fe oxides enriched in As, Co, Ni and Zn occurring as encrustations on stream banks and pebbles are ubiquitous in the streams of the poorly drained soils in contrast to their virtual absence in regions of freely drained soils.

Variations in the relations of the bedrock, soil and stream sediment geochemistry are controlled by differences in the physico chemical (pH-Eh) characteristics of the secondary environment giving rise to variations in the form of the metal in the stream sediment. The recognition of this phenomenon is of considerable importance in the interpretation of geochemical data. Provisional criteria are presented for distinguishing geochemical stream sediment patterns related to bedrock and mineralisation as opposed to those of the secondary environment.

ACCUMULATION OF ORE METALS BY MESQUITE PLANTS

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Sets of paired samples of mesquite and of the alluvial soil in which the mesquite was growing were collected at 55 places around copper deposits near Safford, Arizona. Spectrographic analyses of the soil and of the plant ash show that boron, copper, molybdenum, and strontium tend to be accumulated by mesquite whereas barium, beryllium, chromium, gadolinium, lead, manganese, nickel, silver, titanium, vanadium, yttrium, zinc, and zirconium are concentrated mostly in the alluvial soil. Apparently the molybdenum in the plants is derived largely from molybdenum-rich ground water. If the movement of the ground water can be deciphered, the distribution of molybdenum in mesquite can be used as an exploration guide to find molybdenum-bearing porphyry copper deposits. The copper content of mesquite tends to be moderately high even where the copper contents of the alluvial soil and the ground water are low; hence the copper content of the mesquite plants appears to be of less value as an exploration guide. The significance of the high boron and strontium content of the plants has not yet been investigated.

NICKEL-CHROMIUM-COBALT ENRICHMENT IN TROPICAL SOILS OVER SERPENTINITES, WANAMU - BLUE MOUNTAINS AREA, NORTHWEST DISTRICT, GUYANA

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Guyana (formerly British Guiana) is situated on the northeast coast of South America and the Wanamu-Blue Mountains area is in the Northwest District of Guyana. The geology of the area is complex. Igneous and metamorphic rocks of the Precambrian Guiana shield generally form bedrock, and in the Wanamu-Blue Mountains area basic rocks occur as "mantles" around granite. The topography is formed by a series of low, but rugged, hills that rise to elevations of 700 ft. Dense tropical rain forest covers the entire area. Laterization of soils is in process, but true laterites are not abundant.

Weathered bedrock serpentinite dikes contain nickel, chromium, cobalt, and other elements in amounts close to the normal background values. Abundant magnetite, but very little chromite, also occurs. The soils over the serpentinite bodies have a high manganese content and low iron content. Nickel, chromium, and cobalt are enriched in the soils. Anomalies closely follow the trend of the serpentinite bodies; however, the chromium anomalies are broader and stronger than the other two. Threshold values of nickel are about 1000 ppm, with peak values of 10,000 ppm; the threshold for chromium is 2500 ppm, with peak values in excess of 20,000 ppm; and the threshold for cobalt is 400 ppm, with peak values of up to 1500 ppm. Copper values are low, although higher than regional background; the threshold is about 100 ppm and peak values are 300 ppm. Vanadium and scandium are enriched. The peak values of copper, vanadium, and scandium are laterally displaced on either side of the nickel-chromium-cobalt highs.

Over the serpentinite, nickel and cobalt values increase with depth. Nickel is concentrated near bedrock and cobalt slightly above bedrock. The chromium content is highest near the surface.

In this isolated field area, a field test for day-to-day sampling guidance is desirable. Nickel was not readily extracted by cold tests, but cobalt in soils, as measured by the Canney - Nowlan ammonium citrate-soluble field test for cobalt, was found to consistently reflect bedrock concentrations of cobalt, its $CxCo: Co$ ratio being about 10%. Because cobalt coincided with nickel highs, it is suggested that this test may prove useful in exploration for lateritic nickel deposits in this area.

DISPERSION OF MERCURY FROM CINNABAR AND STIBNITE DEPOSITS, WEST TURKEY

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A detailed investigation has been made of the distribution of Hg in the soils and stream sediments about the Halikoy cinnabar mine. A comparative study about the Ivrindi stibnite mine revealed anomalous dispersion of mercury similar in magnitude to that at Halikoy, despite the absence of any mercury minerals. In addition, antimony was found to have very similar distribution to mercury in the soils and stream sediments at Ivindi; a plot of mercury vs antimony approximating to a straight line.

The granulometric and profile distribution of mercury is described. Investigations have been carried out, using differential heating techniques, into the forms of mercury in the naturally occurring materials. Particular reference is made to the relative importance of mechanical, chemical and gaseous dispersion.

AN ORIENTATION STUDY OF THE URANIUM DISTRIBUTION IN LAKE WATERS, BEAVERLODGE DISTRICT, SASKATCHEWAN

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An orientation survey was conducted in the Beaverlodge uranium district during the summers of 1964-65 to evaluate surface water sampling as a method of delineating regions of epigenetic pitchblende mineralization.

Deterioration studies revealed that the chemical parameters of pH, bicarbonate content, specific conductance and uranium metal content were sufficiently stable to allow analytical work to be performed in a central laboratory.

Detailed study of thirteen control lakes indicate that, with the exception of the spring break-up period, there is no significant variation in the uranium content of lake water which can be attributed to seasonal temperature changes or precipitation. Although seasonal variations in the pH and bicarbonate content do occur, these changes are not sufficient to affect the solubility of uranium.

Correlation studies indicate an increase in the specific conductance of lake water in the vicinity of mineralized areas.

Lake water assays show that the Beaverlodge uranium district is delineated by an analytical plateau of 0.9 ppb U_3O_8 , approximately twice the regional background value of 0.4 ppb U_3O_8 . Numerous peaks occur within this analytical plateau.

MULTI-ELEMENT ANALYSIS IN GEOCHEMISTRY: A SIX CHANNEL ATOMIC ABSORPTION SPECTROPHOTOMETER

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Atomic absorption methods of analysis for geochemical samples afford high precision of results thus enabling multi-element data to be interpreted more readily.

A multi-channel atomic absorption spectrophotometer incorporating resonance detectors as monochromators is used for the simultaneous determination of copper, nickel, cobalt, lead, zinc and silver in geochemical samples. The advantages of this type of unit are its simplicity of operation and the speed of analysis. For samples in the range 5-500 ppm one hundred analyses per hour can be handled. At the 200 ppm level, the precision for routine geochemical work is 5%-10% relative standard deviation.

The sample preparation is carried out to ensure a suitable dilution in order that, with appropriate adjustment of the respective light paths through a single burner, the measured absorptions will lie in a convenient range.

URANIUM IN LAKE WATER FROM THE KAIPOKOK REGION, LABRADOR

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Numerous uranium occurrences, including the Kitts deposit, have been found in the Kaipokok Region of Labrador since the initial discovery of pitchblende in 1954. With the recent renewed interest in uranium exploration, the uranium content of lake water was examined in an orientation survey covering the area of known mineralization in September, 1966. This sampling program established procedures which were used in the reconnaissance survey of a 500 square mile region the following summer. Sixty to seventy small lakes were sampled each day, permitting completion of the regional survey within four days. Samples were collected from float-equipped helicopter landings with on-site measurement of Eh and temperature using probes attached to the sampling bottle. The environment was further defined by determination of sample pH and analytical CO₂ at the end of each traverse. Uranium analysis in the sub-ppb range was performed fluorimetrically, and the intensity of yellow organic coloring was estimated by comparison with standards prepared from similar lake water.

The shallow lakes of the Kaipokok Region are glacial in origin

with the majority occurring in irregular depressions within ground moraine, and in ice-scour rock basins. Small seepage ponds were sampled in preference to lakes forming part of an established drainage system. Seasonal variations in uranium concentration are apparent in a comparison of results from lakes sampled in both September and July, with a three- to four-fold increase in lake water uranium content in the autumn. This factor contributed to a median uranium concentration of 0.4 ppb for the orientation survey, compared with the 0.1 ppb median of the mid-summer regional sampling. The effects of seasonal and short term variations were minimized by the brief duration of the reconnaissance survey, combined with base station sampling at the start of each traverse. The frequency distribution of uranium in lake water is approximately lognormal in both cases.

Results of the 1966 orientation survey indicated that a threshold of 1.0 ppb would outline catchment areas enclosing the majority of known deposits, while uranium concentrations as high as 5.8 ppb were found in small seepage lakes adjacent to known prospects. This survey also located an anomalous area, remote from uranium showings, which was later confirmed to have associated anomalous radioactivity during an airborne scintillometer check traverse.

EXPERIMENTAL DESIGN IN GEOCHEMICAL EXPLORATION

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Sampling in many geochemical exploration programs is either highly subjective, consisting of the collection of materials judged most likely to contain concentrations of the metals being sought, or is basically haphazard. Analysis of the data is also highly subjective and no attempt is made to summarize the analytical results quantitatively or to evaluate them in terms of probability theory. The success of this type of approach has been abundantly documented. However, as the search for ore becomes more difficult and the anomalies more subtle and difficult to evaluate, it may become necessary to plan the sampling procedures according to rigorous experimental designs, just as one might plan a laboratory experiment. The design should allow one to estimate the importance of all the various sources of variability in the final data — such as analytical error, sampling error, and the remaining variability which is of interest in exploration.

Results obtained from preliminary designs can be used to plan final sampling programs that are efficient in terms of the number of samples required, and also sufficiently powerful to accomplish the program objectives. The final sampling program best suited for the problem will depend on the types and amounts

of variability in both the analytical method and in the materials being examined. The estimation of variability demands some degree of randomization, or at least some objectivity, in both sampling and analysis. Randomization in analysis would be especially helpful in validating experimental results.

NATURAL ORGANIC ACIDS IN THE MOBILIZATION OF GOLD

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Interactions of various forms of gold, as plates, coarse particles (0.15mm), colloids (1.1 μ), and ions (AuCl_4^-), with different types of natural organic acids show that gold is not oxidized and complexed by the organic molecule as reported by some investigators. To the contrary, organic concentrations in the range of 3-30 ppm have the capacity to reduce gold chloride solutions to negatively charged colloids of metallic gold. The reduction process is accompanied by the formation of a protective coating of the hydrophilic organic molecules around the hydrophobic gold sol, which renders the gold sol very stable and not easily precipitated by cations. This protective layer is also formed when colloids of gold are mixed with organic acids.

Addition of excess sodium ions (0.13-0.26 M) to organic protected gold sols (12 ppm Au) causes the sols to become stable once again due to the reversal of charge of the sols from negative to positive, because of the adsorption of sodium ions. For the unprotected gold sols, addition of sodium ions in the amounts greater than 0.03 M, causes immediate precipitation of the gold and no reversal of charge is possible.

The formation of organic protected gold sols is responsible for the mobility of gold in the surficial environment and may explain much of the gold found in the humus layer of a soil profile, as well as the high gold concentrations associated with organic matter as reported in the literature.

RECENT ADVANCES IN THE CHROMATOGRAPHIC ANALYSIS OF GEOLOGIC MATERIALS

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Modern chromatographic techniques are related to the essentials of chromatography. Published analyses and analytical methods are recorded. *Paper chromatography*: Agrinier (1964) devised quantitative methods for (Na, Ta, Ti), (Ni, Mn, Co, Cu, Fe), (U, Th), (Sm, Ge), (As, Sb, Bi), Be, Au, (Pb, Zn, V, Mo). Alberti et al. introduced a new medium ("CeP paper") which

gives good separations for Li, Na, K and Rb, Co and is suitable for field work. Rattigan (1965) defines the position of chromatographic analysis in exploration work. Ritchie (1965) outlines field analysis by chromatography. A field semi-quantitative determination of uranium in natural waters by fluorescence paper chromatography (Alberti et al 1960) is shown to detect uranium to 0.0018%. Trace amounts of niobium in cassiterite, wolframite and scheelite were determined by Viktorova and Saltykova (1966). A fast quantitative separation for Fe (II) and Fe (III) is given by Qureski et al (1966). Popper et al (1966) report a new reagent to detect Cd, Bi and Pb.

Lederer (1967) gives separatory methods for La-Sr; Ba-Sr; Sr-Ca and other metals. *Thin layer chromatography (T.L.C.)*. The methods of Sijperda and De Vries (1966) and Brinkmann et al (1966) for rapid qualitative analysis of sulphide minerals for 20 metals is discussed. Silica gel impregnated Amberlite La-1, an ion-exchanger, is used after mounting on microscope slides. Ritchie (unpublished) reports results by the same method but using the newly available commercial thin layers on inert plastic sheets (Polygram Cel 300 PEI and Cel 300 by Brinkmann). The method of Hashmi and Adil (1967) for the quantitative determination of Rh, Ru, Pt, Au, Os, Pa and Ir is presented. *Ion-exchange chromatography*: The separation of rare earths from thorium extracted from monazite on a De-acidite FF column (Edge, 1963) is described. Ion-exchange in T.L.C. and paper chromatography is discussed. *Gas chromatography*: The limitation of this method to volatile samples has narrowed its application to geology mainly to the analysis of hydrocarbons in petroleum exploration and of amino-acids in fossils. The gas chromatography of metal chelates (Moshier and Siever, 1965) seems on the threshold of the application of this technique to the exploration for metals.

USE OF GEOCHEMISTRY AT THE BALD BUTTE MOLYBDENITE PROSPECT, LEWIS AND CLARK CO., MONTANA

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Geochemical soil sampling led to the discovery of interesting molybdenite mineralization associated with an unexposed porphyry intrusive. The area of interest is not marked by bleaching or limonitic discoloration but is outlined by the 10 ppm Mo contour. The molybdenum anomaly as outlined by soil samples coincides well with anomalous molybdenum values in bedrock. The generally low-level anomalous values, most of which are under 100 ppm Mo, were obtained from the -35 mesh fraction of the soil samples.

A comparison of results from soil and rock samples indicates molybdenum leaching. Under the slightly acid pH conditions prevailing, one would expect molybdenum values to be generally

fixed in situ. On the basis of some laboratory test work we suspect that this leaching is due to a shift in the molybdenum stability field caused by significant amounts of calcium.

This case history serves to illustrate that the merits of a prospect cannot be evaluated on the basis of geochemical values alone. It also points out the need for more knowledge of factors governing the geochemical mobility of molybdenum.

TRACE ELEMENTS IN ACCESSORY CALCITE — A POTENTIAL EXPLORATION TOOL IN THE MICHIGAN COPPER DISTRICT

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Mineralization in the Michigan Copper District is of two types: (1) as chalcocite and native copper in fine grained sediments in the Nonesuch shale, as in the case of White Pine; and (2) as native copper in lava flows and inter-layered conglomerates of the Portage Lake Lava Series, as found in the active mines of Houghton and Keweenaw Counties. Some sulfide mineralization is known in lavas and conglomerates, but is not economic at this time.

In areas of sulfide mineralization, copper anomalies from soil sampling are found and have been previously described. In areas of native copper mineralization, however, soil or water samples do not yield distinct anomalies, probably because (1) the surface is fresh because of glaciation about 10,000 years ago; and (2) the relative insolubility of native copper under the chemical conditions present at the glacial drift-ore interface.

In an effort to establish an exploration tool for use in the lava series-conglomerate area, trend surface analysis of trace elements in ore minerals and accessory minerals was attempted. Calcite was chosen as the accessory mineral to be used because of its wide distribution, its close relationship with copper mineralization in time, and its relative ease of dissolution. Cobalt, copper, chromium, manganese, nickel, magnesium, iron, and mercury concentrations were obtained by means of atomic absorption spectrophotometry. Concentrations were determined by comparison with known standards.

Statistical correlation showed that manganese in calcite most nearly correlated with ore-grade native copper mineralization, and that concentrations of manganese in native copper and calcite showed similar trends. Trend surface analysis was very useful in smoothing the data.

This method is potentially useful as an exploration tool in the district.

EVALUATION OF MERCURY VAPOR ANOMALIES AT COLORADO CENTRAL MINES, CLEAR CREEK COUNTY, COLORADO

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Mineralization at the Colorado Central Mines consists principally of galena, sphalerite, pyrite, and the silver minerals polybasite, pyrrargyrite and tetrahedrite, in steeply dipping veins 1/10 inch to 4 feet wide. These veins occur throughout a northeast trending, steeply dipping shear zone. The zone is greater than 1000 feet in vertical extent, 50 to 200 feet wide and cuts Precambrian granite, schist and gneiss.

Narrow anomalies of mercury in soil and air occur above veins in the shear zone, both where known mineralized veins intersect the subcrop and where they are "blind," but apparently connected to surface by fractures. Similar anomalies occur where the presence of mineralization has not been established. Some of these can be ascribed to surface contamination. Others are related to minor mineralization along fractures. Additional tools must be employed (1) to distinguish between subcrop and blind deposits, (2) to determine the depth to blind deposits, and (3) to evaluate the economic significance of each mercury anomaly.

Mercury anomalies over subcrop mineralization are readily distinguished from blind mineralization by the presence (subcrop) or absence (blind) of anomalous Ag, Pb, Au and Cu in the soil.

The depth to blind deposits of significant size is approximated by Afmag Electromagnetics (for good electrical conductors), by induced polarization (particularly for disseminated sulfide zones) and by high frequency Electromagnetic techniques. These are principally effective for depths of 500 feet or less.

The economic significance of each mercury anomaly can be evaluated utilizing a combination of these methods. An economic sulfide-bearing vein swarm intersecting the subcrop has strong mercury, heavy metal, and E.M. and/or I.P. responses. A blind economic, sulfide-bearing vein swarm has moderate mercury, and weak to strong E.M. and/or I.P. responses depending on depth, size, and sulfide content. Weakly mineralized veins and vein swarms reflected by mercury anomalies commonly show no electrical responses, or poor electrical responses caused principally by the wet clayey material associated with the veins.

EXPLORATION BY OVERBURDEN DRILLING AT UNITED KENO HILL MINES LIMITED

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The Galena Hill-Keno Hill area is in the central Yukon, 35 miles northeast of Mayo and some 220 miles due north of Whitehorse. The area lies in the northeastern part of the Yukon Plateau and the terrain is mountainous with elevations ranging from 2300 feet to 6750 feet.

Silver mineralization was first discovered in 1906. Since then mining operations have been carried on from 1913 to the present day with an interruption from 1941 to 1946.

The silver rich veins are considered to be mineralized faults. Ore grade mineralization is most commonly found where the veins cut competent quartzite and greenstone. The ore shoots are very irregular, both vertically and horizontally, within the veins.

Silver is associated with lead, zinc and copper minerals. Common gangue minerals are siderite, pyrite and occasionally arsenopyrite and barite.

The majority of the veins are covered by overburden which has been found on occasion to exceed 100 feet in depth and varies from a glacial till to bedrock detritus or a combination of both. Most of the overburden is permanently frozen.

Solifluction has moved float from the veins downhill. The old-time prospectors found many of the veins by tracing mineralized float by pitting to its source. Their method was frustrated in areas of deep overburden. The overburden drilling technique is a mechanical and chemical adaption of the old-time prospector's method. It allows favourable areas to be systematically gridded and then drilled to sample the overburden surface to bedrock.

After experiments on sampling deep overburden, an Atlas Copco Overburden Drill was obtained in the spring of 1963. Following encouraging results over a known vein system a program developed which to date has drilled 301,389 feet in 3,954 holes.

The drill unit consists of a heavy duty BBE 51 rock drill motor with a chain feed mast with two air winches on a BVB 31 wagon drill. The unit is capable of drilling holes from vertical to 57°. A diesel compressor of 600 c.f.m. capacity supplies air at 100# to the drill. Both units are mounted on heavy skids and moved by a TD20 tractor equipped with blade and winch.

Holes are drilled dry and the cuttings air-flushed to the collar of the hole where they are deflected into a catch pan. Samples are taken at 5 foot intervals and are approximately 10 lbs. in weight.

At the laboratory the sample is emptied into a 14 mesh screen. Two splits of approximately 300 grams are taken, one for storage and the other for geochemical analysis. The remaining sample is washed through the screen into a gold pan. Coarse material is logged visually while the fine material is panned and the resulting concentrate is identified under a microscope.

From 1963 to 1966, hot aqua regia digestion was used. Dithizone was used to determine lead and zinc and biquinoline to determine copper. In 1967, samples were analyzed for lead, zinc and silver using the atomic absorption method.

All holes are surveyed for location and all information plotted in profile from which an interpretation is made and plotted on plan maps.

Vein material in float can be recognized geochemically by anomalous highs in lead, zinc and copper. As lead has a limited chemical migration, it is found to be the most reliable indicator, zinc tends to reflect the lead trends but is much more widespread. The determination of copper was discontinued because it seldom reflected a vein system and interpretation was difficult because of anomalous trends in greenstone and sericite schist. Silver has been used for one season and appears to be a good indicator of vein zones.

Recognition of vein material is made in the coarse material either from the screenings and/or from the panning concentrates.

A further adaption is to use the overburden drill in place of a diamond drill. Angle holes are used to test vein systems in bedrock to a 100 feet below surface. This method has proved fast and economical, providing close to 100% recovery of cuttings.

Angle hole samples are processed the same as vertical holes except a second sample is saved for assaying purposes.

Today studies are being made for underground development of a vein system found by our overburden drill sampling method. This is the first new vein system to be found by United Keno Hill Mines Limited from a surface exploration programme and is located under 20 to 40 feet of overburden on a relatively flat area at the base of Galena Hill.

THE BEARING OF TIN MINERALS AND ORES IN THE WEATHERING ZONE AND THE POSSIBILITY OF GEO-CHEMICAL EXPLORATION FOR TIN

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1. Many granitic intrusions associated with tin deposits contain tin in proportions varying from several tens to several hundred

grams per ton of granitic rock. The tin is contained mainly in micas. In the oxidation zone tin passes through weathering products.

2. In the majority of tin deposits, cassiterite is accompanied by tin sulfides. In the oxidation zone sulfides are destroyed by the formation of soluble sulfate and residual tin minerals such as varlamoffite which dissolve easily in acids. They are very soft and can be reduced to sub-microscopic particles and mixed with soils.

3. Cassiterite itself remains stable in the weathering zone. In river beds coarse grained cassiterite is transported to only a short distance from the primary deposits.

In river gravel the wearing and polishing of cassiterite grains produce very fine particles the dimensions of which may be measured in microns and fractions of microns. This fine grain fraction of cassiterite can be transported for long distances from the source of the deposit and can be mixed with soils from river basins.

4. Tin which is derived from the alteration of granitic rocks, from the decomposition of tin sulfides, from the destruction of residual minerals such as varlamoffite and from the finely grained fraction of cassiterite is mixed with soil obtained from the erosion of granitic rocks and associated metamorphics. This results in the soil's formation of local and regional geochemical anomalies for tin.

5. The author has had the opportunity, over a period of 20 years, of studying a well isolated granitic intrusion, closely associated with important tin deposits of the maniema region (République Démocratique du Congo). The annexed map indicates the shape of granitic intrusions and the distribution of alluvial, eluvial and primary tin deposits.

6. Tests were performed with the view of establishing a simplified geochemical method to be used in the exploration for tin. A sampling profile was placed across the granitic intrusion following a road. Samples of soil were taken beginning at a distance of 50 kilometers from the workable alluvial tin deposits. Outside the zone of workable cassiterite deposits, samples were taken every 1000 metres, inside every 500 metres.

7. After pulverization, samples were processed on a Bausch and Lomb spectrograph and the relative intensity of the lines were measured with a densitometer.

8. In conclusion, it seems that in exploration for tin, under conditions of thick equatorial vegetal cover and very scarce out-cropping of granitic rocks, promising granitic intrusions may be easily detected by the method outlined.

9. Other experiments were conducted for the location of eluvial placers under conditions of thick equatorial forest cover. These results are not complete but are showing promising possibilities.

ATOMIC ABSORPTION TECHNIQUES IN GEOCHEMICAL EXPLORATION — PROBLEM OR PROGRESS

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Atomic absorption measurements have much in their favor such as simplicity, sensitivity, specificity, and objectivity and in contrast to emission measurements, they are considered relatively free of interelement effects. However, detailed studies of atomic absorption measurements of a given element in the presence of a suite of other elements such as occurs during analysis of geologic materials reveal severe interferences, especially when the accompanying elements are present in large excess. Sample dissolution for atomic absorption methods is similar to that of wet chemical trace methods and the interferences resulting from variations in composition of the matrix are not only present in the sample solution, but often unknown, unpredictable and may preclude establishment of a routine procedure.

Overall precision measurements of the copper content of rocks such as quartz monzonites and basalts and of minerals such as hornblende and biotite show a 2 to 3 fold improvement after nullifying interelement effects by appropriate dilution of the acid concentration of samples and standards.

Solvent extraction is used to isolate as well as concentrate the element being measured, but at the same time introduces other variations in the flame temperature and rate of sample intake which is related to the population of atoms in the ground state and thus indirectly to the absolute sensitivity.

These observations point to the fact that despite the favorable characteristics of atomic absorption techniques, the most satisfactory determination is one in which the element being measured is in solitary confinement in an aqueous medium of the lowest possible ionic strength.

Partial
Campus View Map

