

Eugene M. Shoemaker (California Institute of Technology) on the accretion and cratering history of the solar system. Superimposed cratering as illustrated by moon photos will progressively mask earlier craters (example: Crater Korolev) until a "saturated surface" or steady state distribution is reached. Thus the present moon surface topography dating at 3.3 b.y. documents only the vestige of a major cratering event - probably the "tail end sweep up" from the birth of the planets at 4.6 b.y. Shoemaker suggests that most of the earth's current radius was achieved in the first 200 m.y. of accretion. Volatiles and alkalis were plated on during the tail end of the cratering episode. Crustal material was not "sweated out" from the mantle but rather was a later addition. Archean geologists should take note of this potential source for low strontium ratios.

Saturation cratering for the Archean earth puts an upper age limit on isotopic systems but also implies world wide vestiges of "old" ages. Zircon ages of 3.5 b.y. are now reported for tonalite-granite gneisses of the Watersmeet area, N. Michigan (Z. E. Peterman, U.S.G.S.). We anticipate similar old ages from the English River gneisses.

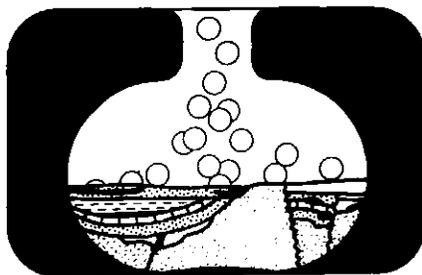
### Concluding Remarks

The Institute on Lake Superior Geology conferences have grown in recent years sufficiently to require synchronous sessions. The same time has seen a proliferation of conferences with overlapping regions and themes, (annual Geotraverse, Toronto; Archean Crust in Canada, Nov. 1975, Hamilton). Perhaps a restructuring of the Institute and the branching of an Archean Division with its separate and annual Archean conference could accommodate this multiplicity of meetings and tighten the conference theme.

### References

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## Exploration Geochemistry in the Appalachians

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The Association of Exploration Geochemists holds major international symposia every other year, with a venue in North America every fourth year. The concept of regional meetings arose to allow continuity of contact between geochemists, especially since relatively few North American members are able to travel to the Sixth International Symposium which is to be held in Sydney, Australia this year. The first regional meeting "Exploration Geochemistry in the Appalachians" was held on the University of New Brunswick campus on April 22 and 23, 1976, with field excursions to mining properties in New Brunswick on April 20 to 21 and 23 to 24. The Chairman of the Organizing Committee for the meeting was G. J. S. Govett.

The technical programme was attended by 190 delegates from eight Canadian provinces, 14 U.S. states, France, Sweden, and the U.K. representing mining companies, universities, provincial and state organizations, the U.S. Geological Survey, the Geological Survey of Canada, and the Swedish Geological Survey. The keynote address - "New Brunswick: where it all began" - was given by Dr. H. E. Hawkes and recounted some of the early history of exploration geochemistry, including the world's first regional drainage survey he led in New Brunswick in 1953-1955. The address complemented the speech by the Hon. R. C. Boudreau, Minister of

Natural Resources of the Province of New Brunswick which reviewed the state of the mining industry in the Province today.

The technical papers illustrated that in northern latitudes the usefulness of drainage surveys in exploration is limited in many cases by several environmental factors: a general lack of fine-grained stream sediment suitable for analysis; frequent high concentrations of Fe and Mn oxides that scavenge other metallic elements; and ubiquitous organic material that also tends to concentrate metals. An outstanding paper given by J-O. Larsson (Geological Survey of Sweden), "Organic Stream Sediments in Regional Geochemical Prospecting, Precambrian Pajala District, North Sweden", demonstrated how these adverse conditions can be overcome and, indeed, used to advantage. The drainage reconnaissance technique described is based upon deliberate collection of organic rather than mineral samples; the samples are ashed and - in Larsson's work - analyzed by X-ray fluorescence for Y, U, Th, Zr, Zn, Rb, and W, and by emission spectroscopy for Pb, Zn, Mo, Co, Mn, Ni, Mg, V, Ti, Ca, Ba, Sr, Ag, Bi, As, Sn, Be, and Cr. The results from more than 10,000 samples collected over an area of 8,000 km<sup>2</sup> (3,000 sq. mi.) showed that the wide availability of organic samples allowed the desired sample density to be maintained. Moreover, the high trace element content in organic material is an enormous analytical advantage (e.g., the mean background for U is 22 ppm compared to background in mineral sediment of around one ppm), and the anomalies are also more homogeneous and extensive. All analytical data in the paper are corrected for the effect of variable Fe, Mn, and organic content by step-wise regression analysis.

The survey described by Larsson is a model of integrated exploration where final interpretations are based on the drainage data, regional geology, quaternary geology, aeromagnetic and aeroradiometric surveys, and heavy mineral analysis in tills - all plotted on 1:50,000 maps. (The routine integration of all available exploration techniques is a gratifying trend evident in a number of other papers providing case history data). Another potentially valuable innovation described in Larsson's paper is a detailed follow-up technique based

on the collection of samples around the margins of bogs in anomalous areas defined by the reconnaissance drainage survey. One of the great operational advantages of this modern approach for northern latitudes is that samples may be collected in winter when the surface waters are frozen; thus, it is possible to keep field sampling crews intact throughout the year and also to ensure a more regular supply of samples to laboratories. Although Larsson's paper has no geographical nor geological affinity to the Appalachians, it has an enormous general practical significance to exploration geochemistry in the northern Appalachians, the Canadian Shield, and other similar areas.

Two other papers dealt with the problems in interpretation of geochemical data from stream sediments caused by the scavenging of Fe and Mn. In a paper "Concretionary manganese-iron oxides in streams and their usefulness as a sample medium for geochemical prospecting" by G. A. Nowlan (U.S. Geological Survey), the results of analyses of Fe-Mn oxide nodules, Fe-Mn oxide coatings on sediments, and normal bulk stream sediments from Maine showed that anomaly to background contrast is enhanced for some elements in the oxides. Of 30 elements investigated it was found that As, Cd, Co, Cu, Mo, Ni, Pb, Tl, and Zn were scavenged by the Mn-Fe oxides. The distribution of some of the rarer elements - such as Cd and Tl - can be studied more readily in the Mn-Fe oxides because their concentrations reach levels that can be measured by routine analytical techniques. A paper by V. Austria (New Brunswick Department of Natural Resources) and C. Y. Chork (University of New Brunswick), "A study of the application of regression analysis for trace element data from stream sediments in New Brunswick", demonstrated another aspect of the Fe-Mn problem: where base metal mineralization is accompanied by abnormally high Fe and Mn there will be anomalously high Fe and Mn in stream sediments that are related to bedrock and are not due to environmental causes.

Efforts to increase the usefulness of stream sediment geochemistry in more southern latitudes were described by J. E. Callahan (Appalachian State University, North Carolina) in his paper

"A geochemical survey based on stream sediments in Watauga County, North Carolina, U.S.A.". He compared results obtained on the minus 80-mesh fraction, a panned concentrate, and a heavy liquid concentrate of heavy minerals and found that Zn, Pb, and possibly Cu give a better contrast in the heavy fraction; moreover, the simple panned concentrate was virtually identical to the costly and tedious heavy liquid separated fraction.

The concern with impending energy deficiencies was reflected in three papers on uranium exploration. In the U.S. the NURE (National Uranium Resource Evaluation Program) includes a reconnaissance geochemical survey of the entire U.S. using stream sediments, stream water, and groundwater. This is the largest geochemical survey ever undertaken in the U.S. - and possibly the largest in the world. Two papers discussed concepts of this programme: "Tests of geochemical techniques for detection of uranium occurrences in sedimentary rocks of eastern Pennsylvania" by A. W. Rose and M. L. Keith (Pennsylvania State University) and "National uranium resource evaluation program (NURE) hydrogeochemical and stream sediment reconnaissance" by R. B. Ferguson and V. Price (Savannah River Laboratory, South Carolina). In both these studies U was determined by the Delayed Neutron Activation Technique. Rose and Keith demonstrated that U in stream waters shows considerable seasonal variation (causing differences in U content by as much as a factor of 10), while generally stream sediments are not seriously affected. They also showed that measurement of the exchangeable fraction of U in stream sediments (as leached from the sample by acetic acid and hydrogen peroxide) is far superior to measurement of total U for detection of U anomalies. Rose and Keith also investigated the effect of Fe, Mn, and organic matter on U content of stream sediments; they found that the effect of Fe and Mn is small, but if the organic content exceeds 10 per cent correction of the uranium concentration then becomes necessary. Ferguson and Price gave results of measurement of a wide range of elements (including U) and other parameters in stream sediments, stream water, well and spring

water, and suspended solids in water; they concluded that for the southern Appalachians determination of U in the minus 100-mesh fraction of stream sediments yields as much or more information as obtained from water or suspended solids.

In Canada, Federal and Provincial agencies are engaged in the Uranium Reconnaissance Program (URP). Some preliminary results for the programme were described in a paper "Well water trace element reconnaissance in eastern Maritime Canada" by W. Dyck (GSC), A. K. Chatterjee (Nova Scotia Dept. of Mines), D. E. Gemmell (New Brunswick Dept. of Natural Resources) and K. Murrice (P.E.I. Dept. of Industry of Commerce). They found that U (measured by the fluorimetric method), Ru, He, F, conductivity, and alkalinity show regional patterns that are highly suggestive of a typical roll front - although the U contents of the well waters indicate that economic mineralization is not likely. Other measurements on the well waters showed that the largest  $CH_4$  anomaly is related to the St. Joseph's oil and gas field, and most of the Cu, Pb, Zn, Fe, and Mn anomalies can be related to known base metal occurrences.

In soil geochemistry one of the greatest problems is to determine the optimum sample density that will yield adequate exploration information and will also be operationally economic. The problem was illustrated by two excellent case histories. A. W. Lockhart's paper "Geochemical prospecting of an Appalachian porphyry copper deposit at Woodstock, New Brunswick" shows that drilling based on a large soil geochemistry anomaly shown by a 500 ft sample interval on 700 ft line spacings was negative; subsequent more detailed soil sampling at a 100 ft interval along lines 200 ft apart showed that the original drilling was sited precisely in a "hole" in the anomaly. Drilling based on the follow-up soil geochemistry established that ore-grade (but not yet ore-tonnage) porphyry-type Cu mineralization is present in the northern Appalachians. Lockhart concludes that a 200 ft grid is probably the optimum sampling spacing. G. J. Dickie and C. J. Sampson in their paper "Exploration for zinc and lead in western Newfoundland based on geochemical surveys" came to the quite contrary conclusion that their "detailed"

soil sampling at 200 ft intervals along lines with 400-500 ft spacings gave little more information useful in locating mineralization than their reconnaissance soil sampling grid of 500 ft intervals along lines spaced at 1,000 ft; they suggest that in the Cambro-Ordovician carbonate environment of western Newfoundland the optimum soil sampling interval would be a 500 ft grid. Another case history for Newfoundland given by A. Harris - "Definitions and priority ratings of exploration targets in the Coldspring Pond area, central Newfoundland" illustrated the selection of exploration targets on the basis of combined geological-geophysical-geochemical surveys.

The problems and results of using exploration geochemistry in the southern Appalachians were discussed in two papers: "Techniques of geochemical exploration in the southeast Piedmont" (J. E. Worthington, E. M. Jones, and I. T. Kiff); and "Use of mercury in geochemical exploration for Mississippi Valley type of deposits in Tennessee" (J. G. Gustavson). The data from both these comprehensive papers served to contrast the geochemical response in terrane of thick residual soil and contamination due to population with the glacial drift-covered and sparsely settled areas of the Canadian Appalachians. One of the solutions to the problems of surface contamination is the use of biogeochemical techniques, as described by S. C. Adams (Purdue University) and W. C. Hood (Southern Illinois University) in a paper describing their work in Missouri - "Biogeochemical Prospecting for Copper and Zinc using *Juniperus virginiana* L."

Some of the work on measurements of elements, pH, and conductivity on water extracts of soils, rocks, and stream sediments being done by the Exploration Geochemistry Group at the University of New Brunswick was described in "Water-extracts of volcanic rocks - detection of anomalous halos at Brunswick No. 12 and Heath Steel B-zone massive sulphide deposits" by W. D. Goodfellow and J. L. Wahl. The paper documents earlier conclusions that conductivity and pH measurements on water slurries of earth materials and direct measurement of elements on a filtered aqueous extract is potentially a

rapid and cheap technique of exploration.

A general paper - "Geochemical prospecting: extensive versus intensive factors" - by W. S. Fyfe and R. W. Kerrich of the University of Western Ontario discussed the necessity of attempting to determine whether a given area had an appropriate geological potential for the formation of economic ore deposits in terms of the possibility of transport of large volumes of ore solutions, energy sources, appropriate source rock for metals, and suitable structures for localization of ore deposition. The use of data from fluid inclusions, stable oxygen isotopes, and especially the oxidation states of Fe were proposed as useful techniques to assess the ore potential of an area. Considerable doubt was expressed during the discussion regarding the practicability of the proposals for exploration samples from the surface environment.

The meeting - the success of which was materially aided by the hospitality of the Province of New Brunswick and the University of New Brunswick and the whole-hearted support of the local mining industry - brought together practising and research geochemists with experience in a wide range of geological and geographic conditions; discussion and debate was lively both during the formal technical sessions and in the more informal "Author's Corner" between the sessions where authors were available to discuss their papers. Throughout the meeting the contrast between the environmental factors (cultural and geochemical) between northern and southern latitudes was repeatedly evident. There were, nevertheless, a number of general themes in the development of exploration geochemistry that appeared in most of the papers to a greater or lesser extent:

- 1) Increased work on determination of processes in geochemical dispersion and less reliance on empirical observation.
- 2) A general trend towards multi-element analysis of samples - determination of 30 or more elements now appears common.
- 3) A general use of computers and advanced statistical techniques to process and interpret data.

#### Note

The papers will appear in full as a special 200-page issue of the *Journal of Geochemical Exploration* to be published in November 1976. Separate copies of this can be obtained at a cost of \$25.00 by placing a prepaid order with the Association of Exploration Geochemists (c/o G. J. S. Govett, Dept. of Geology, University of New Brunswick, Fredericton, N.B.). Copies of the Field Excursion Guidebook (109 pages) are also available at \$2.50 at the same address.

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