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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
TOPICAL REPORT NO. 93

REPORT ON THE FIRST MEETING OF THE COMMITTEE FOR A METALLOGENIC MAP OF NORTH AMERICA, WASHINGTON, D. C., September 28-30, 1964

BY
W. D. McCARTNEY

OTTAWA
1964

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REPORT ON THE FIRST MEETING OF THE COMMITTEE FOR A METALLOGENIC MAP OF NORTH AMERICA, WASHINGTON, D.C. SEPTEMBER 28-30, 1964

Summary

The background and summary of past meetings of the Subcommission for the Metallogenic Map of the World are outlined. Conclusions reached at Washington are summarized, and a few observations are made on each of the many speakers called on by the North American Chairman, P.W. Guild. The full text of the opening Canadian report on Metallogenic Maps and Research is appended.

Conclusions and Recommendations

The meeting was semi-formal for the first two days, but observations and comments were interspersed throughout. From these, it is clear that many different points of view remain to be ironed out by trial and error, but the following decisions were agreed to in principle.

1. The North American Metallogenic Map is to be on the 1:5,000,000 base as used for the tectonic map. (This is the largest possible scale that can be fitted on two large sheets.)
2. Trial compilations in each country should proceed, and part of such trials should use the proposed European legend.
3. The tectonic and geological maps for the south half of North America will be provided.
4. Trial compilations should emphasize elements of mainly epigenetic occurrence (Cu, Pb, Zn, Ag, Au, Sn, W, Sb) rather than sedimentary deposits (evaporites, phosphates, etc.).

5. The lower limit of inclusion of mineral occurrences is to be subject to experiment on small scale maps. Minor occurrences should be used when possible to outline metallogenic areas.
6. Secretaries of the Commission should maintain and distribute bibliographies and translations relevant to metallogeny.
7. Should a Canadian subcommittee be formed, contributing Provincial representation should be emphasized.
8. Trial results should be available for comparison and further decisions by April, 1965, at a proposed meeting in Mexico. Mexico would invite representation from Cuba, Guatemala and Greenland as well as the United States and Canada.

Subcommission for the Metallogenic Map of the World

The above Subcommission was constituted by the International Geological Congress in Mexico in 1956. Formed at the same time as the Subcommission for the Tectonic Map of the World, it is associated with the Commission for the Geological Map of the World which was formed in 1952. Members of the Metallogenic Subcommission were defined as the National Geological Surveys, each represented by a delegate. "On the other hand, the Subcommission may ask the participation of specialists in the field of mineral deposits who may be designed by the different countries as being apt to bring valuable assistance."

Following the 1956 Congress, a questionnaire was distributed in preparation for the first meeting in Paris, April, 1958. Dr. W.D. Johnston, Jr., U.S. Geological Survey, was elected President of the Metallogenic Subcommission, M.P. Routhier of 20, rue Monsieur, Paris 7e, was named Secretary, and provision was made for the subsequent appointment by Johnston of P.W. Guild, U.S. Geological Survey, as the American Secretary. Amongst the resolutions adopted, what I think seems the principal one called for experimentation by individual countries in preparing national metallogenic maps for display by 1960. Separate maps for coal and iron were recommended.

Canada's commitment to the 1960 Copenhagen meeting were met by a display map prepared by A.H. Lang and W.D. McCartney on transparent material, showing past and present producing mines on a scale of one inch to 120 miles, superimposed on the Geological Map of Canada. Published maps for Uranium, Beryllium, Molybdenum and Iron on transparent paper were displayed. Dr. Y.O. Fortier represented Canada at this meeting. A committee to prepare a metallogenic map of Europe was formed under the Chairmanship of Pierre Laffitte.

The inter-Congress meeting of the Metallogenic Map Subcommission was attended by Dr. A.H. Lang in Paris, December, 1962. By previous agreement, the Metallogenic Map of Europe had been given first priority, and various proposed legends and maps were discussed by European delegates.

At Zakopane in September, 1963, a complex legend was proposed by E.T. Chatalov, U.S.S.R., and some features of the tectonic base have been incorporated in the current European legend (in press, Paris). One of the features of the Soviet proposal was to indicate whether mineralization was pre-orogenic, orogenic or post-orogenic where known. These distinctions are not incorporated in the European legend, but may deserve further consideration in some parts of Canada on large-scale maps. The complete Soviet legend was borrowed from P.W. Guild and copied by McCartney, but is too complex to be readily reproduced without hand colouring.

P.W. Guild was appointed Chairman for the North American Committee by W.D. Johnston, Jr., in March, 1961, and W.D. McCartney was appointed Canadian representative by J.M. Harrison in May, 1964. An informal exploratory meeting was held by Guild, Allen Heyl, McCartney and S.M. Roscoe in New York, November 18, 1963. It was agreed that a publication scale of

1:5,000,000 on the same base and scale as the new tectonic and geological maps of North America would be most practical, and that a formal meeting of the North American Metallogenic Map Committee would be held in Washington prior to the December, 1964 meeting of the International Geological Congress.

In the above résumé, a great deal of discussion, questions and some reports on meetings have been omitted because the degree of eventual agreement is summarized in the accepted European legend. A major influence on North American decisions will be the small scale of 1:5,000,000 used for maps of the continent prepared for this Subcommission. (Note that large scale maps prepared by Provinces or in preparation by G.S.C. may have more flexibility of legends.

First Meeting of the North American Committee, Washington, September 28, 29, 30, 1964

Delegates and Contributors

Delegates comprised:

P.W. Guild, Chairman,	U.S. Geological Survey
Allen Heyl,	U.S. Geological Survey
Guillermo P. Salas	Director del Instituto de Geologia, CD. Universitaria, Mexico 20, D.F., Mexico
Jenaro González Reyna	Culle Diagonal No. 10 Colonia del Valle, Mexico 12, D.F., Mexico
W.D. McCartney	Geological Survey of Canada

Special Guests and Contributors included:

T.B. Nolan	Director, U.S. Geological Survey
W.D. Johnston, Jr.	President of the World Subcommission

Carlos Ruiz	Director, Instituto de Investigaciones Geológicas, Chile, and Chairman, South American Metallogenic Map Committee
Pierre Laffitte	Chairman, European Metallogenic Map Committee, 74 rue de la Federation, Paris 15
Vincent E. McKelvey	U.S. Geological Survey
Douglas M. Kinney	U.S. Geological Survey
George V. Cohee	U.S. Geological Survey
Tom Thayer	U.S. Geological Survey
David F. Davidson	U.S. Geological Survey, Denver, Col.
Thor Kiilsgard	U.S. Geological Survey
Harold M. Bannerman	U.S. Geological Survey

Summary of Presentations

Dr. Nolan welcomed the group and mentioned the continuing and growing needs of North America for mineral resources. Future sources might be more efficiently discovered by "metallogenic" research and guidance, particularly as lower-grade "ores" were needed.

Dr. W.D. Johnson, Jr., outlined his feelings as president of the World Metallogenic Map that a high degree of flexibility and independence should still be maintained, and that the European map and legend should be considered a first attempt rather than a final, fixed format for all such maps. Mineral location maps were necessarily a first step.

Dr. V. E. McKelvey, Assistant Chief Geologist, pointed out that metallogenic provinces, related geological or genetic features and actual locations of known deposits should be shown on a metallogenic map. All such information for most elements can not be shown on a single map, thus in general he favoured a map for each mineral. (The North American map for chromite discussed later by Tom Thayer was in keeping with Dr. McKelvey's views, but the unique geological control of chromite in alpine ultramafic rocks makes it an unusually suitable example.)

Metallogenic maps of other continents were discussed, namely a mineral distribution map of Asia and the Far East which I believe is published. No information is given on mineralization in Communist China. Progress on the African map under the chairmanship of Lombard and involving the Association of African Geological Surveys was mentioned.

Dr. Carlos Ruiz outlined progress of the South American committee under his chairmanship, and displayed and explained his mineral distribution map of Chile. Mineral distribution maps of the Continent are in preparation, and their geological map is near completion.

Turning to North American problems, P.W. Guild introduced some lines of thought on nation-wide metallogenic maps and emphasized the common Soviet phrase; a search for regularities in the laws governing the distribution of mineral deposits. A final metallogenic map should illustrate such regularities and help to answer the many questions of mineral genesis and distribution. Progress made in publishing nation-wide commodity maps was reviewed.

Douglas M. Kinney displayed the geological map of North America prepared under the chairmanship of E.N. Goddard at a scale of 1:5,000,000. The wash-coat proof will be displayed at New Delhi in December, 1964. The map displayed was coloured in accordance with international recommendations, but the published map will use colours more effective for North American geology. Further discussion on colours would be warranted between the available Survey Directors at New Delhi.

The new tectonic map of the southern half of North America, prepared by P. King, U.S.G.S., and received that morning, was discussed by

George V. Cohee. It also will be displayed at New Delhi. Prints will be sent to the metallogenic delegates along with a colour photograph to allow colouring here. Subdivisions of the limited area of the Canadian Shield on the map follow C. Stockwell's treatment.

W.D. McCartney complied with P. Guild's request to review metallogenic maps and research in Canada. Federal and Provincial maps were discussed and studied by the delegates. A complete text of this brief is attached as Appendix I. The practise of showing large-scale insets of crowded mining areas, as on the Ontario Mineral Map and the G.S.C. iron map, was noted with interest by the Mexican delegates.

G.P. Salas summarized the metallogenic provinces of Mexico and displayed sets of 1:1,000,000 mineral distribution maps for various elements and non-metallic minerals. They do not have a nation-wide compilation for lead, zinc and copper. (Canada has only a map of past and present producers in excess of 36,000 tons of ore on hand for these elements.)

P.W. Guild outlined the U.S. commodity maps, 24 of which have been completed. Five have been published for Alaska. The mineral spot maps on film transparency are most effective to compare with a geological underlay. Each commodity officer was given a free hand in his choice of classification, size data or other features which he wished to show. The inclusion of latitude and longitude on locality indexes has proven very useful. Some industry representatives have reported the mineral distribution maps to be extremely useful.

Tom Thayer described the chromite map of North America which was compiled from U.S.G.S. and G.S.C. sources for display at Paris in 1962. Alpine peridotites and associated gabbros were used as a base to the chromite localities. V. McKelvey considered this a good North American metallogenic map, and recommended a similar treatment for tungsten. In my opinion, most other elements would be less clear-cut in their metallogenic distribution.

Allen Heyl described his work on the platform deposits and western Appalachians, where he treats all mineralization in a selected region. Each mineralized district lies on a dome or on the flank of a larger structure.

Thor Kiilsgaard presented delegates with Mineral and Water Resource reports of Utah and Nevada prepared at the request of U.S. Senators by Federal and State geologists. (Mineral and Water Resources of Nevada, U.S. Senate, 88th Congress, 2nd Session, Document No. 87.) Eight such reports are now in press. Each gives a concise report on the geology and mineral resources of the state. Various styles of maps have been used and the format of the reports should be of interest to Provincial geologists and to G.S.C. authors currently revising Ec. Geol. Series No. 1.

David F. Davidson, Geochemical Census Branch, Denver, outlined their plans to handle analytical data from U.S.G.S. laboratories by computer and X-Y plotter. He expects the geochemical maps which would eventually result, would be very closely allied to metallogenic maps.

P. Laffitte arrived from Paris for the last day of the meeting, and gave a summary of the European Metallogenic legend. Note that numerous colours of background have been left out of the European legend to allow their use in fold belts of different ages elsewhere in the world. Size of deposits are indicated as either more than or less than 0.05% of world reserves. He projected about six coloured slides of European metallogenic maps, but each warranted more study than we could discern on the screen, and translations of legends would be needed. P. Laffitte emphasized that the proposed European legend could be almost as simple as one wished to make it; a point which I had tried to bring out the day before at an unusually active moment of the meeting.

The final discussion was restricted to P.W. Guild, W.D. Johnston, Jr., P. Laffitte, C. Ruiz, G. Salas, J.G. Reyna and W.D. McCartney.

The conclusions given on page one of this report were reached, and P.W. Guild undertook to prepare a report to the Subcommission meeting at New Delhi. W.D. Johnston would be the only one directly involved attending the meeting, but as President of the Subcommission his responsibilities suggest that someone else may be asked to present the North American report. It is hoped that Dr. Fortier will find time to represent Canada at the Metallogenic sessions.

Personal Prejudices

The European legend as proposed has incorporated many of the tectonic features of the Soviet proposals but has eliminated even the simplified Soviet proposal which would indicate the tectonic stage of mineralization. From experience in eastern Canada, the reliable dating of age of mineralization is normally very difficult or not possible. For example, massive, semi-concordant pyritic deposits in eugeosynclinal volcanic assemblages are most popularly accepted as more or less contemporaneous with volcanism. Yet many Canadian workers interpret the evidence of cross-cutting and structurally controlled mineralization, possibly caused by mobilization of pre-existing sulphides during the main orogeny, as evidence of initial mineralization related to the middle tectonic stage of major granitic intrusion. The massive (not vein) deposits of the Bathurst camp in New Brunswick, and the deposits of Anyox and Britannia, B.C., are examples where individual geologists would either use a pre-orogenic Soviet symbol or relate them to the Devonian granite at Bathurst or to the Coast Range intrusives. This personal interpretation feature of the Soviet legend has, I think, already been incorporated in error in the works of Bilibin and others, where the nation-wide compilation of "facts" from various Soviet regions has also incorporated interpretation by the geological experts of these widely-removed districts. In general, the European and probably a general Japanese acceptance of such deposits as "volcanic exhalative" is more explicit than I think we can prove, but agrees with my prejudices.

Thus, on a world-wide basis where geologists by training are subject to various biased trains of thought, the Soviet proposals for defining age of mineralization within the tectonic cycle of mobile belts has a "built-in" factor of error. It would work best only if all geologists involved in compiling the metallogenic map of the world could agree that certain types of deposit are either related to or significantly later than their enclosing rocks. I think that a metallogenic map of the world will be a convincing demonstration that such deposits are related to contemporary pre-orogenic or eugeosynclinal volcanism, rather than to the main orogenic granites which are intruded in only some regions into the eugeosynclinal environment. For example, North-Central Newfoundland and the Eastern Townships of Quebec, where Devonian granites are commonly lacking near pyritic deposits, are probably more illuminating in showing these relations than Triassic volcanics engulfed in the Coast Range intrusions. It is likely that each mobile belt can contribute various unique features as the facts are assembled.

The proposed European symbols for mineralization, even without the "genetic arrows", should serve to distinguish various types of copper mineralization, e.g.

a) concordant-massive sulphides

b) veins

c) stockworks, disseminated (porphyry copper type)

d) concordant, disseminated (cupriferous sandstone type).

When plotted, these various types should form a pattern in relation to the base map which should reflect their pre-orogenic, orogenic, or post-orogenic origin without personal interpretation. Thus I recommend the simpler European legend as opposed to the Soviet proposals for the small-scale world map trials, but I hope to assemble a larger scale map of the Canadian Appalachians incorporating most of the Soviet proposals.

It might be emphasized that metallogenic maps constructed for the World Map should contribute literature and ideas which we can use for larger scale maps prepared for Canadian use by G.S.C., Provinces or Companies.

APPENDIX

A report prepared by the author and presented at the meeting of the North American Committee, Subcommission for the Metallogenic Map of the World, Washington, D.C., September 28-30, 1964.

METALLOGENIC MAPS AND RESEARCH IN CANADA

Introduction

This report summarizes past and present Canadian activity in the field of mineral distribution and metallogenic maps and research. Principal current efforts in the Geological Survey of Canada are seeking the most meaningful parameters affecting mineralization to incorporate in such maps, lesser effort is currently directed to compiling nation-wide maps of mineral distribution. In particular, a large, mineral-rich area in the Canadian Shield is being studied, with emphasis on time relations between mineralization and various orogenic events, and a working hypothesis of mineral distribution as related to tectonic development is being evaluated in the Canadian Appalachians with encouraging results.

In Canada, mineral rights are under Provincial jurisdiction with the exception of the northern areas comprising Yukon and Northwest Territories which are directly administered by the Federal Government. Each province thus has a staff of geologists or mining engineers varying greatly in numbers but with the responsibility of administering the Provincial Mining Laws and, augmented to various degrees by Geological Survey of Canada projects, encouraging and aiding mineral resource development. Actual exploration or development is done by private companies and is not undertaken by the Federal Government and only rarely by a few provinces.

Almost all published or open files or maps on regional mineral distribution are thus produced by Federal or Provincial Departments.

A weekly trade paper, "The Northern Miner", and annual handbooks contain information on current exploration, development and mining activities. Extensive files and compilations maintained by some private companies are of course, restricted to company use.

In the Geological Survey of Canada, only about five per cent of the professional staff is primarily engaged in the study of mineral deposits, although many Survey activities improve the efficiency of private exploration. It is my opinion that as we learn more about the meaningful facets which should be incorporated in metallogenic maps, and the most suitable scales, exploration efficiency will be further increased and some fresh genetic hypotheses should result.

Metallogenic Maps, Geological Survey of Canada

A random sampling of 1842-1957

The Geological Survey of Canada, since its inception in 1842, has taken an interest in and recorded mineral occurrences encountered in the course of its duties. The wartime production of uranium from Great Bear Lake, and our present massive shipments of iron ore from New Quebec - Labrador were initially gleaned from or prophecied in early Survey publications. Our earliest mineral distribution map, for platinum, was published in 1919 (O'Neill). One of the most interesting but unpublished metallogenic maps on a geological base was compiled in 1928 by C.H. Stockwell while completing detailed mapping in the Flin Flon area of Saskatchewan - Manitoba. It indicated key mineral assemblages, such as presence or absence of pyrrhotite, pyrite or arsenopyrite, as well as the major economic elements. Today, Dr. Stockwell will explain with a quiet smile why he omitted it from his publication by saying that everyone knew in 1928 that these deposits were related to the nearest granite and he objectively plotted the occurrences on a geological base to "prove" it. When most types of deposit showed a remarkable disdain for granite distribution, he abandoned the illustration. We might all profit by realizing that the plotted, factual information remains completely valid and useful today; only the popularity of some genetic theories have changed, probably temporarily.

Nation-wide experimental compilations during 1957-1960

In 1957, Dr. A.H. Lang with a small staff began compiling nation-wide metallogenic maps of various elements, in part influenced in his approach by the formation of this Metallogenic Subcommission (Lang, 1960, p. 2). Publications include the maps for uranium, beryllium, molybdenum and iron on translucent paper for overlay on a geological map (Map 1045A) at a scale of 120 miles to the inch (1:7,603,200) (Lang, 1958; Vokes, 1958; Vokes, 1959; Gross, 1959). An additional 12 elements were compiled but have not yet been submitted for publication. A map of present and past producing mines of Canada on transparent material was prepared by A.H. Lang and the writer and displayed at the International Geological Congress in 1960. This was accompanied by an index of mine names, valuable elements, and total production figures. Simple geological types of deposits were differentiated, major elements were assigned specific colours, and a distinction was made between present and past producers. On this 1:7,603,200 scale, I might point out that one symbol may of necessity cover up to ten mines, which are listed individually in the index.

The results of this period were summarized by Lang (1960) in a paper illustrated by two metallogenic maps for major and for minor elements. Unpublished data were in part used in these maps. His bibliography provides a summary of papers on mineral distribution in various regions of Canada.

Current activities: 1960 - present

The pace of publication of these mineral distribution maps has slowed, but maps for manganese and for tin, printed on normal paper over a subdued geological base on the 1:7,603,200 scale, are in press. These are accompanied by more extensive notes on general distribution and on individual occurrences than the older series. In addition, the display map of past and present producers is being revised for submission in 1965 for publication in

1967 on a scale of 1:5,000,000. A limited number of nation-wide commodity studies are in progress on such elements as iron, nickel, copper and vanadium and these final publications will probably be accompanied by distribution maps.

During 1960, the progress to that date in national maps was reviewed and it was felt by some that the small scale and nation-wide coverage made it difficult to bring out the relations of mineralization to its geological setting. Most agreed that the series to date provided a useful and rapid index to localities and references. When the Subcommission decided that the European metallogenic map was to proceed first, with a target date for December, 1964, for a display or preliminary version, we envisaged our main activity for this Committee should begin in 1965 under a more firm frame of reference and against the background of available geological and tectonic maps now nearing completion. Two metallogenic research projects were undertaken in 1962 and 1963, but, before outlining these, I suggest we consider the important contributions of the provinces to mineral distribution maps, indexes, and published data.

Some Provincial Mineral Distribution Maps

While my comments are supposed to be confined to national coverage maps, we cannot overlook the material prepared by various provinces and displayed here. Although my comments are brief, these maps are available for study. They represent examples rather than a fully balanced sample. It is especially important to illustrate some problems of national maps at small scales when even maps at 4 miles to one inch can be rather closely packed with mineral occurrence symbols.

In the Cordilleran region, British Columbia publishes Annual Reports and indexes of mineral occurrences. The mineral distribution map represents a Provincial-Federal joint venture of 1951 (Map 1008A, G.S.C.).

Currently, they are plotting mineral distribution on a series of topographic maps at a scale of 1:250,000, or at larger scales where necessary for clarity. In addition, property descriptions are being standardized on prepared forms, and a punch card system is being devised.

Representative of regional mineral distribution maps in the Canadian Shield is the Mineral Map by the Ontario Department of Mines on a scale of 1 inch to 25 miles (1:1,584,000). Compilations of the geology of major mining camps by the Ontario Department, such as map 2046 of the Timmins district at a scale of 1:253,440, includes mineral occurrences.

The Mineral Deposits Branch of the Quebec Department of Natural Resources have prepared two manuscripts for publication on the same scale of 1 inch to four miles (Dugas, in press; Duquette, in press). The numbers on each occurrence refer to an annotated bibliography to accompany each map. The northwestern flank of the Canadian Appalachians is represented by a series of three maps with accompanying index (Duquette et al, 1963). Note that major metals, location, references and, in most cases, a brief description of each occurrence is covered in the index.

More easterly portions of the Appalachians are covered by the mineral distribution map of Nova Scotia and a rather unusual folio of small-scale maps of Newfoundland published by the Department of Mines and Resources, Newfoundland, in 1958, on a scale of 1 inch to 30 miles and now accompanied by a concise, tabublated index (Johnston, 1962).

In conclusion of this map discussion, I believe this display material might be studied and evaluated as our free time permits. It is representative of the raw materials of Canada's probable contribution to the Metallogenic Map of North America.

Metallogenic Research, Geological Survey of Canada

Numerous projects within the Geological Survey are indirectly or directly related to metallogenic studies. A continuing study of the major base-metal camp at Bathurst, New Brunswick by R.W. Boyle, a comprehensive study of one or more pyrite-copper deposits associated with volcanic rocks coordinated by D.R.E. Whitmore, and several nation-wide studies of specific elements are in progress. These contribute directly to metallogenic efforts. In my opinion, however, the work of this committee embraces the North American continent; thus the continental framework is our fundamental term of reference and all geological research which better defines this framework should aid our work.

Three regional metallogenic projects are now in progress. S.M. Roscoe continues a comprehensive study of the relations between extensive mineralization and the complex geological development of an extensive belt of well-mapped Precambrian rocks. This belt, in general, lies adjacent to and northwest of the Grenville Front. I regret that the pressure of his field season and a current European assignment prevented his preparation of a summary of current progress. A tentative table of Metallogenic epochs prepared early this year by S.M. Roscoe suggests his general temporal approach and emphasis on mineral assemblages and enclosing rocks (Table 1). Two points are well illustrated relevant to this committee; namely the limitations of proposed metallogenic legends with respect to the complex tectonic subdivisions of the Canadian Shield, and the very broad time intervals which are involved in individual epochs as compared to post-Precambrian tectonic events. By way of comparison, the full tectonic cycle in the Canadian Appalachians was completed in about 300 million years, whereas time intervals assigned to some "events", such as the Kenoran orogeny, have a suggested time range of 200 million years. In part, these larger time intervals are a function of the percentage probable errors allowed for in the dating method.

Table 1

A PRELIMINARY DEFINITION OF METALLOGENIC EPOCHS IN THE CANADIAN SHIELD

by S.M. Roscoe, 1964

UPPER PROTEROZOIC	
0.6 by.	Manitou Islands alkalic syenite complex Nb, U
MIDDLE PROTEROZOIC	
0.9 - 1.0 by.	Grenville Orogeny - Ultrametamorphism, granitization, etc. Igneous, metamorphic and metamorphosed mineral deposits U, Th, Be, Felds., Mica, Mg, Fe, Ti, Cu, Ni, Au.
1.0 - 1.2 by.	Killarnean - Keweenawan - basalt, red bed sedimentation, igneous intrusion. Cu in basalt, shale and conglomerate; Cu, Ag, U veins. Nb, Ta, Th, U, Fe, P alkalic syenite complexes. Ni, Cu in Muskox basic complex.
1.2 - 1.6 by.	Athabaska sandstone - U secondary concentration. Martin Lake (N. Sask.) vulcanism, sedimentation, deformation. U veins.
LOWER PROTEROZOIC	
1.6 - 1.8 by.	Hudsonian Orogeny - folding, metamorphism, granitization metamorphism of iron formation to form potential ore (N. Quebec). U, Th pegmatites (Saskatchewan). Au
1.7 - 1.9 by.	Animikean - Kaniapiskau etc. sedimentation and vulcanism. Cu, Pb, Zn, Au, Co, As with gabbro (may be Nipissing or Hudsonian). Ni (Manitoba - Labrador), Cu-Ni-Pt (Sudbury) with ultrabasic and basic intrusives along borders of major tectonic (age) provinces. Iron formation (Labrador). Sulphide deposits (Zn, Cu, Pb) with volcanic and sedimentary rocks (Manitoba, Saskatchewan, Sudbury and Labrador).
2.1 - by. ?	Murray - Creighton granites?
2.1 - by.	Nipissing diabase Ag-Co-As, Cu veins, Cu disseminations, U-Cu disseminations in granophyre, minor U in veins.
2.1 - 2.4 by.	Huronian sedimentation, vulcanism, diagenesis, folding. U, Th, Au, in conglomerates.
ARCHAEAN	
2.4 - 2.6 by.	Kenoran Orogeny - intensive folding, regional metamorphism and granite emplacement. Mobilization of Ni and other concentrations, metamorphism of iron formation to form concentrating ore, U, Th, Mo, Be, Li, Cs, Sn pegmatites, Au, W, Mo, Cu, Pb, Zn veins etc.
+ 2.6 by.	pre-Kenoran vulcanism, sedimentation, intrusion, folding. Au, Mo, Cu assoc. with acidic intrusives, Ni, Asb, Cu with ultrabasic and basic intrusives, massive sulphides Zn, Cu, Ag in volcanic complexes, iron formation

by. - billion yrs.

Zn - important production

D.J.T. Carson has begun a metallogenic study of Vancouver Island, B.C., as a Ph.D. thesis sponsored by the Geological Survey of Canada. Ages and petrology of intrusives and wall rocks associated with mineralization will be emphasized. The project should complement current projects by officers of the B.C. Department and G.S.C.

Dr. Guild has asked that I elaborate on my current metallogenic project in the Canadian Appalachians. This project seeks to discern the place of mineralization with reference to the complete geological development of a relatively uncomplicated, post Precambrian folded belt.

While working on the tectonic development and volcanic and sedimentary facies distribution of the Island of Newfoundland, and later when plotting and classifying some of its mineral deposits, some of the more obvious possible relationships of mineralization to tectonics were suggested. Pursuit of this line of enquiry led to Soviet papers which, when translated for me, showed they had gone much further than I had envisaged. Their generalized concepts as they applied to the Canadian Appalachians were summarized in 1962 (McCartney and Potter), and Table 2 is an unrevised summation of that paper. Since then, field studies have used these concepts as a working hypothesis with encouraging results. In terms of our committee, the emphasis on sedimentary and volcanic facies as well as age of wall rocks in this approach should be reflected in the base for metallogenic maps of orogenic belts. Indeed, I believe the overemphasis by colour on age, per se, on most standard regional geological maps, without regard for the drastically changing facies involved, is in part a misleading representation.

Figure one is a highly diagrammatic model of the tectonic development of the Canadian Appalachians. Known mineral deposits, age and facies of their wall rocks and their relative present position in the geosyncline are fairly factual. We hope to produce a more realistic cross-section of the Appalachians within a few months.

The initial and early stages of the Canadian Appalachian geosyncline in Cambro-Ordovician and Silurian time comprised limestones of the shelf facies on the northwest passing eastward into spilitic-volcanic belts of the Eastern Townships and north-central Newfoundland, with clastic sediments further to the southeast.

A good sampling of mineral deposits in the western portion of the geosyncline is afforded in southeastern Quebec, although similar deposits occur in similar environments in New Brunswick and north central Newfoundland. Beland et al (1962) provide a synthesis of most types of Quebec deposits in relation to their regional geological setting.

Principal deposits in rocks of this age include:

1) chalcopyrite-bornite in marble in the Eastern Townships (Acton and part of Sutton belts) where limestones of the shelf facies merge with mafic volcanics (Acton mine).

2) Deposits of chromite, nickel, asbestos and magnesite in ultramafic bodies (Thetford District).

3) Pentlandite in gabbro associated with ultramafics at St. Stephen, New Brunswick. This deposit is of interest because it had been considered Devonian in age. It thus appeared to clash with this metallogenic model, as formerly discussed (McCartney and Potter, 1962). Biotite-gabbro dated for me by K/Ar in G.S.C. laboratories indicated an Ordovician age of 460 m.y., an age which agrees with the working hypothesis.

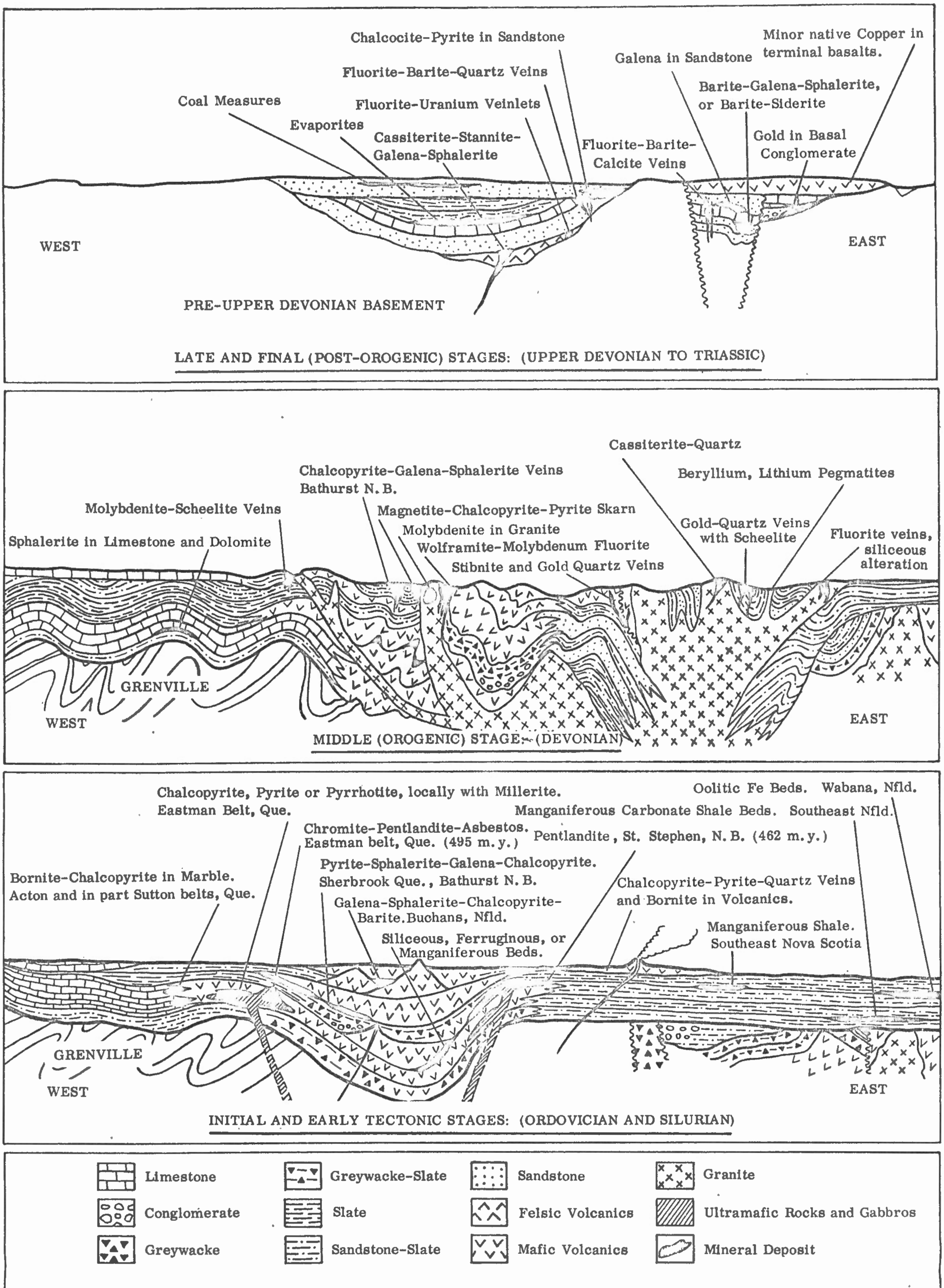
4) Semiconcordant, massive pyrite or pyrrhotite-chalcopyrite deposits in dominantly mafic volcanics with ultramafic intrusives (Eastman Belt, Eastern Townships) (Yves, Smith, Huntingdon Mines). Lead and zinc is minor or lacking, but nickel may be present (Eastern Metals) as millerite and siegenite.

TABLE 2. GENERALIZED SCHEME CF DEVELOPMENT OF A FOLDED BELT, MODIFIED AFTER A.Y. BILIBIN, (1955); A.I. SEMENOV AND V.I. SERPUKHOV, (1957); AND CTHERS

PHASE	APPAL-ACHIAN AGE	TECTONIC MOVEMENTS	SEDIMENTARY AND VOLCANIC ROCKS	TYPE OF INTRUSIVE ROCKS	NO.	COMPOSITION OF INTRUSIVE ROCKS	ENDOGENOUS DEPOSITS	LOCATION	EXAMPLES CANADIAN APPALACHIANS	EXOGENOUS DEPOSITS	EXAMPLES CANADIAN APPALACHIANS
FINAL	PENNSYLVANIAN-TRIASSIC	Weak oscillations, some faulting	Terrestrial sedimentary rocks, pyroclastics, flows								
			Basaltic, andesitic, and rhyolitic volcanic rocks	Commonly absent			Pb, Zn, Cu, F, Ba, Fe (Hg, Sb)	In depressions far from border of mobile zone	Not recognized	Iron oxides and hydroxides	Northern N.S., and Shippigan, N.B.
					F-2	Diabase and labradorite-porphyry, quartz-porphyry granosyenite-porphyry		In activated margins of platform	Walton, N.S.; much barite occurs elsewhere in areas of Carboniferous folding		
			Molasse		F-1	Granodiorite-porphyry, monzonite, diorite, gabbro, pyroxenite, peridotite, alkaline gabbros, nepheline syenites, syenites, granites, trachy-rhyolites, trachy-andesites	Ba, Fe, Ag, Zn, Pb Ni, Bi, Cu, Co, Au, As F			Cu and U sandstones	
LATE	MISSISSIPPIAN	Epirogenic movements (crustal adjustment), formation of great faults	Multicoloured continental and lagoonal formations	Small intrusions, commonly sub-volcanic, (stocks, sills, dykes, laccoliths)	L-6	Dacites, andesites, rhyolites, (commonly absent)	Hg, Sb, As, (W)	Within blocks and late depressions	Not recognized	Coal	Minto, N.B. Sydney, N.S.
			Salt, gypsum		L-5	Alaskite, granosyenite, granite-porphyry, and syenite-porphyry. Diorite, monzonite, granodiorite, granite	Pb, Zn, Ag, (As)	Late internal and border depressions	Not recognized	Salt	Malagash etc.
					L-4	Granodiorite-porphyry, monzonite-porphyry	Al, Mo, Cu, Au			Oil and gas	Moncton, N.B.
			Petroliferous rocks		L-3	Plagiogranite, granite, granosyenite, granite, diorite, gabbro, diabase. In some places alkali-pyroxenites, shonkenites and monzonites	Fe, Cu, Co			Coal	
					L-2	Granite, granodiorite, diorite, and porphyrytic equivalents. In some cases comprise gabbros and diorites, (not accompanied by mineralization)	Pb, Zn, Sn, Ag, As (W, Mo)	Late internal and border depressions	Mt. Pleasant, N.B.	Iron oxides Carbonates Hydroxides	Londonderry
			Terrestrial sedimentary rocks, carbonates		L-1	Granites, granodiorites, quartz-syenites, quartz-diorites, and porphyritic equivalents. Quartz-porphyry and albitophyre	Mo, Au, Cu, (Pb, Zn) As, W, Sb, Hg, Co	Late internal depressions	Not known		
MIDDLE	DEVONIAN	Uplift and intense folding	Erosion	Batholiths	M-3	Ultra acid potassic granites, alaskites, aplites, pegmatites	W, Mo, Sn, Bi, F Li, Be, Ta, Nb	Within or on the borders of structures of diverse mobility, near borders of central geanticlines	Burnt Hill, N.B.; Square Lake, N.B.		
			Flych and flychlike rocks in isolated basins, calcareous shales and limestones, acid to intermediate volcanic rocks		M-2	Granodiorite, biotite-granite, plagiogranite, quartz-diorite	W, Mo, Au, (As, Co) Sn, Fe		St. Lawrence, Nfld.		
		Slight subsidence		Small intrusions	M-1	Quartz-diorite, diorite, diorite-porphyry	Au, (W, As, Sb, Mo)		Nova Scotia gold-quartz-scheelite veins	Iron oxides	Torbrook, N.S.
EARLY	ORDOVICIAN-SILURIAN	Uplift	Erosion	Small intrusions	E-5	Andesite, trachyte, phonolite, rhyolite	Au, Ag		Buchans, and numerous Cu-pyrite deposits in Notre Dame Bay area of Newfoundland		
		Localized folding	Lithic greywacke, shales. Cherts, (basic volcanic rocks not as abundant as in initial phases)	Small stocks or batholiths	E-4	Granodiorite, diorite, granite, and porphyritic counterparts	Cu, Pyrite Ag, Pb, Zn Au, Ba				
					E-3	Quartz-albitophyre, albitophyre, quartz-porphyry and syenite porphyry					
		Subsidence			E-2	Gabbro, diorite, tonalite, plagiogranite	Magnetite-Cu skarn (Co, As)		Not known		
					E-1	Gabbro, monzonite, granosyenite, nepheline syenite, syenite	Au, As, W (scheelite) Cu, Mo				
INITIAL		Deformation localized near great fractures	Predominantly thick basic volcanic flows. Sedimentary rocks include siliceous shales, jaspers, tuffs, greywackes, and minor calcareous rocks.	Chains or belts of bodies of various size and shape, commonly sills or dykes	I-2	Gabbro-norite, gabbro-diorite, pyroxenite, peridotite and dunite	Ti, Fe, Cu, Ni, Cu	Junction of marginal and initial depressions with platform. Also on margins of internal geanticlinal uplifts	Numerous small occurrences in the Eastern Townships and Newfoundland	Iron oxides in basins far removed from mobile zone	Wabana
					I-1	Peridotite, pyroxenite, dunite, serpentinite, gabbro-peridotite, hornblendite, subordinate gabbro, diorite, seldom quartz-diorite, and plagiogranite	Pt, Cr, Fe, Ti, Ni Asbestos			Fe, Mn cherts	Notre Dame Bay, Nfld.

G.S.C.

W.D. McCartney and R.R. Potter, February, 1962



AN IDEALIZED METALLOGENIC MODEL OF THE CANADIAN APPALACHIANS, DEPICTING SOME KNOWN TYPES OF MINERAL OCCURRENCES IN RELATION TO THEIR TECTONIC SETTING AND THE FACIES AND APPROXIMATE AGES OF THEIR WALL-ROCKS

W. D. McCartney
March, 1964

Figure 1.

5) Slightly younger acidic and mafic volcanics enclosing semi-concordant, massive pyrite-galena-sphalerite-chalcopyrite bodies (Bathurst, New Brunswick, and the Sherbrooke Belt, Eastern Townships).

6) Considerably younger pyroclastic and volcanic rocks enclosing massive barite-galena-sphalerite-chalcopyrite as at Buchans, Newfoundland.

7) Chalcopyrite, pyrite-quartz veins and chalcopyrite and bornite in amygdules in mafic Silurian volcanics on the Mascarene Peninsula, southern New Brunswick.

In addition, the important chalcopyrite-molybdenite skarn deposits at Murdochville, Quebec, appear to have formed near the end of this early tectonic stage. Selected, biotite-feldspar-porphyry associated with mineralization collected by the writer has been dated as 390 m.y. (R. Wanless, personal communication). This appears to clarify the problem as discussed in the earlier paper (McCartney and Potter, 1962, p. 84), although some aspects of the mineralization resemble porphyry copper deposits which commonly belong in the post-orogenic tectonic stage. Pyrite, chalcopyrite, molybdenite and native bismuth are found in the skarn zone and in sericitized quartz-feldspar porphyry dykes.

Sedimentary deposits known in these beds include cherty iron and/or manganese beds in the eugeosynclinal environment, and manganiferous shales and oolitic iron deposits in the sedimentary rocks to the southeast.

The orogenic or middle tectonic stage is represented by the Acadian orogeny during Devonian time. Elements such as tin, tungsten and molybdenum form discrete deposits (as opposed to accessory traces) for the first time in the geosyncline's history. These deposits may be a function of the first appearance in the geosyncline of anatectic granites resulting from a concentration of tin in the sediments and subsequent downbuckling of the sedimentary pile. Such genetic questions can be suggested by this tectonic approach, and regional geochemical-stratigraphic studies could be suggested to seek supporting evidence.

The principal deposits associated with this stage include:

1) Molybdenite-quartz veins associated with granitic rocks. An interesting example near the St. Cecile stock in the Eastern Townships of Quebec contains molybdenite and minor stannite and scheelite in a gangue of quartz, lesser feldspar and minor muscovite gangue. Selected muscovite samples from the vein collected by the writer recently yielded an age of 360 m.y. (R. Wanless, personal communication) and the nearby stock had formerly been dated as 362 m.y. (Lowden et al, 1960, p. 37).

2) Gold-arsenopyrite-quartz veins occur in Ordovician sediments near Devonian granites in southern Nova Scotia and southern New Brunswick. Locally, as at West Gore, Nova Scotia and Lake George, New Brunswick, stibnite-quartz veins occur and may be similar in age.

3) Cassiterite is present at New Ross, Nova Scotia associated with granite and may occur elsewhere.

4) Wolframite in quartz veins with associated molybdenite occurs at Burnt Hill and Square Lake, New Brunswick associated with a late facies of a large granite body.

5) Pegmatite deposits, including beryllium and lithium-bearing varieties, are known in southern Nova Scotia.

6) Fluorite veins accompanied by silicification of their granite wall rock are mined at St. Lawrence, Newfoundland.

During the post-orogenic tectonic stages, Late Devonian, mainly Carboniferous and Triassic sediments up to 20,000 feet thick were deposited in downfaulted and downwarped basins. As in other mobile belts, post-orogenic fault movements and tilting, with some folding and epeirogenic movements, occurred during sedimentation. These movements are reflected in the common, rapid facies changes in clastic sediments, both locally and regionally.

Post-orogenic rhyolitic volcanics occur in southern New Brunswick and Cape Breton near the base of the Carboniferous section. They are accompanied by stannite-molybdenite-lead-zinc mineralization at Mount Pleasant, and by fluorite-uranium veinlets in rhyolite at Harvey Mills, New Brunswick. However, post-orogenic igneous activity is comparatively sparse in the Canadian Appalachians compared to many mobile belts, and mercury, epithermal gold and post-orogenic porphyry copper deposits may possibly be weakly developed but more likely are not present.

Fissure veins of fluorite-barite-calcite cut Mississippian rocks at Lake Ainslie, Nova Scotia, and a vein of fluorite-barite-quartz cuts and in part replaces red Upper Devonian shale at East Memracook, New Brunswick.

The plateau-type Triassic basalts contain minor occurrences of native copper.

The remaining deposits characteristic of sediments in these late and final tectonic stages are well represented, may be as yet largely undiscovered, are, or are in part, controlled by sedimentary, stratigraphic, and related factors, and have very large tonnage potential.

Coal measures are widespread in Pennsylvanian sediments. Modest amounts of oil and gas have long been produced from Mississippian beds near Moncton, New Brunswick, and numerous oil showings are known.

Evaporites are especially widespread in Mississippian Lower Windsor beds, commonly associated with limestone. Gypsum and salt are being produced, and potash minerals occur in the salt mines of Malagash and Pugwash, Nova Scotia. The known salt domes have not been fully investigated and exploration for potash seems to have been neglected in the past.

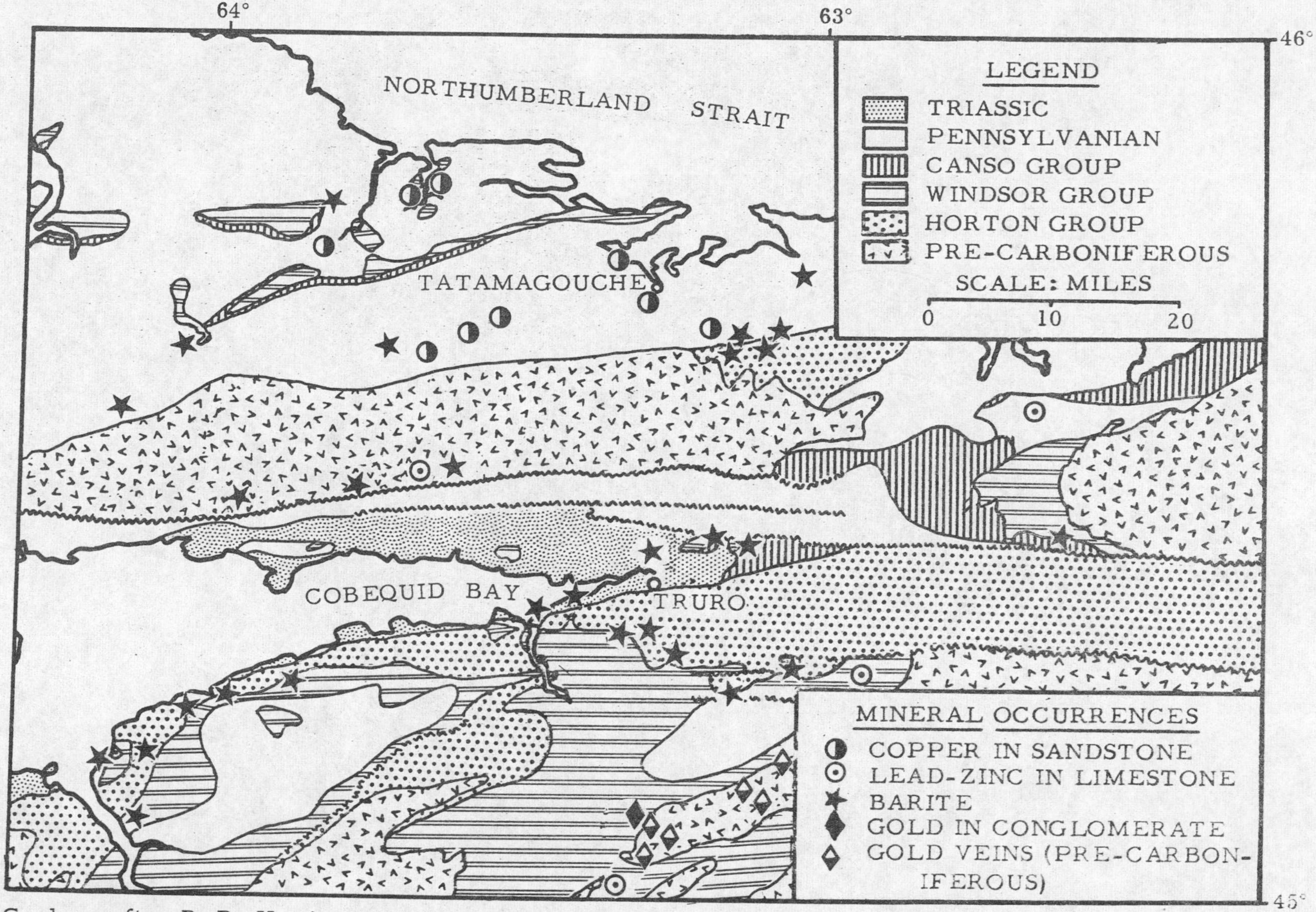
Low grade gold ore was mined at Gays River, Nova Scotia in a Mississippian polymict, basal conglomerate with numerous slate pebbles and boulders. There is little doubt that the deposit represents a fossil placer concentration and that the gold was derived from nearby gold-quartz veins in the Meguma sediments; an interpretation strengthened by Stevenson's report of indicated palaeocurrents in the required direction. Quartz pebble conglomerate rather than polymict conglomerate, where encountered in Mississippian beds in a near-basal position, could be of better grade and should be checked for gold, tin, tungsten and radioactive minerals.

Two types of mineralization of demonstrated or potential economic importance remain to be mentioned and may be interrelated. These are, first, the suite of barite-lead-zinc, barite-siderite, lead-zinc and probably the recently discovered celestite deposits in Lower Mississippian Windsor limestone, characterized by Walton, Brookfield, Smithfield, and Loch Lomond, Nova Scotia, and second, copper-uranium or lead deposits in grey sandstones or siltstones in the overlying red-bed sequences. The latter types are represented by copper-uranium occurrences in sandstones near Northumberland Strait, and the large tonnage of stratified, lead-bearing, possible ore at Salmon River, Nova Scotia.

Figure 2 shows the actual distribution of some of these deposits in Carboniferous beds in central Nova Scotia. In the south we have the pre-Carboniferous gold veins shown as open diamonds which were available to contribute to the gold-bearing Mississippian basal conglomerate at Gays River, shown as the solid diamond.

The stars indicate barite occurrences and deposits, with mineralization controlled by the well known lower contact of the Windsor limestone, and by major and minor faults and tight folds. Lead-zinc at Smithfield has the same stratigraphic and structural controls. Galena and sphalerite are disseminated in undisturbed Windsor limestone at Gays River.

Some preliminary heavy mineral studies along one major fault suggest that faults without favourable stratigraphy are not significantly mineralized.



Geology after R.D. Howie and L.M. Cumming, 1963

Figure 2

Barite also occurs in Lower Mississippian conglomerate near its contact with overlying, finer grained Pennsylvanian beds. The Windsor limestone is lacking in the section. Thus a favoured stratigraphic position for barite includes, in these cases, the contact of coarse clastics with overlying finer grained sediments, especially with Windsor limestone.

Grey sandstones containing copper-uranium-pyrite mineralization are shown in circles in figure 2 and lie in a red-bed sequence of Pennsylvanian arkoses and mudstone. Delicate replacement of coal fragments by pyrite is common, and chalcocite and minor covellite with uranium are associated with these.

Conclusion

This rapid review of the terms of reference of the Appalachian study is thought to be applicable to this meeting because it explains my growing conviction that the base selected for a metallogenic map is of critical importance, yet background features related to mineralization of, for example, the orogenic (middle tectonic) stage may have very little bearing on most post-orogenic mineralization. Mineralization in post-orogenic cover sediments should be plotted on a background embodying both obvious and subtle facies changes, should distinguish between oligomict and polymict conglomerates, should show and differentiate between those faults active during and after sedimentation (especially major transverse faults), should suggest depth to basement and basement topography, and should indicate palaeocurrents and the nature and position of land masses existing during sedimentation. Dr. Guild has called this meeting in part to see if we can answer the questions of how to distinguish between what "should" be shown in the base and what is practical with regard to available data, available ready-made or readily modified bases, available man-power and time, our anticipated publication scale and the necessary compromises required where deposits of widely differing origin are displayed on a common base. The Japanese maps prepared by Y. Sekine and his colleagues, 1957, 1960, where each of four maps is devoted to specific time intervals, is one possible way of changing the base to meet changing conditions of mineralization with time, but such partial solutions would seem more practical for larger scale maps than that for which we are responsible.

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