

Project 750051: Uranium Reconnaissance Program

E. M. Cameron

Resource Geophysics and Geochemistry Division

Introduction

The Federal-Provincial Uranium Reconnaissance Program commenced in 1975; at the time of writing the second field season is closing. The program consists of complementary airborne radiometric and geochemical surveys. The former is a common method used for all environments, i. e., the only restrictions are that the terrain be suitable for low-level flying and that surface variations in radioactivity are measured. By contrast, a number of geochemical methods are being employed in the program, each of which is considered optimal for the specific geological and physiographic environment. This paper briefly discusses these geochemical methods, their implementation, and the apparent response

they give to uranium mineralization. Although the discussion will be largely concerned with the search for uranium, the geochemical component of this program attempts to outline areas with a potential for a variety of mineral commodities.

During 1975, work was concentrated mainly on areas within the Canadian Shield using methods of lake sediment reconnaissance that had been developed in previous years by the Geological Survey and others in the Northwest Territories (e.g. Allan *et al.*, 1973; Cameron and Durham, 1974), Newfoundland (e.g., Davenport *et al.*, 1975; Hornbrook *et al.*, 1975), Saskatchewan (e.g. Arnold, 1970; Hornbrook and Garrett, 1976) and Ontario (e.g. Coker and Nichol, 1975). Also a trial well water survey of parts of the

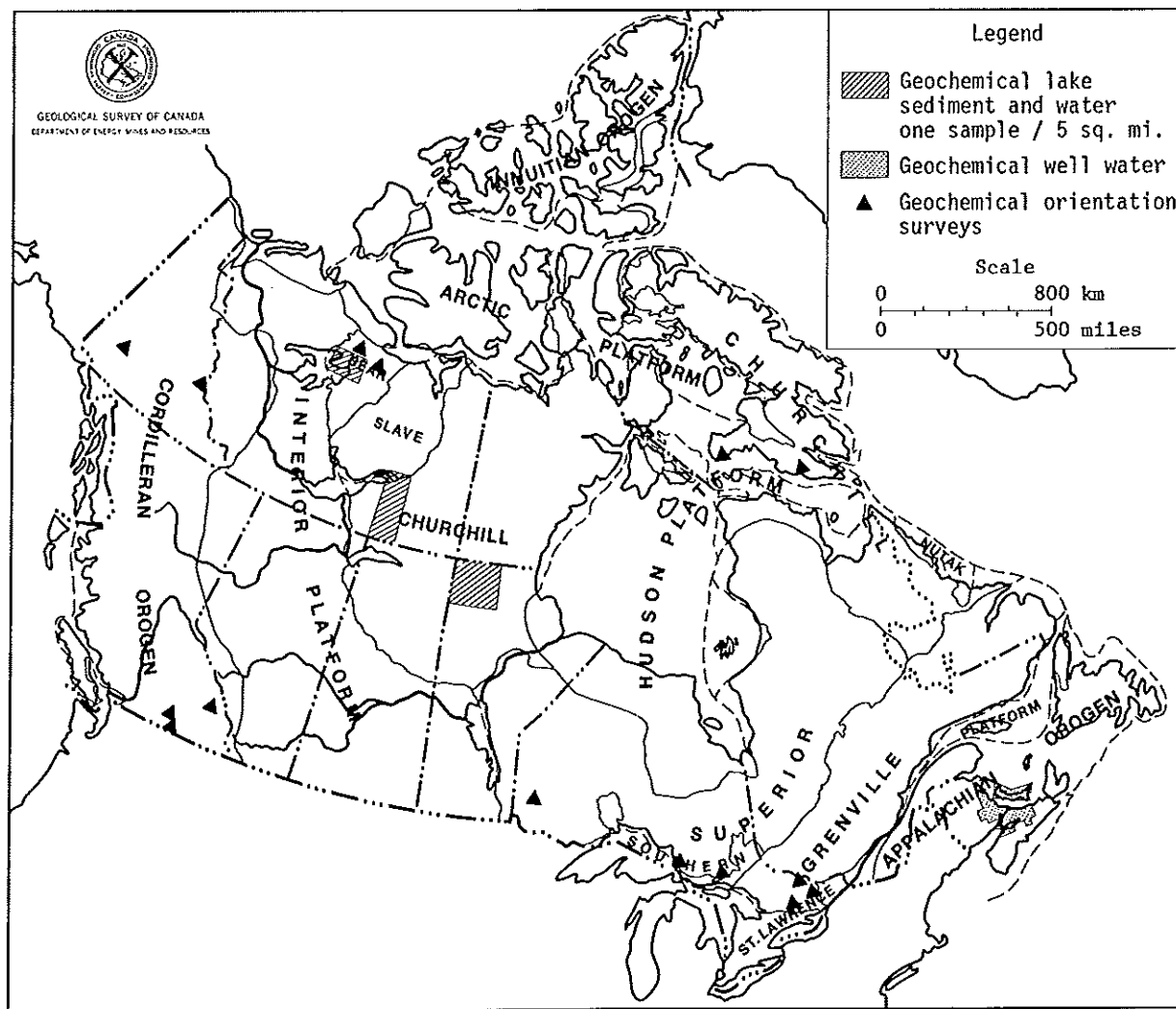


Figure 44.1. 1975 geochemical surveys, Federal-Provincial Uranium Reconnaissance Program.

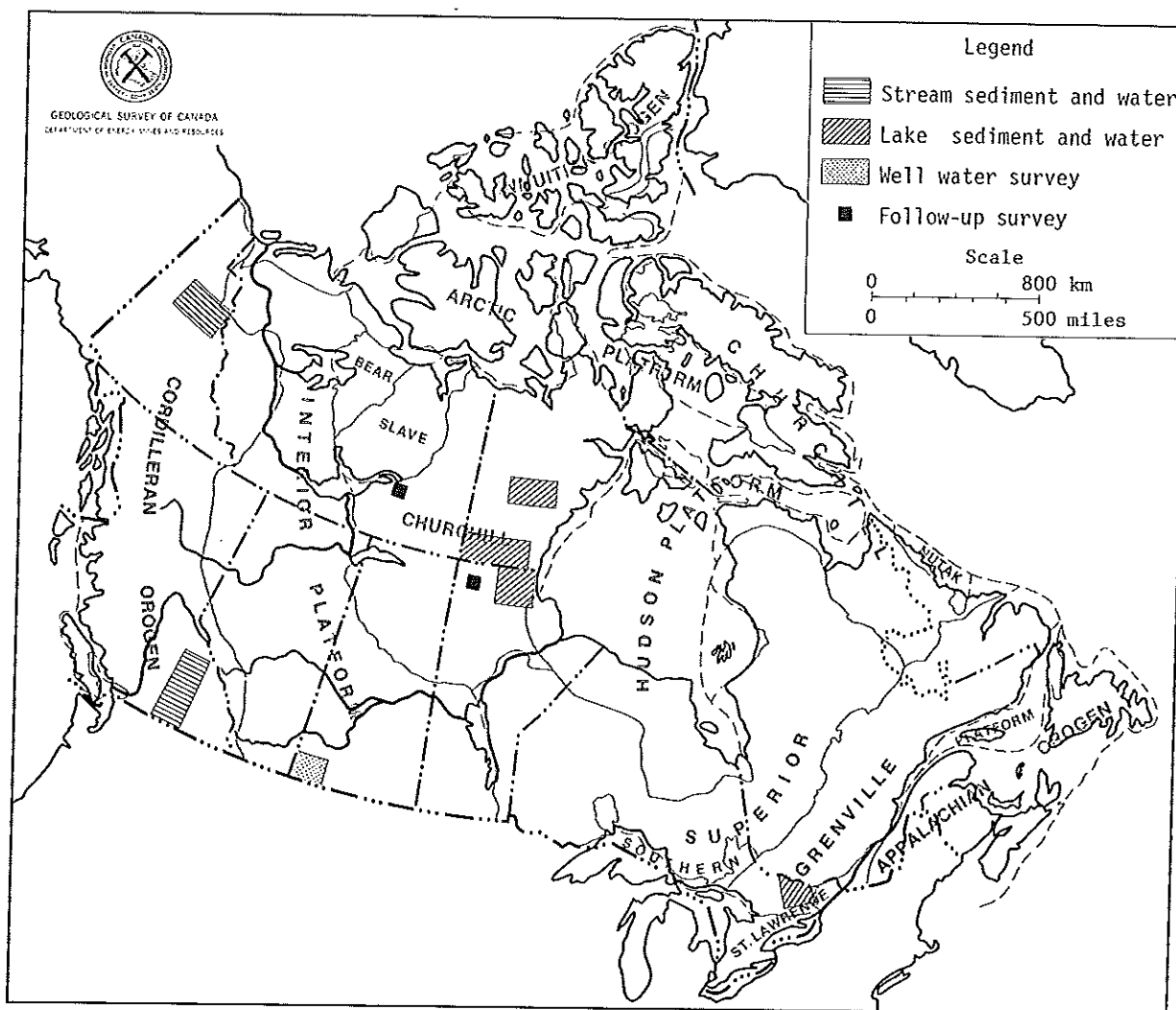


Figure 44.2. 1976 geochemical surveys, Federal-Provincial Uranium Reconnaissance Program.

Carboniferous Basin of the Maritime Provinces was carried out (Dyck *et al.*, 1975, 1976). In a number of areas where full-scale reconnaissance surveys were anticipated for future years, orientation surveys were performed in 1976, including work in Ontario (Coker and Jonasson, 1976), Baffin Island (Maurice, in press), British Columbia (Ballantyne and Bottriell, 1975), the Yukon Territories (Gleeson and Jonasson, 1975) and the Great Bear Lake area (Durham and Cameron, 1975). These various 1975 activities are summarized in Figure 44.1.

The 1976 geochemical reconnaissance program can be subdivided as follows: -

(a) Further lake sediment and lake water reconnaissance in the Canadian Shield, specifically in southeastern Ontario, northern Manitoba, southern Keewatin, and the Baker Lake area. The total area covered is 44 000 square miles.

(b) Follow-up investigations in areas where lake sediment reconnaissance was carried out in 1975.

(c) Large-scale stream sediment and water reconnaissance in southern British Columbia and the Yukon, totalling 29 000 square miles. The Yukon work included a substantial amount of further orientation surveys.

(d) The application of the well water techniques used in the Maritime Provinces in 1975 to a 6000 square mile area of southwestern Saskatchewan.

The locations of these various activities are shown in Figure 44.2. Reports 45, 47, 48, 49, and 50 of this publication describe the 1976 work of the Uranium Reconnaissance Program. Report 46 presents results of the 1975 orientation studies in the Yukon.

National Geochemical Reconnaissance

In a national program of this type it is important that the data are comparable from year to year and between different areas of the country. To achieve this it is necessary to establish consistent sampling,

sample preparation, analysis, and data presentation methods and to monitor these with effective quality control procedures. The approach will be applied to a variety of federal and federal-provincial geochemical programs, not only the Uranium Reconnaissance Program. The term National Geochemical Reconnaissance (N.G.R.) is applied to data obtained by these consistent methods.

It should be recognized that these N.G.R. data, as well as serving the immediate purposes of mineral exploration and resource evaluation, provide an important national source of information that can be applied to environmental, agricultural, or geological investigations. For example, in 1976 the Inland Waters Branch of the Department of the Environment commenced studies of natural toxic metal anomalies based on N.G.R. data.

N.G.R. surveys are subdivided into five district phases: sample collection, sample preparation, analysis, data compilation and cartography, and quality control. In 1975, at the start of the program, the sampling of lake sediments and the analysis were carried out by Canadian contractors, with the Geological Survey responsible for the other three phases. In 1976, sample preparation was completed under contract also and by 1977 it is anticipated that, in addition, data compilation and cartography will be by contract. The Geological Survey of Canada will continue to be responsible for quality control, which is carried out at each phase of the work.

The primary form of N.G.R. data release is 1:250 000 scale element symbol maps and data listings, both printed and on magnetic tape. In response to requests from industry for a cheap and readily stored format for these data, the maps of the 1976 surveys will also be available on microfiche. The release of this primary information has been made in the spring of the year following field work, in order that the data may be used by mining companies for summer field programs. As the program expands, with further provinces joining, it will probably be necessary to spread the release of data over a longer period of the year. As well as 1:250 000 presentation, 1:1 000 000 element compilation maps will be published as data accumulate for large areas of the country.

The cost of geochemical surveys for the Uranium Reconnaissance Program was originally budgetted at \$10-\$15 square mile. This provided, for instance, a sampling density of 1 per 10 square miles in the Canadian Shield. Through increased efficiency, particularly in sampling, it has been possible to maintain this cost during the 1975 and 1976 operations, while, in the Shield, increasing the sampling density to 1 per 5 square miles. This includes the analysis of 13 components in sediment and water samples. Studies are presently being carried out to determine optimum sampling intervals for various indicator elements in different environments, using the 1975 and 1976 N.G.R. data. This may cause a change in the sampling density employed in 1977 and subsequent years and a more flexible approach to sampling density, based on the requirements of the particular terrain.

The methods used in the N.G.R. surveys have been devised and implemented by E.H.W. Hornbrook, R.G. Garrett, and J.J. Lynch. The work is carried out under their direction.

Follow-up Studies

An important part of the Uranium Reconnaissance Program is to monitor the effectiveness of the program and to gain a better understanding of the processes that lead to the development of geochemical and radiometric anomalies. With this information it will be possible to reach the most appropriate balance between radiometric and geochemical methods; to upgrade the reconnaissance methods; and to provide guidelines on the interpretation of the data.

Much of this knowledge hopefully will come from the mining companies that use the data in their exploration programs. In addition, there will be a limited amount of follow-up work by the Geological Survey and by the provincial departments particularly during the early years of the program. This will allow study of not only anomalies related to mineralization of possible economic interest but also anomalies related to variations in bedrock composition, or to features of the environment.

In 1976 the most comprehensive follow-up study was in northwestern Manitoba in areas surveyed by airborne radiometric and lake sediment reconnaissance in 1975. This involved complementary geochemical, geophysical, geological and surficial geological investigations directed by W.B. Coker, B.W. Charbonneau, and L. Dredge. A similar study, under the direction of Y.T. Maurice, was carried out in the Nonacho belt, Northwest Territories, to follow-up lake sediment reconnaissance also completed in 1975. Both these operations had field laboratory facilities, that are considered essential for geochemical follow-up.

Many of these detailed studies were carried out in areas that had been acquired by mining companies as claims or permits as a result of the release of the 1975 reconnaissance results and earlier work. By arrangement with these companies, publication of results from these areas will be delayed. Thus specific details of the field data are not contained in Reports 49 and 50 of this publication. However, both reports present preliminary findings of a general nature.

Geochemical Reconnaissance Methods for Uranium

The use of centre-lake sediments for geochemical reconnaissance in the Shield depends on two important factors: one logistical, the other geochemical. The first is that samples may be collected routinely, rapidly and economically by helicopter. The second is that uranium is dispersed widely in solution from a point source of mineralization, before being precipitated in the sediments of a lake. The Shield is an area of generally low relief where immobile elements, such as lead, can only travel short distances along the lake drainage systems (Cameron, 1975). If a geochemical exploration method was to rely on mechanical dispersion,

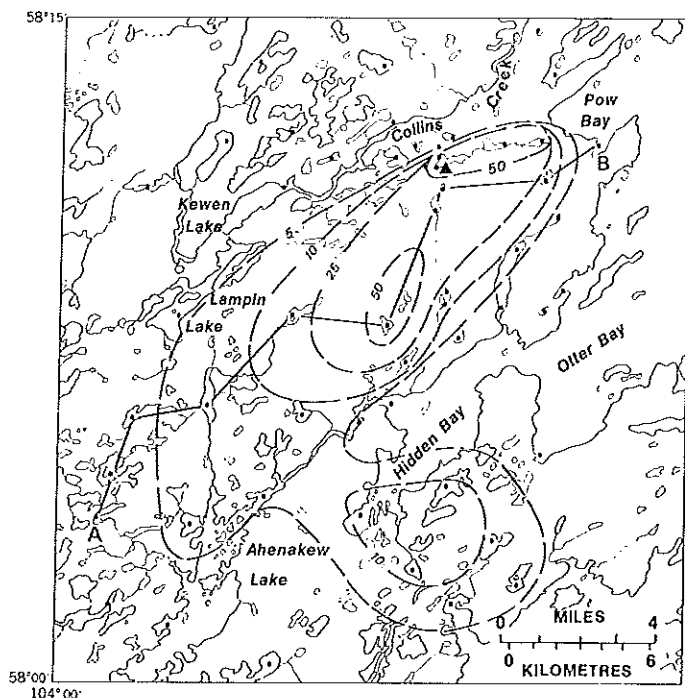


Figure 44.3. Uranium in lake sediments, as parts per million, Rabbit Lake area, Saskatchewan. Uranium deposit shown by solid triangle.

close sampling intervals would be required; intervals that would be prohibitively expensive for reconnaissance purposes. Fortunately, uranium is a highly mobile element in the secondary environment. It retains the mobility at the near-neutral pH values that are characteristics of most Shield lakes. This is in contrast to the behaviour of many heavy metals that become less mobile with increasing pH. Notwithstanding the above, samples are also analyzed for immobile elements in the Shield Uranium Reconnaissance Program. This is because such elements, derived from widespread sources, such as rock units of distinctive composition, or till sheets, rather than point sources, can provide useful information at reconnaissance-level sampling.

If the concept that anomalous levels of uranium in lake sediments have been transported in solution is correct, there should be a relatively close correlation between uranium in sediments and uranium in the waters of the same lakes. In many cases this is true. For instance, in the area of the Rabbit Lake uranium deposit, Saskatchewan, a close relationship exists between the anomaly patterns for uranium in the two media (Figs. 44.3 and 44.4; Table 44.1). A detailed description of these data are given by Cameron and Ballantyne (in prep.). In carbonate-rich alkaline environments, uranium forms highly soluble complexes. This may delay the precipitation of uranium in the bottom sediments and weaken or destroy the correlation between the uranium content of the two media (Dyck, 1974; Cameron and Hornbrook, in press; Maurice, in press).

In view of the above discussion it is reasonable to ask why waters are not the primary sampling media in the Shield because they can be collected more rapidly and economically than lake sediments. In part the answer is demonstrated by examining the anomaly patterns for the Rabbit Lake area (Figs. 44.3 and 44.4). The anomaly for uranium in water is more restricted in areal extent than the sediment anomaly. The water anomaly is apparently truncated by the detection limit of the fluorimetric method of analysis of 0.05 ppb U. Although this is of little importance in the case of the Rabbit Lake area because of the extent and intensity of both anomalies, it may be important in places where the signal given by mineralization is much weaker.

The uranium content of lake waters in the Shield is generally low as is shown by the two examples given in Figure 44.5; both are from areas that are reasonably prospective for uranium mineralization. The vast majority of waters must be measured at the parts per trillion level, rather than in parts per billion. While this is possible at the research level, proper procedures for the collection, preservation and analysis of thousands of samples have not yet reached the stage that we feel confidence in using waters as the primary sampling medium in the Shield. This may change with greater sophistication of the methods. For elements that are rather less mobile than uranium in the surface environment (e.g. Cu), the use of sediments is even more important.

Only a small part of the variation shown on geochemical reconnaissance maps for uranium is due to the influence of potentially economic uranium mineralization. The great majority of the variation is due to compositional differences in the rocks of an area

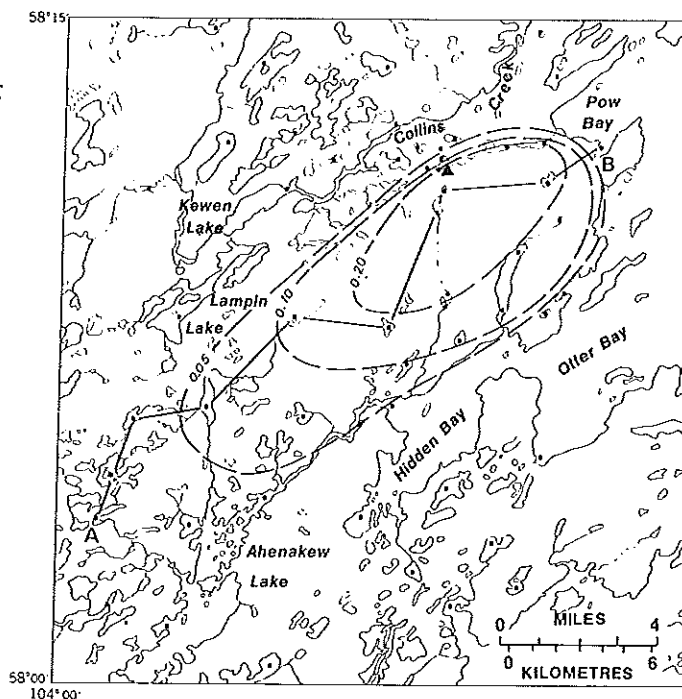


Figure 44.4. Uranium in lake waters, as parts per billion, Rabbit Lake area, Saskatchewan.

Table 44. 1

Uranium in lake sediments and lake waters
along the profile A-B, Rabbit Lake area,
Saskatchewan (see Figs. 44. 3 and 44. 4)

	U, ppm in sediments	U ppb in waters
A	3	0. 04
	3	0. 04
	3	0. 04
	8	0. 08
	14	0. 14
	83	0. 16
	43	0. 44
	32	0. 24
	11	0. 27
B	4	0. 04

and the surficial cover. It is one of the purposes of the follow-up studies to classify the various types of anomaly. Some general conclusions may be drawn from the 1976 studies and from earlier work (e.g. Dyck and Cameron, 1975). A distinct lake sediment and water anomaly may be derived from a point source of uranium mineralization (Fig. 44.6a). Alternatively, an equally strong anomaly may be generated by a weaker, but more widely distributed source of labile uranium (Fig. 44.6b). Such a source may often be granitic or pegmatitic terrain enriched in uranium. Because uranium is highly mobile relative to most of the other components of the granitic rock (e.g. Si, Al, K, Th), there may be considerable enrichment of uranium in the lake sediment compared to the source. Apparently enrichments of an order of one magnitude are not uncommon. A similar phenomenon has been shown by Allan *et al.* (1973) for zinc and copper in areas of sulphide-veined rocks.

Much attention has been devoted recently to concepts of the genesis of uranium deposits by surface and near-surface leaching of uranium than transportation and concentration. The resulting deposits are located near unconformities (e.g. Knipping, 1974). The processes upon which geochemical reconnaissance for uranium in the Shield depends are the same as those required for the genesis of these deposits. The present-day process depicted in Figure 44. 6b mimics the development of certain unconformity-related uranium deposits. Recent work in southern British Columbia shows that this analogy is not too far fetched (Smee and Ballantyne, 1976). Uranium occurs at the Fuki-Donen deposit and related prospects in conglomerates at the base of a Tertiary basalt sequence. The conglomerates rest on Cretaceous granites and granodiorites, samples of which contain readily leachable uranium. Measurements of stream waters derived from areas of these granitic rocks contain anomalously high contents of uranium. Because some of these streams drain through the permeable conglomerates they may have contributed in the recent geological past, or even at present, to the development of the uranium mineralization (Fig. 44.6c).

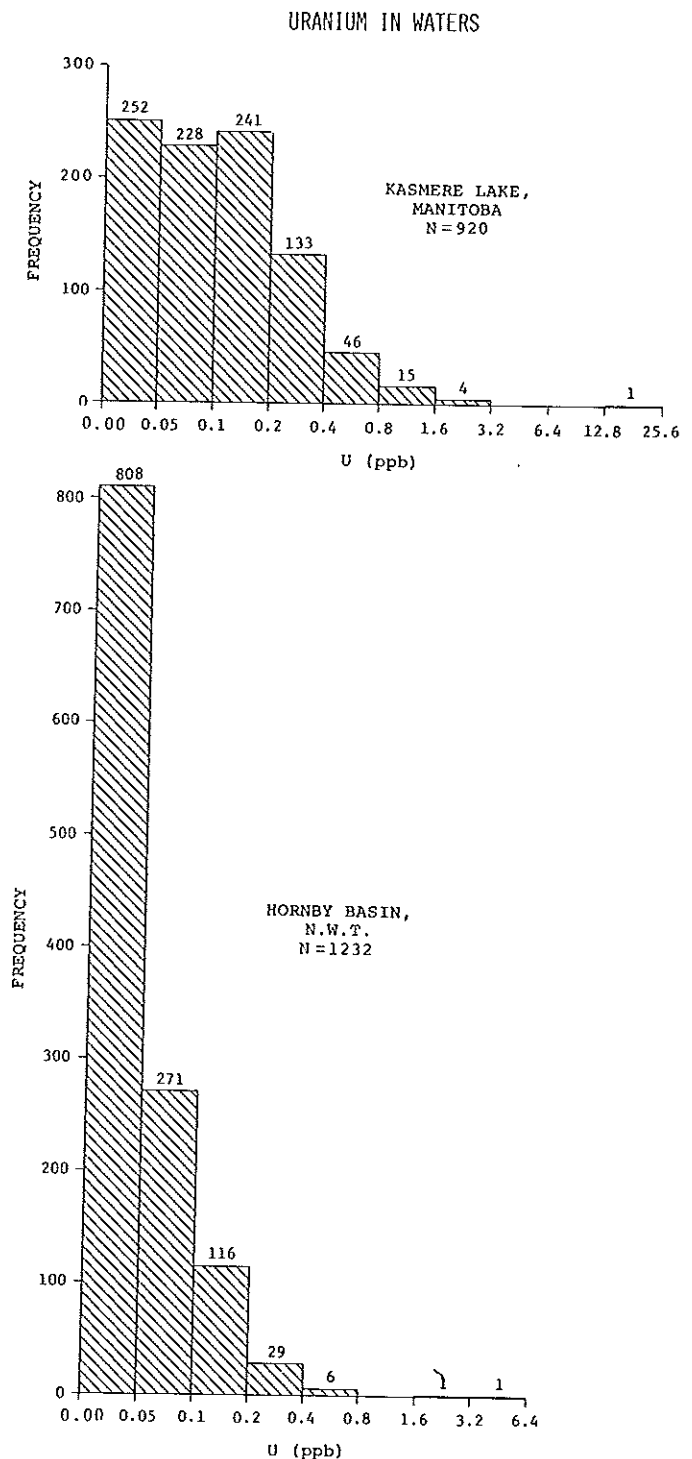


Figure 44. 5. Histograms of the distribution of uranium in surface lake waters from the Hornby basin, Northwest Territories, and from the Kasmere Lake map-area, Manitoba.

Anomalies derived from widespread source areas of labile uranium require careful interpretation. A few of these enriched rock bodies may, of course, contain sufficient local concentrations to warrant

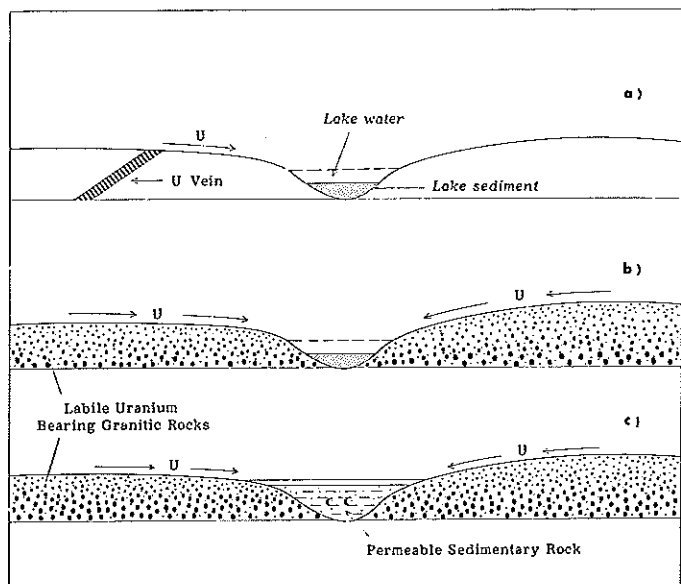


Figure 44.6. Derivation of uranium anomalies in lake sediments and waters from concentrated (a) and dispersed (b) sources. The same processes of weathering and dispersion can lead to the formation of ore deposits (c).

exploration. However, all such bodies are potential sources for the secondary leaching, dispersion and concentration of uranium. The information provided by the geochemical data must be integrated into the total appraisal of geological environments suitable for uranium ore genesis.

The concepts of geochemical reconnaissance for uranium discussed above is biased to the Canadian Shield environment, where the Geological Survey recently has had its greatest amount of experience. However, these concepts can readily be extended into the other environments in which the Uranium Reconnaissance Program is active.

In the Cordillera both mechanical and hydromorphic dispersion in streams may be considered as bases for geochemical reconnaissance. The high relief allows extensive mechanical dispersion along streams, and also promotes active ground-water flow conducive to hydromorphic dispersion. Both the 1975 orientation work (e.g. Gleeson and Jonasson, 1975) and the 1976 reconnaissance and detailed studies have attempted to evaluate the relative importance of the two processes in terms of geochemical exploration. The preliminary indications are that water analysis may be an important complement to stream sediment analysis in parts of the Cordillera.

The work of Dyck and his colleagues on well water reconnaissance for uranium (Dyck *et al.*, 1975, 1976a, b) is a novel application of geochemical exploration to Canada. It is designed principally for areas of relatively flatlying sedimentary rocks that may be host to roll-type or similar uranium deposits.

The identification of aquifers with anomalous concentrations of uranium or other indicator elements, such as radon, helium or copper, may be one or few possible methods of locating prospecting targets. However, the difficulties of interpreting such anomalies are greater than for most other environments.

In the western United States exploration for roll-type deposits has, in general, proceeded from known surface occurrences to concealed deposits. It is possible that in Canada these deposits may occur in areas where there are only minor or surface showings. In the Carboniferous Basin of the Maritimes, the humid environment will promote the removal of surface occurrences. Exploration for this type of mineralization may be more analogous to oil exploration with careful attention to stratigraphy, structure and hydrodynamics.

Elements other than Uranium

Costs of analysis are generally small in proportion to sampling costs and this allows a variety of elements to be determined on samples collected for this program. These data serve two purposes. Firstly, since uranium deposits contain a variety of elements, additional evidence of the presence of uranium mineralization is revealed. Secondly, information is provided on a wide range of other mineral commodities. A number of collaborating provinces consider that this information is at least as important as the data provided on uranium.

In the Cordillera much information has been gained since the Second World War on the use of geochemistry in the search for base metals. The Uranium Reconnaissance Program surveys will utilize this knowledge and, hopefully, add to it. In the 1976 reconnaissance surveys in the Cordillera U, Zn, Cu, Pb, Ni, Co, Mo, Ag, Ba, W, Mn and Fe are being determined in stream sediments and U and F in waters.

For the Canadian Shield samples U, Zn, Cu, Pb, Ni, Co, Mo, Ag, As, Hg, Mn, Fe, and Loss on Ignition are being determined on centre lake sediment samples and U in waters. Within the northern Shield, where the greatest number of Geological Survey studies have been carried out, the active oxidation of many base metal deposits and the wide dispersion of mobile elements, such as zinc and nickel, is favourable to reconnaissance geochemistry. Work in the southern part of the Shield has shown the environment to be more complex, which appears to give rise to less clearcut reconnaissance data. Features that contribute to this complexity are the more extensive surficial cover and the greater biological activity which produces a greater range of limnological environments and greater metal-organic complexing (Nichol *et al.*, 1976). Also the rate of oxidation of base metal deposits in the south relative to the north is not known. Greater attention by geochemists at the Geological Survey to these problems are planned for 1977 and, in addition, this department is currently supporting research at Queen's University and the University of New Brunswick on mechanisms of element dispersion from base metal deposits.

Acknowledgments

The work described here is the product of the efforts of many colleagues in the Geological Survey of Canada and the staff of contractor companies. Special thanks are due to the geologists and geochemists of a number of provincial governments, who have contributed their knowledge to the design of the geochemical program.

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