METHODS OF INTERPRETATION AND FOLLOW-UP OF RECONNAISSANCE LAKE SEDIMENT DATA IN THE NORTHERN CANADIAN SHIELD

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ABSTRACT

A detailed follow-up program was undertaken in 1976 in the Nonacho Lake area, Northwest Territories, to assess the significance of regional lake sediment data obtained the previous year under the Canadian Uranium Reconnaissance Program. The study was primarily aimed at developing interpretation and follow-up techniques.

The Nonacho sedimentary basin exhibits a low geochemical relief but is considered favourable for the occurrence of uranium mineralization because it is adjacent to a uranium enriched basement. Follow-up within the basin should be concentrated over such favourable geological features as the unconformity and associated basal conglomerates, pyritiferous sediments, and major lineaments. Several element associations in basement lakes were found to be indicative of uranium mineralization; these include U-Mo-Cu, U-F, and U-Pb. Principal component analysis was found to be a useful technique for differentiating mineralization-related metal associations from regional element correlations associated with secondary environmental or other factors.

Follow-up investigations were carried out in selected areas. The procedure consisted of sampling all lakes within arbitrary boundaries of regional geochemical anomalies or favourable geological features. Sampling lake waters instead of, or in addition to, lake sediments is recommended because certain chemical conditions, often associated with ore deposits, are found to inhibit fixation of metals in the sediments; high acidity associated with sulphide-bearing rocks, high and variable bicarbonate concentrations in lake waters, and low organic content of lake sediments are particularly significant factors.

The information provided by detailed sampling of lakes is, in many cases, sufficient to allow follow-up to proceed on the ground. However, other semi-detailed techniques, including multiple sampling of individual lakes and airborne geophysics, may be used to further define the geochemical anomalies.

INTRODUCTION

Since the inception of the Uranium Reconnaissance Program (U.R.P.) in 1975 (Darnley *et al.*, 1975), about 410,000 km^2 of the Canadian Shield have been surveyed by reconnaissance geochemical methods. These have been described by Hornbrook and Garrett (1976) and are the result of nearly ten years of research and development undertaken by various groups in Canada. Briefly, they consist of sampling sediments from the profundal basins of lakes at a density of one sample per 13 km^2. The samples are routinely analysed for Zn, Cu, Pb, Ni, Co, Ag, Mn, U, As, Mo, Hg, Fe and loss-on-ignition (L.O.I.) to estimate the organic carbon content. Surface lake waters are also collected and they are analysed for U, F and pH.

The data are contained in several Geological Survey of Canada (G.S.C.) Open File reports and are largely intended for usage by the mineral industry. Parallel follow-up programs were undertaken by

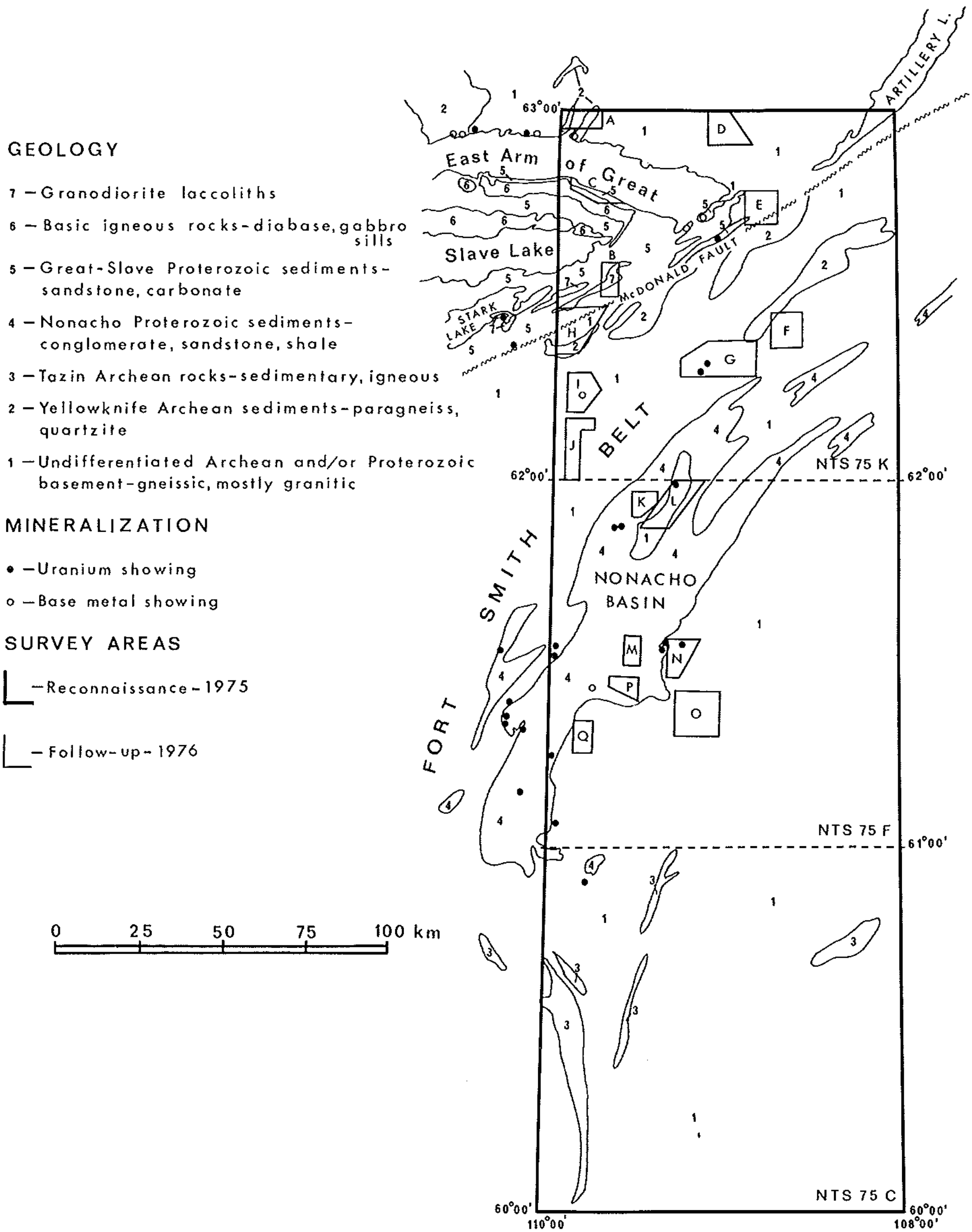

FIGURE 1. Geology, mineralization and location of study areas.

G.S.C. personnel in selected parts of the Canadian Shield to assess the usefulness of the reconnaissance data from a mineral exploration viewpoint and also to develop and recommend to the mining industry suitable methods for interpretation and follow-up. One such program was carried out in 1976 in the Nonacho Lake area, including the eastern extremity of the East Arm of Great Slave Lake in the Northwest Territories, where some 36,300 km^2 (NTS maps 75C, F and K) had been surveyed by reconnaissance methods the previous year. The extent of the area covered by reconnaissance geochemistry as well as the regions selected for follow-up are shown in Figure 1. The reconnaissance data are the subject of G.S.C. Open File reports 324 to 326 (Hornbrook *et al.*, 1976) which include symbol plots on 1/250,000 scale National Topographic System (NTS) map bases with bedrock geology and drainage systems indicated, as well as complete listings of the analytical data and field observations as described by Garrett (1974). The complete follow-up data are contained in G.S.C. Open File report 489 (Maurice, 1977a), which includes geologically interpreted symbol plots on 1/50,000 scale NTS map bases, field and analytical data listings, as well as tables of basic statistics.

The emphasis of this paper is on the techniques used for interpretation of the reconnaissance data and on the methods employed in the subsequent follow-up program, especially as it applies to uranium because the region is particularly favourable for the occurrence of uranium deposits. The results of the follow-up surveys, however, will not be discussed here except when they have a bearing on the methodology. Prior to 1976, lake waters collected in reconnaissance surveys were not analysed routinely and, consequently, only limited water data were available to aid in the interpretation of the reconnaissance lake sediment results in the present study.

GEOLOGY AND MINERALIZATION

The study area is situated south of the tree line and is characterized by generally good bedrock exposure and relatively flat topography, except around the East Arm where the terrain is hilly and the shorelines are often marked by steep cliffs. The East Arm region and the Nonacho basin are formed essentially of unmetamorphosed Lower Proterozoic sediments that unconformably overlie heavily deformed, undifferentiated Archean and Proterozoic basement rocks of mostly granitic composition (Figure 1). The Nonacho sediments comprise a clastic sequence of basal polymictic conglomerates overlain by conglomeratic arkoses, arkoses, quartzites, shales and greywackes. These rocks are considered to be of fluviatile and lacustrine origin. The total thickness of the sedimentary pile was estimated at 3,000 m (Burwash and Baadsgaard, 1962).

The rocks in the East Arm region, on the other hand, are a mixture of carbonates and clastic sediments of fluviatile and marine derivation containing thick sequences of volcanics. These rocks have been invaded by various types of intrusive units (Hoffman *et al.*, 1977).

Uranium and base metal mineralization occur at several localities both within the Proterozoic sediments and the surrounding basement (Fig. 1). The uranium occurrences are genetically complex, probably originating from a large variety of mineralizing processes. Nevertheless, two types predominate: magmatic mineralization and vein-type mineralization.

The magmatic mineralization consists of radioactive minerals that are either disseminated in the host rock or concentrated in dykes representing late-stage magmatic activity. Host rocks include syenites, felsic porphyries, and granodiorites; most of the magmatic occurrences are found within the basement and probably represent the oldest mineralization in the area. It is suggested that these uraniferous rocks along with extensive zones of abnormally high radioactivity within the Fort Smith belt, to the west of the Nonacho basin (Charbonneau, in press), acted as sources of uranium in the genesis of other types of mineralization in the region. The magmatic mineralization is characteristically enriched in Th, F, Mo, Pb, V, P, and rare-earth elements and, at times, also contains above normal concentrations of Cu, Zn and Ni.

Vein-type mineralization consists of radioactive minerals within fractures in heavily chloritized or silicified host rocks. These occurrences are frequent in the Nonacho sediments but they are also found at several localities within basement rocks. The mineralized veins are generally enriched in Cu and Pb, but a few occurrences were found to contain anomalous concentrations of Ag, Bi, Ba, V, and rare-earth elements. The Th content of these veins is generally very low.

Other types of uranium occurrences are also found. Morton (1974) describes what may be important epigenetic sandstone-type uranium mineralization in the East Arm region and several stratiform, possibly syngenetic, uranium occurrences are found in such lithologies as conglomerates, arkoses and greywackes in the Nonacho basin.

Fracture-filling copper mineralization occurs at several localities mainly in the East Arm region (McGlynn, 1971). Most occurrences consist of quartz-carbonate veins with variable amounts of chalcopyrite and chalcocite. Host rocks include Archean metasediments along the north shore of the East Arm, and Proterozoic quartz diorites and sediments. McGlynn (1971) also describes a chalcopyrite-chalcocite-bornite occurrence in a granitic inlier within the Nonacho basin.

INTERPRETATION OF THE RECONNAISSANCE DATA

REGIONAL TRENDS

The most apparent features on the U.R.P. reconnaissance geochemical maps are the regional patterns of enrichment, often several thousand square kilometers in surface area, generally related to parts of the crust containing above-average trace element concentrations. The ability of regional geochemical data to focus on individual mineral deposits is somewhat restricted because, as Brink (1974) pointed out, the contribution of a given metal in even the best-exposed typical ore deposit to its concentration in the regional sample is small with respect to the total contribution for that metal from the surrounding host rock. However, the U.R.P. is governed by the concept that economic mineral deposits are often located within or in proximity to extensive zones of crustal enrichment (Roscoe, 1969, Smith, 1974, Dodson *et al.*, 1974, and Dahlkamp, 1977) or occur in clusters, producing local but detectable signals (Cameron, 1975).

Figure 2 shows a regional pattern for U and Mo in basement rocks to the east of the Nonacho basin (NTS map 75F). The basin itself presents a relatively low geochemical relief but its proximity to uranium-enriched basement rocks constitutes a favourable situation. The clastic sediments that form most of the surface exposure in the basin are probably deficient in uranium because they are likely to have undergone a certain amount of leaching prior to and/or during transportation. The uranium thus removed may have concentrated elsewhere such as (1) in fractures or other traps near paleosurfaces, (2) as heavy mineral concentrates in placer-type deposits, or (3) in areas where sedimentation took place under reducing conditions. Several uranium concentrations in the basin have characteristics that suggest such mechanisms.

Reconnaissance geochemistry, in the present case, established the existence of potential source rocks that could have supplied uranium in subsequent mineralizing processes. Important uranium concentrations could exist at depth within or under the Nonacho sediments without producing recognizable surface anomalies in a reconnaissance survey. To explore for such deposits, detailed follow-up should be carried out over favourable geological features. In the Nonacho area, these include (1) the unconformity and basal conglomerates where they occur near uranium-enriched basement rocks, (2) the pyritiferous greywaches and shales, and (3) the major lineaments. The latter are particularly important not only as loci for mineralization but also as channelways through which metals may have dispersed to generate near-surface anomalies that may be detectable only at a detailed level of exploration.

Northeast-trending fracture systems that transect uranium occurrences at C and D (Fig. 2) should be carefully examined by detailed geochemical methods for possible leakage from underlying mineralization. The significance of the U-Mo-Cu anomaly situated within the Nonacho sediments about 10 km NE of C has not been fully investigated but is interesting because it lies along the same fracture system as the mineralization at C.

In summary, the processes of interpretation, which ultimately focus on the relatively small follow-up areas, should make maximum use of not only the geochemical data, but also of all available geological and geophysical information. The interpreter should examine all possible genetic models that could have resulted in economic concentrations of the metal sought.

ELEMENT ASSOCIATIONS

Reconnaissance geochemical data often provide the best means of identifying favourable ground for detailed exploration. The task of the geochemist consists of selecting portions of regional patterns that appear more favourable than others or in distinguishing isolated anomalies that are associated with mineralization from other local patterns related to other causes (e.g. variations in the physico-chemical character of lakes or proximity to certain rock types).

Multielement assemblages in lake sediments are often more revealing than single element patterns. However, maximum benefit from multielement analysis will be achieved only if the geochemist has

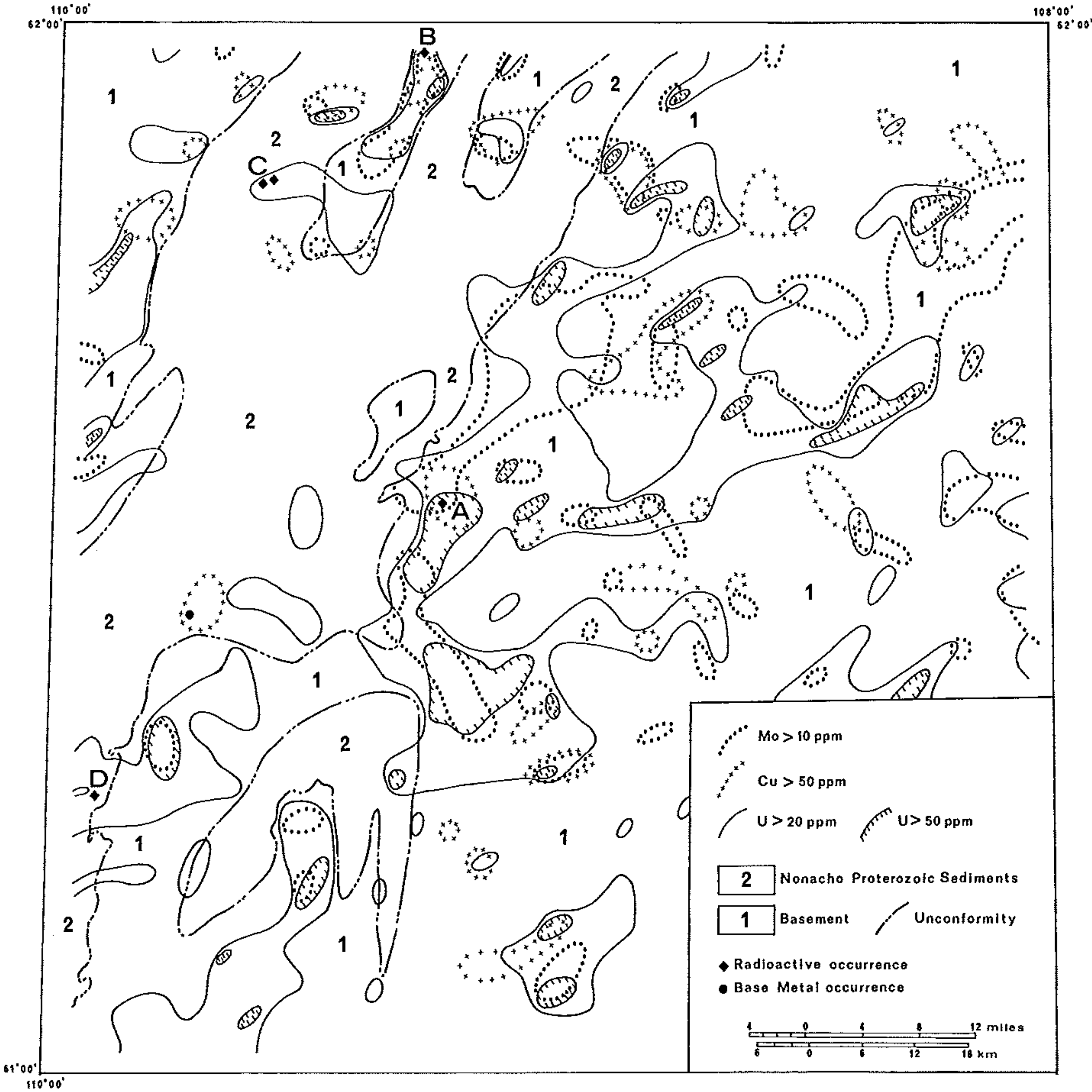

FIGURE 2. Reconnaissance lake sediment geochemistry in the Nonacho sediments and adjacent basement.

knowledge of the nature of the element associations for a given type of mineralization. There are general guidelines that can be followed (Boyle, 1974), but multielement characteristics can best be ascertained in orientation studies that should include the examination of known mineralization, of its host rock, and of the chemistry of surrounding lake sediments or other appropriate sampling media.

Basement rocks east of the Nonacho basin are regionally enriched in U and Mo and locally host magmatic-type uranium mineralization. Interesting occurrences are found within the U-Mo regional pattern at A and B (Fig. 2). At both localities, the lake sediments are also enriched in Cu, which suggests that anomalous Cu concentrations in lake sediments elsewhere within U-Mo enriched basement are indicative of magmatic-type uranium mineralization and could constitute interesting targets to prospect.

Fluorine may also be useful in interpreting regional geochemical data, particularly in uranium exploration. This element is very mobile and it can generally be detected in lake waters at considerable distances from F-enriched rocks. In the Nonacho area, anomalous fluorine concentrations in lake waters were detected in the vicinity of F-enriched magmatic-type uranium occurrences. Elsewhere, this element has been reported as a reliable indicator of uranium-enriched intrusive rocks that often generate strong uranium anomalies in lakes. For example, W. B. Coker (pers. comm.) found anomalous amounts of F in lake waters in association with high levels of U and Mo in lake sediments in the vicinity of Hudsonian granitoid bodies in northwestern Manitoba. Although there is the possibility that rocks such as these may be exploitable as large-tonnage low-grade deposits, in most cases they are non-economic and should be assigned a low exploration priority. However, because of the frequent association of F with uranium mineralization as well as with U-enriched igneous rocks, detailed work should be carried out to assess the significance of U-F geochemical anomalies.

Another element assemblage that was found to be indicative of uranium mineralization in the Nonacho area is the association of Pb with U (Maurice, in preparation). As a radiogenic decay product of uranium, lead is always associated with Precambrian uranium ores in sufficient concentrations to generate secondary dispersion patterns that are often traceable in lake sediments. However, because of the relatively low mobility of lead, caution should be exercised in using this interpretive method in wide-interval reconnaissance surveys.

MULTIVARIATE STATISTICAL ANALYSES

In the preceeding section, we discussed element associations in lake sediments that specifically indicated areas of mineral potential. These associations normally reflect the chemistry of the mineralization and, as stated previously, confirmation of their significance is best obtained in orientation studies. They generally do not account for a large proportion of the total data variability because secondary dispersion from mineral occurrences normally represents only a small fraction of the total chemical dispersion taking place in an area several thousand square kilometers in size.

The bulk of the secondary dispersion in large areas will generate element associations that have regional rather than local characteristics. These will primarily reflect factors related to causes other than mineralization such as the natural affinity of certain elements, changes in secondary environmental conditions, or regional variations in bedrock geology. Because these associations account for a large proportion of the total data variability, they tend to obscure the more subtle mineralization-related associations. It is, therefore, useful to identify these regional associations in order to facilitate the interpretation of the less obvious features.

There are a variety of ways that this can be achieved. Computer-oriented methods, ranging from the examination of simple correlation coefficients to multilinear regression and factor analyses, are generally favoured over purely visual techniques because of the large number of samples and variables involved in reconnaissance surveys. The application of principle component analyses (Harman, 1967), utilizing a computer program written by Garrett (1967), was found to be particularly helpful in the investigation of interelement relationships in the Nonacho area. The six-component model for the northern part of the survey area (map 75K, 81 samples) is presented in Table 1.

Most of the data variability (59%) is accounted for by components 1 (L.O.I.-Hg-Zn-Cu) and 2 (Fe-Mn-Co) which probably represent scavenging of relatively mobile metals by organic matter and Fe and Mn hydroxides respectively. Hg shows a particularly strong dependence on the organic content of the lake sediments. It is unlikely that such a strong sympathetic relationship derives from adsorption alone; rather, the correlation suggests that Hg plays a role in the biological cycle of lakes. Some of the highest factor scores of component 2 coincide with areas of basic igneous rocks in the East Arm region (unit 6, Fig. 1), which show sharp geochemical contrast with surrounding granitic and sedimentary rocks. These basic rocks are

TABLE 1
PRINCIPAL 6-COMPONENT ANALYSIS OF GEOCHEMICAL DATA FROM LAKE SEDIMENTS, NONACHO LAKE AREA.

	Communality	Component 1	2	3	4	5	6
U	0.838	.281	.110	.472	.721	−.065	.016
Zn	0.820	.604	.174	.129	.342	.084	−.533
Cu	0.835	.640	.061	.169	.355	.073	−.511
Pb	0.912	−.022	.033	.928	.030	.065	−.210
Ni	0.917	.165	.138	.132	−.032	.137	−.913
Co	0.839	.074	.554	.154	.194	.132	−.669
Mn	0.878	−.048	.918	.034	.157	.061	−.060
As	0.996	−.014	.215	.055	.015	.957	−.175
Mo	0.875	.290	.117	−.134	.858	.056	−.140
Fe	0.858	−.035	.876	.008	−.010	.183	−.236
Hg	0.897	.936	.030	.065	.106	.002	−.065
LOI	0.870	.812	−.279	−.185	.290	−.088	−.083
Proportion of variability, percentage		37.5	21.5	9.6	8.9	5.9	4.3
Cumulative percent		37.5	59.0	68.6	77.5	83.4	87.7

enriched in Fe and Mn and in a host of trace elements some of which may become incorporated in the Fe-Mn hydroxides in the lake sediments.

Components 3 and 4 (U-Pb and U-Mo-Cu-Zn), which represent respectively 9.6% and 8.9% of the data variability, have been identified as potential indicators of uranium mineralization in the Nonacho area. The sympathetic relationship between U and Pb partly derives from the fact that the two elements are enriched in the same types of rocks (e.g. felsic intrusives). Nevertheless, their association in uranium deposits tend to produce U-Pb anomalies, and high factor scores of this component are, in certain cases, indicative of uranium mineralization.

As noted earlier, the association U-Mo (component 4) is a regional feature of bedrock geology in the Nonacho area. When Cu is also associated, it may be an indicator of uranium mineralization. The relatively low factor loading of Cu in this component, however, results in this element having only minimal influence on the factor scores. Consequently, high scores of this component will indicate high U-Mo granitic bedrock rather than Cu-bearing uranium mineralization (Fig. 2).

Most of the As variability is accounted for by component 5 (5.9% of data variability). Its significance is not well understood but high As concentrations could indicate sulphide-bearing lithology. This element has long been used as a pathfinder for gold but its usefulness as such in the Nonacho area has not been established. A positive loading for Fe in component 5 as well as a positive As loading in component 2 suggest that As and Fe are associated in the lake sediments.

Component 6 (Ni-Co-Zn-Cu) accounts for only 4.3% of the data variability but may be very significant from a mineral exploration viewpoint. The highest factor scores for this component are found inland from an area of base metal occurrences along the north shore of the East Arm of Great Slave Lake (area A, Fig. 1) which suggests a possible inland extension of these metalliferous rocks.

METHODS OF FOLLOW-UP

The interpretive methods described in the previous section allows the geochemist to set priorities for the follow-up operation. High priority should logically be placed upon reconnaissance anomalies or geological features having specific characteristics favourable to the presence of mineralization.

A technique that has been found useful as a preliminary step in the follow-up of reconnaissance lake sediment data in the Canadian Shield consists of sampling all lakes within arbitrary boundaries of anomalies. In most parts of the Canadian Shield, this procedure results in a sample density of one sample per 1 to 3 km^2. This sample density greatly enhances anomaly definition, which often results in significant reduction in the size of search areas.

Establishing the boundaries of the areas of interest can be quite critical. Although operating costs will increase with area size, the boundaries should be set so as to include both the anomalous lakes and a "safe" amount of background terrane, especially updrainage from the anomaly. Commonly, the peak of a reconnaissance anomaly occurs at a considerable distance, often several kilometers, from the source of the metal. Possible explanations are that the anomalous lakes that lie nearest to the mineralization have not been sampled during the reconnaissance survey or that the conditions required for the precipitation of the metals are only met at a certain distance down-drainage from the source. For example, the acidic conditions that are often associated with ore deposits have been found to retard precipitation of certain metals in lake sediments. Similarly, a high bicarbonate content in the water may retard the precipitation of uranium.

For the follow-up, sampling lake waters instead of sediments should be seriously considered. Although waters are only suitable for a relatively narrow range of analytical determinations, they are more economical to sample and more appropriate for analysis in a field laboratory because they require no sample preparation; filtration is not generally required as lake waters from the northern Canadian Shield are mostly clear, and acidification is unnecessary if the samples are analysed within a few days of collection. Lake waters are rarely depleted in mobile metals when the sediments are enriched, whereas lake sediments have the frequent disadvantage of being depleted when the waters are enriched. For example, Cameron (1977) reports steadily increasing concentrations of zinc in surface waters with diminishing distance from a massive sulphide prospect near Agricola Lake, N.W.T. The lake sediments along the same drainage system showed maximum zinc concentrations at 4.5 km from the source. Acid conditions were preventing the precipitation of metals in the lakes nearest to the mineralization.

In the Nonacho area, detailed uranium patterns in lake waters and sediments were found to be generally very similar. However, linear relationships were not always observed and several factors have been found to affect the relative amounts of uranium in the waters and sediments in lakes.

The effect of dissolved bicarbonate on the solubility of uranium has long been recognized (Bowie *et al.*, 1971, Maurice, 1977b). Cameron and Hornbrook (1976) also pointed out that very low organic content of lake sediments, resulting in a reduction of their sorptive capacity, can lead to the sediments not reflecting the uranium content of the coexisting waters. The following is an example that shows the importance of analysing lake waters in areas where they are high in bicarbonate and/or where the lake sediments are low in organic matter.

Figure 3 a and b represent respectively the distribution of uranium in lake sediments and in lake waters in an area of mixed carbonate, clastic and igneous geology in the East Arm of Great Slave Lake (area B, Fig. 1). A strong U-in-water anomaly, in excess of 2.0 ppb U, which has no equivalent in the sediments, developed over the carbonates north of and adjacent to the granodiorites. Figure 4 shows that the strongly anomalous lakes (U_w>2.0 ppb) all have high bicarbonate

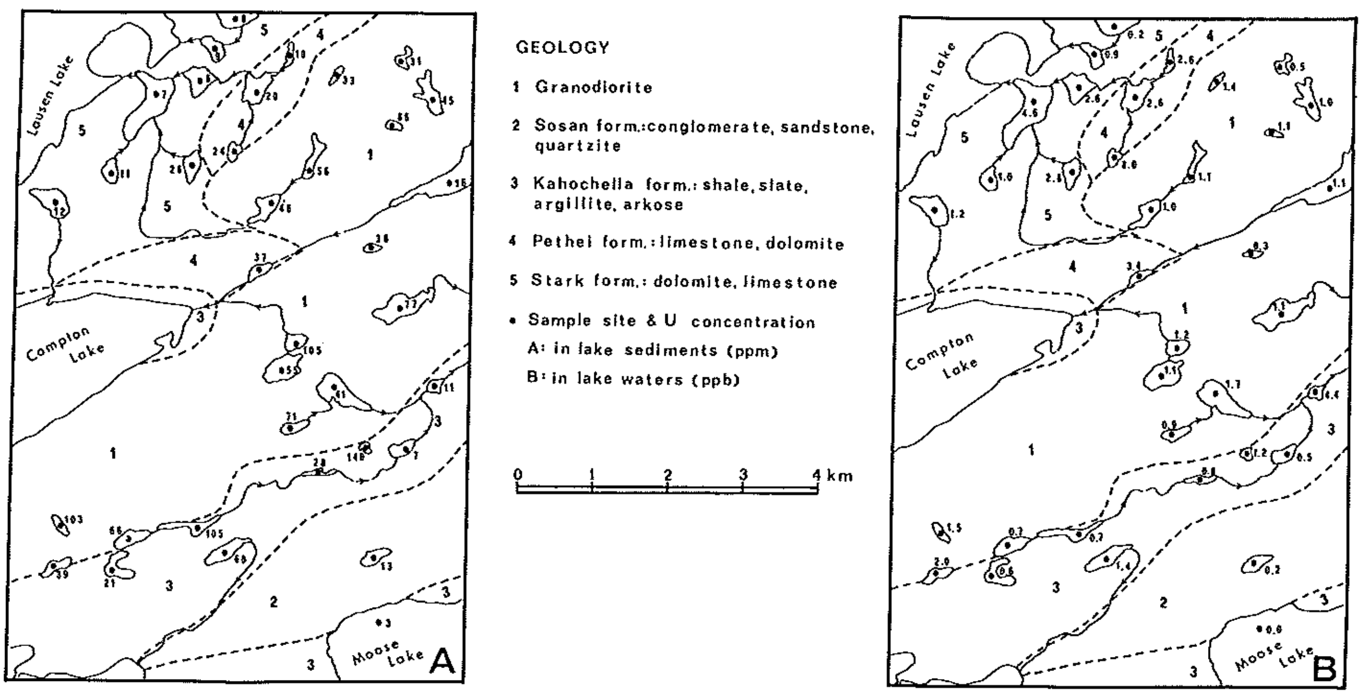

FIGURE 3. Detailed uranium distribution in lake sediments (A) and lake waters (B) in the East Arm of Great Slave Lake (Area B, Fig. 1).

waters (HCO⁻>100 ppm) and many also have low organic sediments (L.O.I. <20%). In fact, throughout the range of uranium concentrations in Fig. 4, lakes with high bicarbonate waters and/or low organic sediments have proportionally more uranium in their waters than in their sediments. No uranium mineralization has yet been found in association with this anomaly, but it has potential because granodiorites of the same type are mineralized at their margins forming an interesting prospect near Stark Lake, about 30 km southwest of the survey area (Fig. 1).

High bicarbonate waters are generally associated with areas underlain by carbonate rocks. It is, however, considerably more difficult to generalize the conditions that will promote low organic sediments. As a rule, lakes situated north of the tree line have sediments with considerably less organic content than lakes south of the tree line. Also, it has been observed that strongly alkaline lakes often support less organic growth than more acid lakes. But most importantly, erratic organic content of lake sediment samples within an area is largely due to the regime of individual lakes or the spot within the lake where the sample was collected. Lakes fed by rapid-flowing streams, for example, will tend to contain proportionally more clastic sediments than lakes fed by slow-flowing streams. Similarly, some lakes exhibit physiographic complexities on their bottoms (glacial features, multiple basins, etc.) so that the sampling of organic-rich central basin sediment is not always achieved or even possible.

The relationship between uranium content of sediments and waters is more or less sympathetic in areas of uniform lake water alkalinity and uniform organic

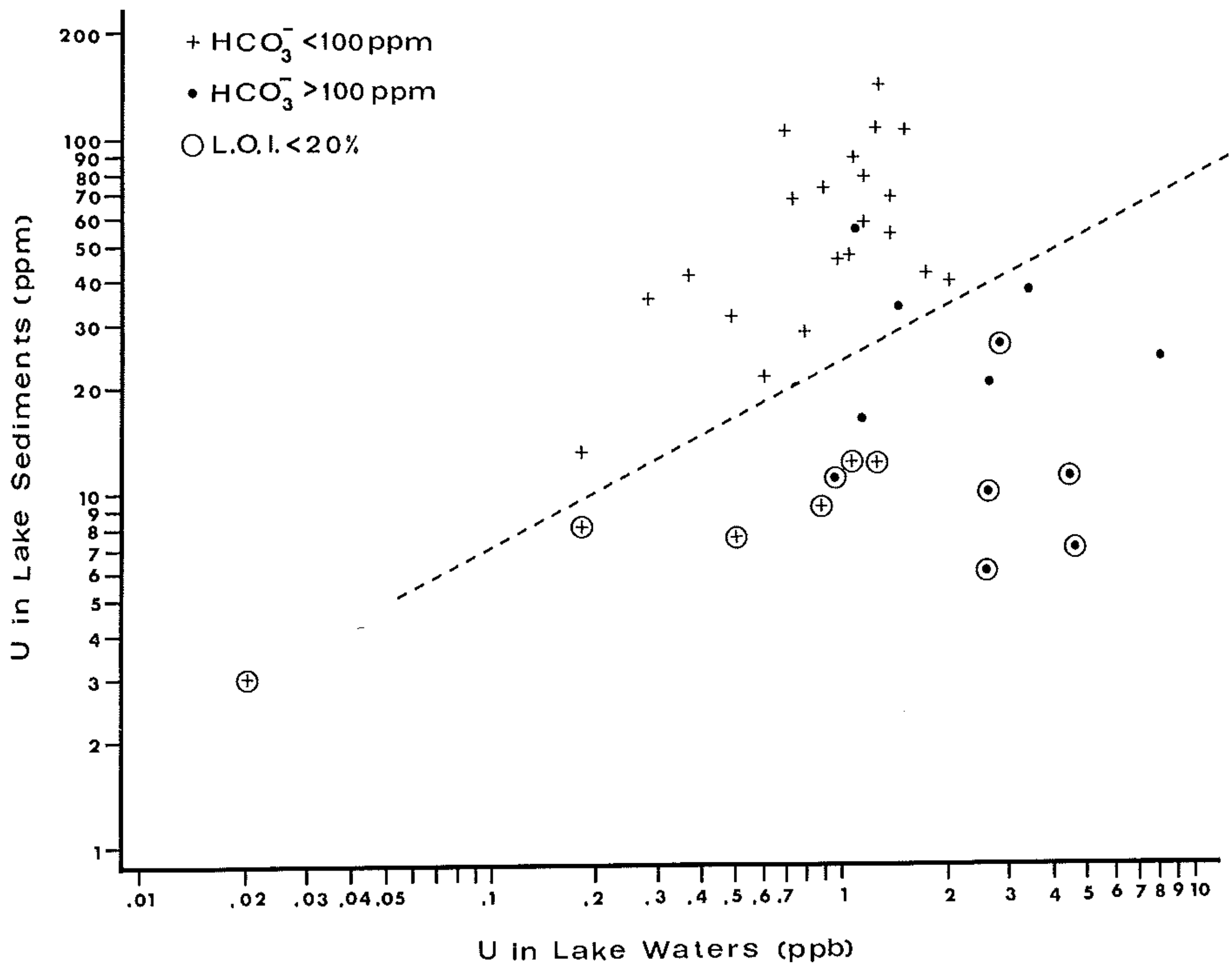

FIGURE 4. U in lake sediments vs U in lake waters for samples collected in the area shown in Fig. 3.

content of sediments. However, during the detailed lake sampling program in the Nonacho area, some small ponds (≃0.05 sq.km) were found to contain proportionally more uranium in their waters than in their sediments (Fig. 5). This may be due to several causes:

1. The waters of small lakes in the Canadian Shield often show organic-derived coloration or suspension which may adsorb the uranium or react with it to form soluble organic complexes.
2. Acidic conditions which are often encountered in organic-rich ponds will tend to keep uranium in solution.
3. Metalliferous waters are less diluted when they flow into small lakes than when they enter large lakes.
4. Small, shallow lakes often produce vigorous organic growth which results in an increased rate of sediment accumulation thereby diluting the metal content of these sediments and causing an increase in the U_w/U_s ratio.

The data shown in Fig. 5 were obtained from acidified samples by fission track technique several months after collection. A number of samples, mainly from small acid ponds, are shown on the diagram at or below the analytical limit of detection for water (0.02 ppb and 0.01 ppb U respectively). These samples do not follow the generally linear distribution pattern established by the other samples and it is suggested that these waters were deficient in uranium relative to their sediments at the time of sampling. However, there is the possibility that the uranium may have precipated out of solution during storage although analysis of the unacidified samples in the field by fluorimetry within a few hours of collection also indicated low uranium in most of these waters. In any

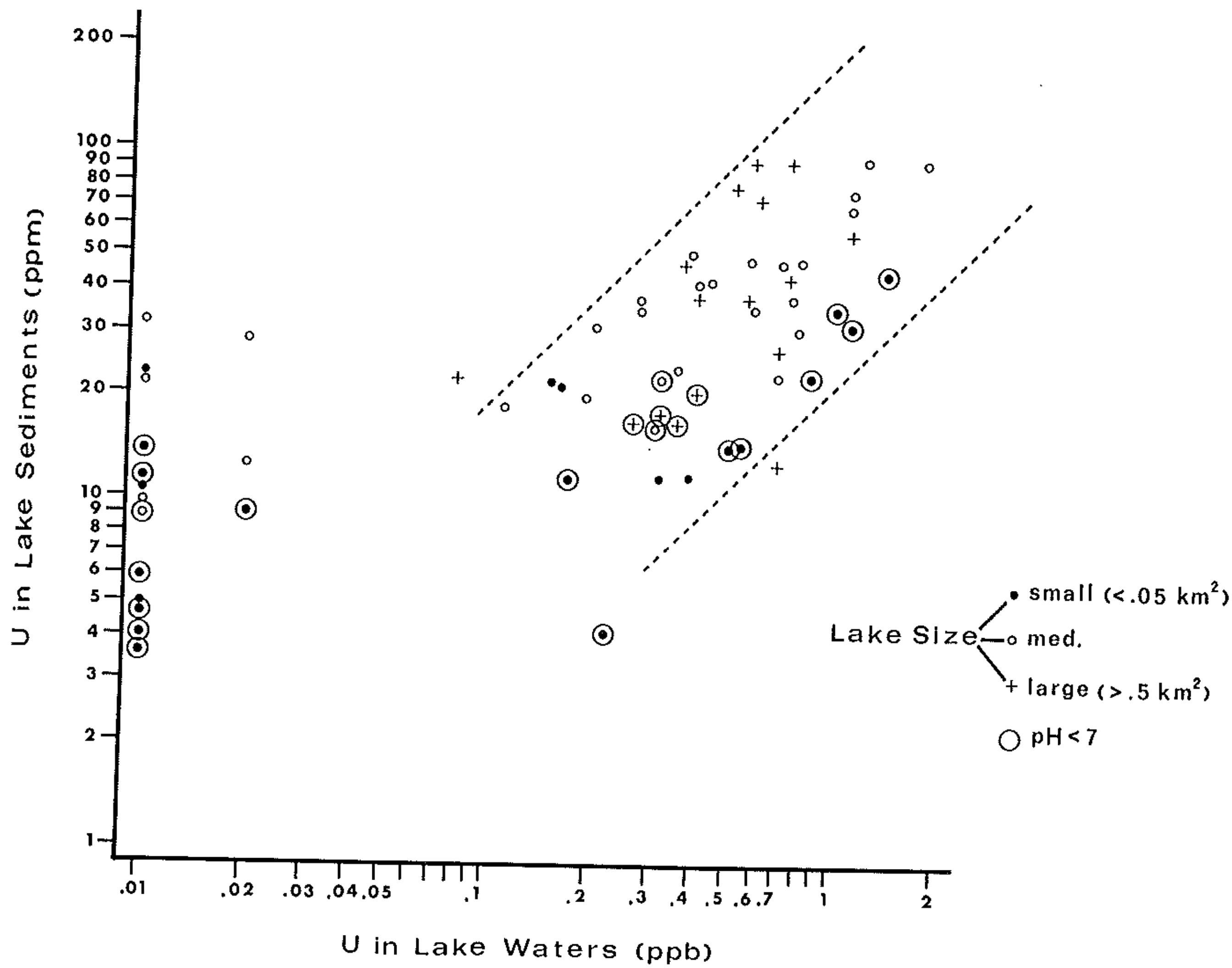

FIGURE 5. U in lake sediments vs U in lake waters for samples collected in an area of basement rocks adjacent to the Nonacho basin (Area N, Fig. 1).

case, it is apparent from Fig. 5 that small, organic ponds may produce erratic water results and therefore, they are best avoided in the sampling program.

Detailed lake sampling may define an anomaly to the point where it becomes feasible to apply detailed ground methods such as soil surveys or ground geophysics, but it is often desirable to further restrict the search area by using other semi-detailed methods. Stream sampling is a possible choice but in many parts of the Canadian Shield, streams are either ill-defined or of difficult access. An alternate method, which is still at the experimental stage, consists of collecting several sediment samples from anomalous lakes. The object is to study the distribution of different elements within these lakes in order to establish points of inflow of metal-carrying waters and from there, determine the likely location of the source by examining the local surface and groundwater drainage systems. Data gathered to date are still inconclusive, but indications are that the less mobile metals (e.g. Pb) have a tendency to accumulate to higher levels near the points of inflow while the more mobile metals show higher concentrations at the center of the lakes. This technique should be examined for possible application in areas covered by large lakes or in exploring for mineralization suspected to lie under bodies of water. Groundwater movement along a metal-bearing structure could generate metal accumulation in overlying lake sediments. Sampling should preferably be carried out during the winter on a grid pattern encompassing the entire lake. Small-to medium-size lakes, on the other hand, could be sampled in the summer using a small boat.

Airborne geophysics may also help define areas of interest after the detailed lake sampling program. In the Nonacho area, helicopter-borne γ-ray spectrometry, using ½ km line spacing and 30 m ground clearance, was successful, on several occasions, in locating radioactive outcrops in areas of U-enriched lakes. Ideally the terrain should be flat and the bedrock exposed although careful measurements in till-covered areas may also be useful because radioelement concentrations in glacial drift often reflect the concentrations in the underlying bedrock (Charbonneau *et al.*, 1976).

SUMMARY

In order to assist the user of U.R.P. reconnaissance lake sediment data, interpretation and follow-up methods are being developed at the Geological Survey of Canada. The guidelines presented in this paper are based on both reconnaissance and detailed work undertaken in the Nonacho Lake area, N.W.T. Similar surveys in other parts of the Canadian Shield have either been carried out or are planned for the future. These surveys should provide additional data that will allow adjustment of the methodology to different regions of the Canadian Shield.

It is recommended that follow-up activity be performed over geochemically anomalous areas outlined by the reconnaissance surveys, as well as over favourable geological features. In selecting geological features for follow-up, regional geochemical patterns should be studied because of the frequent association of ore deposits with zones of crustal enrichment. This approach, however, requires full assessment of the metallogenic concepts that may be applicable to the different study areas.

Multielement rather than single element patterns should be examined when selecting geochemical anomalies for follow-up. This procedure makes it easier to differentiate between non-significant and mineralization-related patterns, particularly when preliminary orientation work has been carried out in the vicinity of known mineral occurrences. In the Nonacho area, the associations U-Mo-Cu, U-F, and U-Pb seem to be indicative of uranium mineralization in basement rocks. Multivariate statistical analysis may also help differentiate mineralization-related associations from other regional correlations related to secondary environmental or other factors.

Follow-up areas should be carefully selected and should incorporate sufficient ground beyond the anomalous zones. Investigations should begin with sampling in all lakes within the selected areas. Sampling lake waters in addition to, or instead of, lake sediments should be considered because lake waters often reflect the composition of nearby rocks more accurately than do sediments.

Detailed sampling of lakes, as described above, may be sufficient, in certain cases, to allow follow-up to proceed on the ground. However, other semi-detailed surveys may be required in order to further define the anomalies. Multiple sampling of individual lakes to trace the source of inflowing metal-bearing waters is a possible technique but is also one that needs additional testing. Stream sampling or detailed airborne geophysical methods may be used as an alternative.

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