39.

FURTHER STUDIES OF HYDROGEOCHEMISTRY APPLIED TO MINERAL EXPLORATION IN THE NORTHERN CANADIAN SHIELD

Project 730009

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Introduction

In 1974 hydrogeochemical studies were carried out in eastern and northern parts of the Slave Province (Cameron and Lynch, 1975; Cameron and Ballantyne, 1975). The Slave Province has been a principal area used by the Geological Survey for the development of methods of lake sediment geochemical reconnaissance. In part, the hydrogeochemical studies were initiated to gain an understanding of the processes of secondary dispersion in this permafrost terrain. Such knowledge is essential for the proper interpretation of lake sediment data. In addition, these studies showed that hydrogeochemical sampling might be of value in its own right for mineral exploration or assessment in the region. While lake sediment surveys appear to be the method of choice for broad scale reconnaissance, lake water sampling has many advantages for more detailed programs (i.e., one sample per 2 square miles to four samples per square mile) such as that carried out by the exploration industry (Cameron and Ballantyne, 1975). The principal advantages result from the speed and relative simplicity of water sampling, preparation, and analysis, plus, in the northern Shield, the great abundance of lakes. This allows areas of 1000 square miles or more to be covered rapidly with the results, provided by field laboratories, being available within a day or so of sampling. Targets that are outlined by lake water anomalies can be more closely defined by analysis of spring or seep waters.

One of the principal objectives of the 1975 program was to test more efficient methods of water sampling using helicopters. Of equal importance was the testing of concepts and procedures on which hydrogeochemical sampling in the northern Shield is based. This includes seasonal changes in water chemistry; the choice of sampling interval; and the effects on trace element chemistry of filtering, acidification and storage of the water samples. One further objective was to refine the techniques and logistics of field laboratories set in the barren lands, in particular to reduce the weight and complexity of equipment which must be air transported.

The 1975 field program can be subdivided as follows:

1. Hydrogeochemical sampling for uranium over the Hornby Bay sandstones and the underlying rocks of the Wopmay Subprovince in the Lac Rouvière-McGregor Lake areas. This work is described elsewhere (Durham and Cameron, this publ., rept. 54).
2. Study of temporal variation in lake water chemistry in the Agricola Lake and Hackett River areas of the eastern Slave Province. The analytical work for this project is in progress.
3. A hydrogeochemical survey for Zn and Cu in a 1300 square mile area of the northern Slave Province (centred on High Lake). This area is being actively explored by mining companies for massive sulphide mineralization in Archean metavolcanic rocks. The preliminary results of this project are summarized in this report.

Sampling Apparatus

In 1974, lake water sampling was accomplished in simple fashion by the sampler leaning from the helicopter float, immersing a bottle in the water, and allowing it to fill. At that time it was felt that even a modest increase in sophistication would increase the sampling rate, with the additional benefit of easing the work of the sampler; perhaps even adding to the credibility of the technique. Since pH and, more obviously, temperature are subject to change if measurement is delayed, it was desirable to measure these parameters *in situ*, or as soon after sampling as possible.

The basis for the design was to collect a fairly large water sample as quickly as possible on the lake surface. Then, en route to the next site, some of the sample could be bottled for future analysis, while the remainder was used to measure pH, conductivity and temperature, before being dumped prior to the next landing.

A small, high capacity, immersible plastic pump connected to the helicopter power supply was fixed to the skid of the helicopter, just below the front portion of the float. In this position it draws water from a depth of approximately 20 cm and lifts it through plastic tubing into three plastic containers, each of 500 ml capacity, situated in the rear compartment of the Hughes 500 helicopter. The first container (right, Fig. 39.1) is used to fill a 500 ml plastic sample bottle, the second holds a pH electrode, and the third (left, Fig. 39.1) contains temperature and conductivity probes. The pump motor switching, the flushing, filling and draining of the three containers, and the labelling of the sample bottles are carried out by an operator in the rear compartment (Fig. 39.1). An electronic console in the front compartment of the helicopter provides digital readings of pH, conductivity, and temperature. A navigator sitting to the right of the pilot (Fig. 39.2) records these measurements and the locations of the sample sites. The sampling apparatus was constructed by Viking Helicopters Ltd. The electronic console was designed by Q. Bristow and built in the Geochemistry Section instrumentation laboratory by J.J. Parker.

Using the apparatus it was possible to collect at least 30 samples per hour, only 8 to 12 seconds being spent on the lake surface. Under these conditions sampling rates are determined by the speed, acceleration,

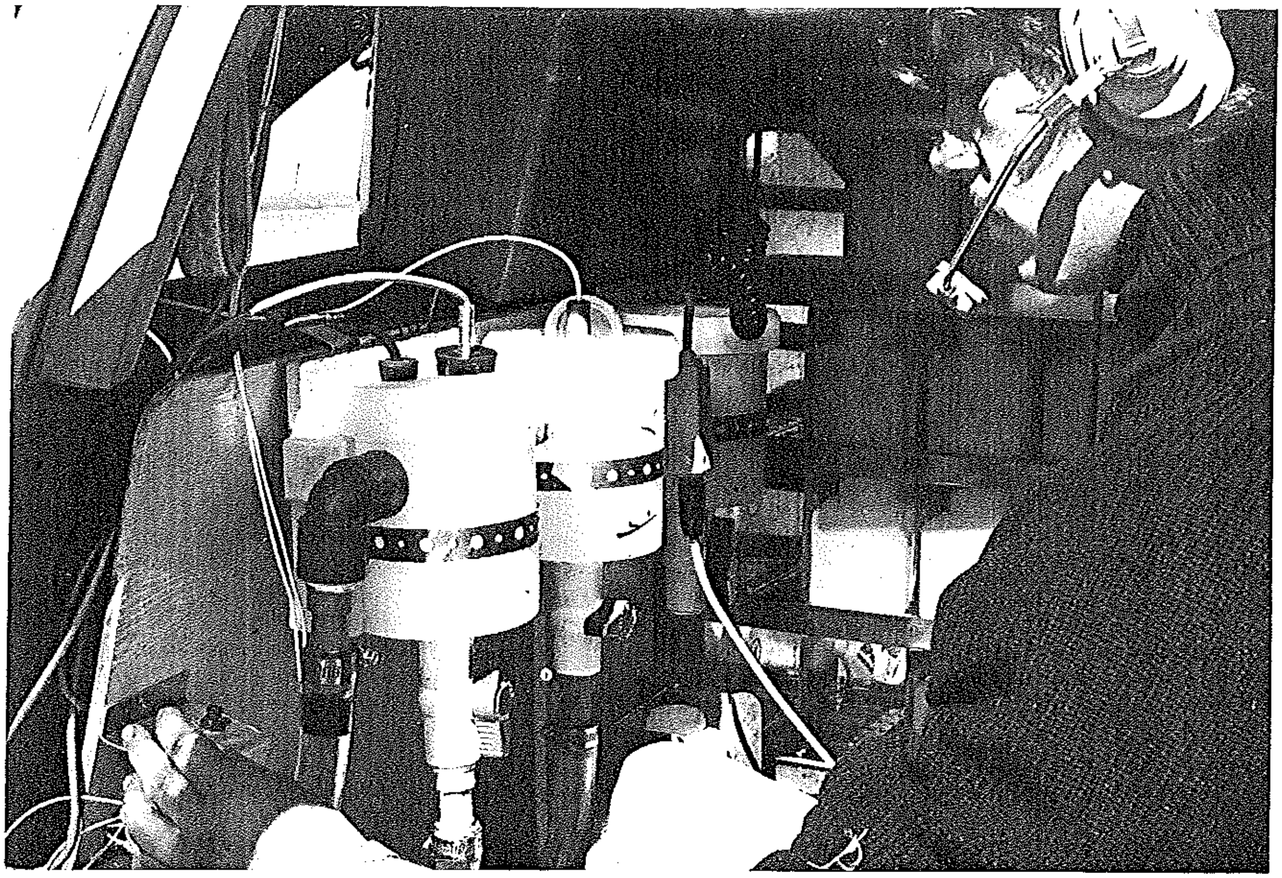

Figure 39.1. Rear compartment of water sampling helicopter. The three plastic containers are (left to right): for temperature and conductivity measurement; for pH measurement; and for filling sample bottles. Operator's left hand is on pump motor switch. In background is a rack with capacity for up to 200 500 ml sample bottles.

and manoeuvreability of the helicopter and by the skill of the pilot, navigator and sampler. In most respects the small, turbine-powered Hughes 500 helicopter is an ideal aircraft for this work. Although "start-up" problems restricted the number of temperature and conductivity readings, satisfactory pH measurements were obtained throughout the summer.

To test possible sample to sample contamination by the apparatus a very highly anomalous lake was sampled (High Lake). This was immediately preceded by a sampling of a nearby lake with background contents of Zn and Cu and immediately followed by three successive landings and samplings of the same background lake. The chemical data from this test are shown in Table 39.1. They indicate that contamination is satisfactorily low--in the range 1-3%.

Field Analysis

Water samples were analyzed in the field laboratory for Zn and Cu. The analytical method used was similar to that described for the 1974 program (Horton and Lynch, 1975). Fifty ml of unacidified and unfiltered water are extracted with APDC-MIBK and the extract is aspirated into the air-acetylene flame of an atomic absorption spectrometer. In order to improve extraction efficiency, mechanical shaking of the separatory funnels was used in 1975. All analytical equipment and supplies, plus the three analysts involved, were carried in one load of a Twin Otter aircraft (∿2500 lb.). The facility was accommodated in one longhouse tent (12 feet by 14 feet). Two, sometimes three, analysts measuring Zn and Cu kept pace with the 150 samples that could comfortably be collected each day. Detection limits for the method are 0.5 ppb for both Zn and Cu.

Table 39.1

Successive water sampling to estimate contamination caused by helicopter sampling system

SAMPLE	LAKE TYPE	Zn ppb	Cu ppb
2829	Background	<0.5	<0.5
2830	Anomalous	235	90.2
2831	Background	3.5	2.5
2832	Background	<0.5	<0.5
2833	Background	<0.5	<0.5

Figure 39.2

Front compartment of water sampling helicopter. The electronic console fitted in front of the navigator's position measures the pH, temperature and conductivity of the water.

Notes on Sampling and Preparation Procedures

One of the most attractive features of the hydrogeochemical approach that was apparent during the 1974 studies was the relative simplicity of sampling and preparation methods. For example, it was shown (Cameron and Ballantyne, 1975) that for the two lakes tested, surface waters are very homogeneous in Zn and Cu content within a given lake. Also, it was not found necessary to filter or acidify samples prior to analysis. As well as saving time, particularly under field conditions, possible contamination of the sample is avoided.

Workers studying waters from different environments have frequently found filtering and/or acidification essential to successful analysis of the samples. In order to provide a firmer basis for the procedures used some samples were analyzed in the field after filtering and/or acidification and compared with analyses made on the same untreated waters. Analysis of these samples will be continued during the 1975 winter to estimate the effects of acidification and filtering on the storage properties of the samples.

Table 39.2 gives data on the analysis of High Lake waters in the field to estimate the effects of sample treatment. This is a highly anomalous lake adjacent to a Cu-Zn massive sulphide body (*see* Cameron and Ballantyne, 1975 for location of the site). Each value given is the mean of one determination on each of 4 bottles of High Lake water. Acidification consisted of adding 1 ml concentrated HNO_3 per 500 ml water.

The data given in Table 39.2 indicate that acidification has little effect on analyses of High Lake water made within a few days of collection. Filtering has no noticeable effect on the measured content of Zn in this water, but does cause a slight decrease in the Cu content.

Table 39.2

Sample treatment comparisons, High Lake waters

TREATMENT	Zn ppb	Cu ppb
Untreated	229	78.9
Acidified	235	77.2
Filtered 0.45μ	227	65.1
Filtered 0.22μ	235	66.4
Filtered 0.45μ and Acidified	233	67.2
Filtered 0.22μ and Acidified	235	65.7

High Lake Hydrogeochemical Survey

In 1974, an area of 1000 square miles, centred on High Lake, N.W.T. was sampled at a density of one sample per 3.5 square miles (9 km^2). Data on pH, Zn and Cu for these samples has since been published,

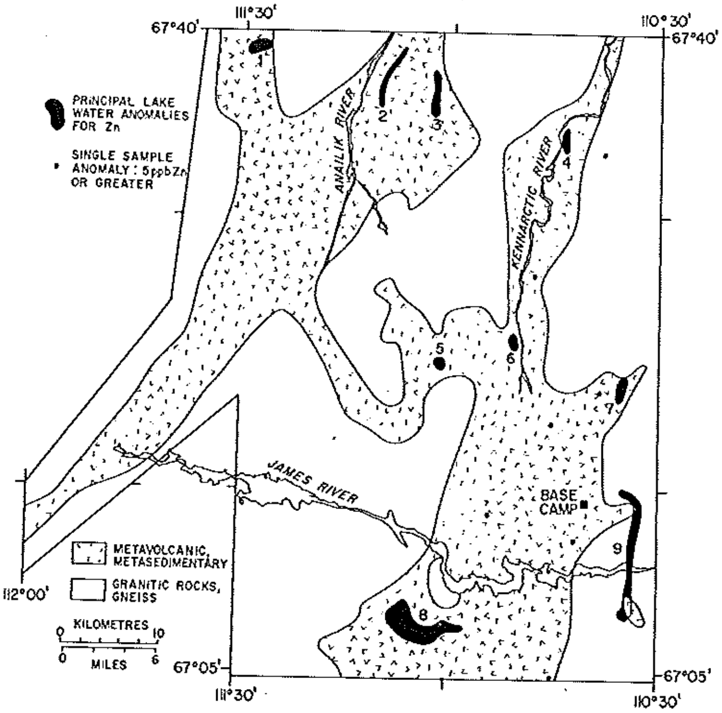

Figure 39.3. Lake water geochemical survey, High Lake area, N.W.T., 1975. Geology after Fraser (1964).

along with similar data for lake waters from the Hackett River massive sulphide camp to the southeast (Cameron and Ballantyne, 1975). The results were of sufficient interest to encourage further study of the High Lake area. In 1975, a 1300-square-mile (3367 km^2) area was sampled an area that includes a majority of the previously mapped metavolcanic rocks within 1:250 000 NTS sheet 76M (Fig. 39.3). The sample density employed was one sample per square mile. Previous lake sediment or lake water surveys in the northern Shield have employed wider sample intervals up to one per 10 square miles. The rationale for using these wide intervals is that the ubiquitous massive sulphide mineralization of the Archean tends to occur in clusters, rather than as single, isolated bodies (Cameron, 1975). To detect such clusters it is not necessary to choose a sample interval capable of identifying each body within the cluster. The relatively close sample interval used for this 1975 work was chosen to test this clustering concept in an area that is believed to have good massive sulphide potential.

The area studied in 1975 is the scene of moderately intensive exploration activity. While this region of the Slave Province has seen sporadic mineral exploration during the past several decades, this work increased sharply in 1974 and again in 1975. Despite the earlier work, exploration is still largely in the reconnaissance phase. During 1975, the principal exploration activities were geological mapping, airborne E.M. surveys, and some lake sediment sampling, with a limited amount of drilling on previously defined targets. On the basis of information kindly provided by exploration geologists, it was possible to judge the probable usefulness of lake water surveys at this stage in exploration.

The High Lake area has a rugged local relief of up to 300 feet. Although there is a general south to north dip to the land surface, much of the area sampled lies close to the 1000-foot contour. Only along the northern boundary of the survey area is there a rapid drop to the shores of Coronation Gulf. There is an abundance of lakes in the area, that would allow a much higher sample density than one per square mile to be used, if such was necessary. Overburden is generally thin. The area is far north of the treeline and is on the zone of continuous permafrost. Gossanous outcrops, in places spectacular, are common throughout the area underlain by metavolcanic rocks.

As the results for Zn and Cu became available, it was apparent that the close sample density of the 1975 survey was outlining the same anomalies previously defined in 1974. There is an apparent lack of smaller targets that can only be discovered by the closer-spaced sampling.

Another feature of the 1975 data was the lower level of Zn in waters from background (non-anomalous) areas. In 1974, the median Zn content was 8.8 ppb for 285 waters, and <1.0 ppb for Cu. For 1975 median values were <0.5 ppb for both Zn and Cu. The reasons for this difference in Zn for the two years was not at first apparent. However, after a number of tests it is now clear that it was caused by slight but consistent contamination from the sample bottles used in 1974. These were formed from linear polyethylene. In 1971 and 1972 tests were carried out on similar bottles in the course of collecting waters from the Slave Province (Allan *et al.*, 1972). These showed that negligible contamination of Zn and Cu was contributed by the plastic bottles, even with acidification of samples. Similarly, the linear polyethylene bottles used for the 1975 sampling contribute nil contamination of Zn or Cu. Only the first waters collected in any of the 1974 bottles became contaminated. In 1974 the available bottles had to be reused several times. Thus, the published data for Hackett River (Cameron and Ballantyne, 1975) and for Agricola Lake (Cameron and Lynch, 1975) are not affected by contamination.

The principal lake water anomalies shown in Figure 39.3 are based on a number of samples within the same area containing 5 ppb Zn or more. Some samples within the areas may contain 100 ppb Zn or more and anomalous results for Zn are often accompanied by anomalous values for Cu. However, only in one case did the Cu content of an anomalous water exceed the Zn content. Lake waters containing 5 ppb or more of Zn are relatively rare away from the principal anomalies (Fig. 39.3).

Anomalies 1, 2, 3, 5, 6 (High Lake), and 8 (Canoe Lake) are associated with felsic volcanic rocks. Anomalies 4, 7 and 9 appear to be associated with mainly metasedimentary strata. Because of inclement weather at the end of the season this could not be checked for anomaly 4 by ground traversing. Although the area occupied by anomaly 9 is shown as being mainly granitic on Figure 39.3, metamorphosed greywacke and argillite are the dominant rock types in the immediate area of the anomaly.

As noted above, gossans are common throughout the area underlain by metavolcanic rocks. In the case of the anomalies associated with felsic volcanics (1, 2, 3, 5, 6, 8) gossans are present. A limited number of samples were taken from these gossans. In the case of the anomalies associated with the metasedimentary rocks (4, 7, 9) there were no gossans observed in the immediate area. The elongate anomalies (2, 3, 8, 9) are oriented parallel to the strike of the associated metavolcanic or metasedimentary rocks.

There appears to be an interesting spatial distribution to the anomalies. Anomalies 1, 2, 3 and 4 occur along an east-west trend that is roughly perpendicular to the strike of the metavolcanic-metasedimentary belt. Similarly, anomalies 5, 6 and 7 are along an east-west axis and anomaly 9 is to the east of the Canoe Lake area anomaly. The separation of these three east-west axes is roughly equidistant at an approximate interval of 17 miles (27 km). It should be noted that the anomalies associated with metasedimentary rocks (4, 7, 9) occur lateral to the anomalies associated with the felsic volcanic rocks. In the Slave Province metavolcanic rocks generally occur along the margin of the greenstone belts, where they form the base of the volcanic-sedimentary sequence of the belts. The axial portion of the belts are composed of metamorphosed flysch facies sediments. To the present there has been insufficient geological work carried out in the northern part of the Slave Province to define the structural relationships between the Archean volcanic and sedimentary rocks. However, in the north-northwest trending Beechey Lake belt to the southeast, volcanic rocks are along the western flank of the belt and metasediments in the axial portion. In this belt there is a well developed base metal lake sediment and water anomaly in the Agricola Lake area that is associated with felsic volcanic rocks (Cameron and Durham, 1974; Cameron and Lynch, 1975). Eight miles (13 km) to the east, within the metasedimentary portion of the belt, is another well developed base metal anomaly. The cause of this anomaly is unknown for, like those associated with metasediments in the High Lake area, there are no gossans present or other obvious signs of base metal mineralization. This phenomenon requires further study.

Most of the anomalies shown in Figure 39.3 were confirmed by resampling the anomalous lakes and by more detailed sampling. These data will be given in a later paper. A limited number of seep waters were collected in order to more closely define the source base metals for anomalous lakes. The very dry summer of 1975 was not, however, conducive to this follow-up work.

For exploration in this and similar regions, hydrogeochemical methods can probably play an important role in mineral exploration. They provide targets of limited areal extent within which geological, geophysical and geochemical studies can be focussed. The more anomalous base metal values can probably only be derived from actively oxidizing sulphide bodies, so that the effects of glacial transport of metal-rich overburden are reduced. Compared to lake sediment surveys, sampling is simpler, faster and more economical. It is practical to analyze the waters under field conditions. As noted in a previous paper (Cameron and Ballantyne, 1975) anomalies in lake sediments may be recognizable further from the source than those in lake waters. This, together with the uncertainty over the extent of temporal variation in lake water chemistry, and the restriction in the application of hydrogeochemistry to the more mobile elements, determines that lake sediment surveys are presently more suited to broad scale reconnaissance in the northern Shield. But for more detailed surveys of restricted application, such as might be required for exploration for massive sulphides within a given volcanic belt, these disadvantages are of little consequence. In this case the advantages of hydrogeochemical methods noted above may become dominant.

Acknowledgments

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