Geochemical reanalysis of archived regional lake sediment samples, central Baffin Island, Nunavut

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Abstract

The central Baffin Island area, which is underlain by Paleoproterozoic supracrustal rocks of the Piling Group and Archean basement rocks, has long been an area of interest for mineral exploration. In 1978, the Geological Survey of Canada conducted a large regional geochemical survey of lake-bottom sediment to evaluate the mineral potential for various commodities. A total of 1774 lakes, throughout an area of nearly 26 000 km^2, were sampled at a density of one sample site per 13 km^2 in central Baffin Island (west and southwest of the Barnes Ice Cap; parts of NTS 27B, C, 37A, D).

Samples were originally analyzed by atomic absorption spectroscopy in 1978 and subsequently by instrumental neutron activation analysis in 1998. This project involved the reanalysis of the archived sediment samples using an aqua-regia dissolution followed by inductively coupled plasma–mass spectrometry to generate geochemical data for a suite of 65 elements. These new data will provide a more complete and up-to-date dataset to assist mineral exploration in the area.

Résumé

La zone centrale de l'île de Baffin, qui recouvre les roches supracrustales paléoprotérozoïques du groupe de Piling et les roches du socle archéen, a longtemps été une zone d'intérêt en matière d'exploration minérale. En 1978, la Commission géologique du Canada a réalisé un vaste levé géochimique régional des sédiments de fond lacustre afin d'évaluer le potentiel minéral de divers produits minéraux. Au total, 1774 lacs, répartis sur près de 26 000 km^2, ont été échantillonnés selon une échelle d'un échantillon au 13 km^2, correspondant à une région couverte en partie par les feuillets 27B, C, 37A et D du SNRC (ouest et sud-ouest de la calotte glaciaire de Barnes).

Les échantillons ont été analysés pour la première fois en 1978 par spectrométrie d'absorption atomique et, plus récemment en 1998, par activation neutronique instrumentale. La présente étude porte sur les résultats de nouvelles analyses d'échantillons archivés pratiquées au moyen de la dissolution à l'eau régale et de la spectrométrie de masse avec plasma à couplage inductif afin de produire des données géochimiques pour une série complète de 65 éléments. Ces nouvelles données fourniront un ensemble de données plus complet et à jour susceptible de faciliter les activités d'exploration minérale dans la région.

Introduction

The objective of this project is to generate new up-to-date geochemical data on archived lake sediment samples to promote mineral exploration over a large part of central Baffin Island, Nunavut. The study area comprises parts of four 1:250 000 scale NTS map areas (NTS 27B, C, 37A, D; Figure 1), west and southwest of the Barnes Ice Cap.

The central Baffin Island area, which is underlain by Paleoproterozoic supracrustal rocks of the Piling Group and Archean basement rocks, has long been an area of interest for mineral exploration. In the latter part of the 1970s, under the terms of the Federal Uranium Reconnaissance Program, the Geological Survey of Canada (GSC) carried out a series of reconnaissance geochemical surveys of lake sediment and water across the Arctic region and other parts of

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Canada (Darnley et al., 1975) to evaluate the mineral potential for uranium and various other commodities (Coker et al., 1981). In 1978, a central Baffin Island National Geochemical Reconnaissance (NGR) survey (Figure 1; Hornbrook and Lynch, 1979a–c) was completed with a total of 1774 sites sampled for lake sediments and water (sample locations on Figure 2). The survey area covered nearly 26 000 km^2 and was sampled at a density of one sample site per 13 km^2. An important section of the mineralized rocks of the Piling Group underlies the study area (Government of Nunavut, Indian and Northern Affairs Canada, Nunavut Tunngavik Incorporated and Canada-Nunavut Geoscience Office, 2002; St-Onge et al., 2007, Indigenous and Northern Affairs Canada, Government of Nunavut, Nunavut Tunngavik Incorporated and Canada-Nunavut Geoscience Office, 2017).

Analytical techniques at the time generated values for 11 elements plus loss-on-ignition in sediment samples, and uranium, fluoride and pH in water samples. Anomalous levels, particularly of arsenic, revealed by this study and in a preliminary interpretation by Cameron (1986), sparked renewed interest in the area. In 1998, the Qikiqtaaluk Corporation, through the North Baffin Partnership Program, provided funds to reanalyze lake sediments collected by the GSC in 1978 (Friske et al., 1999). The instrumental neutron activation analysis (INAA) of archived sediment samples generated geochemical data for an additional 25 elements. These data confirmed an extensive As anomaly and identified numerous Au anomalies over the Piling Group, several significant multielement base metal anomalies in the Flint Lake area (Figure 2) as well as anomalous rare-earth–element (REE) concentrations over Archean intrusive rocks.

Recently, with support from the GSC's Geo-mapping for Energy and Minerals program (GEM), the GSC reanalyzed archived regional lake sediment samples from other areas of Nunavut, including the Melville Peninsula (Day et al., 2009), Nueltin Lake area (McCurdy et al., 2012a) and Baker Lake area (McCurdy et al., 2012b), using a modified aqua-regia digestion followed by inductively coupled plasma–mass spectrometry (ICP-MS) analysis. With the publication of up-to-date geochemical datasets containing values for a large number of elements, these reanalysis projects had success in creating renewed interest in exploration in these areas. The central Baffin Island lake sediment samples were reanalyzed following similar analytical methods.

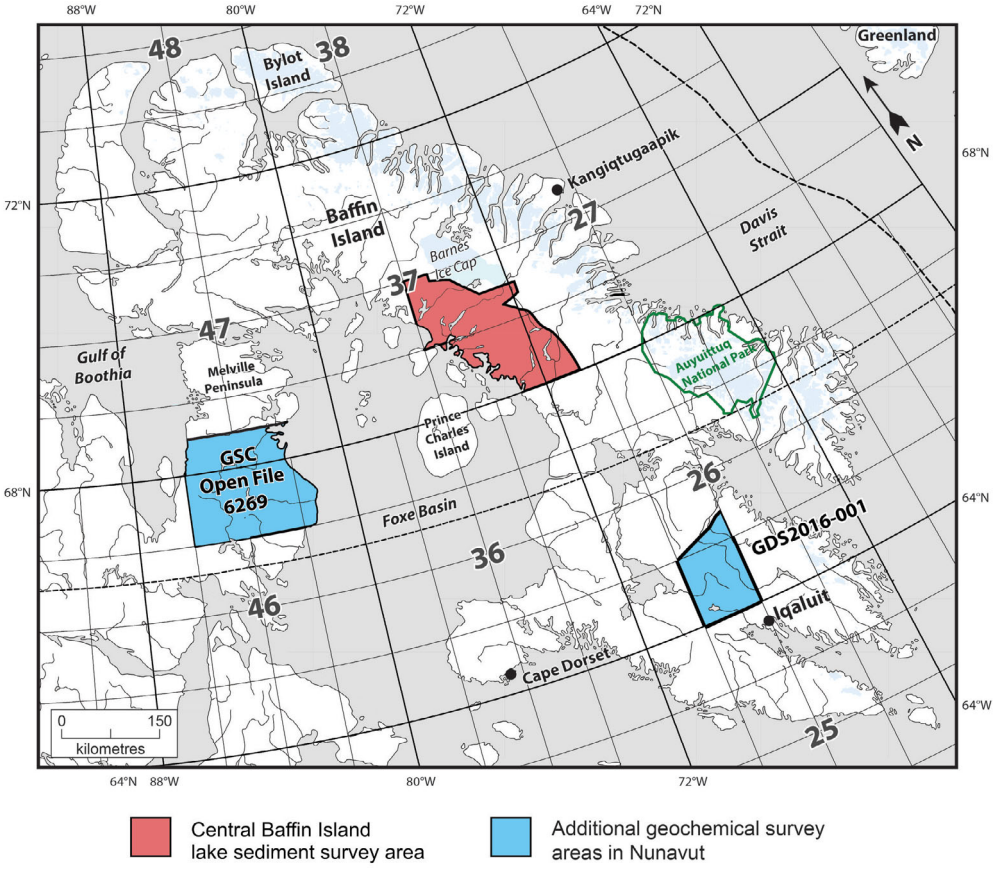

Figure 1: Index map of regional geochemical surveys on Baffin Island and Melville Peninsula by the Geological Survey of Canada (GSC Open File 6269 [Day et al., 2009]) and Canada-Nunavut Geoscience Office (Geoscience Data Series [GDS] 2016-001 [Tremblay et al., 2016]). Red area represents the survey area of Hornbrook and Lynch (1979a–c) and this study. Modified from McCurdy et al. (2014).

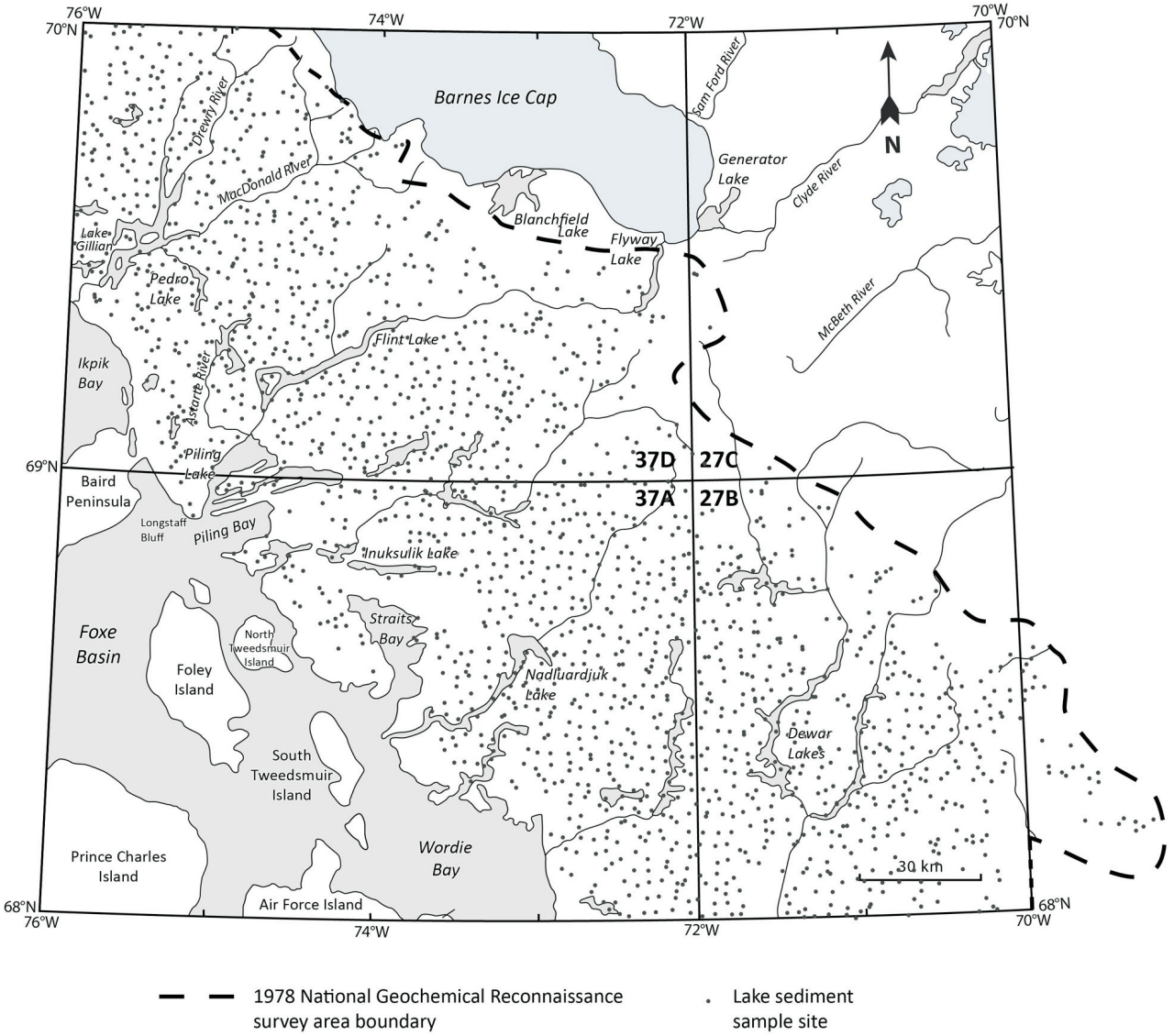

Figure 2: Location of reanalyzed lake sediment sample sites, central Baffin Island, Nunavut (base map from Dredge, 2004). Survey area of Hornbrook and Lynch (1979a–c).

All data and metadata for NGR and other GSC surficial geochemical surveys are downloadable from the Canadian Database of Geochemical Surveys (Natural Resources Canada, 2018). Adcock et al. (2013) describe this database's structure and how the GSC maintains its integrity with the always increasing complexity of analytical techniques.

Regional setting

The study area lies in the central part of western Baffin Island and covers approximately 26 000 km^2 (Figure 2). The area has a gently rolling and tilted surface rising toward the northeast. There are two broad physiographic regions: in the west, the Foxe Basin lowlands coastal area and in the east, the flanks of the highlands that form the eastern coastline of Baffin Island. The Barnes Ice Cap forms part of the northeastern boundary of the study area. Elevations range from near sea level in coastal areas along Foxe Basin to 500–600 m along the eastern boundary of the survey area. Rivers and streams flow southwest into Foxe Basin. On the highlands to the east, rivers, such as the Sam Ford, Clyde and McBeth, flow toward Baffin Bay in the northeast. The area lies within continuous permafrost. The regional bedrock geology and the Piling Group rocks in particular are described in Corrigan et al. (2001), Scott et al. (2002, 2003), St-Onge et al. (2007) and Partin et al. (2014). Surficial geology data and maps are contained in Dredge (2002, 2004), Dredge et al. (2007) and Utting et al. (2008, 2015).

Methodology

Sampling method

The collection of sediment samples from the centre of lake bottoms and surface water samples was carried out during the summer of 1978 using a helicopter equipped with floats (Hornbrook and Lynch, 1979a–c). Sampling density followed GSC protocols at an average density of one site per 13 km^2 (Friske and Hornbrook, 1991) throughout the 26 000 km^2 covering the central Baffin Island study area. Sample site and grid cell duplicate samples were routinely collected for each analytical block of 20 samples.

Sample preparation

Field-dried lake sediment samples were shipped to laboratories and air-dried, crushed and ball-milled (Hornbrook and Lynch, 1979a–c). The –80 mesh (177 µm [microns]) fraction was recovered and used for subsequent analyses. At this time, control reference and blind duplicate samples were inserted into each block of 20 sediment samples. For the water samples, only control reference samples were inserted into the block. There were no blind duplicate water samples.

Analytical methods

Lake sediment (1978)

The original analysis provided data for 11 elements (Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe, As, Mo, U) in lake sediment samples. These samples were also submitted for loss-on-ignition testing. Results were released in GSC open files (Hornbrook and Lynch, 1979a–c).

The following analytical method descriptions for lake sediment analysis are taken from Hornbrook and Lynch (1979a–c). For the determination of Zn, Cu, Pb, Ni, Co, Ag, Mn and Fe, a 1 g sample was reacted with 6 ml of a mixture of 4 mol HCl and 1 mol HNO_3 in a test tube overnight at room temperature. After digestion, the test tube was immersed in a hot water bath at room temperature and brought up to 90°C and held at this temperature for two hours with periodic shaking. The sample solution was then diluted to 20 ml with metal-free water and mixed. The concentrations of Zn, Cu, Pb, Ni, Co, Ag, Mn and Fe were determined by atomic absorption spectroscopy (AAS) using an air-acetylene flame.

Arsenic was determined by AAS using a hydride evolution method wherein the As was evolved as AsH_3 and passed through a heated quartz tube in the light path of an atomic absorption spectrophotometer.

Molybdenum was determined by AAS using a nitrous oxide acetylene flame. A 0.5 g sample was reacted with 1.5 ml concentrated HNO_3 at 90°C for 30 minutes. At this point, 0.5 ml concentrated HCl was added and the digestion continued at 90°C for an additional 90 minutes. After cooling, 8 ml of 1250 ppm Al solution were added and the sample solution diluted to 10 ml before aspiration.

Uranium was determined using an INAA method with delayed neutron counting. Boulanger et al. (1975) provides a detailed description of the original method. In brief, a 1 g sample was weighed into a 25 cm^3 (7 dram) vial, capped and sealed. The sample was irradiated in a SLOWPOKE reactor with an operating flux of 1012 neutrons/cm^2/s. The samples were pneumatically transferred from an automatic loader to the reactor, where each sample was irradiated for 60 seconds. After irradiation, the samples were again transferred pneumatically to the counting facility where after a 10 second delay the sample was counted for 60 seconds with six BF3 detector tubes embedded in paraffin. Following counting, the samples were automatically ejected into a shielded storage container.

Loss-on-ignition was determined using a 500 mg sample. The sample, weighed into a 30 ml beaker, was placed in a cold muffle furnace and brought up to 500°C over a period of two to three hours. The sample was held at this temperature for four hours then allowed to cool to room temperature for weighing.

Lake water (1978)

Uranium, fluoride and pH were determined in lake water samples. After testing, the remaining sample of water, approximately 225 ml, was acidified with 3 ml of concentrated HNO_3. The following analytical method descriptions for water analysis are taken from Hornbrook and Lynch (1979a–c).

Uranium was determined by placing sample aliquots on a polycarbonate tape and dried. The tape was then irradiated in a nuclear reactor for one hour in a flux of 1013 neutrons/cm^2/s. The tape was subsequently etched with 25% NaOH solution and the fission tracks were counted with an optical counter fitted to a microscope. The number of tracks was proportional to the uranium concentration. Each tape contained its own calibration standards, blanks and sample duplicates.

Hydrogen ion activity (pH) was measured with a Beckman glass-calomel combination electrode and a Model 401 Orion specific ion meter.

Fluoride was determined using a Model 401 Orion specific ion meter with an Orion fluoride electrode. Prior to measurement, an aliquot of the sample was mixed with an equal volume of a modified total ionic strength adjustment buffer (TISAB). The modification consisted of adding 60 ml of 8 mol KOH solution to the buffer. This permitted the reanalysis of fluoride in acidified water samples when required. When this analysis was necessary, acidified standard solutions were used for calibration.

Lake sediment (1998)

This first reanalysis, as described below, provided supplementary data in the form of an additional 25 elements derived from nondestructive INAA. Results were released in GSC Open File 3716 (Friske et al., 1999).

The following analytical method is described in Friske et al. (1999). Weighed and encapsulated samples were packaged for irradiation along with internal standards and international reference materials. Samples and standards were irradiated together with neutron flux monitors in a two megawatt pool-type reactor. After a seven-day decay period, samples were measured on a high-resolution germanium detector. Computer control was achieved with a Microvax II computer. Typical counting times were 500 seconds.

Lake sediment (2018)

This second reanalysis provides an up-to-date dataset by providing a full suite of 65 elements (Table 1) on archived lake sediment samples (n=1768). A total of six samples were not reanalyzed due to insufficient material remaining. A modified aqua-regia dissolution was used prior to ICP-MS analysis and was carried out by Bureau Veritas Commodities Canada (BVCC; Vancouver, British Columbia).

The full suite of elements was determined by a modified aqua-regia partial dissolution using BVCC package AQ250-EXT. Pulp-splits of 0.5 g samples were leached with a 6 ml mixture of HCl, HNO_3 and distilled/deionized water (2:2:2 volume to volume ratio) at 95°C for one hour. The sample solution was diluted to 20 ml and analyzed by ICP-MS. Method description taken from McNeil et al. (2018b).

Data quality was estimated using control reference materials with known elemental concentrations to evaluate accuracy, and analytical duplicate samples to evaluate analytical precision. Field duplicate data were used to carry out an analysis of variance (ANOVA) in order to compare the estimated sampling and analytical variability and judge whether the data are suitable for mapping purposes.

The new dataset, as well as a compilation of all pre-existing geochemical analyses on the lake sediment and water samples, is available in McNeil et al. (2018a)[4].

Table 1: List of elements determined in lake sediments with a modified aqua-regia dissolution followed by inductively coupled plasma–mass spectrometry analysis.

Element	Unit	LOD*	Element	Unit	LOD*
Ag	ppb	2	Na	%	0.001
Al	%	0.01	Nb	ppm	0.02
As	ppm	0.1	Nd	ppm	0.02
Au	ppb	0.2	Ni	ppm	0.1
B	ppm	20	P	%	0.001
Ba	ppm	0.5	Pb	ppm	0.01
Be	ppm	0.1	Pd	ppb	10
Bi	ppm	0.02	Pr	ppm	0.02
Ca	%	0.01	Pt	ppb	2
Cd	ppm	0.01	Rb	ppm	0.1
Ce	ppm	0.1	Re	ppb	1
Co	ppm	0.1	S	%	0.02
Cr	ppm	0.5	Sb	ppm	0.02
Cs	ppm	0.02	Sc	ppm	0.1
Cu	ppm	0.01	Se	ppm	0.1
Dy	ppm	0.02	Sm	ppm	0.02
Er	ppm	0.02	Sn	ppm	0.1
Eu	ppm	0.02	Sr	ppm	0.5
Fe	%	0.01	Ta	ppm	0.05
Ga	ppm	0.1	Tb	ppm	0.02
Gd	ppm	0.02	Te	ppm	0.02
Ge	ppm	0.1	Th	ppm	0.1
Hf	ppm	0.02	Ti	%	0.001
Hg	ppb	5	Tl	ppm	0.02
Ho	ppm	0.02	Tm	ppm	0.02
In	ppm	0.02	U	ppm	0.1
K	%	0.01	V	ppm	2
La	ppm	0.5	W	ppm	0.1
Li	ppm	0.1	Y	ppm	0.01
Lu	ppm	0.02	Yb	ppm	0.02
Mg	%	0.01	Zn	ppm	0.1
Mn	ppm	1	Zr	ppm	0.1
Mo	ppm	0.01	*Limit of detection		

Economic considerations

Mineral resource exploration in the Arctic is challenging due to its difficulty of access. Companies and individuals who do so undertake considerable financial risks. The lack of publicly available baseline geoscience data discourages industry from establishing exploration programs. However, given the potential for economic mineralization in central Baffin Island and other areas of Nunavut, up-to-date baseline geochemical data coverage can offset some of the financial risk.

In the region, the Proterozoic Piling Group rocks hold potential for a variety of mineral deposit types (Scott et al., 2003), including Zn (Flint Lake Formation), sedimentary exhalative (SEDEX) base metals (Astarte River Formation), Ni-Cu-PGE (Bravo Lake Formation), Pb-Zn-Ag and Au (upper Dewar Lakes Formation), Sn and Ta (Longstaff Bluff Formation). Exploration for Au, Ni-Cu-Pt-Pd and Zn-Pb-Ag was conducted in the Piling Group (Government of Nunavut, Indian and Northern Affairs Canada, Nunavut Tunngavik Incorporated and Canada-Nunavut Geoscience Office, 2002). Gold exploration is still underway in this

[4] *CNGO Geoscience Data Series GDS2018-001, containing the data or other information sources used to compile this report, is available online to download free of charge at http://cngo.ca/summary-of-activities/2018/.*

sector (Indigenous and Northern Affairs Canada, Government of Nunavut, Nunavut Tunngavik Incorporated and Canada-Nunavut Geoscience Office, 2017).

In addition to being a useful mineral exploration dataset, regional geochemical data are essential for decision-making in future environmental assessments by establishing environmental baselines predating economic development–related activities (Tarvainen, 1996).

Summary

Geochemical reanalysis was conducted on archived lake sediment samples (n=1768), originally collected by the Geological Survey of Canada during a National Geochemical Reconnaissance survey conducted in 1978. The samples were analyzed for a full suite of 65 elements by aqua-regia dissolution followed by inductively coupled plasma–mass spectrometry. The new dataset, as well as a compilation of all pre-existing geochemical analyses on the lake sediment and water samples, will be useful in assisting mineral exploration programs explore for various commodities as well as being used to assist in establishing environmental geochemical baselines.

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