



GEOLOGICAL SURVEY OF CANADA

OPEN FILE 6671

MANITOBA GEOLOGICAL SURVEY

OPEN FILE 2010-3

**Regional Lake Sediment Geochemical Data, Great Island–Seal
River Area,
Manitoba (NTS 54L, 54M, 64I, 64P)**

M.W. McCurdy, C.O. Böhm, J.E. Campbell, S.J.A. Day and R.J. McNeil

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Open files are products that have not gone through the GSC formal publication process.

Regional Lake Sediment and Water Geochemical Data, Great Island–Seal River Area, Manitoba (NTS 54L, 54M, 64I, 64P)

Introduction

New analytical data for up to 58 elements resulting from the reanalysis of 806 lake sediment samples collected from the Great Island–Seal River area, northern Manitoba, in 1976 are presented in this joint Geological Survey of Canada (GSC) and Manitoba Geological Survey (MGS) open file release. Field observations and analytical data originally reported in GSC Open File 407 (GSC, 1977a) and GSC Open File 408 (GSC, 1977b) are included in a separate digital file within this report. These data represent a subset of samples from 2,755 lake sediment samples originally collected in 1976 and published in GSC Open Files 407 and 408. Over 18,000 lake sediment samples from northern Manitoba collected between 1975 and 1991 are currently stored in a GSC archive facility in Ottawa.

The area shown in Figure 1 was sampled in 1976 under the Federal Uranium Reconnaissance Program and a split archived at GSC. Funds for the reanalysis of archive samples were made available under the Geo-Mapping for Energy and Minerals (GEM) Program of Natural Resources Canada (NRCan) and the Manitoba Far North Geomapping Initiative of the MGS. The GEM Program is a 5-year investment by the Government of Canada in geoscience information leading to the discovery of new energy and mineral resources in Canada. GEM is delivered at the federal level by NRCan and the Polar Continental Shelf Project (PCSP). The major focus is on large areas of Canada's North where insufficient public geoscience information exists to attract and guide effective private sector investment. The GEM Minerals component (MGM) is designed to raise the level of geoscience knowledge of Canada's North, with emphasis on the acquisition and rapid release of data for mineral exploration and land-use planning. Supported by geochemical and geophysical information, multidisciplinary teams (federal, territorial/provincial, university-based collaborators and students) are targeting areas with high potential for base and precious metals, diamonds and rare metals.

The Manitoba Far North Geomapping Initiative of the MGS, in partnership with NRCan and universities, focuses on the southeast margin of the Archean Hearne craton in Manitoba, with the goal of furthering the understanding of the nature, evolution and mineral potential of one of the principal geological building blocks of Manitoba's Precambrian shield north of 58°N. The initiative applies integrated bedrock and surficial geological mapping and is aimed to develop effective mineral exploration tools for various terrain types in drift covered areas.

Geochemical data from reanalysis of lake sediment samples support ongoing bedrock and surficial geology studies in the Great Island–Seal River Project (2008-2011). Reanalysis of archive lake sediment samples provides data for more elements than was originally provided in 1977 as well as improved, lower detection limits for many elements, at approximately 5% of the cost of collecting new samples. Analytical results and field observations form part of a national geochemical database used for resource assessment, mineral exploration, geological mapping, and environmental studies. Sample collection, preparation procedures and analytical methods are strictly specified and carefully monitored to ensure consistent and reliable results regardless of the area, the year of collection or the analytical laboratory undertaking the analyses.

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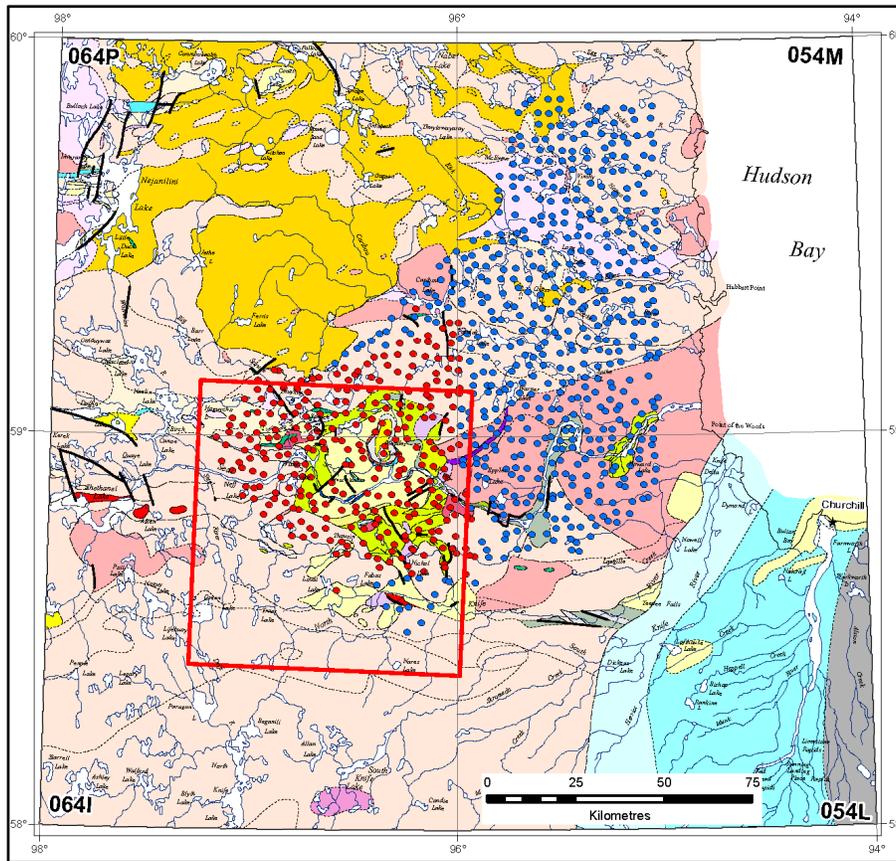
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Legend

SILURIAN

Severn River Formation: limestone, dolomitic limestone and dolomite, very fine grained, tuffoidal

ORDOVICIAN

Churchill River Group: Caution Creek Formation: microcrystalline calcitic dolomite, Red Head Rapids Formation: dolomite, thin-bedded, in part argillaceous

Bad Cache Rapids Group: Portage Chute Formation: basal quartz sandstone overlain by microcrystalline limestone

PROTEROZOIC

gabbro-norite; layered gabbro, leucogabbro, anorthosite

polymictic metaconglomerate, magnetite bearing; quartzose conglomeratic paragneiss

felsic intrusive rocks: tonalite, granodiorite, quartz diorite, rhyolite, pegmatite, aplite

granite, granite gneiss, hybrid granite, pegmatic granite, aplite, porphyritic granite

granodiorite, granodiorite diatexite

anorthositic gabbro

calc-silicate rock

sempelitic paragneiss to metatexite

conglomerate, volcanic derived (probably Archean), grey to grey-green phyllite

"Churchill" quartzite, phyllite, schist

quartz porphyry

sandstone, psammitic gneiss, meta-arkose, metasilstone

grey tonalitic to granodioritic gneiss, hypersthene tonalite, quartz diorite

ultramafic rocks

pyroclastic rocks; volcanoclastic rocks and derived schist

migmatite derived from greywacke

pegmatite

diorite, leucodiorite, quartz diorite, gabbro, tonalite, locally porphyroblastic

felsic volcanic rocks

andesite and minor basalt, interlayered tuff and pillowed andesite

amphibolite

ARCHEAN

enderbitic gneiss, garnet bearing, with mafic/ultramafic inclusions; minor ophiolitic gneiss

hypersthene granite (monochamockite) with hybrid granite

Lake Sediment Reanalysis Sites

Analytical Method

- ICP-ES/MS only
- ICP-ES/MS and INAA

Geophysical survey (2009) outline



Figure 1. Map of northeast Manitoba with geology background and legend showing locations of lake sediment samples collected and analyzed in 1976 and reanalyzed for this report. Bedrock geology is modified after Schledewitz (1986). A 1:500,000-scale map, with sample numbers, can be viewed by clicking the 'Map' button on the Autoplay opening screen.

Description of Survey and Sample Management

Original lake sediment samples were collected during the summer of 1976 and data for 12 elements released in 1977 in two GSC open files (407, 408). The 806 sample sites from which sediments were reanalyzed for this report, shown in Figure 1, are distributed throughout the 11 500 km² area at an average density of one sample per 14.3 km².

A bottom-valved, hollow-pipe sampler was used to collect approximately one kilogram of wet lake sediment. Field observations for each site were recorded on standard forms used by the GSC (Garrett, 1974). At GSC laboratories in Ottawa, field-dried samples were air-dried and sieved through a minus 80 mesh (177 micron) screen before milling in ceramic-lined puck mills. Typically, one kilogram of the organic gel, the preferred collection material, yielded about 50 g of material for analysis. After milling, control reference and blind duplicate samples were inserted into each block of twenty sediment samples. For quality control purposes, the original samples were arranged in groups (consecutively-numbered blocks) of twenty. Each group of twenty contained site duplicate samples, that is, two samples from a single site; the group also contained an analytical duplicate sample pair (a single site sample split and assigned two non-consecutive sample numbers). Finally, each group included a control reference sample. Before publication, thorough inspections of the field and analytical data were made to check for any missing information and/or analytical errors. A more detailed description of collection and quality control methods used by the GSC for lake sediment samples can be found in Cook and McConnell (2001). Samples selected for reanalysis were removed from the GSC archive facility in Ottawa and shipped to commercial labs for reanalysis. Within these reanalysis suites, the above-described pattern of distribution of quality control samples was maintained, with the exception that new control reference standards replaced the original ones inserted in 1976.

Quality assurance/quality control measures for the reanalysis of the data by Inductively Coupled Plasma Emission Spectroscopy/Mass Spectrometry (ICP-ES/MS) were carried out by the Applied Geochemistry section staff (2010) at the GSC.

Analytical Procedures (2010)

ICP-ES/MS

For the determination of 35 elements listed in Table 1, a one-gram sample was leached with 6 ml of a mixture of HCl, HNO₃, 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 analysed by inductively coupled plasma emission spectroscopy on a Jarell-Ash instrument and inductively coupled plasma mass spectroscopy on a Perkin-Elmer Elan instrument. Data for Au and B were not published here because of inadequate lower detection limits and/or precision. Analyses were carried out at Acme Analytical Laboratories, Limited, Vancouver, British Columbia.

Table 1. Elements Determined by ICP-ES/MS Reanalysis of Archive Lake Sediment Samples

| Element | Detection Limit | Units of Measurement | Analytical Method |
|----------------|------------------------|-----------------------------|--------------------------|
| Ag | 2 | ppb ¹ | ICP-MS |
| Al | 0.01 | pct ² | ICP-MS |
| As | 0.1 | ppm ³ | ICP-MS |
| Ba | 0.5 | ppm | ICP-MS |
| Be | 0.1 | ppm | ICP-MS |
| Bi | 0.02 | ppm | ICP-MS |
| Ca | 0.01 | pct | ICP-ES |
| Cd | 0.01 | ppm | ICP-MS |

| | | | |
|-----------|-------|-----|--------|
| Ce | 0.1 | ppm | ICP-MS |
| Co | 0.1 | ppm | ICP-MS |
| Cr | 0.5 | ppm | ICP-MS |
| Cs | 0.02 | ppm | ICP-MS |
| Cu | 0.01 | ppm | ICP-MS |
| Fe | 0.01 | pct | ICP-ES |
| Ga | 0.2 | ppm | ICP-MS |
| Ge | 0.1 | ppm | ICP-MS |
| Hf | 0.02 | ppm | ICP-MS |
| Hg | 5 | ppb | ICP-MS |
| In | 0.02 | ppm | ICP-MS |
| K | 0.01 | pct | ICP-ES |
| La | 0.5 | ppm | ICP-MS |
| Li | 0.1 | ppm | ICP-MS |
| Mg | 0.01 | pct | ICP-ES |
| Mn | 1 | ppm | ICP-ES |
| Mo | 0.01 | ppm | ICP-MS |
| Na | 0.001 | pct | ICP-MS |
| Nb | 0.02 | ppm | ICP-MS |
| Ni | 0.1 | ppm | ICP-MS |
| P | 0.001 | pct | ICP-MS |
| Pb | 0.01 | ppm | ICP-MS |
| Pd | 10 | ppb | ICP-MS |
| Pt | 2 | ppb | ICP-MS |
| Rb | 0.1 | ppm | ICP-MS |
| Re | 1 | ppb | ICP-MS |
| S | 0.01 | pct | ICP-MS |
| Sb | 0.02 | ppm | ICP-MS |
| Sc | 0.1 | ppm | ICP-MS |
| Se | 0.1 | ppm | ICP-MS |
| Sn | 0.1 | ppm | ICP-MS |
| Sr | 0.5 | ppm | ICP-MS |
| Ta | 0.05 | ppm | ICP-MS |
| Te | 0.02 | ppm | ICP-MS |
| Th | 0.1 | ppm | ICP-MS |
| Ti | 0.001 | pct | ICP-MS |
| Tl | 0.02 | ppm | ICP-MS |
| U | 0.1 | ppm | ICP-MS |
| V | 2 | ppm | ICP-MS |
| W | 0.1 | ppm | ICP-MS |
| Y | 0.01 | ppm | ICP-MS |
| Zn | 0.1 | ppm | ICP-MS |
| Zr | 0.1 | ppm | ICP-MS |

- 1) parts per billion (ppb)
- 2) per cent (pct)
- 3) parts per million (ppm)

Instrumental Neutron Activation Analysis (INAA)

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. Typical counting times were 500 seconds. Elements determined by INAA include: Ag, As, Au, Ba, Br, Cd, Ce, Co, Cr, Cs, Eu, Fe, Hf, Ir, La, Lu, Mo, Na, Ni, Rb, Sb, Sc, Se, Sm, Sn, Ta, Tb, Te, Th, Ti, U, W, Yb, Zn, and Zr. The sample weights were also reported. Data for Ag, Cd, Ir, Mo, Ni, Se, Sn, Te, Zn, and Zr were not published because of inadequate detection limits and/or precision. Analyses were carried out at Becquerel Labs, Mississauga, Ontario.

Table 2. Variables determined by INA Reanalysis of Archive Lake Sediment Samples

| Variable | Detection Limit | Units of Measurement | Analytical Method |
|-----------------|------------------------|-----------------------------|--------------------------|
| As | 0.5 | ppm ¹ | INAA |
| Au | 2 | ppb ² | INAA |
| Ba | 40 | ppm | INAA |
| Br | 0.5 | ppm | INAA |
| Ce | 5 | ppm | INAA |
| Co | 5 | ppm | INAA |
| Cr | 20 | ppm | INAA |
| Cs | 0.5 | ppm | INAA |
| Eu | 1 | ppm | INAA |
| Fe | 0.2 | pct ⁴ | INAA |
| Hf | 1 | ppm | INAA |
| La | 2 | ppm | INAA |
| Lu | 0.2 | ppm | INAA |
| Na | 0.02 | pct | INAA |
| Rb | 5 | ppm | INAA |
| Sb | 0.1 | ppm | INAA |
| Sc | 0.2 | ppm | INAA |
| Sm | 0.1 | ppm | INAA |
| Ta | 0.5 | ppm | INAA |
| Tb | 0.5 | ppm | INAA |
| Th | 0.2 | ppm | INAA |
| Ti | 500 | ppm | INAA |
| U | 0.2 | ppm | INAA |
| W | 1 | ppm | INAA |
| Wt | 0.1 | g | |
| Yb | 2 | ppm | INAA |

- 1) parts per million (ppm)
- 2) parts per billion (ppb)
- 3) grams (g)
- 4) per cent (pct)

Analytical Procedures (1976)

Atomic Absorption Spectroscopy (AAS) and Other Analyses

For the determination of Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe, and Cd, a 1 g sample was reacted with 3 ml concentrated HNO₃ 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 30 minutes with periodic shaking. One ml of concentrated HCl was added and heating continued for another 90 minutes. The sample solution was then diluted to 20 ml with metal-free water and mixed. Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe and Cd were determined by AAS using an air-acetylene flame. Background corrections were made for Pb, Ni, Co, Ag, and Cd.

Molybdenum was determined by AAS using a nitrous oxide acetylene flame. A 0.5 g sample was reacted with 1.5 ml concentrated HNO₃ 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 30 minutes with periodic shaking. 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.

Mercury was determined by the Hatch and Ott procedure with some modifications. The method is described by Jonasson *et al.* (1973). A 0.5 g sample was reacted with 20 ml concentrated HNO₃ and 1 ml concentrated HCl in a test tube for 10 minutes at room temperature prior to two hours of digestion with mixing at 90° C in a hot water bath. After digestion, the sample solutions were cooled and diluted to 100 ml with metal-free water. The Hg present was reduced to the elemental state by the addition of 10 ml 10% weight per volume (w/v) SnSO₄ in 1 M H₂SO₄. The Hg vapour was then flushed by a stream of air into an absorption cell mounted in the light path of an atomic absorption spectrophotometer. Absorption measurements were made at 253.7 nm.

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.

Arsenic was determined by a colorimetric method using silver diethyldithiocarbamate. Sample material was digested by heating a 1 g sample with 20 ml of 6M HCl at 90°C for 1.5 hours. Arsenic in the reaction solution was converted to arsine, which was evolved and then complexed with silver diethyldithiocarbamate. The intensity of the colour of the complex was determined with a spectrophotometer. Colorimetric measurements were made at 520 nm.

Analyses for LOI and the 12 elements described above were carried out at Chemex Laboratories, Vancouver, British Columbia.

Uranium was determined using a neutron activation method with delayed neutron counting. A detailed description of this method is provided by Boulanger *et al.* (1975). In brief, a 1 g sample was weighed into a 7-dram polyethylene vial, capped and sealed. The samples were pneumatically transferred from an automatic loader to a 'Slowpoke' reactor, where each sample was irradiated for 60 seconds in an operating flux of 10¹² neutrons/cm²/sec. After irradiation, the samples were transferred to a counting facility where, after a ten second delay, each sample was counted for 60 seconds with six BF₃ detector tubes embedded in paraffin. Following counting, samples were ejected into a shielded storage container. Analysis of uranium in lake sediments was carried out at Atomic Energy of Canada, Limited (AECL), Ottawa, Ontario.

Table 3. Summary of original elements determined and methods used.

| Element | Detection Limit | Units of Measurement | Analytical Method |
|----------------|------------------------|-----------------------------|--------------------------|
| Ag | 0.2 | ppm | AAS ¹ |
| As | 1.0 | ppm | COL ² |
| Co | 2 | ppm | AAS |
| Cu | 2 | ppm | AAS |
| Fe | 0.02 | pct | AAS |
| Hg | 10 | ppb | CV-AAS ³ |
| LOI | 1.0 | pct | GRAV ⁴ |
| Mn | 5 | ppm | AAS |
| Mo | 2 | ppm | AAS |
| Ni | 2 | ppm | AAS |
| Pb | 2 | ppm | AAS |
| U | 0.5 | ppm | NADNC ⁵ |
| Zn | 2 | ppm | AAS |

- 1) Atomic Absorption Spectrometry (AAS)
- 2) Colorimetric (COL)
- 3) Cold vapour Atomic Absorption Spectrometry (CV-AAS)
- 4) Gravimetric methods (GRAV)
- 5) Neutron activation – delayed neutron counting (NADNC)

FORMAT OF DATA FILES

Analytical results from 2010 are presented in an Excel® spreadsheet file included with this report: **GSC OF 6671/MGS OF 2010-3 DATA**. There are five worksheets in this file:

| <u>Worksheet</u> | <u>Contents</u> |
|-----------------------------|--|
| Field Data | site-specific field observations including sample locations |
| Original Data -1977 | AAS and specific methods analytical data for samples analyzed in 1977 |
| Reanalysis–ICP-2010 | ICP-ES/MS analytical data for lake sediment samples analyzed in 2010 |
| Reanalysis–INAA-2010 | INA analytical data for lake sediment samples analyzed in 2010 |
| GIS Data-ICP-2010 | GIS-ready ICP analytical data for lake sediment samples analyzed in 2010 |
| GIS Data-INAA-2010 | GIS-ready INA analytical data for lake sediment samples analyzed in 2010 |

Brief descriptions of the field headers used in the ‘Field Data’ worksheet can be found in Appendix 1.

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E.H. Hornbrook (GSC) directed the original surveys carried out in 1976, coordinating the activities of contract and GSC staff. Contracts for sample preparation and analysis were managed by J.J. Lynch (GSC).

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The authors would also like to thank Beth McClenaghan, GSC, for her suggestion to Christian Böhm, MGS, that a talk on the GSC collection of archive lake sediments from northern Manitoba might be of interest at the 2009 Manitoba Mining and Minerals Convention.

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Appendix 1

Descriptions of Field Headings in Field Data Spreadsheet

UniqID – A 10-digit alphanumeric combination of the NTS Sheet (see below), two digits indicating the year of collection, a one-digit number identifying the collection party, and a three-digit sequential number from 1 to 999 identifying each individual sample in the order it was collected, e.g. 054L761002. This format is used to identify all National Geochemical Reconnaissance samples

NTS Sheet – National Topographic System 1:250,000 index reference, consisting of three numbers and one letter, e.g. 054L.

Year – a two digit number identifying the year in which a sample was collected, e.g. 76 (1976)

SampleNum – a combination of two-digits indicating the year of collection, the collection party identifier and the three digit number identifying the sample in the order it was collected (001 to 999). This number, preceded by the NTS Sheet within which the sample was collected, was originally used as the sample identifier for National Geochemical Reconnaissance samples.

RepStat – A one-digit number, either 0, 1 or 2, identifying samples as either routine samples (0), first sample collected in a field duplicate pair (1), or second sample in a field duplicate pair. Field duplicates are two samples collected from the same site.

Latitude (NAD83), Longitude (NAD83) – sample location in decimal degrees, North American Datum

Lake area – approximate area of the water body sampled

| | |
|---------------|---------------------------------------|
| Pond – | less than 0.25 square kilometres |
| 0.25 – | 1.0 sq km - 1/4 to 1 square kilometre |
| 1 – 5 sq km - | 1 to 5 square kilometres |
| >5 sq km - | greater than 5 square kilometres |

Lake Depth – the depth, in metres, below the water surface from which a sample of lake sediment was collected

Terrain Relief – relief of land immediately surrounding the lake sampling site

- Low - land is flat-lying, lake is often within or adjacent to swamp, bog, marsh or fen; drainage poor
- Medium – surrounding or adjacent land is hilly, usually treed, drainage is good
- High – mountainous terrain

Contamination – possible sources of anthropogenic or natural sediment contamination

- None - no apparent sources of human or natural contamination present
- Work – evidence of mining or industrial activity (past or present) within lake catchment basin
- Camp – signs of recreational activity, such as cottages, camps, docks, etc.
- Fuel – fuel barrels (empty or full) observed on land surrounding lake (or in lake)
- Gossan – signs of intensely oxidized, weathered or decomposed rock within the lake catchment basin

Sediment Colour – the colour of the wet sediment as observed by the collector at the site; more than one colour can be selected, e.g. Green Brown

Suspension – an indication of the presence of suspended material (clastic and/or organic) observed in surface waters at the lake sediment sampling site.

- None - visibility in water unrestricted by suspended material, i.e. water appears clear
- Light - some suspended material apparent, but visibility in surface water exceeds one metre
- Heavy - surface water appears cloudy, visibility one metre or less