J. Phys. IV France **107** (2003)
© EDP Sciences, Les Ulis
DOI: 10.1051/jp4:20030361

A 6,000-years record of atmospheric mercury accumulation in the high Arctic from peat deposits on Bathurst Island, Nunavut, Canada

N. Givelet, F. Roos-Barraclough, M.E. Goodsite[1] and W. Shotyk[2]

Institute of Geological Sciences, University of Berne, Baltzerstrasse 1-3, 3012 Berne, Switzerland
[1] *Department of Chemistry, University of Southern Denmark, Campusvej 55, 5230 Odense, Denmark*
[2] *Institute of Environmental Geochemistry, University of Heidelberg: Im Neuenheimer Feld 236, 69120 Heidelberg, Germany*

Abstract. *There is a growing interest in the atmospheric transport, deposition, and accumulation of anthropogenic Hg in the Arctic. To quantify the impact of industrial Hg emissions, the natural rate of atmospheric Hg accumulation must be known. Mercury concentration measurements and age dating of peat from the Canadian Arctic show that natural "background" Hg flux rather constant (ca. 1 microgram per sq. m per yr.) throughout the past 6,000 years. Mercury concentrations in surface peat layers are much higher, but chronology of these changes cannot be interpreted until more age dates are available. The elevated Hg concentrations in surface layers, however, are out of proportion with Br and Se, suggesting that there has been a significant human impact. Peat cores from southern Canada provide a record of atmospheric Hg accumulation extending back nine thousand years, with similar background fluxes. Thus, pre-anthropogenic Hg fluxes in the High Arctic were not significantly different from atmospheric Hg fluxes in the temperate Zone.*

1. INTRODUCTION

There is a long-standing interest in atmospheric pollution of the Arctic environment. Recent attention has begun to focus upon the possible health effect of environmental pollution by "heavy metals", and the entire spectrum of terrestrial and aquatic ecosystems in the Arctic has received growing attention. The present state of the Arctic environment has been summarized in a comprehensive reports published by AMAP [1]. Some of the main features of this study are as follow: some Arctic population groups are among the most exposed population in the world to certain environmental contaminants; contaminant levels in some Artic birds and mammals exceed some thresholds associated with reproductive, immunosuppressive, and neurobehavioral; mercury (Hg) seems to be increasing in aquatic sediments and in marine mammals. According to detailed review by [2], the "lack of temporal trend information for most of the contaminant is perhaps the most significant knowledge gap at the present time".
The main goal of the study was to quantify the modern and pre-anthropogenic rates of atmospheric deposition of Hg in the High Arctic of Canada using peat cores. In particular, we proposed to reconstruct a complete record of atmospheric Hg for the past 8,000 ^{14}C years.

2. MATERIAL

Peat cores were collected from peat deposits on Bathurst Island (75 degrees north latitude) in the High Arctic of Canada. Two sites in Polar Bear Pass National Wildlife Area were sampled: Bracebridge Inlet (BI) and Museum Station (MS). The coring site at BI took place at the apex of a peat polygon. The non-frozen layer was cut away as a block by hand using a serrated, stainless steel knife. After removing

and wrapping the blocks, the underlying frozen layer was collected using a motorized SIPRE type-drilling machine built especially for the expedition. At BI, 90cm of peat was recovered: the first 14cm as blocks of non-frozen peat, and the other 76cm as cores of frozen peat. At MS, only 70cm of peat was found: 30cm blocks of non-frozen peat were collected from the surface, and 30cm was recovered as frozen peat by drilling. All samples were frozen at -18°C at the Polar Continental Shelf Project for storage and subsequent transportation to Berne.

3. METHODS

In the laboratory, cores were cut (while frozen) into 1cm slices using a stainless steel band saw. The outside edges of each slice was cut away, dried overnight at 105°C in a drying oven and milled in a centrifugal mill with titanium sieve. The powder sample of each slice was manually homogenized and used for further analysis. Selected major and trace elements were measured using XRF spectrometers. Four plugs were subsampled from the middle of each slice with a stainless tube. One of them was used to determine the dry bulk density. The three others were measured using the method developed by [3] and results average. Mercury concentrations were measured in solid peat samples using LECO AMA 254. Selected powdered bulk samples of the cores were age dated using 14C AMS at the University of Åhrus in Denmark and at the ETH Zurich, Switzerland. The near surface samples of MS core were dated using the 14C carbon bomb pulse method.

4. RESULTS

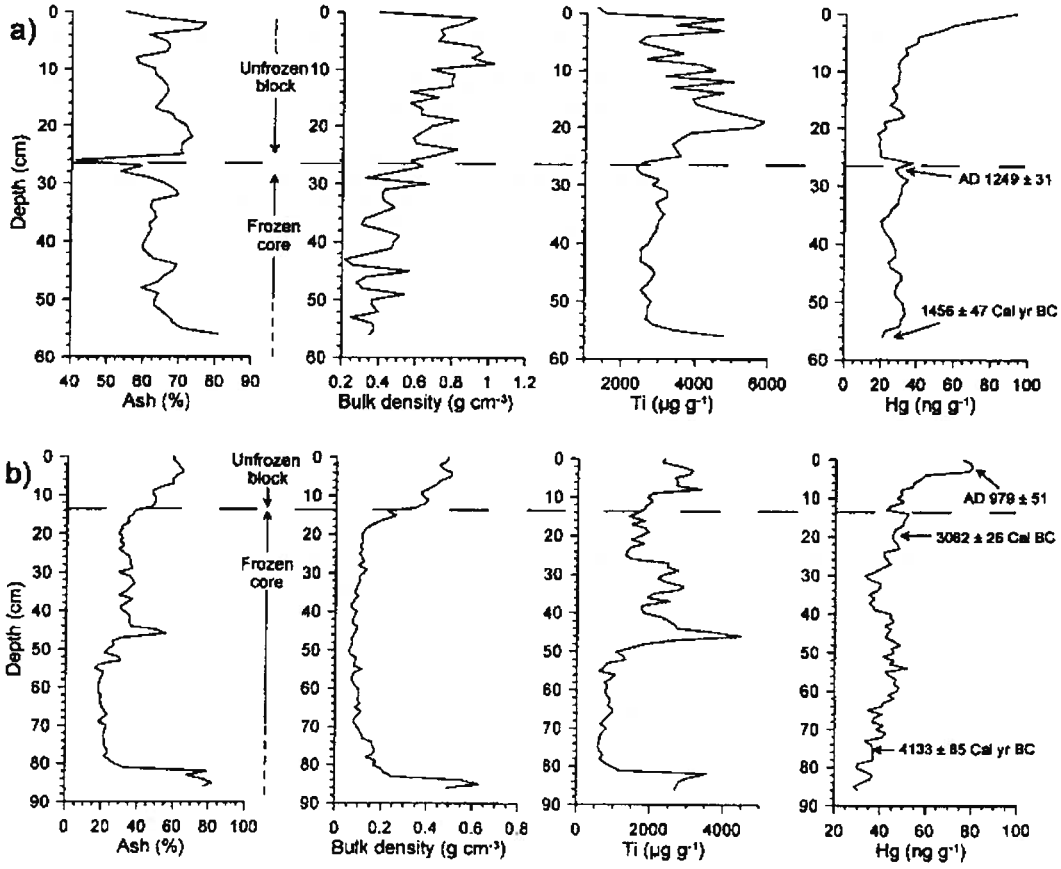

Figure 1. Ash content, bulk density, titanium and mercury concentrations profiles for a) Museum Station and b) Bracebridge Inlet. Some uncalibrated age dates are shown for convienience.

At MS, total Hg concentrations are in the range from 25 to 75 ng g^{-1} with the largest increase in Hg beginning at 10 cm and maximum concentration at the top of the hummock. In the underlying peat, Hg concentrations are relatively uniform (28 ± 4 ng g^{-1}). At BI, Hg concentrations are in the range 30 to 76 ng g^{-1}, and also reach a maximum concentration at the surface.

5. DISCUSSION

5.1. Atmospheric transport: primary pathway of mercury deposition

The Hg concentrations are independent of the amount of mineral matter in the peat cores, clearly indicating that this mineral matter is not an important source of mercury in the cores. While there is an increase in bulk density at the top of MS (ca. 27%), this cannot explain the increase in Hg concentrations (ca. 3×). Mercury appears to have been supplied primarily by atmospheric deposition; this interpretation is supported by the U concentration profiles, which indicate that there have been intense and highly variable mineral-water interactions, but that processes have not affected the Hg concentrations.

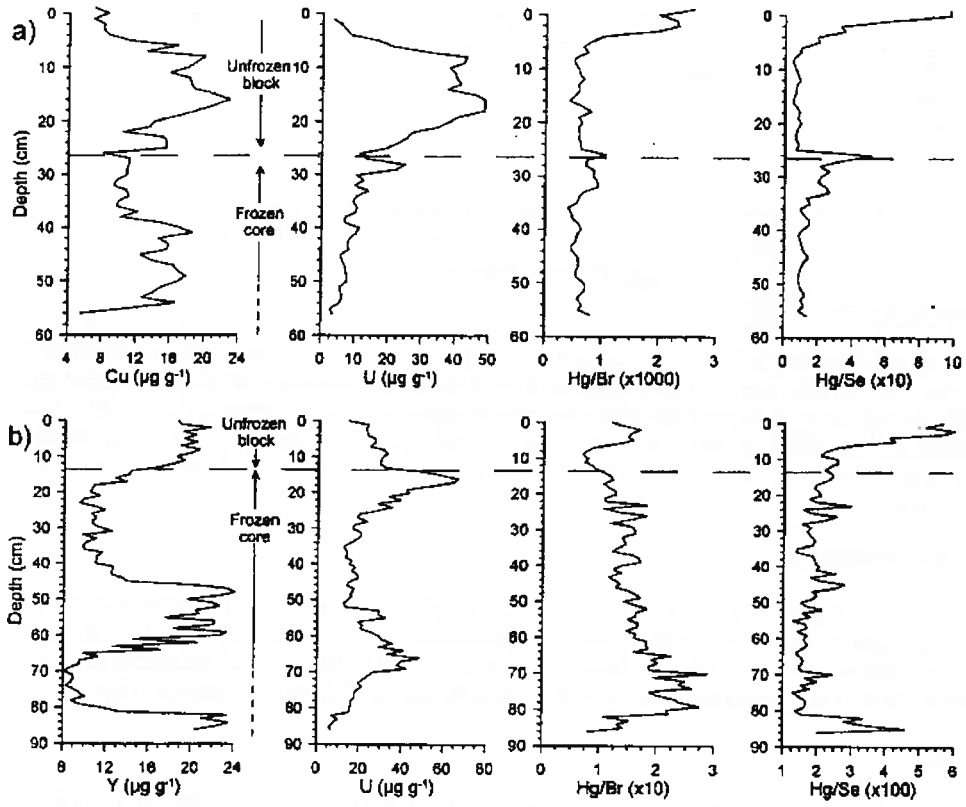

Figure 2. Cupper, uranium and yttrium concentrations profiles, and Hg/Br and Hg/Se profiles from a) Museum Station and b) Bracebridge Inlet.

5.2. Hg accumulation rates

To estimate the atmospheric fluxes, Hg accumulation rates (AR) expressed in µg m^{-2} yr^{-1} were calculated using: AR = 10 × {Hg} × BD × GR where {Hg} is the Hg concentration (ng g^{-1}), BD the bulk density of the peat (g cm^{-3}) and GR is the growth rate (cm yr^{-1}). Given the ages calculated using the age-depth relationships, we estimate that the natural background atmospheric mercury deposition rates on

Bathurst Island were approximately 1 $\mu g\ m^{-2}\ yr^{-1}$ (range 0.5 to 1.5 $\mu g\ m^{-2}\ yr^{-1}$) from 4,000 cal years BC to AD 1200. The natural background Hg accumulation rates in the High Arctic of Canada as well as the temperate locations of southern Ontario [4] and Maine are very similar. Assuming that the re-emission of Hg from the bog surface is negligible [5], these rates reflect the natural range in atmospheric fluxes. The values reported in the present study are within the natural range of Hg accumulation rates recorded by a Swiss peat bog for samples dated from ca. 14,500 to 1,000 years ago [6], and for peat samples from southern Greenland. Thus, natural variation in the pre-anthropogenic Hg fluxes in the High Arctic and southern Greenland (0.5 to 1.5 $\mu g\ m^{-2}\ yr^{-1}$) is well within the range of the corresponding fluxes in southern Ontario, northeastern USA, and central Europe.

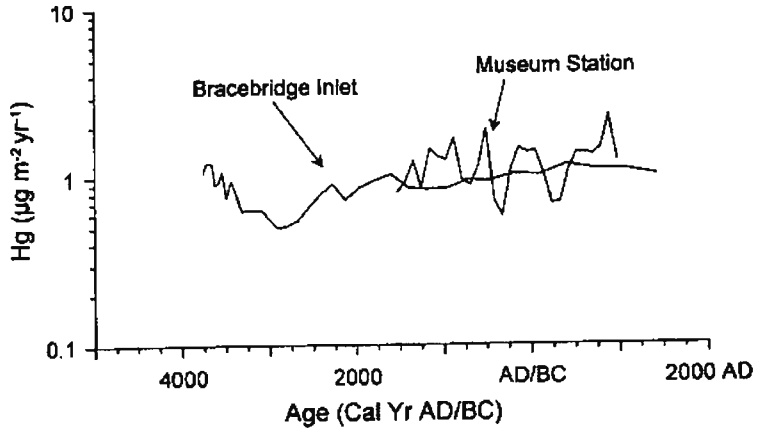

Figure 3. Net mercury accumulation rates

Modern Hg accumulation rate in the Arctic require better quantification, for comparison with the pre-industrial fluxes. Specifically, a series of replicate cores will be sub-sectioned for chemical analyses and age dating. These replicates cores will be measured for Hg again, and trace element using XRF. This level of detailed sub-sampling of the hummock, carefully new chemicals analysis and extensive age dating, is necessary in order to obtain an accurate chronology of the changing Hg concentrations toward the top of these hummocks.

ACKNOWLEDGEMENTS

Sincere thanks to Drs. A.K. Cheburkin, J. Heinemeier, and G. Bonani for analysis. Financial support for this work was provided by the Swiss NSF (grants 21-061688.00 and 21-55669.98) to W.S. Peat cores collection in the High Arctic of Canada was made possible by a grant to W.S. by the International Arctic Research Centre (IARC) and Cooperative Institute for Arctic Research (CIFAR), Fairbanks, Alaska.

REFERENCES

1. AMAP, Arctic Monitoring and Assessment Program (AMAP), Oslo, Norway, 2002: p. 112 pp.
2. Braune, B., D. Muir, B. DeMarch, M. Gamberg, K. Poole, R. Currie, M. Dodd, W. Duschenko, J. Eamer, B. Elkin, M. Evans, S. Grundy, C. Hebert, R. Johnstone, K. Kidd, B. Koenig, L. Lockhart, H. Marshall, K. Reimer, J. Sanderson, and L. Shutt, Sci. Tot. Environm., 1999. **230**: p. 147-207.
3. Roos-Barraclough, F., N. Givelet, A. Martínez-Cortizas, M.E. Goodsite, H. Biester, and W. Shotyk, Sci. Tot. Environm., 2002. **292**: p. 129-139.
4. Givelet, N., F. Roos-Barraclough, and W. Shotyk, Environm. Sci. Technol., Submitted.
5. Lodenius, M., A. Seppänen, and A. Uusi-Rauva, Chemosphere, 1983. **12**: p. 1575-1581.
6. Roos-Barraclough, F., A. Martínez-Cortizas, E. Garcia-Rodeja, and W. Shotyk, Earth Planet. Sci. Lett., 2002. **202**: p. 435-451.