THE IMPORTANCE OF GEOLOGICAL CONTROLS ON THE NATURAL DISTRIBUTION OF MERCURY IN LAKE AND STREAM SEDIMENTS ACROSS CANADA

P.W.B Friske and W.B. Coker
Geological Survey of Canada, Natural Resources Canada
601 Booth Street, Ottawa (Ontario) K1A 0E8, Canada.

Abstract. The Geological Survey of Canada (GSC) has surveyed a significant portion of Canada using systematic stream and lake surveys under the National Geochemical Reconnaissance (NGR) program. Total mercury (Hg) data, available for most of the sites, reveal significant natural variation. Much of the observed variation in Hg concentration can be directly related to the composition of the bedrock, regolith and glacial deposits in the surrounding watershed. Some of the highest Hg values within the sediments of Ontario lakes occur southwest of Thunder Bay in an area underlain by shales known to be naturally enriched in Hg and other trace metals.

1. Introduction

Since 1973, a significant part of Canada has been covered by systematic stream and lake surveys under the National Geochemical Reconnaissance (NGR) program designed to establish and maintain a nationally consistent geochemical database. To date (1994), more than 200 surveys have been completed to NGR standards, representing over 180,000 sites, covering 2.2 million km^2 throughout Canada (Figure 1). A detailed description of NGR survey methodology is given by Friske and Hornbrook (1991). Data for up to 35 elements are available for many of the sediment samples. The purpose of this paper is to draw attention to the voluminous amount of NGR data available on the natural distribution of Hg and other elements and to illustrate the relevance of these data to environmental issues.

2. Sample collection, preparation and analytical methods

All sample collection, preparation and analyses follow the stringent NGR protocols (Friske and Hornbrook, 1991). The organic-rich lake sediments (gyttja) were generally collected from >30 cm depth in the sediment column to exclude the surficial sediment which is physiochemically active and potentially anthropogenically impacted. Stream sediments were collected from the active part of first and second order streams. Both media were air dried, and a <63 μm fraction prepared. Mercury was determined by the Hatch and Ott (1968) cold vapour atomic absorption technique, with some modifications (Jonasson *et al.*, 1973). Quality control of all analytical data was maintained by monitoring control reference standards and blind duplicates, inserted at a frequency of 5%.

Water, Air, and Soil Pollution 80: 1047–1051, 1995.

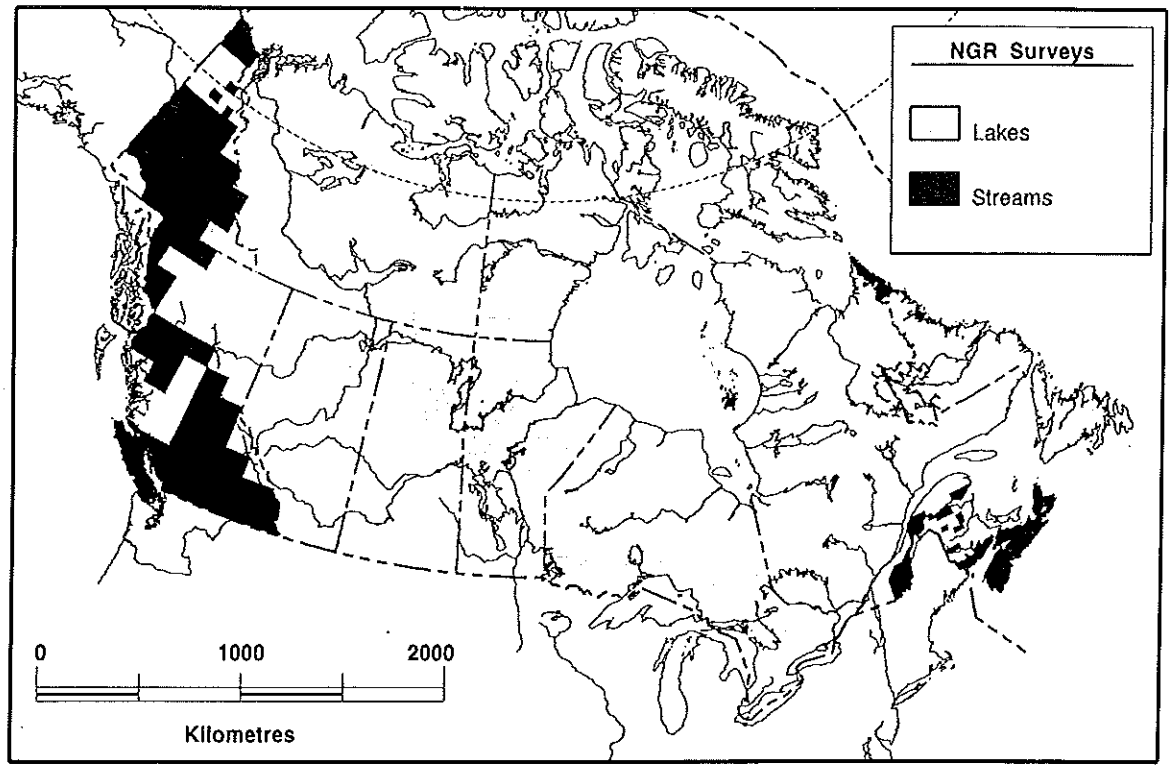

Fig. 1. National Geochemical Reconnaissance (NGR) stream and lake survey coverage (1973 to 1994) in Canada

3. Results and discussion

Mercury, like other elements, is preferentially concentrated in certain rock types through igneous, metamorphic and sedimentary processes. In Cannon's (1978), tabulation of the concentration of 21 elements in 10 natural materials, average Hg concentrations vary from 40 to 50 ppb in limestones and sandstones up to 500 ppb in black shales.

There are many examples in the literature illustrating the effects of changing bedrock chemistry on the composition of related lake sediments (c.f., Hornbrook and Garrett, 1976; Jonasson, 1976; Cameron and Ballantyne, 1977; Maurice, 1977; Coker and Shilts, 1979; Friske, 1985; Johnson *et al.,* 1986; Kerr and Davenport, 1990; Fortescue and Vida 1990; Garrett *et al.,* 1990). Table I summarizes the distribution of approximately 100,000 analyses for Hg in stream and lake sediments. Assuming that the 5th and 95th percentiles are reasonable estimates of the range of background variation, the contrast between the lower and upper limits of background is almost 9 times for lake sediments (N=69,884; 5th=20 ppb, 95th=175 ppb); and 23 times for stream sediments (N=26,124; 5th=10 ppb, 95th=230 ppb). Table I shows how geological factors affect the distribution of Hg in drainage basins in Ontario. Using a lower value of 5 ppb (5th percentile for marble) and an upper value of 305 ppb (95th percentile for shale), 'normal' background values

within the survey area range from 5 to 305 ppb depending on the local bedrock geology (a range of 61 times the lower background value). This illustrates the importance of determining 'local background' values for an area. For example, a sample with a concentration of 200 ppb Hg coming from a lake underlain by marble is highly enriched (anomalous), whereas the same concentration from a lake over shales is well within the range of normal background variation.

TABLE I

Hg (ppb) summary statistics for lake and stream sediment data from the NGR database and for lake sediments for specific rock types within Ontario.

	Total Dataset		Ontario Lake Sediments			
				Rock Type		
	Lakes	Streams	Total	Shale	Marble	Diabase
Number of Values	69,884	26,124	13,813	38	38	277
Mean	74	72	119.4	169.2	54.7	190.4
Std Deviation	99	114	198.3	70.5	36.4	366
5th Percentile	**20**	10	**35**	**90**	**5***	**45**
10th Percentile	30	15	47	90	19	60
25th Percentile	40	25	70	110	28	97
50th Percentile	**60**	**40**	**110**	**165**	**45**	**140**
75th Percentile	90	80	150	192.5	80	199
90th Percentile	140	151	195	291	110	251
95th Percentile	**175**	**230**	**222**	**305**	**132**	**295**

* Detection limit for Hg is 10.0 ppb. Values less than 10.0 set to 5.0 for calculations.

Figure 2 is a 'smoothed' contour plot of Hg data for sediments from Ontario lakes. The area of elevated Hg southwest of Thunder Bay coincides with shales known to be enriched in Hg (Coker and Shilts, 1979; Friske, 1985). The discontinuous band of elevated Hg, extending east from Sault Ste. Marie and then northeast to New Liskeard, is associated with sporadic exposures of diabase sills and dykes that are relatively enriched in Hg. Some of the lowest Hg levels encountered in Ontario lake sediments occur west of Ottawa in areas underlain by marble. It is particularly noteworthy that some of the highest Hg concentrations occur in relatively isolated areas, while some of the lowest values are encountered in southeastern Ontario, the more highly populated and industrialised region.

4. Summary

Anthropogenic inputs of Hg and other trace elements into the environment are superimposed on a highly variable natural geochemical background. Variations in the natural abundance levels in bedrock vary widely, and can range over severals orders of

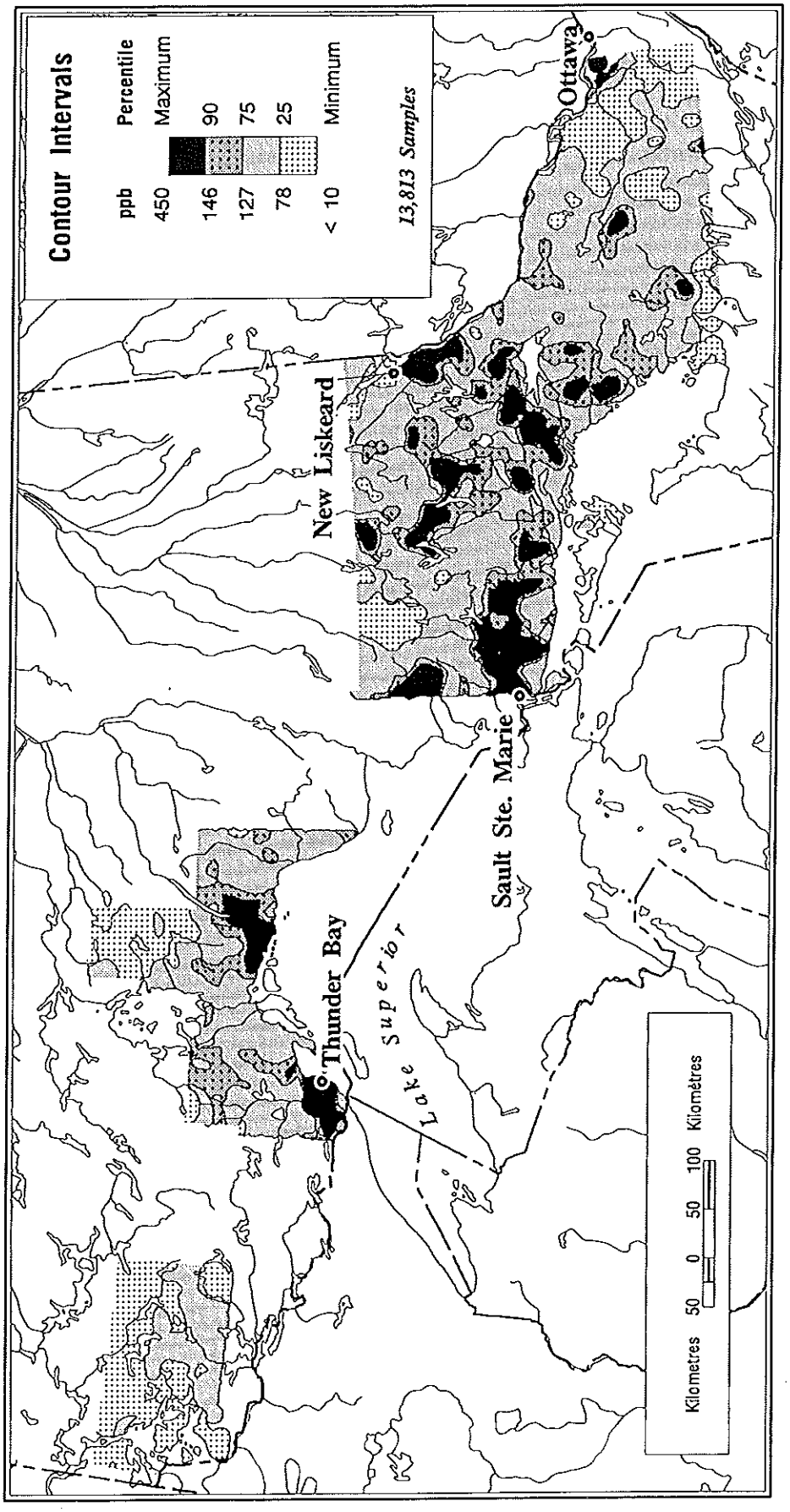

Fig. 2. Regional distribution of Hg in Ontario lake sediments.

magnitude. These natural geochemical variations are reflected in the chemical composition of the waters, soils, drainage and glacial sediments associated with each bedrock type.

Distinguishing Hg and other trace element contributions from natural sources from those related to anthropogenic inputs is a major challenge, particularly for agencies charged with developing sediment quality guidelines. Any assessment of possibly 'contaminated' areas needs to be evaluated in the context of the local natural background. The NGR database provides a voluminous amount of data pertinent to establishing this background for many elements in the surfical environment.

References

Cameron, E.M., and Ballantyne, S.B.: 1977, *Canadian Instit. of Mining and Metallurgy* Bull., Vol. 70, 76-85.
Cannon, H.L.:1978, *Geochemistry and the Environment* Vol. 3; Report of the Workshop at South Seas Plantation Captiva Island, Florida, 17-31.
Coker, W.B. and Shilts, W.W: 1979, *Geological Survey of Canada*, Paper 79-1C, 1-15.
Friske, P.W.B.: 1985, *Geological Survey of Canada*, Paper 84-21, 38 p.
Friske, P.W.B. and Hornbrook, E.W.H.: 1991, *Trans. Instit. of Min and Metallurgy*, Sect. B; Vol. 100, 47-56.
Fortescue, J.A.C. and Vida, E.A.: 1990, *Ontario Geological Survey*, Map 80 806.
Garrett, R.G., Banville, R.M.P. and Adcock, S.W.: 1990, *Jour of Geochemical Exploration*, Vol. 39, 91-116
Hornbrook, E.H.W. and Garrett, R.G.: 1976, *Geological Survey of Canada*, Paper 75-41, 20 p.
Jonasson, I.R.; Lynch, J.J. and Trip, L.J.: 1973, *Geological Survey of Canada*, Paper 73-21.
Jonasson, I.R.: 1976, *Geological Survey of Canada*, Paper 76-13, 37 p.
Johnson, M.G., Culp, L.R. and George S.E.: 1986, *Can Jour. Fisheries and Aquatic Sci.*, Vol. 43, 754-762.
Kerr, A. and Davenport, P.H.: 1990, *Journal of Geochemical Exploration*, Vol. 39, 225-247.
Maurice, Y.T.: 1977, *Canadian Institute of Mining and Metallurgy* Bulletin, Vol. 70, 96-103.

Fig. 2. Regional distribution of Hg in Ontario lake sediments.