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By:

C. Lewis, P. Mukhopadyay, M. Kruge

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ENVIRONMENTAL GEOLOGY OF WESTERN LAKE ONTARIO: ACOUSTIC LINEAMENTS AND ORGANIC COMPONENTS OF SURFACE SEDIMENTS

by

LEWIS, C.F.M. Geological Survey of Canada Atlantic, Box 1006, Dartmouth N.S. B2Y 4A2, Canada. E-mail: mlewis@agc.bio.ns.ca

MUKHOPADYAY, P.K., Global Energy Research, Box 9469, Halifax N.S. B3K 5S3, E-mail: muki@ns.sympatico.ca

KRUGE, MA., Department of Geology, Southern Illinois University, Carbondale IL 62904-4324, U.S.A. E-mail: kruge@geo.siu.edu

COAKLEY, J.P., National Water Research Institute, Box 5050, Burlington, Ont. L7R 4A6, Canada. E-mail: John.Coakley@CCIW.ca

NWRI Cont. # 98-261

MANAGEMENT PERSPECTIVE

Title: Environmental Geology Of Western Lake Ontario: Acoustic Lineaments And Organic Components Of Surface Sediments

Authors and affiliations: LEWIS, C.F.M. Geological Survey of Canada Atlantic, Box 1006, Dartmouth, N.S., MUKHOPADYAY, P.K., Global Energy Research, Halifax N.S., KRUGE, MA., Department of Geology, Southern Illinois University, Carbondale IL, COAKLEY, J.P., National Water Research Institute, Box 5050, Burlington, Ont.

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Issue:

Lake-wide management plans for Lake Ontario assume that all major sources of contaminants monitored in bottom sediments have been identified. The present work investigates the possibility of additional sources of contamination to the offshore regions of western, namely combustion wastes and detritus from trans-lake commercial ships during the approximate period 1850 - 1950.

Current Status:

Linear zones of acoustic backscatter detected in sidescan sonar and recent mapping tend to radiate from Niagara-region ports and into Toronto Harbour's ship canal entrance are possibly related to debris from shipping. Crushed limestone and coal were recovered from two of these anomalies, providing evidence that at least these two resulted from underway cargo sweeping (cleaning) by self-unloading cargo ships. Cross-lake reflectivity lineaments were revealed by multibeam bathymetric mapping also. We postulate the source is buried and may relate to ash debris from former steamship traffic.

Next steps:

Trace metal and organic chemical analysis of the top sections of selected cores will be carried out to confirm the presence and levels of contamination.

ENVIRONMENTAL GEOLOGY OF WESTERN LAKE ONTARIO: ACOUSTIC LINEAMENTS AND ORGANIC COMPONENTS OF SURFACE SEDIMENTS

ABSTRACT

Lake Ontario, about 300 km long and 60 km wide, is situated at the downstream end of a chain of 5 North American Great Lakes which drain to the North Atlantic Ocean via St. Lawrence River. The western third of Lake Ontario (Niagara basin) is oriented ENE and reaches depths of 150 m. The basin is asymmetric with a steeper southern margin. The gently sloping northern margin reflects the southward dip of underlying Ordovician limestone and shale bedrock; the basin is thought to have resulted mostly from preglacial erosion and glacial scour. The present lake dates from about 11 ka BP after the retreat of the last ice cover and drainage of glacial lakes. Since its inception, differential glacial rebound has raised the northeastern basin rim (outlet) and caused relative lake level to rise (transgress) about 100 m in the western end of the basin. The present mean inflow via Niagara River from upstream lakes is 175 km3yr-1 and mean outflow is 209 km3 yr-1, with the difference made up by local precipitation and runoff. Although a weak anti-clockwise gyre is apparently associated with Niagara River outflow, most motion in the lake is wind-driven as waves, currents, storm surges and seiches.

The shores are largely erosional under the wave regime. Wave-drifted sand has formed barrier spits and beaches in front of spacious lagoons at Toronto and Hamilton, providing natural harbours for these cities. A sparse thin sandy lag over eroded glacial sediments occurs on much of the northern flank of the basin. Soft silty clay mud lies in offshore areas of the Niagara basin, below 40-60 m water depth on the southern margin, and below 40 to 130 m on the northern margin. The principal sediment sources stem from erosion of drainage basin, shore and shallow lakebed. Mainly composed of quartz, feldspar and mineral clay, the organic C content of surface sediment ranges 2-4 %. The mud is accumulating in the order of 1 mm.yr-1 and contains a record of land use around the lake. An increase in Ambrosia (ragweed) pollen concentration in sediment cores marks the onset of settlement and European-type agriculture in the early part of the 19th century. The lake itself has been heavily used for transportation. Since the 1940s, the onshore region was rapidly urbanized and now supports a population of about 7 million. Anthropogenic effects are present in the surface sediments, especially in the nearshore zones close to major cities

and harbours; contaminants including Hg and Mirex have been detected. In addition to water circulation, some contaminants may be delivered by atmospheric deposition. The sediments of Lake Ontario carry evidence of historically increased biological production and sedimentation of organic matter and calcite (lake eutrophication) starting in the mid 1800s and accelerating since 1940 due to increased anthropogenic-related input of nutrients, especially phosphorus.

In recent years, extensive sonar and seismic surveys have been conducted on the lake in search of disturbed sediment to test hypotheses for neotectonism and seismicity localized by reactivation of ancient faults in the current compressional stress regime. Linear zones of acoustic backscatter had been detected in sidescan sonar and attributed previously to neotectonism. However, the recent mapping suggests these anomalies tend to radiate from ports and a ship canal entrance, and therefore better relate to debris from shipping. Crushed limestone and coal were recovered from two of these anomalies, providing evidence that at least these two resulted from underway cargo sweeping (cleaning) by self-unloading cargo ships. Cross-lake reflectivity lineaments were revealed by multibeam bathymetric mapping also. These do not align with known tectonic features but surface sampling reveals no cause for the reflectivity (e.g. coarse fraction within the mud). Currently, we postulate the source is buried and may relate to ash debris from former steamship traffic.

Twelve of the above surface sample sites which provide a regional transect of the Niagara basin were analysed to reveal the nature and concentrations of natural and anthropogenic organic matter using petrologic and geochemical techniques. The samples incorporated sediment from 0- 5 and 5-10 cm below the lakefloor, intervals estimated to include deposition during the last 15-45 and 30-90 years respectively. Petrologically, huminite, vitrinite, inertinite, clasts of organic-rich rocks, spore, pollen, cutin, algae and fungi were identified within the natural organic component. Fragments of coal (lignite to low-volatile bituminous), combustion residues (fly ash, char and coke), petroleum products (solid bitumen, light refinery products and tar) and chemical products (plastics and paint) were identified as anthropogenic components. A major component at many sites is amorphous organic matter (AOM), thought to be transitional between anthropogenic and natural sources. The AOM may be derived from enhanced bacterial alteration of natural aquatic components whose productivity was enhanced by the addition of anthropogenically-related

nutrients, especially phosphorus. Phosphorus input has been largely controlled and reduced since about 1970 although organic C flux remains high.

Analysis of bottom sediment by pyrolysis-gas chromatography/mass spectrometry was shown to be effective in assessing the organic contaminants. Alkylbenzene and alkyl phenol distributions in the pyrolyzates were most compatible with derivation from aquatic (algal and bacterial) organic matter. The organonitrogen compounds in the pyrolysis products indicated the presence of degraded proteinaceous material derived from aquatic sources, such as phytoplankton productivity stimulated by nutrient input. Normal and polycyclic aromatic hydrocarbon distributions indicated contributions of fossil fuels and combustion residues. These observations were confirmed by the organic petrologic examination. The ubiquitous input of aquatic organic matter to the sediments was supplemented by fossil fuel-derived contamination, in proportions increasing with proximity to industrial sites and shipping lanes.

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National Water Research Institute
Environment Canada
Canada Centre for Inland Waters
P.O. Box 5050
867 Lakeshore Road
Burlington, Ontario
L7R 4A6 Canada

National Hydrology Research Centre
11 Innovation Boulevard
Saskatoon, Saskatchewan
S7N 3H5 Canada

NATIONAL WATER RESEARCH INSTITUTE
INSTITUT NATIONAL DE RECHERCHE SUR LES EAUX

Institut national de recherche sur les eaux
Environnement Canada
Centre canadien des eaux intérieures
Case postale 5050
867, chemin Lakeshore
Burlington, Ontario
L7R 4A6 Canada

Centre national de recherche en hydrologie
11, boul. Innovation
Saskatoon, Saskatchewan
S7N 3H5 Canada

Environment Canada Environnement Canada

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