6. The Geochemical Map of Ontario Pilot Project: Summary of Preliminary Results from the 80W Meridian Project

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INTRODUCTION

Fortescue et al. (1992) described the first part of a pilot project designed to test the feasibility of "meridian sampling" as a basis for a Geochemical Map of Ontario (GMO). They described a map of sample sites and graphs of water pH patterns for a geochemical traverse from Lake Erie to James Bay along the 80W meridian (Figure 6.1). This paper describes additional information obtained from this project after October 1, 1992.

A GMO was suggested by Fortescue in 1983, however, at that time it was considered impractical for 2 reasons; one was the supposed ineffectiveness of the geochemical mapping techniques then in use and the other was the large logistical problem involved in obtaining geochemical samples on the scale required.

During the past 5 years, worldwide advances in geochemical mapping methodologies (e.g., Darnley and Garrett 1990, Dickson and Hsu 1993) have demonstrated that geochemical mapping of areas the size of Ontario are now relatively common. For example, it has been shown by several Scandinavian workers that large geochemical patterns associated with metallogenic provinces on a continental scale can be delineated by geochemical mapping. In Norway, patterns of this type, discovered by low-density geochemical mapping, led to the modification of existing geological maps in some areas (Bolviken et al. 1990). A recent development has been work done in China where numerous geochemical provinces have been delineated (Xie and Yin 1993). These developments, and others like them described in the literature (e.g., Darnley 1990, 1992), have led to the design of the OGS Meridian Project.

The Meridian Project is part of the Canada–Ontario Northern Ontario Development Agreement (NODA). The project was designed as a pilot project leading to the future preparation of a GMO. A GMO has three aims: 1) to assist mineral exploration, 2) to satisfy province-wide needs of environmental geochemistry, and 3) to foster the study of geochemistry in province-wide studies of the health and nutrition of plants, animals and man.

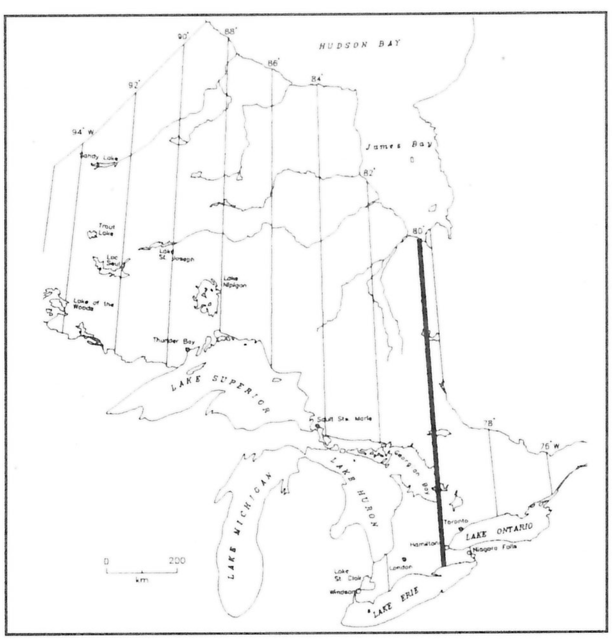

Figure 6.1. Location map of the 80th meridian.

APPROACH

A meridian-based geochemical map (*see* Figure 6.1) is analogous to a soil geochemical map except that the former is on a province-wide scale. A 1° meridian map of Ontario has: 1) a line spacing interval of approximately 50 km, 2) sampling lines (corridors) 10 km wide, and 3) "sample points" 5 to 10 km apart along the corridors. Sample media consisted of stream sediments, stream water and "B" horizon soils in southern Ontario and lake sediments and lakewaters in northern Ontario.

THE VISUAL INTERPRETATION OF MERIDIAN GEOCHEMICAL PATTERNS

During 1992 and 1993, preliminary interpretation of the 80th meridian landscape and geochemical data was completed using 3 conceptual models. The conceptual models were designed to compare both abundance and spatial data patterns for: 1) 14 elements in water samples, and 2) 41 elements in stream sediments, lake sediments and soil "B" horizon samples collected from 94 sample sites (located at 10 km intervals) along the 80th meridian. The 3 models included: 1) a Landscape Conceptual Model to summarize meridian wide landscape conditions (physiographic regions, bedrock and Quaternary cover), 2) a Quicklook Model Diagram to compare geochemical patterns for 41 elements in the same sample media (e.g., water or sediment) along the entire meridian, and 3) a Clarke Meridian Diagram designed to use Clarke units to compare geochemical element patterns among the 4 sample media collected from the 80th meridian.

The Landscape Conceptual Model is a diagram which summarizes the major landscape features of the meridian for quick comparison with geochemical data plots such as sawtooth diagrams of the 80th meridian corridor. For example, Figure 6.2 includes bars from this model for 1) physiographic regions, 2) Quaternary geology, and 3) bedrock geology. In addition to these bars, the Quicklook Diagram (*see* Figure 6.2) displays 12 "sawtooth" geochemical patterns. The sawtooths are prepared by plotting raw geochemical data sets expressed as percentages. Two of the sawtooths (Ca and pre-*Ambrosia* Pb) are plots of regression residuals in an effort to filter out the effects of loss on ignition (LOI) variability. This procedure was attempted on those elements which featured a strong correlation with LOI. Difficulties with this procedure were due to non-linearity of the LOI/element ratios and the inconsistency of the relationships along the entire length of the meridian. This "LOI problem", or organic matrix effect (Garrett et al. 1990) with lake sediments can be minimized by selective sampling or data compositing to ensure LOI values fall in the range of 20 to 50%.

Eleven of the sawtooths represent elements in stream sediment/pre-*Ambrosia* lake sediment data sets and the other is for percentage LOI in the sediment. Tick marks on the x-axis indicate the 94 micromodules along the meridian. The value denoted at each tick mark is a composite of 4 geochemical samples (or data), one taken from each quarter of the micromodule concerned.

The sawtooth patterns on Figure 6.2 represent 3 groups of elements: 1) major elements (e.g Ca, Mn, P), 2) minor elements (e.g., Ni, Y, Cu), and 3) trace elements (e.g., Be, As, Au). Also included are 2 sawtooths showing Pb

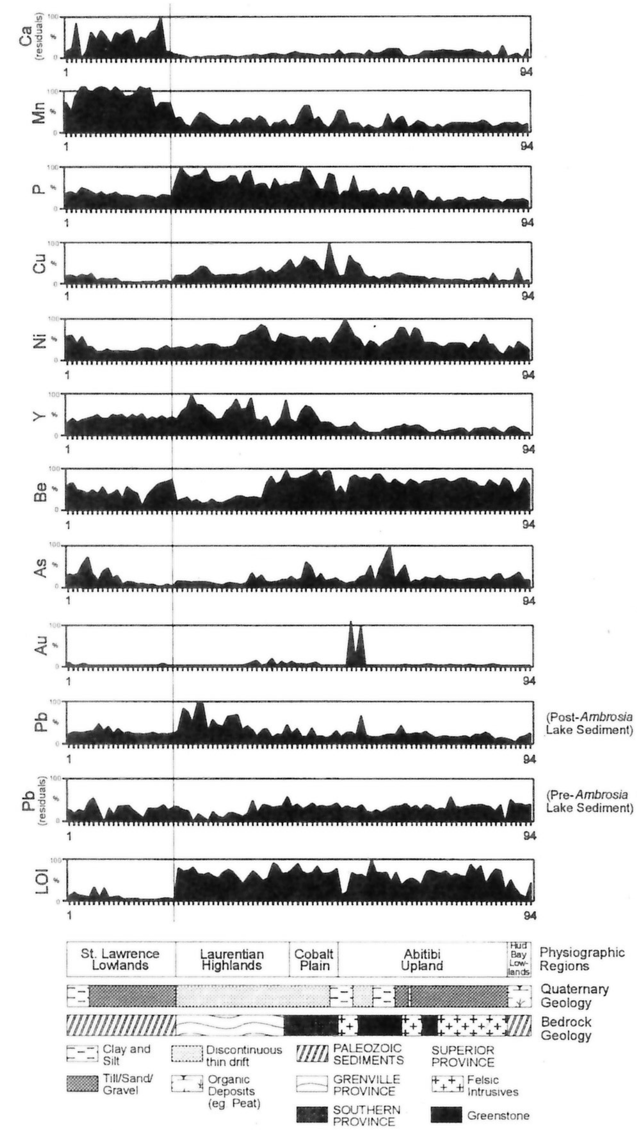

Figure 6.2. 80th meridian Quicklook Diagram: Geochemical data sawtooth plots for 10 elements and LOI. Pb in pre-*Ambrosia* and post-*Ambrosia* lake sediment is displayed to illustrate an anthropogenic geochemical pattern.

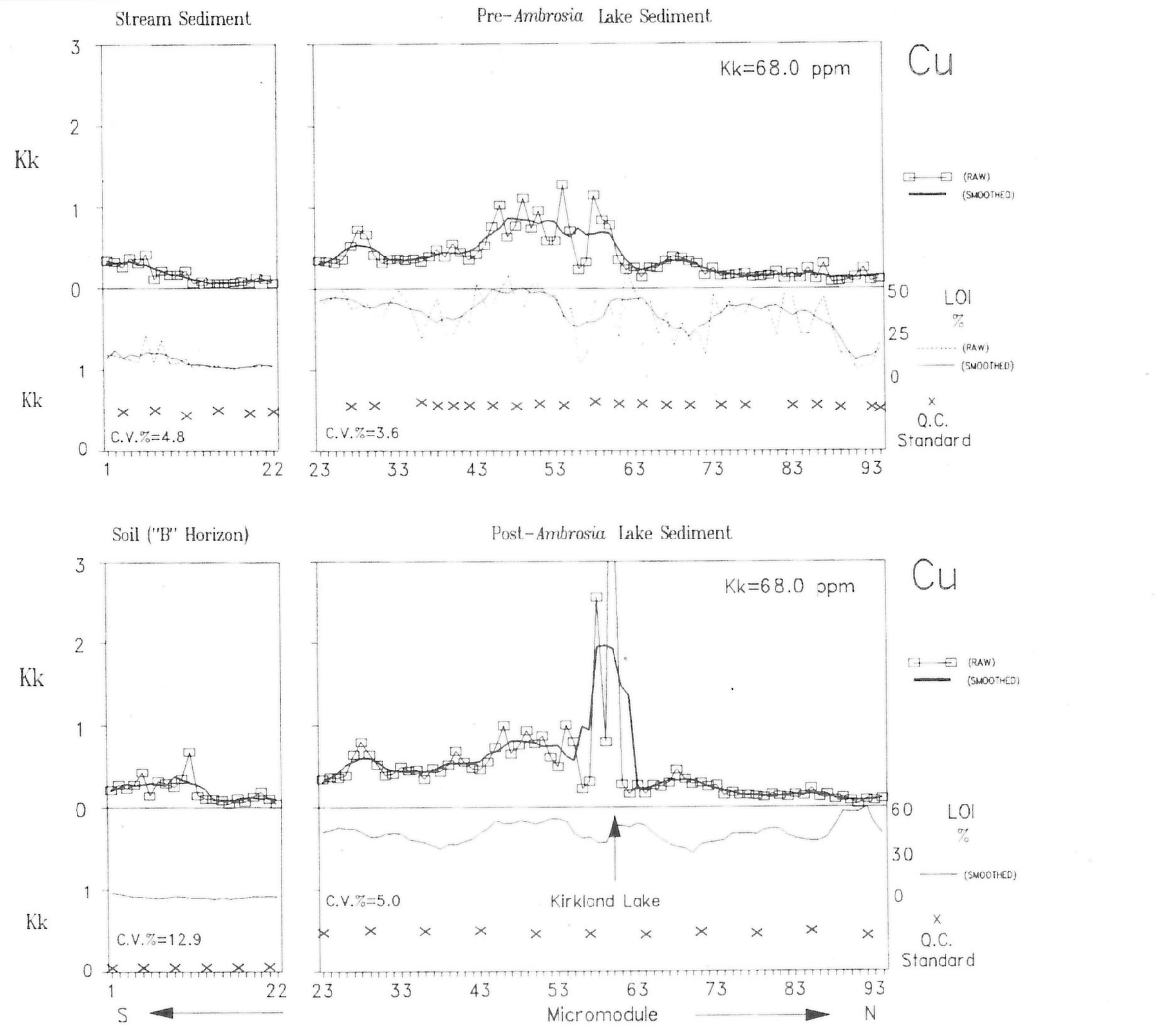

Figure 6.3. Clarke Meridian Diagram for Cu. 57–277.

patterns for stream sediment/pre-*Ambrosia* lake sediment and soil "B" horizon/post-*Ambrosia* data. The Pb plots were included to illustrate the effect of non-point source (anthropogenic) pollution on 80th meridian geochemical patterns.

The Clarke Meridian Diagram for Cu (Figure 6.3) is one of 41 similar diagrams prepared to display meridian geochemical data patterns. These diagrams use Clarke transformed data to compare geochemical patterns along the meridian in the 4 sample media: 1) stream sediment, 2) pre-*Ambrosia* lake sediment, 3) post-*Ambrosia* lake sediment, and 4) soil "B" horizon samples. Clarke Meridian Diagrams (*see* Figure 6.3) also include: a) data on the performance of the analytical method (i.e., percent coefficient of variation and plots (x's) of the precision of replicate analyses) for each sample material. Data for the LOI in each sample material are plotted as a thin line on each of the 4 media diagrams.

RESULTS

The bars at the bottom of Figure 6.2 show landscape variation along the 80th meridian. The bar patterns indicate how the physiographic regions along the meridian are usually associated with major changes in bedrock type. For example, Paleozoic sediments underlie both the St. Lawrence and Hudson Bay lowland regions. In other physiographic regions (e.g., the Abitibi upland), Quaternary cover and Precambrian bedrock lithology vary considerably within one physiographic region. Regional landscape variations are usually accompanied by local variations in landscape development. These contribute to some of the noise in the sawtooth diagrams for some elements. Such local landscape variations are usually too small in area to be included in a meridian wide landscape conceptual model.

(A) AN 80th MERIDIAN QUICK LOOK DIAGRAM

Space does not allow for a detailed interpretation of the element patterns included in Figure 6.2. A major feature of all these patterns is the geochemical sample media change from stream to lake sediments at micromodule 23 (*see* Figure 6.2).

MAJOR ELEMENT SAWTOOTH PATTERNS

Patterns for 3 major elements shown on Figure 6.2 include examples of several province-wide geochemical patterns. For example, north of micromodule 23 in the vicinity of Parry Sound, the Ca pattern has a weak positive gradient. This may be associated with an increasing level of calcium carbonate in the glacial material northwards to the Hudson Bay Lowland. On a province-wide scale, the Mn pattern in Figure 6.2 is flat and relatively noisy. The noise is due to variations in LOI (i.e., organic content) and to local variations in the geochemistry of landscapes which affect the rate of accumulation of Mn in lake sediment. An unexpected, province-wide, regional geochemical pattern is a negative regional gradient evident on the P sawtooth. This gradient occurs in both the pre-*Ambrosia* lake sediment pattern (included in Figure 6.2) and in the post-*Ambrosia* (not included in Figure 6.2). This P gradient extends north from Parry Sound nearly to James Bay. Variations in LOI and local landscape conditions also contribute to the noise on the P graph.

MINOR ELEMENT SAWTOOTH PATTERNS

Sawtooths for Cu, Ni and Y (*see* Figure 6.2) are typical for minor elements along the 80th meridian. In general the Cu patterns are similar to those in the Chinese conceptual model described by Xie and Yin (1993). The Cu patterns are described in greater detail below. The Ni sawtooth pattern is of a more common type. It resembles the Mn pattern, although more of the noise is clearly due to LOI variation. The Y geochemical province pattern associated with the Proterozoic rocks in the Laurentian Highlands and Cobalt Plain north of Parry Sound (*see*

TRACE ELEMENT SAWTOOTH PATTERNS

Sawtooths for Be, As and Au (*see* Figure 6.2) were chosen as examples of trace element patterns along the 80th meridian. As expected, the sawtooths for trace elements suffer from landscape noise and relatively high detection limits (e.g., Au). In spite of this, some interesting element patterns were found. For example, the Be pattern shows a "low" geochemical province pattern where the meridian is underlain by Proterozoic Grenville rocks. The As pattern is of interest because it has high values in stream sediments in southern Ontario and several localized high peaks in lake sediments further north, coincident with the greenstone belts at Kirkland Lake and Temagami. The pre-*Ambrosia* Au pattern indicates gold anomalies at Kirkland before mining commenced in the area. The weak Au province extending south from Kirkland Lake is also of interest.

ANTHROPOGENIC SAWTOOTH PATTERNS

Lead patterns in the pre-*Ambrosia* lake sediment (*see* Figure 6.2, lower Pb profile) are fairly flat across the meridian. This contrasts with the pattern for Pb in the post-*Ambrosia* sawtooth which has a marked negative geochemical gradient extending northwards from the Parry Sound area (*see* Figure 6.2, upper Pb profile). This is attributed to atmospheric fallout from a non-point source (i.e automobile exhaust fallout).

(B) AN 80W MERIDIAN CLARKE DIAGRAM

A total of 41 Meridian Clarke Diagrams, similar to that for Cu in Figure 6.3, facilitate visible comparisons among the 80th element data sets. All the element data are plotted in Clarke units to facilitate geochemical pattern comparisons along the meridian. Figure 6.3 displays data for Cu in 4 sample media plotted in Clarke (Kk) units. The individual Cu data points are connected by a plot of 5 point moving average values.

It is evident from Figure 6.3 that: 1) The performance of the analytical method for Cu is satisfactory, 2) the level of Cu along the meridian in all media is almost always less than 1 Clarke (68 ppm), 3) Cu is consistently higher in lake sediments than in stream sediments (or soils), and 4) locally a strong Cu/LOI ratio is apparent, therefore some of the noise in the Cu data can be attributed to this relationship.

From the geological viewpoint the Cu patterns show: 1) a small Cu province associated with mafic rocks in the Mesoproterozoic rocks of the central gneiss belt underlying the Laurentian Highlands just north of Parry Sound, and 2) a more marked Cu geochemical province pattern extending south from Kirkland Lake to Lake Nipissing. The small geochemical anomaly between #67 and #72 to the north of Kirkland Lake (#60) may be due to a local decrease in LOI. These 3 patterns are present in both the pre- and post-*Ambrosia* lake sediments (*see* Figure 6.3). Figure 6.3 also shows that anthropogenic activity around the Kirkland Lake mining camp has produced a strong Cu anomaly in post-*Ambrosia* lake sediment.

SUMMARY

In general, landscape complexity along the 80th meridian is associated with complex geochemical patterns. Adding to this complexity is the heterogeneity of lake sediment along the meridian and reflected by the variable LOI of the samples. To minimize this complexity of meridian patterns, the 1993 experiment was completed west of Thunder Bay where the bedrock and landscape conditions are simpler than along the 80th meridian (Fortescue and Dyer, this volume). The second meridian was chosen in this way because, although it is relatively easy to add complexity to a simple landscape model, it is often impossible to extract simplicity from a complex landscape model.

Technical problems encountered in the 1992 meridian experiment included: 1) the relative insensitivity of analytical method used for water analysis, 2) the need to reduce local landscape geochemical noise in lake sediment data sets so that geochemical province patterns can be defined more precisely, 3) the general problem of the heterogeneity of lake sediments as a media for geochemical mapping, and 4) the choice of sequenced statistical and image processing methods for the interpretation of meridian geochemical data patterns.

CONCLUSIONS

We conclude that: 1) The meridian approach to the production of a GMO is logistically practical; 2) Several aspects of the scientific approach described here require further development before a GMO based on meridian mapping can be planned realistically.

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