Personal Computer (PC) - Based Methods for Integrating, Processing and Visualizing Multivariate Data: Review of Geology, Till Geochemistry, Lake Sediment Geochemistry, and Airborne Geophysical Data from the Beardmore-Geraldton District, Ontario, Canada.

Greg Hollyer (Geosoft Inc.) and L. Harvey Thorleifson (Geological Survey of Canada)

Multivariate data collected from geological, geochemical and geophysical sources historically have not been managed and evaluated in a single PC-based environment. This tendency is, in part, due to the lack of techniques for integrating, processing and visualizing high-volume datasets from different sources. In this short discussion, the objective is to review the methodologies used to integrate, process and visualize a multivariate dataset originally acquired by the Geological Survey of Canada (GSC) and the Ontario Geological Survey (OGS) in the vicinity of the Beardmore-Geraldton Greenstone Belt in Ontario. Although some methodologies, such as geostatistical kriging, that were employed are quantitative, this exercise was primarily qualitative in nature and was intended to illustrate practical techniques that can help set the stage for more detailed numerical and statistical analysis.

Multivariate Data Overview

The geochemical data available for this exercise included raw Excel and Lotus format spreadsheet data from a 1989 lake sediment survey and a 1991 till geochemistry survey conducted by the GSC and the OGS. High-quality geochemical data were acquired using rigourous sampling and analysis techniques documented in the reports included as References.

Briefly, lake sediment data were analyzed for 42 elements plus loss on ignition. Analysis methods included AAS, HY-AAS, NADNC, CV-ASS, GRAV and INAA techniques. For this exercise, a partial suite of elemental data including analyses for Au, As (AAS and INAA), Cu and Sb was used. In the case of the till geochemistry data, the elemental analysis was based on analysis of the <63 micron fraction, the <2 micron fraction and the non-ferromagnetic heavy mineral concentrates. For this exercise, an extensive set of data from 34 elemental analyses was made available, including fire-assay, ICP-AES and INAA data from the <63 micron fraction and <2 micron till fractions.

Available geophysical data included raw total field and gradient magnetic grids from airborne surveys flown on behalf of the OGS in 1991. Geological data included a comprehensive description of glacial and Precambrian geology, and report-sized geological maps. Figure 1 shows a geological map, geochemical sample locations from both geochemistry surveys and geophysical total-field magnetic data.

Data Import, Location and Integration

The initial problem in working with multivariate data from different sources is determining how to import, locate the data spatially (i.e. georeference) and integrate it so that it can be displayed, processed and visualized. The strategy in this exercise was to use a commercial PC-based geoscience data processing and analysis system with multiple database and map window functionality.

For the lake sediment survey, located data were provided so that the import process was trivial. Spreadsheet data were exported in ASCII format, manipulated in a word processor to remove blank values and the ASCII data were then imported into a designated database. For till data, the process was similar except that <63 micron and <2 micron data were identified by sample numbers only. Therefore, an additional step was required -- namely to import location data (Easting and Northing) into designated <63 micron and <2 micron databases and then import elemental data into the corresponding databases.

Importing, locating and integrating geological data required manipulation of a scanned black and white image. An image was first scanned at 1200 X 1200 resolution and stored in a standard bitmap format. It was then imported into a map window and georeferenced semi-interactively by selecting points on the image and assigning them to known UTM coordinates. Next, the bitmap was warped to transform all points to UTM coordinates and saved in a grid format. For geophysical data, the data was provided in grid format and therefore the import, location and integration process required a single step.

As a result of the import process, all data were integrated into a single workspace containing location, <63 micron and <2 micron databases; a geological grid and two geophysical grids.

Initial Data Review and Selection

For elemental data from the till survey, a methodology was required for quickly selecting data for further analysis. In this case, data were evaluated visually by displaying random line data in profile format in the PC workspace and visually looking for problems related to inadequate detection limits. This first-look procedure resulted in the identification of 18 of 34 elements for further processing. A second step was to plot groups of elements to visually identify relationships between precious metals and indicators (Au, As and Pt), base metals (Cu, Pb, Zn) and heavy metals (Cr, Co, Fe and Ni). This heuristic approach led to the selection of Au, As, Cu, Cr and Co for gridding and visualization. For lake sediment data and geophysics, all parameters were included in the exercise since only specific data were available.

Geochemical Data Processing

Statistical gridding employs the method of kriging to determine a value at each grid node based on the data. The routine used here first calculates a variogram of the data which shows the correlation as a function of distance. The farther apart the points become, the less is the correlation expected between points. The variogram shows this phenomena for a particular dataset and based on the variogram, the model that best defines the variance of the data can be selected.

For each set of geochemical data (till and lake sediment), data were gridded using a geostatistical kriging method and a power model was assumed for the variogram. This resulted in the series of till and lake geochemistry images for Beardmore-Geraldton shown in Figure 2. Maps bg1_ and bg4_ show the kriging and error grids for Au in the <63 micron fraction of till and maps bg3_ and bg6_ show the kriging and error grids (containing the standard deviation of the estimates at each grid node) for Au in lake sediments. Sample locations are overlain for illustrative purposes.

Multivariate Data Visualization

For this exercise, grids were shadowed -- creating a three-dimensional appearance that helps in recognizing systematic trends in images. Another visualization technique consisted of adding related data layers consisting of proportional size symbols, sample locations, geologic maps and basemaps. For space reasons, only selected elements, sample maps and geophysical data are displayed in Figure 2.

In practice, each available image was displayed interactively, and expanded or contracted to view data in detail. Dynamic links were also used to interactively georeference specific locations on multiple maps and evaluate relationships in different multivariate data images.

Brief Analysis of Multivariate Data

Analysis of data consisted of a qualitative review of kriging results from different geochemical surveys and a cursory interpretation of recognizable spatial trends in the integrated multivariate dataset.

In comparing kriging data from the till and lake sediment surveys, the images show the same general spatial relationships for Au in maps bg1_ and bg3_ and Cu in maps bg2_ and bg5_. Visual evaluation identifies key characteristics of the kriging process related to the sampling pattern and sample density. In the case of the <63 micron fraction of till, the error grid assumes a “brain coral” appearance with the distribution of values with low errors concentrated in a pattern closely approximating the dendritic sampling pattern along roads. In the case of the lake sediment data, the error grid assumes a “pitted” appearance that reflects the influence of individual isolated samples. The effect of sample density is also apparent with the more highly sampled lake sediment data having a much tighter “focus” than their till counterparts.

In analyzing the complete set of multivariate data, certain spatial trends are apparent. Regional magnetics in map bg_total_mag_shadow correspond directly to the regional geology map bg_geol_reg -- showing strong E-W oriented linear magnetic anomalies (red) delineate metavolcanic belts in this area. Comparison with map bg9_ shows an E-W oriented anomaly in Sb in the vicinity of metasedimentary rock units (sandwiched between metavolcanic belts). Magnetic lows (blue) in the western portion of the map correspond to mafic intrusives (solid black) in the geology map.

For geochemistry data, the lake sediment Au data indicate a string of isolated Au anomalies along the central metavolcanic / metasedimentary contact. Other apparent relationships include the concentration of Co values in the vicinity of the mafic intrusives in the west of the map area and the increase of Cu values to the northeast of Beardmore (indicated by the dynamic link). Arsenic appears to be relatively uniformly distributed along the metavolcanics and within the metasediments.

Conclusions

With the development of new software technologies (such as PC-based geoscience data processing and analysis systems), true integration, processing and visualization of multivariate geochemical, geophysical and geological data is now possible in the personal computer environment. In this exercise, a variety of data from different sources were quickly imported, processed and visualized together. This type of qualitative approach can help set the stage for more comprehensive analysis of historical multivariate data from different sources that have not previously been integrated, processed and visualized together. By extension, this approach may represent a departure point for analyzing more recently acquired multivariate data. Finally, the approach described here is largely qualitative but can be readily refined to more rigourously apply numerical and statistical analysis procedures at any point in the process.

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References

L. H. Thorleifson and F. J. Kristjansson, 1993. Quaternary Geology and Drift Prospecting, Beardmore-Geraldton Area, Ontario. Geological Survey of Canada, Memoir 435.

Regional Lake Sediment and Water Geochemical Data, Ontario, 1990. GSC Open File 2177, NGR 139-189; Parts of NTS 42E, 42L and 52H.

In addition to these two sources, readers may be interested in referencing large-scale data compilations currently being conducted by the GSC and OGS. The GSC recently released regional Cu geochemistry data for the entire province of Ontario and is working on regional Hg, Zn, Ni and other data. In March 1996, the OGS released the first in a series of 20 large-scale geophysical datasets containing re-processed data flown in various locations in Ontario.

Contact Information

Greg Hollyer
Geosoft Inc.
Suite 500, 204 Richmond St. W.
Toronto, Ontario, Canada M5V 1V6
E-Mail: greg@geosoft.com
Phone: (416) 971-7700
Fax: (416) 971-7520
WWW: http://www.geosoft.com

L. Harvey Thorleifson
Terrain Sciences Division
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario, Canada K1A 0E8
Phone: (613) 992-3643
Fax: (613) 992-2468

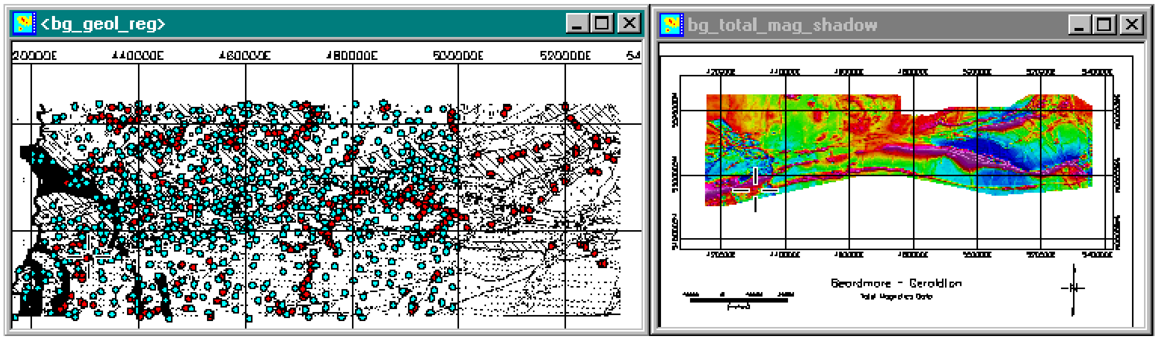

Figure 1: Integrated Geology, Geochemistry and Geophysics from the Beardmore-Geraldton district, Ontario. Map on left shows scanned, georeferenced geology layered over regional till geochemistry (cyan) and lake sediment geochemistry (red) survey sample locations. Map on right shows shadowed total-field magnetic geophysical data. The dynamic link cursors (crosses) provide a local reference (Beardmore, ON). *Raw data and grids courtesy of the Geological Survey of Canada and the Ontario Geological Survey.*

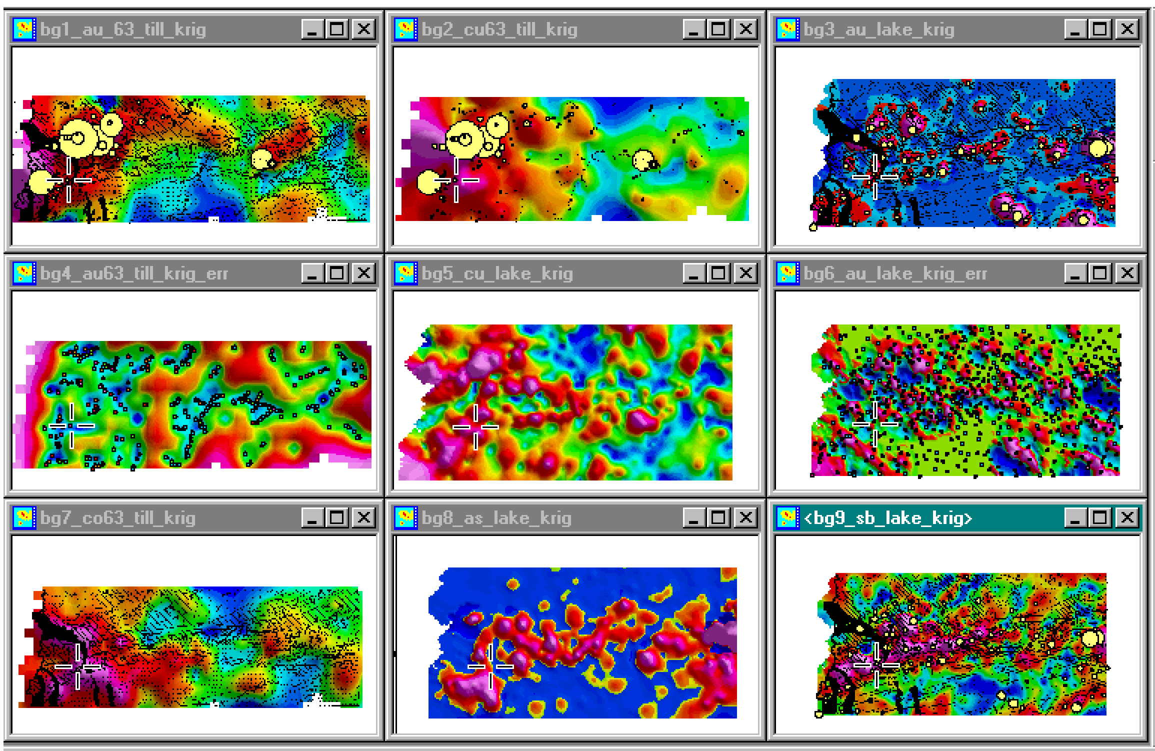

Figure 2: Till and Lake Geochemistry Images for Beardmore-Geraldton. Maps bg1, 2, 4 and 7 show geostatistical kriging (selected elements) and error (Au) grids from the <63 micron fraction of till samples. Maps bg1 and 2 have proportional Au symbols (<63 micron) superimposed. Maps bg3, 5, 6, 8 and 9 show geostatistical kriging (selected elements) and error (Au) grids for the lake sediment survey. Maps bg3 and 9 have proportional Au symbols (<170 micron fraction) superimposed. Maps bg1, 3, 7 and 9 have scanned geology superimposed (not resolvable at page scale).