Current Research (1994) Newfoundland Department of Mines and Energy,
Geological Survey Branch, Report 94-1, pages 301-311

A DIGITAL GEOPHYSICAL ATLAS: IMPLICATIONS FOR ITS DESIGN AND CONSTRUCTION

G.J. Kilfoil and P.A. Bruce
Geochemistry, Geophysics and Terrain Sciences Section

ABSTRACT

Digital geophysical datasets available for the province are being compiled and organized into a comprehensive and accessible database. Presently, data from government-sponsored airborne surveys represent, by far, the largest proportion, by volume, of this information. These regional geophysical surveys, systematically flown over large areas of the province, provide a useful background to which more detailed surveys may be referenced. The compilation of these datasets into a single database, complete with access software and a visually oriented digital index, in essence, constitutes the basis for a digital geophysical atlas.

A PC-based software package designed to display and query geo-referenced information has been under evaluation by the Geological Survey Branch (GSB). Data are stored as text, point, line, polygon, or image 'coverages' in a compatible database. Several coverages of diverse data types can be imported, combined and interpreted for integrated studies, from which various features may be isolated and enhanced for map production.

Here, the characteristics of each of the constituent regional geophysical datasets is discussed in light of how each might be best represented in the digital atlas. As part of an ongoing project, data are being captured digitally from many of the larger airborne surveys that have been flown by the mineral-exploration industry to provide detail in areas of high perceived potential. The status of these detailed geophysical surveys and the proposed methods of their incorporation into the digital atlas are also reviewed. It is proposed to portray several of the datasets as more than one representation in the digital atlas, yielding multiple data coverages. Adopting a multi-layered approach will result in much greater flexibility in the possibilities for combining geophysical data coverages with related geoscientific data. The basic structure and conceptual design of the digital geophysical atlas are similar to those for other digital atlases being compiled at the GSB to ensure compatibility and to allow ready access and cross-reference capabilities. When properly assembled, the digital atlas should lead to a wider range of applications for the data, from province-wide land-use planning studies to property-level mineral exploration.

INTRODUCTION

For the past several years, efforts have been underway at the Geological Survey Branch to organize geoscientific databases into computer processible formats to increase their accessibility and use by a variety of interested users. In terms of the regional geophysical component, the organizational task is reaching maturity. Therefore, considerable thought is being given to the options available for distribution of, and access to, large amounts of digital geophysical data.

Thoughts on archiving digital datasets and how they might be accessed have given rise to the concept of a digital atlas of compiled data, generated images and reference information. Ideally, the digital atlas would be constructed with a spatially referenced digital index (Kilfoil, 1993) to navigate through the province-wide databases to a subset in the area of interest to the user.

This paper will review the characteristics and current status of various geophysical datasets, outline how these data might be best represented in a digital atlas, and relate some experiences in selecting a software package capable for distribution and access of the various types of data.

Throughout the text, the distinction will be made between 'regional' and 'detailed' datasets. Although these two classes of data are obtained by similar methods and share many characteristics, their major difference lies in the purpose and design of the individual surveys. Regional surveys are generally sponsored by government agencies and cover large areas using constant survey parameters in order to obtain uniform coverage and information for a variety of uses. Detailed geophysical surveys are usually carried out by mineral-exploration companies, confined to one or more claim blocks, and have survey parameters specifically designed for mineral exploration in those areas. Regional surveys often provide a background to which data from detailed surveys may be referenced.

DATABASE REQUIREMENTS

In order to choose the optimum data structure and accompanying access software to drive the digital atlas, some desirable characteristics should be defined.

The software must be versatile; it must have the ability to access a variety of data types and combine them in various ways to create, at various scales, visual images on a computer screen and as plots on paper. All steps, from access to final arrangement, display and output, should be relatively simple and intuitive, such that much of the process is transparent and users spend less time programming and more time analyzing the information.

The database must be modular due to the finite nature of computer hardware. Within reason, the ultimate database should enable the user to view and query as little or as much data as desired, limited only by the user's computer and output hardware and its configuration. Database modularity is important for another reason. As each component dataset becomes organized or updated, it must be imported to the database with ease and without sacrificing the integrity of the existing data structure.

Since increasingly more powerful, desktop personal computers (PCs) are in common use and generally accessible, the database and software should operate on the PC, so that its wider distribution and ease of use is assured. In order to maintain compatibility as personal systems mature, the software should be operative on several computing platforms and the digital atlas should be easily moved across platforms.

CURRENT SYSTEM DESIGN

For over a year, ArcView™ (Environmental Systems Research Institute Inc.®, 1992), a display and query package developed for datasets organized in the ArcInfo format and operating in Microsoft Windows™ environment (Microsoft Corporation, 1992), has been under evaluation as a candidate for distribution of the Branch's databases. To date, many different types of geoscientific data have been each organized into one or more of the basic types of data 'coverages' acceptable in the ArcView™ data structure: points, lines, polygons, images and text. These include geological unit boundaries (faults and contacts), lake-sediment analyses, polygonal survey outlines, claim blocks, topographic features, gridded geophysical data, and digital elevation models. Each of the point, line and polygon coverages has an associative, structured database file containing a record linked to each entity in the coverage. These database files can be edited with any database editor to include up to 128 fields of descriptive information for each entity.

Despite the diversity of geoscientific data types that exist, one or more of the basic classes of coverages have so far provided a means of incorporating each without sacrificing its integrity or detail.

REGIONAL GEOPHYSICAL DATASETS

TOTAL-FIELD MAGNETIC DATA

The province has been systematically covered by airborne surveys of total field aeromagnetic data flown by the Geological Survey of Canada (GSC) from the early 1950s in central Newfoundland to the early 1980s in northern Labrador. With the objective of obtaining a consistent data coverage over large tracts of land, these surveys were flown at approximately 800-m line spacing and 305-m ground clearance with orientation (usually east–west or north–south) varying with survey area, generally perpendicular to the strike of geological units.

The older data, recorded by analog methods, have been recovered in digital form by digitizing flight-line contour intersections from 1:63 360-scale maps. The data have since been edited, matched along survey boundaries, systematically processed to remove levelling errors during survey, referenced to the Definitive Geomagnetic Reference Field (DGRF) and interpolated to a 200 m interval (Kilfoil, 1990). The gridded data for Newfoundland have been released by 1:250 000-scale map area as digital datafiles (Kilfoil and Bruce, 1990) and as colour shaded-relief maps with selected digital topographic features included (e.g., Kilfoil, 1993).

These data would be best represented within a digital atlas as raster images and as contour lines. Colour magnetic intensity images and colour or grey-scale shaded-relief images could be easily produced to be used as background when displaying other datasets. Contour lines of magnetic intensity could conversely be displayed over raster images or filled polygons of other datasets, such as geochemical element concentration, digital elevation models or bedrock geology, to aid in the interpretation of corresponding features in these datasets. Incorporating a sufficiently large range of contours would enable particular levels to be selected to highlight or outline only the features of interest. The traces of flight lines may be added for reference, but, due to the general invariance of orientation over large areas, their presence is less important to interpreting the dataset at the regional scale than for detailed surveys.

VERTICAL MAGNETIC GRADIENT

Since 1982, high-resolution magnetic and vertical magnetic gradient have been flown by the GSC in selected 1:50 000-scale map areas within the Central Volcanic Belt, central Newfoundland, as part of federal–provincial mineral-development agreements. The surveys have been flown at 150 m elevation with flight lines nominally spaced at 300 m and oriented east–west across the belt. Total-field and quadrature components of VLF-EM signal were also recorded from two transmitters to assist interpretation.

Total-field magnetic data referenced to the DGRF and vertical gradient magnetic data have been interpolated to a 60-m grid interval and subsequently corrected for inter-flight line-levelling errors. These two parameters should be represented in the digital atlas in a similar fashion to the regional aeromagnetic data: shaded-relief and colour images, contour lines, and flight-line traces.

RADIOMETRIC DATA

Airborne gamma-ray spectrometer surveys have been flown over selected contiguous areas of Newfoundland since

1982 under federal–provincial mineral-development agreements. Surveys, flown at 150 m altitude and 1 km nominal flight-line spacing, were chosen in areas underlain by dominantly intrusive rock types in order to characterize the plutonic regimes of Newfoundland. The most recent survey, however, was flown at 500-m line spacing over volcanic and sedimentary rocks comprising the Victoria Lake Group of the Central Volcanic Belt. To aid in interpretation of the data, ancillary channels of the total-magnetic field as well as the total-field and quadrature signal from each of two VLF-EM transmitters were recorded during these surveys.

Although there are many naturally occurring radioactive elements, only three sources produce gamma radiation of the intensity and abundance to be accurately measured during airborne surveys (International Atomic Energy Agency, 1991). They are the potassium isotope ^{40}K, the daughter isotope ^{214}Bi in the ^{238}U decay series and the daughter isotope ^{208}Tl in the ^{232}Th decay series. Since these parent radioactive species naturally occur in a fairly constant proportion to non-radioactive species, estimates of equivalent concentrations of potassium, uranium and thorium in surface rocks can be calculated from the measured gamma-ray emissions at the energies specific to the three radioactive species.

Thus, three corresponding windows in the gamma-ray energy spectrum, as well as the measure of total gamma-ray flux or 'exposure', are measured during these surveys. Data are corrected for atmospheric and cosmic sources of gamma-ray emissions, to yield calculated equivalent concentrations of the three parent elements (potassium, uranium and thorium), total exposure, and the ratios U/K, Th/K and U/Th. A problem inherent in collecting radiometric data is that the gamma-ray signal is strongly attenuated by bodies of water and attenuated to varying degrees by Quaternary surficial deposits and very dense vegetation cover such as that present in peat bogs within the province.

Attempted removal of the effects of signal attenuation by water bodies from gamma-ray profiles, interpolation onto regular grid files, and comparisons of results for each of the four primary channels over spatially variable surficial till deposits have been reported previously (Kilfoil *et al.*, 1993). Shaded-relief images have been generated from corrected grid files and imported into ArcView™. Survey flight lines have been imported as a line coverage for reference. As with the magnetic data, the radioelement concentrations and their ratios should also be represented as contour line coverage in the geophysical atlas. A point coverage could also be constructed with fields for each of the radioelements, their ratios, total field magnetic data and the VLF-EM values recorded (see below). However, the disk space and access-time requirements for a point coverage containing all the information would limit its practicality at this time.

GRAVITY

The gravity dataset for the province has been collected mainly by personnel from the federal Department of Natural Resources (DNR) and Memorial University of Newfoundland since the 1950s. A systematic regional data network was established by DNR during the 1960s at station spacings of approximately 12 km for onshore regions of Newfoundland and 8 km for Labrador during the 1960s and 1970s. In many areas of the province, these data remain as the only coverage. More detailed surveys carried out by MUN in the better accessible areas of Newfoundland have filled in the regional network to 6 km inland, 2 km along roads. In offshore regions adjacent to the province, a greater density of gravity values has been recorded during the 1970s by Canadian Hydrographic Survey vessels. The complete set of data collected onshore and in the nearshore for the province is referenced to the GRS67 geoid (International Association of Geodesy, 1967) and resides as a point database at the Geological Survey Branch.

Values of free-air and Bouguer anomalies are determined from the raw data collected. Typically, Bouguer anomalies are used in onshore regions and free-air anomalies in the offshore for potential field modelling or for generating potential maps. Gravity anomalies have been interpolated by random gridding algorithms onto regular grids in specific areas of the province to aid in interpreting deep structure.

As with magnetic data, Bouguer and free-air anomaly raster images could be generated from interpolated grid files. Given the maximum density of sites, particularly in onshore regions, and the regional nature of the data, interpolation to a 500-m grid interval is sufficient to represent the data. Therefore, these images are most useful for regional mapping, i.e., 1:1 000 000, 1:500 000 and possibly 1:250 000. The gravity collection sites also form a point database that could be interrogated within ArcView™ for display with other geoscientific information. Other parameters contained in the database for this point coverage are the site elevation, year of survey, data source, project number and fields recording the various corrections applied to the raw data.

VLF-EM

Very low frequency electromagnetic (VLF-EM) signals (15 to 30 kHz) from powerful radio transmitters positioned around the globe are often recorded with airborne surveys as an inexpensive means of characterizing the conductive properties of bedrock and surficial materials located near the earth's surface. As a result, as indicated earlier, VLF-EM data have been recorded digitally in conjunction with each of the government-sponsored vertical magnetic gradiometer and gamma-ray spectrometric surveys carried out in the province. The total VLF-EM magnetic field and quadrature component of the vertical magnetic field from the signals of two transmitters were generally recorded when these signals were available. Depths of penetration ranging from 10 to 200 m can be achieved with the VLF-EM method, depending upon the frequency and ground conductivity (Sinha, 1990).

Profiles of the total-field and quadrature signals from Cutler, Maine recorded in the Baie Verte area, as well as Fraser-filtered quadrature values, have each been interpolated onto regular grids. Images generated from gridded datafiles exhibit linear patterns and textures that can be attributed to faults and regions of conductive contrast in the underlying bedrock. These parameters should be represented in the geophysical atlas both as shaded-relief images and contour line coverages. Stacked profiles, using flight-line profiles as references, should also be included in the atlas.

DETAILED SURVEYS

Detailed geophysical surveys consist of both airborne and ground-based surveys. Airborne surveys are generally undertaken over areas encompassing several properties in order to justify the cost, whereas surveys carried out on the ground are usually designed to investigate all or portions of a single claim block. Efforts to recover detailed geophysical survey data from assessment reports to date have been concentrated on airborne surveys due to their greater aerial extent. Results of larger ground surveys will be digitized following the capture of all relevant airborne survey information.

Airborne and ground-based surveys are often designed with similar parameters, with differences resulting from the scale of observation. Ground-based surveys have a higher positional accuracy and often result in greater resolution of features due to measurements being taken more proximal to the sources of an anomalous natural field (i.e., magnetic) or perturbations of an external or inducing field (i.e., VLF-EM). However, the increased resolution is often offset by nonuniform coverage, reduced rate of survey and impediments to surveys carried out on the ground. These may be due to obstructions, terrain or the proximity to undesirable disturbances (i.e., power lines in magnetic surveys or conductive wire fences in EM surveys).

TOTAL-FIELD MAGNETIC SURVEY

The results of total field magnetic surveys carried out on the surface share many characteristics with airborne surveys. The density of measurement sites is generally greater and the measurement is taken closer to the source. This allows the data to be interpolated to a much finer interval which results in greater definition of anomalous features. Where highly magnetic sources (such as iron formations, ultramafic rocks) outcrop, the results of ground-based surveys may exhibit extreme local variability rendering them more difficult than airborne surveys both to interpolate onto a regular grid for integration into a database or perform modelling to constrain subsurface configurations.

Detailed ground and airborne magnetic survey data would be best imported into ArcView™ as raster images and vector files of magnetic contours. Survey lines should be imported as a reference vector coverage to show location, orientation and to help summarize the survey extent. Detailed surveys would differ from regional surveys in their limited areal extent and higher resolutions.

VLF-EM

Detailed VLF-EM data has been collected for mineral exploration in areas of the province since the late 1960s. Until a relatively recent increase in sensitivity in instrumentation, only the signals from Cutler, Maine and Annapolis, Maryland were of sufficient signal strength to reliably record the in-phase and quadrature components associated with conductive horizons in regions of interest for mineral exploration within the province. The angle of incidence of signal from both of these stations on the Island of Newfoundland is approximately from the southwest. Fortunately, this signal is well oriented for maximum coupling with predominantly northeast-striking geological structures in most areas.

Instrumentation in common use today is capable of integrating the acquisition of total field magnetic, magnetic gradient, VLF-EM and gamma-ray spectrometer measurements. Increased sensitivity of receiving coils allows weaker VLF-EM signals from distant transmitters to be used. As well, all components of the primary and secondary VLF-EM magnetic field are commonly recorded digitally, allowing much better characterization of the anomalous field arising from conductive horizons.

Values of the recorded in-phase and quadrature components of the VLF-EM field for a field area in Newfoundland have been interpolated to a regular interval. Shaded-relief images have been generated successfully in ArcView™ format from these secondary VLF-EM field components and their Fraser-filtered equivalents. Several linear anomalies on these images have been shown to correlate with positions of known strike-slip and thrust faults mapped on the surface. The various VLF-EM field parameter strengths could also be represented in ArcView™ as a vector coverage of contour lines. As well, the values of all VLF-EM parameters recorded at each site should be imported as a point data coverage. If total-field magnetic measurements are recorded along with the VLF-EM data, values could be included as an extra field in the associated database.

ELECTROMAGNETIC DATA (ACTIVE SOURCE)

Very many different equipment configurations and frequencies are used in active electromagnetic surveying. Airborne surveys usually employ coupled pairs of transmitters and receivers located either onboard the aircraft, attached to its wings or tail, or within a towed bird (Becker *et al.*, 1990). Typically, two or more pairs operate at specific frequencies in a spectrum and each pair generates in-phase and quadrature responses of the earth beneath the aircraft. Through analysis of the EM responses from a range of frequencies, certain characteristics about conductors giving rise to anomalies can be obtained, such as source material (conductive overburden, graphite, bedrock), depth and conductivity-thickness product. If the survey orientation is nearly perpendicular to the strike of conducting horizons, their continuity can be determined by correlating anomalous responses from one line to the next.

Since many detailed airborne surveys were flown in exploration for massive sulphide deposits in the province, several include some form of the active EM survey method. Many of the assessment reports for airborne EM surveys list the response parameters of EM anomalies determined automatically. Often these reports include a map showing locations of the picked EM anomalies, an interpretation of causative conductor continuity across flight lines, and faults assumed by abrupt lateral conductor termination. To aid in interpreting lateral continuity, conductors are often classed according to conductivity-thickness values. A few assessment reports for airborne EM surveys also include the in-phase and quadrature responses either in profile form or as stacked profiles on maps.

The locations of anomalous EM responses have been digitized from several assessment reports. These have been associated with data entered from EM response tables to construct point coverages in ArcView™. The EM response parameters can be used in ArcView™ to graduate symbol sizes, which produces a very effective display when overlaid on interpolated magnetic or VLF-EM images. Figure 1 shows an example of an ArcView™ view consisting of EM anomalies graduated by conductivity-thickness product overlain on a colour shaded-relief image of total field magnetic data from the Glover Island area in central Newfoundland (Hudson's Bay Oil and Gas Co. Limited, 1978). The inset in the lower right corner of Figure 1 displays the results of a query to the digital index of all airborne geophysical surveys conducted in Newfoundland.

In cases where available, EM profiles can be digitized. These results can be included in ArcView™ either as a stacked profile line coverage or parameters may be interpolated to yield band-interleaved images. In addition, profiles of fixed-loop time-domain EM data have been recently transformed by Karous-Hjelt filtering (Karous and Hjelt, 1983) to yield current density pseudosections in order to highlight conductive zones or conductivity contrasts (Smith and Whitaker, 1993). Stacked current density pseudosections could be incorporated into ArcView™ views as colour-composite images (for example, see Figure 3).

RADIOMETRIC DATA

Detailed airborne gamma-ray spectrometer surveys have been flown in certain areas of the province, primarily in the search for uraniferous ores. The concepts of the survey technique and recording parameters used during the survey are generally similar to those employed in regional surveys.

In certain instances, contour maps of recorded radioelement concentrations are submitted with mineral-assessment reports; other reports include profiles of recorded energy channels corresponding to radioelements. The radioelement contour maps can be digitized and the results handled similarly to the magnetic data captured from contour maps. Gamma-ray profiles have been digitized as continuous lines and positions along each profile have been scaled to fiducial locations extracted from location maps to generate georeferencing.

Digitized profiles or profiles generated from contour maps can be represented in ArcView™ as profile line coverages or as images generated from interpolated values.

INDUCED POLARIZATION SURVEYS

Unlike the geophysical methods discussed so far, induced polarization measurements can only be carried out on the ground. Typically, such bedrock parameters as apparent resistivity, chargeability and metal factor are determined from survey outputs. Induced polarization measurements are usually conducted at three or more electrode spacings to yield these parameters at various pseudo-depths. Traditionally, IP data is plotted and contoured in pseudosections; increasingly, plan views, created by interpolating data across profiles at constant pseudo-depth, are used to trace anomalous parameters throughout the survey area.

Geophysical data from extensive ground surveys carried out in the Northwest Gander River area in Newfoundland have been input manually (Mercer, 1988; Burton, 1987). IP parameters recorded in the Chiouk Brook east survey have been interpolated across sections at pseudo-depths and ArcView™ images have been generated from the results. Figure 2 shows metal conductance factor values recorded at a pseudo-depth of 25 m (electrode spacing = 25 m; N=2) and the VLF-EM in-phase anomaly profiles added along the survey lines used to produce the pseudo-depth image. The inset in the upper right corner of this image gives an expanded view centred on an anomaly located midway along survey line 900 East (fourth line from the west) with VLF in-phase anomalies posted along the survey lines. The lower right inset shows the result of a query to the database of VLF-EM data at the position indicated by the white arrow in the upper inset.

Alternatively, IP data could be presented in ArcView™ as a series of stacked contoured pseudosections in a vector coverage or as stacked interpolated raster images. The entire dataset of IP parameters could also be stored in a database file associated with and accessed through a point coverage in ArcView™. As an example, a raster image created from IP metal factor pseudo-sections from the Chiouk Brook east survey grid are shown in Figure 3. As in Figure 2, the upper right inset in Figure 3 is an expanded view centred on the IP anomaly located midway along line 900 East, with metal factor values posted in the pseudosection format. This IP anomaly has the typical inverse 'V' shape of that due to an ore horizon located at shallow depth. The lower right inset of Figure 3 shows a query to the induced polarization database at a point centred within the anomaly and at a pseudo-depth of 25 m (N=2).

CONCLUSIONS

A digital format for a geophysical atlas is being proposed that is designed to access geophysical and related data from each survey area as one or more data layers or coverages. The ArcView™ format is sufficiently versatile to accommodate data from the variety of geophysical methods and scales of survey currently used in mineral exploration. Data from a single method and survey area can often be represented in many ways using multiple layers, adding versatility to the geophysical atlas. The user may select the data representation and combination, which optimizes the display of information relevant for a particular target.

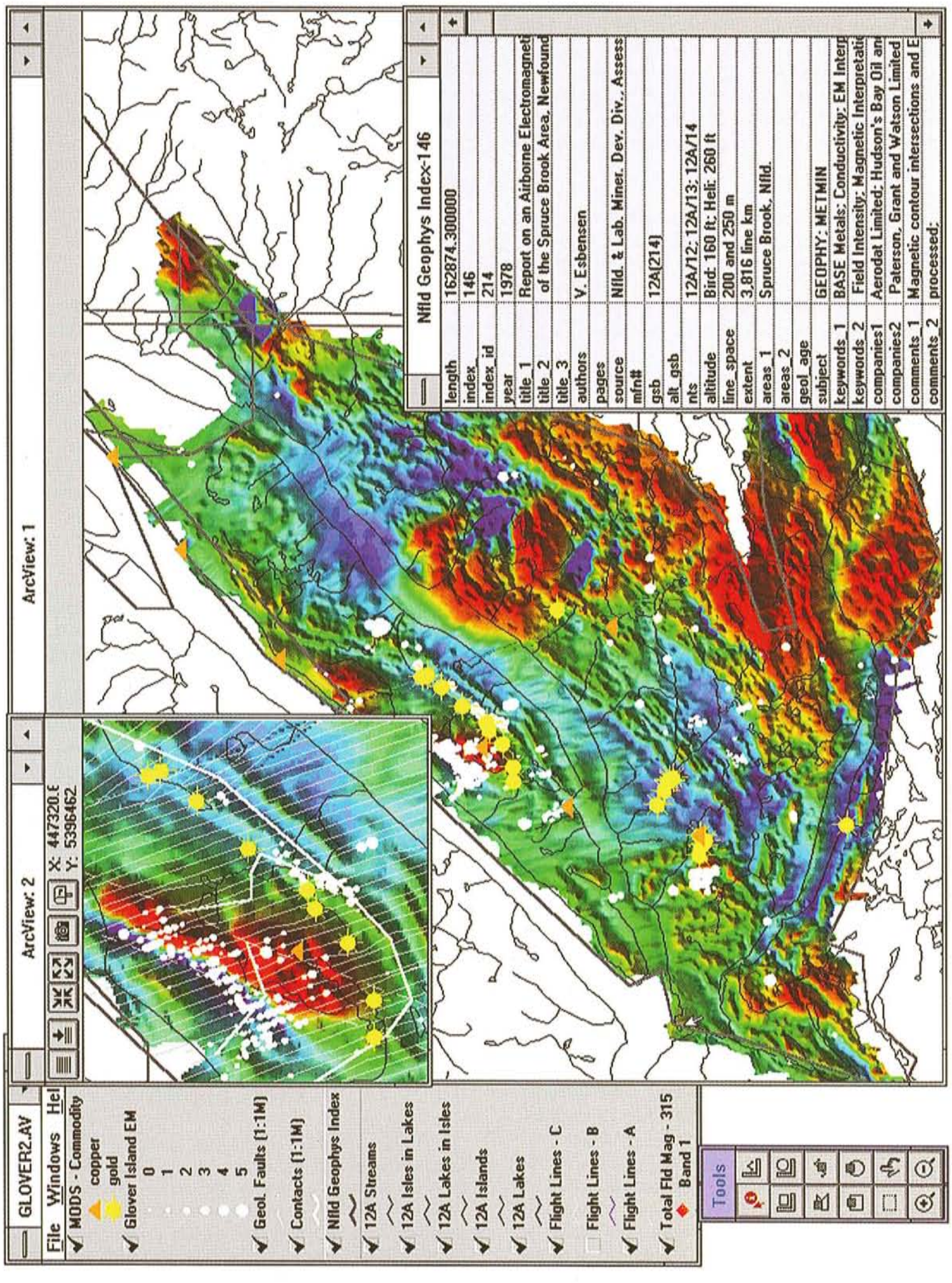
GLOVER2.AV
File Windows Hel
MODS - Commodity
copper
gold
Glover Island EM
0
1
2
3
4
5
Geol. Faults (1:1M)
Contacts (1:1M)
Nfld Geophys Index
12A Streams
12A Isles in Lakes
12A Lakes in Isles
12A Islands
12A Lakes
Flight Lines - C
Flight Lines - B
Flight Lines - A
Total Fld Mag - 315
Band 1
Tools
ArcView: 2
X: 447320.E
Y: 5396462
ArcView: 1
Nfld Geophys Index-146
length 162874.300000
index 146
index_id 214
year 1978
title_1 Report on an Airborne Electromagnet
title_2 of the Spruce Brook Area, Newfound
title_3
authors V. Esbensen
pages
source Nfld. & Lab. Miner. Dev. Div., Assess
mfn#
gsb 12A(214)
alt_gsb
nts 12A/12; 12A/13; 12A/14
altitude Bird: 160 ft; Heli: 260 ft
line_space 200 and 250 m
extent 3,816 line km
areas_1 Spruce Brook, Nfld.
areas_2
geol_age
subject GEOPHY; METMIN
keywords_1 BASE Metals; Conductivity; EM Interp
keywords_2 Field Intensity; Magnetic Interpretatio
companies1 Aerodat Limited; Hudson's Bay Oil an
companies2 Paterson, Grant and Watson Limited
comments_1 Magnetic contour intersections and E
comments_2 processed;

Figure 1. *Screen capture of an ArcView™ view featuring geophysical data extracted from an assessment report covering an airborne survey in the Spruce Brook area, central Newfoundland (Hudson's Bay Oil and Gas Co. Ltd., 1978). The colour image was produced from total field magnetic data illuminated from the NW. The variable-sized white dots mark the locations of conductive anomalies determined from EM data, where the dot size increases with the conductor strength. The yellow dots and orange triangles are locations of gold and copper mineral occurrences, respectively, taken from the MODS database (Stapleton* et al., *this volume). The light black lines are lakes and watercourses taken from the 1:250 000-scale digital topographic database. The heavy dark lines are outlines of airborne geophysical surveys conducted within this area from the digital index. The lower right inset shows the results of a query made to the database by pointing to the boundary of this survey (see small white arrow near western boundary). The upper left inset shows an enlargement of an anomalous area in the central part of Glover Island. Here, flight lines have been included as light white lines, and geological contacts and faults from the 1:1 000 000-scale geology map have been added as heavier white lines and light dashed lines, respectively, to help identify possible sources for magnetic and EM anomalies in this area.*

Once assembled, the geophysical atlas compiled in ArcView™ format should prove to be a very powerful interpretive tool for a variety of users. The regional datasets have proven most useful for bedrock mapping at 1:50 000 scale. In concert with other types of data, regional geophysical data could be used for land-use planning and environmental sensitivity studies. Efforts are underway at the Geological Survey Branch to recover the geophysical components of detailed mineral-assessment reports (Kilfoil *et al.*, 1993) and several of these have already been converted to ArcView™ data coverages. In addition to enhancing the regional data coverage, the detailed component of the geophysical data atlas should prove even more useful for such projects as detailed mapping, property level mineral assessment and municipal land-use planning.

The modular nature of datasets assembled in the ArcView™ format and the ease with which they may be imported and interrogated greatly enhance and encourage their possible end uses. The modular aspect also allows the atlas to be used even when only partially assembled and easily accommodates the addition of other modules as data becomes available and organized.

The concept of a digital index to provide a road map to various datasets has already been implemented with the compilation of information for all airborne geophysical surveys in the province. Digitized survey outlines have been imported into ArcView™ as a line coverage, which is linked to bibliographic information exported from the Geoscan database (Patey and Gillespie, *this volume*). Although the implementation of the digital index is visually appealing and informative, the links to existing datasets for selected surveys is rudimentary and requires further refinement. Much of the extensive regional geophysical survey data available for the province has either already been imported into ArcView™ or is in an organized form that can be readily converted. The addition of certain datasets, such as the VLF-EM data and portions of the gamma-ray data, is pending further processing and decisions on best methods to present the information in ArcView™. The release of digitized geophysical data from detailed surveys in ArcView™ format has already been initiated (i.e., Kilfoil *et al.*, 1992); detailed datasets will be added in modular fashion as their digital capture and processing progresses.

ArcView™ has provided an important starting point for the organization of diverse data types and the creation of a digital geophysical index. Previously, in the absence of a vehicle for ready access and integration of very different types of data, it was difficult to determine how geophysical data might be best organized to be internally compatible and to mesh with related geoscientific datasets. The digital geophysical atlas may eventually be migrated to a different display and query software package as databases mature, pending such factors as versatility, cost and computing platforms in common use. However, having already assembled the atlas in a digital form, the transition should require much less effort. In the interim, geophysical and related datasets will continue to be organized at the Geological Survey Branch for distribution in the ArcView™ format.

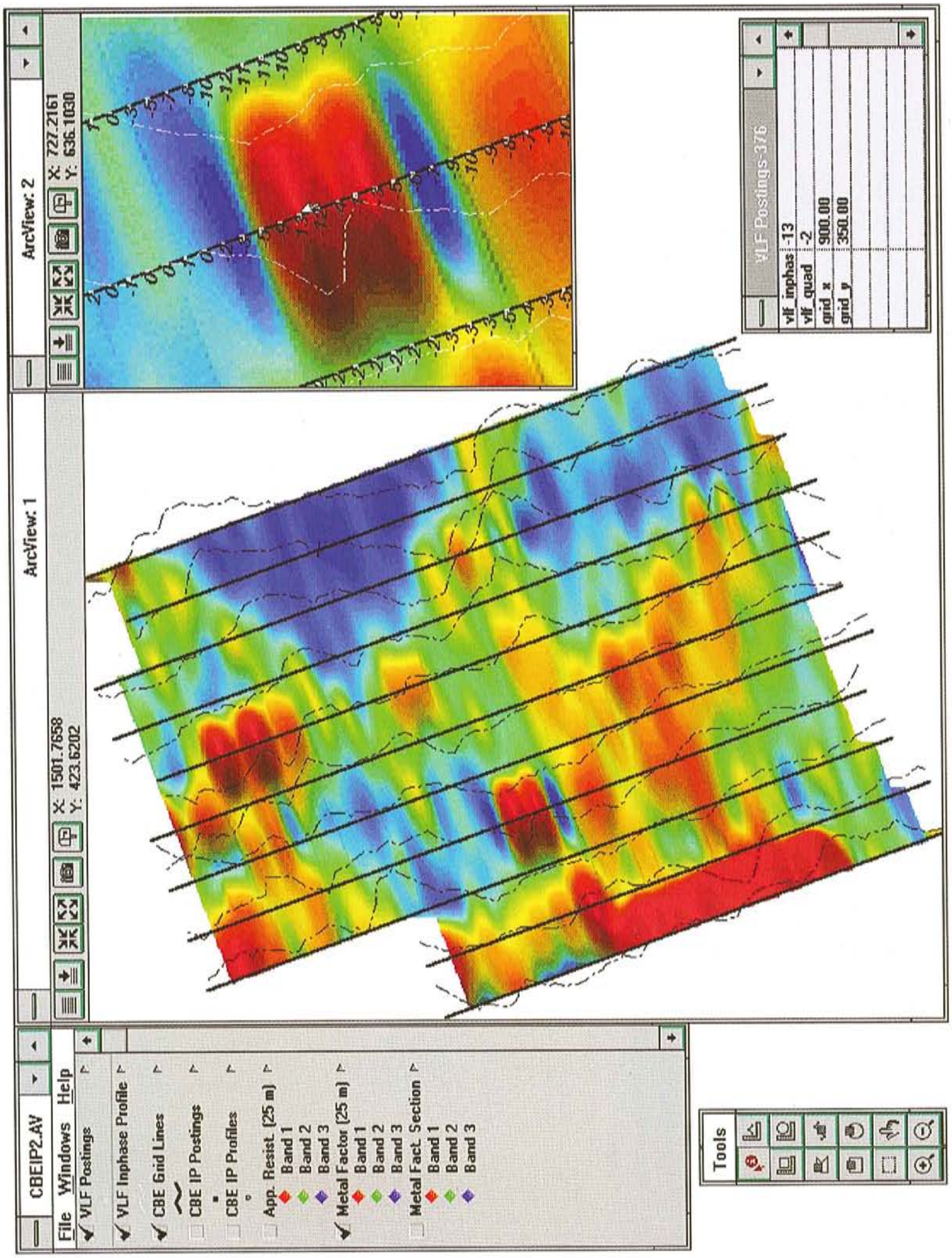
ArcView: 2
X: 727.2161
Y: 636.1030
ArcView: 1
X: 1501.7658
Y: 423.6202
VLF Postings-376
vlf_inphas -13
vlf_quad -2
grid_x 900.00
grid_y 350.00
CBEIP2.AV
File Windows Help
VLF Postings
VLF Inphase Profile
CBE Grid Lines
CBE IP Postings
CBE IP Profiles
App. Resist. (25 m)
Band 1
Band 2
Band 3
Metal Factor (25 m)
Band 1
Band 2
Band 3
Metal Fact. Section
Band 1
Band 2
Band 3
Tools

Figure 2. *Screen capture of ArcView™ session shows colour shaded plan image of interpolated metal conductance factor values from induced polarization data recorded for a pseudo-depth of 25 m (electrode spacing = 25 m; N=2) along NNW-oriented survey lines (heavy black lines) in the Chiouk Brook east survey of the Northwest Gander River area, central Newfoundland (Mercer, 1988). North is up on this diagram. The dashed black lines added to the image are VLF-EM in-phase anomaly profiles (positive values plotted ENE of lines) recorded along the survey lines used to produce the pseudo-depth image. The inset in the upper right corner gives an enlarged view centred on a metal factor anomaly located midway along survey line 900 East (fourth line from the west) with VLF in-phase anomalies posted along the survey lines. The lower right inset shows the result of a query to the VLF-EM database at the position indicated by the white arrow in the upper inset.*

ACKNOWLEDGMENTS

Dr. Peter Davenport is thanked for suggested improvements to a preliminary version of this manuscript.

REFERENCES

Becker, A., Barringer, A.R. and Annan, A.P.
1990: Airborne electromagnetics 1978-1988. *In* Developments and Applications of Modern Electromagnetic Surveys. *Edited by* D.V. Fitterman. U.S. Geological Survey, Bulletin 1925, pages 9-20.

Burton, W.B.
1987: First year assessment report on geological, geophysical and diamond drilling exploration for licences 2738 on the Chiouk Brook prospect in the Great Bend area, Newfoundland. W.B. Burton for U.S. Borax Limited, 49 pages. [2D/11(171)]

Environmental Systems Research Institute Inc.®
1992: ArcView™ Geographic Exploration System, User's Guide & Software, Environmental Systems Research Institute, Inc., Redlands, CA, USA. 155 pages.

Hudson's Bay Oil and Gas Co. Limited
1978: Report on an airborne electromagnetic and magnetic survey, Spruce Brook area, Newfoundland, 13 pages and Appendices. [12A(214)]

International Association of Geodesy
1967: International gravity formula, Geodetic Reference System (GRS67), Special Publication No. 3, Paris, France.

International Atomic Energy Agency
1991: Airborne gamma ray spectrometer surveying. International Atomic Energy Agency, Technical Report Series 323, Vienna, Austria.

Karous, M. and Hjelt, S.E.
1983: Linear filtering of VLF dip-angle measurements. Geophysical Prospecting, Volume 31, pages 782-794.

Kilfoil, G.J.
1990: From analog aeromagnetic contour maps to enhanced colour images: getting the most from an existing potential field dataset. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 90-1, pages 107-113.

1993: Colour, shaded-relief aeromagnetic maps of the Bay of Islands and Sandy Lake (NTS 12G and 12H) map areas. Newfoundland Department of Mines and Energy, Geological Survey Branch, Maps 93-110a & 93-110b, scale 1:250 000. [NFLD/2346]

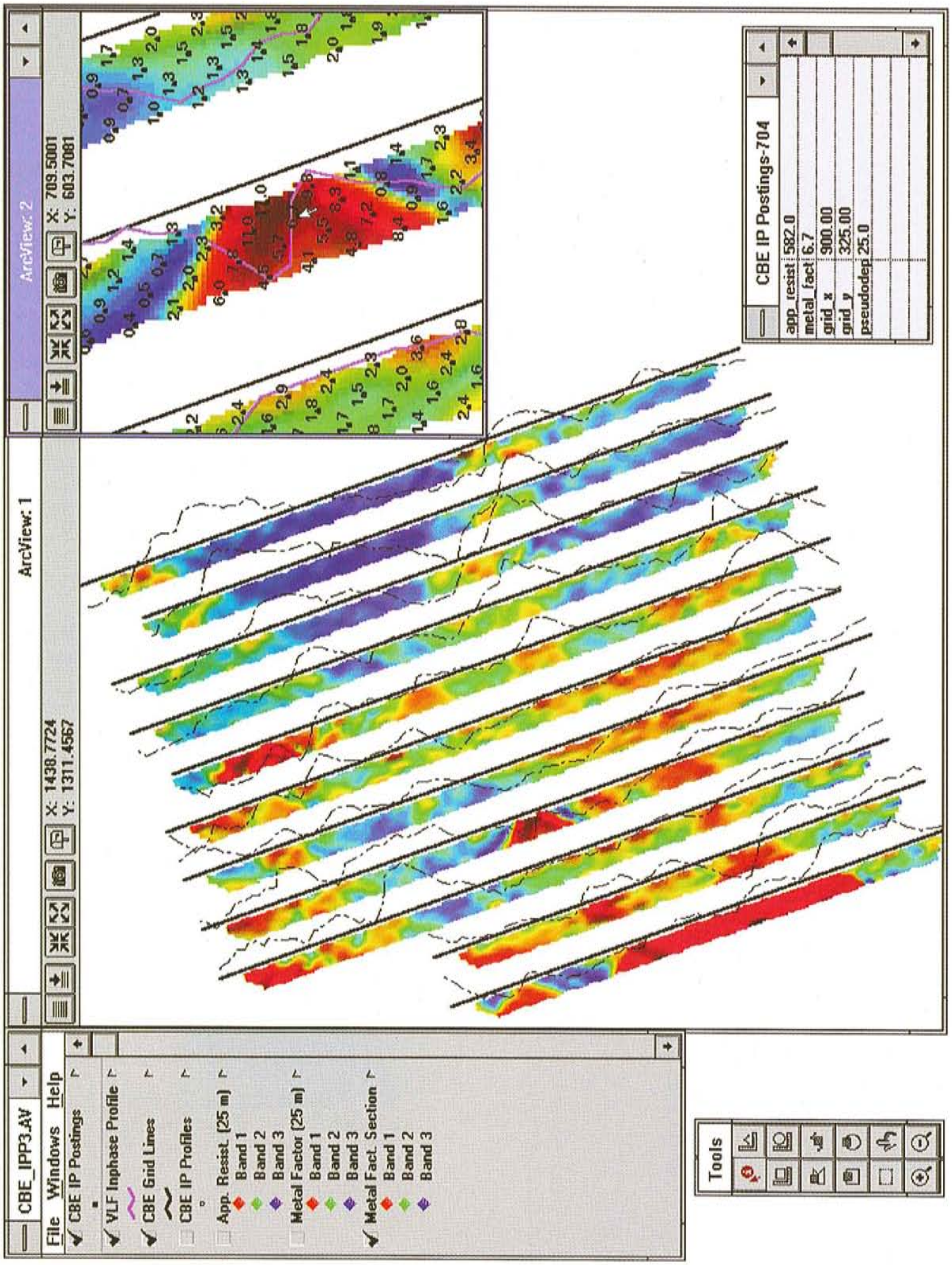
ArcView: 1
X: 1438.7724
Y: 1311.4567
ArcView: 2
X: 709.5001
Y: 603.7081
CBE IP Postings-704
app_resist 582.0
metal_fact 6.7
grid_x 900.00
grid_y 325.00
pseudodep 25.0
CBE_IPP3.AV
File Windows Help
CBE IP Postings
VLF Inphase Profile
CBE Grid Lines
CBE IP Profiles
App. Resist. (25 m)
Band 1
Band 2
Band 3
Metal Factor (25 m)
Band 1
Band 2
Band 3
Metal Fact. Section
Band 1
Band 2
Band 3
Tools

Figure 3. *Screen capture of ArcView™ views for same area as Figure 2. Here, metal conductance factor values are shown as colour pseudo-depth sections with depth increasing away from the survey lines. VLF-EM in-phase profiles (dashed lines) have been added to help correlate anomalies in the two datasets across adjacent survey lines. The enlarged view of the middle portion of the pseudo-section for survey line 900 E with metal factors posted shows anomalous values in an inverted 'V' pattern that typifies a possible ore horizon located at shallow depth. Note that the metal factor anomaly appears localized as it has not been detected on adjacent survey lines. A query to the IP database at a point centred in the anomalous region (white arrow) also reveals the apparent resistivity, the pseudo-depth and location in survey coordinates (lower inset). Other fields, such as descriptive text could be added to the IP database.*

Kilfoil, G.J. and Bruce, P.A.
1990: Regional aeromagnetic data grids (200 m grid cell), in digital form, for all of insular Newfoundland, Version 1.0. Newfoundland Department of Mines and Energy, Geological Survey Branch, Open File NFLD (2063), 24 pages.

Kilfoil, G.J., Bruce, P.A. and Honarvar, P.
1993: Reclaiming geophysical data from mineral-assessment reports: An update. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 93-1, pages 443-449.

Kilfoil, G.J., Honarvar, P. and Bruce, P.A. (Compilers)
1992: A set of digital aeromagnetic and total field VLF-EM gridded data files and related information captured from a mineral assessment file submitted by BP Minerals–Billiton Canada Joint Venture covering a 1982 helicopter-borne geophysical survey of the Florence Lake greenstone belt, Labrador. Newfoundland Department of Mines and Energy, Geological Survey Branch, Digital File DF 92-1.0.

Mercer, B.J.
1988: First and second year assessment report on geological, geochemical and geophysical exploration for licences 2751, 2753, 2744-2777, 3270 and 3272 on property in the Great Bend area, Newfoundland. B.J. Mercer for A.C.A. Howe International Limited, 66 pages. [2D/11(169)]

Microsoft® Corporation
1992: User's guide for the Microsoft® Windows™ Operating System, Version 3.1. Microsoft® Corporation, U.S.A. 650 pages.

Patey, C. and Gillespie, J.
This volume: GEOSCAN–the national database for geological information: the Newfoundland contribution.

Sinha, A.K.
1990: Application of airborne very low frequency electromagnetic surveys in geophysical exploration. *In* Developments and Applications of Modern Electromagnetic Surveys. *Edited by* D.V. Fitterman. U.S. Geological Survey, Bulletin 1925, pages 117-131.

Smith, R.S. and Whitaker, S.A.
1993: Line current filtering of fixed-loop transient electromagnetic data. Geophysical Prospecting, Volume 41, pages 969-982.

Stapleton, G., O'Driscoll, C.F., Parsons, W.K., Smith, J., King, D. and Jacobs, W.J.
This volume: Mineral occurrence data system.

Note: Geological Survey Branch file numbers are included in square brackets.