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RECLAIMING GEOPHYSICAL DATA FROM MINERAL-ASSESSMENT REPORTS

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ABSTRACT

A project was initiated to extract geophysical information in computer-processable (digital) form from mineral-assessment reports, submitted over the last 40 years. A pilot project was designed to initially extract information from only those files containing airborne geophysical surveys for Labrador. The digitized outlines of these surveys have been merged with corresponding GEOSCAN bibliographic information to create a digital index that can easily be queried on a PC. Two methods of capturing the data, by digitizing and optical scanning, from contour maps taken from the assessment reports were investigated for their accuracy and efficiency. At present, despite the time and resource requirements, digitizing is the superior method of data input due to manual control over data entry and minimal data-storage requirements.

Aeromagnetic data from two detailed industry surveys were assessed by comparison to the existing data from surveys conducted by the Geological Survey of Canada. In these examples, the digitally processed data from detailed industry surveys provide better definition of geological features than the more regional survey data.

INTRODUCTION

The objective of this project is to begin to build a well-organized, computer-processable geophysical database for the province, to support mineral exploration and other government and university geoscientific programs. Most of the digital geophysical data now publicly available are from regional surveys conducted by the Geological Survey of Canada. These are being organized and processed using a set of PC-based programs (Kilfoil and Nolan, *this volume*) to form a regional framework for the database.

A considerably greater amount of geophysical data is contained in assessment reports submitted to the Department of Mines and Energy by mineral-exploration companies. These industry surveys are varied in their type, scale, documentation and, we expect, quality. Furthermore, almost all survey data exist in our files only as paper (or mylar) copies or on microfiche. The main part of this project is concerned with filling in the regional framework of digital geophysical data with these industry data in digital form. To accomplish this, the industry surveys must be first catalogued, their quality and level of documentation assessed, and selected surveys digitized, processed and included. To keep the project to a manageable size at the outset, the first surveys to be examined are airborne geophysical surveys reported in non-confidential assessment files for Labrador. This pilot project will allow the design and costing to be determined for a more comprehensive project that would include the whole province and all geophysical surveys, as well as an evaluation of the benefits of such a project.

CONSTRUCTING A DIGITAL INDEX

Catalogues of geophysical and geochemical surveys for the province have been compiled in booklet form from time to time (Mullins *et al.*, 1969; Withycombe and Fogwill, 1978), or as maps (Harris, 1977). For this project, a digital index is being designed. This contains relevant synoptic information from assessment reports linked to digital survey boundaries through a computer database with graphical output. The digital index will permit much more effective search, browse, retrieval and update of the file, and will be eventually linked to the actual data in the geophysical database, probably through a WINDOWS (Microsoft, 1990) application.

By the end of August, 1991, the outlines of all airborne geophysical surveys for Labrador had been digitized from maps submitted as part of the reports in Geofiles. As each survey boundary was input, the survey was classed into three broad categories by the type of survey flown: magnetic, radiometric and electromagnetic. No distinctions were made between the various types of electromagnetic receivers, whether active or passive, used during the survey. Figure 1 shows the outlines of industry-sponsored, airborne geophysical surveys (approximately 120 surveys from 70 assessment reports) flown to date in Labrador, coded by the possible combinations of survey type as seven line types and weights. This coding readily illustrates the distribution of surveys that exist for an area of interest and identifies each by survey type. Note the concentration of surveys in the southern Labrador Trough and over the Central Mineral Belt.

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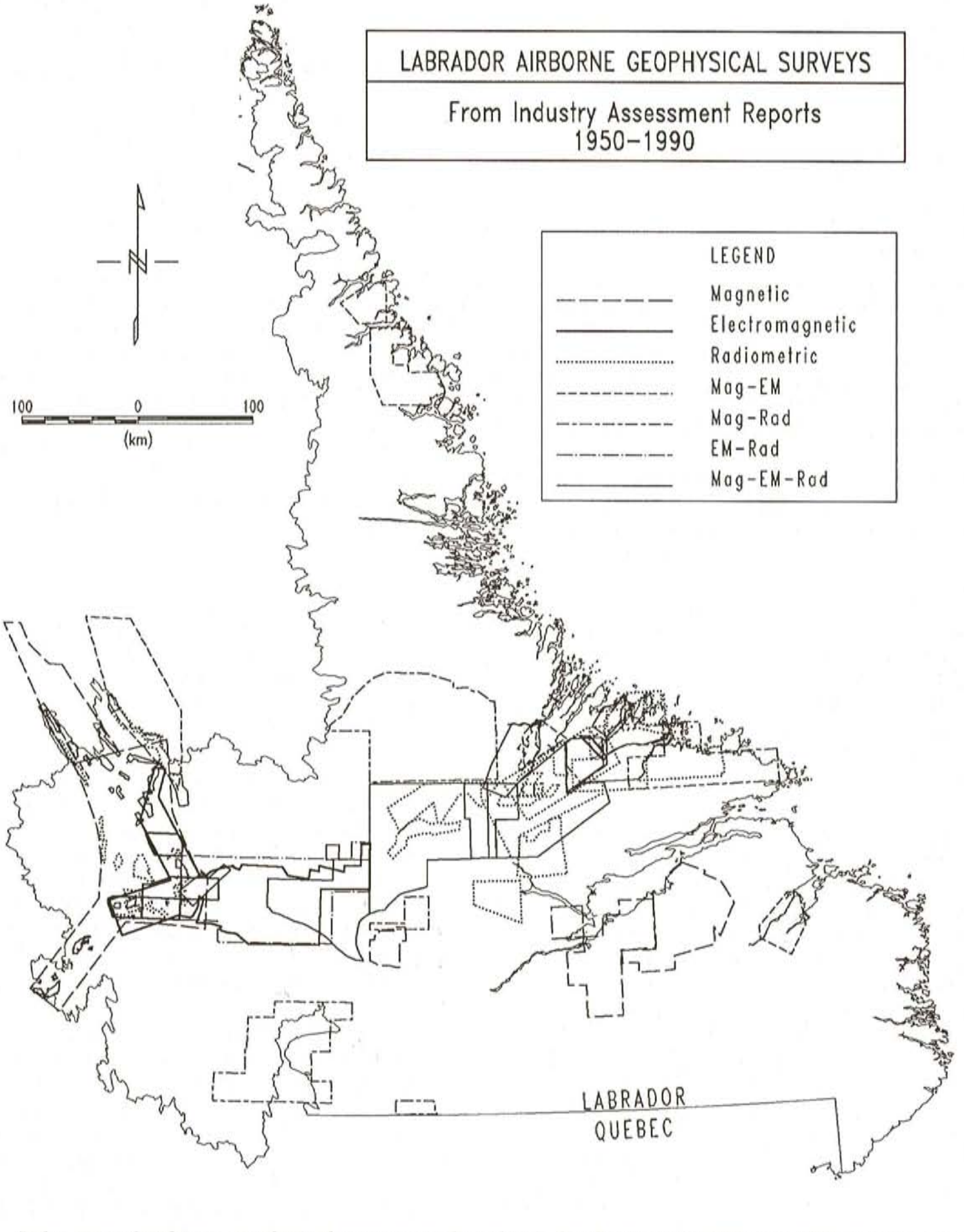

Figure 1. *Index map of airborne geophysical surveys conducted in Labrador between 1950 and 1990. Surveys are coded by line type according to geophysical method. The map was output from a digital map index database, which consists of survey outlines having corresponding bibliographic information from the GEOSCAN database.*

To form the foundation for a digital index, a relational database was constructed from bibliographic and spatially referenced information. First, selected descriptive text fields were exported from the records of all airborne geophysical surveys conducted in Labrador and contained in the national GEOSCAN bibliographic database (Patey and Gillespie, *this volume*). These were reformatted and imported into a dBase III format (Ashton-Tate, 1988) database file. The UTM coordinates defining the individual survey outlines were digitized, reformatted and written to a memo file and referenced to a separate relational database file using the MKPOLY utility from the QUIKMap (Environmental Sciences Limited, 1990) graphical mapping package. Finally, corresponding records from the two relational database files were merged (using a Clipper routine) to create a digital index database file.

As part of the pilot project, the InFOcus (Earth and Ocean Research, 1990) desktop-mapping software package was evaluated for its suitability as a graphical interface to the digital index database. The InFOcus package is a menu-driven link to information contained in a relational database and also provides a user-friendly selection of QUIKMap utilities. In turn, QUIKMap provides the interface from the database to output devices, such as a VGA monitor or line plotters. The QUIKMap utilities provide a mouse-driven graphical display that enables convenient zooming and point-and-click selection of polygonal survey outlines to access data associated with survey areas. An option in the InFOcus menu allows vector information existing in other databases, such as the outlines of claim blocks, geological contacts or topographic features, to be selected for overlay as base maps, on the graphical image of survey outlines. Written in FoxPro (Fox Software Inc., 1990), InFOcus quickly accesses information concerning a selected survey in the database file and presents it in an adjustable text box that overlays on top of the graphical image. Information displayed in the text box can be interactively edited. A multitude of criterion-based searches can be instituted from the InFOcus menus; records meeting the search criteria are quickly flagged for display through the efficient database access of FoxPro. The combination of InFOcus coupled to QUIKMap also provides the ability to select data for output to plotters at any specified scale or projection.

Although the InFOcus software provides efficient database access, display, editing and zooming capabilities, a few inherent shortcomings limit its suitability as a graphical interface for the digital index. First, the procedure required to construct the digital index database is not intuitive. As well, a single assessment report commonly describes geophysical surveys carried out in more than one area. Conversely, more than one assessment report may be submitted for a single survey. No simple method is apparent for establishing such complex links between survey outlines and textural information within the database. If the areas enclosed by survey outlines overlap and the screen pointer is clicked in the overlap area, only information from the first record, which corresponds to one of the areas encountered in the database, will be displayed in the text box. In short, a simultaneous query of information from multiple database records that may exist for a specified location cannot be easily accomplished within the current version of InFOcus.

Alternative software packages upon which to base the digital map index are currently being sought. Its functional and adaptable capabilities, ease of use and cost are seen as the major criteria in graphical interface selection. The graphical database access software should be reasonably priced to ensure the widespread use of the digital index by mineral-exploration companies. The compiled index and digitized outlines of airborne geophysical surveys for Labrador currently exists as a relational database in dBase III format and as ASCII text files, either of which could be reformatted for import to an alternative database structure.

A digital index has several advantages over the traditional booklet or index map. Being PC-based, bibliographic information can be retrieved faster and more efficiently. The digital index is more comprehensive in that all existing assessment-report information can be combined into a single database, which can be readily updated, and from which the user can select the level of bibliographic information to be output or displayed on the computer screen. The graphically oriented display of survey boundaries is more visually appealing to the user and, through zooming facilities, the level of spatial detail to be displayed, or output, is unconstrained. When fully developed and linked to geophysical data files from individual surveys, the digital index will theoretically be the 'roadmap' for navigating through the geophysical database.

DIGITAL DATA INPUT (DIGITIZING VERSUS SCANNING)

Two methods of capturing geophysical data from analog paper maps or plots were evaluated and the merits of each compared: 1) selective input from a digitizer, or 2) total input by digital scanner, followed by selective editing of the converted vector data.

As an example, a map from an assessment report covering the 1982 survey flown in the Florence Lake area, Labrador (BP Minerals Ltd. and Billiton Canada Ltd., 1983) was selected to compare the two data-capture methods. In particular, the contoured, total-field aeromagnetic map for the northern part of the Florence Lake survey was selected because the lines comprising this computer-generated map are relatively uniform in weight and density, the map area is of manageable size for scanning, and a mylar copy (not as prone to paper shrinkage or distortion) was available.

Since the data on the map consists of contours and flight-line paths with fiducial points, it is impossible to completely recover the original raw survey data. On maps such as these, the intersections of flight lines with contours are the points where the original data are considered to be best represented (Kilfoil, 1990) because only along flight lines are data collected that will constrain the position of contours. Therefore, the aim in capturing the data digitally is to obtain a sequence of X and Y coordinates with associated data values at contour intersections along the flight lines.

The map was converted to a raster image by a large format scanner with 400 dots/inch resolution. The raster image was then vectorized into line segments, in AutoCAD format, by GTX conversion hardware/software. The raster image, stored in a binary (PCX) format, requires approximately 5 megabytes of disk storage space; the converted file of vector line segments for the map, stored (as

ASCII) in the AutoCAD Data eXchange Format (DXF), occupies 7.7 megabytes of disk storage space. The X and Y coordinates of points comprising vector line segments are in thousandths of an inch at the map scale. The vector line segments in the AutoCAD DXF file were plotted on a pen plotter (see Figure 2). The darker areas on Figure 2 indicate locations where adjacent lines, which are close together and/or thick on the original map, have merged on output to a single line or a filled area. These effects are caused by a combination of the finite scanner resolution and locally degraded quality on the original map. As well, contour lines are incomplete or discontinuous in areas (on Figure 2) where the original map lines are faint. This results from the inability of the digital scanner to adjust to non-uniform line quality on the original.

Each contour line segment in the vectorized data-file includes positional information along its total length, whereas only along flight lines is this information constrained by original survey data. Scanned contour line segments do not have an associated attribute to reflect the magnetic field strength values that they represent. The vector file also contains a substantial proportion of extraneous information (map borders, titles, north arrow on Figure 2) that, in this vector format, are not essential to the geophysical content of the map. Thus, in order to obtain a datafile that approximates the original geophysical data, the scanned digital data must undergo extensive editing, followed by a conversion of map coordinates to a geographic coordinate system. Due to the large size of the vector datafile that results from scanning this map, such editing has not yet been attempted, as the present editing software limitations would significantly slow extraction of relevant information.

The intersections of all contours with flight lines were also digitized manually from the same aeromagnetic map that was scanned. The digital data were subsequently edited, gridded and processed to remove any inter-profile levelling errors. The data were then contoured (Figure 3) for comparison with the map from which the data were digitized.

A major advantage of digitizing over scanning is that the operator is selective and systematic about data entry. Datafiles generated from digitizing are of significantly smaller size (two orders of magnitude) than the equivalent scanned images and, if points are digitized in sequence along each flight line, are more logically organized for subsequent data processing. The digitized aeromagnetic data for the northern part of the Florence Lake survey required only 70 kilobytes (in ASCII) of disk-storage space. The quality of datafiles that result from digitizing is not nearly as dependent on original map quality as that which results from optical scanning.

Among the obvious disadvantages of digitizing data from a contoured map are the slow progress and tediousness that are inherent in the task. For instance, the digitizing of the data from which Figure 3 was produced required three days to complete, and to digitize all the geophysical data from this one assessment report would take one person about one month to complete. However, the size of scanned images (and resulting vector files) are too large to be effectively edited at present, and, if efficient software were available for this purpose, the time and resource requirements could very well exceed those for digitizing.

Digitized and/or manually input data is also prone to non-systematic human error, whereas optically scanned data tend to contain only errors of a systematic nature (i.e., errors uniformly distributed throughout the output images). A common example of a non-systematic human error would be incorrect assignment of the data value to a flight-line/contour intersection by the user. This type of error can often be detected and rectified during subsequent digital processing of the data. These errors are not confined to digitized files either, as vector files that result from optical scanning are also subject to human errors if such output requires subsequent interactive editing by an operator.

ASSESSING DATA QUALITY

Having input the aeromagnetic data from a contour map in the form of data profiles, it can be easily checked for errors through an iterative process of alternately gridding and checking data values within profiles. By interactively generating a series of colour, shaded-relief images of the gridded datafile on a PC using the in-house DISPLAY program (Kilfoil and Nolan, *this volume*), even very small errors in the data will become evident as subtle discontinuities. The locations of discontinuities in the gridded data can be checked on the original contour map for the existence of an erroneous value. A graphical profile editing program allows a specific profile to be rapidly located, an erroneous data point to be pin-pointed along the profile, and the data value to be corrected interactively.

After correcting any detected errors in the input data, the quality of the survey needs to be assessed. The most obvious method for assessing data quality is comparison with any existing related dataset for which the data quality is known. A coincidence of anomalies or features in two similar datasets from different surveys helps to establish a confidence level in the data from each survey.

In the case of airborne magnetic data, regional coverage for the entire province has been flown by the Geological Survey of Canada at a nominal flight altitude of 300 m and line spacing of 800 m. In addition, magnetic data were recorded along profiles during surveys of the gamma-ray spectrometric program carried out by the GSC during the 1980's. Currently these surveys, flown at 120-m ground clearance and 1-km flight-line spacing, extend over approximately two-thirds of the Island of Newfoundland.

The data for the area covered by the northern part of the Florence Lake survey was extracted from the levelled, corrected and gridded data from the GSC surveys (Kilfoil, 1991). Since the grid-cell spacing of the extracted data was 200 m, the data was regridded to 50 m to match the grid interval for the BP-Billiton survey. The result was contoured

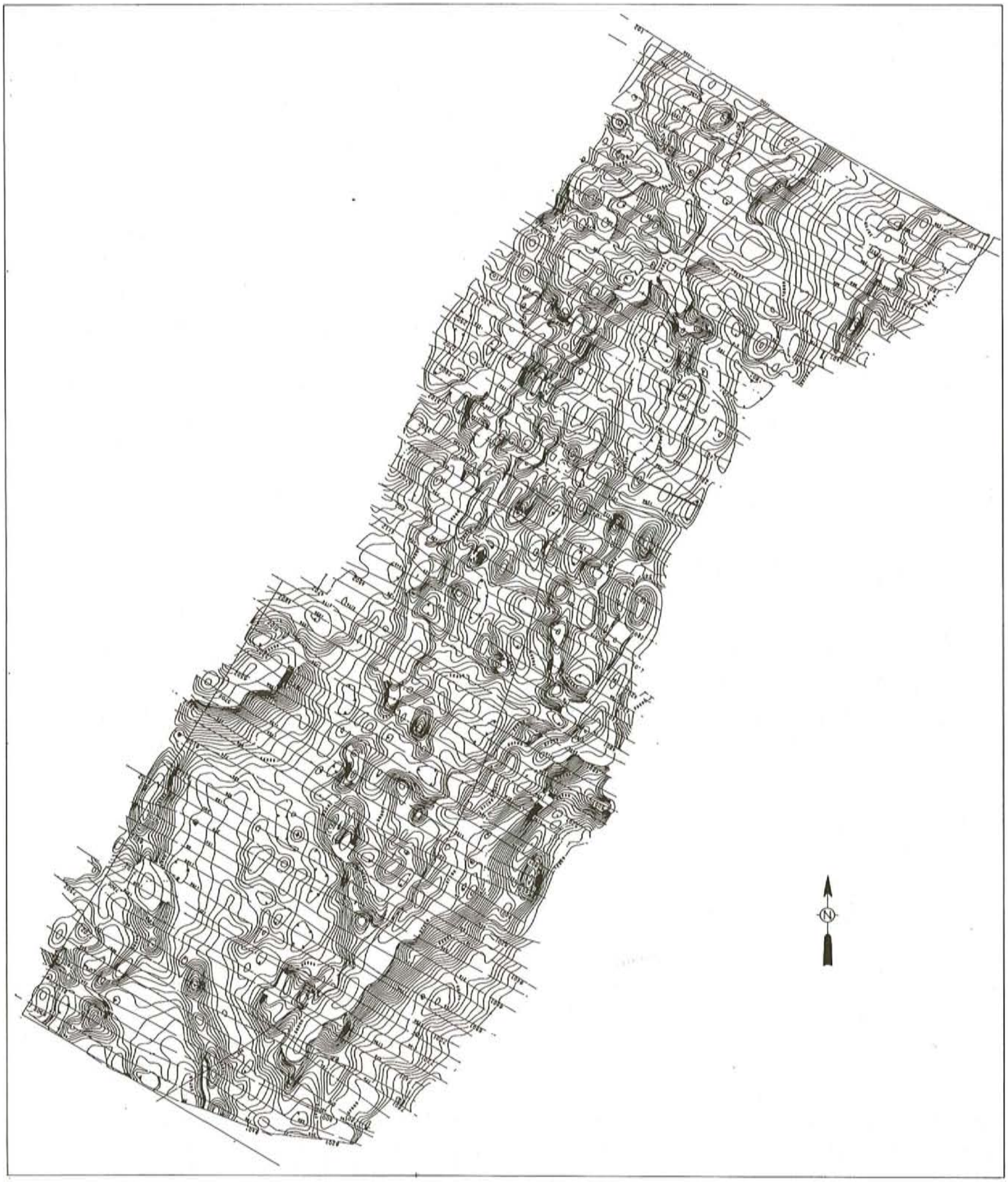

Figure 2. *Plot of an optically scanned, total field aeromagnetic contour map for the Florence Lake (North) area, from a mineral-assessment report submitted by BP-Billiton (1983). The consistently spaced lines on this plot, which strike to the southeast, are the flight-line paths. Certain flight lines and contours appear discontinuous where these lines were faint on the original map. Note also that where lines are closer than the scanning resolution, the subsequent vectorization yields a single thick line or filled area.*

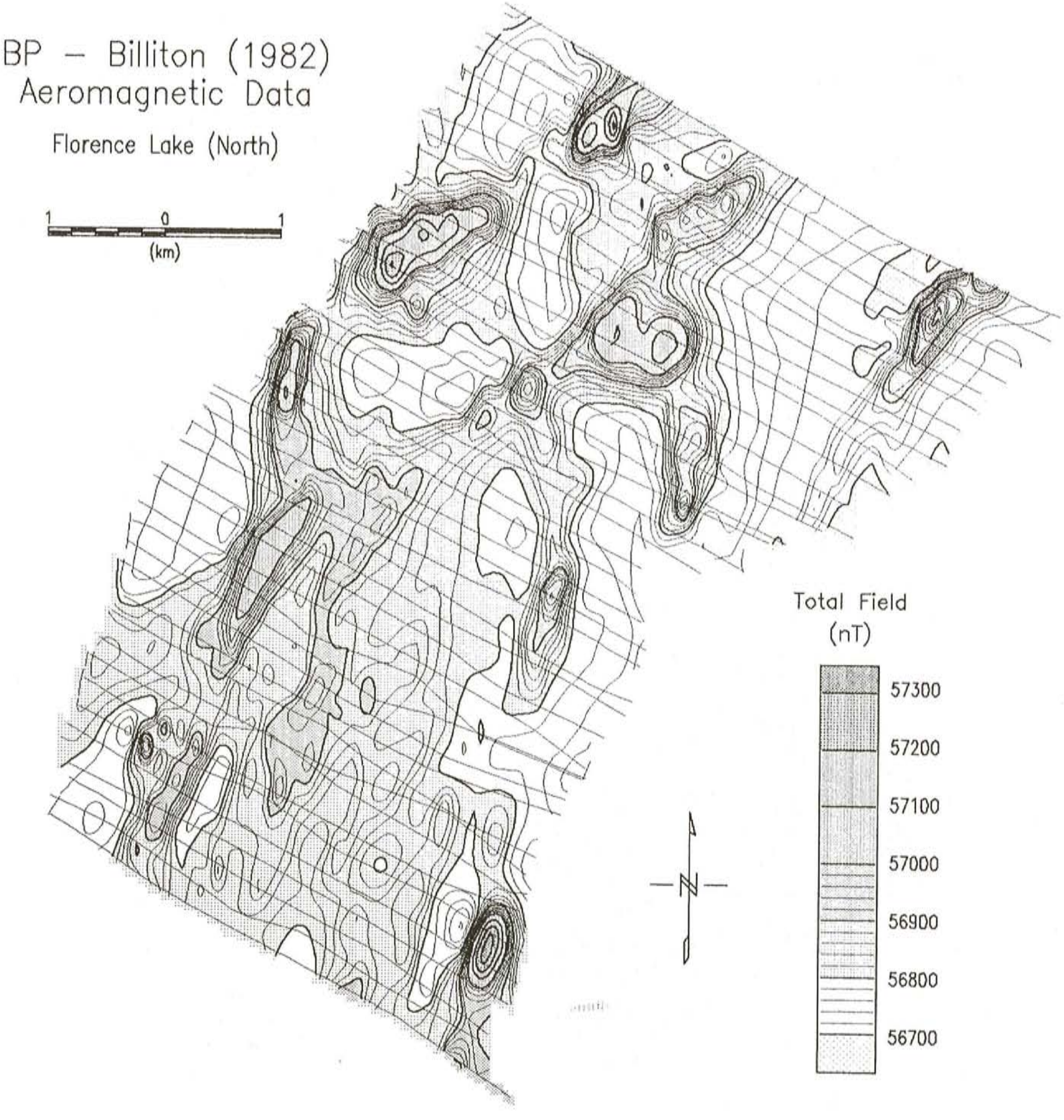

Figure 3. *Shaded, aeromagnetic contour map for the Florence Lake (North) area, produced from the digitized location of intersections of contours with flight lines on maps submitted by BP-Billiton in 1983. The area covered is the northeast half of that shown in Figure 2. Total-field values have not been referenced to the International Geomagnetic Reference Field (IGRF), and are variably shaded to indicate anomalous magnetic field intensity. The nominal survey altitude is 30 m and flight-line spacing averages 200 m.*

and is presented here as Figure 4. A quick comparison with Figure 3 reveals a strong correlation of long-wavelength (broad) anomalies, which lends credence to both datasets and indicates that the two surveys are properly geo-referenced. However, the comparatively smooth contours on Figure 4 indicate that the data from the BP-Billiton assessment report, despite being reconstructed by digitizing a contour map, contains significantly more detail. Anomalous zones and

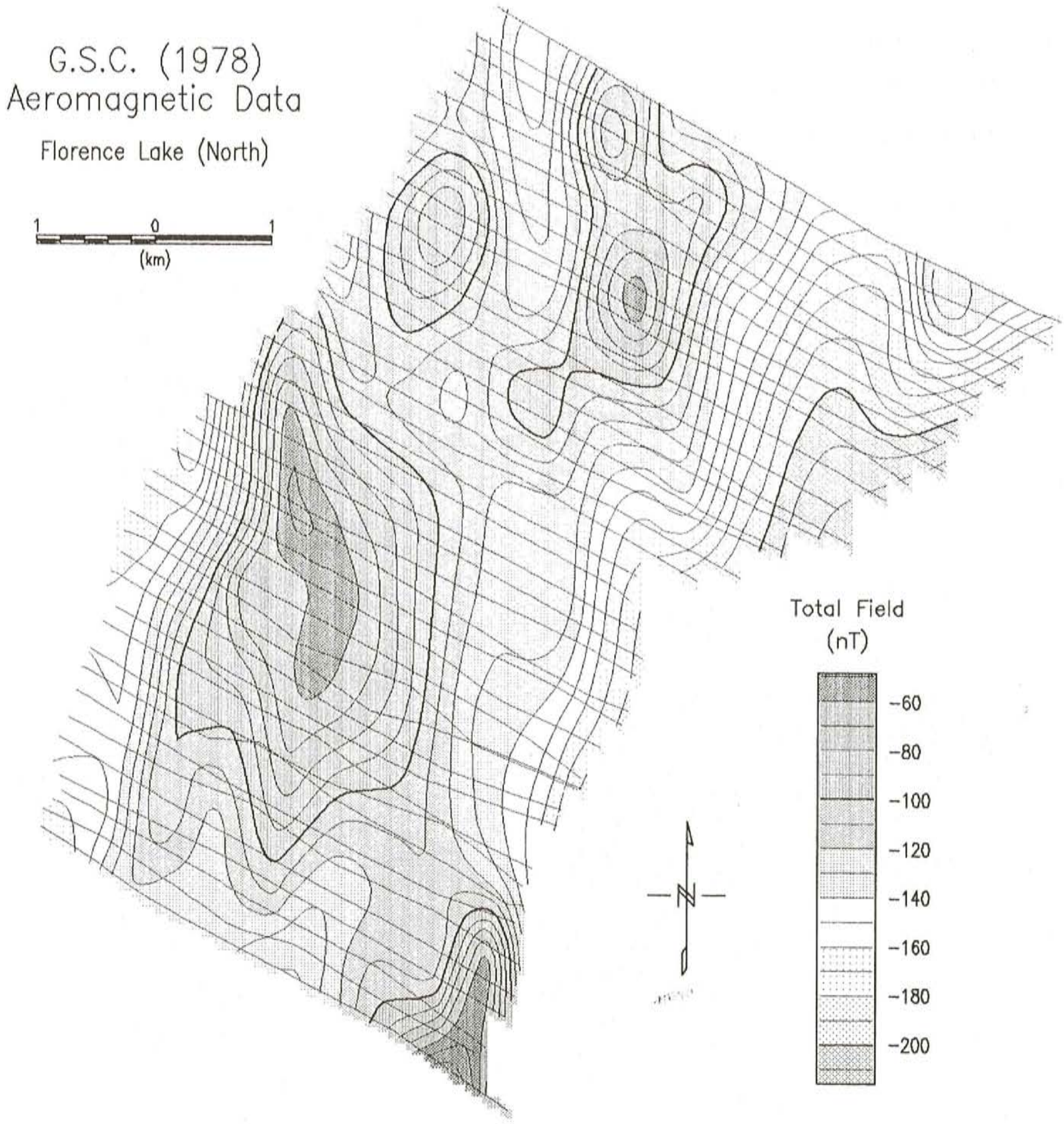

Figure 4. *Shaded, aeromagnetic contour map for the same area as in Figure 3, produced from the existing regional dataset flown by the Geological Survey of Canada during 1978. Note in the legend that total-field magnetic data have been referenced to the IGRF and are variably shaded, similarly to Figure 3, to indicate areas of anomalous magnetic field intensity. The survey was flown at an altitude of 300 m and average flight-line spacing of 800 m.*

linear features are much better defined on Figure 3, and, in certain areas, broad anomalies on Figure 4 are clearly defined as two distinct anomalies on Figure 3. A similar comparison of colour, shaded-relief images from the two datasets shows this contrast in detail more clearly. The superior resolution of features in the industry survey can be largely attributed to the lower survey altitude and more closely spaced flight lines. The east-southeast orientation of flight lines in the industry survey (in contrast to east-west oriented flight lines in the regional survey), perpendicular to the strike of ultramafic units in the Florence Lake area, is also a minor contributing factor to the difference in resolution of features in the two surveys.

Through digital processing and presentation, the example from the Florence Lake area has clearly shown the advantages of digitally capturing geophysical data from industry surveys, presently existing as maps in mineral-assessment reports. The geophysical data component of existing assessment reports for the province represents a huge volume of information. If the bulk of this information could be obtained from the sponsoring companies as raw digital data (as magnetic tapes or other storage media), the savings in resource requirements would be substantial. As well, much of the original information recorded during the survey is simply not recoverable from maps submitted with assessment reports. For example, subtle information, which may have been recorded at locations between contours on a contour map, cannot be retrieved. As well, certain anomaly maps and interpretation maps only provide the locations of the most anomalous data values or those that the contractor or interpreter considered to be significant. Requests for copies of any digital data have been sent to the mineral-exploration companies, which sponsored all airborne geophysical surveys in Labrador.

Digital airborne geophysical data from 52 survey blocks were submitted on magnetic tapes by Labrador Mining and Exploration Company Limited (1980, 1982). To evaluate the advantages of having original digital survey data, profiles of total field magnetic data for an area approximately 75 km southeast of Schefferville (Block 135 South) were extracted from this dataset. The data were then gridded to a 40-m grid-cell size, approximately one fifth the nominal flight line spacing of 200 m. Images generated from the gridded datafile showed the existence of inter-flight-line levelling errors and data 'spikes' or erroneous values distributed randomly throughout the data. The data spikes were removed by applying a non-linear filter to the profile data and levelling errors were diminished by adding constants to the magnetic values along certain profiles and by directional filtering applied to the gridded datafile. A shaded, contour plot of the corrected data is shown in Figure 5. The series of accentuated magnetic linear features that strike to the north in the centre of this map and swing off to a north-northwest direction near the top of the map correspond to the locations of iron formation.

As in the Florence Lake example, a corresponding window of gridded data values was extracted from the (200-m grid cell) GSC gridded data for comparison and evaluation. Figure 6 is a shaded contour plot from the GSC data for the area covered by Figure 5. Although all of the larger anomalies that exist on Figure 5 are present on Figure 6, these anomalies are broader and less defined. In the western half of the map area, the region underlain by iron formation, two distinct linear anomalies, evident on Figure 5, are represented as a single broad anomaly in Figure 6. Thus, although the regional trends and larger magnetic features are apparent in the GSC data, the detailed (digital) survey data contains sufficient information to distinguish anomalous zones to much finer resolution.

When compared to the Florence Lake area, the availability of raw digital data for Block 135 (South) significantly reduced the time required to prepare, process and output a corrected, gridded dataset. The entire process, from retrieving the raw ASCII data on magnetic tape to the levelled and filtered grid file, required approximately one day for an operator using a PC. In addition, having established a processing sequence for the first of the 52 areas for which digital data is available, the process could be automated to reduce operator intervention and the total processing time reduced to half. Whereas the optimum method (digitizing data plots, at present) of data input requires time on the order of weeks to months per map area, the time required to process data already held in digital for an equivalent area is on the order of hours to days. Thus, not only are there distinct advantages, in terms of data detail and accuracy, of obtaining the original data in digital from source, but significant savings in resource requirements can be realized.

RESULTS AND CONSIDERATIONS FOR THE FUTURE

The digital index of airborne geophysical surveys for Labrador will be expanded to include coverage of the larger geophysical (and possibly geochemical) surveys conducted on the ground. Upon completion of the Labrador digital index, a similar index will be constructed for insular Newfoundland. Since coordinates for survey outlines in the Labrador index will be in UTM zone 20 and those for insular Newfoundland will be referenced to UTM zone 21, the present plans are to maintain a separate index for the two parts of the province.

As computer technology evolves (increasing data storage, internal memory and scanner resolving capacities; advances in processing software), the capability to effectively edit large vector datasets, such as the scanned aeromagnetic contour map for Florence Lake, may soon become realistic on a PC. If the software can be adapted to automatically extract flight-line/contour intersections from such vector files, then digital scanning may prove to be a more cost-effective alternative to manually digitizing the data. An advantage of the digital scanning method is that a raster image file is generated as an intermediate product. This file can be archived for future editing and viewing within image analysis systems. At present, however, such advantages as the selective entry of data and drastically reduced database sizes afforded by digitizing far outweigh the less restrictive disadvantages, thereby making digitizing the better data input alternative.

A comparison of aeromagnetic data from a variety of sources has revealed that the more detailed data from surveys conducted by industry for mineral assessment have the potential for better definition of geological features than the

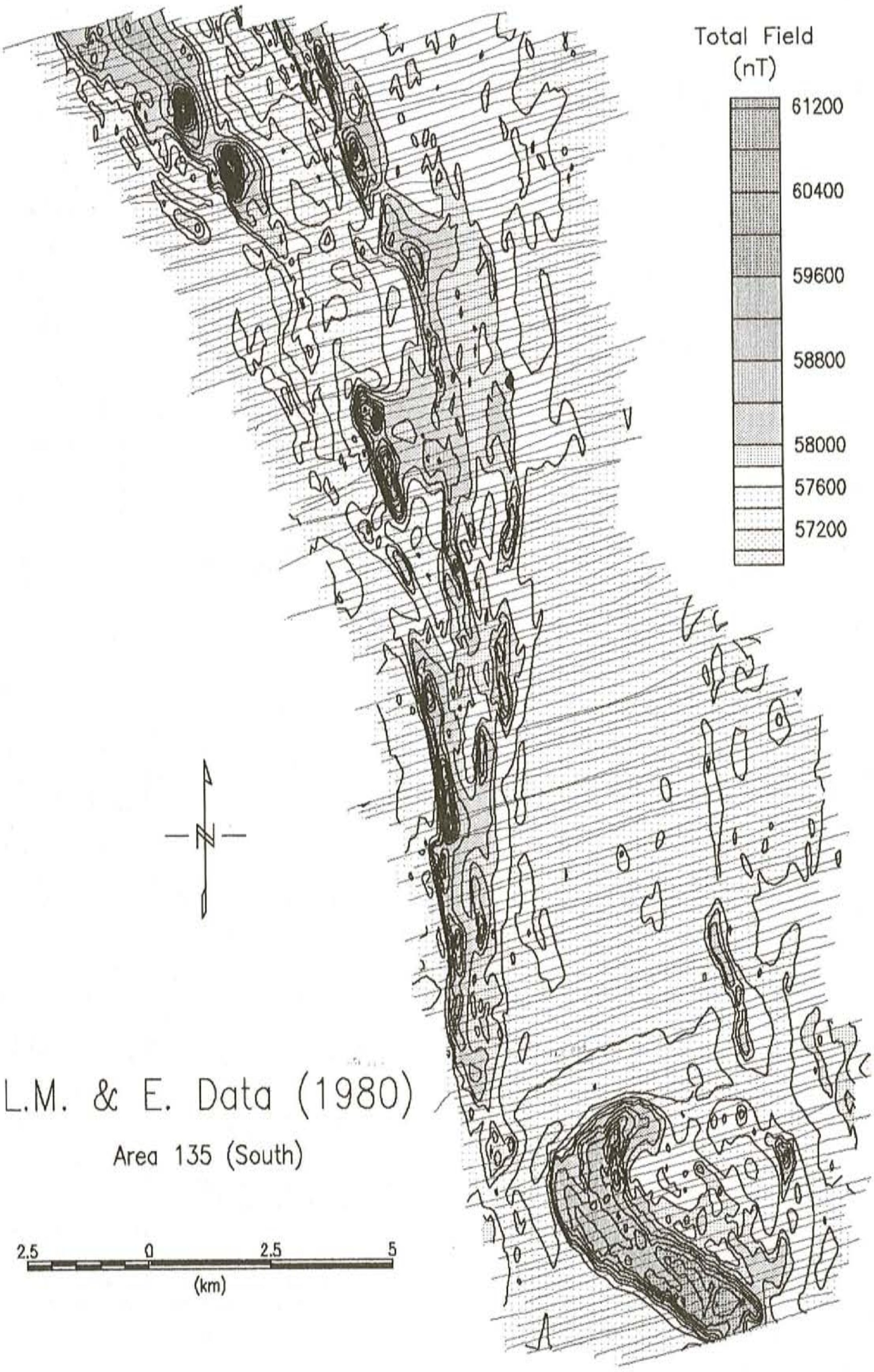

Figure 5. *Shaded, aeromagnetic contour map for Block 135 (South), produced from digital data from surveys flown by Labrador Mining and Exploration Limited during 1980. Total-field values have not been referenced to the IGRF, and are variably shaded to indicate anomalous magnetic field intensity. The diagonal lines striking east-northeast through the area are the survey flight paths. The survey was flown at an altitude of 46 m and average flight-line spacing of 200 m.*

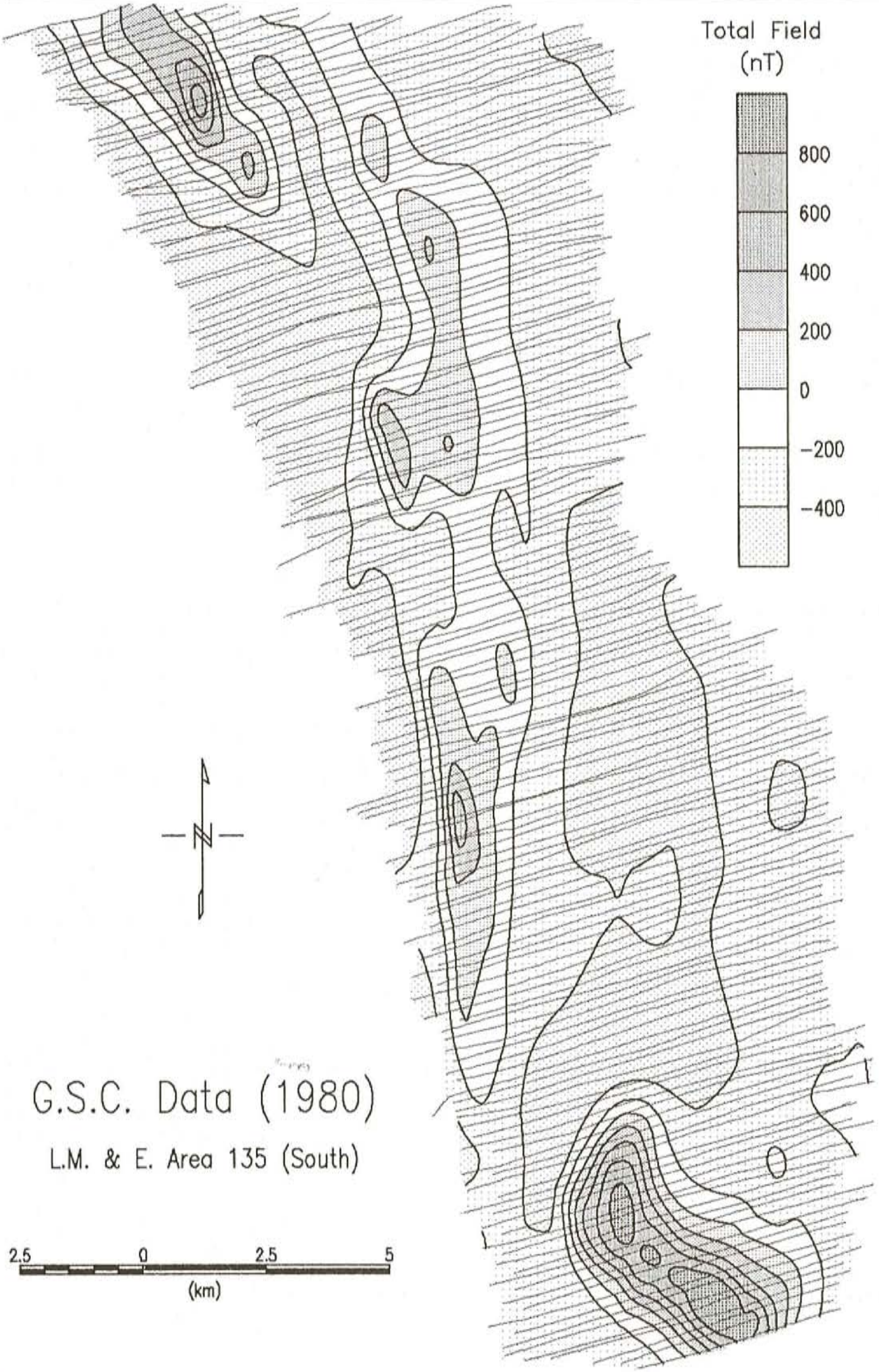

Figure 6. *Shaded, aeromagnetic contour map for the same area as in Figure 5, extracted from a regional aeromagnetic dataset flown during 1980 by the Geological Survey of Canada. Note on the legend that total-field magnetic data have been referenced to the IGRF. Variable shading to accentuate anomalous magnetic field intensity is comparable to that for Figure 5 and the flight paths from the Labrador Mining and Exploration Limited survey have been included for purposes of cross-referencing. The survey was flown at an altitude of 300 m and average flight-line spacing of 800 m.*

more regional data from surveys conducted by the Geological Survey of Canada. Nonetheless, the complete coverage of regional airborne data provides an excellent framework by which to assess the quality of the more detailed surveys.

Efforts underway to obtain, from source, original digital geophysical data will be further pursued. However, much of the existing data will likely not be available in digital form. Data from older surveys, in particular, would have only been recorded by analog methods and would have to be digitized (or optically scanned) from the analog survey records (if they exist). Due to the volume of existing information in assessment reports, the digital capture of relevant data will be prioritized. Priority will have to be assigned by weighting such factors as existing presentation quality, mineral potential of the area, and active exploration interest.

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