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ENHANCEMENT AND INTERPRETATION OF REGIONAL GEOPHYSICAL DATASETS IN CENTRAL NEWFOUNDLAND

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ABSTRACT

High resolution aeromagnetic data for an area south of Buchans in the Central Volcanic Belt was digitally filtered and displayed on an image analysis system. Several lithological units are readily identified by their magnetic signature on images of the data, shaded using a false sun inclined 45° from the northeast.

Structural lineations trending north-northeast locally interrupt the northeast regional trend of magnetic units, and are interpreted to be an expression of flexure at the latter stages of sinistral strike-slip movement along the major northeast-oriented regional faults. A series of northwest-oriented late mega-fractures', apparently transecting all earlier structures, are traced across the entire breadth of the Central Volcanic Belt. These mega-fractures exhibit only minor offsets on steeply dipping, northeast-oriented magnetic units identified in the data, and thus are interpreted as expressing vertical movement on structural units that cannot be easily identified by surface mapping. These late meta-fractures are most probably an expression of isostatic readjustment or tension.

The structural features described herein are compared and related to known occurrences of massive sulphide and precious-metal mineralization in the Central Volcanic Belt.

INTRODUCTION

During 1987 and 1988, a project was undertaken to manipulate and display available high resolution airborne magnetic, vertical gradiometric and VLF-EM datasets collected throughout the belt of volcanic and sedimentary rocks of the Victoria Lake Group near Buchans (areas 1 to 4 on Figure 1) by the Geological Survey of Canada. The results of the survey in the Notre Dame Bay area (area 5 on Figure 1), have only recently been released (Tod and Ready, *this volume*). Digital data from the 1985 survey, areas 1 to 3, were selected as the focus of this investigation for reasons of recent or concurrent mapping, the variety of geological units represented and its mineral potential. A series of total-field magnetic and gradiometric colour maps of the data from this GSC survey have been published at 1:50,000 scale (Geological Survey of Canada, 1985a,b,c,d,e). The purpose of this study is to digitally filter and combine these geophysical datasets in such a manner as to gain additional information that would reflect the underlying geology and structure, not readily apparent on the surface.

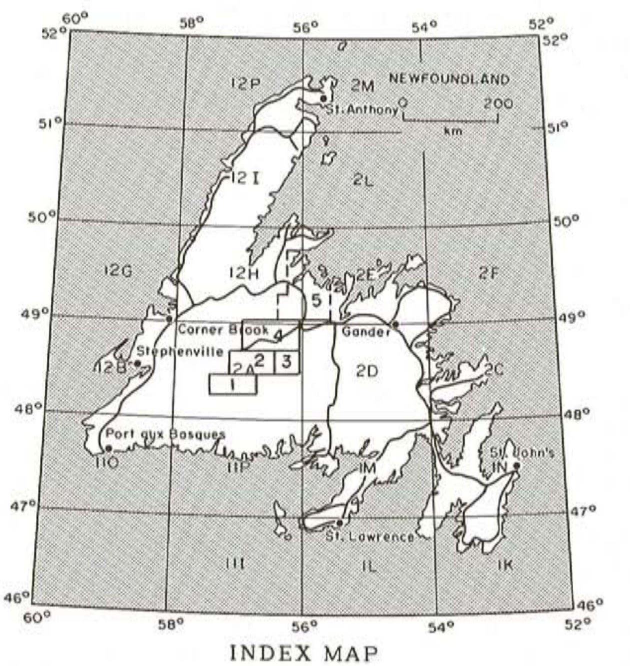


Figure 1. *Location map in central Newfoundland of Geological Survey of Canada high-resolution airborne total-field magnetic and gradiometer surveys carried out under the Canada–Newfoundland Mineral Development Agreement, 1984-89. Areas 1-3: Lower Victoria Lake Group–Noel Paul's Line; area 4: Buchans–Badger; area 5: Notre Dame Bay.*

METHODOLOGY

Total-field aeromagnetic and vertical magnetic gradiometer datasets were pre-processed using the Newfoundland Department of Mines' mini-computer system, transferred to digital tape and loaded onto the Dipix Aries III image analysis system at NORDCO Limited for display and hardcopy output. Digital processing consisted of IGRF

This project is a contribution to the Canada–Newfoundland Mineral Development Agreement, 1984–1989

removal from the total-field data, variable false sun-angle shaded relief, and calculated first and second vertical derivatives. The digitally filtered total-field data images included as Figures 2a and 3a are mosaics of photographed images. Although a series of colour images were produced, only the grey-tone versions are included in this publication.

Directional filters of varying angles of false sun illumination were applied to the total-field magnetic (IGRF removed) and vertical gradient datasets to optimally enhance their subtle features (Teskey and Broome, 1984), as well as features that have a large relative magnetic relief. As a result, some information regarding the total-field strength of the local magnetic field is sacrificed in the filtering process. The various calculated gradient maps (first and second derivatives), and the gradiometric data themselves, were shown to be valuable interpretive tools in tracing the boundaries of local bedrock lithologies, particularly in areas of overburden. A series of shaded-relief aeromagnetic maps have proven to be of most value as an interpretational aid to the geologist or geophysicist.

First-order interpretation of characteristic magnetic signatures, such as those expressed by volcanogenic sediments, nearly homogeneous plutonic rocks and large-scale flexures, correspond to those identified on the surface. In addition, several small-scale and subtler features are enhanced by specific illumination directions. Among these are foliation orientations within plutonic bodies and a series of large-scale, late-stage, northwest-oriented fractures not readily detected on the surface. The latter features are of particular interest because of their relationships to gold and massive sulphide mineralization within the Victoria Lake Group rocks.

RESULTS

Areas 1 and 2

The grey-tone photo-mosaic of Figure 2a shows the image, which results from directional filtering applied to aeromagnetic data for areas 1 and 2 (Figure 1), using a false sun inclination of 45° and declination of 45°. Figure 2b shows the boundaries of major geological units (dotted line) compiled from quoted sources, and the geophysically identified geological unit boundaries and structural lineations (solid and dashed lines, respectively) identified in this study. In addition to 'real' magnetic features enhanced on the image of Figure 2a, the presence of any local data-levelling errors resulting from corrections applied between adjacent east–west flight lines are exaggerated by shading from this oblique angle. Leveling errors, or flight-line noise, gives the image a corrugated appearance that is most pronounced in Figure 2a, along latitude 48°30'N. The regular 'bubbly' appearance of several of the northeast-trending magnetic features throughout the image is an artifact of their oblique trends relative to the east-west direction of both flight lines and the orientation of gridding.

The variations in trend of magnetic units from northeast to north-northeast are obvious in Figure 2a, as traced by the solid and dashed lines in Figure 2b. Magnetic anomalies associated with units in the region commonly have an asymmetrical, elongated lobate shape resembling a magnetic hysteresis loop. This diamond shape is an expression, on a local scale, of the regional flexure resulting from changing stresses during deformation in a sinistral strike-slip regime (Kean and Evans, 1988).

In the upper central part of Figure 2a, the belt of magnetic units trending to the northeast are the Victoria Lake Group mafic to felsic volcanic and sedimentary rocks ('A' in Figure 2a) of the Central Mobile Belt. Linears defined by variations in trends of these units are illustrated by dashed lines on Figure 2b. The Victoria Lake Group units pinch out in a major flexure located near the southwest corner of this image (just north of 'C', Figure 2a).

The large, foliated granite (informally named the Snowshoe Pond granite), located at 'B' in the south-central region of Figure 2a, shows a distinct non-magnetic character and is evident here as a lobate area of low relief. A large linear magnetic anomaly forms the southwestern boundary of this lobate pluton and separates it from the Buck Lake granite pluton of the North Bay Granite ('C' in Figure 2a). Aside from the flight line interference present in the southwestern portion of Figure 2a, the Buck Lake granite shows a mottled appearance on the shaded relief image relative to that of the Snowshoe Pond granite, indicating its greater variability in magnetic content. The nature of this seemingly sharp contact between the two plutons is unknown, as this area is characterized by swamp or bog and no significant lithological difference has been reported (Kean, 1977a). As a result, the two plutons have not been previously distinguished as distinct map units (Kean, 1977a, 1982). A gabbro unit is mapped just north of the Buck Lake granite (Kean, 1982) ('D' in Figure 2a) where the northwest oriented magnetic division between the two plutons obliquely intersects the Victoria Lake Group sediments to the northwest. The continuity in magnetic expression of the boundary between the two plutons southeastward from the gabbro suggests that the gabbroic or mafic dyke rocks may be found along the contact between the two plutons. Alternatively, the anomaly may arise from migmatized Spruce Brook Formation sediments located to the southeast (Colman-Sadd, 1988). A magnetic 'striping' can be observed within the Buck Lake granite boundary of Figure 2a, and running parallel to its contact with the Snowshoe Pond granite. This may indicate that the Buck Lake granite and bordering country rocks have been variably altered along this contact during its emplacement.

The southeastern area on Figure 2a (at 'E') is underlain by granites and metasediments of the Meelpaeg Subzone of the Gander Zone (Williams, *et al.*, 1988; Colman-Sadd, 1988). The high-grade, quartz-rich metasediments equated to the Spruce Brook Formation (Colman-Sadd, 1988) show a variable magnetic pattern and a northeast oriented layering that is less pronounced than that of the Victoria Lake Group. The magnetic expression of the metasediments is further complicated by the presence of at least two varieties of Silurian to Devonian intrusive rocks; these are foliated to locally mylonitic or polydeformed, syntectonic granites (Snowshoe Pond granite) and undeformed to slightly foliated, probable posttectonic units (Kean, 1982; Colman-Sadd, 1988).

The Valentine Lake quartz monzonite, located north of the Snowshoe Pond granite, can be identified on Figure 2a ('F') by the curvilinear magnetic anomaly trends that form its outline. The variable magnetic field strengths within the pluton are due to its phases, which vary from granitic to gabbroic in composition. A wedge of metasediments ascribed to the Meelpaeg Subzone separate the Valentine Lake quartz monzonite from the Snowshoe Pond granite to the south. A lens of Codeross Lake gabbro is identified just to the east ('G' in Figure 2a) by its variable appearance, in sharp contrast to the magnetic signature of the Snowshoe Pond granite that nearly encompasses it.

The Rogerson Lake Conglomerate is characterized on Figure 2a ('H') by a low magnitude, smooth magnetic linearity, the boundaries of which are defined by magnetic anomalies. Though the conglomerate narrows to 200 m along the southeastern border of the Valentine Lake quartz monzonite (Kean, 1982), the belt continues uninterrupted from beyond Noel Paul's Brook map area east of Figure 2a to the shores of Victoria Lake in the southwest. This unit is thought to mark the presence of a major tectonic break (Kean and Evans, 1988). The Rogerson Lake Conglomerate separates members of the Victoria Lake Group to the northwest from similar volcanic-rich units to the southeast, which are considered (Colman-Sadd, 1988) as Victoria Lake Group equivalents.

The mottled magnetic pattern that may be observed in the northwest corner of Figure 2a ('I') arises from variably magnetic gabbros and granites within the Topsails Intrusive Suite, which overthrust the Victoria Lake Group (Kean, 1978, 1979, 1982). The Skidder basalt can be identified in Figure 2a (at 'J') by its characteristic magnetic pattern. The large area of magnetic low relief, that flanks the Topsails Igneous Suite to the southeast ('K' in Figure 2a) corresponds to the location of a small Carboniferous subbasin (Kean, 1979) filled with magnetically transparent sediment, similar in character to that of Carboniferous subbasins found elsewhere in Newfoundland (*cf.* Kilfoil, 1988). A linear wedge of Harbour Round Formation volcaniclastic sediments (Kean, 1977b) is situated at the southeastern margin of the Carboniferous sedimentary subbasin ('L' in Figure 2a). The elevated magnetic total-field values observed for this unit in Figure 2a are due to mafic lava units within the siltstones, cherts and breccias.

The 45° declination angle of illumination delineates a series of large-scale, late-stage, northeast-oriented lineaments (as indicated by arrows on Figure 2a) corresponding to gradiometer anomalies of Kean and Evans (Figure 4, 1988). Locations of known gold and/or massive sulphide occurrences, indicated by dots on Figure 2b, have been included for the purpose of correlation with identified structural lineations. The subtle northwest-oriented features are of interest for possibly providing a conduit system along which hydrothermal alteration and mineralization within rocks of the Victoria Lake Group occurred.

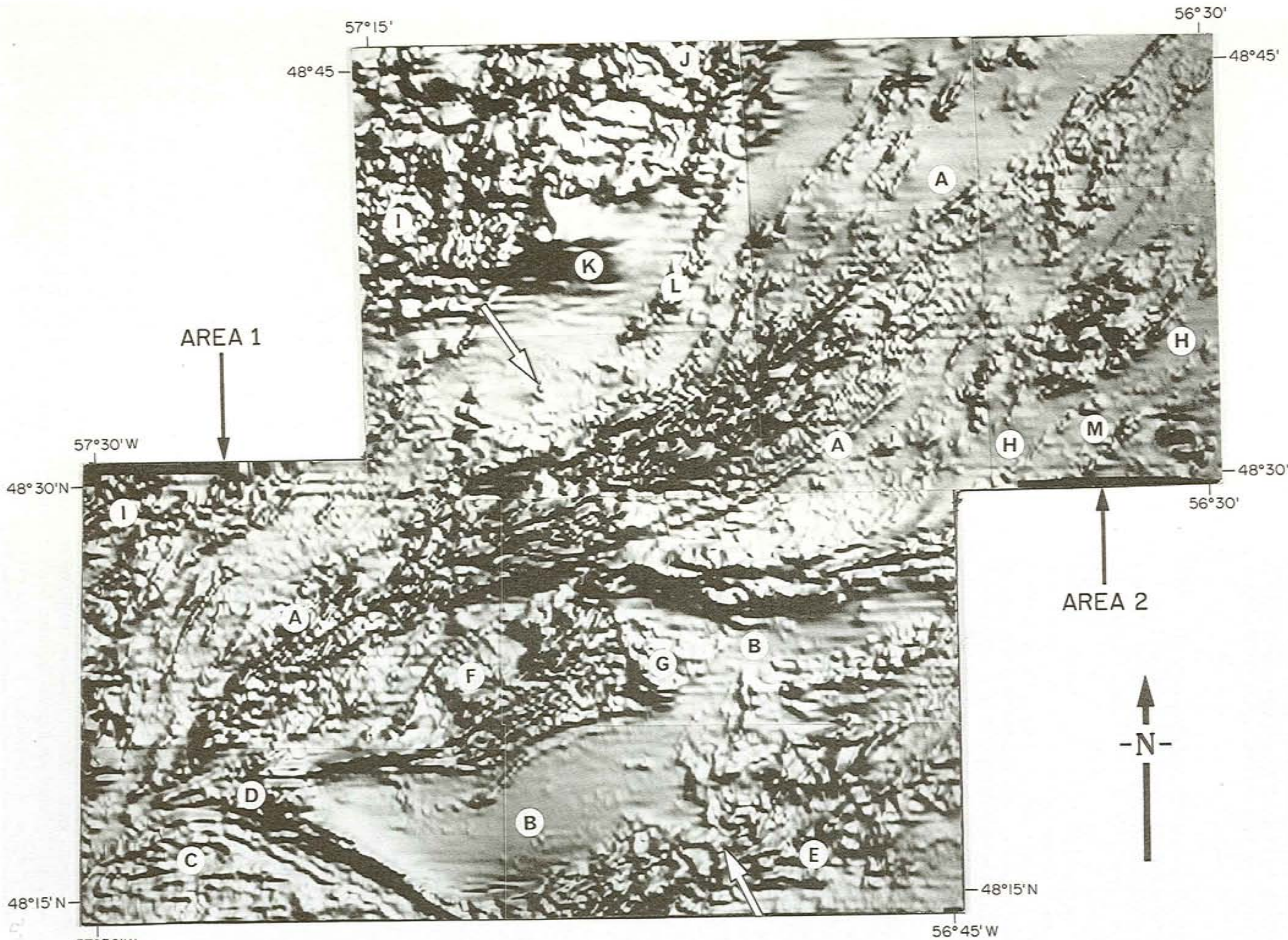
Although not displayed here, the flight line 'noise' that pervades the image is appreciably diminished on images generated by shading from 90° declination as this illumination direction is parallel to that of flight lines. In addition, the subtle expression of a north-northeast oriented foliation within the Snowshoe Pond granite is notably enhanced on the image shaded from the east.

Area 3

Figure 3a contains an image of the gridded aeromagnetic data for Noel Paul's Brook (NTS 12A/9, Area 3 of Figure 1) enhanced by the same false sun direction as that of Figure 2a. Overlap of the weste n border of Figure 3a with the eastern border of Figure 2a allows several features to be matched. Figure 3b shows both the established boundaries of the major geological units (dotted line) within the study area and the geophysically identified geological unit boundaries and structural lineations (solid and dashed lines, respectively) identified in this study.

The most prominent feature on Figure 3a is the smooth, low-relief region underlain by the non-magnetic Overflow Pond Granite (at 'A') (Kean and Jayasinghe, 1980), which occupies a large area in the east-central portion of the map area. This coarse grained, two mica granite exhibits a consistently low magnetic field in which only the minor effects of the flight lines are apparent when digitally enhanced. The geophysically interpreted southern boundary of the granite is situated south of that mapped by Jayasinghe (1978). However, geological mapping in this portion of the map area is based on sparse outcrops. The two circular magnetic anomalies located within the area occupied by granite, just northeast of 'A' on Figure 3a, are likely due to either roof pendants of surrounding magnetite-rich migmatized sediments or mafic plugs having a greater magnetic content than the granite. Each of these anomalies is situated over a circular bog-filled depression identified from aerial photographs, and both were investigated on the ground in 1985 (D. Evans, personal communication, 1989). Although granite forms the only outcrop around the perimeter of these bog-filled depressions, their associated magnetic expression is thought to indicate differential weathering of the more strongly magnetic material.

The linear nature and the sharp magnetic contrast of the Overflow Pond Granite with the country rock along its northern boundary, suggest a steep or near vertical contact and that the thickness of the granite here, is considerable. In contrast, the jagged appearance of the southern boundary suggests that at this contact the pluton dips northward at a shallow angle. The northeastward continuation of linear magnetic units located to the south into the granite (dashed lineations immediately north and northeast of 'J' of Figure 3a) indicates that the granite is relatively thin along this southern boundary.



Figures 2a and b. *Enhanced image results and geological sketch map, respectively for the southern part of the Victoria Lake Group, central Newfoundland (areas 1 and 2, Figure 1).* **Figure 2a:** *Grey-tone shaded relief image mosaic of high-resolution aeromagnetic total-field data. Note the lineament between the arrows. Features labelled (also discussed in text): A–Victoria Lake Group volcanics and sediments; B–gabbro; C–Snowshoe Pond granite; D–Buck Lake granite; E–Spruce Brook Formation metasediments, migmatites and granite of the Meelpaeg Subzone; F–Valentine Lake quartz monzonite; G–Rodeross Lake gabbro; H–Rogerson Lake Conglomerate; I–Topsails Intrusive Suite; J–Skidder basalt; K–Carboniferous subbasin; L–Harbour Round Formation; M–Victoria Lake Group?*

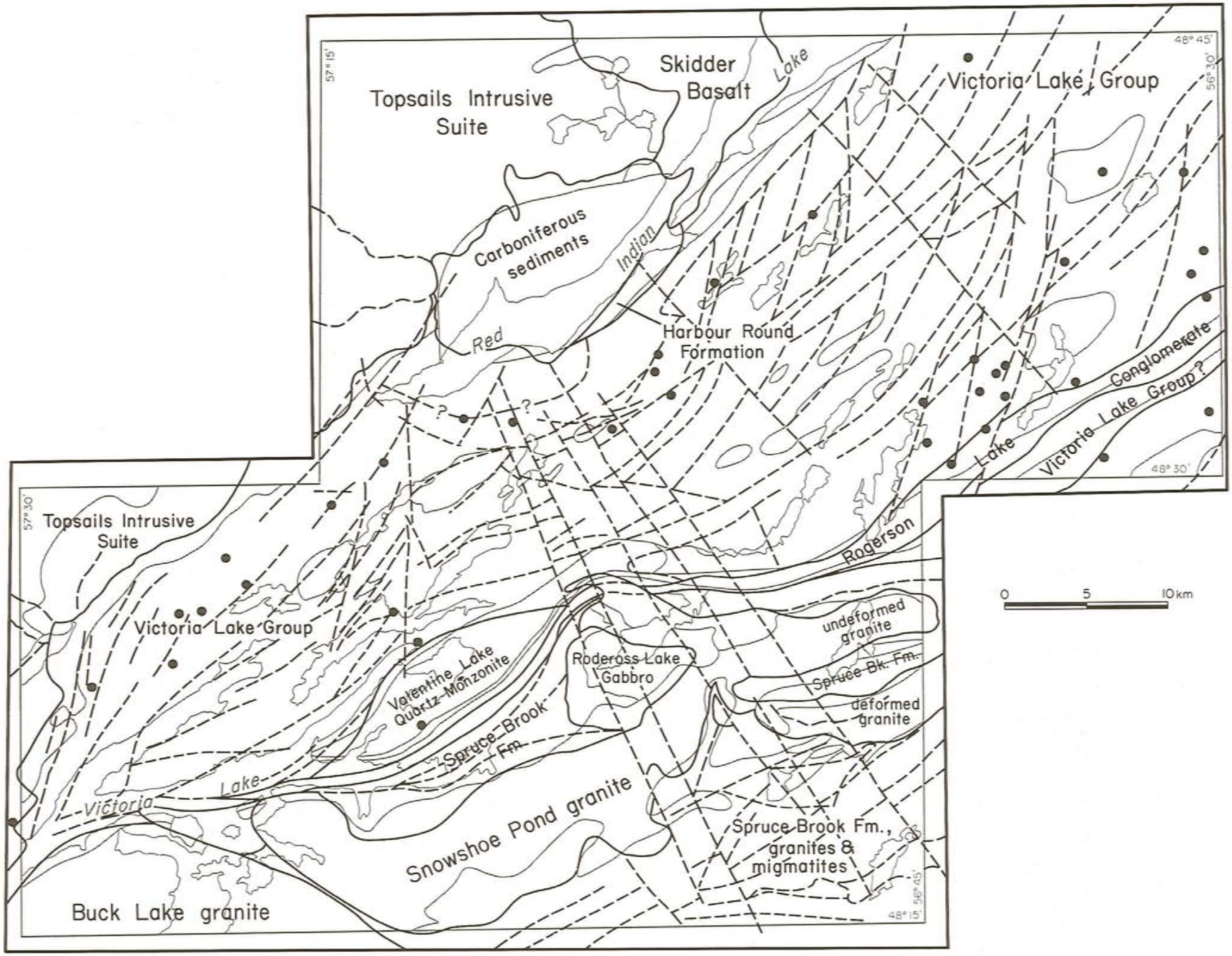
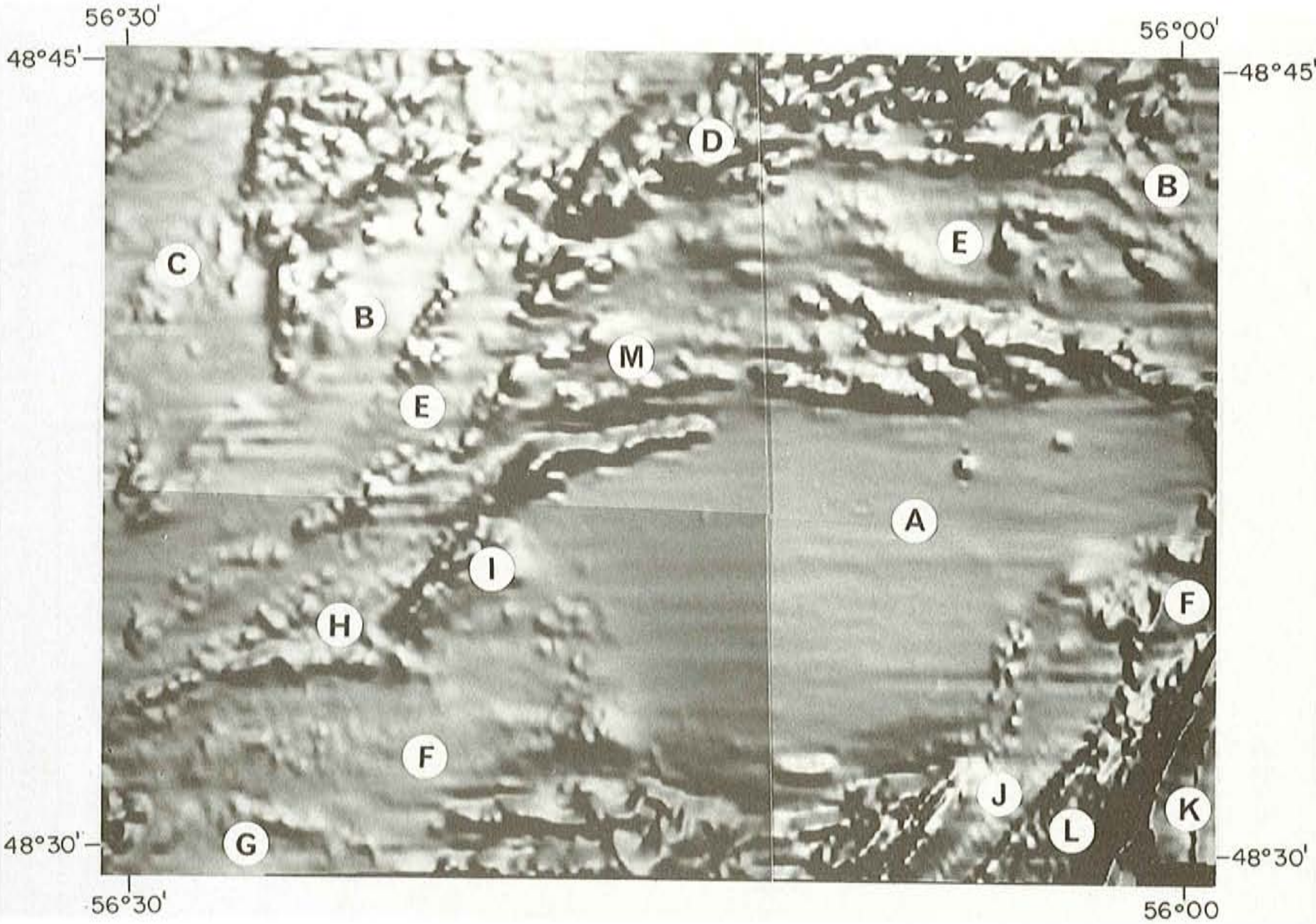


Figure 2b: *Solid and dashed lines are magnetic unit boundaries and lineations, respectively. Lighter lines are outlines of selected geological units (from Kean, 1977a, 1977b, 1978, 1979, 1982; Kean and Jayasinghe, 1980; Colman-Sadd, 1987, 1988). Larger dots mark locations of known gold and massive sulphide mineralization (Kean and Evans, 1988; D. Evans, personal communication, 1989).*



Figures 3a and b: *Enhanced image results and geological sketch map, respectively, for Noel Paul's Brook (12A/9) map area, (area 3 of Figure 1); this area adjoins the upper east boundary of the area covered by Figure 2.* **Figure 3a:** *Grey-tone shaded relief image mosaic of high-resolution aeromagnetic total-field data. Features labelled (also discussed in text): A—Overflow Pond Granite; B—Victoria Lake Group volcanics and sediments; C—gabbro; D—Crippleback Lake Quartz Monzonite; E—Rogerson Lake Conglomerate; F—metasediments of the Meelpaeg Subzone; G—granite; H—Carter Lake Formation volcanics; I—gabbro; J—Great Burnt Lake granite; K—Pipestone Pond complex ultramafic rocks; L—Baie d'Espoir Group volcanogenic sediments; M—Pine Falls Formation volcanics.*

The northwestern portion of Figure 3a (near 'B') shows the trends of the more magnetic rich mafic volcanics within the volcanic and sedimentary package of the Victoria Lake Group. As in Figure 2a, the prominent northeast trends of units in the Victoria Lake Group are locally interrupted by faults trending north-northeast to north, as indicated by dashed lines in Figure 3b. These faults, associated with later deformation stages and flexuring, are most apparent near the northwest corner of the figure, where members of the Victoria Lake Group have the largest magnetic contrast. Two small gabbro bodies underlying areas in the northwest corner of Figure 3b (indicated by dotted lines north of position 'C' on Figure 3a) do not have a discernible magnetic expression. However, based on the magnetic anomaly at position 'C', a large gabbro body is interpreted to underlie this area.

The Crippleback Lake Quartz Monzonite, located at the northern edge of Figure 3a (at 'D'), exhibits a variable magnetic character indicating a strong magnetic zonation, probably reflecting a foliation. The boundaries of the monzonite defined by geophysical expression are mainly coincident with those mapped (Figure 3b). Lenticular mafic and felsic volcanic-rich units of the Victoria Lake Group that border the pluton tend to complicate its magnetic signature.

In this map area, the Rogerson Lake Conglomerate, identified by 'E' in Figure 3a, separates members of the Victoria Lake Group ('B') from volcanic rocks of the Pine Falls Formation ('M') to the southeast (Kean and Jayasinghe, 1980). The geophysically interpreted boundaries of the conglomerate are locally not coincident with those mapped on the ground (Figure 3b), and suggest that the unit is more consistent in width than surficial mapping would indicate.

The southwestern corner of Figure 3a is underlain by metamorphosed sediments (indicated by 'F') included in the

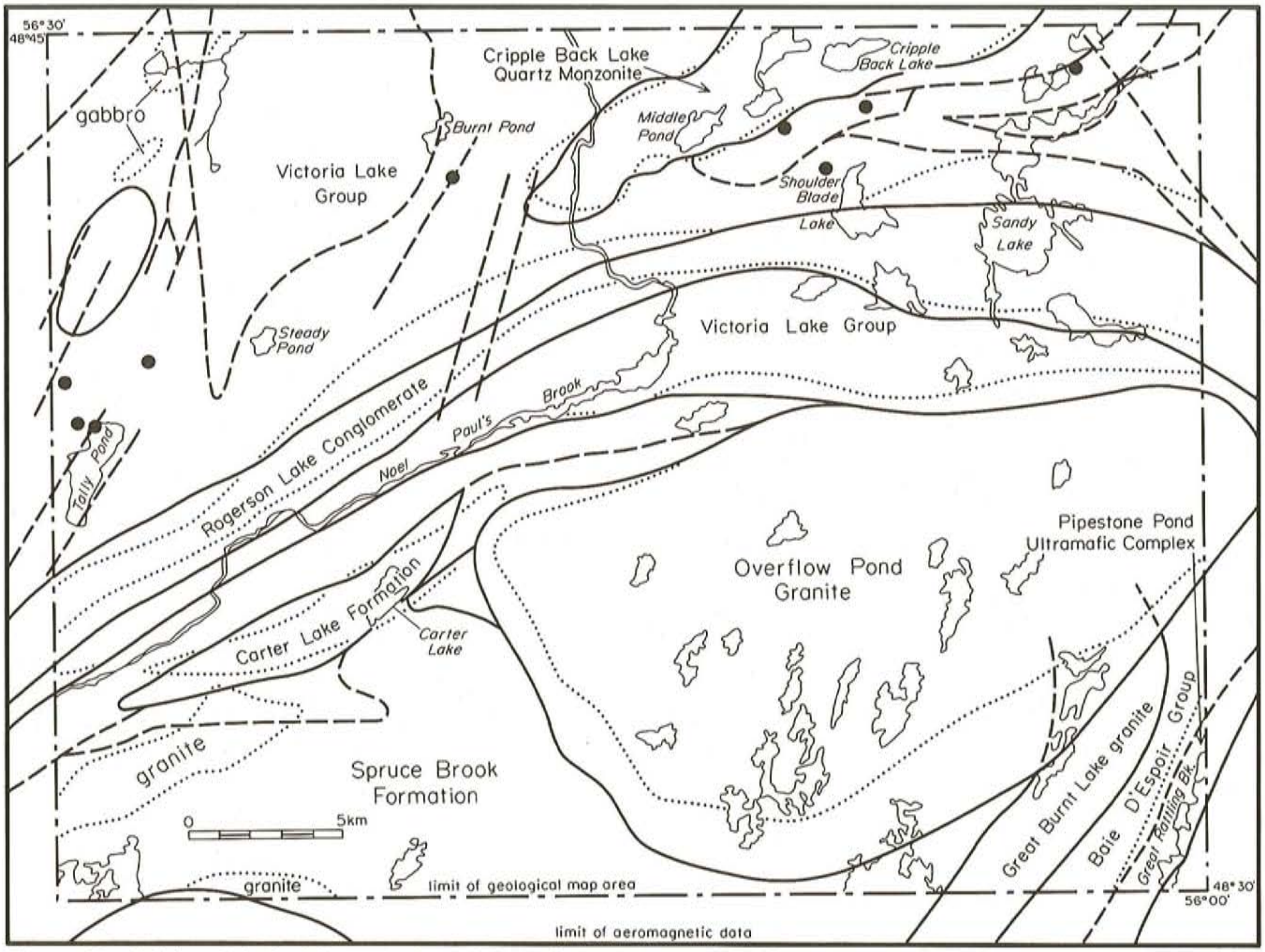


Figure 3b: *Solid and dashed lines are boundaries of magnetic units and lineations, respectively. Dotted lines are outlines of geological units selected from Kean and Jayasinghe (1980); Jayasinghe (1979). Larger dots mark locations of known gold and massive sulphide mineralization (D. Evans, personal communication, 1989).*

Meelpaeg Subzone of Williams *et al.* (1988), who correlate them with probable Spruce Brook Formation equivalents mapped to the south and southwest in the Great Burnt Lake and Snowshoe Pond map areas, respectively (Colman-Sadd, 1985, 1988). The magnetic character varies from a relatively smooth field in the east to a variable field in the west, probably reflecting the increasing presence of mafic dykes to the west, as noted by Colman-Sadd and Swinden (1984a). Although two granite bodies have been mapped within the metasediments (Jayasinghe, 1979), only the southern pluton ('G' in Figure 3a) shows a discernible geophysical signature.

A lens of volcanic rocks ('H' in Figure 3a), the Carter Lake Formation (Kean and Jayasinghe, 1980), occurs adjacent to the metasediments. The geophysically defined boundaries of the unit differ slightly from the mapped boundaries (Figure 3b). A small gabbroic body may be present on the southeast flank of the Carter Lake Formation ('I' in Figure 3a) on the basis of correlation of its magnetic signature with those of gabbroic bodies elsewhere (cf. Snowshoe Pond granite, Figure 2a). A narrow lens of gabbro and pyroxinite also borders the Overflow Pond Granite along its eastern extreme in the Miguels Lake (NTS 2D/12) map area (Colman-Sadd and Russell, 1981, 1982).

The linear feature having a smooth magnetic field, located in the southeastern corner of Figure 3a at 'J', correlates with recently studied foliated, megacrystic, biotite granite outcrop (Colman-Sadd, personal communication, 1989) not identified in earlier studies (e.g., see Kean and Jayasinghe, 1980), which corresponds to a northward extension of the Great Burnt Lake granite, a linear granite body that transects the entire length of the Great Burnt Lake (12A/8) map area to the south (Colman-Sadd and Swinden, 1984a; Colman-Sadd, 1985). The strong northeast foliation to local mylonitization in this granite is not enhanced by this illumination angle. The linear magnetic anomalies that trace out its contacts with the Meelpaeg Subzone metasediments (Spruce Brook Formation?) to the northwest and Baie d'Espoir Group conglomerates and mafic volcanics to the southeast, may be followed into the Overflow Pond Granite by anomalies of decreasing magnitude. This granite is considered to be pretectonic, since, it is locally as strongly foliated as surrounding sedimentary units. In Figure 3b, the northward surrounding sedimentary units. In Figure 3b, the northward continuation of these anomalies into the granite is depicted by curvilinear dashed lines, which hint that the package of Great Burnt Lake granite and metasediments are warped by a fold, the axis of which is situated beneath the younger undeformed Overflow Pond Granite.

The extreme southeast corner of the map area ('K' in Figure 3a) is underlain by ultramafic rocks forming a northward extension of the Pipestone Pond complex units defined to the south in the Great Burnt Lake map area (Swinden, 1988). The serpentinites, pyroxenites and gabbros that comprise the complex define the western boundary of a tectonic klippen, in which rocks of the Gander Zone are exposed through those of the Dunnage Zone (Colman-Sadd and Swinden, 1984b). On the shaded relief image of Figure 3a, these ultramafic rocks contrast with the mafic volcanics and conglomerates of the Baie d'Espoir Group (Colman-Sadd and Swinden, 1984a) and Meelpaeg Subzone metasediments (Colman-Sadd and Russell, 1981, 1982), which are situated to the immediate northwest ('L' in Figure 3a), by their uniform magnetic signature and by an elevated level of magnetic field strength (Geological Survey of Canada, 1985c). The northwest boundary of the ultramafic units is marked by a large negative anomaly in Figure 3a, much as expected to the northwest of rocks of high magnetic susceptibility in the presence of the steeply inclined field of higher magnetic latitudes. A subtler northeast-oriented magnetic anomaly, situated just north of the Pipestone Pond complex, separates Baie d'Espoir Group volcanic-rich units to the southeast from the metasediments on its northwest side.

Known massive sulphide and/or gold occurrences are identified by dots in Figure 3b (D. Evans, personal communication, 1989). The good correlation of mineralization associated with north-northeast oriented linears within the Victoria Lake Group (Kean and Evans, 1988), particularly at Tally Pond and near Burnt Pond, is noteworthy (Figure 3a,b). These linears are interpreted as northwest-directed thrust faults, which displace interleaved mafic and felsic volcanic-rich members of the Victoria Lake Group. Mineralization also appears to be associated with magnetic linears located near the northern boundary of Figure 3b, on the southeast margins of the Crippleback Lake Quartz Monzonite.

FUTURE STUDIES

A methodology for combining the various geophysical datasets directly has, as yet, not been developed. As well, the VLF-EM datasets, quadrature and total-field, have not been incorporated into the study. Since each data type expresses a different characteristic of surface rocks, the potential existing in the proper combinations of these regional data types has not been exploited. The geophysical datasets can be digitally integrated with geochemical, digital topographic and digital geological datasets and models to further delineate areas of good economic potential. Such studies will be extended to the north of the study area by application of image enhancement techniques to high-resolution aeromagnetic, gradiometer and VLF-EM data, recently released for the Notre Dame Bay region, area 5 of Figure 1.

Recently, the manipulation and display of VLF-EM data from the GSC Skyvan survey of south-central Newfoundland has commenced. Colour profile plots of VLF quadrature, total-field and Fraser-filtered quadrature values have been produced. Aside from cultural features and the conductive coastline anomalies due to salt water, several conducting lithologies have been identified. Of particular interest are a large conductor near Gander Lake, coherent conductors within the Ackley Granite, and those within St. Joseph's Cove Formation sediments (Dickson, 1986) of the Baie d'Espoir Group in an area of extensive overburden.

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