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T. Skulski, S. Castonguay, N. Côté, V.J. McNicoll, M. Currie, A. Magee, B. Harris, and C.R. van Staal

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doi:10.4095/298754

This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

Recommended citation
Skulski, T., Castonguay, S., Côté, N., McNicoll, V.J., Currie, M., Magee, A., Harris, B., and van Staal, C.R., 2017. Digital geoscience atlas of Baie Verte Peninsula, Newfoundland and Labrador; Geological Survey of Canada, Open File 7342, 1 .zip file. doi:10.4095/298754

Publications in this series have not been edited; they are released as submitted by the author.

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Abstract

The Baie Verte Peninsula is located in the northern Appalachians of Newfoundland. It is underlain by the ancestral Laurentian continental margin (Humber zone), the accreted (Taconic Orogeny) Cambrian Baie Verte Oceanic Tract and its Ordovician ophiolite volcano-sedimentary cover. These three marine successions were intruded by late Ordovician to Silurian felsic plutons and associated subaerial volcanic cover emplaced prior to, and during the Salinic Orogeny. There is a long history of mineral exploration and mining on the Baie Verte Peninsula, with the most important commodities being gold, copper and asbestos. To assist in the understanding and exploration of this geologically diverse region, the Baie Verte digital geoscience atlas, a companion output to three previously released Canadian Geoscience Maps, contains GIS datasets including new and compiled bedrock geology (with 1:50,000 pdf maps). These are combined with compiled structural geology, geochronology (U/Pb and $^{40}Ar/^{39}Ar$), lithogeochemistry, metallogeny (mines and drilled prospects), reprocessed aeromagnetic survey data (government and industry survey data), a digital elevation model, and base-map data (topography, hydrographic etc.). These GIS data are compatible with a number of GIS platforms, and have also been organized into a project suitable for viewing via ESRI® ArcReader™ (links provided).

Introduction

The Baie Verte Peninsula occurs on the north central shore of the Island of Newfoundland, between Notre Dame Bay in the southeast and White Bay to the northwest (Figures 1 and 2). This area was the subject of a multidisciplinary bedrock mapping initiative (fieldwork 2006-2008) by the Geological Survey of Canada as part of Natural Resources Canada's Targeted Geoscience Initiative (TGI-3). Three 1:50,000 scale bedrock geology maps were published as part of this project (Skulski et al., 2015a, b, c), and these along with compiled map data (Hibbard, 1983) form the basis for the present digital geoscience atlas, which includes a new peninsula-scale bedrock compilation map (e.g. of_7342_1.pdf, of_7342_2.pdf and of_7342_3.pdf in \Maps_Report_References_Excel\Maps_Legend folder). This area forms part of the northeastern Appalachians, and has been long recognized as a key region for studying the tectonic history of this ancient mountain belt. Western Baie Verte Peninsula is underlain by the Laurentian continental margin of the Humber Zone (Williams, 1979; Hibbard, 1983). Along the western edge of the Humber Zone and in tectonic contact, lies the Birchy Complex, a faulted prism of Neoproterozoic (time scale of Cohen et al. 2013) hyperextended continental crust including metavolcanic (with synvolcanic intrusive rocks), metasedimentary, and allochthonous mantle slivers (van Staal et al., 2013). The Baie Verte line (Williams and St-Julien, 1982) separates this tectonic lower plate in the west, from an overriding eastern sequence comprising allochthonous, ophiolite of the Cambrian Baie Verte oceanic tract and Ordovician volcano-sedimentary submarine cover. Uplift of this tectonic collage in the Upper Ordovician coincided with wide-scale emplacement of granitic batholiths, followed by episodic, Silurian continental felsic plutonism and volcanism. These magmatic events coincided with the Silurian Salinic Orogeny, and were followed by Devonian to Carboniferous strike-slip deformation, extensional collapse and continental sedimentation.

Baie Verte Peninsula has a rich history of copper, gold and asbestos mining (Hibbard, 1983; for mine location *see* Table 5 in of_7342_1.pdf). Ophiolite-hosted, Cambrian volcanogenic massive sulphide deposits include: Tilt Cove Mine (Cu ±Au ±Ag) was producing between 1864 and 1917 and re-opened between1957 and 1967; Betts Cove Mine (Cu) was producing between 1875 and 1883; Terra Nova Mine (Cu, ±Au, ±Ag) was producing between 1860 and 1864 and reopened between 1902 and 1904; Rambler Main Mine (Cu-Zn ±Au, ±Ag) was producing between 1961 and 1967; Big Rambler Pond Mine (Cu) was producing in 1969; East Mine (Cu) was producing between 1967 and 74; Ming West Mine (Cu-Au) was producing between 1995 and 1996; Ming Mine (Cu, Au, ±Ag) was producing between 1971 and 1982 and since 2011. The Ordovician ophiolite cover sequence hosts a number of gold mines including: Goldenville Mine (Au) was producing between 1904 and 1906; Nugget Pond Mine (Au) was producing between 1997 and 2000; and Pine Cove Mine (Au) has been producing since 2008. Asbestos was extracted from altered ophiolitic rocks at the Baie Verte Mine between 1963-1981 and 1982-1990.

This digital atlas includes digital base-map, bedrock geology, geochronology, whole-rock geochemistry, metallogenic, aeromagnetic data, and a digital elevation model. The bedrock geology data include the peninsula-scale bedrock compilation (outer green polygon in Figure 1), which comprises the areas covered by the bedrock maps CGM 156, CGM 159, and CGM 160 (Skulski et al. 2015a, b, c), and the digital bedrock geology including shape file polygons of the compilation map, shape file point data of structural symbols and associated legend and map font files. New and compiled geochronological data include U/Pb and $^{40}Ar/^{39}Ar$ age determinations and these are included as point shape and Excel files. Similarly, lithogeochemical and metallogenic (e.g. drilled showings, past- and currently-producing mines) data are included as point shape and Excel files. The aeromagnetic data representing various government and industry surveys on Baie Verte Peninsula, have been re-processed here (details below) and are presented as geotiff files. A single harmonized reference list (Word® .docx files) is provided that contains citations for bedrock map, structural, geochronological, geochemical and metallogenic data sources. The structure- (column/field headings), compilation methods, ancillary calculations, and analytical methods as they pertain to these files, are described below. The contents of the geoscience atlas and instructions for loading files and projects are summarized in part in a digital file entitled readme.rtf in the root directory.

GIS compilation

Data were formatted for use in ArcGIS™ desktop version 10.2, developed by ESRI®. Data were compiled in a file Geodatabase™ specifically designed for visualization using ArcMAP™ .mxd format and ArcReader™ format. The GIS compilation is available as a published map file (PMF) and data package that can be opened with ArcReader™. ArcReader™ is a free ESRI® product that will allow end users to view and explore the compilation with the same layout as the mxd. For more information on ArcReader™ please refer to:
http://www.esri.com/software/arcgis/arcreader.

A master reference list for compiled bedrock map, structural, geochronological, metallogenic, geochemical and geophysical data can be found in the folder \Maps_Report_References_Excel\Report_References as a Microsoft™ Word™ document.

Basemap files

Digital base-map data (\Data\GDB, \Data\PMF, and \Data\SHP\CartoElements), were assembled from 1:50,000 scale data (Natural Resources Canada) with modifications. The following NTS sheets were used: 12-I/1; 2-L/4; 2-E/14; 2-E/13; 12-H/16; 12-H/15 (east); 12-H/10 (east); 12-H/9 (west-central) and part of 2-E/12. Contour elevations above mean sea level are expressed in meters for NTS sheets: 12-I/1; 2-E/13; 12-H/16; 12-H/15; 12-H/10 and 12-H/9, and feet for NTS sheets: 2-E/12, 2-E/14 and 2-L/4. All of the data in this atlas use the Universal Transverse

Mercator (UTM) conformal projection, zone 21 north, and the NAD 1983 vertical datum.

Digital elevation model

The dem_hillshade.tif file (\Data\Imagery) is a generated product from the Canadian Digital Elevation Model (CDEM). The CDEM stems from the existing 1:50,000 scale Canadian Digital Elevation Data (CDED). In these data, elevations can be either ground or reflective surface elevations http://geogratis.gc.ca/api/en/nrcan-rncan/ess-sst/-/(urn:iso:series)canadian-digital-elevation-model-cdem?sort-field=relevance) The geotiff file has the following characteristics: sun azimuth: 315°; inclination of light source: 45°; vertical exaggeration: 5; data resolution: 20 m.

Bedrock geology files

A 1:50,000 scale map (northern, southern, and legend) entitled: Digital geoscience atlas of Baie Verte Peninsula, Newfoundland and Labrador, comprises the backbone of this atlas (\Maps_Report_References_Excel\Maps_Legend, (\Data\GDB, \Data\PMF, and \Data\SHP\Geology). This map is based on three 1:50,000 scale bedrock geology maps (Skulski et al., 2015a, b, c) with compiled data (primarily Hibbard, 1983) used to complete the geology of the peninsula. Data sources used in making the map are shown in Figure 1. Interpretation of geological contacts is constrained by outcrop observations, compiled bedrock data (contacts, outcrops, structures; see below), new and compiled lithogeochemical data on volcanic and intrusive rocks (*see* below), remotely sensed data including public and industry aeromagnetic survey data, aerial photography and a digital elevation model.

Digital bedrock data are provided as an ESRI geodatabase (Geology.gdb) as well as individual shape files including polygons (GEO_UNIT), polylines (GEO_LINE) and points (GEO_POINT; discussed below). The map is included as a pdf file (of_7342_1 and of_7342_2) including legend and surround (of_7342_3). ArcGIS legend and symbol files and Windows font files used in symbolizing the map are included (StylesFonts folder; see below).

The GEO_UNIT.shp file (1506 records) contains fields (attribute columns) that include: 1) polygon *label* (linked sensibly to the legend; geochemical and geochronological point data (below) are cross-referenced with the same polygon labels); 2) *Geocode* (and *SYMBOL*), which are linked by number to a lookup table for polygon colour (RGB); 3) Stratigraphic order (*str_order*) which assigns a numerical value of 0 to unmapped areas, and from 1 to 137 corresponding to the main map legend (in ascending age or legend position). Remaining columns are either essential fields inherent to shape files (*FID, Shape*, ORIG_FID*), or calculated geometry (*Shape_Leng, Shape_Area*).

The GEO_LINE.shp file (5731 records) contains fields that include: 1) Line type (*CODE*; i.e. fold hinge, fault, geological contact, unconformity, thin stratigraphic units etc.); 2) a field (CONTACT) that identifies whether a line is a polygon boundary (marked *yes* or other linear feature that may cross polygon boundaries (marked *no*); 3) the orientation of folds is indicated in the field SENS and indicates whether folds are upright or overturned; 4) the structural generation (D_1, D_2 etc.; *GENERATION*) of fold hinges; 4) the label (*NAME*) assigned to named structures (e.g. faults, shear zones); 5) a qualifier (*QUALIF*) field indicating whether a contact, fold or fault etc. are defined (observed), approximate (constrained by structural observations) or inferred (constrained by geophysical and/or widely-spaced observations); 6) a symbol code (*SYMBOL*) relating the structure to the symbol legend lookup table; 7) a numerical identifier field

(GEOLINEID).

The station.shp file contains the location of outcrops visited during the course of this study (2006-2008). It contains the station identifier (*STATIONID*), the date and time the outcrop was mapped (*VISITDATE* and *VISITTIME* respectively) and the location of the outcrop in decimal degrees (*LATITUDE* (north) and *LONGITUDE* (west of the Central Meridian)) and in UTM coordinates (UTM zone 21 N, NAD 1983; *EASTING* and *NORTHING* in meters), the elevation in meters as estimated by hand held GPS (*ELEVATION*). The method used in locating the outcrop (*ENTRYTYPE*) was typically by GPS or manually using a map or air photo. The position dilution of precision (PDOP) is a measure of the precision of the GPS location (e.g. values <3.5 have approximately 1 m horizontal precision). The number of satellites used in the GPS calculation is shown by the field *SATSUSED*. The type of outcrop is described either as outcrop or road crop (*OBSTYPE*) and finally, general notes about the location are shown in a text field (*SLS_TYPE*).

Structural geology file

The GEO_POINT.shp file (12,764 records) contains new and compiled structural measurements (bedding, pillow facing, foliation, lineation, fold axes, dyke orientation etc.). This includes the following fields: 1) a field indicating whether the point is plotted (*REVEAL*) on the map (pdf version; y=yes, n=no); 2) a revised description of the structure (*DETAIL_REV*) and structural interpretation (generation of structure, e.g. S2 foliation inclined); 3) UTM coordinates in meters (zone 21, NAD 83; *EASTING, NORTHING*); 4) original description and generation of a structure (*DETAIL*) from the original source; 5) the outcrop station number where the measurement was made (*STATIONID*); 6) the strike or trend of a structure (in degrees relative to north =0° or 360°) using the right hand rule (*AZIMUTH*); 7) the dip or plunge (*DIPPLUNGE*) of a structure in degrees relative to the horizon (0°); 8) the source of the data (*SOURCE*) as listed in the reference list (\Maps_Report_References_Excel\Report_References\of_7342_References.docx); 9) for data from this study, a unique identifier (*STRUCID*) linking structure to station or outcrop number; 10) for data from this study, original field notes describing the structure measured; 11) for data from this study, a relative intensity scale (*INTENSITY*) describing the degree of fabric development in shear zones; 12) The relative development of L-tectonite (constrictional strain) versus S-tectonite (flattening strain; *FLATTENING*); 13) Basic classification of structures (*TYPE*) into planar or linear; 14) two columns devoted to point symbol type (*PNT_SYM*) and a plotting symbol cross-referenced to a look-up table in the symbol legend (*SYMBOL*).

Legend files, symbol sets, font files

Style and fonts are in the StylesFonts folder (\StylesFonts). The following general style files are provided: FGDC_GSC_BaieVerte.style, and GSC_Bedrock_BaieVerte.style. Specific style files for the Arc project include: Line_OF7342.style, Marker_OF7342.style, and Polygon_OF7342.style. Instructions for loading these files are included in the readme.rtf file. Digital versions of the legend (of7342_mapunit.xls) and map symbols (of7342_symbol.xls) can be found in the folder \Maps_Report_References_Excel\Excel\.

Geochronology file

The file Geochronology.shp (\Data\GDB, \Data\PMF, \Data\SHP\Geochronology and Excel format in \Maps_Report_References_Excel\Excel\Geochronology.xls; 111 records) contains new and compiled U/Pb zircon, titanite, monazite and rutile ages and $^{40}Ar/^{39}Ar$ hornblende, muscovite, and biotite ages. $^{40}Ar/^{39}Ar$ ages (new and historic data) have been calculated using a total K decay constant of 5.463E -10 (Min et al., 2000). Some plateau ages (*see* below) have been recalculated using Isoplot version 3.7 of Kenneth Ludwig (http://www.bgc.org/isoplot_etc/isoplot.html) using recalculated ages of steps (in light of revised decay constant and internal standard ages) using Noah Mclean's ArArReCalc_7-31-09 Excel program (notes and program, *see* links in *New EARTHTIME Ar tool*: http://www.earth-time.org/ar-ar.html.). A summary description of recalculation of individual ages is provided in tables 4a and 4b in map of_7342_1.pdf (in \Maps_Report_References_Excel\Maps_Legend). The Geochronology.shp (and Excel™ file) file contains the following fields: 1) a unit code that coincides with the map polygon label (*CODE*); 2) brief rock type description (*ROCK_TYPE*); 3) the age in million years (Ma; *AGE_MA*) of the record for plotting on the map (errors not included); 4) a comment field (*COMMENT*) providing an interpretation of the age; 5) the source reference (*REFERENCE*) cross-referenced to the of_7342_references.docx in the folder \Maps_Report_References_Excel\Report_References\.; 6) the mineral phase dated (*MINERAL*); 7) the name of the stratigraphic (legend unit; *UNIT*) in which the dated rock is found; 8) a number field (*Number*) for the assigned age; 9) the sample number (*Sample*); 10) UTM coordinates in meters (zone 21, NAD 83; *EASTING, NORTHING*); 11) The revised or final age of the sample (*Age_revise*) which for $^{40}Ar/^{39}Ar$ ages may reflect age recalculation (*see* Notes); 12) notes (*Notes*) on details of recalculation (for $^{40}Ar/^{39}Ar$ data, this may include revised decay constant, revised age of standard, or recalculations of plateau age), description of age spectra and sample dated, or U/Pb geochronology; 13) Published original $^{40}Ar/^{39}Ar$ age before recalculation(*Age_legacy*); 14) age method (*Method*) used where SHRIMP is sensitive high resolution isotope mass spectrometer, TIMS is thermal ionization mass spectrometry, LA-ICPMS is laser ablation inductively coupled plasma mass spectrometry; 15) abridged notes (*Note_short*) for geochronology tables in published maps; 16) plotting symbol (*Symbol*) cross-references lookup-table for geochronology; 17) abbreviated name of mineral phase dated (*ABREVIATIO*); 18) abbreviated reference source (*REF_Table1*) for geochronology tables on published maps.

Geochemistry file

The file Geochemistry.shp (\Data\SHP\Geochemistry and Excel format in \Maps_Report_References_Excel\Excel\Geochemistry.xls; 1536 records) contains new and compiled whole rock lithogeochemical analyses of volcanic, plutonic and sedimentary rocks (rare). A list of analytical methods used for the new and compiled data is provided in Table 1.The analyses contain major, minor and trace elements and were recalculated so that total iron is expressed as FeO. Rejected analyses include samples where: 1) locations were not provided; 2) key major elements were not reported (e.g. K_2O, TiO_2); 3) where totals (major elements, Fe as FeO, and loss on ignition) were greater than or equal to 102%, or where the sum was less than or equal to 95%. In the latter case, recasting some of the iron in an analysis of an igneous rock as ferric iron (Fe_2O_3; e.g. XFe^{3+}=0.15), has the effect of raising chemical totals. The shape file contains the following fields: 1) a unique identifier field (*FID_test_3*) for shape files; 2) sample number (*SAMPLE*; may include field number for samples from Bédard et al., 2000); 3) UTM coordinates in meters (zone 21, NAD 83; *EASTING, NORTHING*); 4) rock family (*CLASS*; volcanic, plutonic, sedimentary, mantle); 5) rock type in light of geochemical analyses and field description (*ROCK*), this may reflect CIPW norm, alkali-silica classification Le Bas et al., (1986), A/CNK versus A/NK (Shand, 1943), K_2O-SiO_2 variation in volcanic rocks Peccerillo &

Taylor (1976), and Nb/Y versus Zr/Ti classification (Winchester and Floyd, 1977); 6) tectonic complex, igneous suite of major stratigraphic group (*COMPLEX*); 7) stratigraphic unit (formation, member, igneous suite; *UNIT*); 8) field or published rock description (*DESCRIPT*); 9) reference or source of data linked to of_7342_references.docx in the folder \Maps_Report_References_Excel\Report_References\; 10) major elements in weight percent including: SiO_2 TiO_2, Al_2O_3, FeO (total iron), MnO, CaO, Na_2O, K_2O, P_2O_5 and loss on ignition (LOI); 11) minor and trace elements (in parts per million) analyzed by XRF (element symbol_X) including: Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, Pb, Th and U; 12) trace elements (in parts per million) analyzed by ICP-MS, INAA or ICP-ES (*see* Table 1 notes for abbreviations): V, Cr, Co, Ni, Cu, Zn, Ga, Ge, As, Rb, Sr, Y, Zr, Nb, Sn, Sb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Tl, Pb, Bi, Th and U; 13) map unit (*label*) determined by intersection of sample location with GEO_UNIT shapefile.

Metallogeny files

Two metallogeny shape files are included here entitled: Mine, and Drill_Prospect (\Data\GDB, \Data\PMF, \Data\SHP\Metallogeny and in Excel™ format in \ Maps_Report_References_Excel\Excel\). The Mine file is a point shape file containing basic information on active (at of the time of publication) and past-producing mines on Baie Verte Peninsula including: 1) the name of the mine (*Name*); 2) its status (*Status*; Producing or Past Producer); 3) the principal commodity (*Commodity*) associated with the mine (copper, gold or asbestos); 4) location information of the headframe (*Easting; Northing*; projected coordinate system UTM zone 21N, vertical datum NAD 1983); 5) a symbol code (Code) for plotting on the map; 6) the map label associated with commodity type (*Com_label*; Cu, Au, Asb); 7) secondary commodities associated with the mine (*Sec_Com*) in relative order of abundance; 8) a number (*Map_Label*) linking map symbol to table data on the map; 9) a symbol code (*SYMBOL*) linked to a lookup table for map symbols.

The drilled prospects file (Drill_Prospect) was downloaded (June 16, 2014) from the Geoscience Atlas, maintained by the Department of Natural Resources, Newfoundland and Labrador (http://gis.geosurv.gov.nl.ca/). Detailed descriptions of the various fields in the Newfoundland and Labrador mineral occurrences deposits database (MODS) from which the drilled prospect data were extracted can be found at: http://www.nr.gov.nl.ca/mines&en/geosurvey/mods/helptext/; a summary description is provided here. Revised stratigraphic nomenclature and updated ages of mineralization and/or host rocks from this study have been included. The Drill_Prospect file contains the following fields: 1) National mineral inventory number (*NMINO*); 2) the primary commodity (*MODSLABEL*) listed in the mineral occurrences database system (MODS); 3) a record identification (*RECID*) number that can be used in the search function of the Geoscience Atlas (above; http://gis.geosurv.gov.nl.ca/) by using (hand lens icon) the drop down menu option "Mineral Occurrences" entering this number (RECID), and then from the abbreviated record (similar to data included in Drill_Prospect) choose *links* to get the full MODS description for the drilled prospect; 4) the deposit or prospect name (*DEPNAME*); 5) an alternative name for the deposit or prospect (ALTNAME); 6) the name of the principal commodity (*COMNAME*); 7) other commodities associated with the deposit or prospect (*COMMODS*); 8) ore minerals present (*OREMIN*); 9) gangue minerals associated with mineralization (*GANGUE*); 10) a deposit type code (*DEPTYPE*) keyed to the list of deposit types described in MMODS help file (http://geoatlas.gov.nl.ca/custom/help/ModsHelp.html) and described in the adjoining column

(#11, DEPDESC); 11) deposit description (*DEPDESC*) from MMODS (*see* link in #9); 12) alteration minerals present in the host rock (*WRALT*); 13) alteration type based on the alteration mineral assemblage (*ALTTYPE*); 14) age of host unit or mineralization (*AGECODE*; revised from MODS to reflect data from this study); 15) type of deposit (*STATUS*; all are prospects); 16) *DDH* Indicates if the occurrence has been drilled (0=drilled but number of holes uncertain, >0 = number of holes) or not (null); 17) what object has been used to locate the prospect (*ENTCOM*) and the Geofile report number (Newfoundland and Labrador assessment file number); 18) 1:50,000 scale mapsheet (*NTS*); 19) UTM zone (*UTMZONE*); 20) latitude in decimal degrees (*LATITUDE*); 21) longitude in decimal degrees (*LONGITUDE*); 22) the unit label code (*UNIT*) corresponding to the polygon which hosts the drill collar or prospect; 23) a sequence number code (*LABEL*); 24) plotting symbol linked to a lookup table (*SYMBOL*); 25) major stratigraphic entity (this study) hosting the prospect (*COMPLEX*); 26) the individual stratigraphic unit hosting the prospect (*STRAT_UNIT*; from this study); 27) UTM easting (*EASTING*; zone 21 north; NAD 1983) in meters; and 29) UTM northing (*NORTHING*).

Aeromagnetic files

The results of nine aeromagnetic survey blocks and parts of a regional survey were reprocessed and are included here as georeferenced tiff files (geotiff files in \Data\Aeromagnetic\; Figure 2 and Table 2). These files can be imported into GIS software as raster images and may (see below) include for each survey: residual total field, reduced to pole with scale, first vertical derivative and second vertical derivative images with scale, and shaded relief images of all of these. The data were projected into UTM zone 21 north, with a vertical datum of NAD 1983. The nomenclature in naming files includes from left to right: 1) the Geofile name (Table 2); a letter symbol (e.g. N, S, NE) identifying survey blocks (blank if not applicable); N83 indicating spatial reference (NAD 83 zone 21N); GE50 indicating a gradient enhanced grid calculated at 50 m cell spacing (Table 3; blank if not applicable); RTF for reduced total field (IGRF subtracted; Table 3); LC for levelling of tie-lines using carefully levelled grid option (blank if not applied); ML for micro-levelled grid (Table 3; blank if not applied); RTP reduced to pole (Table 3; blank if not applied); 1VG first vertical gradient; 2VG second vertical gradient (Table 3; blank if not calculated); SHD shaded relief (sun angle at 315 degrees azimuth and 45 degrees inclination).The aeromagnetic surveys presented here (Table 2, Figure 2) include detailed (50–250 m line spacing) helicopter-borne surveys flown by the mineral exploration industry over small areas, and regional, fixed wing surveys (400-800m line spacing) flown on contract for government agencies. The industry data are included in mineral assessment reports filed with Government of Newfoundland and Labrador, Department of Natural Resources, Mineral Lands Division. The relevant reports are cited in the footnote to Table 2. The original digital data (xyz text files for older data; Geosoft™ format grid and database format files for more recent data), web links to survey reports and summary of survey parameters are available online from the Geological Survey of Newfoundland and Labrador by using the following link and inserting the relevant survey number (from column 4 in Table 2) in the link (e.g. for survey DN08786, the web address reads "…id=DN08786"; http://www.geosurv.gov.nl.ca/airborne/disp_airborne.asp?survey_id=DN08786). The reader is referred to Kilfoil (2009) for further details. A number of surveys in Table 2 comprise more than one survey block which may or may not be physically adjoining, have different flight line orientation, or different line spacing. These various blocks were reprocessed separately below.

The original aeromagnetic data were levelled by the survey contractors to account for systematic errors including diurnal variation of the Earth's magnetic field (base level correction), lag, heading and tie-line corrections as described in the respective contractor reports. Examination of the high frequency content of the helicopter-borne surveys using the second vertical gradient (e.g. Figure 3) reveals that despite the levelling reported, most of these surveys still show tie lines, and all of them would benefit from micro-levelling to remove flight line artefacts. The higher frequency signal in these data contains valuable information from shallow levels in the crust, and so all of the original data were re-processed using Geosoft® Oasis Montaj® software to fine tune the tie-line correction using careful levelling, and remove flight line artifacts with micro-levelling (Table 3; Figure 3). In order to accomplish this the following steps were performed on the data (Table 3): 1) a residual total field was calculated by subtracting from the initial levelled magnetic field the Earth's magnetic field calculated at the position (longitude and latitude) of each survey measurement along lines, and extrapolated to the mid-date of the survey from the closest International Geomagnetic Reference Field (IGRF) year calculated (along with inclination and declination) at a height of 300 m above sea level; 2) the Simple and Careful levelling routines (levelling.gx) were used to level tie-lines; 3) a new grid was calculated using the minimum curvature gridding algorithm on levelled flight line data; 4) the MAGMAP.gx algorithm was used to microlevel this grid (*see*: http://www.geosoft.com/media/uploads/resources/technical-notes/microleveling%20tech%20note.pdf) with the step-by step algorithm; 5) the grid was first converted to the frequency domain (fast Fourier transform); 6) a noise grid was prepared by fine tuning of the Butterworth and directional cosine filters; 7) the frequency domain data were converted back to space domain (inverse fast Fourier transform); 8) the resulting noise grid was subtracted from the original grid; 9) the second vertical gradient was calculated (in frequency domain) from this difference grid and evaluated to minimize flight line noise and ringing (Gibbs phenomenon); 10) the final micro-levelled data were reduced to the magnetic pole (RTP) using a magnetic pole calculated from the midpoint of the survey block. The RTP calculation introduced significant ringing in the grid that is apparent in the second vertical gradient. As a result, the RTP corrected data were used to create reduced total field and first vertical gradient images; second vertical gradient images were calculated on the micro-levelled data only. The results of this procedure (processing parameters in Table 3) are shown for the southern part of survey block DN07001 in Figure 3.

Second vertical gradients were not included for the three surveys including the regional GSC survey (GSC-N-07), the Noranda survey (north and south blocks 12H-1030), and the Bayswater survey (12H09-2013). The 1966-69 GSC survey showed abundant flight line artefacts in the second vertical gradient that could not be removed in these older data originally acquired in analog form. Similarly, the 1986 Noranda survey was flown in the pre-GPS era where aircraft position was determined by a local radio beacon. In areas of high relief, positional accuracy using radio beacons can be affected by line of sight issues rendering fine scale data correction problematic. The 2007 Bayswater data revealed substantial, persistent ringing (Gibbs phenomenon) in the second vertical gradient.

The Altius survey (12H16-1831) was flown as two adjoining blocks at different line spacing; 50 m in the east and 100 m in the west (Table 2). For the purpose of this study, the data were combined and resampled to a 20 m grid cell spacing (1/5 of the western survey line spacing; Table 3). Micro-levelling of the data were guided by the line spacing of the finer resolution, eastern survey block where the cut off wavelength of the Butterworth filter was set at 200 (m; i.e. 4 x 50 m line spacing; Table 3).

Acknowledgements

This work was supported by the Geological Survey of Canada Appalachian Targeted Geoscience Initiative Program 3. We are grateful to Jim Hibbard, Jean Bédard, Steve Piercey and Bill Kidd for introductory field trips to the geology of Baie Verte Peninsula. We thank Monica Escayola, Joe Whalen, Guoxiang Chi and Sasha Turchyn for discussions in the field, and Bill Church, Neil Rogers and Alex Zagorevski for their insights on Newfoundland and Appalachian geology. We thank Scott Anderson, John Bursnall, Peter Cawood, Greg Dunning, George Gale, Jim Hibbard, Mohan Kambampati, Bill Kidd, Ryburn Norman, Stephen Piercey, Pam Stella and John Tuach for permission to use unpublished data. We were ably assisted in the field by Yves Moussallam, Ian Kerr, Jason Duff, Stephen Hinchey, Katie Sheridan, Ian Ames, Michael Tucker and Liam Hartree. We are grateful to Bill Morris, Hernan Ugalde and their students Heather Slavinski, Bill Spicer, Brett Miles, Victoria Tschirhart and Sara-Lise Underhay for their assistance with geophysical surveys. We thank Gerry Kilfoil and Heather Slavinski for initial processing of aeromagnetic data used in making the bedrock maps. T. Skulski is grateful to Hernan Ugalde, Gerry Kilfoil, Warner Miles and Frank Kiss for introducing him to processing aeromagnetic data using Oasis Montaj®. We thank Neil Rogers for his review of this atlas and leadership in running the Appalachian TGI-3 project.

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Table 1. Whole rock analyses: analytical methods

Source	Samples	major elements	minor elements	trace elements
Bédard (1999b; et al. 2000)	BC-94-	XRF FD	XRF PP	XRF PP, INAA
Bédard (1999b; et al. 2000)	BC-95-, 96-, 97-	ICP-ES	ICP-ES	ICP-MS
Coish (1977)*		XRF FD	Na, XRF PP	XRF PP, REE*
DeGrace et al. (1976)*		AA		
Epstein (1983)		XRF FD (Na XRF PP)	XRF PP	
Gale (1971)		XRF PP	XRF PP	XRF PP
Hibbard (1983)	1340001-57	AA	P-S	XRF PP
Hibbard (1983)	1340058-82	AA	P-C	XRF PP
Hudson (1988)*		AA	XRF PP	XRF PP
Jenner (1977)		XRF FD	XRF PP	XRF PP, REE*
Kambampati (1984)		XRF FD		
Kerr (1994)*		ICP-ES	ICP-ES	ICP-ES, INAA
Miller (1994)*		ICP-ES	ICP-ES	ICP-ES, INAA
Piercey (1996)		XRF PP	XRF PP	ICP-MS
Ramezani (1992)		AA, ICP-OES, XRF	XRF	XRF, ICP-MS
Saunders (1985)*		AA	XRF PP	XRF PP
Stewart (1995)		ICP-ES	ICP-ES	XRF PP, ICP-ES
This study (2015)	06-SNB-	XRF FD	XRF PP, ICP-MS	ICP-MS
This study (2015)	07-SNB-	XRF FD	ICP-MS	ICP-MS
This study (2015)	08-SNB-	XRF FD	ICP-MS	ICP-MS
Upadhyay (1973)		AA		
van Staal et al. (2013)	DC-	XRF, ICP-OES	XRF, ICP-OES	ICP-MS
van Staal et al. (2013)	SNB-	ICP-OES	ICP-OES	ICP-MS
Whalen (2012)	WX81-	XRF FD, Na-AAS	XRF PP	
Whalen (2012)	WX89-	XRF FD	XRF PP	ICP-MS
Whalen (2012)	07-SNB-	XRF FD	ICP-ES	ICP-ES, ICP-MS

Note: AA atomic absorption spectroscopy; ICP-OES inductively coupled plasma optical emission spectroscopy or ICP-ES inductively coupled plasma emission spectroscopy; ICP-MS inductively coupled plasma mass spectroscopy; INAA instrumental neutron activation analysis; P-S phosphorus by spectrophotometry; P-C phosphorus by colorimetry; XRF x-ray fluorescence spectroscopy using FD fused disk or PP pressed pellet; REE* rare earth elements pre-concentrated by ion exchange chromatography and paper analyzed by XRF. Source data marked by an asterisk (*) were obtained from Newfoundland and Labrador Geological Survey. "Volcanic Database." Newfoundland and Labrador GeoScience Atlas OnLine. Last update: August 2009. http://geoatlas.gov.nl.ca. [downloaded February 16, 2010] and described in Saunders (1995).

Table 2. Aeromagnetic survey parameters

Name	Date	Geofile	Survey	Type	Spacing (m)	Azimuth	Length (km)	Height (m)
Carroll north	11-21-2002	12H16-1659	DN07001	rotary	100 m	N165E	354.7	51
Carroll south	11-21-2002	12H16-1659	DN07001	rotary	100 m	N-S	922.6	51
Altius east	07-09-2006	12H16-1831	DN09997	rotary	50 m	E-W	278.6	65
Altius west	07-09-2006	12H16-1831	DN09997	rotary	100 m	E-W		65
Celtic Minerals	03-19-1996	NFLD-2657	DN08786	rotary	100 m	N150E	297.6	45
Noranda north	12-16-1986	12H-1030	N00105	rotary	200 m	N155E	1776	45
Noranda south	12-16-1986	12H-1030	N00106	rotary	200 m	N115E	1106	45
Bayswater	11-22-2007	12H09-2013	DN13924	rotary	100 m	N45E	4346	60
GSC 2007	03-31-2007	NFLD-2942	DN09902	fixed	250 m	N120E	10450.1	100
GSC_N_07	1966-1969			fixed	805 m	N135E		305

Note: The following reports are linked to these surveys: GSC_NL07 see: http://gdr.agg.nrcan.gc.ca/gdrdap/dap/search-eng.php Newfoundland #07, magnetics, 1969, 805 m; N00105 and N00106 Smith (1987); DN08786 St-Hilaire (1996); DN07001 Fiset (2002); DN09997 Smith (2006); DN13924 Mouge and Largeaud (2007); DN09902 Pelletier (2007). Geofile is the unique file name identifier used in online document searching (aeromagnetic survey reports in this case) of the Geofiles Search database of the Mines branch, Department of Natural Resources, Newfoundland and Labrador. Survey is the data file name used by the Geological Survey of Newfoundland and Labrador where original geophysical digital data (grids and x-y-z data) can be downloaded (see text for links). Aircraft type used in the survey is described in the Type column (rotary wing and fixed wing). Individual surveys are identified in Figure 2 by their Geofile name, as are the folder names used for the final geotiff images (geotiff images associated with 1966-1969 data are in a folder called GSC-N-07).

Table 3. Processing parameters, aeromagnetic survey data

Survey	Grid	Cell	BTWR	DCOS	IGRF	RTP	Note
GSC-N-07*	MC	200	3200/8/H	90/1.0/P	1967/08/01/300		ML
N00105*	MC	50	800/5/H	155/0.8/P	1986/11/30/300	71.99/-25.75/20	ML
N00106*	MC	50	800/5/H	115/0.8/P	1986/11/30/300	71.84/-25.51/20	ML
DN09997	MC	20	200/8/H	90/1/P	2006/07/09/300	70.39/-21.64/20	LC, ML
DN08786	MC	25	4800/6/H	150/1/P	1996/03/20/300	71.22/-24.24/20	LC, ML
DN07001 N	MC	25	700/8/H	165/1.4/P	2002/11/20/300	70.66/-22.70/20	LC, ML
DN07001 S	MC	25	700/8/H	0/1.5/P	2002/11/19/300	70.6/-22.7/20	LC, ML
DN09902	G	50			2007/03/21/300	70.37/-21.50/20	Goldak
DN13924*	MC	25	400/6/H	45/1.6/P	2007/11/22/300	70.19/-21.22/20	LC, ML

Notes: Data processed by T. Skulski using Geosoft®, Oasis Montaj® v. 7.5 with MAGMAP and levelling gx software packages.
Survey: Aeromagnetic survey ID number (Table 2) used by Geological Survey of Newfoundland and Labrador (GSNL).
Grid: algorithm MC=minimum curvature. G=Goldak™ proprietary gridding algorithm (GVT gradient variable trend)
Cell: grid cell size in meters, typically 1/4-1/5 line spacing
BTWR: Butterworth filter, cut off wavelength (in ground units, m) / filter order / H = high pass
DCOS: Directional cosine filter, center direction in space domain (line azimuth in degrees) / degree of cosine function / P=pass
IGRF: International Geomagnetic Reference Field = total field (line levelled) – IGRF (interpolated between mid-date of survey and closest IGRF release (every 5 years)); mid date of survey (in year/month/day format) / elevation (m) at which IGRF is calculated.
RTP: Reduction to Earth's magnetic pole, calculated in middle of survey area with inclination / declination / and amplitude correction inclination (=20 in northern hemisphere)
LC: Levelling of tie-lines using carefully-levelled grid option in levelling gx.
ML: Micro-levelled grid, original grid - noise grid (calculated using BTWR and DCOS) using grid math
Goldak: Proprietary algorithm used by Goldak™ to micro-level aeromagnetic survey.
(*): Second vertical derivative not included due to excessive ringing (Gibbs phenomenon) and/or flight line artefacts

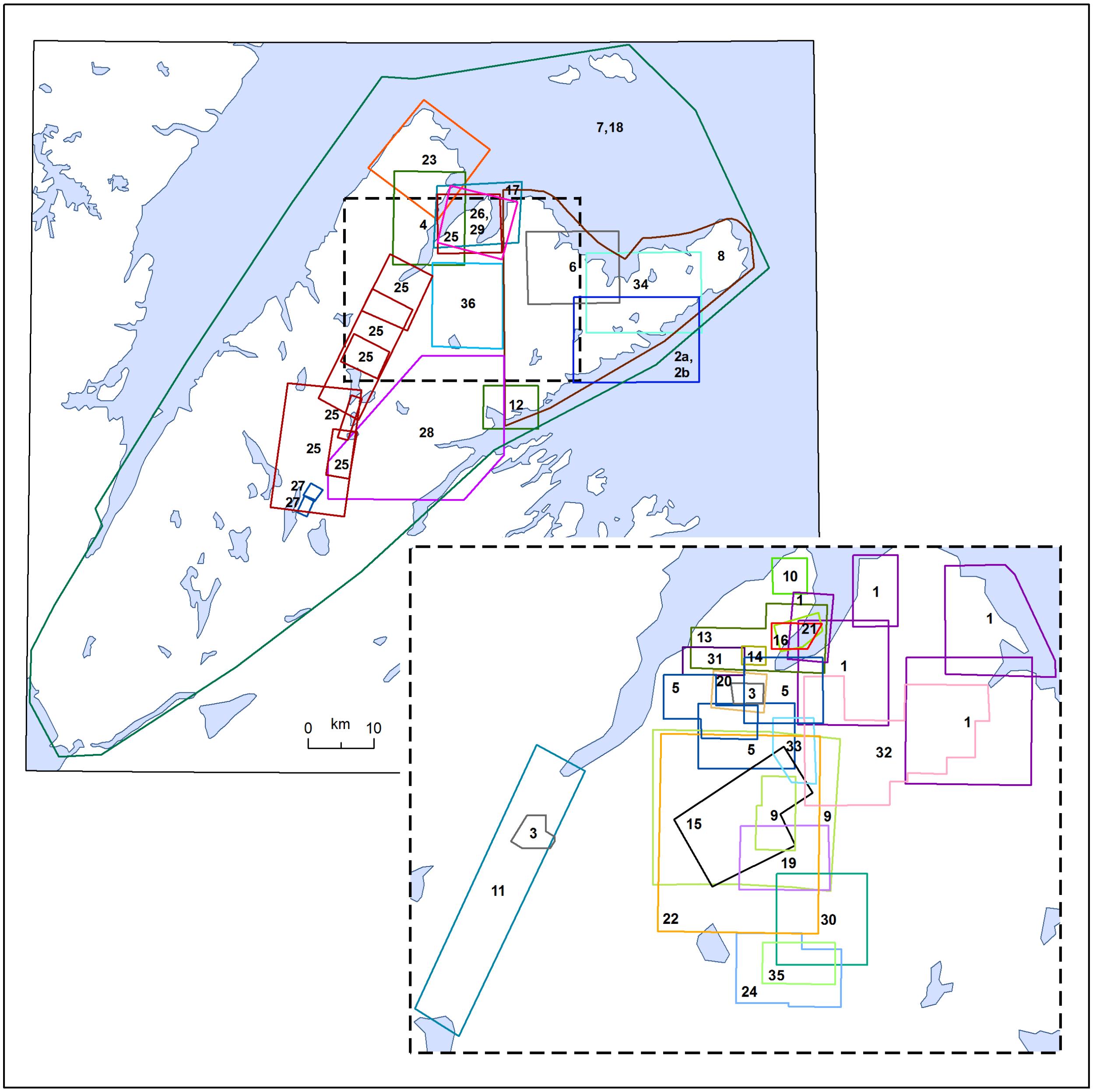

Figure 1. Map sources: 1 = Anderson, 1998; 2a = Bédard et al., 1999a; 2b = Bédard et al., 2000; 3 = Bélanger, 1995; 4 = Bursnall, 1975; 5 = Christie and Dearin, 1986; 6 = Coates, 1970; 7 = Colman-Sadd and Crisby-Whittle, 2002; 8 = DeGrace et al., 1976; 9 = Dimmell and MacGillvray, 1991; 10 = Dubé et al., 1993; 11 = Dunsworth, 2004; 12 = Epstein, 1983; 13 = Evans, 2004; 14 = Fitzpatrick, 1981; 15 = Gale, 1971; 16 = Gower, 1987a; 17 = Gower, 1987b; 18 = Hibbard, 1983; 19 = Huard, 1990a; 20 = Huard, 1990b; 21 = Jourdain and Oravec, 1996; 22 = Kambampati, 1984; 23 = Kennedy, 1971; 24 = Kerr and Collins, 1983; 25 = Kidd, 1974; 26 = Kidd et al., 1978; 27 = MacDougall et al., 1989; 28 = Miller and Abdel-Rahman, 1994; 29 = Norman, 1973; 30 = Piercey, 1996; 31 = Regular, 2005; 32 = Shepperd et al., 1987; 33 = Snow, 1989; 34 = Stella, 1987; 35 = Stewart, 1995; 36 = Tuach, 1976.

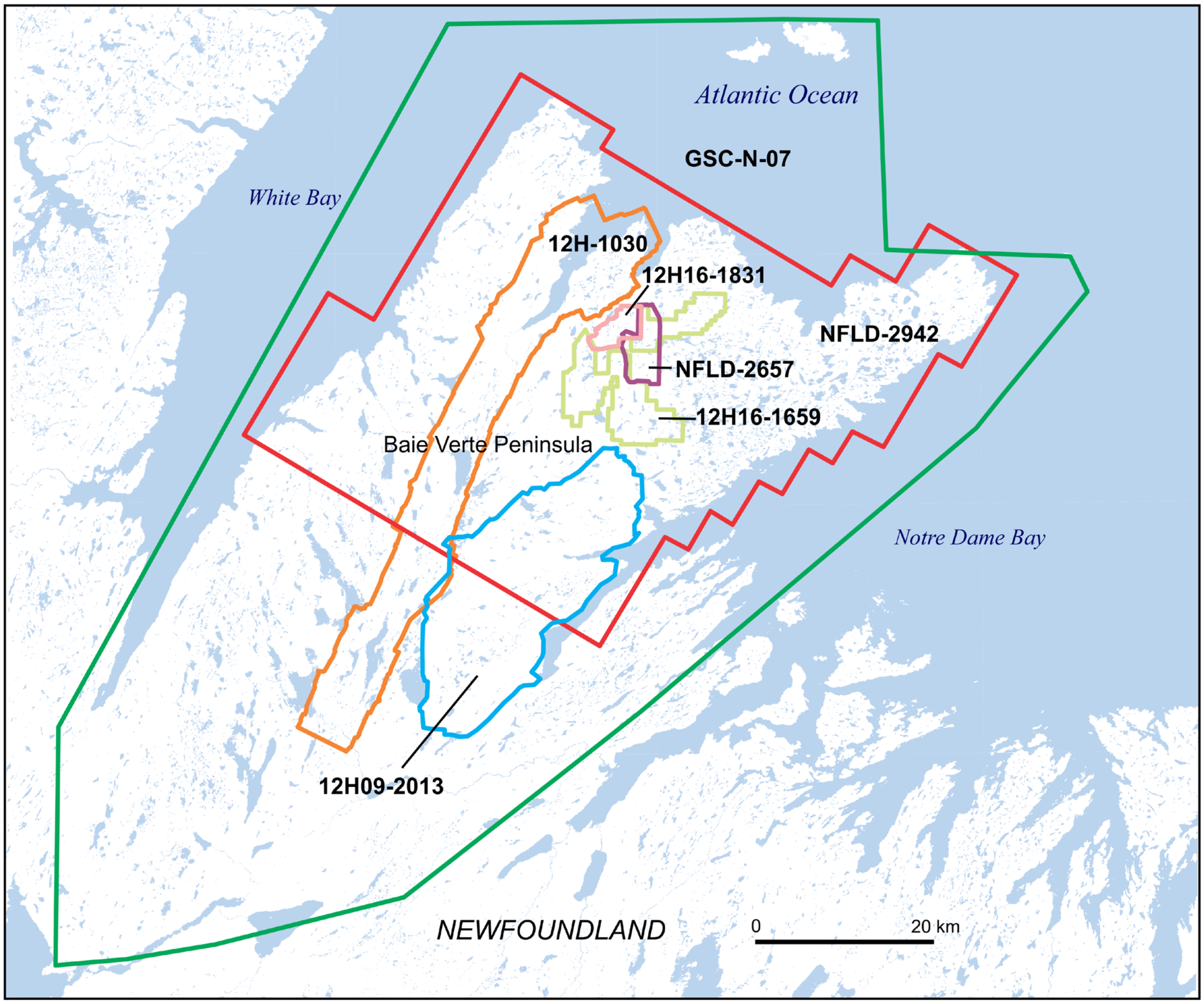

Figure 2. Location of aeromagnetic surveys used in this study

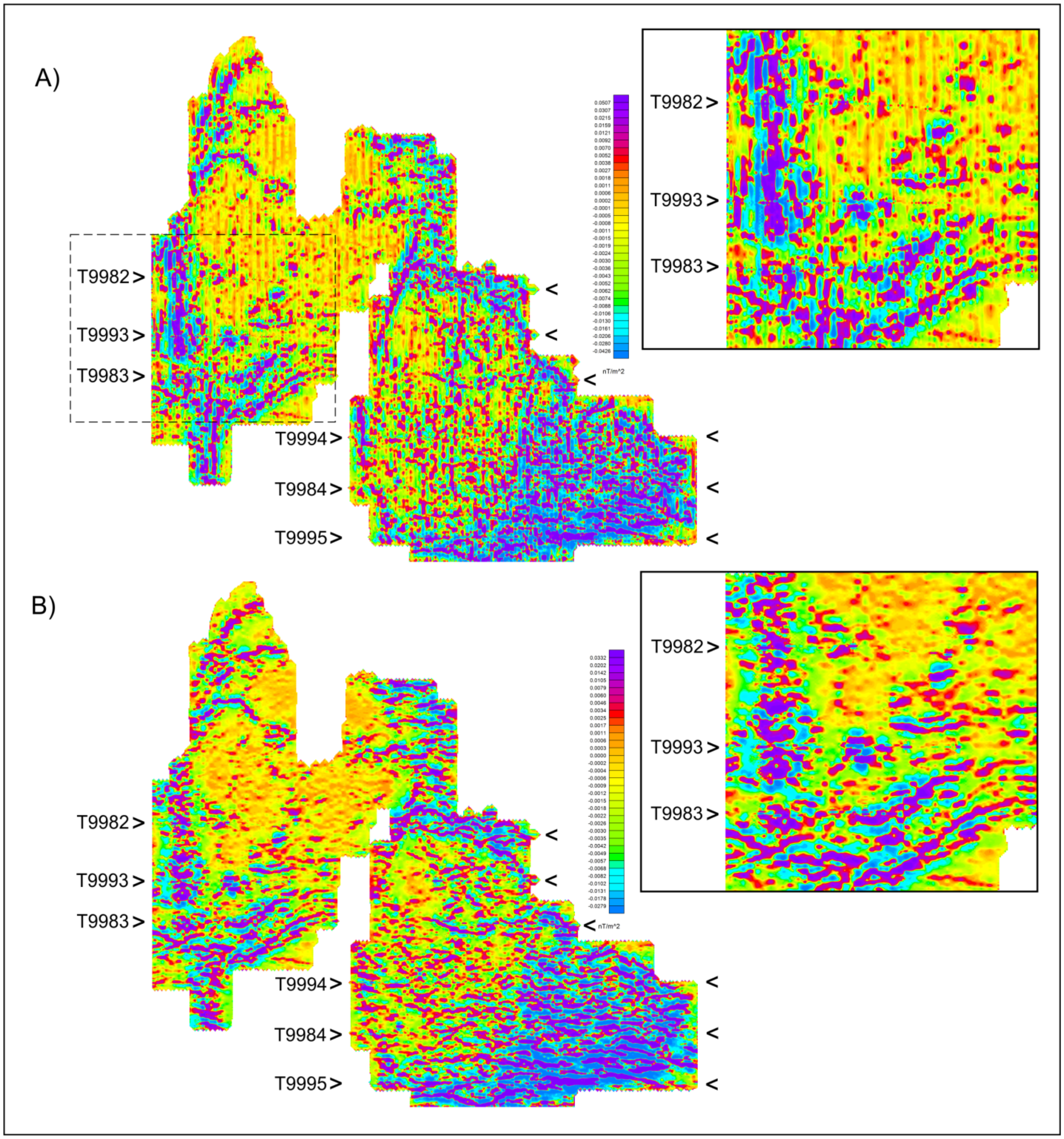

Figure 3. Results of levelling and micro-levelling of aeromagnetic data, southern block of DN07001 survey (survey parameters Table 2; Carroll south, 13.53 km (E-W) by 13.06 km (N-S)). A) Minimum curvature grid of original flight- and tie-line data accompanying Geofile 12H16-1659 (mag channel; levelled by contractor) modified here by subtracting International Geomagnetic Reference Field (IGRF; calculated to Nov. 22, 2002, Table 3) and displayed as 2nd vertical gradient to accentuate high frequency signal. Prominent N-S flight lines (corrugation; *see* inset) and subtle E-W tie-lines (T) are evident in second vertical gradient. B) Same grid following: i) Geosoft® "simple-" and "careful levelling" (errors in tie- and flight-line intersections fit to Akima spline for each tie-line); ii) micro-levelling in frequency domain (Table 3) using Butterworth and directional cosine filters to minimize flight-line corrugation by generating and subtracting a noise grid (compare inset). In atlas, tie- and flight-line data were first levelled as above (Table 3), and subsequently, only gridded flight-line data were micro-levelled for final maps.