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Geochemical and isotopic (Nd, O, Pb and Sr) data from igneous rocks of the Notre Dame subzone and adjacent tectonostratigraphic zones, western and central Newfoundland

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2012

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doi:10.4095/291593

Recommended citation
Whalen, J.B., 2012. Geochemical and isotopic (Nd, O, Pb and Sr) data from igneous rocks of the Notre Dame subzone and adjacent tectonostratigraphic zones, western and central Newfoundland; Geological Survey of Canada, Open File 7202. doi:10.4095/291593

Geochemical and isotopic (Nd, O, Pb and Sr) data from igneous rocks of the Notre Dame subzone and adjacent tectonostratigraphic zones, western and central Newfoundland.

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The following report presents a compilation of geochemical and isotopic data collected in the course of a numbers of projects starting in 1981 with geological mapping and geochemical sampling of the Silurian Topsail igneous suite (TIS) (Whalen and Currie, 1988; Whalen et al., 1987a,b,c). A Canada-Newfoundland Cooperation Agreement (CNCA) (1990-1994) funded project focused mainly on Ordovician plutonism within the Notre Dame subzone (Fig. 1) (Whalen et al., 1997b) but included isotopic work on the TIS (Whalen et al., 1996). During the Red Indian Line Project, which was funded under the auspices of the 2000 to 2003 Targeted Geoscience Initiative (TGI), more extensive work was carried out within the southern Notre Dame subzone and the northern Dashwoods subzone (Whalen et al., 2006; van Staal et al., 2007, 2008). With funding from the 2005-2010 Targeted Geoscience Initiative 3 Program (TGI3) some further geochemical and isotopic work was carried out in the Buchans-Robert's Arm belt and the Burlington Peninsula, the results of which are included in this report.

The geochemical data presented herein should provide significant assistance in the regional correlation of units, as well as for constraining their tectonic setting and igneous petrogenesis. It complements previously released geochemical databases for central Newfoundland (e.g., Davenport et al., 1996; Jenner, 2002; Rogers, 2004; Zagorevski and Rogers, 2011).

Tectonic and geologic context

This brief overview is mainly summarized from van Staal et al. (1998, 2004, 2009) and van der Velden et al. (2004), and references therein. The Newfoundland Appalachians are interpreted as a relic collision zone between Laurentia, in the west, represented by Grenvillian basement to the Humber Zone, and Gondwanan terranes in the east, represented by Neoproterozoic basement rocks to parts of the Exploits subzone, and the Gander and Avalon zones (see Fig. 1). The western margin of Iapetus (Humber Zone), an Early Paleozoic passive margin sequence deposited on the leading edge of Laurentia, is divided into western external and eastern internal sectors, based on increasing deformation and metamorphism toward the east. Prior to 470-475 Ma, a narrow oceanic tract (Humber seaway) is thought to have separated the Humber margin from the Notre Dame arc (NDA) (Notre Dame plus Dashwoods subzones in Fig. 1). This continental magmatic arc is thought to have evolved on a ribbon continent, referred to as Dashwoods, which rifted from Laurentia between 550-530 Ma. Closure of the Humber seaway along the Baie Verte Line (BVL) by east-directed subduction beneath Dashwoods was accompanied by ca. 475 Ma obduction of the Tremadoc-early Arenig suprasubduction zone rocks of the Baie Verte oceanic tract onto the Humber margin and 488-480 Ma arc magmatism of the NDA. It was followed by voluminous tonalite plutonism between 466-459 Ma within the NDA, attributed to break-off of the oceanic slab attached to the downgoing Humber margin. Closure of the main Iapetan ocean basin was accomplished during the Caradoc (455-450 Ma) by simultaneous east- and west-directed subduction. These processes juxtaposed the peri-Laurentian NDA and the associated Annieopsquotch accretionary tract (AAT) with the peri-Gondwanan Victoria arc along the Red Indian Line (RIL) (Fig. 1). Accretion of the Victoria arc to composite Laurentia was followed (1) by accretion of the Gander zone along the Dog Bay Line, as a result of west-directed subduction of the Exploits back-arc basin, producing the Silurian Salinic orogeny, and (2) by accretion of the Avalon Zone along the Dover-Hermitage Bay fault, producing the Early Devonian Acadian orogeny.

Early Silurian magmatism and sedimentation west of the RIL, within the Notre Dame subzone, form stitching plutons and overlap basins on the accreted terranes. These events overlap in time with a major pulse between ca. 435-425 Ma of regional deformation plus metamorphism (Salinic orogeny) followed by rapid uplift and cooling within the Humber internal zone. Overall, this activity has been interpreted as reflecting Exploits back-arc closure and subsequent slab break-off.

This report presents a compilation of geochemical and isotopic data collected mainly from Ordovician and Silurian igneous rocks of the Notre Dame and Dashwoods subzones of western Newfoundland (see Fig. 2 for sample distribution). Interpretations based on data contained in this compilation were fundamental to our current understanding of the complex accretionary events that are outlined above.

Geochemical Database

This open file contains 607 whole rock geochemical samples presented as Microsoft Excel® worksheet with the shared link between files being sample number. These samples comprise surface silicate rock samples of mainly plutonic, lesser volcanic and minor epiclastic rocks. The background information is presented as Adobe Acrobat®, Microsoft Word® documents or Microsoft Excel® tables, as appropriate, with the data type indicated by the file names. Background information includes analytical procedures and unfiltered data tables, as produced by the laboratories (these tables include repeats, standards, etc.), for samples which were analyzed post-1989. Such lab sourced files are not available for samples that were analyzed pre-1989. These files are grouped in folders named after the project or program during which sampling and analytical work was carried out: Topsail project, Canada-Newfoundland Cooperation Agreement (CNCA) (1990-1994) project, Red Indian Line project and Target Geoscience Initiative (TGI) 3 project. Samples with a WX-prefix were collected, submitted for analysis and interpreted by the author. Samples with HPA-, MRB-, PQB-, VL-, VL-LH-, and VO- prefixes were submitted for analysis and interpreted by the author. Samples with VL01A- and VL01J- were interpreted by the author.

Location Table: The location table contains the sample location data in the UTM, easting and northing (Zone 21; NAD27) format. Locations for samples collected between 1981 and 1994 were compiled from 1:50 000 topographic sheets. Location data for samples collected post-2000 were determined by handheld GPS. In addition to the exact position for each sample, an overall sense of the location of the sample can be deduced from the NTS map sheet name and number. Sample distribution relative to NTS sheets is shown in Figure 2.

Description Table: The description table contains a number of columns that the user can employ to sort or group the data. The column 'Zone' is the Newfoundland tectonostratigraphic zone, based on Williams et al. (1988) (see Fig. 1 for key to abbreviations), in which the sample was collected. This is followed by 'Type' (volcanic, plutonic or sedimentary) and 'Subtype' (mafic (<55 wt. % SiO_2), intermediate (>55 and <65 wt. % SiO_2) or felsic (>65 wt. % SiO_2); this column is blank for sedimentary rocks. The next column gives the name of the person who collected the sample. The following two columns 'Suite, Complex or Pluton Name' and 'Map Unit' were derived from published geological maps given in the 'Reference' column and listed near the end of this document. These maps can be downloaded for free from this NRCan web site (http://apps1.gdr.nrcan.gc.ca/mirage/db_search_e.php). The final column in this table is a free-form rock-type description. Abbreviations employed in these descriptions are as follows:

vfg = very fine grained	amph = amphibole
fg = fine grained	bt = biotite
mg = medium grained	chl = chlorite
cg = coarse grained	cpx = clinopyroxene
vcg = very coarse grained	ep = epidote

eq = equigranular	feld = feldspar
porph = porphyritic	hbl = hornblende
mass = massive	ms = muscovite
fol = foliated	ol = olivine
incl = inclusions	plag = plagioclase
alt = alteration	px = pyroxene
comp = compositional	qtz = quartz
bk = black	kfld = K-feldspar
dk = dark	mag = magnetite
pk = pink	opx = orthopyroxene
wt = white	sl = sillimanite
	st = staurolite

Chemistry Table: The whole rock chemistry data file is presented as a Microsoft Excel® worksheet file which contains whole-rock geochemical analytical data. Major elements are recorded as weight percentages of their oxides. Where the oxidation state was determined, iron is presented as FeO and Fe_2O_3, otherwise it is represented as FeO (total). Volatiles are represented as either CO_2 and H_2O or LOI (loss-on-ignition). The minor, trace and rare earth elemental compositions are presented in parts per million. Details of the analytical procedures are presented in the background information folder. Where an element was analysed using multiple methods the value determined by the method that appears most reliable is presented. Elements not determined are given as 0, whereas element analyses that are below the detection limits are presented as a negative value with the number being the detection limit. A large proportion of the geochemical data presented in this report has been previously presented and interpreted in earlier publications given in the reference list including van Staal et al. (2007, 2008), Whalen (1986, 1989), Whalen and Currie (1984, 1988, 1990), Whalen et al. (1987a, 1987b, 1996, 1997a, 1997b, 2006). Also there is overlap in geochemical data presented herein with that contained in the compilation of Rogers (2004).

Isotopes Table: The isotope table contains: whole rock ‘Delta18O’ (δ^{18}O‰ SMOW); whole rock ‘i87Sr/86Sr’ (initial ^{87}Sr/^{86}Sr); ‘m87Sr/86Sr’ (measured ^{87}Sr/^{86}Sr); ‘i206Pb/204Pb’ (initial ^{206}Pb/^{204}Pb); ‘i207Pb/204Pb’ (initial ^{207}Pb/^{204}Pb);‘i208Pb/204Pb’ (initial ^{208}Pb/^{204}Pb) (all determined on K-feldspar); whole rock ‘ENd(460)’ (ε_{Nd} at 460 Ma); ‘ENd(T)’ (ε_{Nd} calculated at age given in column ‘Age (T)’ in Ma (some ages are determined U-Pb zircon ages some interpreted estimates); ‘TDM(Gold)’ (Nd age in Ga based on model of Goldstein et al. (1984)); ‘TDM(DeP)’ (Nd age in Ga based on model of DePaolo (1981)); ‘(143/144)m’ (^{143}Nd/^{144}Nd measured); ‘(147/144)m’ (^{147}Sm/^{144}Sm measured); ‘(143/144)i’ (^{143}Nd/^{144}Nd initial); ‘CHURi’ (CHUR initial); and Nd and Sm in ppm by isotope dilution. Model ages were not calculated

(NC) for samples for which $(^{147}Sm/^{144}Sm)_m$ was greater than 0.15. To enable easy linkage between tables, the many samples for which no isotopic data is available are included as blank rows. Details of the isotopic analytical techniques and labs where determinations were made are given in the analytical procedures. Almost all the isotopic data presented in this report has been previously interpreted and published in scientific journal papers given in the reference list (van Staal et al., 2007, 2008; Whalen et al., 1987c, 1996, 1997a, 1997b, 2006). As well there is overlap in Nd isotopic data presented herein with that contained in the compilation of Rogers (2004).

Complete Table: This file combines location, description, rock chemistry and isotopes tables.

Discussion of geochemical data

Samples utilized in this study were collected in the course of regional scale mapping in order to identify the geochemical fingerprints of different igneous suites within tectonostratigraphic terranes and to establish geochemical-isotopic characteristics of terranes to aid regional correlations. A discussion of the tectonic significance, distribution and correlation of the volcano-plutonic rocks presented in this database is beyond the scope of this report. For this the reader is referred to various references by the author and van Staal et al. given in the references at the end of this report. Herein, the intent is to highlight the diversity of rock types included in this database and the range of tectonic settings within which they likely were generated.

The geochemical data from igneous rocks was subdivided based on silica content into three groups; (1) mafic (SiO_2< 55 wt.%); (2) intermediate (SiO_2> 55, <65 wt.%; and, (3) felsic (SiO_2> 65 wt.%). A plot of all these groups on the Q'- ANOR plot of Streckeisen and LeMaitre (1979) (Fig. 2a) illustrates the large diversity of plutonic rock types included in the dataset. As cogenetic igneous suites normally do not cut across boundaries in a K_2O-SiO_2 plot (Fig. 2b), this plot shows that the dataset includes shoshonitic, high-K, medium-K and low-K igneous suites. Intermediate and felsic igneous rocks are plotted on Rb-Y+Nb and Nb-Y granitoid rock tectonomagmatic discrimination plots (Fig. 3a and 3b) which show that the dataset consists mainly of volcanic arc, within-plate and post-collisional granites. Mafic igneous rocks are plotted on various basalt trace element tectonomagmatic discrimination plots (Fig. 4) which suggest the dataset consists of basaltic rocks that formed within diverse arc-related settings. For a discussion of the isotopic data and its interpretation, the reader is referred to Whalen et al. (1987c, 1996, 1997a,b, and 2006).

Acknowledgements

This is a contribution to the Targeted Geoscience Initiative (TGI) 4 (2010-2015). The following are acknowledged for providing access to their unpublished geochemical data: Johan Lissenberg (Cardiff University, Wales), Sally Pehrsson (Geological Survey of Canada) and Alex Zagorevski (Geological Survey of Canada). Additional acknowledgement is also given to Neil Rogers for his contribution as project leader for the TGI 3 and TGI 4 programs in Newfoundland and for critically reviewing this open file.

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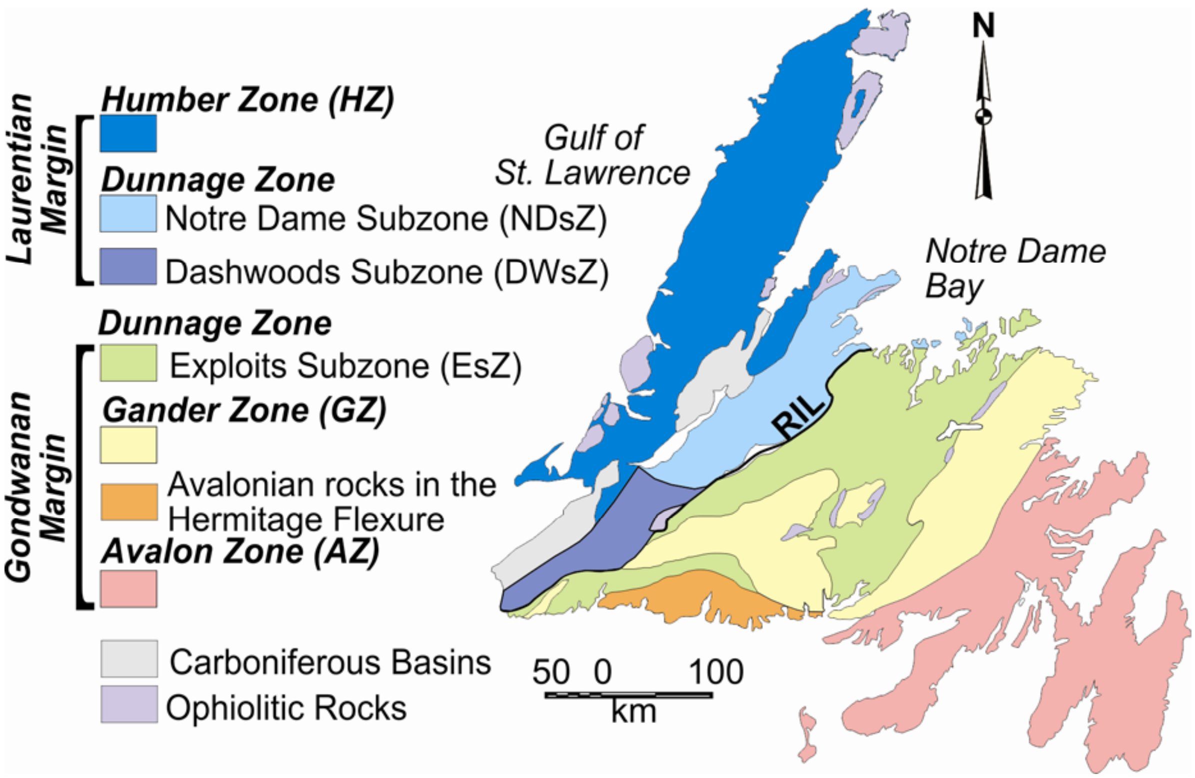

Figure 1. Tectonostratigraphic zones and subzones of the Newfoundland Appalachians (modified after Williams et al. (1988) and Piasecki et al. (1990)). Abbreviations used for zones in the 'Description Table' are given in the figure legend; RIL = Red Indian Line.

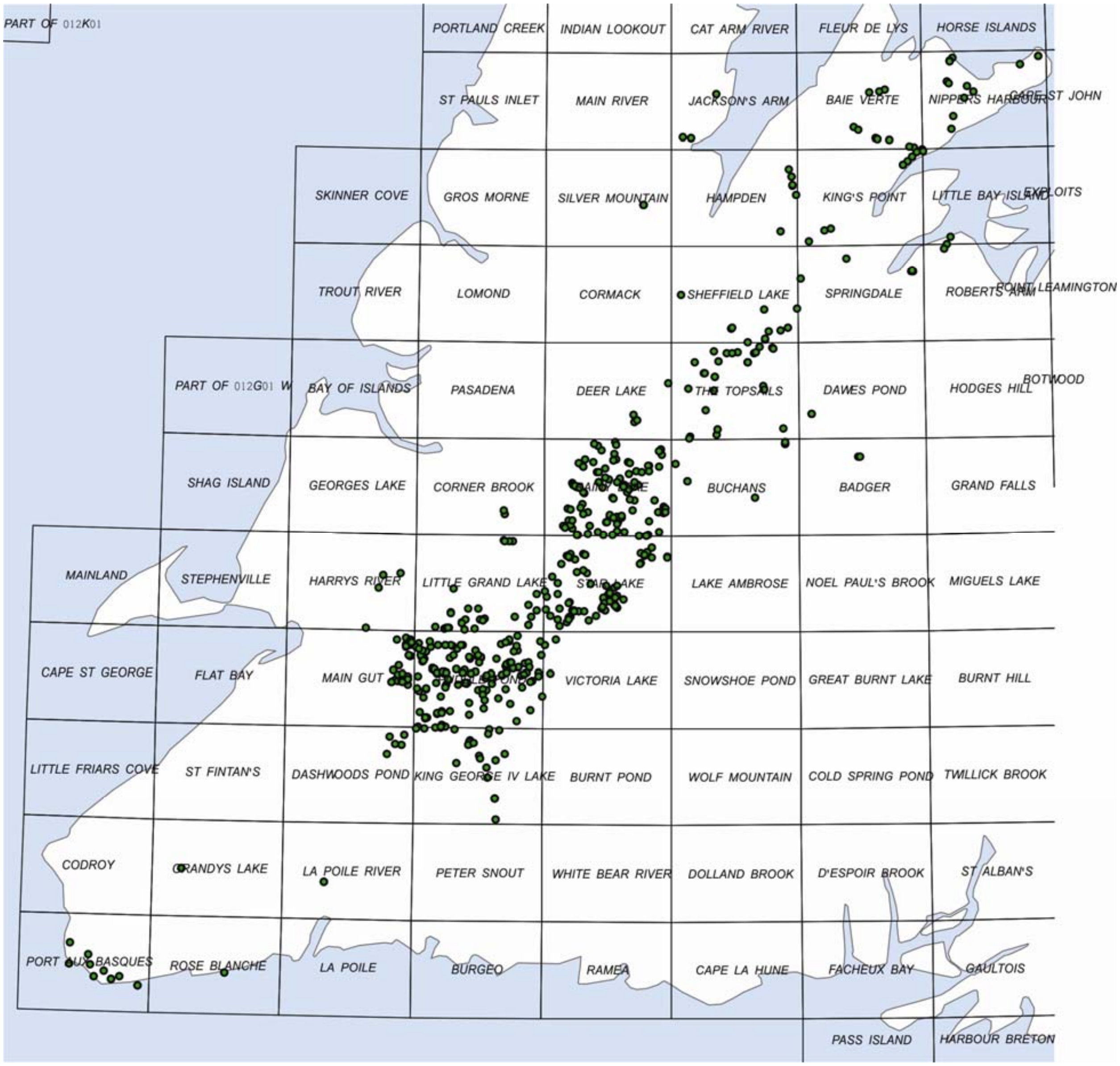

Figure 2. Sample distribution within NTS sheets of western Newfoundland.

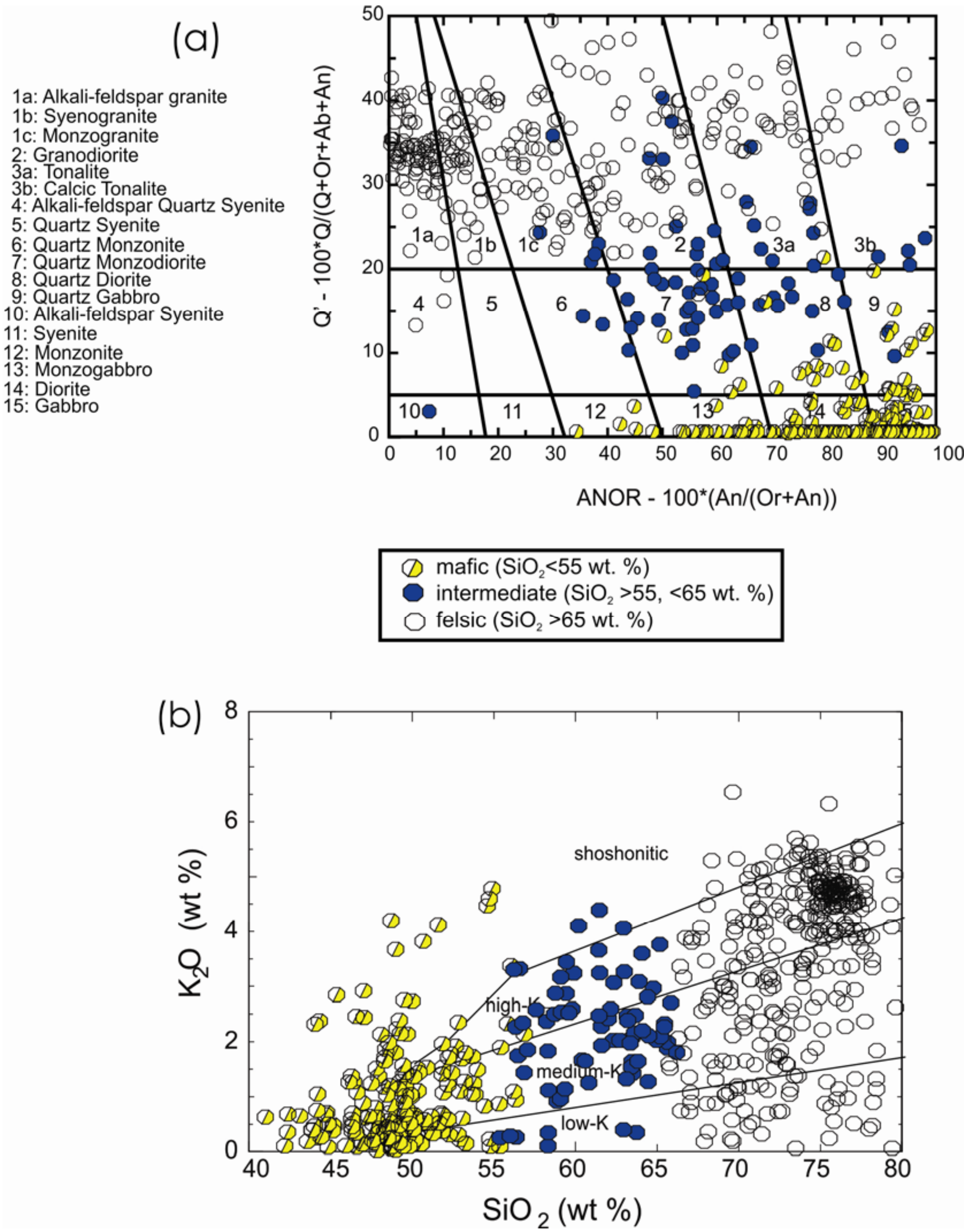

Figure 3. Western Newfoundland igneous rocks, grouped by silica content, plotted on: (a) the Q'-ANOR CIPW normative plutonic rock classification diagram of Streckeisen and LeMaitre (1979); and (b) the K_2O versus SiO_2 diagram of Le Maitre (1989) with shoshonitic field from Peccerillo and Taylor (1976). Samples were grouped based on hydrous analyses and plotted anhydrous, thus some samples plot at higher silica content than the grouping parameters.

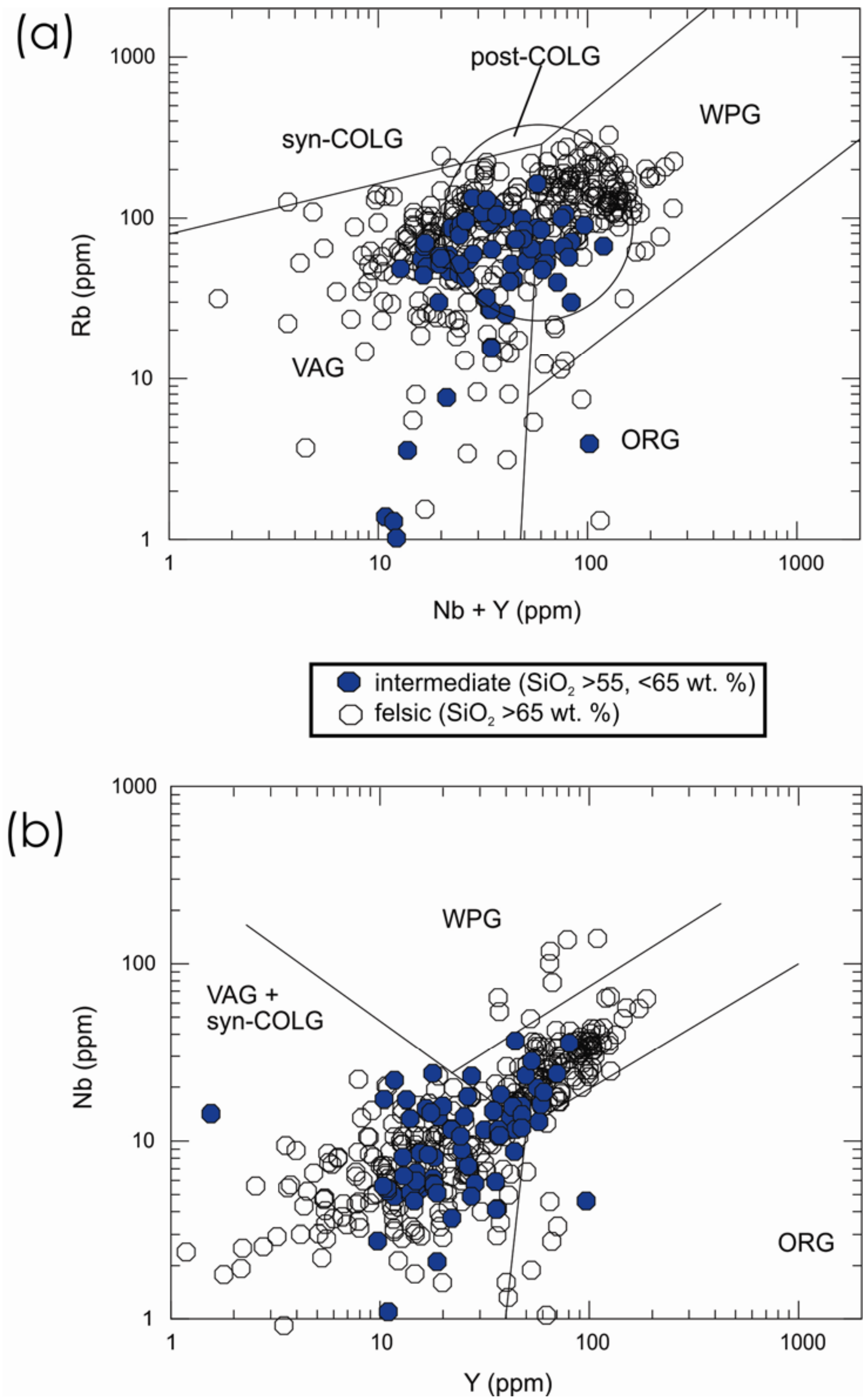

Figure 4. Western Newfoundland intermediate and felsic igneous rocks plotted on the (a) Rb versus Y+Nb diagram of Pearce (1996); and (b) the Nb versus Y diagram of Pearce et al. (1984). Abbreviations are: syn-COLG and post-COLG, syn- and post-collisional granites; VAG, volcanic arc granites; ORG, ocean ridge granites; WPG, within plate granites.

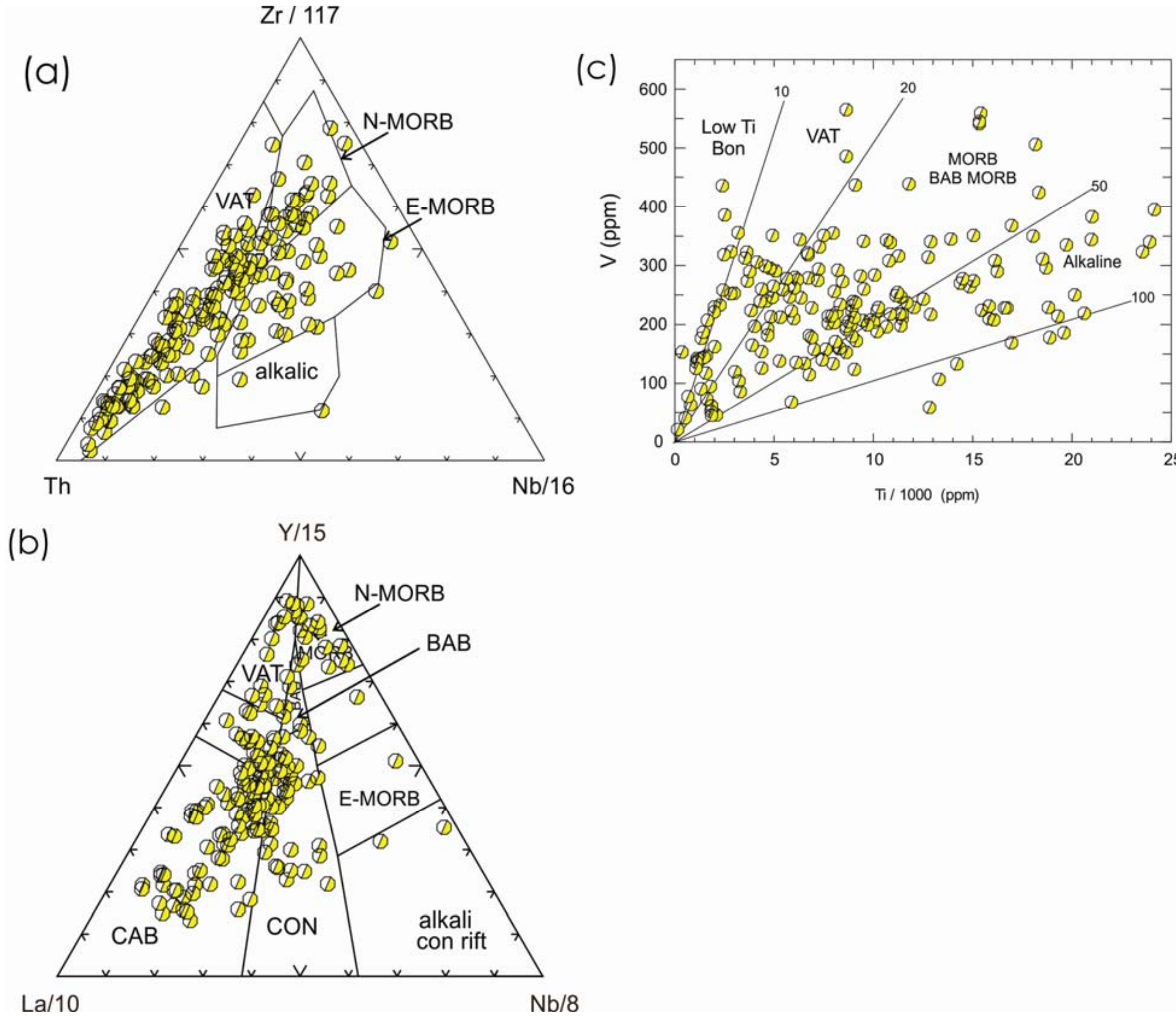

Figure 5. Western Newfoundland mafic (<55 wt.% SiO_2) igneous rocks plotted on; (a) the Th-Zr-Nb diagram of Wood (1980); (b) the La-Y-Nb diagram of Cabanis and Lecolle (1989); (c) the V-Ti diagram of Shervais (1982). Abbreviations: VAT, volcanic arc tholeiite; N- and E-MORB, normal and enriched mid-ocean ridge basalt; CAB, calc-alkaline basalt; CON, continental tholeiite; alkali con rift, alkaline continental rift basalt; BAB, back-arc basalt.

Contents

readme.rtf – contents and file structure.
TGI4 NL Geochemical-Isotopic Database.pdf – summary document outlining the database.
licence_agreement.rtf – formal end-user licence agreement for digital data.

Primary Data Files
Complete.xls –location, description, chemistry and isotopes of silicate samples
Locations.xls – location of samples included in this open file
Description.xls – descriptive information on the samples included in this open file
Chemistry.xls – whole-rock geochemical data on silicate samples
Isotopes.xls – isotopic data on silicate samples

Background Information

Analytical Procedures
- analytical_techniques.pdf
- Standards_duplicates.xls

Unprocessed Analytical Data
- CNCA lab files
  - XRAL major elements.xls
  - MUN XRF on powder pellets.xls
  - MUN ICPMS traces 1.xls
  - MUN ICPMS traces 2.xls
- Red Indian Line lab files
  - 02037xtr.xls
  - 02064XTR.xls
  - 03002xem.xls
  - 01053.xls
  - TL0001-0048-SmNd calc.xls
- TGI3 lab files
  - 07013XRF.xls
  - 07013MS.xls
  - 0713ET-WHA.xls
  - O7013XRF_C_complete.xls
  - CarletonU_Nd_results.xls