GEOLOGICAL SURVEY OF CANADA
OPEN FILE 6016

Geochemical Database of Proterozoic Intraplate Mafic Magmatism in Canada

Background Notes

R.E. Ernst and K.L. Buchan
With samples from L.B. Aspler, W.R.A. Baragar, M.T. Corkery, A. Davidson, R.F. Emslie, W.F. Fahrig (archives), S.S. Gandhi, J. Goutier, H.C. Halls, M.A. Hamilton, J.A. Hanes, B.A. Kjarsgaard, A.N. LeCheminant, H.C. Palmer, J.A. Percival, T. Peterson, W.C. Phinney, H.A. Sandeman, M.C. Smyk and M.-C. Williamson

2010

Canada

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 6016

Geochemical Database of Proterozoic Intraplate Mafic Magmatism in Canada

Background Notes

R.E. Ernst[1] and K.L. Buchan[2]
With samples from L.B. Aspler, W.R.A. Baragar, M.T. Corkery, A. Davidson, R.F. Emslie, W.F. Fahrig (archives), S.S. Gandhi, J. Goutier, H.C. Halls, M.A. Hamilton, J.A. Hanes, B.A. Kjarsgaard, A.N. LeCheminant, H.C. Palmer, J.A. Percival, T. Peterson, W.C. Phinney, H.A. Sandeman, M.C. Smyk and M.-C. Williamson

1. **Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8; Richard.Ernst@ErnstGeosciences.com**
2. **Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8; kbuchan@NRCan.gc.ca**

2010

©Her Majesty the Queen in Right of Canada 2010

This publication is available from the Geological Survey of Canada Bookstore (http://gsc.nrcan.gc.ca/bookstore_e.php).
It can also be downloaded free of charge from GeoPub (http://geopub.rncan.gc.ca/).

Ernst, R.E. and Buchan, K.L. 2010. Geochemical database of Proterozoic intraplate mafic magmatism in Canada; Geological Survey of Canada, Open File 6016, 1 CD-ROM.

Open files are products that have not gone through the GSC formal publication process.

INTRODUCTION

A Microsoft Excel® spreadsheet file is presented with new geochemical data for 923 samples from approximately 70 different Proterozoic, mainly mafic, magmatic events, as well as three of Phanerozoic age. The age distribution of these events is illustrated in Figure 1. Their geographic distribution is displayed by double clicking on the kml file (providing that internet access is available to Google Earth®). Most of the events are interpreted to belong to an intraplate setting. All samples are from sites located in Canada, with the exception of 43 from southwest Greenland and 12 from the northern United States. In addition, for quality control, 26 duplicate measurements and 18 measurements of an internal CANMET standard (TDB-1) were interspersed in the sample stream. All samples were analyzed for the same elements at the same laboratories, resulting in a homogeneous dataset. Specifically, major elements, trace elements (including REEs), and volatiles (including high precision S) were analyzed at the Geological Survey of Canada Laboratories (Analytical Chemistry Services), Pt and Pd were analyzed at Acme Analytical Laboratories Ltd., and a selected subgroup of 75 samples were analyzed for Au, Pt, Pd, Rh, Ru and Ir at Geoscience Laboratories (Geo Labs).

APPLICATIONS OF THE DATABASE

This geochemical database will be of potential value to many types of users. It provides a geochemical 'fingerprint" for about 70 mafic magmatic events, which can be used as a reference tool to correlate undated magmatic units with specific events. Trace elements are particularly valuable in such correlations. A preliminary version of the database was employed by Ernst et al. (2006) and Buchan et al. (2007) for this purpose. In addition, the database can be helpful in evaluating platinum group element (PGE) potential. For example, a preliminary version of the database was used by Ernst and Hulbert (2003) to identify magmatic events with PGE potential. Finally, the Ni, Cu and high precision S values, along with the rest of the compositional data, can potentially be useful in assessing Ni and Cu potential.

SAMPLE SOURCES AND BACKGROUND INFORMATION

The researcher(s) who provided each sample is identified in the database. Background information, such as unit name, sample source, unit type, swarm trend, dyke trend, age, references, location (within unit), thickness of unit, comments, location (latitude, longitude), was also provided by the researcher or derived from publications.

Unit names in the spreadsheet file correspond for the most part to those in various summaries on mafic-ultramafic magmatism in Canada (e.g. Buchan and Ernst, 2004; Ernst and Buchan 2001, 2004), but in a few cases have been updated to correspond to more recent usage. References that are included in the spreadsheet provide an overview of specific magmatic units and (or) describe geochemical studies of specific units, commonly using earlier geochemical analyses of the same samples that have been reanalyzed in the present study.

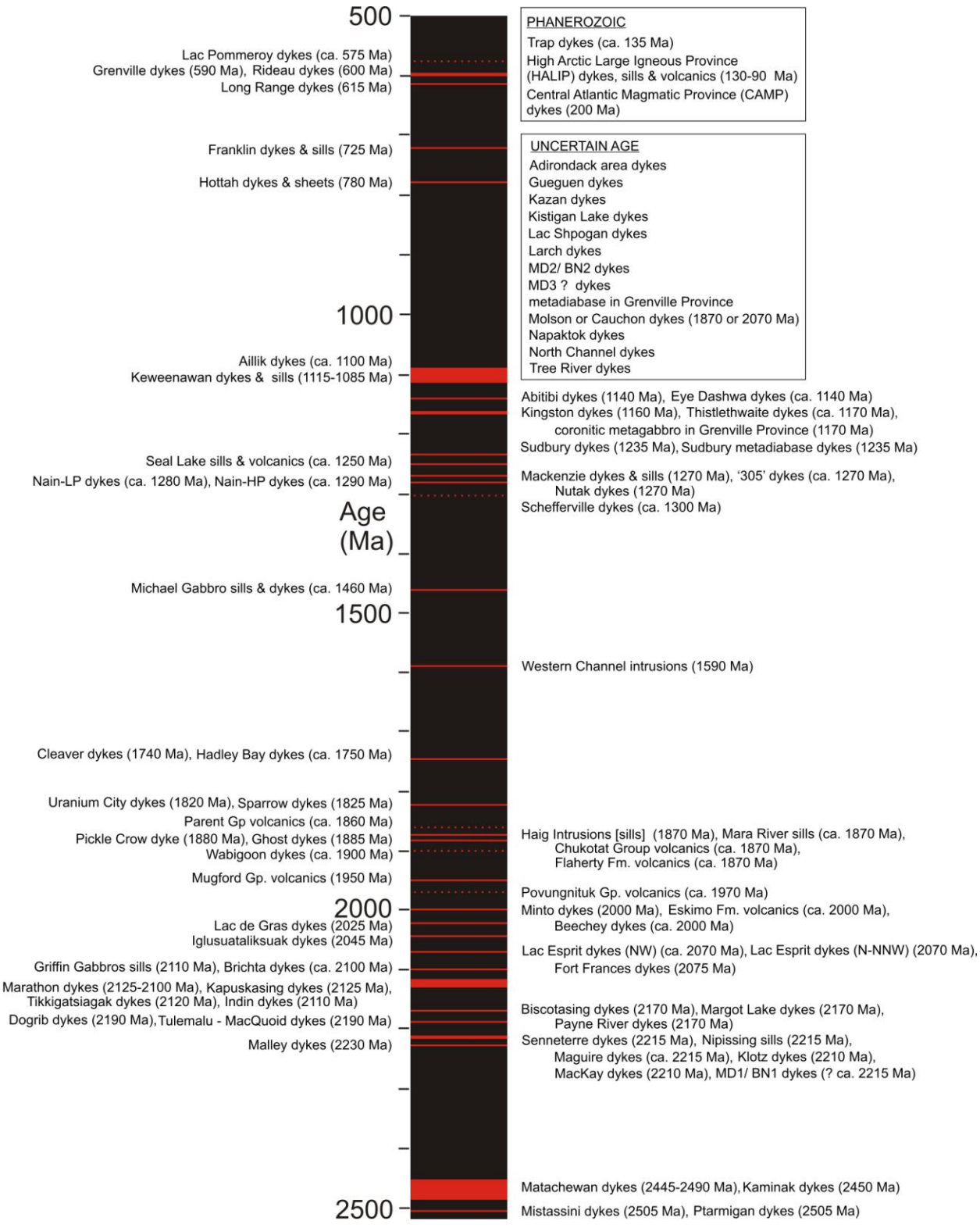

Figure 1: Age distribution of magmatic events whose geochemistry is reported in this study.

SAMPLE LOCATIONS

Latitude - longitude locations are provide for each sample, typically quoted to three decimal places of a degree. However, the actual accuracy could be somewhat less in some cases because: 1) many of the sample collections pre-date the routine use of modern Global Positioning System (GPS) measurements, and were obtained from field maps and air photos of variable scale and accuracy, and 2) the geoid datum for some sample collections has not been verified, yielding an uncertainty up to ~200 m.

GEOCHEMICAL METHODOLOGY

Samples were provided as hand samples, coarse crush, or powders. Hand samples and coarse crush were powdered at the Geological Survey of Canada using a ceramic ring mill. Most previously powdered samples were also prepared in a ceramic ring mill. However, an aluminum ring mill was used for some Matachewan dyke samples, and a tungsten carbide mill for some Abitibi dyke samples. Given the analytical techniques used in this study, there is no contamination effect on the major and trace element analyses.

Geochemical analyses for major and trace elements were performed at the Geological Survey of Canada Laboratories (Analytical chemistry services) (http://gsc.nrcan.gc.ca/labs/chem_e.php). Major elements were determined by fused disk wavelength dispersive X-ray Fluorescence (XRF), and trace elements by Inductively Coupled Plasma - Emission Spectrometry (ICPES) and Inductively Coupled Plasma - Mass Spectrometry (ICPMS). Ferrous iron is determined using the Wilson Method (titrimetric), and ferric iron is calculated from the difference with Fe total (from XRF). H_2O (total), CO_2 (total) and S (total) are determined using combustion followed by infra-red spectrometry. High precision Fl, Cl and S are determined by the pyrohydrolysis method followed by ion chromatography (IC). Loss on ignition is determined by gravimetry at 900^o C. Detection limits are provided in the spreadsheet file.

Pt and Pd were determined at Acme Analytical Laboratories Ltd. (www.acmelab.com). The method was lead collection fire-assay fusion for total sample decomposition, followed by digestion of the Ag dore bead and ICP-MS analysis. Detection limits are provided in the spreadsheet file. Note that the Au detection limit may vary due to natural contamination in commercial flux and sample size. Rh values are qualitative to semi-quantitative depending on the nature of the samples.

In addition, 75 samples were sent to Geoscience Laboratories (Geo Labs; http://www.mndm.gov.on.ca/mines/ogs/labs/default_e.asp) for precious metal determination by nickel sulphide fire-assay (NiS FA) with an ICP-MS finish. This is considered the foremost method for the determination of Au and the PGEs in geological samples. The sample is fused with a mixture of Ni and S to produce a nickel sulphide button. Dissolution of the button is followed by co-precipitation with Te that produces a concentrate containing all six precious metals that is dissolved in aqua regia prior to analysis. Data were obtained for Au, Pt, Pd, Rh, Ru and Ir. Detection limits are provided in the spreadsheet file.

Each batch of samples that were submitted for analysis included material from CANMET standard TDB1 as a ‘blind’ internal check. TDB1 is a certified geochemical standard of Mackenzie diabase from Tremblay Lake, Saskatchewan

(http://www.nrcan.gc.ca/mms-smm/tect-tech/ccrmp/cer-cer/tdb-1-eng.pdf). These internal standard analyses are included in the spreadsheet file. They exhibit excellent reproducibility, and match the 'best values' quoted on the above website, and therefore confirm the high quality of the entire dataset.

Unavailable data (e.g. where the titrimetric analysis for FeO wt% was not done) are indicated by -999. Analyses below the detection limit for that element are indicated by the negative of the detection limit.

ACKNOWLEDGEMENTS

The data in the spreadsheet file were obtained under TGI-1 (Targeted Geoscience Initiative; http://ess.nrcan.gc.ca/tgi/tgi1rev_e.php) project TGI010004 (2001-2003) "Locating new platinum group element exploration targets in Canada based on a mantle plume model". Preparation of this database as an Open File was funded under the GEM (Geo-mapping for Energy and Minerals; http://gsc.nrcan.gc.ca/gem/index_e.php) program. Tim West prepared the kml file displaying the sample locations on Google Earth®. We thank Wouter Bleeker for a helpful internal GSC review.

REFERENCES (includes references for these Background Notes and accompanying spreadsheet file):

Aspler, L.B., Cousens, B.L., and Chiarenzelli, J.R., 2002. Griffin gabbro sills (2.11 Ga), Hurwitz Basin, Nunavut, Canada: long-distance lateral transport of magmas in western Churchill Province crust; Precambrian Research, v. 117, p. 269-294.

Baragar, W.R.A., 1974. Volcanic studies in the Cape Smith – Wakeham Bay belt, New Quebec; Geological Survey of Canada, Paper 74-1, p. 155-157.

Baragar, W.R.A., 2007. Geology, Sleeper Islands, eastern Hudson Bay, Nunavut; Geological Survey of Canada, Map 2114A, scale 1:75,000.

Baragar, W.R.A., Ernst, R.E., Hulbert, L., and Peterson, T., 1996. Longitudinal petrochemical variation in the Mackenzie dyke swarm, northwestern Canadian Shield; Journal of Petrology, v. 37, p. 317-359.

Bostock, HH., and van Breemen, O., 1992. The timing of emplacement and distribution of the Sparrow diabase dyke swarm, District of Mackenzie, Northwest Territories; *in* Radiogenic age and isotopic studies, Report 6, Geological Survey of Canada, Paper 92-2, p. 49-55.

Buchan, K.L. and Ernst, R.E., 2004. Diabase dyke swarms and related units in Canada and adjacent regions; Geological Survey of Canada, Map 2022A, scale 1:5,000,000 and accompanying notes.

Buchan, K.L. and Ernst, R.E., 2006. Giant dyke swarms and the reconstruction of the Canadian Arctic islands, Greenland, Svalbard and Franz Josef Land; *in* (ed.) E. Hanski, S. Mertanen, T. Rämö, and J. Vuollo; Dyke swarms: time markers of crustal evolution, Taylor & Francis / Balkema, Netherlands, p. 27-48.

Buchan, K.L., Ernst, R.E., Bleeker, W, Davis, W.J., Villeneuve M., van Breemen, O., Hamilton, M., and Söderlund, U., 2010. Proterozoic magmatic events of the Slave craton, Wopmay Orogen and environs; Geological Survey of Canada, Open File 5985.

Buchan, K.L., Goutier, J., Hamilton, M.A., Ernst, R.E., and Matthews, W.A., 2007. Paleomagnetism, U-Pb geochronology and geochemistry of Lac Esprit and other dyke swarms, James Bay area, Quebec, and implications for Paleoproterozoic deformation of the Superior Province; Canadian Journal of Earth Sciences, v. 44, p. 643-664.

Buchan, K.L., Halls, H.C., and Mortensen, J.K., 1996. Paleomagnetism, U-Pb geochronology, and geochemistry of Marathon dykes, Superior Province, and comparison with the Fort Frances swarm; Canadian Journal of Earth Sciences, v. 33, p. 1583-1595.

Buchan, K.L., Harris, B.A., Ernst, R.E., and Hanes, J.A., 2003. Ar-Ar dating of the Pickle Crow diabase dyke in the western Superior craton of the Canadian Shield of Ontario, and implications for a possible plume centre associated with ca. 1880 Ma Molson magmatism of Manitoba; Geological Association of Canada - Mineralogical Association of Canada - Society of Economic Geologists, Joint Annual meeting, Abstracts, v. 28, p. 17.

Buchan, K.L., LeCheminant, A.N., and van Breemen, O., 2009. Paleomagnetism and U-Pb geochronology of the Lac de Gras diabase dyke swarm, Slave Province, Canada: implications for relative drift of Slave and Superior provinces in the Paleoproterozoic; Canadian Journal of Earth Sciences, v. 46, p. 361-379.

Buchan, K.L., Mortensen, J.K., and Card, K.D., 1993. Northeast-trending Early Proterozoic dykes of southern Superior Province: multiple episodes of emplacement recognized from integrated paleomagnetism and U-Pb geochronology; Canadian Journal of Earth Sciences, v. 30, p. 1286-1296.

Buchan, K.L., Mortensen, J.K., Card, K.D., and Percival, J.A., 1998. Paleomagnetism and U-Pb geochronology of diabase dyke swarms of Minto Block, Superior Province, Quebec, Canada; Canadian Journal of Earth Sciences, v. 35, p. 1054-1069.

Cadman, A.C., Heaman, L., Tarney, J., Wardle, R., and Krogh, T.E., 1993. U-Pb geochronology and geochemical variation within two Proterozoic mafic dyke swarms, Labrador; Canadian Journal of Earth Sciences, v. 30, p. 1490-1504.

Cadieux, I., 1980. Differentiation of a basic sill, Sleeper Islands, N.W.T.; B.Sc. thesis, University of Ottawa, Ottawa, Canada, 111 p.

Condie, K.C., Bobrow, D.J., and Card, K.D., 1987. Geochemistry of Precambrian mafic dykes from the Southern Province of the Canadian Shield; *in* (ed.) H.C. Halls and W.F. Fahrig; Mafic dyke swarms, Geological Association of Canada, Special Paper 34, p. 95-108.

Davis, W.J., Bleeker, W., Hulbert, L., and Jackson, V., 2004. New geochronological results from the Slave Province Minerals and Geoscience Compilationand Synthesis Project, GSC Northern Resources Program, 32nd Yellowknife Geoscience Forum Abstracts, v. 2004, p. 20.

Davidson, A. and van Breemen, O., 1988. Baddeleyite – zircon relationships in coronitic metagabbro, Grenville Province, Ontario: implications for geochronology; Contributions to Mineralogy and Petrology, v. 100, p. 291-299.

Davidson, A., Hamilton, M.A., Heaman, L.M., Ernst, R.E., and Buchan, K.L., 2009. Grenville diabase dyke swarm: extent, age and comparative geochemistry; EOS Transactions of the American Geophysical Union, v. 90 (22), Joint Assembly Supplement, Abstract GA13B-01.

Emslie, R.F., Hamilton, M.A., and Gower, C.F., 1997. The Michael Gabbro and other Mesoproterozoic lithospheric probes in southern and central Labrador; Canadian Journal of Earth Sciences, v. 34, p. 1566-1580.

Ermanovics, I., and Van Kranendonk, M.J., 1998. Geology of the Archean Nain Province and Paleoproterozoic Torngat Orogen in a transect of the North River-Nutak map area, Newfoundland (Labrador) and Quebec; Geological Survey of Canada, Bulletin 497, 156 p.

Ernst, R.E., 1994. Mapping the magma flow pattern in the Sudbury dyke swarm in Ontario using magnetic fabric analysis; Geological Survey of Canada, Current Research, 1994-E, p. 183-192.

Ernst, R.E. and Baragar, W.R.A., 1992. Evidence from magnetic fabric for the flow pattern of magma in the Mackenzie giant radiating dyke swarm; Nature, v. 356, p. 511-513.

Ernst, R.E. and Bell, K., 1992. Petrology of the Great Abitibi Dyke, Superior Province, Canada; Journal of Petrology, v. 33, p. 423-469.

Ernst, R.E. and Buchan, K.L., 1993. Paleomagnetism of the Abitibi dyke swarm, southern Superior Province, and implications for the Logan Loop; Canadian Journal of Earth Sciences, v. 30, p. 1886-1897.

Ernst, R.E. and Buchan, K.L., 2001. Large mafic magmatic events through time and links to mantle-plume heads; *in* (ed.) R.E. Ernst and K.L. Buchan, Mantle plumes: their identification through time; Geological Society of America, Special Paper 352, p. 483-575.

Ernst, R.E. and Buchan, K.L., 2004. Large igneous provinces (LIPs) in Canada and adjacent regions: 3 Ga to present; Geoscience Canada, v. 31, p. 103-126.

Ernst, R.E. and Hulbert, L.J., 2003. Background Pt-Pd levels in mafic Large Igneous Provinces (LIPs) in Canada; Geological Survey of Canada, Open File 4472.

Ernst, R.E., Buchan, K.L., Heaman, L.M., Hart, T.R., and Morgan, J., 2006. Multidisciplinary study of north- to north-northeast-trending dikes in the region west of the Nipigon Embayment: Lake Nipigon Region Geoscience Initiative; Ontario Geological Survey, Miscellaneous Release-Data (MRD) 194, 22 p. (CD-ROM, ISBN 0-7794-9937-9).

Fahrig, W.F., 1976. Paleomagnetism and age of the Schefferville diabase dykes; Geological Survey of Canada, Paper 76-1B, p. 153-155.

Fahrig, W.F., 1987. The tectonic settings of continental mafic dyke swarms: failed arm and early passive margin; *in* (ed.) H.C. Halls and W.F. Fahrig; Mafic dyke swarms, Geological Association of Canada, Special Paper 34, p. 331-348.

Fahrig, W.F. and Larochelle, A., 1972. Paleomagnetism of the Michael Gabbro and possible evidence of the rotation of Makkovik subprovince; Canadian Journal of Earth Sciences, v. 9, p. 1287-1296.

Fahrig, W.F., Christie, K.W., Chown, E.H., Janes, D., and Machado, N., 1986. The tectonic significance of the some basic dyke swarms in the Canadian Superior Province, with special reference to the geochemistry and paleomagnetism of the Mistassini swarm, Quebec, Canada; Canadian Journal of Earth Sciences, v. 23, p. 238-253.

Fahrig, W.F., Christie, K.W., Eade, K.E., and Tella, S., 1984. Paleomagnetism of the Tulemalu dykes, Northwest Territories, Canada; Canadian Journal of Earth Sciences, v. 21, p. 544-553.

Fraser, J.A., 1963. Geology, Northeastern District of Mackenzie, Northwest Territories; Geological Survey of Canada, Map 45-1963, scale 1:506,880.

Frith, R.A., 1982. Second preliminary report on the geology of the Beechey Lake-Duggan Lake map areas, District of Mackenzie; Geological Survey of Canada, Current Research, Part A, Paper 82-1A, p. 203-211.

Green, J.C., Bornhorst, T.J., Chandler, V.W., Mudrey, M.G., Myers, P.E., Pesonen, L.J., and Wilband, J.T., 1987. Keweenawan dykes of the Lake Superior region: evidence for evolution of the Middle Proterozoic Midcontinent Rift of North America; *in* (eds.) H.C. Halls and W.F. Fahrig: Mafic dyke swarms, Geological Association of Canada. Special Paper 34, p. 289-302.

Hall, R.P. and Hughes, D.J., 1990. Precambrian mafic dykes of southern Greenland; *in* (ed.) A.J. Parker, P.C. Rickwood, and D.H. Tucker; Mafic dykes and emplacement mechanisms, Balkema, Rotterdam, p. 481-495.

Halls, H.C., 1986. Paleomagnetism, structure, and longitudinal correlation of Middle Precambrian dykes from northwestern Ontario and Minnesota; Canadian Journal of Earth Sciences, v. 23, p. 142-157.

Halls, H.C., 1991. The Matachewan dyke swarm, Canada: an early Proterozoic magnetic field reversal; Earth and Planetary Science Letters, v. 105, p. 279-292.

Halls, H.C. and Davis, D.W., 2004. Paleomagnetic and U-Pb geochronology of the 2.17 Ga Biscotasing dyke swarm, Ontario, Canada: evidence for vertical-axis crustal rotation across the Kapuskasing Zone; Canadian Journal of Earth Sciences, v. 41, p. 255-269.

Halls, H.C. and Heaman, L.M., 2000. The paleomagnetic significance of new U-Pb age data from the Molson dyke swarm, Cauchon Lake area; Canadian Journal of Earth Sciences, v. 23, p. 142-157.

Halls, H.C. and Palmer, H.C., 1990. The tectonic relationship of two Early Proterozoic dyke swarms to the Kapuskasing Structural Zone: a paleomagnetic and petrographic study; Canadian Journal of Earth Sciences, v. 27, p. 87-103.

Halls, H.C., Davis, D.W., Stott, G.M., Ernst, R.E., and Hamilton M.A., 2008. The Paleoproterozoic Marathon Large Igneous Province: new evidence for a 2.1 Ga long-lived mantle plume event along the southern margin of the North American Superior Province; Precambrian Research, v. 162, p. 327-353.

Hamilton, M.A., 1993. Preliminary report on the geology of the Mugford Group volcanics, northern coastal Labrador; Geological Survey of Canada, Paper 93-1C, p. 349-357.

Hamilton, M.A., 1994. Tholeiitic and weakly alkalic basaltic volcanism of the Mugford Group, northern Labrador: preliminary geochemical results; Geological Survey of Canada, Current Research 1994C, p. 333-342.

Hamilton, M.A. and Buchan, K.L., submitted. U-Pb geochronology of the Western Channel Diabase, northwestern Laurentia: implications for a large 1.59 Ga magmatic province,

Laurentia's APWP and paleocontinental reconstructions of Laurentia, Baltica and Gawler craton of southern Australia; submitted to Precambrian Research.

Hamilton, M.A., Buchan, K.L., and Hodych, J.P., 2010. Nain/Gardar-aged mafic dykes as a temporal and magmatic 'bridge' across Atlantic cratonic blocks: geochronologic, paleomagnetic and geochemical evidence from Labrador and SW Greenland; Sixth International Dyke Conference, Varanasi, India, abstract.

Hamilton, M.A. and Stott, G.M., 2008. The significance of new U/Pb baddeleyite ages from two Paleoproterozoic diabase dikes in Northern Ontario; *in* Ontario Geological Survey, Summary of Field Work and Other Activities 2008, Open File Report 6226, p.17-1 to 17-10.

Hamilton, M.A., Ryan, A.B., Emslie, R.F., and Ermanovics, I.F., 1998. Identification of Paleoproterozoic anorthositic and monzonitic rocks in the vicinity of the Mesoproterozoic Nain Plutonic Suite, Labrador: U-Pb evidence; *in* Radiogenic age and isotopic studies: Report 11, Geological Survey of Canada, Current Research 1998-F, p. 23-40.

Harlan, S.S., Heaman, L., LeCheminant, A.N., and Premo, W.R., 2003. Gunbarrel mafic magmatic event: a key 780 Ma time marker for Rodinia plate reconstructions; Geology, v. 31, p. 1053-1056.

Hart, T.R. and MacDonald, C.A., 2007. Proterozoic and Archean geology of the Nipigon Embayment: implications for emplacement of the Mesoproterozoic Nipigon diabase sills and mafic to ultramafic intrusions; Canadian Journal of Earth Sciences, v. 44, pp. 1021-1040.

Heaman, L.M., Easton, R.M., Hart, T.R., Hollings, P. MacDonald, C.A., and Smyk, M. 2007. Further refinement to the timing of Mesoproterozoic magmatism, Lake Nipigon region, Ontario; Canadian Journal of Earth Sciences, v. 44, p. 1055-1086.

Heaman, L.M., LeCheminant, A.N., and Rainbird, R.H., 1992. Nature and timing of Franklin igneous events, Canada: implications for a Late Proterozoic mantle plume and the break-up of Laurentia; Earth and Planetary Science Letters, v. 109, p. 117-131.

Hollings, P., Hart, T., Richardson, A., and MacDonald, C.A., 2007. Geochemistry of the Mesoproterozoic intrusive rocks of the Nipigon Embayment, northwestern Ontario: evaluating the earliest phases of rift development; Canadian Journal of Earth Sciences, v. 44, p. 1087-1110.

Hollings, P., Smyk, M., Heaman, L.M., and Halls, H., 2010. The geochemistry and paleomagnetism of dikes an d sills associated with the Mesoproterozoic Midcontinent Rift near Thunder Bay, Ontario, Canada; Precambrian Research, in press.

Irving, E., Baker, J., Hamilton, M.A. and Wynne, P.J., 2004. Early Proterozoic geomagnetic field in western Laurentia: implications for paleolatitudes, local rotations and stratigraphy; Precambrian Research, v. 129, p. 251-270.

Kjarsgaard, B.A. and Wyllie, R.J.S., 1993. Geology of the Paul Lake area (76 D/9), Lac de Gras, N.W.T.; Geological Survey of Canada, Open File Map 2739, scale 1:50,000.

Kjarsgaard, B.A., Wilkinson, L., and Armstrong, J.A., 2002. Geology, Lac de Gras kimberlite field, central Slave Province, Northwest Territories-Nunavut; Geological Survey of Canada, Open File 3238, scale 1:250,000.

Kumarapeli, P.S., 1993. A plume-generated segment of the rifted margin of Laurentia, southern Canadian Appalachians, seen through a completed Wilson cycle; Tectonophysics, v. 219, p. 47-55.

Legault, F., Francis, D., Hynes, A., and Budkewitsch, P., 1994. Proterozoic continental volcanism in the Belcher Islands: implications for the evolution of the Circum-Ungava Fold Belt; Canadian Journal of Earth Sciences, v. 31, p. 1536-1549.

LeCheminant, A.N. and Heaman, L.M., 1989. Mackenzie igneous events, Canada: Middle Proterozoic hotspot magmatism associated with ocean opening; Earth and Planetary Science Letters, v. 96, p. 38-48.

LeCheminant, A.N., Rainbird, R.H., and Villeneuve, M.E., 1996. Precambrian geology of northern Wellington Inlier, Victoria Island, Northwest Territories; in Current Research 1996-C, Geological Survey of Canada, p. 1-10.

LeCheminant, A.N., Stubley, M.P., Heaman, L.M., French, J.E., and Creaser, R.A., 2007. 1.17 Ga magmatism in the central Slave Province; Geological Association of Canada/ Mineralogical Association of Canada, Abstracts, v. 32, p. 47.

MacLaren, A.S. (compiler), 1947. Senneterre, Quebec; Geological Survey of Canada, Map 997A, scale 1:126,720.

Madore, L., and Larbi, Y., 2000. Géologie de la région de la rivière Arnaud (SNRC 25 D) et des régions littorales adjacentes (SNRC 25 C, 25 E et 25 F); Ministère des Ressources naturelles du Québec, RG 2000-05, 37 p.

Marzoli, A., Renne, P.R., Piccirillo, E.M., Ernesto, M., Bellieni, G., and De Min, A., 1999. Extensive 200-million-year-old continental flood basalts of the Central Atlantic Magmatic Province; Science, v. 284, p. 616-618.

McGlynn, J.C. and Irving, E., 1975. Paleomagnetism of Early Aphebian diabase dykes from the Slave Stuctural Province, Canada; Tectonphysics, v.26, p. 23-38.

McGlynn, J.C., Hanson, G.N., Irving, E., and Park, J.K., 1974. Paleomagnetism and age of Nonacho Group sandstones and associated Sparrow dikes, Distrcit of Mackenzie; Candian Journal of Earth Sciences, v. 11, p. 30-42.

Morelli, R.M., Hartlaub, R.P., Ashton, K.E., and Andsell, K.M. 2009. Evidence for enrichment of subcontinental lithospheric mantle from Paleoproterozoic intracratonic magmas: geochemistry and U-Pb geochronology of Martin Group igneous rocks, western Rae craton, Canada; Precambrian Research, v. 175, p. 1-15.

Moore, J.M., 1977. Orogenic volcanism in the Proterozoic of Canada; *in* (ed.) W.R.A. Baragar, L.C. Coleman, and J.M. Hall; Volcanic regimes in Canada, Geological Association of Canada, Special Paper 16, p. 127-148.

Morse, S.A., 1969. The Kiglapait layered intrusion, Labrador; Geological Society of America, Memoir 112, 204 p.

Ootes, L., Sandeman, H., Lemieux, Y., and Leslie, C., 2008. The 780 Ma Tsezotene sills, Mackenzie Mountains: a field, petrographic, and geochemical study; Northwest Territories Geoscience Office, NWT, Open File Report 2008-011.

Osmani, I.A., 1991. Proterozoic mafic dyke swarms in the Superior Province of Ontario; Chapter 17 *in* Geology of Ontario, (ed.) P.C. Thurston, H.R. Williams, R.H. Sutcliffe, and G.M. Stott; Ontario Geological Survey, Special Volume 4, pt. 1, p. 660-681.

Phinney, W.C. and Halls, H.C., 2001. Petrogenesis of the early Proterozoic Matachewan dike swarm, Canada, and implications for magma emplacement and subsequent deformation; Canadian Journal of Earth Sciences, v. 38, p. 1541-1563.

Picard, C., Lamothe, D., Piboule, M., and Oliver, R. 1990. Magmatic and geotectonic evolution of a Proterozoic ocean basin system: the Cape Smith Thrust-Fold Belt (New Quebec); Precambrian Research, v. 47, p. 223-249.

Puffer, J.H., 2002. A Late Neoproterozoic eastern Laurentian superplume: location size, chemical composition, and environmental impact; American Journal of Science, v. 302, p. 1-27.

Sandeman, H.A. and Ryan, J.J., 2008. The Spi Lake formation of the central Hearne domain, western Churchill Province, Canada: an axial intracratonic continental tholeiite trough above the cogenetic Kaminak dyke swarm; Canadian Journal of Earth Sciences, v. 45, p. 745-767.

Smith, A.R. and Sutcliffe, R.H., 1989. Keweenawan intrusive rocks in the Crystal Lake-Pigeon River area; Ontario Geological Survey, Preliminary Map P. 3139, scale 1:50,000.

St-Onge, M.R., Lamothe, D., Henderson, I., and Ford, A., 2007. Digital geoscience atlas of the Cape Smith Belt and adjacent domains, Ungava Peninsula, Quebec-Nunavut; Geological Survey of Canada, Open File 5117, DVD.

St. Seymour, K. and Kumarapeli, P.S., 1995. Geochemistry of the Grenville dyke swarm: role of plume-source mantle in magma genesis; Contributions to Mineralogy and Petrology, v. 120, p. 29-41.

Villeneuve, M. and Williamson, M.-C., 2006. ^{40}Ar-^{39}Ar dating of mafic magmatism from the Sverdrup Basin Magmatic Province; *in* (ed.) R.A. Scott and D.K. Thurston; Proceedings of the Fourth International conference on Arctic margins, OCS study, Minerals Management Service (MMS) 2006-003, U.S. Department of the Interior, p. 206-215.

Wiebe, R.A., 1985. Proterozoic basalt dikes in the Nain anorthosite complex, Labrador; Canadian Journal of Earth Sciences, v. 22, p. 1149-1157.

Wilkinson, L., Kjarsgaard, B.A., LeCheminant, A.N., and Harris, J., 2001. Diabase dyke swarms in the Lac de Gras area, Northwest Territories, and their significance to kimberlite exploration: initial results; Geological Survey of Canada, Current Research 2001-C8, 10 p.

Williamson, M.-C., 1988. The Cretaceous igneous province of the Sverdrup Basin, Canadian Arctic: field relations and petrochemical studies; Ph.D. thesis, Dalhousie University, Halifax, 417 p.