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Miscellaneous Release—Data 308 – Revised

New and Compiled Whole-Rock Geochemical and Isotope Data of Midcontinent Rift-Related Rocks, Thunder Bay Area

by R.M. Cundari[1, 2], M.A. Puumala[1], M.C. Smyk[1,2] and P. Hollings[2]

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This publication can be downloaded from
http://www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=MRD308-REV

This digital data release is an update of the Midcontinent Rift geochemical database released in 2013 as Miscellaneous Release—Data (MRD) 308. MRD 308—Revised includes new whole-rock and trace element analyses for 124 bedrock samples of mafic igneous rocks related to the Mesoproterozoic Midcontinent Rift. The release also includes a compilation of geochemical data for Midcontinent Rift-related rocks from the following previously released digital data sets: Miscellaneous Releases—Data (MRD) 114, 132, 133, 146, 147, 190, 261—Revised, 308, 319, 345, 352 and 368. The historical compilation includes 2821 spatially referenced data points with geochemical analyses. Additionally, 132 samples with Rb, Sr, Nd, Sm and/or ε_{Nd} isotope data are also included in this release, compiled from various sources. The compilation of data and a brief overview of the referenced MRDs and analytical procedures are presented in 2 Microsoft® Excel® for Office 365 (*.xlsx*) and 2 portable document format (*.pdf*) files.

The Microsoft® Excel® for Office 365 workbook, *MRD308-REV_MCR geochem compilation.xlxs*, consists of 4 worksheets, or tabs. The "INDEX" worksheet provides information on the source of information in each of the 3 other worksheets, as well as a list of abbreviations used in the various worksheets. The "FINAL_COLLATED" worksheet combines data from both the compiled and new analyses for a total of 2945 data points. The newly released data are highlighted also under the "NEW_DATA" worksheet. In the "NEW_DATA" worksheet, raw data for all samples are organized according to laboratory analytical method. Additionally, worksheet "Various_Samples" contains results for 68 samples furnished by the Ontario Geological Survey for various igneous rocks associated with the Midcontinent Rift. These 68 analyses were completed at various labs with minimal analytical information preserved. They are included in a separate tab in the Microsoft® Excel® file compilation because analytical methods and detection limits are unknown.

Note that in the "FINAL_COLLATED" worksheet, the detection limit reported is not always applicable to a specific individual analysis, as the analytical detection limits for select methods have varied over time. Therefore, it is recommended that the user refer to the original Miscellaneous Release—Data releases for specific detection limit information. For individual analyses that were reported under and over the detection range, the applicable detection limits are accurately reported.

The Microsoft® Excel® for Office 365 workbook, *MRD308-REV_MCR isotope compilation.xlxs*, consists of 2 worksheets, or tabs. The "INDEX" worksheet provides information on the sources of information for data in the other worksheet. The "Master_Isotope_Comp" worksheet combines data from the compiled analyses for a total of 132 data points.

The 2020 Geo Labs Brochure, which describes the analytical methods used at the Ontario Geological Survey Geoscience Laboratories in Sudbury, is provided in this release. Brochures for previous years may be obtained by contacting Geo Labs at geoscience.labs.ndm@ontario.ca .

Analytical Procedures

Whole-rock geochemistry

Samples were cut, crushed and milled to ~200 mesh in an agate ring mill to reduce the risk of trace element contamination (Jenner 1996). Tools and all working surfaces were cleaned with acetone between each sample. Samples were analyzed for major elements by X-ray fluorescence (XRF) and for trace and rare earth elements (REE) by inductively coupled plasma mass spectrometry (ICP–MS) at the Geoscience Laboratories (Geo Labs) of the Ministry of Energy, Northern Development and Mines in Sudbury, Ontario. Selected trace elements (e.g., Zr and Y) were analyzed by XRF using a pressed pellet to allow comparison with data generated by ICP–MS. Totals for major element oxide data were generally 100 ± 2%. Detection limits for major elements are 0.01 weight % and relative standard deviations of duplicate analyses are within 5%. Trace elements, including the rare earth elements and high-field strength elements (HFSE) analyzed at the Geoscience Laboratories, were completed on a Perkin-Elmer Elan 9000 inductively coupled mass spectrometric (ICP–MS) instrument following a variation on the protocol described by Burnham and Schweyer (2004) and Tomlinson, Bowins and Hechler (1998). Twenty-four trace elements were determined using 200 mg aliquots of powder digested by a two-stage procedure involving an initial decomposition in a closed beaker by a mixture of HF with lesser amounts of HCl and $HClO_4$, followed by a second mixture of dilute HCl and $HClO_4$ as described by Burnham et al. (2002). Detection limits for some critical elements, defined as 3σ of the procedural blank, are as follows: Th (0.032 ppm), Nb (0.044 ppm), Hf (0.085 ppm), Zr (3.2 ppm), La (0.048 ppm) and Ce (0.08 ppm) (Burnham and Schweyer 2004). All analyses performed during the course of this study utilized standards, duplicate samples and blanks, both in-house, as part of the normal procedures of the analytical facilities, as well as standards submitted for replicate analyses. Chondrite-normalized (e.g., La/Sm_n) and primitive mantle-normalized ratios (e.g., Th/Nb_{pm}) are calculated from the values of Sun and McDonough (1989).

Data Acquisition

Table 1. Summary of MRDs compiled in this work (MRD 308—Revised). A brief overview of each MRD is provided as well as links to download the MRD data from GeologyOntario.

MRD	Units Included	Sample Numbers	Reference
MRD 114	Osler Group, Mamainse Point Formation, Nipigon Embayment intrusive units	95pcl#, 89pcl#, 1-49, 87ARS-#, 88ARS-#, 79RHS-#, 80RHS-#, 81RHS-#, 82RHS-#, 01TRH#	Hart, T.R. 2002.
MRD 132	Nipigon sills, Sibley Group, Jackfish sills, English Bay Complex, Inspiration sill, Pillar Lake volcanics, Archean intrusive, metavolcanic and metasedimentary rocks	03CAM#, 02TRH#	MacDonald, C.A. and Tremblay, E. 2004.
MRD 133	Nipigon sills, Disraeli intrusion, Seagull intrusion, Sibley Group, Quetico Subprovince Archean rocks	02TRH#, 03TRH#	Hart, T.R. and Magyarosi, Z. 2004a.
MRD 146	Nipigon sills, Sibley Group, Jackfish sill, Inspiration sill, Pillar Lake volcanic rocks, Archean intrusive, metavolcanic and metasedimentary rocks	03CAM#, 04CAM#, 04TRH#	MacDonald, C.A. and Tremblay, E. 2005.
MRD 147	Nipigon sills, Hele intrusion, Disraeli intrusion, Seagull Intrusion, Sibley Group, Quetico Subprovince Archean rocks	02TRH#, 03TRH#, 04TRH#	Hart, T.R. 2005a.
MRD 190	Nipigon sills, McIntyre sill, Shillabeer sill, Seagull intrusion, Kitto intrusion, Sibley Group, Rove Formation, Quetico Subprovince Archean rocks	ADH3-#, LN#, ADH5-#, ADH6-#, AML-01-#, AML03-#, KH-#	Fralick, P.W., Hollings, P., Kissin, S.A., Heggie, G.J., Metsaranta, R., Richardson, A.J., Rogala, B. and Somarin, A.K. 2006.
MRD 261-REV	Nipigon sills, Logan sills, Pigeon River dikes, Cloud River dikes, Mount Mollie dike, Current Lake Intrusive Complex, Gunflint Formation sedimentary and volcanic rocks, Rove Formation, Moss Lake intrusion, Devon volcanic rocks, Riverdale sill	DB-#, RC#, RP#	Hollings, P., Cundari, R., Pulchalski, R. and Smyk, M.C. 2011.
MRD 308 (superseded by this release)	Robert Cundari MSc thesis samples, Christian Carl HBSc thesis samples	1##, CL-RC-#, SP-RC-#, WR#, PL#, CF-RC-#	Cundari, R.M., Carl, C.F.J., Hollings, P. and Smyk, M.C. 2013.
MRD 319	Brent Trevisan MSc thesis samples, Thunder intrusion	RTT-BT-#, RTTC-BT-#	Trevisan, B., Hollings, P. and Ames, D.E. 2015.
MRD 345	Sarah Davis HBSc thesis samples, Wolf Camp Lake volcanic rocks	WL-RC-#, WG-RC-#, LP-RC-#	Davis, S., Hollings, P. and Cundari, R.M. 2017.
MRD 352	Matt Melchiorre HBSc thesis samples, Copper Bar prospect	MM-#	Melchiorre, M., Hollings, P. and Puumala, M.A. 2018.
MRD 368	Sean O'Brien MSc thesis samples, Mount Mollie intrusion	Various	O'Brien, S., Hollings, P. and Miller, J. 2018.

Abbreviations: HBsc, Honours Bachelors of Science; MSc, Masters of Science.

Miscellaneous Release—Data 114 (Hart 2002) combined new geochemical data as well as data from the Ontario Geological Survey's Earth Resources Library and Information System (ERLIS) geochemical database and Open File Reports, including Sutcliffe (1986), Smith and Sutcliffe (1987), Lightfoot, Doherty and Sutcliffe (1989), Lightfoot (1995), Hill (1998), Lightfoot et al. (1999), and Hart, Jolette and terMeer (2002). New analytical data presented in MRD 114 were concentrated on the Osler Group volcanic rocks on Simpson Island and St. Ignace Island and the Black Bay Peninsula, as well as Lake Superior islands in Crooks Township, south of Thunder Bay. Data taken from previous studies include those from the aforementioned studies as well as from intrusive rocks of the Nipigon Embayment and the volcanic rocks of the Mamainse Point Formation.

Miscellaneous Release—Data 132 (MacDonald and Tremblay 2004) contains data gathered from the 2003 mapping program completed in the northwest Nipigon Embayment as part of the Lake Nipigon Regional Geoscience Initiative (LNRGI). This data release accompanied Open File Report 6136 (MacDonald 2004). Units included within this study are Nipigon sills, Sibley Group sedimentary rocks, the Jackfish sill, English Bay Complex, the Inspiration sill, Pillar Lake volcanic rocks and Archean intrusive, metavolcanic and metasedimentary rocks.

Miscellaneous Release—Data 133 (Hart and Magyarosi 2004a) contains data gathered from mapping in the northern Black Sturgeon River to Disraeli Lake area in the southwest Nipigon Embayment as part of the Lake Nipigon Regional Geoscience Initiative (LNRGI) in 2003. This data release accompanied Open File Report 6138 (Hart and Magyarosi 2004b). Units included within this study are Nipigon sills, the Disraeli intrusion, the Seagull intrusion, Sibley Group sedimentary rocks and Archean rocks of the Quetico Subprovince.

Miscellaneous Release—Data 146 (MacDonald and Tremblay 2005) contains data gathered from the 2004 mapping program in the west-central Nipigon Embayment as part of the Lake Nipigon Regional Geoscience Initiative (LNRGI). This data release accompanied Open File Report 6164 (MacDonald, Tremblay and Easton 2005). Units included within this study are Nipigon sills, Sibley Group sedimentary rocks, the Jackfish sill, the Inspiration sill, Pillar Lake volcanic rocks and Archean intrusive, metavolcanic and metasedimentary rocks.

Miscellaneous Release—Data 147 (Hart 2005a) contains data gathered from mapping in the area between the southern Black Sturgeon River and Seagull Lake (southwest Nipigon Embayment) as part of the Lake Nipigon Regional Geoscience Initiative (LNRGI) in 2003. This data release accompanied Open File Report 6165 (Hart 2005b). Units included within this study are Nipigon sills, the Hele intrusion, the Disraeli intrusion, the Seagull intrusion, Sibley Group sedimentary rocks and Archean rocks of the Quetico Subprovince.

Miscellaneous Release—Data 190 (Fralick et al. 2006) comprises the data released in tables and/or appendixes of Open File Report 6174 (Rogala, Fralick and Metsaranta 2005), Open File Report 6175 (Richardson, Hollings and Franklin 2005) and Open File Report 6176 (Kissin, Heggie, and Somarin 2006). Units included within this release include Nipigon sills, the McIntyre sill, the Shillabeer sill, the Seagull intrusion, the Kitto intrusion, Sibley Group sedimentary rocks, Rove Formation sedimentary rocks and Archean rocks of the Quetico Subprovince,

Miscellaneous Release—Data 261 – Revised (Hollings et al. 2011) includes samples collected from Midcontinent Rift-related mafic rocks on the Black Bay and Sibley peninsulas and around Thunder Bay. Units included in this study are Nipigon sills, Logan sills, Pigeon River dikes, Cloud River dikes, the Mount Mollie dike, the Current Lake Intrusive Complex, Gunflint Formation sedimentary and volcanic rocks, Rove Formation sedimentary rocks, the Moss Lake intrusion, the Devon volcanic rocks and the Riverdale sill.

Miscellaneous Release—Data 319 (Trevisan, Hollings and Ames 2015) includes whole-rock and trace element analyses for 104 surface and drill-core samples of mafic and ultramafic igneous rocks related to the Thunder intrusion. The data and interpretation presented in this publication represent part of an unpublished Master of Science (MSc) thesis by Trevisan at Lakehead University.

Miscellaneous Release—Data 345 (Davis, Hollings, P. and Cundari 2017) includes whole-rock and trace element analyses for 34 samples from the Mesoproterozoic Wolfcamp Lake basalts. These results form part of an Honours BSc thesis study that was a collaborative project between Lakehead University and the Ontario Geological Survey.

Miscellaneous Release—Data 352 (Melchiorre, Hollings and Puumala 2018) includes whole-rock and trace element analyses for 22 surface samples of mafic and ultramafic igneous rocks from the Copper Bar intrusion. These data form part of an Honours BSc thesis study that was a collaborative project between Lakehead University and the Ontario Geological Survey.

Miscellaneous Release—Data 368 (O'Brien, Hollings and Miller 2018) includes lithogeochemical data from 101 field and drill-core samples of the Mount Mollie dike. The data and interpretation presented in this publication represent part of an unpublished Master of Science (MSc) thesis by O'Brien at Lakehead University, Thunder Bay.

Isotope analysis

Results of isotope analysis were compiled from various sources listed in Table 2. All compiled isotope analyses follow the methods described here. Samples were analysed for radiogenic isotopes (Sr, Sm and Nd) at the Isotope Geochemistry and Geochronology Research Centre at Carleton University, Ottawa, Ontario. Strontium and rare earth elements (REE) were separated using Dowex AG50-X8 cation exchange resin. Strontium procedural blanks were less than 250 picograms. Strontium samples were loaded onto single tantalum filaments with H_3PO_4 for analysis. Strontium isotope ratios were normalised to $^{88}Sr/^{86}Sr = 8.375$ using the NIST SRM987 standard: $^{87}Sr/^{86}Sr = 0.710234 \pm 14$, n = 22. Samarium and neodymium were separated on Eichrom Ln Resin chromatographic columns containing Teflon powder coated with HDEHP (di(2-ethylhexyl)) orthophosphoric acid (Richard, Shimizu and Allegre 1976). Total procedural blanks for Nd were less than 50 picograms, and less than 6 picograms for Sm. Samples were spiked with a mixed ^{148}Nd-^{149}Sm spike prior to dissolution. Concentrations were precise to ±1%, but $^{147}Sm/^{144}Nd$ ratios were reproducible to 0.5%. Sm and Nd samples were loaded with H_3PO_4 on one side of a rhenium double filament for analysis. Isotope ratios were normalized to $^{146}Nd/^{144}Nd = 0.72190$. Analyses of the USGS standard BCR-1 yielded Nd = 29.02 ppm, Sm = 6.68 ppm, and $^{146}Nd/^{144}Nd = 0.512668 \pm 20$ (n = 4). The international La Jolla standard results gave $^{143}Nd/^{144}Nd = 0.511847 \pm 7$, n = 26 (February 2005–June 2007) and an internal lab standard gave $^{143}Nd/^{144}Nd = 0.511818 \pm 8$, n = 28 (February 2005–June 2007) and 0.511819 ± 10, n = 94 (February 2005–August 2009).

Table 2. Summary of data sources for isotope analyses compiled in this work (MRD 308—Revised).

Author or Publication	Units Included	Sample Number Codes	Reference
Hollings et al. 2007	Nipigon sills, McIntyre sill, Jackfish sill, Inspiration sill, Jackfish sill, Shillabeer sill	LN#, ADH#, AML#, 03CAM#	Hollings, P., Richardson, A., Creaser, R. and Franklin, J. 2007. Radiogenic isotope characteristics of the mid-Proterozoic intrusive rocks of the Nipigon Embayement, northwestern Ontario; Canadian Journal of Earth Science, v.44, p.1111-1129.
Hollings, Smyk and Cousens 2012	Riverdale sill, Devon volcanic rocks, Mount Mollie dike, Pigeon River dike, Cloud River dike, Logan sill, granophyre, Rove Formation	DB#	Hollings, P., Smyk, M. and Cousens, B. 2012. The radiogenic isotope characteristics of dikes and sills associated with the Mesoproterozoic Midcontinent Rift near Thunder Bay, Ontario, Canada; Precambrian Research, v.214-215, p.269-279.
MRD 308 (superseded by this release)	Pigeon River dike, Devon volcanic rocks, Mount Mollie dike, Logan sill, Cloud River dike, Coubran Lake volcanic rocks, Nipigon sill	SP-RC-#, 1##, GL-RC-#, 03CAM#, 03TRH#	Cundari, R.M., Carl, C.F.J., Hollings, P. and Smyk, M.C. 2013. New and compiled whole-rock geochemical and isotope data of Midcontinent Rift-related rocks, Thunder Bay Area; Ontario Geological Survey, Miscellaneous Release—Data 308.

Author or Publication	Units Included	Sample Number Codes	Reference
Trevisan 2015	Thunder Intrusion	RTTC-BR-#	Trevisan, B.E. 2015. The petrology, mineralization and regional context of the Thunder mafic to ultramafic intrusion, Midcontinent Rift, Thunder Bay, Ontario; unpublished MSc thesis, Lakehead University, Thunder Bay, Ontario, 299p.
Hollings, P., Fralick, P. and Cousens, B.2007	Osler Volcanics, Sibley Group	OV-#, 03RM#	Hollings, P., Fralick, P. and Cousens, B. 2007. Early history of the Midcontinent Rift inferred from geochemistry and sedimentology of the Mesoproterozoic Osler Group, northwestern Ontario; Canadian Journal of Earth Sciences, v.44, p.389-412.
Heggie 2005	Seagull Intrusion	SW#, WM#	Heggie, G.J. 2005. Whole rock geochemistry, mineral chemistry, petrology and Pt, Pd mineralization of the Seagull Intrusion, northwestern Ontario; unpublished MSc thesis, Lakehead University, Thunder Bay, Ontario, 364p.
Laarman 2007	Kitto Intrusion	ED#	Laarman, J.E. 2007. Geochemistry and PGE mineralization of the Kitto intrusion: A product of Mesoproterozoic plume magmatism through fault bounded Archean crust, east Nipigon Embayment, northern Ontario; unpublished MSc thesis, Lakehead University, Thunder Bay, Ontario, 276p.

Acknowledgments

The data presented in this publication represent part of an ongoing study focused on the geology and geochemistry of Midcontinent Rift-related intrusive and extrusive rocks present in northern Ontario, Canada. The study focuses on Midcontinent Rift-related rocks along the north shore of Lake Superior and around Lake Nipigon in order to elucidate the geochemical characteristics of Midcontinent Rift-related rocks and investigate geochemical evolutionary signatures through time. Further information pertaining to this body of work is available from the authors.

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