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Miscellaneous Release—Data 384
Geochemical Data from Ultramafic Rocks in the Lake of the Woods Greenstone Belt, Northwestern Ontario
by C. Boucher and P. Hollings

This publication can be downloaded from
http://www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=MRD384

This digital data release includes geochemical data collected as part of a project to examine ultramafic volcanic rocks in the Lake of the Woods greenstone belt near Kenora. This analytical work was supported by an Ontario Geological Survey–Lakehead University Mapping School Agreement and these data are part of an unpublished Master of Science (MSc) thesis by the senior author (Boucher 2019). Analytical support was provided by the Ontario Geological Survey (Project NW-17-003). Analytical methods are described in detail in Geoscience Laboratories (Geo Labs) brochures included on this release. This release comprises 1 Microsoft® Excel® for Office 365 (*.xlsx*) workbook file and 2 documents in portable document format (*.pdf*).

Contents

There are 3 files provided in this release (in addition to the Readme and metadata accompanying documents):

MRD384_Lake of the Woods_Geochemistry.xlsx consists of 2 worksheets that contain the results of whole-rock geochemical analyses performed at the Geoscience Laboratories (Geo Labs), Ontario Geological Survey, Sudbury.

“Sample Descriptions” worksheet provides brief descriptions and geographic co-ordinates for all samples collected as part of the project during the 2017 and 2018 field seasons. Sampling targeted ultramafic volcanic rocks, specifically komatiites, but analyzed samples also consist of intermediate to mafic volcanic rocks and sparse mafic intrusive rocks. All Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 15.

“Geochemistry” worksheet provides the major and trace element results for all 109 samples analyzed by the Ontario Geological Survey Geoscience Laboratories.

2017 Geo Labs Brochure.pdf describes the analytical methods used by the Ontario Geological Survey Geoscience Laboratories for rock samples analyzed during 2017.

2018 Geo Labs Brochure.pdf describes the analytical methods used by the Ontario Geological Survey Geoscience Laboratories for rock samples analyzed during 2018.

Summary of Project

Preliminary results of the project were reported by Boucher and Hollings (2017, 2018, 2019). Full project results can be found in Boucher (2019).

Komatiites are ultramafic rocks that are widespread in Archean terranes and are typically associated with plume magmatism; however, it has been speculated that komatiites may also be associated with subduction-related processes (e.g., Grove and Parman 2004). A long-standing debate continues over the nature of Archean plate tectonic processes, specifically if these processes are dominantly horizontal or vertical. Therefore, an evaluation of komatiitic units within the Lake of the Woods greenstone belt of the western Wabigoon terrane may provide insight into the accretionary processes along the southwestern margin of the Superior Province at *circa* 2.7 Ga.

Komatiites are widespread in Archean terranes and together with spatially associated tholeiitic basalts form an important part of many Neoarchean greenstone belts. The Archean komatiites of the Lake of the Woods greenstone belt formed on the western extension of the southern margin of the Superior Province and have not been studied using modern analytical methods. This digital compilation release consists of whole-rock geochemical analyses for 109 bedrock samples from the Lake of the Woods greenstone belt, Kenora, Ontario. Sampling targeted ultramafic volcanic rocks, specifically komatiites, but also included intermediate to mafic volcanic rocks and rare mafic intrusive rocks. Samples were collected during the 2017 and 2018 field seasons. Preliminary results were presented at the end of each field season (Boucher and Hollings 2017, 2018).

The Lake of the Woods greenstone belt is located in the western Wabigoon terrane, which consists mainly of mafic volcanic rocks and large tonalite-granodiorite plutons. It is situated along the northwestern margin of the western Wabigoon terrane, bounded to the north by the Winnipeg River and English River terranes and to the south by the Quetico terrane (Ayer and Davis 1997). The Lake of the Woods greenstone belt is divided into 3 supracrustal assemblages: 1) the lowermost mafic volcanic Lower Keewatin assemblage; 2) the compositionally diverse, predominantly volcanic, Upper Keewatin assemblage; and 3) the overlying, predominantly sedimentary, Electrum assemblage (Ayer and Davis 1997).

Detailed mapping focussed on the Upper Keewatin assemblage, which includes previously identified komatiites on the southern margin of the Long Bay Group (Boucher and Hollings 2018; Boucher 2019). The komatiites are typically metamorphosed to upper greenschist facies and include schistose varieties that do not show any preserved primary textures or mineralogy. Polyhedrally jointed flow tops were observed in a few locations. Mineral assemblages include dominantly anthophyllite-tremolite-chlorite and serpentine-tremolite-chlorite schists, as well as lesser talc-tremolite-chlorite schists. These units are moderately to intensely foliated with chlorite and lesser amphibole defining the foliation. In addition, they also include randomly oriented bladed amphibole grains that typically have tremolite cores and anthophyllite rims. The amphiboles show a chemical transition from core to rim with a loss in calcium as anthophyllite appears. Accessory phases include chromite, magnetite, ilmenite and apatite. The ultramafic rocks are very fine-grained, and their mineralogy was determined using a compilation of petrography, X-ray diffraction and scanning electron microscope analysis, as detailed in Boucher (2019).

The Upper Keewatin assemblage is composed of dominantly mafic to intermediate volcanic rocks that are typically of tholeiitic affinity with rare calc-alkalic units. A total of 41 samples were determined to be ultramafic in which the komatiite units are aluminum-undepleted komatiites (AUKs) that display major and trace element concentrations consistent with melts derived from above the garnet stability zone. The komatiites can be subdivided using trace elements into 3 suites with primitive mantle patterns that display 1) strong thorium and niobium depletion with flat HREE patterns (heavy rare earth elements), 2) weak thorium and niobium depletion with flat HREE patterns, and 3) enriched thorium with moderate niobium depletion and flat HREE. There is little to no variability in mineralogy, mineral chemistry or major element geochemistry between samples of the 3 suites defined by the trace element data.

Neodymium isotope analyses reported in Boucher (2019), in conjunction with the trace element geochemistry, suggest that some units have been weakly to moderately contaminated. Mafic tholeiitic basalt units have low- and high-titanium varieties, in which most units are dark grey to black amphibolites and rare chlorite-tremolite schists. The mafic units show similar trace element trends as the ultramafic units. The komatiites displayed varied trace element signatures, such that 3 primitive mantle patterns are present, typically with most of the variability being amongst the thorium-niobium-light rare earth element (Th-Nb-LREE) systematics. Progressive thorium enrichment and niobium depletion were present in a small population of komatiite samples, with little to no variability in mineralogy, mineralogy chemistry or major element geochemistry.

Based on the geochemical results, it is likely that multiple komatiitic flows exist in the laterally extensive Upper Keewatin assemblage. The trace element signature of the komatiite samples suggests that 3 possible flows exist. It is possible that each primitive mantle pattern noted above represents an individual flow and, thus, various interactions with contaminants and/or fluids may have occurred within each. The parallelism of trace element geochemical patterns between the thorium-enriched komatiites and the weakly niobium-depleted tholeiite basalts, and the results from numerical contamination modelling presented in Boucher (2019), suggests that the thorium-enriched komatiites were likely contaminated by tholeiitic basaltic magma. The rare tholeiite basalts that plot along the mid-ocean ridge basalt (MORB) array have slight LREE enrichment and moderate niobium depletion relative to other tholeiitic units and may have undergone minor contamination. An ascending plume with a tholeiitic contaminant and without contamination by rocks of the Lower Keewatin assemblage was likely the source for normal mid-ocean ridge basalt (N-MORB) komatiites and the thorium-enriched komatiites.

The chemistry noted in the komatiitic units suggests inclusion of contaminants upon eruption; however, the variation in niobium-depletion requires more complex processes that cannot be achieved by a single contaminant. Although it is likely that contamination occurred, it is possible also that greater fractionation within an individual flow could also result in the observed trace element variation.

The tectonic setting of the Upper Keewatin assemblage requires voluminous mafic magmatism with relatively sporadic ultramafic magmatism in a subaqueous setting given the widespread presence of pillow basalts. The belt evolution is interpreted to represent an initial primitive oceanic arc with subaqueous tholeiitic magmatism followed by calc-alkalic dominant magmatism following arc evolution. Tholeiites originating from the primitive arc display weak niobium depletion and, through geochemical modelling, it is possible that they are the contaminant that produced the thorium-enriched komatiites (Boucher 2019).

Typically, island arcs are segmented into belts, with these belts being separated by deep-penetrating crustal-scale faults that accommodate along-strike variations in the dip of subduction zones. Large-scale crustal weaknesses can act as potential magma conduits for ascending plumes, resulting in chemical and isotopic differences between the upwelling asthenosphere and arc magmatism. This could result in interaction between the rising plume and subduction-derived fluids, producing the niobium-depletion present in the komatiite samples from the Upper Keewatin assemblage.

To summarize, the Upper Keewatin assemblage hosts a variety of rock units with complex geochemistry. The data from this study are consistent with arc-related magmatism associated with abundant plume magmatism, and it is likely that some degree of plume-arc interaction occurred. With respect to accretionary processes along the southwestern margin of the Superior Province at *circa* 2.7 Ga, it is apparent that subduction-related magmatism resulted in both calc-alkalic and tholeiitic magmatism and had subsequent interaction with a rising plume that generated aluminum-undepleted komatiites (AUKs) and tholeiitic mafic volcanic rocks.

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