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The complex magmatic evolution of the Midcontinent Rift System: Reevaluating the plume model for a 1.1 Ga LIP

PETE HOLLINGS[1], MATTHEW BRZOZOWSKI[2], ROB CUNDARI[3] AND JAMES TOLLEY[1]

[1]Lakehead University
[2]Chang'an University
[3]Ontario Geological Survey

The 1.1 Ga Midcontinent Rift System (MRS) of North America comprises a series of Mesoproterozoic flood basalts and intrusive rocks emplaced in the Lake Superior region. Geochemical data from intrusive rocks of the MRS, coupled with improved constraints on timing relationships between units, suggest there are multiple, distinct mantle-source characteristics with highly variable crustal contamination histories, implying a complicated magma plumbing system. The geochemical variations suggest that units related to the MCR were tapping a heterogeneous mantle source that varied over time.

Radiogenic isotope data (Re-Os, Sm-Nd & Rb-Sr) of early MRS diabase sills, mafic–ultramafic sills and intrusions, and subaerial volcanics provide further insights into the mantle source of the MRS. The γOs(i) values of the early MRS rock suites range from slightly depleted (~10) to highly radiogenic (3857), with Initiation Stage melts exhibiting the smallest variability (4 to 50) and Early Stage melts exhibiting the greatest variability (~10 to 3857). This range of Os isotope compositions could not have resulted from variable degrees of partial melting, garnet retention in the mantle, or crystal fractionation as the values do not correlate with proxies for these. Mixing models in γOs(i)–εNd(i) space suggest that the early mafic–ultramafic intrusions and sills likely crystallized from hybrid magmas representing mixtures of enriched SCLM-derived melts with lesser plume derived melts. An SCLM source for these early MRS intrusions implies that rifting of the North American continent likely initiated passively. Given their negative to highly positive γOs(i) values, the diabase sills and subaerial lavas are suggested to have crystallized from melts derived from a depleted source region of the Keweenaw Plume and were contaminated to variable degrees by crustal material.

The fact that early MRS rock suites did not all crystallize from plume-derived melts suggests that rifting did not initiate as a result of plume impingement. Rather as the earliest rock suites (>1109 Ma) crystallized from melts derived from the SCLM, a passive rifting model is more likely.