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The 1.1 Ga Midcontinent Rift of N. America – passive rather than active rifting and the implications for mantle sources and Ni-Cu-PGE mineralization

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The ~1.1 Ga Midcontinent Rift (MCR) of North America comprises ∼1, 500, 000 km^3 of basaltic sheets, flows and intrusive rocks emplaced in the Lake Superior region during the Mesoproterozoic. The region is host to a number of Ni-Cu-PGE deposits including the Eagle Mine in Michigan, the Tamarack deposit in Minnesota, the Current Lake and Great Lakes Nickel in Ontario and the Sunday Lake and Saturday Night discoveries near Thunder Bay, Ontario. The majority of these deposits are hosted in mafic-ultramafic intrusions that were emplaced early in the history of the rift and are often associated with long-lived crustal structures.

The mantle plume model for the Midcontinent Rift (MCR) is generally accepted but cannot be fully reconciled with recent geochronological, geochemical and mineralogical data. Contrary evidence includes geochronological data which shows that MCR magmatism spans at least 20 and perhaps as much as 60 million years compared to the majority of plume-related Large Igneous Provinces (LIPs) which are characterized by a short-duration magmatic pulse or pulses (less than 1–5 m.y.). Unlike plume-related LIPS, which are typically associated with, or even recognized by, the presence of giant, radiating dike swarms up to 3000 km long, no radiating dike swarm has been associated with the MCR. Rather, the majority of MCR-related dikes occupy extensional, rift arm-parallel structures, inconsistent with a central piercing point. The presence of ultramafic rocks in the MCR has been used to argue in favour of a plume but mineral chemistry analyses from the ultramafic intrusions shows that they have maximum olivine forsterite compositions consistent with a parental magma with 8-10 wt% MgO rather than an ultramafic mantle source.

Recent studies of an extensive database of ~3000 whole rock analyses from the MCR has identified four distinct trends: the Nipigon sill trend; the Jackfish, McIntyre, Inspiration and Logan trend (JMIL); the Dyke trend (including the Pigeon River dykes, Cloud River dykes, Mount Mollie dyke and the Crystal Lake gabbro); and the Devon volcanics and the Riverdale sill trend (DR). These four trends suggest a complex and heterogeneous mantle source for the MCR that underwent a progressive depletion in incompatible elements as MCR development progressed.

The long duration of MCR magmatism, absence of primary ultramafic magmas, lack of a radiating dike swarm and heterogeneous mantle source characteristics all suggest that a passive rifting model may be more appropriate for the MCR. Upwelling of material underplated by earlier plume events centered in the vicinity of the present-day Lake Superior (e.g. the Marathon LIP) could account for the OIB-like geochemistry of the MCR. The long-lived nature of the MCR, problems with the current model and the fact that prospective intrusions may have been emplaced throughout the span of MCR-related magmatism make it increasingly important to fingerprint prospective intrusions. Identifying the unique characteristics of fertile magma sources will aid in vectoring toward new discoveries.