

# Vitric Compositions in the Onaping Formation and Their Relationship to the Sudbury Igneous Complex, Sudbury Structure\*

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## Abstract

The 1.85 Ga Sudbury structure is the largest, well-preserved, exposed example of a terrestrial impact crater; it contains world-class Ni-Cu-platinum-group element (PGE) ores associated with the igneous component. A new understanding of the geology and geochemistry of the vitric crater-fill sequence, the Onaping Formation, provides constraints on the evolution of 1.85 Ga igneous rocks in the Sudbury structure. The Onaping Formation has a well-defined mappable stratigraphy composed of three members, seven stratigraphic units, and two types of intraformational dikes that are overprinted by an impact-generated hydrothermal system. Stratigraphic and alteration mapping provided a basis for well-constrained sampling and allowed the definition of the geochemical characteristics of the less altered rocks from each unit, including vitric bombs and blocks and intraformational vitric dikes. Significantly, the identification of a least altered composition of the vitric Onaping Formation enabled an investigation of the link between the early formed vitric melt phase in the impact crater-fill sequence and the Sudbury Igneous Complex and offset dikes.

The least altered vitric Onaping Formation, represented by the massive, xenolith-poor cores of vitric bombs, blocks, and intraformational dikes, is andesitic in composition, consistent with a crustally derived melt. The melt composition (61.6 wt % SiO<sub>2</sub>, 4.28 MgO, 60 ppm Ni) is remarkably uniform throughout the Onaping Formation with a typical enrichment of large ion lithophile and light rare earth elements and pronounced negative Nb and Ti anomalies. Incompatible trace element ratios and bulk concentrations of the Onaping Formation coincide with the main mass norite and offset quartz diorite compositions of the underlying Sudbury Igneous Complex but differ distinctly from the granophyre and quartz gabbro. Root mean squared differences in composition of the vitric Onaping Formation with the units of the Sudbury Igneous Complex and quartz diorite offset dikes show that the vitric Onaping Formation does not directly match any of these igneous units but more closely resembles the composition of the Ministic and Manchester offset dikes.

The quartz diorite offset dikes have been proposed as representative of the bulk composition of the original melt of the Sudbury Igneous Complex. In detail, there are small compositional differences between North and South Range offset dikes and between these offset dikes and the concentric Manchester offset dike; however, such differences are lacking in the Onaping Formation. We propose that the least altered vitric composition of the Onaping Formation represents the best estimate of the bulk composition of an initial quenched melt, or shock melt, formed early in the evolution of the Sudbury structure and is a logical starting liquid to model the evolution of the Sudbury main mass and offset dikes. The offset dike compositions can be derived from Onaping Formation vitric shock melt by assimilation of progressively greater amounts of mafic material at deeper levels in the crater. This mafic-contaminated melt, or impact melt, developed at the base of the melt sheet and was injected into the offset dikes both prior to and contemporaneously with the earliest stages of sulfide precipitation from the Sudbury Complex. Fractionation of the mafic-contaminated melt by plagioclase and pyroxene accumulation produced the North Range felsic and mafic norite and the South Range norites. The chalcophile metal content of the Onaping Formation vitric phase closely reflects the overall metal ratios of the magmatic sulfide ores. The vitric Onaping Formation and unmineralized offset dikes have low liquidus temperatures (1,115–1,125°C) and, if these units represent the source of metals in the sulfide deposits, unusually high mass distribution coefficients for Cu and Ni and high *R* factors are necessary to account for the metal endowment.

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