A Quantitative Analysis of the Ni-Cu-PGE–Bearing Parkin and Trill Offset Dikes, Sudbury Impact Structure, Canada

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The Sudbury impact structure is a 1.85 Ga, 200- to 250-km-wide, tectonically altered multiring impact basin located in central Ontario, Canada. There are 16 known offset dikes surrounding the Sudbury Igneous Complex: seven radial, three concentric, and two discontinuous. The Sudbury structure is host to some of the world's largest Ni-Cu-PGE deposits and has been exploited for well over 100 years, and making new discoveries requires, now more than ever, a detailed understanding of the structure. The purpose of this study was to develop a quantitative and systematic way of describing and comparing the offset dikes in order to gain insight into their similarities, differences, and forming processes.

The Whistle-Parkin is an NE-SW–trending, 12-km radial offset dike located in the northeast corner of the impact structure. The Whistle segment of the dike is connected to the Sudbury Igneous Complex via a 500-m-long and 250-m-wide embayment. The Whistle extends for 1.5 km to the northeast from the embayment, where it is then apparently displaced ~2 km to the northwest. Beyond the apparent displaced fault zone is the Parkin portion of the dike, which is known for another ~10 km to the northeast. Recent exploration activities have discovered a continuation of the Whistle portion of the dike beyond the previously thought fault zone, suggesting Whistle and Parkin represent two different offset dikes, rather than a faulted continuation. The Trill is an E-W–trending, >3.5-km radial offset dike located on the western margin of the impact structure. The Trill and subsequent Trill Ni-Cu-PGE showing were discovered in 2005, roughly 4 km west of the Sudbury Igneous Complex. Since then, it has been traced east toward the Sudbury Igneous Complex, which led to the Trill East discovery in 2013, ~500 m from the Sudbury Igneous Complex and Trill embayment structure.

We present a statistical analysis of the variation in inclusion abundance, lithology, size, and long-axis orientation found along strike of the Parkin and Trill. For Parkin, a northeastern flow direction (i.e., outward from the Sudbury Igneous Complex) is implied via Cartier batholith inclusions found within the dike ~6 km northeast of their source. The Trill was emplaced into a more homogeneous target rock; thus, similar results cannot be concluded. However, many exotic inclusions are observed along strike. The orientation of the inclusions and inferred flow direction of both Parkin and Trill is found to be ≤14.4° of the local orientation of the dike (i.e., near parallel with the dike). In addition, a large geochemical dataset (>1,000 geochemical assays) was amalgamated during this study from a variety of sources for detailed investigation. We conclude that the Parkin and Trill offset dike lithologies are remarkably homogeneous in terms of REE and trace element ratios; the Ni-Cu-PGE mineralization mostly occurs within the inclusion-bearing phase and more proximal to the Sudbury Igneous Complex; and, finally, the least altered vitric composition of the Onaping Formation offers a close geochemical comparison for REE and trace elements ratios, rather than the sublayer, average Sudbury Igneous Complex, and/or host rocks.