EXPLORING THE ORIGIN OF THE OFFSET DYKES AT THE SUDBURY IMPACT STRUCTURE, CANADA.
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Introduction: The Sudbury impact structure is the remnant of a 1.85 Ga impact basin in central Ontario, Canada, with an estimated diameter of 150 to over 250 km [1–3]. The current remnant of the basin is located between the Superior province to the north – which consists of Archean granitoids and gneisses – and the Huronian province to the south – composed of Paleoproterozoic metasediments and metavolcanics. The centre of the structure is dominated by an ellipsoid ,~ 3-km thick differentiated impact melt sheet called the Sudbury Igneous Complex (SIC). From the top down, the units of the SIC are: Upper Contact Unit, Granophyre, Quartz Gabbro, and Norite [4,5]. At the base of the SIC is a mafic to intermediate discontinuous body called the Sublayer from which the Offset Dykes extend. The Offset Dykes are 50-100m thick dykes that extend radially outward from, and concentrically around, the SIC [6]. Recently, exploration completed by Wallbridge Mining Company Limited has uncovered many new outcrops of the Offset Dykes, which has provided an excellent opportunity to study the formation of large impact-related dykes.

The Offset Dykes: There are 11 known Offset Dykes, including 7 radial dykes, 2 concentric dykes, and 2 discontinuous dykes [5–6]. Their lithology is traditionally referred to as 'quartz diorite', although geochemically they are more consistent with granodiorite [7]. There are two main phases of granodiorite: a medium- to coarse-grained inclusion- and sulphide-poor phase found along the margins of the dyke, and a fine-grained inclusion- and sulphide-bearing phase found in the centre of the dyke. The Foy Offset Dyke is a radial dyke that extends northwest from the SIC (Fig. 1) for a strike of 37 km, and ranges from 400 m across at its southern end to 50 m at distal portions [9].

Emplacement Models for the Foy: Various models for the emplacement mechanism(s) and timing of the Offset Dykes have been proposed (see [8] and refs. therein). Two models are examined here for the formation of the Foy Offset Dyke:

Multiple Emplacement Model: The inclusion-poor phase was emplaced first and crystallized. This was followed by a later emplacement of the inclusion-bearing phase that carried the inclusions and sulphides.

Single Emplacement and Flow Differentiation: The dykes were emplaced during a single event that brought the inclusions and sulphides from the base of the melt sheet. The flow was strong enough to produce a velocity gradient that moved the large clasts and heavier sulphides into the centre of the dyke.

Field Observations: Three variations of granodiorite have been observed at the Foy (Fig. 2, 3). The inclusion-poor (IP) variety is found along the margins of the dyke, and is found less-frequently in exposed outcrops closer to the SIC. The inclusion-bearing phase could potentially be subdivided into an inclusion-bearing (IB) and inclusion-rich (IR) phase (Fig. 3d), although the distinction is subtle. The IR phase is slightly coarser, lighter colour, and richer in small felsic clasts. The IR phase appears to occur in 'pods' within the IB phase, and is more common closer to the SIC. The IB phase occurs as thin intrusions within the IP phase (Fig. 3a), and the IP phase has been observed as inclusions within the IB phase (Fig. 3b). The contacts between the phases are gradational (Fig. 3c, d).

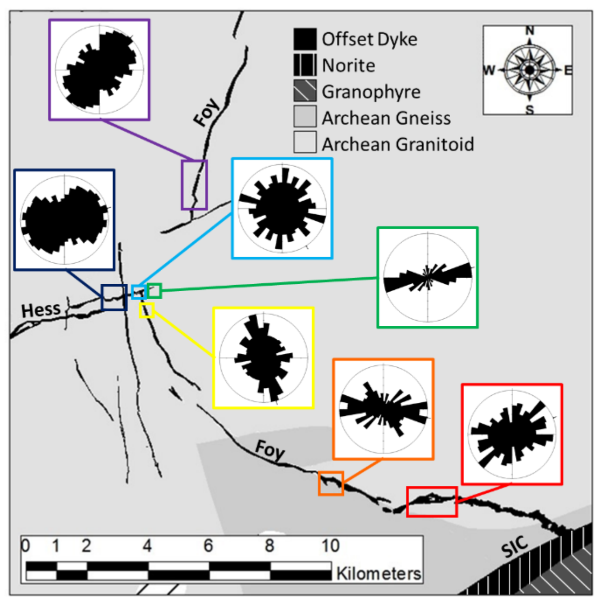

Figure 1. A simplified geological map of the Foy Offset Dyke extending from the SIC. Shown are the orientations of the long-axis of clasts represented by rose diagrams. The rose diagrams are divided into 10˚ segments and the tick intervals represent 2% of the measurements collected.

Inclusions: Clasts are typically small, <2 cm in size; however, they range from <1mm to over 5m. Lithologies include, listed according to decreasing abundance:

granitoids, gneisses, mafic clasts from various dyke swarms in the region (Nippissing Diabase, and the Matachewan Diabase), inclusion-poor and inclusion-bearing granodiorite, and minor amounts of metasediments. Granite clasts have more irregular and fluidal contacts, and are often surrounded by smaller granite clast fragments. Gneiss, quartz diorite, and mafic clasts are typically well rounded with sharp contacts. Granodiorite clasts occasionally have indistinct contacts with very irregular shapes.

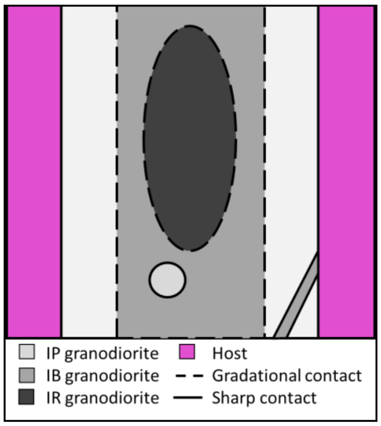

Figure 2. A simplified plan-view of the Foy, showing the relationship of the three phases of granodiorite. See text for description.

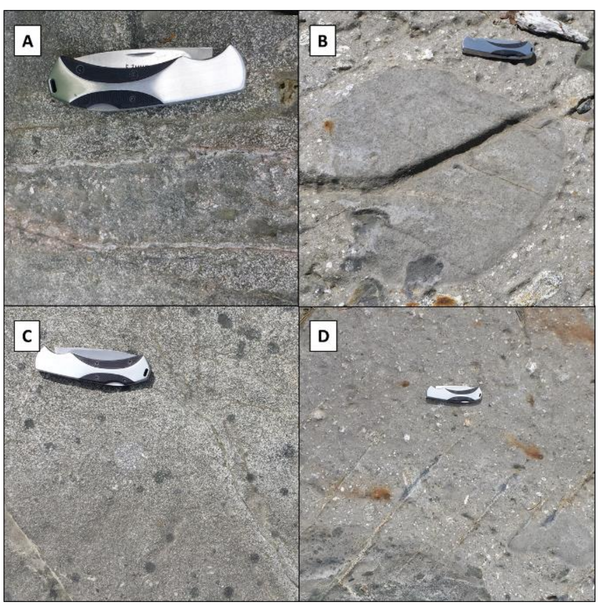

Figure 3. Photographs of the granodiorite phases of the Foy Offset Dyke north of the Foy-Hess Intersection. *A)* A thin dyke of the IB phase intruding the IP phase; *B)* A clast of the IP phase within the IB phase; *C)* A gradational contact between the IP (top) and IB (bottom) phases; *D)* A gradational contact between the IB (top) and IR (bottom) phases.

The clasts are oriented sub-parallel to the local host-dyke contact, with the exception of the Foy-Hess intersection, which showed no clear trends in orientation (Fig. 1). Clasts found closer to the dyke-host contact or contacts between the different phases more commonly share this orientation, whereas clasts in the centre of the dyke are more randomly oriented. The average clast content of each phase per m^2 is: <10 clasts for IP, ~75–125 for IB, and ~150–200 for IR. No significant patterns observed regarding variations in clast size or lithology along strike of the dyke.

Discussion: At present, neither model is sufficient to explain all the observations.

Evidence in support of the *multiple-emplacement* model includes: (1) the clear cross-cutting relationships between the phases. This suggests that there was sufficient time between the initial inclusion-poor emplacement and the later inclusion-bearing phases for the inclusion-poor phase to solidify; and (2) the sharp changes in clast abundance between the phases. If the different phases were due to flow differentiation alone, a gradational change in clast abundance would be expected, rather than a sudden change.

Evidence in support of the *flow differentiation* model includes: (1) the presence of primary sulphides in *all* phases of granodiorite, not just the inclusion-bearing phases. This indicates that both phases were emplaced after sulphides had segregated out from the impact melt sheet; (2) the alignment of clasts parallel to the contacts, which would be expected if flow differentiation occurred; and (3) the gradational nature of the contacts between the phases.

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