FORMATION AND ORIGIN OF METABRECCIA FROM THE PARKIN OFFSET DYKE AT THE SUDBURY IMPACT STRUCTURE. D. Anders[1], G. R. Osinski[1,2], R. A. F. Grieve[1,] and Attila Péntek[3], [1]Dept. of Earth Sciences/Centre for Planetary Science and Exploration, University of Western Ontario, Canada (dander53@uwo.ca), [2]Dept. of Physics and Astronomy, University of Western Ontario, Canada, [3]Wallbidge Mining Company Limited.

Introduction: The 1.85 Ga Sudbury structure, located in Ontario, Canada, is the remnant of a multi-ring basin [1], with an estimated original diameter of 200 – 260 km [2] (Fig. 1). The so called Offset Dykes (Fig. 1), a unique feature of the Sudbury structure, are concentric and radial dykes originating from embayments of the Sudbuy Igneous Complex (SIC) and the Sublayer [3]. The dykes are composed of two major lithologies: the fine-grained and mineralized Inclusion-rich Quartz Diorite (IQD) in the middle of the dyke, and the coarser-grained Quartz Diorite (QD) at the margins, which contains no or less clasts and is free of mineralization [4, 5, 6, 7].

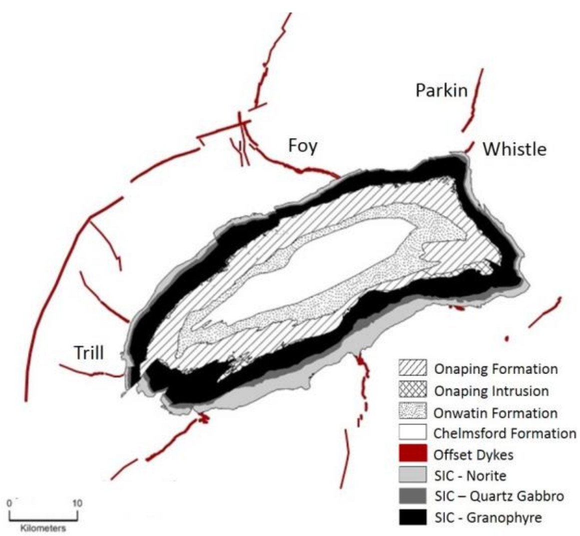

Fig. 1. Simple map of the Sudbury impact structure showing the Offset Dykes in red (modified after [8]).

A third lithology, the so-called Metabreccia (MTBX), has so far only been reported in the North Range at the Southern Parkin, the Whistle, the Trill, and the Foy Offset Dyke (Fig. 1). This is an enigmatic lithology with several proposed origins. It was originally proposed to be metamorphosed Footwall Breccia [9]. More recently, other studies from the Parkin and Whistle Offset Dyke suggested a similar formation process for both, MTBX and QD/IQD, i.e., formed by injection of a melt originated from the SIC into fractures around the Sudbury structure during or after the impact [10, 11]. Despite its economic importance as host for PGE mineralization, little is known about MTBX and it is one of the major overlooked factors in Offset Dyke research. Understanding the formation of MTBX and, thus, the Offset Dykes is an important detail in the process of crater formation at Sudbury.

Methods and Samples: Detailed field investigation of the different lithologies and contact relationships was carried out at Parkin in the summers of 2013 and 2014. Polished thin sections of samples collected from the Parkin Offset Dyke were examined by optical microscopy, in order to characterize mineralogy, microstructures and textures. Inductively coupled plasma atomic emission spectroscopy (ICP-AES) and Inductively coupled plasma mass spectrometry (ICP-MS) whole rock analyses provided major, minor, and trace element compositions.

Field Observations: MTBX has been detetcted as pods within the Parkin Dyke, as clasts within QD/IQD and also intermingling with QD/IQD. It is associated with mineralization, contains disseminated to blebby sulfides and is directly in contact with gossanized pods and gossanized mafic clasts.

MTBX is composed of clasts in an aphanitic, grey to black, locally milky matrix that usually weathers light grey, sometimes with a bluish tint (Fig. 2a). Compared to IQD, it usually has a higher amount of clasts, smaller grain size and does not contain the large green amphiboles typical of IQD. However, it is locally difficult to distinguish MTBX from IQD. The dominant clast population are clasts composed of only quartz, or quartz and feldspar and green to black mafic clasts. A very distinctive feature on the weathered surface are small pits and depressions representing relicts of mafic clasts that have been removed by weathering processes (Fig. 2a).

Petrology: The matrix of MTBX is mainly composed of quartz and feldspar; minor minerals include biotite, pyroxene, amphibole and isolated chlorite, epidote with calcite as a result of hydrothermal alteration. The matrix is characterized by a fine-grained intergrowth of quartz and feldspar with merging, interlocking, and irregular grain boundaries and shows features of recrystallization (Fig. 2b): i) Subgrains included into neighbouring grains as a result of bulging; ii) progressed missorientation of grains leading to subgrain rotation; and iii) small lobated, embayed grains with irregular boundaries, and dark rims are a result of grain boundary migration. No preferred mineral orientation, layering, banding or other deformation features have been detected within the MTBX matrix. Interstitial micrographic intergrowth, which locally has been observed in IQD and QD, has not been detected in MTBX.

Clasts within MTBX display signs of recrystallization. They are usually rounded to subrounded, embayed and show reaction rims composed of mafic minerals, which is a sign of partial melting, dissolution and chemical reaction.

Geochemistry: MTBX is usually more felsic than QD/IQD containing up to 67 wt% SiO_2 while the majority of QD and IQD samples from the Parkin Offset Dyke show less than 60 wt% SiO_2. Rare Earth Element (REE) Spider plots of IQD, QD and MTBX normalized to the average felsic Norite of the SIC [4] are shown in Figure 2c. It is interesting to note that QD and IQD are very similar, while MTBX shares no similarities with IQD or QD. While IQD and QD are enriched in all REEs, MTBX is enriched in light REE and depleted in heavy REE. This specific REE pattern corresponds to the REE pattern of granitic and felsic volcanic country rocks.

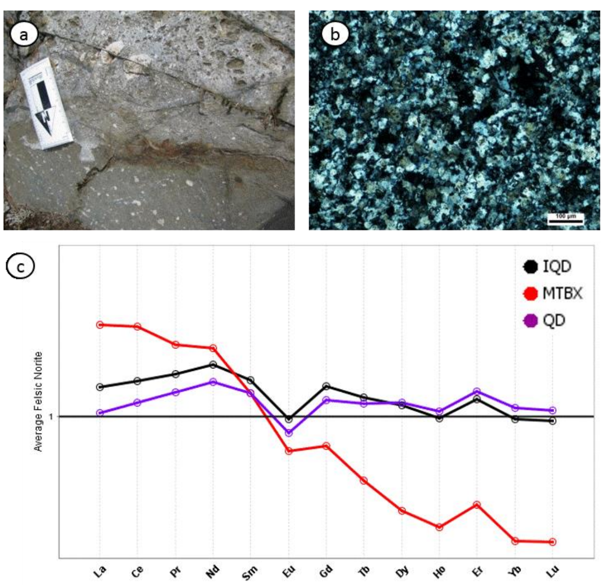

Fig. 2. a) Field image showing MTBX (above) in contact to a clast of Matachewan Diabase from the Parkin Offset Dyke (length of the card is 15 cm). b) Optical photomicrograph of the recrystallized MTBX matrix (width of the image is approximately 1cm). c) REE spider plot of IQD, QD and MTBX from samples of the Parkin Offset Dyke.

Interpretations: MTBX has only been reported from four dykes in the North Range: Southern Parkin, Whistle, Trill and Foy (Fig. 1). However, it seems likely that more MTBX, which has yet to be identified, exist around the Sudbury structure. So far, field observations, optical microscopy, and geochemical investigations carried out in this study do not point to a genetic relationship between QD/IQD and MTBX. While QD/IQD are characterized by an igneous matrix crystallized from a melt, MTBX shows features of intensive recrystallization (Fig. 2b). This observation does not support the theory of a similar formation processes for MTBX and QD/IQD as proposed by Murphy and Spray (2002) and Lafrance et al. (2014). Furthermore, geochemical trace element data points to MTBX being not genetically related to QD/IQD (Fig. 2c), nor to different units of the SIC and the Sublayer.

Based on the investigations of this study, it seems more likely that MTBX is, in fact, a metamorphosed Footwall Breccia as originally proposed by Farrow and Lightfoot (2002). The intensive recrystallized matrix (Fig. 2b) shows similarities with the partially recrystallized and molten Footwall Breccia. Furthermore, Footwall Breccia mainly exists in the North Range, which would explain why Metabreccia is limited to dykes in the North Range of the impact structure.

Footwall Breccia could have been ripped off and transported by the dyke melt when the dykes were emplaced. It subsequently was metamorphosed by the heat from the Offset Dykes leading to recrystallization of matrix and clasts. This would explain the MTBX inclusions within QD/IQD and the intermingling field relationships of MTBX with QD/IQD.

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