THE BASAL ONAPING INTRUSION – THE MISSING ROOF ROCKS OF THE SUDBURY IGNEOUS COMPLEX? D. Anders[1], G. R. Osinski[1,2] and R. A. F. Grieve [1], [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.

Introduction: The Sudbury impact structure, Ontario, Canada (Fig. 1a), was formed at ~1.85 Ga [1] and, with an estimated original diameter on the order of ~200 km [2], ranks among the largest impact structures on Earth. The impact basin contains the Sudbury Igneous Complex (SIC); a coherent, but differentiated, impact melt sheet composed, from bottom to top, of: the so-called Sublayer, Norite, Quartz Gabbro, and Granophyre [3]. It is overlain by Onaping Formation and post-impact sediments of the Onwatin and Chelmsford Formations. Peculiar igneous bodies, the so called "Basal Onaping Intrusion", form sheets and sills mainly at the contact between the SIC and the Sandcherry Member of the Onaping Formation, and occupy approximately 50% of this contact zone [2].

The Basal Onaping Intrusion has typically been considered part of the Onaping Formation [4, 5, 6, 7]. Brockmeyer and Deutsch [8] first suggested the Basal Onaping Intrusion might be an early phase of the SIC, which has been quenched by assimilation of clasts. Here, we present evidence that the Basal Onaping Intrusion represents the roof rocks of the SIC and, thus, is part of the SIC [9].

Samples and Analytical Methods: Two drill cores from the North Range, provided by Vale, were investigated. The 70011 drill core (Northing 495439, Easting 5174637) was drilled in 1981 and core 52847 (Northing 485139, Easting 5169948) was drilled in 1978. Polished thin sections of samples were examined by optical and scanning electron microscopy (SEM), in order to characterize mineralogy, microstructures and textures. Point counting of 6 samples from different depths of core 70011 revealed modal mineralogy, grain size, number of clasts and amount of granophyric intergrowth. Quantitative analyses of feldspars were carried out using a JXA JEOL-8900L Electron Microprobe (McGill) and X-ray-fluorescence (XRF) whole rock analyses provided major and trace element compositions (Western Ontario).

Petrology: The core 70011 is composed of Basal Onaping Intrusion at depths of 15 m to 91 m, followed by Granophyre of the SIC, while core 52847 consists of Sandcherry Member, underlain by 21 m of Basal Onaping Intrusion and Granophyre. The Basal Onaping Intrusion is composed of a dark to black aphanitic assemblage that contains lithic clasts. The matrix is characterized by an intergrowth of feldspar and quartz, minor minerals include amphiboles and pyroxenes, as well as chlorite, epidote and calcite as a result of hydrothermal alteration (Fig. 1a). The grain size tends to increase with increasing depth, which is particularly notable for alkali feldspar and quartz.

Lithic clasts (Fig. 1b) of different composition (felsic, quartzitic, and mafic) within the matrix decrease in number with increasing depth. All clasts are characterized by a rounded to subrounded shape, show a sharp contact with the matrix and may be surrounded by a reaction rim (Fig. 1b). Decorated and annealed PDFs have been detected within quartz clasts of the Basal Onaping Intrusion.

The contact between Granophyre and Basal Onaping Intrusion is gradational. The first isolated patches of graphic intergrowth (granophyric texture) of feldspar and quartz within the matrix of the Basal Onaping Intrusion of core 70011 occur at a depth of 86 m. The amount of granophyric texture then increases and is the dominant texture at 91 m, where the lithology is classified as Granophyre (Fig. 1c). However, the contact zone between Sandcherry Member and Basal Onaping Intrusion in core 52847 appears sharp and no gradational transition has been observed. The Sandcherry Member in core 52847 is characterized by a brown, clastic fine-grained groundmass that contains ~80% angular equant shard vitric clasts, without any reaction rims.

Geochemistry: Whole rock major element analyses demonstrate a relatively high SiO_2 content of the Basal Onaping Intrusion in the core 70011 (63.6 wt% to 70.4 wt%), which is slightly lower than the SiO_2 content of the Granophyre (70.8 wt% to 72.8 wt%). Microprobe analyses of feldspars revealed only Ca-depleted plagioclase (An<4%) and orthoclase (Ab<6%) compositions. Trace element spider diagrams normalized to the average Felsic Norite [10] show that the Basal Onaping Intrusion shares more similarities with Norite (Fig. 1d) than any other SIC unit.

Interpretations: Our observations indicate the igneous nature of the matrix of the Basal Onaping Intrusion, which suggests crystallization of a melt (Fig. 1a). Skeletal intergrowth of feldspar and quartz points to rapidly and simultaneously cooling of those components within the melt. Embayments and budding extensions of lithic clasts is an indication of resorption and melting processes. Rims around clasts (Fig. 1b) can be interpreted as a result of interaction processes between liquid melt and solid target rock clasts. Increasing grain size with increasing depth points to the existence of a temperature gradient within the Basal Onaping Intrusion melt, with slower cooling in proximity to the SIC, leading to longer crystallization times. The varying amounts of clasts with increasing depth is also a function of a temperature gradient. Close to the SIC, temperatures remained high over a longer period of time enabling assimilation of clasts; whereas further from the SIC, temperatures and time-scales were not sufficient for assimilation, resulting in a relatively more rapid crystallization of the melt.

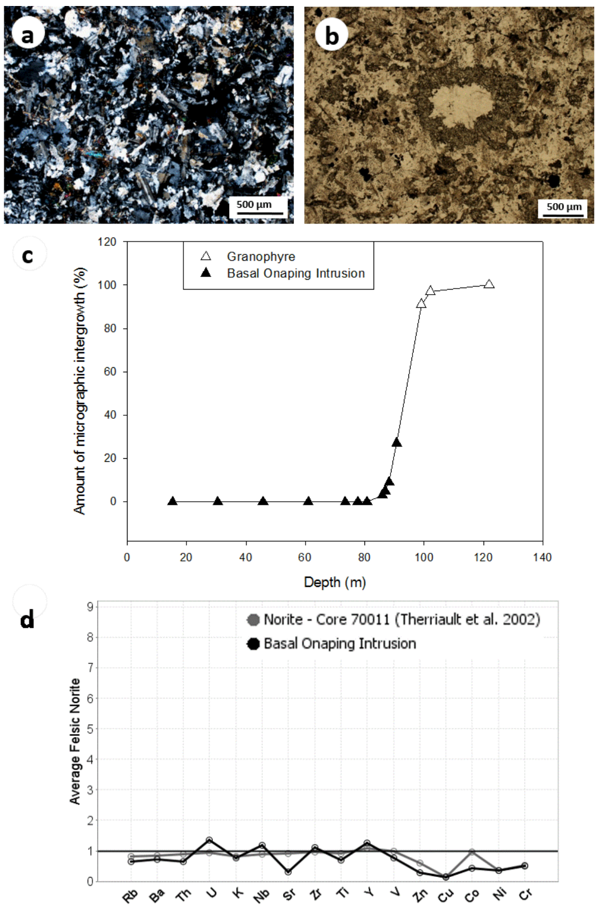

Fig. 1. a) Optical photomicrograph (crossed polars) showing the matrix of the Basal Onaping Intrusion of core 70011 characterized by an intergrowth of feldspar and quartz. b) A quartz clast surrounded by a reaction rim composed of mafic minerals. c) Diagram displaying the increase of the amount of granophyric intergrowth with depth. d) Trace element spider diagram of the Basal Onaping Intrusion and Norite of the SIC [11] normalized to the felsic Norite [10].

The gradational contact between Basal Onaping Intrusion and Granophyre (Fig. 1c) suggests that they are related and may have originated from one melt pool. Granophyre, in general, displays similar mineralogy to the Basal Onaping Intrusion; it is composed of quartz and feldspar, includes mafic minerals of which some are altered to chlorite and epidote. In contrast, the Sandcherry Member does not show any similarities to the Basal Onaping Intrusion. Instead of shocked country rock clasts, seen in the Basal Onaping Intrusion, the Sandcherry Member contains equant shaped shards of altered glass and lithic clast [6]. The groundmass of the Sandcherry Member is fine-grained and clastic while the groundmass of the Basal Onaping Intrusion and the Granophyre is igneous.

Conclusions: The observations of this study provide further evidence of the impact melt origin of the Basal Onaping Intrusion and elucidate a possible relationship to the SIC. The presence of PDFs further indicates that the Basal Onaping Intrusion is an impact melt rock.

Increasing grain size, decreasing amounts of clasts with increasing depth and and a transitional contact between Granophyre and the Basal Onaping Intrusion are general features of roof rocks leading to the hypothesis that the Basal Onaping Intrusion are, in fact, the roof rocks of the SIC and, thus, may represent a composition close to the bulk initial composition of the SIC. Therefore, we propose that the Basal Onaping Intrusion should no longer be considered as part of the Onaping Formation, but rather the uppermost member of the SIC. Based on the analogy with layered igneous intrusions, such as Skargaard and Bushveld [12], we recommend "Upper Contact Unit" of the SIC as a new name for the Basal Onaping Intrusion.

Acknowledgements: We would like to thank Peter Lightfoot from Vale for his support and providing the samples. This study was supported by NSERC, CSA, and MDA through their Industrial Research Chair support to GRO.

References: [1] Krogh T. E. et al. (1996) *AGU Monograph, 95*, 343–353. [2] Grieve R.A.F. et al. (2010) *Meteoritics & Planet. Sci., 45*, 759–782. [3] Dressler, B.O. et al. (1992) *Geological Survey Guidebook, 8, 38.* [4] Peredery W. V. and Naldrett A. J. (1975) *Econ. Geol., 70*, 164–175. [5] Muir T. L. and Peredery W. V. (1984) *Ontario Geological Survey Special Volume*, , 139–210. [6] Ames D. E. et al. (1998) *Geology 26*, 447–450. [7] Ames D. E. 1999. Ph.D. thesis, Carleton University, Ottawa, Ontario, Canada. [8] Brockmeyer P. and Deutsch A. (1989 *LPS XX*, 1. [9] Anders et al. (2015) *Meteoritics & Planet. Sci.*, in print. [10] Lightfoot P.C. et al. (1997a) *Econ. Geol., 92*, 289–307. [11] Therriault A. M. et al. (2002) *Econ. Geol., 97*, 1521–1540. [12] Naslund H. R. (1984) *Journal of Petrology, 25*, 185–212.