AUTOMATED LINEAMENT EXTRACTION TECHNIQUE FOR THE SUDBURY IMPACT STRUCTURE USING REMOTE SENSING DATASETS- AN UPDATE. B. Shankar[1], L. L. Tornabene[1], G. R. Osinski[1], M. Roffey[1], J. M. Bailey[2] and D. Smith[2], [1]Centre for Planetary Science and Exploration, Dept. of Earth Sciences, Western University, 1151 Richmond St. London ON, Canada N6A 5B7 (bshanka@uwo.ca) [2]Wallbridge Mining Company Limited, Lively, ON, P3Y 1L7

Introduction: The impact cratering event produces numerous lineament features such as fractures, faults, dykes, ridges, and scarps. The density, distribution, geometric pattern and orientation of these features are a function of the crater diameter, the crater morphology (e.g., complex vs. multi-ring), and deformational style.

Structural expressions of the largest ancient and most complex impact structures are poorly understood due to the low number of recognizable features, and subsequent modifications from overprinting by later processes. On Earth, the Sudbury impact has been deformed and overprinted multiple times over its geological history, resulting in a poorly-constrained apparent diameter that varies from ~150 – 270 km in the literature [1-3].

The Sudbury impact basin is world-renown for producing high-grade Ni-Cu and PGE ores. Sudbury ore deposits are observed as three main occurrences, ores that are concentrated within the Sudbury Igneous Complex (SIC); within "Offset Dykes" (OD) metre to hundred metres wide igneous intrusions that extend for tens of kilometers occupying roughly radial and concentric structures; and within but not limited to Sudbury Breccias (SB). There is a considerable amount of debate with respect to the origin and emplacement of the OD and SB ore bodies, which hinders efforts to find additional occurrences of these types [4-6].

Objective: The main goal is to improve our understanding of the original structure of the Sudbury impact, through the use of recently acquired satellite and airborne data, and image processing techniques to map the linear quasi-linear features associated with the Sudbury impact structure. The results of this research may provide tighter constraints on the apparent diameter of the basin, and perhaps some additional insights into the origin and emplacement styles of known OD, and possibly locate new occurrences. If successful, the use of remote sensing and these remote sensing and these automated techniques may reduce exploration hazard, time, and cost.

Methods: This study builds on the work and methodology of [7]. Our lineament analysis of Sudbury was conducted using 20 m/pixel DEMs publicly accessible through *Land Information Ontario* (LIO). A more focused study was conducted on a spatial subset of the basin using a high-resolution 0.9 m/pixel Light-Detection and Ranging (LiDAR) acquired by Wallbridge Mining Company Ltd (WM). Shaded relief maps were created from DEMs using low sun angles and multiple azimuths. The automated LINE tool, a line extraction algorithm within PCI Geomatica was applied on DEM-derived shaded relief maps using the parameters defined in Table 1. The results are classified and filtered to exclude features that originate from non-crater related activity (e.g., from tectonism, glacial erosion, extent of wetlands, urban lineaments, etc.). By excluding these features from our analysis, a final lineament/structure map was produced.

Results from both sets of DEM data (LIO and LiDAR) are compared with results from other remote sensing datasets, published geological maps, and previous studies [e.g. 8]. WM owns land beyond the SIC, along several known ODs, therefore results from this study will also be used with WM data to assess the geometric relationships between ODs and our lineament maps.

Filter Radius	10	Line Fitting Error	9
Edge Gradient	30	Angular Difference	30
Curve Length	30	Linking Distance	20

Table 1: Parameter values selected as input for the automated feature extraction algorithm.

Results: The Whistle-Parkin OD located NE of the SIC (Figs. 1-3) is a 12 km radial offset dyke located in the northeast corner of the impact structure. Statistics from the automated extraction process for this small area of investigation are summarized in Table 2.

The spatial trends of extracted lineaments at Whistle-Parkin appear to be uniform in all directions with no strong preference (Fig. 3). The NW-SE trend is part of Matachewan Dike system, which was part of the continental rift – prior to the impact. However, the remaining trend patterns occur with relatively uniform intensity. The assortment in trend directions indicates the potential existence of both radial and concentric features (relative to the SIC which is located south of Whistle-Parkin), and post impact related structures.

Discussion: The automated lineament mapping of Sudbury is complicated by lineament features occuring prior, during, and after the Sudbury-forming event. Erosional, depositional, or post-deformational history can each influence the exposure of structures around an impact feature as large as Sudbury. However, several observations are made that enable us to effectively filter and classify the data. The use of DEM data with multiple sun azimuth directions provides an unbiased result.

Fewer lineaments are derived from the LIO dataset when compared to LiDAR. This is likely the result of the difference in spatial resolution between the LIO and LiDAR DEMs. At the scale of LIO data, several faults are identified that are confirmed from previous mapping and field observations. In contrast, LiDAR derived lineaments appear to be more sensitive to geological contacts and topographic edges.

Thus far, the process of filtering out non-impact related features does not appear to greatly influence the results. Regardless of data type, the regional tectonic and urban lineaments only end up filtering <10% of the original results. This is likely due to the different spatial scales these non-impact generated structures are classified under. Several orogenic events affect the regional geology, at scales several orders less detailed than LiDAR data, but better resolved by LIO data. Further filtering techniques are required at all scales.

Future work: Several steps still remain to be explored. The lineament patterns and statistics need better classification and filtering; however we are beginning to see positive results. Lineaments need to be compared to topographic features, (e.g. rivers and lakes). These analyses need to be replicated at all known offset dykes around Sudbury to determine if they preserve both radial and concentric signatures, and if there are consistent trends that would be useful for identifying new ODs associated with the SIC.

References: [1] Grieve, R and Therriault, A. (2000) *Annual Rev. of Earth & Plan Sci*, 28 (1): 305-338. [2] Krogh, T. E. et al. (1984) *The geology & Ore deposits of the Sudbury structure*, 431–448. [3] Pilles, E. et. al. (2014) *GSA*, Paper 290–11. [4] Wood, C. R. et al. (1998) *MAPS*, **33**: 337-347. [5] Murphy A.J. and Spray, J.G. (2002) *Econ. Geol.* **97**: p. 1399. [6] Tuchscherer, M.G. and Spray, J.G. (2002) *Econ. Geol.* **97**: p. 1377-1397. [7] Shankar, B. and Osinski, G. R. (2015) *LPS XLVI*, abstract # 3004. [8] Butler, H. R. (1994) GSA Special Paper, 293, 319–329.

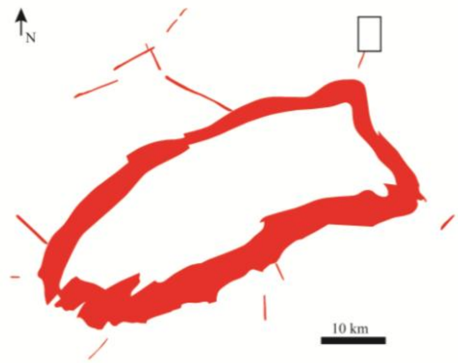

Figure 1: Context view of the Whistle-Parkin area relative to the extent of the Sudbury Igneous Complex (SIC) and other offset dykes.

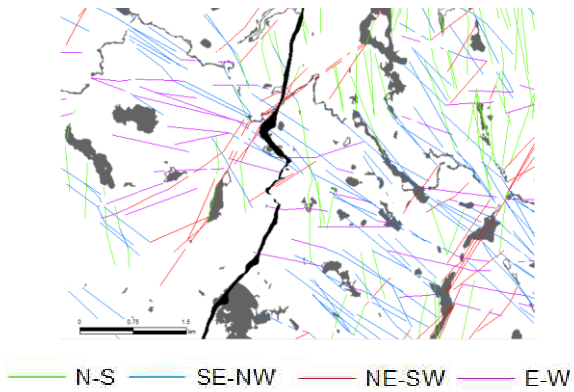

Figure 2: Lineament map of a 10 km x 10 km area surrounding the Whistle-Parkin OD derived from LIO DEM. Image field of view is ~4 km. The offset dyke is outlined in black, lakes and rivers are marked grey.

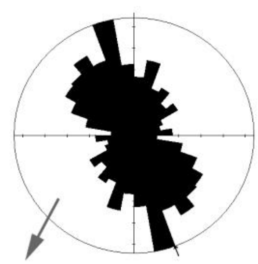

Figure 3: Stereoplot results for the automated lineaments extracted using LIO DEM data for the same area as in Fig. 2. Grey arrow indicates the relative direction of the SIC.

Lineaments	LIO	LiDAR
Total Count	~4,200	~ 2.72 million
Density based on trend	N > NW-SE > NE-SW > E-W	T.B.D.

Table 2: Statistical summary of automatic lineament extraction for the Whistle-Parkin OD.