GEOPHYSICAL SIGNATURES OF SUSPECTED AND CONFIRMED IMPACT STRUCTURES, ONTARIO, CANADA

M.H. Armour[1,2], J. Boyce[1], D. Zilkey[1]

1-School of Geography and Earth Sciences, McMaster University, Hamilton, ON

2-Department of Science and Technology Studies, York University, Toronto ON

Geophysical data are increasingly employed to identify potential impact structures and to model their subsurface structure. In this study we employed 2-D forward magnetic modelling of gravity and magnetic data to investigate the subsurface structure of the Holleford impact crater and two suspected impact structures (Skeleton Lake, Charity Shoal) in Ontario, Canada (Fig. 1). An objective was to determine whether Holleford crater could be used as an geophysical/structural analog for Charity Shoal and Skeleton Lake.

Figure 1 – Study area with locations of confirmed impact craters (Sudbury, Wanapetei, Brent, Holleford) and suspected impact structures (Skeleton Lake, Charity Shoal) in Central and Southern Ontario, Canada

Holleford Crater was identified in 1960 as a simple, ~2.4 km diameter impact crater in Late Proterozoic target rocks (Beals, 1960). The impact origin was confirmed through deep drilling and recovery of breccias with PDF's and high-pressure polymorphs. Gravity surveys conducted in the 1950's demonstrate a well-defined ~ 3 mGal Bouguer anomaly (Fig. 2A) but no magnetic anomaly was identified in aeromagnetic data. Newly acquired ground-based total field magnetic intensity (TMI) surveys conducted in 2016, identified a small (< 20 nT) anomaly over the crater basin (Fig. 2C). The lack of a well-defined TMI anomaly is attributed to the low magnetic susceptibility of the Proterozoic metasedimentary target rocks. 2-D modelling of Bouguer gravity data suggests an heavily eroded impact crater with a depth of ~ 500 m.

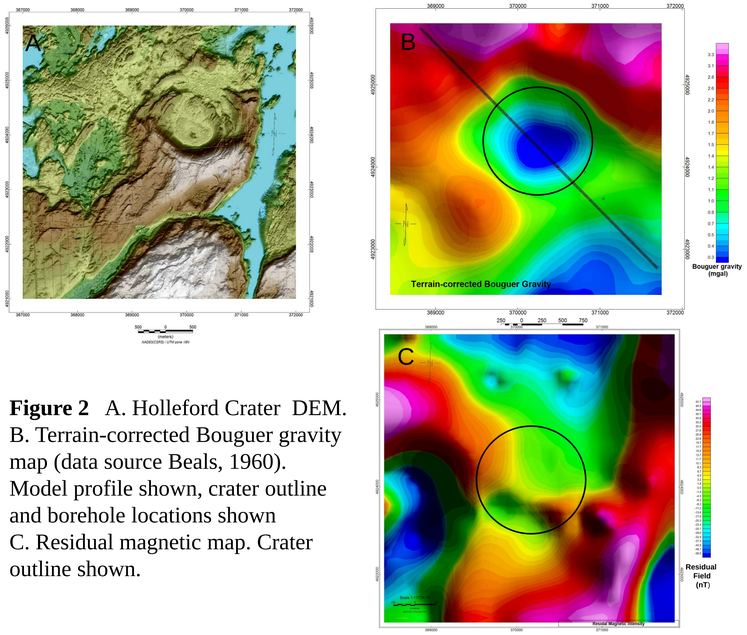


Figure 2 A. Holleford Crater DEM. B. Terrain-corrected Bouguer gravity map (data source Beals, 1960). Model profile shown, crater outline and borehole locations shown
C. Residual magnetic map. Crater outline shown.

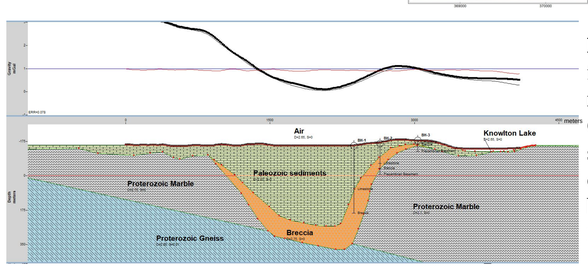
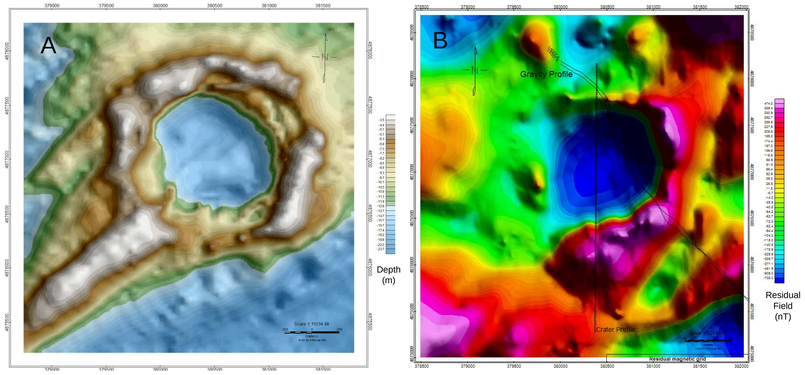


Figure 3 - 2-D forward gravity model of Holleford Crater. Modelled stratigraphy constrained by three boreholes (Beals, 1960).

Charity Shoal is a ~1.4 km diameter suspected impact structure located in eastern Lake Ontario (Fig. 1) with a raised bedrock rim and 20-m deep central basin (Fig. 4A). Lake-based magnetic data acquired in 2015, identified a well-defined ~600 nT TMI anomaly low over the basin. A single Airgrav gravity profile collected by Sander Geophysics Ltd (2009) shows ~ 2 mGal low over the structure (Fig 4C). 2-D modeling yields a crater depth ~450 m (Fig. 5A), consistent with the crater scaling equation for simple impact structures (Pilkington and Grieve, 1992). The TMI anomaly can also be reproduced by a diatreme model (Fig. 5B), but requires a remanence magnetization that opposes the modern field direction. The annular magnetic anomaly may also indicate a zoned low magnetic susceptibility alkalic intrusion (e.g. carbonatite)(Thomas et al., 2016).



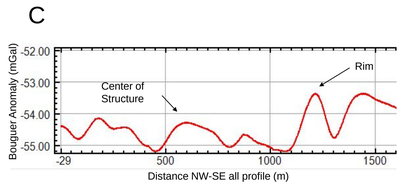


Figure 4 A- Charity Shoal bathymetry map. B - Residual magnetic intensity. Location of model and gravity profile shown. C – NW-SE Bouguer gravity profile.

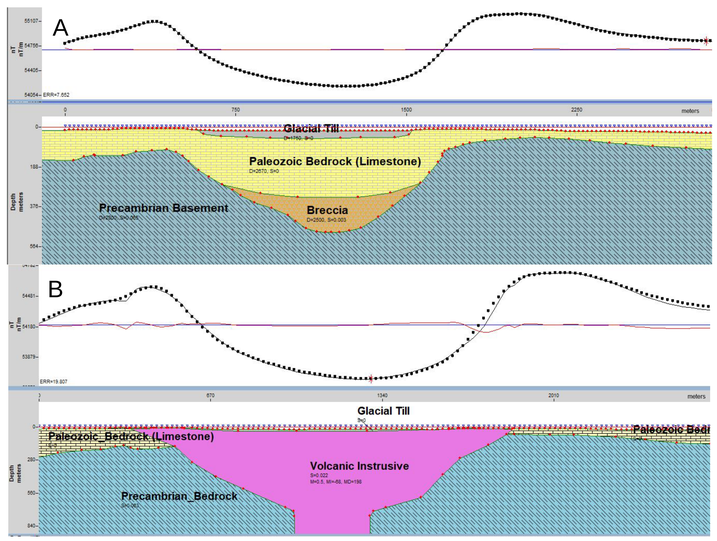


Figure 5 – North-south 2-D forward magnetic models for Charity Shoal. A. Impact crater model. B. Diatreme model (Jurassic age intrusive?) with remanence opposing the main field (Suttak, 2013).

Skeleton Lake is a ~3.6 km suspected impact structure identified in Muskoka, Ontario in the 1960's (Waddington and Dence, 1978). Magnetic and gravity surveys revealed 300 nT low over the structure (Clark, 1982) and a ~3 mGal Bouguer anomaly. A detailed lake-based magnetic survey was conducted in 2017 to better resolve the magnetic anomaly. New magnetic and bathymetric data acquired in 2017, show that the structure clearly truncates the northwest-trending regional magnetic fabric. The residual magnetic map shows a >400 nT magnetic anomaly low centered over a roughly circular lake basin with a maximum water depth of ~60 m. Forward modelling of a simple impact structure (Fig. 7) yields and estimated crater depth of ~500 m and diameter of ~3.5 km. The model suggests that if Skeleton Lake is an impact structure, it has undergone significant erosion, as the crater scaling equations predict a depth of ~800 m.

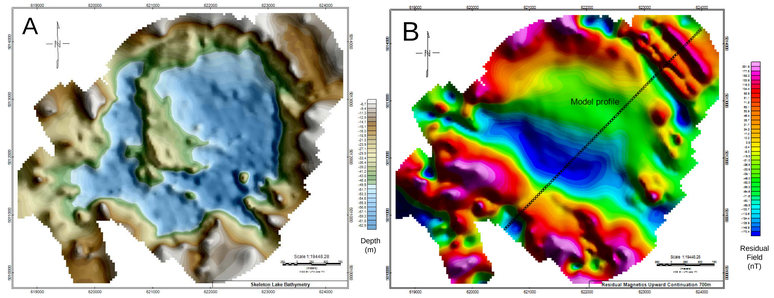


Figure 6 A- Skeleton Lake bathymetry map. B – Residual magnetic intensity map. Line of model profile shown.

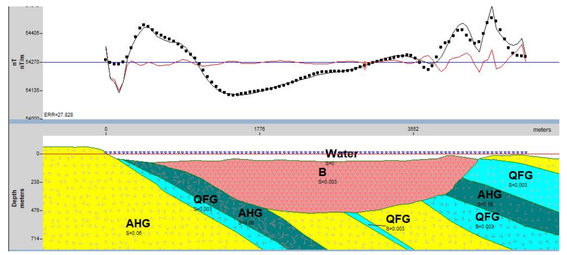


Figure 7 2-D forward magnetic model. QFG= quartzo-feldspathic gneiss. B=breccia AHG=Amphibolite-hornblende gneiss. Magnetic susceptibility values from field measurements.

Geophysical models presented here provide new constraints on the subsurface structure and possible origins of Charity Shoal and Skeleton Lake. However, the magnetic anomaly signatures of two suspected impact structures are significantly different from Holleford crater. This can be attributed to the variable contrast in magnetic susceptibilities of infill sediments and target rocks at the three sites. Our results indicate that Holleford is not a good analog for the two suspected impact structures. Modelling demonstrates that the annular magnetic anomaly of the Charity Shoal structure can be reproduced with a cylindrical source body at shallow depth (e.g. diatreme) with a remanence opposing the main field. This anomaly pattern is also consistent with with magnetic signatures of zoned alkalic intrusions (e.g. carbonatites) described in other areas of Ontario and Quebec (Thomas et. al., 2016).

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Acknowledgements

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