CRATER BREACHING AND PALEOLAKE EVOLUTION AT THE HAUGHTON IMPACT STRUCTURE, CANADIAN HIGH ARCTIC. P. J. Cincio[1,2] and G. R. Osinski[1], [1]Department of Earth Sciences, Western University, London, Canada (pcincio@uwo.ca), [2]Institute for Earth and Space Exploration, Western University, London, Canada.

Introduction: The confluence of meteorite impact cratering and surficial fluvial activity on early Earth and Mars allowed for crater breaching events to occur that formed impact crater lakes [1]. On Earth, breaching and subsequent lake evolution through sedimentation and biological activity suggests that crater lakes may have provided an oasis of environmental conditions and habitats suitable for microbial colonization following an impact [2-4]. The processes by which meteorite impact structures on Earth are breached is understudied, however, recent work by [5] proposed four mechanisms of crater breaching on Mars. Degraded crater rims were breached via (1) rim erosion, (2) depositional rim burial, (3) drainage head erosion, or (4) overflow, which supplied water to the crater interior to form inland lakes and inlet valleys [5]. Discerning crater breaching mechanisms and paleoenvironmental activity are therefore important to understand the processes of landscape and lake evolution on Earth and Mars.

The well-preserved Haughton impact structure contains geomorphologic features and paleolake deposits that are emblematic of a crater breaching event and is a close analogue for Jezero crater and other paleolakes on Mars. The objectives of this research are to: (1) determine the mechanism(s) of breach formation of the crater rim; (2) ascertain the timing of the crater breaching event and chronology of the paleolake sequence; and (3) reconstruct the paleoclimate of the Haughton paleolake. This research aims to establish a framework of post-impact paleolake evolution from crater breaching to lake cessation that is applicable to Earth- and Mars-based crater lake settings.

Haughton Geologic Setting: The 31 Ma [6], 23 km diameter Haughton impact structure is located on Devon Island, Nunavut, in the Canadian High Arctic. The target rocks are comprised of lower Paleozoic carbonates unconformably overlying the Precambrian metamorphic basement [7]. In the west portion of the impact structure lies lacustrine deposits representative of a Miocene aged lakebed known as the Haughton Formation. The Haughton Formation covers an area of ~8.6 km^2 and is composed of a ~48 m thick sequence of unconsolidated, interbedded dolomite-rich lacustrine silt, sand, and mud [8]. To the south of the Haughton Formation are two river valley inlets incising impact melt rock hills that outflow to the northeast towards Thomas Lee Inlet.

Methods: A field expedition to the Haughton impact structure occurred from July 1 – July 14, 2022. A total of 31 sites were sampled along three downward-sloping transects of the main expanse of the Haughton Formation, where visual descriptions and sampling of the paleolake facies were completed. Two isolated outcrops of the Haughton Formation from the southern and central portions of the impact structure, respectively, were also sampled. This research will employ geomorphologic and paleoenvironmental approaches to reconstruct the paleolake evolution.

Crater Breaching: A DEM model will be constructed to derive rim, breach, and inlet profiles of the Haughton Formation region. The crater rim profile (elevation change along distance from crater centre) will be determined based on averages of the crater depth, crater radius, and crater rim height. The breach profile (elevation change along valley profile) will be determined using the inlet width and inlet depth between the two valley shoulders. The longitudinal inlet profile (elevation change along distance from crater centre) will then be mapped. Morphologic observations of the crater rim and walls will also be used to quantitatively determine the crater breaching mechanism. These methods are adapted from [5].

Paleoenvironmental Reconstruction: U/Pb dating techniques will be applied to fossil-bearing nodules and indurated limestones collected from the base of the Haughton Formation, and optically stimulated luminescence dating on the paleolake sediments will be used to establish the geologic age and subsequent chronology of the Haughton paleolake. A sedimentary log of the paleolake deposits will be constructed using the chronology, visual descriptions of the sediments, grain size, magnetic susceptibility, and organic matter content. X-ray fluorescence of reworked impact melt rocks will also be used to determine the mineralogical composition of the paleolake sequence and to correlate between samples. Fossilized diatom remains and stable oxygen and carbon isotope compositions from all paleolake facies will be used to reconstruct the paleoclimate of the Haughton paleolake. The diatom assemblages and stable isotope abundances will be assessed for environmental relationships over time, used to generate paleotemperature and lake level reconstructions, and then biostratigraphically correlated to the sedimentary log to provide a model of the environmental history of the Haughton Formation paleolake.

Preliminary Results: Sedimentological descriptions of an isolated outcrop of the Haughton Formation (Fig. 1) and the main expanse of the Haughton Formation (Figure 2) indicated that the paleolake sediments overly reworked impact melt rocks [9] and are compositionally similar. The isolated outcrop contained about 20 cm of glacial veneer overlying a 1.15 m thick unconsolidated yellowish silty matrix with a lower layer of dark grey clay. The main expanse of the Haughton Formation transect was dominated by altering layers of silty sands and clays, with sandy layers throughout the middle section and larger grained gravels and small pebbles at the bottom. The silty sand matrices were light beige in colour and infrequently contained thin, dark grey horizontal banding. Towards the upper 10cm of the transects, oxidized orange nodules ranging from 2 – 5 cm in size were observed.

Figure 1: Outcrop of the Haughton Formation from the southern portion of the Haughton impact structure showing a layer of yellowish silty sand overlying a dark grey clay unit. The measured section is about 40 cm in height.

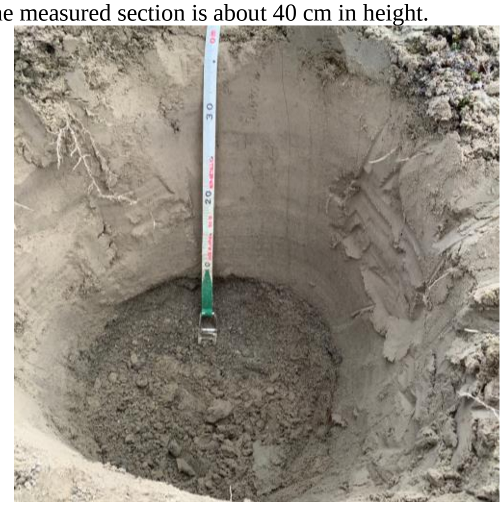

Figure 2: A light beige silty sand matrix with thin dark grey banding overlying well rounded to sub rounded gravel and pebbles at the bottom of the Haughton Formation. The measured section is about 45 cm in height.

Contributions: Future work will involve the crater breaching and paleoenvironmental reconstruction methods described above. The limited understanding of crater lake analogues on Earth necessitates a deeper assessment of the associated physical and paleoenvironmental processes to ascertain Earth's history and contextualize paleolakes on Mars. This proposed research will be the first detailed study chronicling post-impact crater breaching and paleolake evolution in an Arctic setting, which will elucidate crater breaching mechanisms on Earth, strengthen the paleoenvironmental record of the Haughton Formation, improve the understanding of impact crater lake formation and evolution on Earth and Mars.

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References: [1] Irwin, R.P., et al. (2005). JGR, 110, E12S15. [2] Cockell, C. S., & Lee, P. (2002). *Biol. Rev.*, *77*(3), 279-310. [3] Osinski, G. R., et al. (2020). *Astrobiology*, *20*(9), 1121-1149. [4] Michalski, J. R., et al. (2022). *Nat. Astron.*, 1-9. [5] Bamber, E. R., et al. (2022). *Icarus*, *378*, 114945. [6] Erickson, T. M., et al. (2021). *GCA*, *304*, 68-82. [7] Osinski, G. R., et al. (2005). *Meteorit. Planet. Sci.*, *40*(12), 1759-1776. [8] Hickey, L. J., et al. (1988). *Meteoritics*, *23*(3), 221-231. [9] Osinski, G. R., & Lee, P. (2005). *Meteorit. Planet. Sci.*, *40*(12), 1887-1899.