THE EFFECT OF METEORITE IMPACTS ON THE ELEMENTS ESSENTIAL FOR LIFE. G. R. Osinski[1], C. S. Cockell[2], P. Lindgren[3], and J. Parnell[4], [1]Depts. of Earth Sciences/Physics and Astronomy, University of Western Ontario, London, ON N6A 5B7 (gosinski@uwo.ca). [2]Centre for Earth, Planetary, Space and Astronomical Research (CEPSAR), Open University, Milton Keynes, MK7 6AA, UK. [3]Dept. of Geology, University of Aberdeen, Aberdeen AB24 3UE, UK. [4]Department of Geology and Geochemistry, Stockholm University, SE10691 Sweden.

Introduction: Impact cratering is a fundamental geological process common to all planetary objects with a solid surface. Unlike other geological processes such as volcanism or plate tectonics, impact cratering is ubiquitous throughout the solar system and from the beginning to end of the lifetime of a planetary body.

The destructive geological, environmental, and biological effects of meteorite impact events are well known – although not necessarily well understood. This has been driven by the quest to understand the effects of past large impact events and the potential consequences of future events. Indeed, ever since the discovery of the ~180 km diameter Chicxulub impact structure, Mexico, and its link to the mass extinction event that marks the end of the Cretaceous Period 65 Myr. Ago [1], there has been substantial interest and, therefore, research as to the environmental consequences of impact events [2-4].

In the past few years it has become apparent that impact events also have certain beneficial effects, particularly for microbial life [5]. Of particular interest is the generation of a hydrothermal system within an impact crater immediately following its formation. Research suggests that impact-associated hydrothermal systems will likely form following impacts into any H_2O-bearing solid planetary body [6, 7]. Numerical models of these hydrothermal systems suggest that they may last several Ma for large 100 km-size impact structures [8]. This may have important implications because many researchers believe that hydrothermal systems in general might have provided habitats or "cradles" for the origin and evolution of early life on Earth, and possibly other planets such as Mars [9].

Other potential habitats created by impact events include crater lakes, impact glasses [10] and impact-processed crystalline rocks that have increased porosity and translucence compared to unshocked materials, thus improving microbial colonization [11, 12].

This research is driven by the question: *what is the effect of meteorite impact events on the concentration and distribution of elements essential for life?*

Elements essential for life: The building blocks of life are cells and within all cells, similar molecules are found; namely, water, nucleic acids (DNA and RNA), amino acids, lipids and carbohydrates. These molecules are themselves built from a variety of chemical elements. Over two-dozen elements have been identified that commonly participate in metabolic processes within a diverse set of microbiological systems (e.g., see review by [13]). Of these, C, N, H, O, P, and S are considered essential for all life, while Ca, K, Mg, and Na are considered major cations for life; Cl is considered one of the major anions for all life [13].

Effect of meteorite impact events on life-essential elements – Previous work: In order to understand the effect of impact events on the concentration and distribution of elements essential for life, a requirement is an impact crater where post-impact modification and redistribution of elements has been minor or absent. This requirement is met by the 23 km diameter, 39 Ma Haughton impact structure, Arctic Canada, which today lies in a polar desert environment [14]. Haughton formed in a ~1.9 km thick series of sedimentary rocks overlying crystalline basement. Previous work at Haughton yielded the perhaps surprising observation that the total organic carbon measured in various "unshocked" and "shocked" target lithologies is not statistically different [15]. In another study, this time of crystalline rocks, shocked samples were found to have lower concentrations of MgO, K_2O, Na_2O, TiO_2 and P_2O_5 [16]; although it is not clear as to the equivalence of the shocked and unshocked samples.

Effect of meteorite impact events on life-essential elements – This study: This study focuses on the preservation of the other life-essential elements noted above, with the exception of O and H. Samples were grouped into 5 categories:

Unshocked. These samples represent target material collected from outside the Haughton structure and are used as a reference and baseline.

Low shock. Samples were collected from the central uplift of the Haughton structure. The presence of shatter cones indicates shock pressures of >2 GPa with an upper limit estimated at ~10 GPa.

Impact melt breccias (IMB). This lithology forms a lens in the central part of the structure. It comprises variably shocked lithic and mineral clasts set in a fine-grained groundmass of silicate glass, calcite, and anhydrite, derived from melting of the pre-impact sedimentary target rocks [17]. The IMB samples represent the fine-grained fraction of the rock that will contain groundmass and fine-grained clastic material.

IMB clasts. Large carbonate clasts were separated out from the IMB and analysed separately.

Post-impact sediments. The Haughton Formation represents a series of lacustrine sediments laid down in a crater lake some time after the impact event.

Analytical procedures. Samples were analysed using X-ray fluorescence (XRF) techniques using a PHILIPS PW2440 4kW automated XRF spectrometer system by Geochemical Laboratories, McGill University, Montreal, Canada. The detection limits were 35, 100, 95, 15, 75, and 25 ppm for P, Cl, Mg, Ca, Na, and K, and 0.01 wt% for S and N.

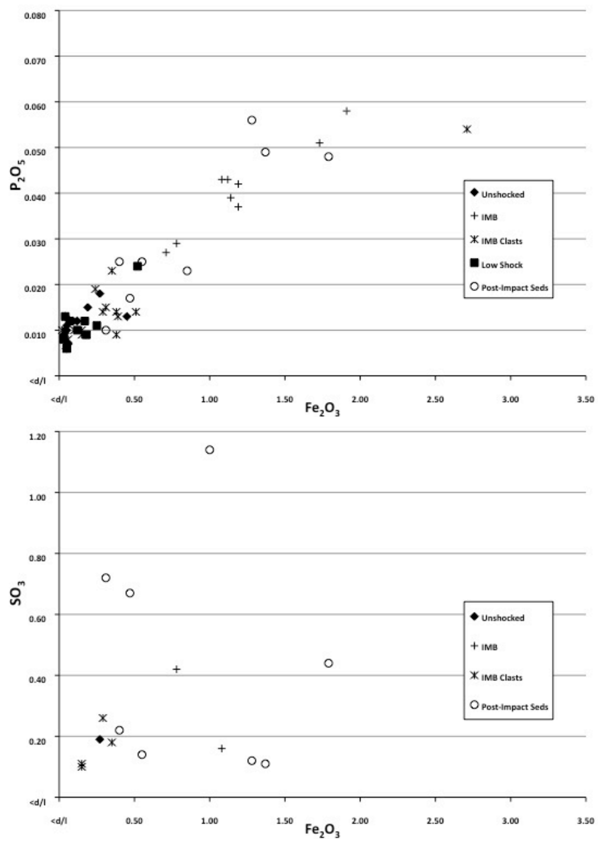

Figure 1: Harker plots of phosphorous (top) and sulfur (bottom) concentrations in various lithologies from the Haughton impact structure.

Results and discussion: Our hypothesis at the outset of this study was that the life-essential elements may be preferentially lost during the impact process, particularly in the IMB where temperatures reached >2000 ^{o}C [17]. For P it is clear that in the IMB samples, the values are actually higher (Fig. 1). The reason(s) for this is unclear but it could be that P- and S-rich rocks (evaporites or crystalline rocks) incorporated into the breccia are responsible; however, the clasts from the IMB largely reflect the same lithologies as the unshocked samples and there are still slightly higher values. For S, there is less data but a similar result is seen (Fig. 1). For N, there was no difference between the different groups of samples, with all analyses being <0.03 wt% N; many samples were below the detection limit of 0.01 wt% so there may be subtleties at low concentrations that are not revealed in our analyses. For Ca, K, Mg, and Na no significant differences are revealed in the data. Cl was generally below detection (100 ppm) for all pre-impact and impact-affected lithologies.

Summary and preliminary conclusions: In summary, our study – which primarily was carried out on carbonate lithologies – mirrors earlier studies by Lindgren et al. [15] with respect to organic carbon, in that there does not seem to be a major loss of the elements essential for life during meteorite impact events. We should note that further analyses are planned to expand the dataset to reduce the uncertainty of whether inter-sample heterogeneities are partly responsible for these results. In addition, these results are applicable to the impactites preserved and formed within an impact crater; distal ejecta may behave differently. And finally, these results for the carbonate lithologies appear to be different than an earlier study of crystalline rocks [16]; again, further analyses are planned to assess whether this difference is real or due to the restricted sample database previously analysed.

The study of the preservation and alteration the elements essental for life during impacts events is important in a context of astrobiology, including the detection of organic molecules which are critical for life. If organic carbon and other life-essential elements can be preserved after a high-temperature impact event, this will certainly increase the possibility of finding organic signatures that are derived from extraterrestrial life, if this life exists or has existed, when searching on other planets where impact-processed rocks make up substantial proportions of the planets surface.

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