PRESERVATION OF ORGANIC CARBON IN IMPACT MELT BRECCIA, HAUGHTON IMPACT STRUCTURE. P. Lindgren[1], J. Parnell[1], S.A. Bowden[1], C. Taylor[1], G.R. Osinski[2], P. Lee[3], [1]Dept. of Geology, University of Aberdeen, Aberdeen AB24 3UE, U.K., (P.Lindgren@abdn.ac.uk), [2]Canadian Space Agency, Saint-Hubert, Quebec J3Y 8Y9, Canada, [3]SETI Institute, NASA Ames Research Center, Moffett Field, CA 94035-1000, U.S.A.

Introduction: The ~39 Ma [1], 23 km (apparent) diameter Haughton impact structure [2] is located on Devon Island in the Canadian High Arctic. The target rocks comprise a thick sedimentary succession, mainly carbonates and dolomites, containing pre-impact organic matter. Haughton is a relatively young and well-preserved impact structure, located in an area where no tectonic activity or other significant heating events have taken place after the impact and subsequent impact-associated hydrothermal activity. This makes Haughton suitable for studies concerning the preservation of organic matter in impact-processed rocks. It is important for astrobiology, including our future search for life on Mars and other planets, to determine how much organic matter can be preserved after an impact event. Impact cratering is widespread and therefore impact-processed rocks are abundant on the surface of planets with little or no crustal re-working. Previous research regarding the organic matter in Haughton [3] showed that biological markers are preserved in rocks affected by the impact, and that these organic compounds can be used to measure the degree of heating in different parts of the crater, including the degree of heating in lithic carbonate clasts contained within impact melt breccia [4]. From these previous studies we know that organic compounds are preserved in the Haughton crater rocks. In this study we investigate the proportion of the total organic carbon preserved after impact.

Target succession and impactites: The Haughton target succession consists of a 1880 m Lower Paleozoic sedimentary sequence, overlying a Precambrian crystalline basement. Carbonate rocks comprise ~75-80% of the sedimentary succession, evaporites ~8% and the remaining ~12-17% is mainly composed of sandstones and shales [5]. The thick sequences of carbonates account for the majority of organic matter in the target. The impact caused the formation of an impact melt breccia, consisting of lithic (and melted) clasts derived from the various target rocks, primarily dolomite and limestone, set in a fine-grained groundmass composed of a variety of carbonate, sulfate and silicate impact melt phases [6].

Samples and analytical procedure: To estimate the total organic carbon preserved after impact, we measured the total organic carbon (TOC) in the various target lithologies, estimated the amount of each lithology that contributed to the impact melt breccia, and measured the total organic carbon in the end product, i.e. the impact melt breccia. The melt breccia is made up of several components; various lithic (and melted) clasts set in a fine-grained melted groundmass. In addition to measuring the total organic carbon in the whole melt breccia, we also analysed lithic carbonate clasts, with sizes of a few cm in diameter, to investigate the amount of organic carbon preserved after the carbonate clasts had been affected by a high temperature (>1750 ºC initial post-impact temperature [6]) impact melt. The samples of target bedrock that were analysed in this study come from a wide range of pre-impact depths in the sedimentary target succession and include material from different formations: Allen Bay Fm, Thumb Mountain Fm, Bay Fiord Fm, Eleanor River Fm and Blanley Bay Fm. This corresponds to 10 samples of target carbonate, 2 samples of target sulphate, 4 samples of target sandstone and 4 samples of target shale. From the impact products, 5 samples of whole melt breccia from 4 different localities, and 6 lithic carbonate clasts, from 6 different localities, were analysed. We assume that any carbon depletion would be evident in the impact melt breccia but not in the bedrock. The bedrock show changes in biomarker maturity in different parts of the crater [3], but that should not imply a change in the total carbon content. The samples were trimmed with a saw blade to remove surface weathering and contamination, crushed to a fine powder using a TEMA mill and treated with warm 25% HCl for removal of inorganic carbon [7]. The acid residues were analysed with a Carbon-Sulfur analyser (LECO CS225) for the total organic carbon content. To identify the amount of organic carbon that was preserved after impact, we use the following estimates: Osinski et al. [6] showed that the impact melt breccias are derived from targets rocks from >500 m to ~2000 m pre-impact depth. This corresponds to ~74% carbonates, ~10% evaporites, ~8% sandstone and ~8% shale. In this study we have ignored the minor contribution of the target crystalline basement.

Results: The total organic carbon in the various target lithologies and impact products are presented in Table 1. The total organic carbon in the whole melt breccia has an average value of 0.14%. This is lower than the contribution of organic carbon measured in the pre-impact target rocks, 0.66% (Table 1). The average total organic carbon in the pre-impact target carbonates is 0.12%, which is slightly lower than the amount of organic carbon measured in the impact-produced carbonate clasts; 0.14% (Table 1).

Target bedrock	% TOC	Lithology contribution to melt breccia (%)	% TOC input from the target bedrock
Carbonate (10)	0.12	74	0.09
Sulphate (2)	0.08	10	0.01
Sandstone (4)	0.05	8	0.004
Shale (4)	7.01	8	0.56
			Sum: 0.66

% TOC target input	% TOC melt breccia (5)	% TOC target carbonate (10)	% TOC carbonate clasts (6)
0.66	0.14	0.12	0.14

Table 1. Calculation of TOC contents. The upper part of the table shows the total organic carbon content of the different target lithologies, the estimation of the contribution of the lithologies to the melt breccia, and the calculated input of organic carbon derived from the target bedrock. Also shown in the lower part of the table is the organic carbon in the melt breccia compared with the input of organic carbon in the target, and the organic carbon in the carbonate clasts compared with the organic carbon in the target carbonate. The numbers within the parentheses represent the number of different samples that were analysed.

Discussion: The results show a total organic carbon contribution of 0.66% from the target rocks. The organic carbon content of 0.14% in the impact melt breccia, implies that approximately 20% of the organic carbon is preserved after impact. However, the amount of samples that were analysed is limited and will not be representative for the whole target succession. This is evident from the higher organic carbon content of the carbonate clasts 0.14%, compared to the target carbonate, 0.12%. The calculation is highly sensitive to the carbon content of the shale, and its contribution to the melt breccia. Nevertheless, this study more importantly shows that despite the high initial temperatures of an impact melt (>1750 ºC for Haughton [6]), organic carbon is preserved in the impact melt breccia, including in the lithic carbonate clasts. An analogue example of organic carbon being preserved after high temperature treatment is in organic-rich shales intruded by igneous material (sills) on Isle of Skye in Scotland [8]. The fate of carbon after high temperature impact events is still a question of debate. In the Gardnos impact structure carbon is preserved after melting of target rock [9], while in the Mjølnir impact crater it is likely that carbon is lost from the system through generation of soot by combustion of hydrocarbon-bearing rocks [10]. Soot particles at the K/T boundary might also be a result of impact induced carbon loss through burning of hydrocarbon bearing target rocks [11]. Our study of the preservation of organic carbon in the Haughton melt breccias shows that even though carbon is lost from the system after high temperature impact melting, substantial amounts of organic carbon can still be preserved in impact-processed rocks. The study of the preservation and alteration of organic carbon in impact events and other high-temperature events is important in a context of astrobiology, including the detection of organic molecules which are critical for life. If organic carbon can be preserved after a high-temperature impact event, this will 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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