SHOCK METAMORPHISM AND ORGANIC MATTER IN NEW IMPACTITE SAMPLES FROM THE HIAWATHA CRATER, NW GREENLAND. W.R. Hyde[1], A.A. Garde[2], G. Kenny[3], P. Beck[4], L. Johansson[5], J. Gustafsson[6], N.K. Larsen[1], [1]Centre for GeoGenetics, Globe Institute, University of Copenhagen, Øster Voldgade 5-7, 1350 Copenhagen K, Denmark, (william.hyde@sund.ku.dk), [2]Geological Survey of Denmark and Greenland, Øster Voldgade 10, 1350 Copenhagen K, Denmark, [3]Department of Geosciences, Swedish Museum of Natural History, SE-104 05 Stockholm, Sweden, [4]Institut de Planétologie et d'Astrophysique de Grenoble, CNRS/UJF, 38400 Saint-Martin-d'Hères, France, [5]Department of Geology, Lund University, Sölvegatan 12, SE-223 62 Lund, Sweden, [6]Department of Geological Sciences, Stockholm University, SE-106 91 Stockholm, Sweden.

Introduction: Discovered in 2018 [1], the 31km-wide Hiawatha impact crater is one of the 25 largest impact structures on Earth (Fig. 1). The crater is completely covered by the Greenland Ice Sheet and hosted by Palaeoproterozoic migmatitic paragneisses of the Inglefield Formation [2]. Sand-sized glaciofluvial grains from the crater outwash show features diagnostic of impact [1]. Although the crater has not yet been dated radiometrically, the presence of thermally degraded organic matter provides a likely maximum age of ~2.4 – 3.0 Ma [3] and indicates that the Hiawatha crater is the youngest large impact structure on Earth. New impactite rocks collected from the Hiawatha glacial margin, proximal to the crater, display a wide range of impact-diagnostic shock features and contain abundant organic matter.

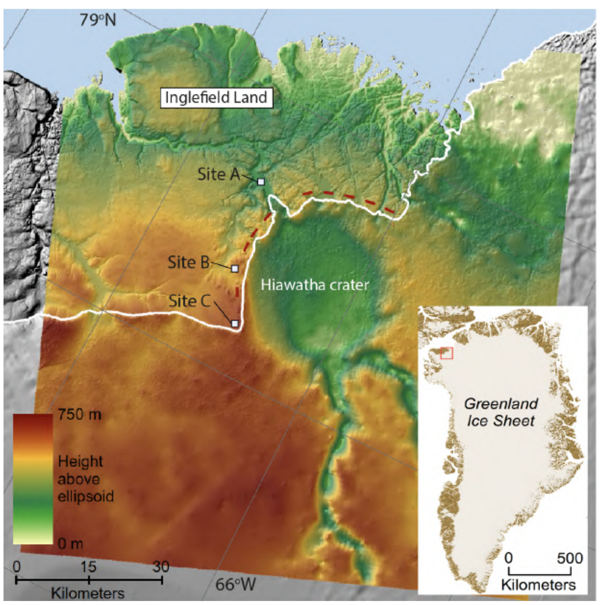

Fig. 1. Location of the Hiawatha impact crater adapted from [1]. Site locations A-C (white squares). Current ice margin of the Greenlandic Ice Sheet (white line). Inset map shows location within Greenland (red square).

Samples and methods: Forty rock samples (HW19-01 to HW19-40) were collected in 2019 from three sites along the glacial margin in the Inglefield foreland (Fig. 1). Impactite samples range from small pebble-sized rocks to >1 kg (Fig. 2). Optical microscopy, scanning electron microscope (SEM) and backscattered electron (BSE) imaging were conducted at Copenhagen, Stockholm and Lund universities. BSE imaging and microstructural characterization using electron backscatter diffraction (EBSD) analysis of zircon grains from samples HW19-01 and HW19-05 was performed at the Swedish Museum of Natural History, Stockholm, following the setup and protocol in [4].

Results: The new Hiawatha impactite samples described here are lithic impact breccias and clast-rich impact melt rocks [5]. All samples contain lithic clasts sourced from paragneiss target rock, dominated by quartz and plagioclase. Melt rocks contain new euhedral microlites in a glassy or microcrystalline matrix which may exhibit flow structures. Amorphous organic matter is dispersed in melts and lining lithic clasts, and larger fragments preserve cell structures [3], see Fig. 3.

Fig. 2. Cut surface of polymict lithic impact breccia (sample HW19-39) with organic fragments (red arrow) and carbonate melt clasts.

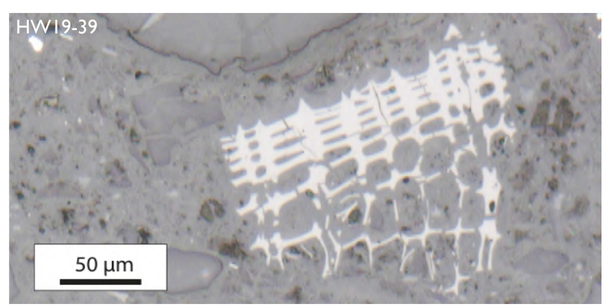

Fig. 3. Photomicrograph (reflected light) of charred organic fragment in impact breccia (sample HW19-39) with preserved equidimensional cell structure, likely from conifer wood [3].

Impact-diagnostic shock features include quartz PDFs, shock-metamorphosed zircon and partially melted plagioclase feldspar with checkerboard texture (Fig. 4). Roughly half of the impactite samples contain quartz PDFs in multiple orientations, which can be decorated, as well as bent and/or curved. Other presumed but not diagnostic shock-induced features include kink bands and/or loss of extinction in biotite, mosaic or undulatory extinction of silicate minerals, carbonate melt inclusions, feather features associated with quartz PDFs and abundant mechanical brecciation.

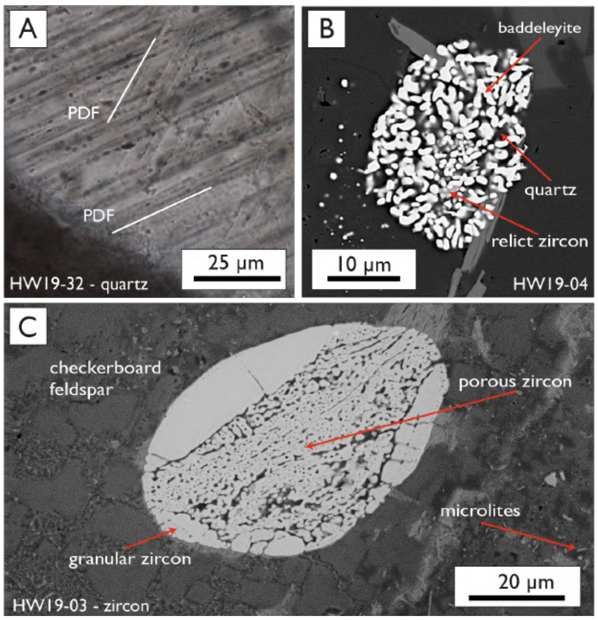

Fig. 4. Shocked mineral grains in impact melt rocks. A) decorated PDFs in quartz in two unknown orientations (transmitted light). B) Baddeleyite with relict zircon and quartz. C) Granular and porous zircon within partially melted checkerboard feldspar, adjacent to melt matrix with new euhedral microlite growth. B, C: BSE images.

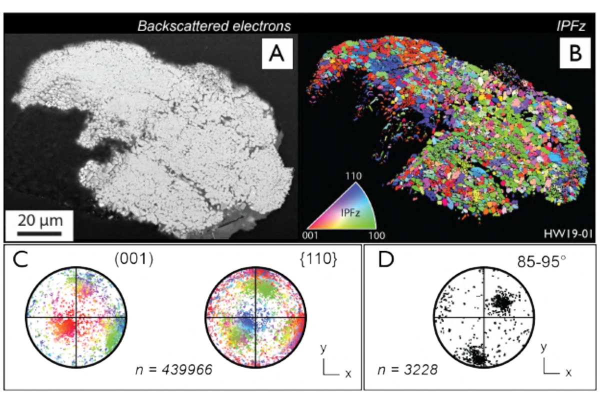

Fig. 5. Granular zircon grain displaying crystallographic relationships which indicate the past presence of reidite. A) BSE image showing granular texture. B) EBSD image displaying granules with relative misorientation. C, D) Pole figures displaying systematic crystallographic misorientation indicating FRIGN zircon [8, 9].

Microstructural SEM-BSE and EBSD analysis of zircon grains reveals partial to complete recrystallization textures (Fig. 5), porous textures, almost complete decomposition of zircon to baddeleyite (Fig. 4b) [6] and up to 20° relative misorientation across grains as a result of crystal-plastic deformation. Many of the recrystallized grains are composed of granules with systematic crystallographic relationship, including: (i) domains of neoblasts systematically misoriented by 90°, (ii) coincidence among (001) and {110} poles, and (iii) high-angle misorientation axes coincident with poles to {110}.

Discussion: Impactites from the Hiawatha crater containing diagnostic, highly shocked minerals provide unambiguous evidence for an impact event, and the different samples reflect a wide range of shock intensities. Organic matter within impactite rocks is uncommon and usually originates from recycled carbon from target rocks. Thermally degraded wood fragments in the Hiawatha impactites with recognisable cell structures indicate that the target area was forested prior to the impact [3], which may have taken place through the Greenland Ice Sheet [7]. Decomposition of zircon to baddeleyite and quartz is likely impact-induced and is observed in other craters, e.g., Ries and Chicxulub [6]. Zircon grains displaying systematic crystallographic relationships [Fig. 5] have previously been interpreted as evidence for recrystallisation from the high-pressure $ZrSiO_4$ polymorph reidite and termed 'former reidite in granular neoblastic zircon' or FRIGN zircons [8, 9], and suggest shock pressures in excess of ~30 GPa [10, 11].

Future work: The recrystallization and porous textures displayed by the FRIGN zircon grains are ideal candidates for U–Pb dating of the impact, e.g., [4]. SEM with high-resolution EDS-based automated quantitative mineralogy mapping and backscattered-electron (BSE) imaging. Electron microprobe (EMP) analysis of melt phases. Raman spectroscopy of carbonaceous material and shock-induced phase transformation of quartz and zircon.

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