A PRELIMINARY SIMULATION OF THE HYDROTHERMAL SYSTEM AT THE BOLTYSH IMPACT STRUCTURE. A. E. Pickersgill[1], E. V. Christou[1], and M. R. Lee[1], [1]School of Geographical & Earth Sciences, University of Glasgow, Gregory Building, Lilybank Gardens, Glasgow, G12 8QQ, UK, (annemarie.pickersgill@glasgow.ac.uk).

Introduction: Hypervelocity impact structures are known to result in post-impact hydrothermal systems that have been tied to the origins of life on Earth and possibly on other planets [e.g., 1–5]. Despite the importance of impact-induced hydrothermal activity in the development of habitable environments, the duration of such systems is poorly constrained, with only a few system lifetimes determined by geochronological measurements and some by numerical simulations.

We present here the results of a preliminary numerical simulation of the hydrothermal system generated by the 25 km diameter, 65.5 Ma Boltysh impact structure, Ukraine, for the purpose of determining how long a structure of this size might support conditions conducive to thermophilic and hyperthermophilic microorganisms. The Boltysh target rocks are Precambrian granites and granitic gneisses making up the crystalline basement of the Ukrainian Shield [6]. The impact structure is overlain by >500 m of Cretaceous and younger sedimentary rocks [6]. Owing to minimal post-impact erosion, a near complete section of impact melt rocks (allochtonous breccias and breccia deposits overlying impact melt) has been preserved. Data from numerous boreholes has provided a comprehensive understanding of the stratigraphy of this structure [6,7]. Boltysh also makes a pleasing target for numerical simulations due to the straightforward target rocks, as they are crystalline, and relatively homogenous granites and granitic gneisses [6,7].

Methods: To understand the lifetime and development of the post-impact hydrothermal system at Boltysh, we simulated the system using the USGS Hydrotherm III code. Lithologic units and positions were based on the published cross sections of the impact structure [6,7]. In the simulation, the rim to rim diameter is set at 25 km, with a maximum crater depth of 1.2 km; the central uplift is 6 km from trough to trough and ~650 m above the lowest point in the crater. For the purposes of this preliminary investigation the simplest lithological units were used as follows: the annular trough is filled by ~300 m of lithic breccia; ~100 m of impact melt rock; and ~100 m of impact melt bearing breccia. The remainder of the structure is filled by sedimentary deposits. Physical properties for each unit were derived from values reported in the literature for similar lithologies from other structures.

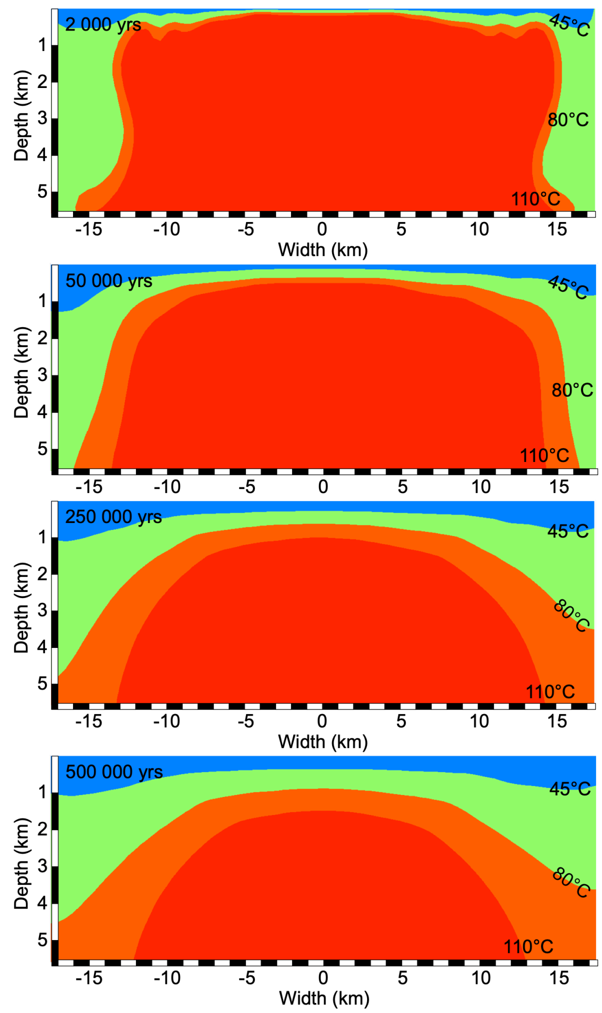

***Figure 1:** Results of the initial simulation showing temperature envelopes for thermophilic (45-80°C) and hyperthermophilic (80-110°C) microorganisms at 2 kyr, 50 kyr, 250 kyr, and 500 kyr.*

Results: Initially, high temperatures are centered around the melt in the annular trough and in the central uplift. After 2 kyr, the melt rock is around 900°C, with the central uplift ~700°C. This heat distribution drives fluid circulation upwards and outwards reaching the surface between the annular trough and the rim.

After 16 kyr the mass flux of liquid water has fallen to less than 1E-7 g/s cm^2 throughout the system. However, fluid movement continues, at a very low flux, to follow the same pattern of flow upwards and outwards from an area just beneath the central uplift as the lithologies continue to cool. After approximately 120 kyr liquid water mass flux is negligible at less than 1E-9 g/s cm^2.

Of particular interest are the zones with temperature ranges suitable for thermophilic (45-80°C) and hyperthermophilic (80-110°C) microorganisms. These zones are illustrated in Figure 1 at time steps of 2 kyr, 50 kyr, 250 kyr, and 500 kyr.

After 2 kyr there is a narrow 45-80°C zone above the crater and outside the annular trough that is roughly 500 m thick and 4 km wide, with a shallower ~80-110°C zone beneath. Temperatures are too high for even hyperthermophilic organisms closer to the central uplift and melt rocks. Beyond the rim the habitable zone is much deeper. Over the next 10 kyr the temperature pattern remains similar, but with the inhospitable zone shrinking down and towards a point 2-3 km below the central uplift. By 50 kyr the 45-80°C zone between the annular trough and the rim has deepened to ~1 km thick, with the 80-110°C zone stretching to just under 1 km in thickness. By 250 kyr both zones have expanded significantly, and by 500 kyr temperatures at 1 km under the surface have cooled to below 90°C.

Discussion: There are various ways to define the end of a hydrothermal system, for example fluid circulation or temperature. The definition favoured by Abramov and Kring [8] is the time taken to reach 90°C at 1 km beneath the surface. Using this definition, the hydrothermal system at Boltysh lasts approximately 500 kyr, with fluid flow becoming negligible after 15-20 kyr.

Numerical calculations of the duration of hydrothermal activity at the similarly sized Nordlinger Ries, Rochechouart, and Haughton impact structures yielded estimates of a couple of thousand to tens of thousands of years [9,10]. However, Schmieder and Jourdan [11] determined the duration of hydrothermal activity at the 23 km diameter Lappajarvi impact structure to be ~600 kyr to ~1.6 Myr using radioisotopic geochronology. Our preliminary results for the duration of the hydrothermal system at the 25 km diameter Boltysh impact structure is a duration of ~500 kyr and so is consistent with the results of Schmieder and Jourdan [11] for the similarly sized Lappajarvi.

This work was motivated by the presence of hydrothermal alteration in the central uplift and crater fill impactites [1,7,12], as well as by the presence of granular alteration in impact-generated glass samples which is suggestive of biologically mediated alteration [13]. An understanding of the possible longevity of the hydrothermal system at Boltysh informs how long microorganisms had to colonize the structure.

Future work: The results presented here are from a first pass at a simulation of this structure and were conducted at low resolution, using assumed permeability values, and without exchange between the structure and the crater lake that developed post-impact. Our next step is to run higher resolution simulations using permeabilities measured directly from the Boltysh samples but also accounting for changes in permeability between shortly after the impact and present-day, and incorporating fluids from the lake as well as precipitation. Investigation of the possible biological implications will include isotopic analysis of sulfides in the breccias to determine whether or not biological sulfate reduction occurred.

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