THE ASTROBIOLOGICAL POTENTIAL OF IMPACT-GENERATED HYDROTHERMAL SYSTEMS.

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Introduction: While there is widespread speculation on the geological setting for the origin of life, there is some consensus that hydrothermal systems may have provided the requisite conditions [1]. Because of this, hydrothermal systems are considered one of the best candidate habitats for the emergence of life, with submarine hydrothermal systems receiving much of the attention [2]. The majority of submarine hydrothermal systems on Earth are driven by plate tectonic processes in marine settings. Given the scarcity of such settings in the planetary context, could other hydrothermal environments also have provided the requisite conditions suitable for the origin and subsequent evolution of life? We propose that hydrothermal systems generated by meteorite impact events represent prime and abundant habitats for life. In this contribution, we review and synthesize the current knowledge of impact-generated hydrothermal systems, provide a generic model for their formation, and highlight gaps in knowledge where further research should be directed.

Impact cratering in the Solar System: It is now widely recognized that impact cratering is the most ubiquitous geological process in the Solar System. Meteorite impact structures are one of the most common landforms on the terrestrial planets and rocky and icy moons of the outer Solar System. Further, impact rates in the inner Solar System were substantially higher during the first few hundred million years of formation [3]. As such, if all impact craters generate hydrothermal systems then such habitats could represent one of the most common hydrothermal environments in the Solar System. But is this the case?

Impact-generated hydrothermal systems: There are three main potential sources of heat for creating impact-generated hydrothermal systems [4]: (a) impact melt rocks and impact melt-bearing breccias; (b) elevated geothermal gradients in central uplifts; (c) energy deposited in central uplifts due to the passage of the shock wave. Reviews of the impact record on Earth have shown that ~70 out of the ~180 known impact craters preserve evidence for hydrothermal alteration [5, 6]. It is important to note that the vast majority of impact craters on Earth have not been well studied and so in many craters, there is only brief mention of hydrothermal alteration minerals (e.g., clays, carbonates) and that the nature of the hydrothermal *systems* in these craters remains poorly constrained. While it seems clear that all large impact craters on Earth appear to have generated hydrothermal systems – with estimates of up to ~1 million years duration for Chicxulub [7] (d = 180 km) and Sudbury [8] (d = 250 km), the lower size threshold required to initiate crater-wide hydrothermal circulation is unknown. This is, of course, an important question to address for planetary exploration missions, as small simple craters are far more abundant than large complex impact craters.

Hydrothermal settings within impact craters: Studies of impact craters on Earth suggest that there are six main locations within and around impact craters where impact-generated hydrothermal deposits can form (Fig. 1): 1) crater-fill impact melt rocks and melt-bearing breccias; 2) interior of central uplifts; 3) outer margin of central uplifts; 4) impact ejecta deposits; 5) crater rim region; and 6) post-impact crater lake sediments.

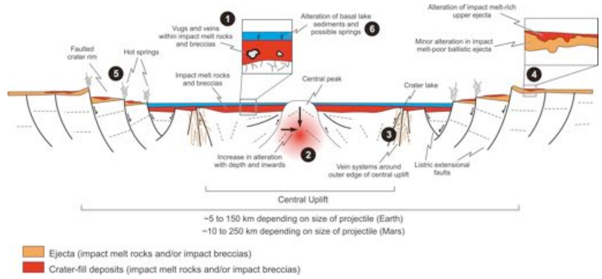

Fig. 1. Schematic representation of the distribution of hydrothermal settings within impact craters (from [6]).

The question of H_2O: The other requirement for hydrothermal systems, besides the heat source, is a fluid. Because of the paucity of comprehensive studies of impact craters on Earth, the details are not completely known; however, it seems clear that the geographical and climatological setting at the time of impact plays a major role in determining how pervasive and long lived an impact-generated hydrothermal system may be [5, 6]. In a nutshell, craters in marine settings and those with deep crater lakes that formed immediately upon impact appear to be more altered, which has important implications for the development of hydrothermal systems on other planetary bodies.

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