IMPACT CRATERS AS ASTROBIOLOGY EXPLORATION TARGETS FOR FUTURE MARS MISSIONS.
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Introduction: Impact cratering is the most ubiquitous geological process in the Solar System and meteorite impact craters are one of the most common geological landforms on Mars. Impact craters have featured prominently in the surface exploration of Mars. Typically they have been highlighted as sites offering unique bedrock exposure (e.g., Eagle, Endurance, Victoria Craters during the MER Opportunity's expeditions) or as sedimentary basins providing unique climate records (e.g., Gale Crater, landing site for the MSL Curiosity rover). We suggest that impact craters offer much more than simply providing exposure and records of infilling and that they represent prime astrobiology exploration targets for future Mars missions. We propose that impact craters would have provided conditions suitable for the emergence of life on Mars through the production of suitable substrates for prebiotic chemistry and through the production of critical habitats for the emergence and survival of life.

Substrates for prebiotic chemistry: One of the major advancements in recent years regarding the origin of life has been the recognition of the important role of mineral substrates [1]. Specifically, it has been proposed that minerals may have played a role in both the formation of organic molecules ranging from formaldehyde to RNA, through reactions mediated by minerals. Clay minerals, and in particular montmorillonite, has been shown to catalyze a variety of organic reactions, in particular the formation of RNA [2, 3].

Clays and other hydrated minerals have been widely documented on Mars with the general view being that these phases formed by aqueous alteration in a wetter climate early in the planet's history [4]. Previous studies have shown that hydrated silicates (particularly clay minerals, zeolites, and hydrated silicate glass) are preferentially associated with the heavily cratered highlands of Mars although some lowland exposures, exclusively in impact craters, have also been found [5]. The interpretation for this association of clays with impact craters has generally been that the craters have simply exposed pre-existing clays. However, it is important to note that impact events can also generate primary clays through impact-generated hydrothermal alteration [6] and through the devitrification of hydrous impact melt products. Thus, clays within impact craters may have a pre-impact (i.e., the excavate pre-existing crustal clays), syn-impact (i.e., impact-generated), or post-impact (i.e., in impact crater lakes) [7]. Regardless of the origin, it is clear that clays, widely held as being important for prebiotic chemistry, are prevalent within impact craters on Mars.

Habitats for emergence and evolution of life: Regardless of the previous discussion, if we now assume that all the necessary prerequisite conditions for life existed on Mars, where could life have originated? On Earth, one of the most widespread theories is that life originated in hot, aqueous environments, in the form of hydrothermal systems [8]. Volcanic heat sources drive all the active hydrothermal systems on Earth today; however, it has also been shown that most large impact events on Mars likely generated hydrothermal systems [6], which based on numerical modeling may have persisted for hundreds of thousands of years [9]. Thus, hydrothermal systems generated by the impact craters themselves may have provided habitats for the emergence of life on Mars.

If we now assume that life did emerge on Mars during the first few hundred million years of its history – as we know it did on Earth – where would life have colonized? Critically, impact events produce several habitats that are highly conducive to life and that were not present before the impact event. Major habitats include: 1) Impact-generated hydrothermal systems, which could provide habitats for thermophilic and hyperthermophilic microorganisms [6]; 2) Impact-processed crystalline rocks, which have increased porosity and translucence compared to unshocked materials, improving microbial colonization [10, 11]; 3) Impact glasses, which, similar to volcanic glasses, provide an excellent readily available source of bioessential elements [12]; and 4) Impact crater lakes, which form protected sedimentary basins with various niches and that increase the preservation potential of fossils and organic material [13].

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