HABITABILITY AND BIOSIGNATURE PRESERVATION IN IMPACT-DERIVED MATERIALS.

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Introduction: The catastrophic biological effects of meteorite impact events are well established. However, meteorite impact events also create unique microbial niches that may have been widespread habitats on early Earth and, as such, are important astrobiological targets on other rocky bodies such as Mars [1]. Impact materials represent understudied microbial substrates both for microbial colonization as well for the potential to preserve evidence of biological activity. Any large enough impact into a H_2O-bearing planetary body will result in an impact generated hydrothermal system (IGHS) [2] that will cool to temperatures capable of supporting thermophilic (heat-tolerant) life, persisting anywhere from thousands to millions of years.

Impact-generated hydrothermal systems: IGHS have been documented in 70 of ~180 terrestrial impact structures [3] and mineralogy and morphology consistent with impact generated hydrothermal activity has been described at several Martian impact crater [4].The interaction of water with heated impact materials forms a high-temperature rock-water circulatory system that can dissolve, transport, and precipitate various mineral species [5]. IGHS and associated mineral deposits are characterized by chemical and thermal disequilibria rendering them attractive systems for microbial colonization. It has been suggested that warm and wet conditions are required to form hydrated silicates on Mars, therefore, clay forming epochs and regions are used to indicate potential habitability [6] and that warm, wet conditions are restricted to the earliest period of Martian history implying that both habitable and phyllosilicate-forming environments are limited to the Noachian Period (e.g., [7]). However, spatially and temporally extensive IGHS and weathering of impact-derived materials provide an alternative mechanism for hydrated silicate generation [4]. IGHS may provide transient, local warm, wet conditions associated with clay formation temporally extending periods of habitability on Mars.

Biosignatures:

Hydrothermal systems: Evidence of microbial colonization has been described in several IGHS deposits. Titanium oxide 'biomineralized' rod-shaped features and associated etch pits on hydrothermal clinoptilolite at the Ries structure [8]; rod-shaped biomorphs in post-impact hydrothermally altered sediments from the Chesapeake Bay structure [9]; evidence of extracellular polymeric substances in a hydrothermally precipitated calcite vein from the Siljan structure [10]; and filamentous 'fossils' hosted in hydrothermally precipitated mineral assemblages within fractured impact breccia from the Dellen structure [11]. We have also reported microbial etching [12] and putative evidence of microbial Fe reduction [13] in hydrothermally altered impact glass clasts from the Ries structure.

Shocked crystalline rock: The process of shock metamorphism is capable of altering pre-existing terrestrial environments such that they become viable biotic habitats [14]. These endolithic habitats offer warm, moist, and UV-protected environments. Studies of impact-generated lithologies indicate that shock metamorphism increases the porosity of the target rocks [15] and increases the colonizable area providing a refugia for microorganisms. Biomass increases with increasing exposure to pressure within the target [16].

Impact glass: Impact glasses also comprise a unique substrate for microbial colonization. Microbial alteration of natural glasses is a widespread natural phenomenon and the habitability of subaerial (e.g., [17]) and submarine (e.g., [18]) natural glasses suggests that impact glasses are potential habitats. Impact generated glasses have been shown to preserve both evidence of pre-impact biological material [19] and evidence of post-impact microbial colonization [13]. With the recent spectral identification of glasses associated with Martian impact craters [20], impact generated lithologies represent exciting new astrobiology targets for future exploration.

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