PRESERVATION OF MICROBIAL-MINERAL BIOSIGNATURES IN CAVES AND PALEO SPRINGS.
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Introduction: Cave environments on Earth possess unique combinations of features that give rise to exquisite preservation of biosignatures, both biomolecular and structural, at micro and macro scales [1]. Caves are famous as places where elaborate and often unique minerals form [2] including the production of highly distinctive biominerals [3, 4]. Caves also house some of the most remarkable preservation of microbial mats and other biopatterns [5,6]. Cave microbial communities often engage in extensive mineral precipitation while they are living, in a sort of "autofossilization" that provides many of the well-preserved life traces that we see in these environments [5].

Caves as Habitats on Earth: As habitats, caves provide many advantages including absence of ordinary surface weather, protection from ultraviolet radiation, protection from dessication and seasonal temperature and humidity extremes, and some protection from predation by other organisms. The price paid is a very oligophilic environment where sources of energy can be scarce, and organic matter is surface derived rendering many cave organisms detrivores. However, many caves also gain energy from geological sources like chemically reduced gases coming from deep crustal or even mantle sources, or accessible oxidizable minerals (e.g. iron, manganese, sulfur compounds and others).

Cave Habitats on Mars: Caves from volcanic processes have been detected on Mars by Cushing et al in 2007. Such subsurface cavities could potentially represent a unique bridge between the risks to life on the Mars surface (harsh oxidizers, large temperature extremes, extreme aridity, radiation, dust storms, etc.) over the course of its diminishing surface habitability [x] and the difficulty in accessing potential Martian life forms yet extant or extinct but preserved in the subsurface (drilling or otherwise trying to sample the interior of Mars). The potential for long term stable ices in Mars caves has been modeled and is of timescales not inconsistent with obliquity super seasons on Mars. Further, such cavities may contain somewhat higher vapor pressures of gases than the aboveground atmosphere. Such subsurface habitats should be interrogated by future missions for biosignatures or even the prospect of extant lifeforms which may be dormant in the current era of Mars' obliquity cycle.

Spring and Paleo Spring Habitats on Mars. In addition to caves, springs can function as refugia for life forms as enviornments degrade either cyclically or monotonically. Springs are direct conduits that bring subsurface life and its characteristic metabolic products to the surface. On Mars large geochemical and physical gradients are possible between the surface and subsurface environments. Springs often generate biologically precipitated, characteristic deposits on the surface such as tufas and silica sinters.

Concentrated brines are ubiquitous in terrestrial Archean shield rocks [1,2]. The ongoing research of the present day transient presence of liquid water on the Martian surface initiated by Malin and Edgett's [3] discovery of active gullies is increasingly focused on concentrated brines and hydrated salts [13]. The biologically rich anoxic brines of the Soudan Mine [4] provide evidence that such brines can host microbes and produce iron oxyhydroxide precipitate "siderothems" analogous to features visible on the Martian surface.

Mars Caves as Mission Targets: Caves allow more ready access to the shallow interior of Mars than any other mode of sampling. Lavatube caves tend to be relatively close to the surface and the task of drilling through a few meters of rock to access cavities is a far less daunting prospect than an open-ended very deep drilling approach to a lake bed or other sedimentary feature, and will yield some of the same types of data, possibly including a history of organic material, climate proxies, and other types of data that have likely been actively destroyed by the highly chemically active and radiation influenced surface.Springs or seeps in caves combine the life advantages of both environments.

Conclusions: Earth caves house an enormous variety of microbial communities, many of whom produce spectacular, distinctive morphological biosignatures that are visible to the naked eye and possess qualities not found in abiotic mineral precipitates. Such biosignatures are tremendously well preserved in the protected environments of caves which escape the ravages of weather and other disturbance. These may be a model for detecting and characterizing unequivocal biopatterns. The Martian subsurface is represented so far by the detection of several thousand volcanic caves in many parts of Mars which could be highly valuable targets for future landed missions.

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