THE SEARCH FOR SUSTAINABLE SUBSURFACE HABITATS ON MARS. M. Ivarsson[1] and P. Lindgren[2], [1]Swedish Museum of Natural History, Department of Palaeozoology, Svante Arrheniusväg 9, Box 50007, 104 05 Stockholm, Sweden, magnus.ivarsson@geo.su.se, [2]University of Glasgow, Department of Geographical and Earth Sciences, Gregory Building, Lilybank Gardens, Glasgow, G12 8QQ UK, paula.lindgren@ges.gla.ac.uk.

Introduction: Subsurface environments have been targeted as plausible settings for the search for a present or a fossil record of life on Mars, since the current conditions on the martian surface are extremely hostile to life [1]. The low atmospheric pressure (~6 hPa), low surface temperature (average of ~240 K), lack of liquid water, UV radiation damaging to DNA, and the oxidized soil chemistry make the martian surface hostile and uninhabitable for life [2]. The subsurface, on the other hand, may provide more hospitable conditions for a martian biota. Hydrothermal activity associated with volcanic activity could provide liquid water, heat and nutrients for a microbial ecosystem.

Ivarsson and Holm [3] performed a study on fossilized microorganisms in basalts from the oceanic crust and pointed out that fossilized microorganisms and ichnofossils in subseafloor basalts have been able to colonize various micro-niches in the subseafloor environments that represent different stages of the alteration of the ocean crust. This indicates that the subseafloor biosphere ar capable to sustain for long periods of time.

Near future Mars sample return missions are limited by the missions payload which excludes heavy drilling equipment and the access to a putative martian subsurface biosphere or fossil record. Impact cratering, on the other hand, is a natural geological process capable of excavating large amounts of rock material from great depths up to the surface. Therefore, by studying impact ejecta, preferably from past hydrothermal environments, on the Martian surface in future missions, one would be able to search for a sustainable Martian deep biosphere without using heavy drilling equipment.

Fossilized microorganisms from subseafloor basalts: The alteration and weathering of ocean-floor basalts, palagonitization, is a process where fresh volcanic glass and basalts are hydrated and leached and finally degraded to a residue called palagonite. While palagonite is the major end product of palagonitization, the zeolite species phillipsite and the clay mineral smectite are the secondary products. The palagonitization process is divided into three major stages: initial, mature and final stages, distinguished by the presence or absence of glass or secondary minerals. The general trend is that the amount of fresh glass decreases and the amount of palagonite and secondary minerals increases toward the final stage.

In samples consisting of drilled ocean-floor basalts from the ODP Leg 197, fossilized microorganisms have been found associated with all three stages of palagonitization. The microfossils range from bored microchannels in volcanic glass, via filaments of different morphologies attached onto altered glass and basalt, to coccoids and filaments both attached onto phillipsites and found within wedge-like cavities in between phillipsite crystals.

The microbial colonization of new niches during ocean-floor alteration and palagonitization extends the occurrence and opportunities for a deep subseafloor biosphere both in time and space. The wide range of different mineralogical habitats opens up new possibilities to find a sub-seafloor biosphere that probably inhabit much larger volumes of the Earth's ocean crusts than was previously known. It further shows that the deep subseafloor biosphere can sustain over geological time as the alteration processes continue.

A possible martian subsurface biosphere: The subseafloor basalts on Earth may necessarily not provide the ultimate analog for martian subsurface conditions but the similarities to potential hydrothermal environments on Mars make them at least worth investigating. Hydrothermal activity has occurred throughout most of the martian history, probably in association with volcanism, and basalts are the dominating rock type on Mars, thus, the geological settings are similar. Recent observations of repeated volcanic activation with phases of activity as young as two million years suggest that volcanoes are potentially still active today [4]. Another factor that is of interest concerning a potential martian subsurface biosphere is the lack of active plate tectonics. On Earth, volcanic and hydrothermal active areas constantly move and the plate tectonics recycle the crust. It is a dynamic system that constantly strives towards a non-equilibrium state in the crust and on the surface. Mars, on the other hand, is characterized by the opposite. No plate tectonics are present to recycle the crust and the volcanic centers are fixed much like intra-plate volcanism on Earth with exception of a moving plate above the active center. This means that a volcanic area on Mars associated with a potential hydrothermal system as well as a potential subsurface biosphere would be spatially isolated. Hydrothermal circulation would be concentrated around the volcanic active area and probably not in contact with another active hydrothermal system. It could have been different on the young Mars with a warmer climate and liquid water both on the surface and in the ground but today there is a risk that sporadic hydrothermal systems are isolated. This would have effect on a potential biosphere that, even though its capability to sustain in the subsurface for long periods of time, eventually would suffer from lack of external contact. Survival of a closed system over billions of years is hard to imagine. However, even though the spatial fixation of volcanic active areas and associated hydrothermal systems might result in limited contact with other active hydrothermal systems and input of necessary nutrients and microorganisms they may be able to support a deep biosphere for long periods of time. The volcanic areas including potential hydrothermal systems will be extended in both time and space compared to volcanism on Earth. First of all are the volcanic areas larger than on Earth and thus can support a more extensive hydrothermal system. Secondly, the martian volcanoes are also active for longer periods of time. Olympus Mons, for example, has been active between 3,800 and 100 Ma. This is equal to 80% of the lifetime of the planet [4] and coincides with a wetter past of the planet. A potential subsurface biosphere that thrives in a hydrothermal system associated with a fixed heat source would have an extensive period of time to evolve in an extensive area of habitat.

Targeting a possible martian subsurface biosphere: Because of the unique capability of hydrothermal systems to preserve microbial life they could contain great quantities of paleobiological information. However, access to deep subsurface environments on Mars is obviously limited by drilling capabilities. They should, nevertheless, be considered as primary targets. Impacts in hydrothermal areas can spread material from great depths onto the surface. Such ejecta could contain traces of subsurface life. Several studies of terrestrial impact deposits show both preservation of pre-impact biosignatures, and introduction of post-impact biosignatures [5,6].

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