RADIATION INACTIVATION OF BACTERIAL SPORES ON MARS. G. Kminek and J. L. Bada, 1 European Space Agency, ESTEC/SER-ACT, Keplerlaan 1, 2200 AG Noordwijk, The Netherlands, Gerhard.Kminek@esa.int, 2 Scripps Institution of Oceanography, University of California, 9500 Gilman Drive, La Jolla, CA 92039, jbada@ucsd.edu.

Introduction: The conditions on Mars are thought to have been more conducive for life during its early history, about 3 billion years ago. If life ever evolved on Mars, would it be possible to see the remnants of a long-extinct biosphere today? Or even more interesting, would it be possible to find Martian bacterial spores that survived for billions of years on Mars?

Bacterial spores exhibit a remarkable resistance to adverse environmental conditions [1]. At the moment, however, no upper limit for the survival of bacterial spores has been established. We propose that the ionizing radiation dose on Mars (and in other environments in general) could well be the Achilles heel for the long-term survival of bacterial spores. To test this hypothesis, we have investigated how the radiation environment on Mars – on the surface, subsurface and potentially in fluid inclusions – would affect the survival of viable bacterial spores.

Results: There are two distinct radiation environments on Mars: the first few meters are dominated by the effect of the Galactic Cosmic Radiation (GCR), while the deeper subsurface is characterized by radiation from the decay of radionuclides. The calculated radiation dose rate from the decay of radionuclides ranges from 350 µGy/year at 3 billion years ago to 130 µGy/year today [2]. The total accumulated dose over the last 3.1 billion years in the Martian sub-surface is close to 750 kGy [2]. This accumulated dose over time can be compared to the radiation inactivation constant of dry bacterial spores. The measured inactivation constant of dry *B. thuringiensis*, *B. subtilis*, and *B. pumilus* spores is in the range of 0.66-1 kGy⁻¹ [2], [3]. Dry bacterial spores show a temperature dependence in their radiation sensitivity, following a van-t'Hoff-Arrhenius law above 130 K [4]. The temperature corrected inactivation constant for a Martian sub-surface temperature of 220 K is 0.59-0.90 kGy⁻¹ for the referenced dry bacterial spores. The chances of finding viable bacterial spores in a 1-g sample of Martian soil is therefore less than 1 in a million after about 100 million years, depending on the radiation inactivation constant used, assuming an optimistic original bacterial concentration of 1x10⁸/g of soil and a reduction of the population by 14 orders of magnitude (Fig. 1).

The probabilities are even lower considering the Martian subsurface that is accessible to *in situ* landers. The depth-dependent dose rate on the surface of Mars ranges from 0.19 Gy/year at the surface to 600 µGy/year at a depth of about 3 meters [2], [5]. Consequently, the probability of finding viable bacterial spores in a 1-g sample of Martian soil within the first meter is 1 in a million within 600,000 years using an average radiation inactivation constant for dry bacterial spores (Fig. 2).

The chances of retrieving ancient viable bacterial spores from Martian halite fluid inclusions is similar to the case of the Martian subsurface – with the radionuclide ⁴⁰K as dominant radiation source [2].
Discussion: Several studies investigated the survival of bacterial spores under simulated Martian conditions [6], [7]. The conclusion of these studies is that bacterial spores show significant survival as long as they are protected from the incident UV radiation. However, no consistent upper limit for the long-term survival of viable bacterial spores is given. Our results show that even in the absence of any other physical or chemical degradation process, ionizing radiation from the environment severely limits the long-term survival of viable bacterial spores on Mars. If any cycle on Mars allows dormant life forms to awake form their dormant state, repair the accumulated damage, and multiply, then the period of this cycle must be shorter than the time until the viability of spores falls below a certain value. In that case, radiation will not limit the long-term viability of dormant life forms other than setting the upper limit for the time between dormant/active cycles. Based on our work, this period has to be on the order of about 100 million years for the deeper Martian sub-surface, and less than 600,000 years for the uppermost surface.

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