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Mars Radiation field and Habitability evolution through time

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Abstract

The actual Martian radiation field is known to be higher than levels compatible with habitability conditions. This work defines critical geophysical parameters associated with geologic evolution and assesses their impact in terms of radiation environment and time evolution of habitability on Mars.

1. Introduction

Radiation levels expected at the surface of Mars are known to have an impact on life form, biological and organic materials. Therefore the ionizing radiation must be studied in order to evaluate the potential organic preservation on Mars.

MarsREC [1] and dMEREM [2] are ionizing radiation environment characterization models based on GEANT4 [3] Monte Carlo applications developed for the European Space Agency. Enabling the interface with geophysical databases, these models allow the evaluation of Martian radiation environment as a function of climatological and geological variables.

This work defines critical geophysical parameters associated with geologic evolution and assesses their impact in terms of radiation environment.

Results show that the erosion of the Martian atmosphere and the regolith, due to LHB era, lead to an important increase of the radiation environment, consequently radiation hazard and lead to the degradation of habitability conditions at the surface of Mars [5].

1.1 Primary ionizing radiation

Primarily, ionizing radiation generated by energetic particles incident at Mars have their origins in both *Galactic Cosmic Radiation* (GCR) and in *Solar Energetic Particle* (SEP) events produced in association with significant flaring.

The modulation of radiation environment at the surface of the planet is evaluated taking into account solar cycle modulation and influences attributable to seasonal effects, atmospheric depth and regolith composition [4].

1.2 Characterization of ionizing radiation field

Planetary ionizing radiation field is generally characterized by primary and secondary particle spectra and by the Ambient Dose Equivalent (ADE).

The Ambient Dose Equivalent (ADE) is the quantity recommended by the *International Commission on Radiation Units and Measurement* (ICRU) as a stable quantity for region radiation monitoring. ADE is a measure of the risk of radiation, that being independent of the target sensitivity is highly dependent on the nature and energy of the radiation environment [5].

2. Geophysical evolution through time

Being Mars a small size planet, with about half the radius of the Earth, Martian geological activity, is accelerated compared to the Earth. Therefore Mars cooled off more quickly than Earth [6].

From the point of view of ionizing radiation, the most important geophysical parameters to evaluate are: the atmospheric evolution, the existence of water at the surface in the form of an ocean or mineral hydration, and the presence of subsurface water [5].

Table 1: Evolution of Martian atmosphere, based on Melosh et al., 1989[7], and Kahn, 1985 [8]

	Noachian	Hesperian	Amazonian
Time (Gyr)	4.5 – 3.5	3.5 – 1.8	1.8 – 0
Ref. pressure (mbar)	1000	100	10 – 1

3. Results

Figure 1 illustrates the evolution of the ambient dose equivalent levels on mars in a reverse timeline.

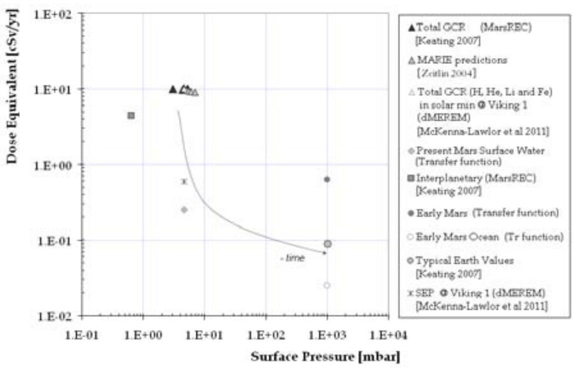

Figure 1: Reverse evolution of ambient dose equivalent levels [5]

4. Discussion and Conclusions

Results show that the erosion of the Martian atmosphere attributed to the LHB era led to an important increase of the radiation environment and radiation hazard, leading to the degradation of habitability conditions at the surface of Mars.

Additionally the evolution of the surface of the planet into the cold and dry Mars of today, led to the loss of radiation attenuation and protection [5].

The existence of a global magnetic field is recognized as a major driver for the evaluation of radiation environment. Nowadays, the remnant magnetic field, acting at a local shielding for low energy electrons and protons, is not effectively reducing the ambient dose equivalents at those locations. However, theories on potential Earth-like magnetosphere present on the early Mars encourage the hypotheses of existence of a safe radiation environment and therefore good habitable conditions in the Noachian/Hesperian era [5].

Sometime in the Hesperian or early Amazonian the change of the atmosphere characteristics led to an important change of the dominant mechanisms for interaction of primary radiation with the atmosphere and soil. The accurate study and simulation of the geophysical environmental conditions in this era may allow a better understanding of the evolution of habitability; enable a more accurate determination of limitations for astrobiology survival; and may help optimizing requirements for the search for life for future Mars exploration missions [5]

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