PROTECTION OF BIOMOLECULES BY MARTIAN ANALOGUE MINERALS AGAINST THE EFFECTS OF GAMMA RADIATION. G. Ertem[1,2] and C. P. McKay[3], [1]University of Maryland, Department of Atmospheric and Oceanic Science, College Park, MD, 20742, [2]Carl Sagan Center, SETI Institute, 189 Bernardo Avenue, Mountain View, CA 94043, [3]Space Science Division, NASA Ames Research Center, Moffett Field, CA 94035

Introduction: Organic compounds formed in space are delivered to planetary surfaces via meteorites, comets and interplanetary dust particles at an amount of 2.4 x 10^8 g carbon/year [1-5]. However, the fate of these compounds on Mars is considerably different than those on Earth due to the thin Martian atmosphere. Our previous research designed to study the effect of UV radiation on biomolecules mixed with Martian analogue minerals demonstrated that organic compounds undergo complete destruction / decomposition in the absence of minerals [6].

Here we present our research designed to investigate the protective role of Martian analogue minerals for biomolecules against the effects of gamma radiation. Gamma rays have considerably higher energy (>2x10^{10-14} Joule), compared to UV radiation (5x10^{-19}– 2 x 10^{-17} Joule).

These organic compounds are considered to be the precursors of RNA and have been identified in meteorites [7].

Experimental: Irradiation experiments were run in the presence and absence of minerals that have been identified on Martian soil, namely calcium carbonate ($CaCO_3$) [8], gypsum ($CaSO_4$) [9], kaolinite [10], and high and low charge density phyllosilicates [10]. Our research investigating the photo-oxidation of these biomolecules by hematite, another Martian analogue mineral, will be discussed in another presentation of this meeting [11].

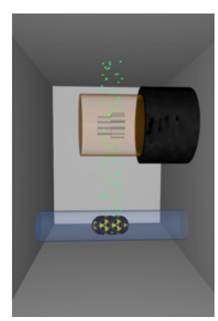
First set of gamma irradiation with a dose corresponding to 15,000 years on Martian surface, i. e., 3 Gy (Gray) was performed using Gamma Cell 40 from a ^{137}Cs source at 25°C [12.] Hassler et al., 2014]. Although ^{137}Cs itself is a beta emitter with a half-life of 30.1 years, its decay product metastable ^{137}Ba further decays by gamma emission to the stable ^{137}Ba with a half-life of only 2.6 min. In the Gamma Cell 40, electrons are trapped before reaching the target sample. In Table, numbers in paranthesis correspond to % organic loss as a result of irradiation corresponding to 15,000 years on Martian surface.

A second set of irradiation experiments were performed by using a Co-60 source: The gamma dose received by the samples corresponded to 500,000 years on Martian surface *(Gamma irradiation: ^{60}Co radiation source: Rad Cal Model 2025 s.n. 3084).* The dose rate of Gamma Cell 40 was 790 Gray/h at the time of these experiments. The dose of Co-60 was 7630 Gray/h.

Control of temperature and gas atmosphere during gamma irradiation simulating Martian surface*:* Mineral-organic compound mixtures in 2 mL polyethylene tubes were placed in 50 mL Falcon tubes containing dry ice (solid CO_2, which undergoes sublimation at -78.5°C) to maintain the low temperature and controlled gas atmosphere. In order to check whether any UV absorbing impurity was present in dry ice, four times the amount of dry ice added to each Falcon tube was added to an empty Falcon tube, irradiated with the same dose as the samples: 36585 Gray. This dose value was calculated using the value of 210 microGray/day as published by Hassler et al. in 2014 [12]. The gamma dose rate on Martian surface has been updated in a most recent work [13]. In our ongoing research, we use the most current dose values, i. e., 233 micro Gray per day [13]. Following the irradiation, the tube was washed off with water and the aqueous solution (extract) was analyzed by UV spectrophotometry: Absorbance *coming from the "impurities" in dry ice* was only 0.014 AU, a very low value compared to absorbance values of organics extracted from irradiated mineral-organic mixtures and controls: 0.300-0.700 AU.

Irradiation of mineral-organic mixtures simulating 5 cm below the Martian surface: Mineral-biomolecule mixtures prepared as described above were placed under 5 cm thick "Martian Garden" which is a mixture of oxides at the proportions shown below:

Composition of MMS-1, Mojave Simulant:
Silicates: 49%
Iron Oxide: 11%
Aluminum Oxide: 17%
Magnesium Oxide: 6%
Sulfates: <1%; Trace: 7%



Analysis of Irradiated Samples: Irradiated mineral-organic mixtures were extracted with 1.0 mL of water. Extraction was repeated three times and combined extracts were analysed by UV spectroscopy at 260 nm. Table shows the analysis results. (Dose on Martian surface: 210 micro Gray/day [13].
TABLE: Protective role of Martian analogue minerals and soil against the effects of gamma radiation for biomolecules on the surface of Mars and placed 5 cm below the "Martian Garden".

Mineral-organic mixture	***On surface*** **% Mean Lost**	***5 cm below*** **% Lost**
$CaCO_3$-Purine	86.9 (13.1)*	48.5
$CaSO_4$-Purine	85.5	n.d.
Kaolinite-Purine	86.7	48.5
$CaCO_3$-Uracil	71.8 (10.1)*	
$CaSO_4$-Uracil	84.7	n.d.
Kaolinite-Uracil	83.2	n.d.

Gamma dose: 500,000 years on Martian surface (numbers in parenthesis show the % mean lost corresponding to a dose of 15,000 years on Martian surface)

The ability of several selected organic compounds to resist radiolysis (survivability) as a function of dose of gamma radiation on Martian surface and beneath the surface will be discussed.

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