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UV Shielding Properties of Jarosite Vs. Gypsum: Astrobiological Implications for Mars

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Abstract: The discovery of liquid water-related sulfates on Mars is of great astrobiological interest. UV radiation experiments, using natural Ca and Fe sulfates (gypsum, jarosite), demonstrate a large difference in the UV protection capabilities of both minerals and also confirm that the mineralogical composition of the Martian regolith is a crucial shielding factor. It is demonstrated that a thin (500 µm-thick) sample of jarosite prevents UV transmission, providing suitable niches for life exploration.

Key words: UV shielding · Mars · jarosite · gypsum · astrobiology

INTRODUCTION

Unlike Earth, there is a significant amount of UV flux on Mars, mainly due to the influence of the shorter wavelengths UVC (100-280 nm) and UVB (280-315nm). Various works on the biological effects of UV radiation [1-3] and the amount of Martian radiation [4] have established that even the present-day instantaneous Martian UV flux would not in itself prevent life. Nevertheless, it is a fact that this UV flux contributes, coupled with the lack of liquid water and extreme low temperatures, to the biologically inhospitable nature of the Martian surface. From the astrobiological point of view, these factors render a practical consequence for the exploration and detection of life on Mars: any living organism, as we know it, should have preferentially developed in a particular sub-surface microenvironment able to protect it from the harsh conditions on the surface. Terrestrial endolithic communities that live in the subsurface layers of rock that provide appropriate microenvironments against extreme external conditions have been proposed [5-8] as possible analogs to life on Mars. Extant Martian life would require strong UV shielding, which, in accordance with our experiments, could be perfectly accomplished by certain minerals already discovered on Mars.

MARTIAN MINERALS: CA AND FE SULFATES

The search for life on Mars has been intimately linked to the identification of unequivocal ancient or modern geomarkers [9, 10] of water (e.g. some water-related minerals) on and inside the planet. Recently, some water-related sulfates (e.g. jarosite, gypsum) were discovered [11-13] on Mars surface. In particular, jarosite has proven to have a great astrobiological importance, not only for its relation with liquid water, but also because it can act as a sink and source of Fe ions for Fe-related chemolithoautotrophic microorganisms, such as those encountered in numerous extremophilic ecosystems (e.g. Tinto river [14-16]). In the present report, we present experimental results on the UV shielding capabilities of the above mentioned minerals: jarosite ($KFe_3(SO_4)_2(OH)_6$) and gypsum ($CaSO_4.2H_2O$).

The samples of jarosite and gypsum used in this work come from two selected areas of the SE Mediterranean region of Spain: Jaroso and Sorbas, which have been proposed as a relevant geodynamic and mineralogical model [17-21] to follow for the astrobiological exploration of Mars. The Jaroso Hydrothermal System is a volcanism-related multistage hydrothermal episode of Upper Miocene age, which includes oxy-hydroxides (e.g. hematite), base-and

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Fig. 1: Typical jarosite pellet. Jarosite sample from El Jaroso ravine, Cuevas del Almanzora Natural Area, Almería province, SE Spain. Each division on the left scale represents 1 mm

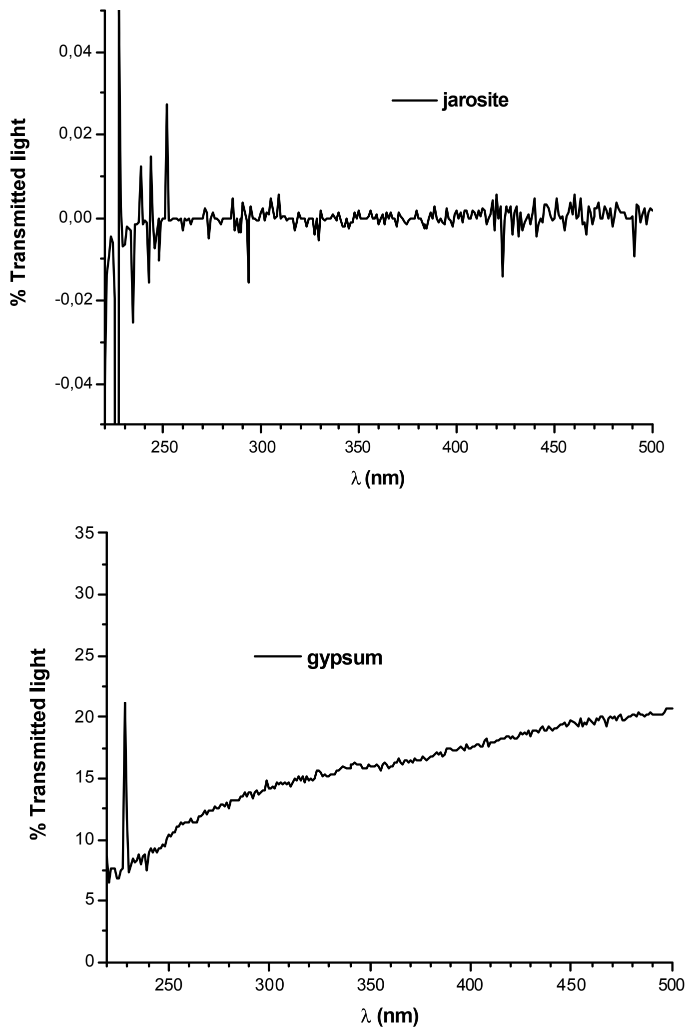

Fig. 2: Light transmission spectrum (expressed as % transmitted light) of jarosite vs. gypsum samples

precious-metal sulfides and different types of sulphosalts. Hydrothermal sulfuric acid weathering of the ores has generated huge amounts of oxide and sulfate minerals [19, 22-24] of which jarosite is the most abundant. It is important to note that jarosite was first discovered on Earth at this area, in 1852, in the "Jaroso Ravine", which is the world type locality of jarosite [25, 26]. The Sorbas basin contains one of the most complete sedimentary successions of the Mediterranean (gypsum karst) reflecting the increasing salinity during the Messinian salinity crisis (desiccation of the Mediterranean Sea) [27-29] and showing a complex paleogeographical evolution, being a signature of its progressive restriction and isolation.

MATERIALS AND METHODS

Jarosite samples were pulverized and shaped by pressure into flat round pellets of 1 cm diameter and 0.5 mm thickness (Fig. 1). Gypsum samples were scratched from a larger specimen. The samples were flattened to different thickness (between 0.1 mm to 1.6 mm) before exposed to UV light. All samples were positioned onto a sample holder which allowed the UV lamp light to go through the samples and be detected by a PMT through a monochromator. The UV light source is a Xe Lamp (SpectralProducts) with an integrated output from 220 nm to 500 nm of 1.2 Wm^{-2} (measured at a distance of 10 cm from the lamp exit and over a disc of 5 mm diameter). A monochromator (SpectralProducts, 1/8 m CM 110) is placed at the output of the lamp, but in our experiments it is set up so that it lets all wavelengths out without deformation of the Xe lamp output. Five (5) cm downstream the light beam irradiates the sample, the light which is transmitted through it is then collected by an optical fiber head (placed 10 cm away from the Xe lamp), which in turns directs the light through a spectrometer (Bentham, CM 150 double monochromator) which records the transmitted light spectrum. The light is detected by a peltier-cooled bi-alkali photomultiplier tube (PMT Bentham, DH-10-Te). Typically, each sample spectrum is measured from 220 nm to 500 nm every 1nm with a rate of approximately 1 nm/s. Usually each sample spectrum is the average of at least 5 spectra.

CONCLUSIONS

It is well known that iron and iron-bearing compounds can provide an UV screen for life. For instance, Martian regolithic dust, along with palagonite-type compositions, have specifically been suggested as a possible safe haven for life [1-3, 30-35]. Our experimental results demonstrate a large difference in the UV shielding capabilities of both minerals (Fig. 2). Whereas gypsum showed a much higher transmission percentage (with an error in the absorption coefficients of roughly 20%), jarosite samples, with a thickness of only 500 µm, prevented transmission. Our mineralogical results complement other recent petrologic studies about shielding effects on Mars surface environment (e.g. basaltic dust, [36]) and have great astrobiological relevance as: a) jarosite typically occurs on Earth as alteration crusts and patinas and b) a very thin crust of jarosite on the surface of Mars would be sufficient to shield microorganisms from UV radiation.

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