MODELLING UV DEGRADATION OF AIRFALL ORGANIC MATERIAL AT GALE CRATER

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Introduction:

UV radiation is poorly attenuated by the Martian atmosphere and will cause any organic material on the surface to degrade. Damaging the bonds of the organic molecule can create radicals which further damage the molecule causing faster degradation (Ehrenfreund et al., 2001). UV radiation received at the surface is dictated by the time of the year and latitude. The origin of organic material on Mars in the modern era is accretion of Interplanetary Dust Particles (IDPs) (Flynn, 1996). According to Flynn 1996, Mars receives almost 8.6 x 10^6 kg/m^2 of unmelted meteoritic material every year, and of the order 10^6 kg/year of this organic material is unaltered. IDPs survive for years on the surface, with smaller particles having lifetimes of up to 4900 years for larger sized IDPs (Moores et al., 2017; Moores & Schuerger, 2012) because most photons incident on the surface do not interact with the individual IDPs, resulting in a of ~ 10^{-6} kg/m^2 of organic carbon on the surface at equatorial latitudes (Moores & Schuerger, 2012). This work aims to probe mechanisms that can preserve organic carbon on Mars and whether the amount will be detectable by future spacecrafts.

Rhythmic sedimentary rocks have been discovered through remote sensing and in-situ observations in the mid-latitude and equatorial regions of Mars. The formations discovered in Gale crater Lewis and Aharonson (2014) propose a depositional timescale of the order Myr for these formations and hypothesize the cause for cyclic bedding to be changes in the obliquity of Mars (Lewis & Aharonson, 2014). The sediments are hypothesized to have formed due to accumulation of falling aeolian dust which changes in atmospheric concentration over variation in orbital oscillations due to climate changes caused by Mars' varying obliquity (Laskar, 2004; Lewis & Aharonson, 2014). IDPs being accreted on Mars can become deposited in these sedimentary rocks along with the dust. Fig 1 demonstrates this process.

IDPs embedded in sedimentary rhythmites will then be shielded from UV radiation and this process might result in enhanced preservation of organic carbon. Martian regolith attenuates the UV rays penetrating the rocks. Studies have shown that depth of 2 – 10 mm are required to shield radioresistant microorganisms from penetrating UV rays for minimum survivability (Moore, 2019). Earlier works have indicated at a covering of 1-2 mm for complete shielding (Mancinelli & Klovstad, 2000; Marschall et al., 2012).

As such, this work aims to address the question of whether rhythmic sedimentary rocks represent an environment that can preserve modern-day infalling organic material (~ 10^6 kg/m^2/year). If so, these sedimentary rhythmites will provide an interesting lithology in which the amount of organic in-fall to Mars can be measured by future spacecraft which will be informed by this work. Gale crater was chosen for this project since the UV environment is well studied and discoveries of sedimentary rhythmites have been made at this site as well.

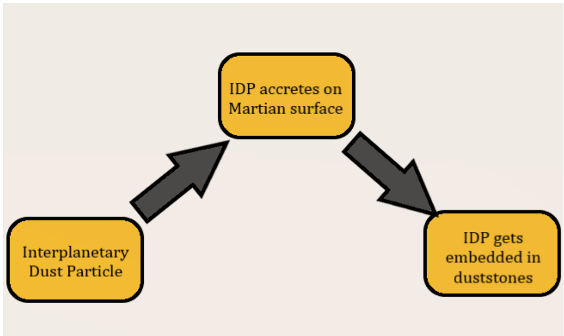

Fig 1: Journey taken by IDPs on Mars

Modeling:

This work makes use of the outputs produced by a 1.5-dimension Mars Doubling and Adding Radiative Transfer model (C. L. Smith & Moores, 2020). The model is similar in functionality to the one developed by Griffith et al. (2012) for Titan and has been adapted for Martian conditions (Griffith et al., 2012).

The model considers the surface of Mars to be a Hapke surface with the radiative response being informed by the observations by the Rover Environmental Monitoring Station (REMS) instrument on Mars Science Laboratory (M. D. Smith et al., 2016). The Doubling and Adding Radiative Transfer model models the atmosphere as consisting of two levels and takes into account gaseous and aerosol absorption, Mie scattering by aerosols, and Rayleigh scattering for the species found in the Martian atmosphere (Moores et al., 2017).

This work develops an additional numerical model bringing the following pieces of information together: a) accretion of IDPs on Mars, b) UV degradation of organic carbon, and c) burial of IDPs in rhythmites and consequent UV shielding. The model devised will explore a parametric space of the range of IDP particle sizes (ranging from 60 to 270 μm Flynn,1996), the amount of carbon in IDPs, deposition rates of the beds, and thickness of sedimentary beds. The parameter space will be informed by existing literature.

Initially the IDPs would be subject to the unshielded UV radiation received at surface, but over time more dust would accumulate on top of the IDPs and the received radiation and degradation from UV would decline until the particles are completely protected. The depositional timescales of the sediments were found to be around 100 kyr per bed with each bed at Gale crater around 40-60 m (Lewis & Aharonson, 2014).

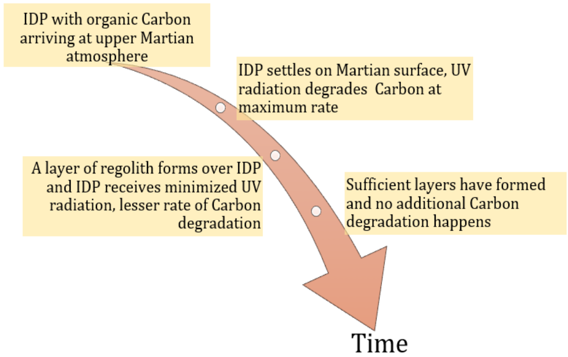

Fig 2: Diagram depicting working of the model

The model will simulate the following environments the IDP passes through and what affect it can have on its Carbon content (summarized in Fig 2):

1. IDP accretes on surface and is exposed to UV radiation without regolith shielding: organic carbon faces maximum degradation. The rate of degradation is dependent on solar longitude (L_s), latitude, amount of dust present in the atmosphere, and other factors which have been incorporated in the Doubling and adding Radiative Transfer model.
2. A layer of dust is accreted on top of the IDPs, embedding them. Organic Carbon is shielded by one layer of regolith. The layer is formed due to gradual accumulation of infalling dust at the rate of 10s of microns per year (Lewis & Aharonson, 2014).
3. More layers are accreted on top, resulting in lesser UV radiation hitting the IDPs as time progresses
4. Eventually, the UV radiation penetrating the top layers of the dust stone becomes negligible and degradation of the organic carbon present in the IDP stops.

Other factors affecting the degradation of IDPs embedded in sedimentary rhythmites:

Radiation from galactic and solar cosmic rays (GCRs and SCRs) are additional radiation sources that degrade organic molecules. SCRs are capable of destroying organic molecules in the first 2 cm of Martian regolith and GCRs penetrate further (Pavlov et al., 2012). The discovery of perchlorate at the Phoenix landing site implies possible oxidization of organics by oxychlorine species (Hecht et al., 2009). Decomposition of perchlorates produces reactive species which degrades organic material (Quinn et al., 2013). This work focuses only on the UV degradation of organics and doesn't consider additional sources of degradation like GCRs, SCRs, and perchlorates.

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