THE SHIELDING EFFECT OF SMALL-SCALE SURFACE GEOMETRY ON ULTRAVIOLET FLUX.

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Introduction: The atmosphere of Mars, does little to attenuate incoming ultraviolet radiation (UV). This high level of UV, especially shortwave UVC, poses serious impediments to the development and sustainability of organic molecules and biological organisms on the surface of the planet [1,2,3]. Not only does this UV destroy complex organic molecules such as DNA [4,5], rapidly deactivating any exposed biological cells, but will also over time reduce many organic molecules to carbon dioxide [6] and possibly help to create organic-destroying oxidizing compounds on the surface itself [7]. Thus the survival of any putative Martian life near the surface depends to a large extent on how much UV radiation is received at its location. As such, variations in small-scale geometry of the surface such as pits, trenches, flat faces and overhangs can have a significant effect on the observed UV flux and create "safe havens" for organisms.

The Model: In order to examine this effect, a 1-D radiative transfer sky model with 836 meshed points (plus the sun) was created so that both diffuse and direct components of the surface irradiance could be considered. This model is based upon Martin Tomasko's radiative transfer code (most recently described in [8]) and uses the doubling and adding method to determine the flux at the boundaries between layers of the atmosphere. The major inputs into this model are mie-scattering due to dust (as determined by the Imager for Mars Pathfinder [9,10] and consistent with MER and Viking [11]), rayleigh scattering due to carbon dioxide and a Mars-Pathfinder like surface. In order to add the complexity of a blocking geometry, elements of the sky mesh are individually 'blacked out' where a line of sight to the target is absent.

There were four separate geometries that were considered. These are: polar faces of rocks, pits and cracks, surfaces below underhangs and the undersurface of the overhang itself. In each case an idealized geometry (Fig. 1) was used and the ratio between the width/distance and height/depth of the geometry as shown was permitted to vary. Since the value of this ratio directly corresponds to the amount of protection being offered to the surface this is the Geometric Shielding Ratio (GSR) and the ratios are chosen such that large GSR corresponds to effective shielding.

The resulting flux levels were finally interpreted using both a planetary protection and astrobiological basis. For planetary protection, the effect on *Bacillus pumilus* SAFR-032, an exceptionally UV-hardy organism, was considered [12]. For an astrobiological context, we considered the effects on a simple organic molecule, glycine [6].

Results: This model has been used to derive the variation of the reduction in UV flux with latitude and an object's Geometric Shielding Ratio as shown in Fig.2. Note that the values presented are averages over one Martian year under present conditions. The best protection is offered by overhangs with flux reduced to a factor of $1.5\pm0.2\times10^{-5}$ of the unprotected value, a reduction which does not vary significantly by latitude. Pits and cracks are less effective with a reduction in UV flux of only up to $5.2\pm0.5\times10^{-3}$ for the modeled sceanrios; however, they are more effective for the same GSR then overhangs at high latitudes due to the low height of the sun in the sky.

Lastly, while perhaps the most common, polar faces of rocks are the least effective shielding geometry considered with at most a $4.4\pm0.5\times10^{-2}$ reduction in UV flux. Polar faces of rocks are most effective at mid latitudes where the sun is never directly overhead and never exposes the back of the rock, as in the case of polar and tropical latitudes.

Conclusions: This data suggests that in the context of surface UVC, organic molecules may be able to persist, shielded by the geometry, for periods greater than an obliquity cycle under all geometries if concentrations greater than $1 g/m^2$ are initially present. In the extreme case considered of an overhang underside with a GSR of 100, survivability of a glycine-like organic molecule may be as high as $4.7\pm3.6\times10^{8}$ martian years g^{-1} m^{-2} and hardy terrestrial microbes, such as *B. pumilis* may persist for as long as 36 ± 8 martian years before reaching the LD_{100} level. In the case of overhangs, the rate of destruction is significantly less than the organic infall rate suggesting that material may build up over time, ignoring all other destruction mechanisms.

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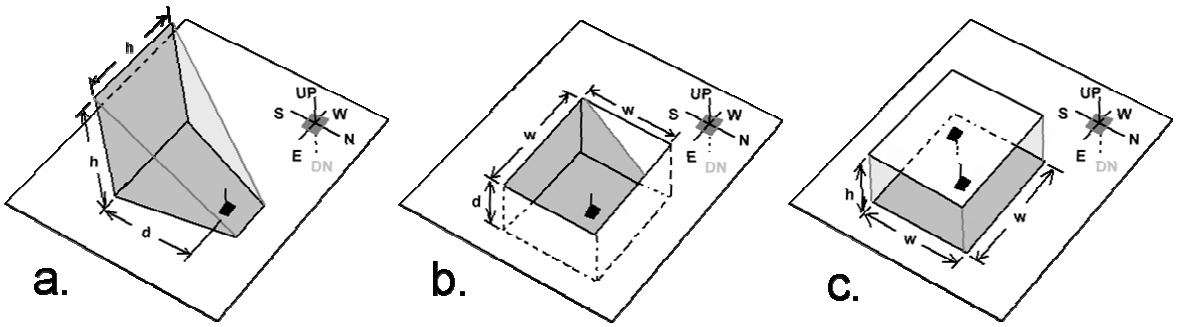

Figure 1 – Illustration of the different families of geometries examined: a pole-facing rock face (a, at left), a pit or crack (b, center) and an overhanging surface (c, right), idealized geometry with relevant parameters shown. Note that for the case of the pole-facing rock surface, only the northern hemisphere (north-facing) example is shown. In the south the geometry is reversed. Dark patches indicate where the flux is calculated.
GSR(a) = h/d ; GSR(b) = d/w ; GSR(c) = w/h

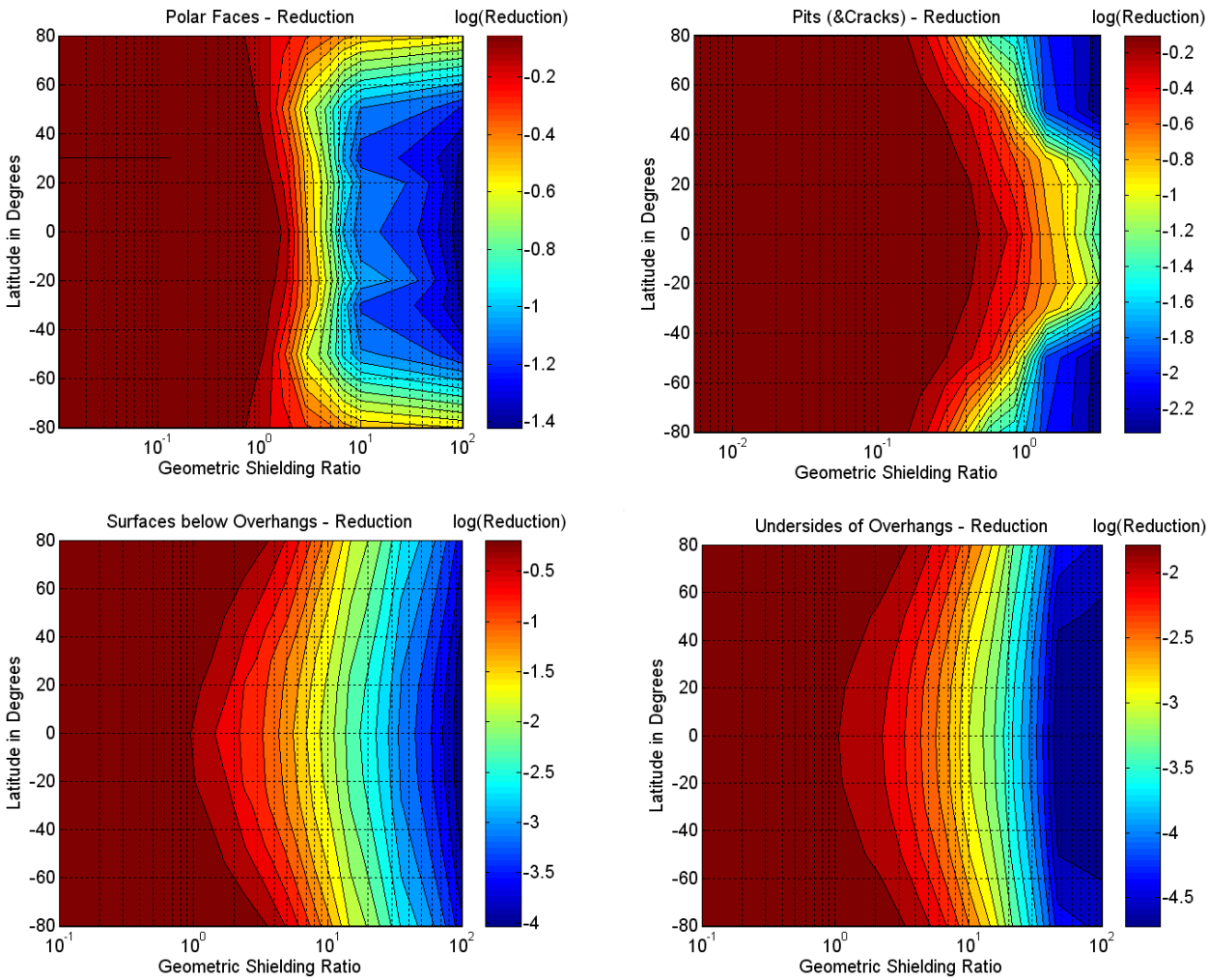

Figure 2 – Reduction in incident energy per square meter per martian year for four geometries: polar faces (top left), pits (top right), surfaces below overhangs (bottom left) and undersurfaces of overhangs (bottom right). Note that the scale bars and extents of the geometric shielding ratio differ between each case. Each contour is 1/20th of the full scale bar.