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First in-situ analysis of dust devil tracks (DDTs) on Earth and their comparison with tracks on Mars

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1. Introduction

Active dust devils on Mars have been observed leaving tracks, which are mostly darker than their surroundings [1]. Image data of the Microscopic Imager (MI) onboard of the Spirit rover in Gusev crater showed that surfaces composed of sand grains (~1 mm) within dust devil track zones are relatively free of finer grained dust compared to the bright regions outside the tracks [2]. The albedo difference is suggested to be caused by the different grain sizes because the brightness is photometrically inversely proportional to grain size [2]. On Earth, dust devil tracks (DDTs) are rare. [3] observed dust devil tracks in ASTER satellite imagery in the Ténéré desert, Niger. Their formation might be due to the bimodal sand characteristics of the soil, with a layer of fine sands overlying coarser sand. The removal of the fine sand by the passage of a dust devil would expose the coarser sands, which increases the surface roughness causing the strong albedo contrast of the tracks to the surroundings in satellite imagery [3]. In this study we analyzed for the first time terrestrial dark dust devil tracks in-situ in the Turpan depression desert in northwestern China.

2. Results

Based on the identification of dust devil tracks in satellite images accessed trough Google Earth (Fig. 1a) we analyzed dust devil tracks at the western edge of the Turpan depression dune field at 42.63°N and 89.86°E. In this study we focus on curvilinear DDT observed on 15. April 2010 with a width of ~1.3 m and a length of about 70 m (Fig. 1b). The track was relatively fresh, in fact it was not identified in the field during a survey performed in the late afternoon of the day before. The flat plain of the study region is characterized by a wind ripple surface (Fig. 1c). The vertical grain size distribution is bimodal. The grain size analyses show that the ripple surface is dominated by coarse sand (0.5 - 1 mm), whereas the surface layer below is dominated by very fine to fine sand (0.063 – 0.25 mm). Based on the morphologic characteristics of the ripples, we sampled three different parts of the ripple surface with the microscopic imager (Fig. 1d); the ripple crest, an intermediate area with small fine sand patches and the ripple trough.

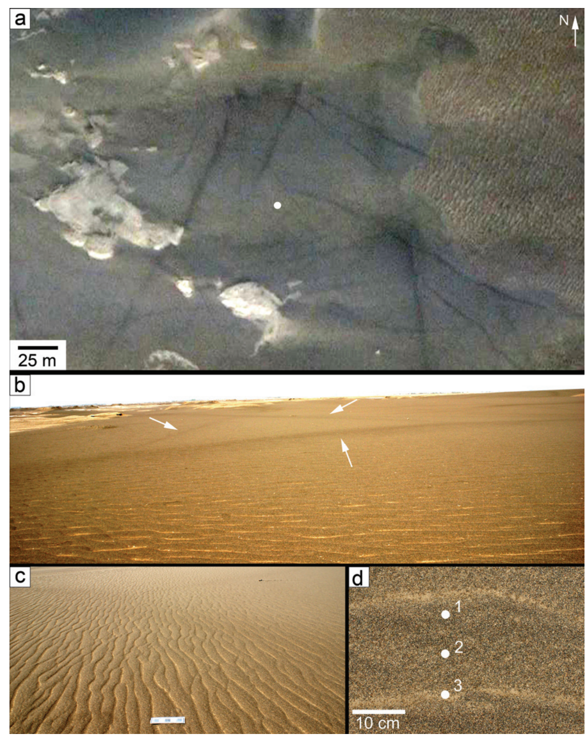

Figure 1: (a) High resolution satellite image of the study region acquired at 03. April 2005 (Quickbird image with a resolution of ~0.6 m/pxl, from Google Earth) showing several linear and curvilinear dust devil tracks. White dot in the middle of the image marks the location of the dust devil track in b as well as the area where the microscopic images (Fig. 2) were taken. (b) View of the study region from northeast. Three dust devil tracks (arrows) were identified on 14. April 2010. The DDT in front was analyzed with the microscopic imager shown in Figure 3. (c) The study region is characterized by a ripple surface. Scale bar has a width of 25 cm. (d) Image of the ripple surface from above. Microscopic images were taken from the ripple crest (1), an intermediate area (2) and the ripple troughs (3).

Lower resolution imagery outside the DDT shows a relatively higher abundance of finer particles (< 63 µm) than inside the DDT in all areas. The difference in abundances is also clearly visible in the high resolution microscopic imagery inside and outside the DDT (Fig. 2). Estimates of the layer thickness were made by measuring the radius of fine particles (diameter of < ~63 µm) in high resolution microscopic images outside the track region (n = 890; A = ~0.57 mm^2). The measured grain sizes ranged from ~4 – <70 µm with a median diameter of ~6 µm. Assuming a material thickness of 2500 kg m^{-3}, our measurements imply that the removal of an equivalent layer removal of ~4 µm is needed to create the albedo differences. However, the loosely packed coarse sand has an effect on the pore volume. Therefore, we assume a pore volume for the coarse sand areas of 50 %, which would lower the maximum equivalent layer thickness to ~2 µm.

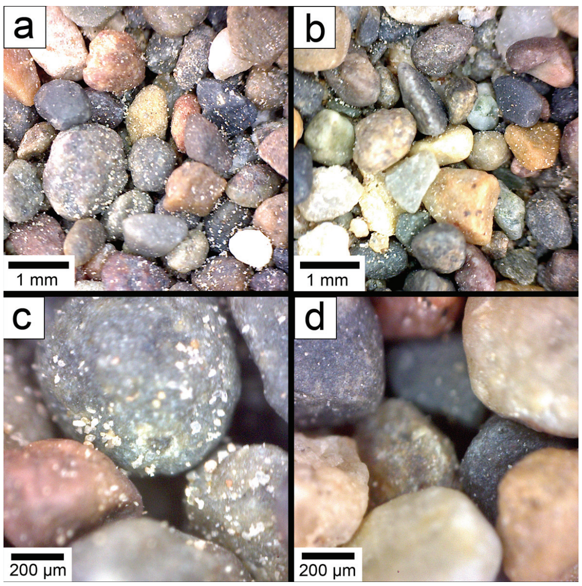

Figure 2: Microscopic imagery of the ripple crest outside (a, c) and inside (b, d) the DDT in two image resolutions.

Figure 3 shows a comparison of microscopic images of ripple crests on Mars and Earth inside and outside of DDTs. For a direct comparison we down-sampled the image resolution of the terrestrial images to 30 µm/pxl. When compared to the DDT investigated by the microscopic imager onboard the rover Spirit at the Gusev landing site [2] the terrestrial DDT show the same effect of a removal of finer particles with the subsequent unveiling of a coarser grained substrate. The grain size of the underlying material is in about the same range (coarse sand). However, the amount of dust mantling on the surfaces, at the boundary and outside the dark track (see also Figure 2c-e in [2]) seems to be much higher on Mars compared to our terrestrial study region, regardless of the different image resolution of the microscopic imagers. In addition, the grain size of the dust on Mars seems to be in general much finer than on Earth.

3. Conclusions

The proposed mechanism by [2] of the removal of a thin layer of dust by suspension as well as downward infiltration and therefore a greater exposure of coarser grain sizes that result in a lower-albedo surface is in agreement with our terrestrial results of the formation of DDTs. Calculations of the removed maximum equivalent layer of fine grained material on Earth based on measurements are around 2 µm. This is at the lower end of proposed removed equivalent layer thicknesses by dust devils on Mars, which are in the range of 2 – 40 µm [4] and 1 – 8 µm [5]. However, our results strongly imply and also confirm the results of [4] and [5] that even a very low removal of overlying fines is able to unveil enough of the underlying coarser material to cause albedo differences and thus the observed DDTs.

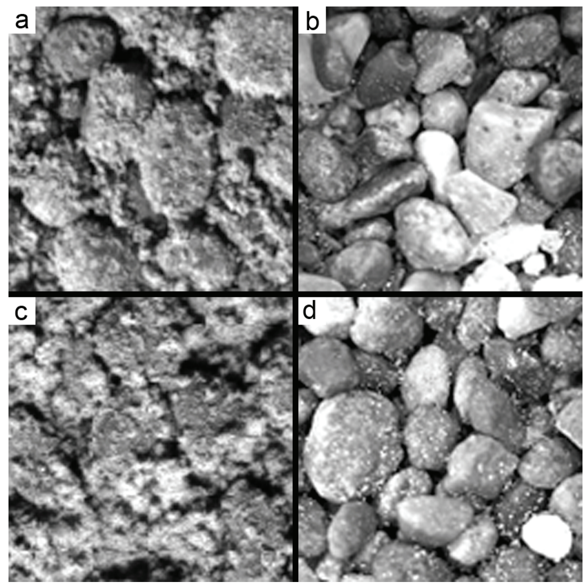

Figure 3: Comparison of microscopic images of ripple crests inside and outside of dust devil tracks on Mars (a, inside; c, outside) (see also [2]) and Earth (b, inside; d, outside). Resolution of Earth images is lowered to 30 µm/pxl for direct comparison with Mars. All images have a scale of 4 × 4 mm.

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