BRIGHT DUST DEVIL TRACKS ON EARTH: IMPLICATIONS FOR THEIR FORMATION ON MARS.
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Introduction: Dust devils are low pressure vortices formed from unstable near-surface warm air generated by insolation and are common on Earth and Mars [1]. On Mars, dust devil tracks (DDTs) were first observed in Mariner 9 imagery as dark filamentary tracks [2]. [3] observed tracks on Mars in Viking orbiter imagery, which they interpreted as “tornado tracks”. Later, with higher resolution imagery it was shown that these tracks are formed by dust devils [4]. On Earth DDTs are rare. [5] and [6] identified dark DDTs in satellite imagery in the Saharan desert and [7] observed dark DDTs in the Turpan Desert, China, and made first in situ analysis [8]. However, some tracks on Mars are brighter than the surrounding material and leaving bright dust devil tracks (BDDTs) [4]. The formation mechanism of these BDDTs is unknown. [9] suggested that they could be formed by removal of dark dust, the excavation of bright underlying material, or a compaction of bright dust by the down draft of dust devils. [10] proposed that a reorientation of dust grains by the passage of dust devils results in a closer packing and produces higher reflective surfaces leading to BDDTs. Here, we report on an alternative interpretation based on results from the first observations and in situ analyses of BDDTs in the Turpan depression desert in northwestern China [11]. We also discuss possible implications of our results for the formation of BDDTs on Mars.

Observations: BDDTs were observed in the Turpan depression desert located in northwestern China. In the evening of 17 April 2010 a rainfall of about five minutes occurred in the normally very dry region. On 18 April 2010 we observed active dust devils leaving bright tracks (Fig. 1) instead of dark tracks, observed the days before [7].

Surface material: Fig. 1a shows several BDDTs on a flat plain of the study region which is characterized by a ripple-bedform surface and Fig. 1b shows a BDDT on a dune surface. The vertical grain size distribution of the undisturbed soil of the ripple-bedform is bimodal. The largest grain sizes occur on the ripple surface and smaller grain sizes below. Grain size analyses show that the ripple surface is dominated by coarse sand (0.5–1 mm), whereas the layer below is dominated by very fine to fine sand (63–250 µm). Smaller grain sizes (≤63 µm) of silt and clay are intermixed. The grain size analyses of the dune soils show an unimodal distribution of very fine to medium sand (63–500 µm) with a dominating grain size of fine sand (125–250 µm, 75% per weight). Smaller grain sizes (≤63 µm) of silt and clay are again intermixed.

Aggregates: The short duration rainfall changed the upper surface due to raindrop impacts forming aggregates of sand, silt and clay (Fig. 2). The formation of surface crusts by raindrop impact is a well known process on Earth [12]. However, in our case the short rainfall duration did not form a homogenous soil crust, but well developed aggregates with a spacing of about 3 cm. The aggregates are up to ~1 cm in diameter and consist of coarse sand, fine sand, silt and clay grain sizes on the ripple bedform plains (Fig. 2c) and of fine sand, silt and clay on the dunes (Fig. 2d).

The cohesion of the aggregates is very weak, probably because of the dry climate in the study region. They immediately disintegrated when touched with the finger. We observed that passages of dust devils can easily destroy the aggregates, which results in smooth surface textures within the BDDTs in contrast to the rough surface textures next to the tracks. These differences in surface textures caused albedo differences due to changes of the photometric properties of the surface. The smooth textures within the tracks appear brighter than the rough textures outside of the dust devil track (Fig. 2a-b). Field observations two days later (20 April 2010) revealed that the aggregates were destroyed. BDDTs were not visible anymore. We suggest that strong surface winds caused the widespread destruction of the aggregates.

Figure 1. Bright dust devil tracks (BDDTs) on (a) the ripple-bedform surface (42.63°N, 89.86°E) and on (b) a dune surface (42.62°N, 89.86°E).
Lunar reported in some regions including the caldera of Arsia Mons [13], northwestern Amazonis Planitia, and Syria Planum [14]. Based on the dust cover index [15], these regions exhibit a thick dust cover. In addition, the BDDTs found by [10] also occur in regions with thick dust covers. We conclude that the occurrence of BDDTs seems to be limited to dusty areas on Mars. Rainfall on Mars under current climatic conditions is impossible. However, there might be alternative processes which lead to the formation of dust aggregates on Mars, including dust electrification [16,17]. Weakly-bound dust aggregates held together by van der Waals, electrostatics, or other interparticle forces have been observed in the “soils” at Gusev crater with the Microscopic Imager (MI) onboard the Mars Exploration Rover (MER) Spirit [18,19,20]. The observed surface dust occurs as very fragile, porous, sand-sized aggregates, which can be easily entrained and disaggregated by dust devils [20,21].

In areas on Mars with thick dust covers, where BDDTs were observed [10,13,14], the disintegration of surficial dust aggregates by passages of dust devils might result in a smoother surface texture within the track due to the then fine-grained dust layer compared to the undisturbed rougher surroundings still composed of dust aggregates. This process would be in agreement with our terrestrial observations. Another possibility for the formation of BDDTs on Mars could be the entrainment of the sand-sized aggregates into the saltation skirt and the exposure of possible underlying loose dust material, which is not aggregated. This formation mechanism would only work if the martian, aggregated dust layer exists as a thin and surficial layer.

Multitemporal imagery revealed that dark and bright DDTs disappeared after 0.18 [4] and 0.25 [14] martian year interval, respectively. If our hypothesis of BDDT formation on Mars due to the disintegration of dust aggregates is correct, the deposition of dust on BDDTs would not change the surface albedo because they already consist of fine-grained dust. The removal of dust adjacent to the BDDTs might work in the broader sense that the proposed dust aggregates are destroyed on large areas (e.g., by strong surface winds). This process would brighten the surface to the same albedo as inside the BDDTs, like observed on Earth. Another probable process would be the re-aggregation of dust within the BDDTs which would result in a darkening to the same albedo values as in the track surroundings.

Conclusions: We propose that due to the thick dust cover the dust removal by vortices is insufficient to expose the coarse-grained underlying surface in BDDTs. Based on our observations of the formation of BDDTs on Earth, the changes in photometric properties between the track (smooth texture) and outside the track (rough texture) might cause the observed albedo differences and lead to the formation of BDDTs on Mars. However, without in situ analyses using microscopic imagery by the MER or future rovers, the formation process of BDDTs on Mars remains speculative.