MORPHOLOGY, FORMATION AND DISTRIBUTION OF DUST DEVIL TRACKS ON MARS: INSIGHTS FROM TERRESTRIAL ANALOGS. D. Reiss, Institut für Planetologie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (dennis.reiss@uni-muenster.de).

Introduction: Dust devils are frequently observed on Mars [e.g., 1-4] and potentially play a key role in maintaining and replenishing the background dust opacity of the atmosphere [e.g., 5]. The passage of dust devils across the surface often leaves dark or sometimes bright tracks [e.g., 6]. Dust devil tracks (DDTs) are abundant [e.g., 5, 7, 8] and can significantly lower the surface albedo of larger regions [9] which affects large-scale weather patterns and recent climate change on Mars [10]. In the following, a summary about different dust devil track morphologic types on Earth and Mars will be given. Furthermore, several hypotheses of martian and terrestrial dust devil track formation will be discussed. Finally, a preliminary global mapping survey of martian dust devil tracks will be presented which could give further insights into dust devil track formation mechanisms on Mars.

Morphology: Figure 1 shows three typical examples of martian DDTs. The most common DDT morphology are low albedo, continuous tracks (Fig. 1A) compared to the low albedo, cycloidal tracks (Fig. 1B). Less common on Mars are high albedo (bright) tracks (Fig. 1C). These main morphologies based on DDT pattern and albedo compared to their surroundings were also identified and analyzed in situ on Earth (Fig.1 D-F) [11-14].

Terrestrial analogs: On Earth, DDTs are rarely observed in satellite imagery [11, 13-18]. In situ studies have so far only been performed in China [11, 12], Morocco [13] and Peru [14].

Continuous dark DDTs. Low albedo, continuous dark DDTs (Fig. 1D) were analyzed in situ in northwestern China [11] and southern Morocco [13]. These studies showed that passages of active dust devils remove a thin, top layer of fine grained material (< ~63 µm), darkening the underlying coarse sands (0.5–1 mm) [11]. This erosional process changes the photometric properties of the surface causing an albedo difference within the track relative to the surroundings (dark track and bright surroundings) [11].

Cycloidal dark DDTs. Low albedo, cycloidal dark DDTs (Fig. 1E) were analyzed in situ in southern Peru [14]. They have a low albedo cycloidal pattern, which is in some areas accompanied by bright margins. They are formed by erosion of very coarse sands at the outer margins and its subsequent annular deposition in the central parts of dust devils [14]. Here, the annular accumulation of coarse sand changes the photometric properties in the central parts of former passed dust devils. This leads to lower reflecting surfaces, hence the low albedo cycloidal DDTs.

Bright DDTs. High albedo, bright DDTs (Fig. 1F) were analyzed in situ in northwestern China [12]. Here, raindrop impact on sand surfaces, forming aggregates of sand, silt and clay, which results in rough surface texture. The cohesion of the aggregates is very weak and easily destroyed by passages of dust devils resulting in smooth surface textures within the track region. The differences in photometric properties between the track (smooth, bright) and outside the tracks (rough, dark) cause the albedo differences [12].

Formation on Mars: DDT formation on Mars can be explained by two main mechanisms based on compositional or photometric differences: (1) Removal or deposition of surface material exposing or covering substrate material of different mineralogic composition (compositional properties), and (2) Removal, deposition, redeposition, reorientation, compaction, or destruction of surface material and, in some cases, exposing or covering substrate material of different grain size (photometric properties).

Continuous dark DDTs. In situ studies of a continuous DDT by the Mars Exploration Rover (MER) Spirit revealed that substrates consisting of sand grains within DDT zones are relatively free of fine grained dust compared to the bright regions outside the tracks [19]. [19] proposed that the albedo difference between the track and its surroundings is caused by the different grain sizes because the brightness is photometrically inversely proportional to grain size [19]. Terrestrial analog studies of continuous dark DDTs [11] are in agreement with this formation mechanism. This formation mechanism is also in agreement with laboratory spectral measusurents by [20] showing that the removal (or deposition) of very thin layers of dust can change the reflectance drastically. Furthermore, numerical simulations [21], terrestrial in situ studies [11, 13], and martian dust deflation calculations of dust devils [22] indicate that the removal of very thin dust layers (equivalent layer of ~1 µm) can be sufficient for the formation of continuous dark DDTs.

Cycloidal dark DDTs. The formation mechanism of cycloidal dark DDTs on Mars remains speculative without in situ studies by rovers on Mars. However, terrestrial in situ studies [14], numerical modeling [14], and laboratory experiments [23] suggests that cyclodial dark DDTs on Mars are formed due to redeposition of sands by erosion of sand material from the outer margins and its subsequent annular deposition in the central parts of dust devils.

Bright DDTs. [5] suggest that they could be formed due to a bright underlying substrate, dark dust, or a compaction of the bright dust by the down draft of dust devils. Another mechanism based on laboratory experiments is the reorientation of individual dust grains resulting in closer packing, hence changing the photometric properties within the track region towards higher reflective (brighter) surfaces [24]. Based on terrestrial in situ studies [12] proposed a bright DDT formation caused by the destruction of dust aggregates leading to smoother (photometrically brigher) surfaces within the DDT areas. However, the formation mechanism of bright DDTs on Mars remains speculative without in situ studies by rovers on Mars.

Distribution: DDTs in Mars Orbiter Camera (MOC) imagery were surveyed in the equatorial latitude region from (30°S - 30°N). In this preliminary analysis MOC images acquired between December 2000 and March 2005 (three full martian years) were used with a resolution < 3 m/pxl, and only dark and bright tracks were distinguished. The geographic occurrence (latitude/longitude) of identified bright and dark tracks were used to extract Thermal Emission Spectrometer (TES) albedo values [25], thermal inertia [26], and Dust Cover Index (DCI) [27] values. First results indicate that bright DDTs occur in high albedo (~0.28), low thermal inertia (~75 J m^{-2} $s^{-1/2}$ K^{-1}), and high dust cover (DCI~0.94) areas, whereas dark DDTs occure in moderate albedo (~0.2), moderate thermal inertia (~250 J m^{-2} $s^{-1/2}$ K^{-1}), and moderate dust cover (DCI~0.96) areas. This indicates that bright DDTs occur in regions with a relatively thick dust cover and dark DDTs in regions with a relatively thin dust cover. Our derived albedo and thermal inertia values are in general agreement with the results of [24]. Currently, additional MOC and High Resolution Imaging Science Experiment (HiRISE) images are surveyed and continuous and cycloidal dark DDTs will be distinguished. The final results might give new insights in terms of their formation and will be compared to previous DDT studies [eg., 5, 7, 8].

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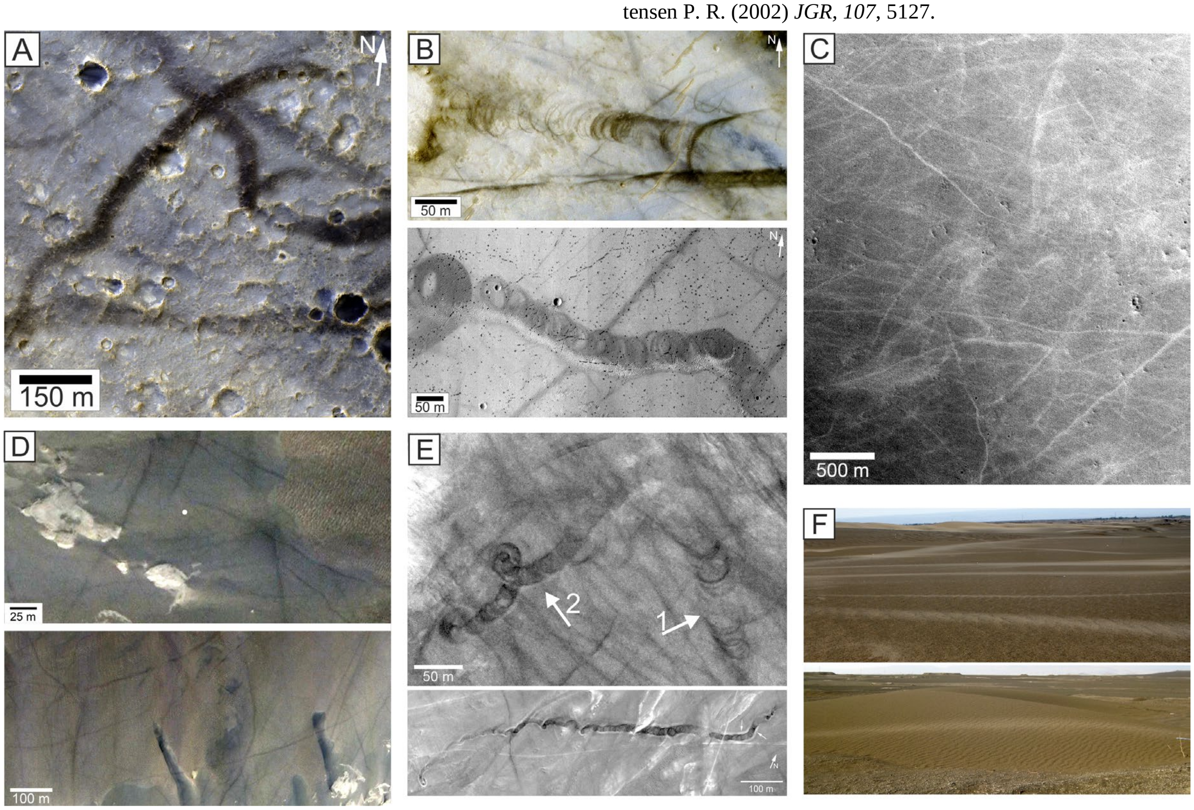

Figure 1. DDT morphology on Mars (A-C) and Earth (D-F). Continuous dark DDTs on Mars (A) and Earth (D, see [11]). Cycloidal dark DDTs on Mars (B) and Earth (E, see [14]). Bright DDTs on Mars (C) and Earth (F, see [12]).

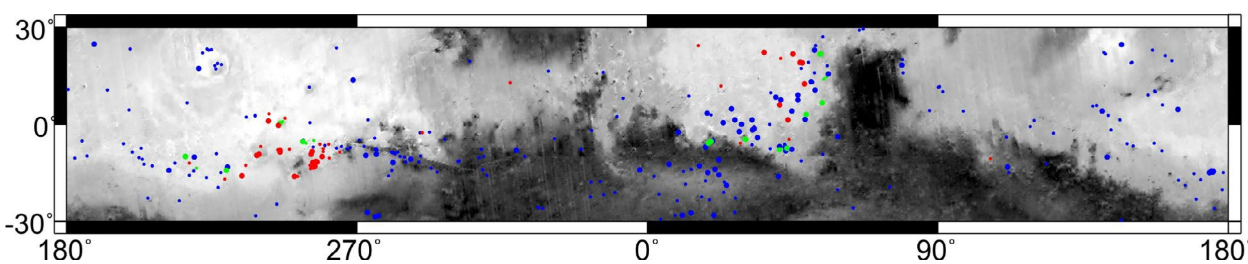

Figure 2. Distribution of dark and bright DDTs from the MOC-survey. Blue = dark DDT; Red = bright DDT; Green = dark and bright. Small circles = few DDTs; Large circles = many DDTs.