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Spectral and Petrologic Analysis of Basaltic Dune Sand from Hawaii: Implications for Martian Dunes

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1. Introduction

Dark aeolian deposits on Mars are thought to consist of volcanic materials due to their mineral assemblages, which are common to basalts. However, the sediment source is still debated. Basaltic dunes on Earth are promising analogues for providing further insights into the assumed basaltic sand dunes on Mars. The dunes in Hawaii are especially promising analogues for addressing the source of Martian dunes because of the co-occurrence of active volcanic processes and dune development. This rare geologic setting allows the study of the entire process of dune formation from the emplacement of probable source materials to the resulting aeolian bedforms. Our study is intended to (i) characterize the basaltic sands petrologically, (ii) to determine if the dune sands originate from the stripping of Keanakako'i tephra or from local reworked tephra emplaced by larger phreatomagmatic eruptions, (iii) to determine the material's transport mechanisms (i.e., fluvial and/or aeolian), and (iv) to assess the implications for the potential sediment sources of Martian basaltic dunes.

2. Methods

Three different dark basaltic dunes and one sand sheet were sampled during a field trip to Ka'u Desert in August 2009. This sample set represents aeolian dune sediments in varying distance to the source, i.e. Kilauea caldera. For comparison we selected three Martian dunefields, which represent the majority of the Martian aeolian deposits spectrally, morphologically, and physically. These exemplary Martian deposits were selected by their geographic locations at various distances to volcanic provinces. Next to microscope and microprobe analyses, visible/near-infrared reflectance spectra of the dune sand samples were acquired under ambient and vacuum conditions conditions from 0.5 to 2.5 μm.

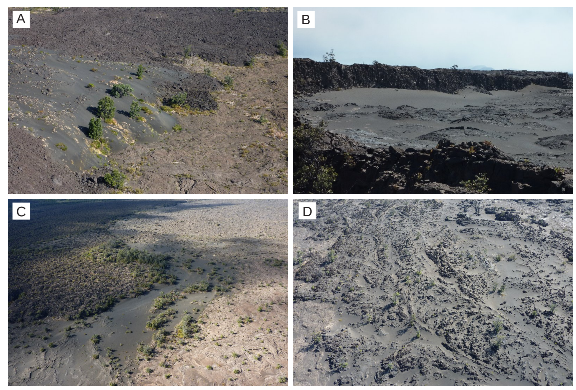

Figure 1: Basaltic aeolian bedforms in Ka'u Desert. A: Aerial photograph of a falling dune located off the Footprints Trail. B: Climbing dune located at the base of Kalanaokuaiki Pali along the Mauna Iki Trail. C: Aerial photograph of a vegetated parabolic dune located off the Ka'u Desert Trail. D: Aerial photograph of a sand sheet trapped within an aa lava flow.

3. Results

Microscope analyses revealed a high amount of volcanic glass fragments in the sand samples, with subsidiary amounts of feldspars, olivine, and pyroxene. Grain shapes are dominated by subrounded to subangular shapes, whereas grain sizes range between medium to coarse sand. Following the microprobe analyses all glasses show bulk silica contents between 49-50 wt.% and are classified as basaltic. The difference of the sum of oxides to 100 wt.% is often attributed to dissolved volatiles (primarily H_2O) in the glass which cannot be measured with an electron microprobe. To a first-order-approximation, this difference from 100 wt.% is equal to the bulk water content either dissolved in the melt or adsorbed through hydration. The spectral analysis confirms the water content of the terrestrial sands. As shown in Fig. 2 all terrestrial spectra show slight water-related absorptions bands at 1.9 and 2.23 μm, as emphasized once the continuum was removed (see insets). The overall spectral shape is consistent with a mixture of olivine and pyroxene as indicated by the deep broad absorption band at 1.0 μm and the shallower broad band around 2 μm, both attributed to Fe^{2+} in the minerals. The latter band, which is typical for pyroxene, is less distinct but is clearly identifiable when the continuum is removed. This overall spectral shape correlates well with the Martian spectra, showing the same spectral features (Fig. 2). The main difference between the terrestrial and the Martian spectra is the presence of the H_2O and OH associated bands at 1.9 and 2.23 μm in the spectra of the Hawaiian samples. These bands are still visible in the spectra of the dried samples measured under vacuum conditions which rules out the possibility that the bands were caused by adsorbed water or pore water in the samples. Thus, these features indicate juvenile water in the glass particles, i.e. dissolved OH and H_2O in the melt or in some cases meteoric water by glass hydration. The latter case may be true for those glass particles that are less fresh and show an early stage of recrystallization. These findings confirm the results of our microprobe analysis, which arrives at a water content of the volcanic glass particles of 5.3 to 5.7 wt.%. Our results are consistent with the findings of [1] who detected opaline (amorphous, hydrated) silica in different samples of lava flows, ash deposits, and solfatara incrustations collected in Ka'u Desert.

4. Conclusions

We conclude that the Ka'u Desert sands were derived from airfall ashes from phreatomagmatic eruptions of Kilaulea and reworked lava. Grain shapes indicate transport by aeolian rather than fluvial processes. Compositionally, the Ka'u Desert dune samples are dominated by olivine, pyroxene, plagioclase, and glasses resulting from the volcanic source of these aeolian sediments. This composition correlates very well with the composition of Martian dark aeolian sediments, which are dominated by pyroxene and olivine [2]. We conclude that this correlation can be seen as a further indication for a volcanic origin of the Martian dark sediments similar to the origin of the basaltic sands of Hawaii. Furthermore, we suggest that, analogously to the terrestrial volcanic sands, a similar high amount of volcanic glass can be expected in the Martian sands. Unlike the Martian dark aeolian sediments analyzed, the spectra of the terrestrial basaltic sands show indications of hydration and slight alteration which is presumably related to the comparatively humid conditions on Earth.

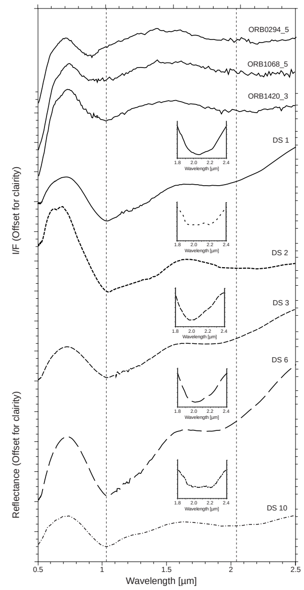

Figure 2: Comparison of Martian (OMEGA: ORB0294_5, ORB2197_3, ORB1154_3) and terrestrial (PEL: DS1, DS2, DS3, DS6, DS10) reflection spectra of dark dune sands. Olivine and pyroxene are represented in all spectra by the broad 1-and 2-μm bands. The insets show the broad 2-μm bands and shallower hydration bands at 1.9 and 2.23 μm in continuum removed views.

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