AEOLIAN DUNE FIELDS AMONG VOLCANIC LANDFORMS IN A HYPER-ARID, DESERT ENVIRONMENT: EVIDENCE OF PAST EXPLOSIVE VOLCANISM IN THE THARSIS REGION, MARS.

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INTRODUCTION AND SUMMARY: Two aeolian dune fields have recently been recognized in high-resolution *Viking* orbiter images of parts of the southwestern Tharsis region of Mars. In terms of surface area, one of these dune fields is the largest yet found outside the martian polar regions. Both dune fields appear to be old, presently inactive, and mantled by dust. Both dune fields are located among lava flows and aeolian erosional landforms such as yardangs and pedestal craters. Dunes are composed mainly of grains which saltate in wind; on Mars typical mineral/rock grains would need to be sand-sized (62.5 to 2000 µm) [1]. On Earth, the best sources for windblown sand are fluvial, lacustrine, and marine-littoral environments. No evidence for these environments is found on the western slopes of Tharsis. The only plausible source for large amounts of sand in this region is volcanism. In the absence of water action, the best explanation is that the sand grains have a pyroclastic origin. The presence of ancient dune fields exposed at the surface in southwestern Tharsis is an indication that explosive volcanism occurred in the region at some time in the Amazonian Epoch. The presence of these two dune fields in association with the radar "Stealth" feature detected by *Muhleman et al.* [2] and the east end of the Medusae Fossae Formation units might bolster claims that these features are also the result of large, explosive volcanic events [*e.g.,* 3].

OBSERVATIONS: The regional context of the two dune fields is shown in Fig. 1. One dune field is located northwest of Biblis Patera, around 5°N, 126°W ("A", Fig. 1). The other is located northwest of the giant lobate feature on the west flank of Arsia Mons, at 2°S, 130°W ("B", Fig. 1).

Dune field "A", northwest of Biblis Patera, was imaged by *Viking 1* on orbit 733 in a series of 18 pictures with resolutions of about 24 m/pixel. A portion of the dune field is shown in Fig. 2. The bedforms are transverse, crescentic dunes with their crests oriented south-southwest /north-northeast. In the same region all around the dunes are found yardangs and some pedestal craters— both of which indicate aeolian erosion. The yardang ridges are nearly perpendicular to the dune crests. Also in Fig. 2, a pedestal crater is seen to be superposed on the dune field. The presence of this crater superposed on the dunes indicates that the dune field must be relatively old because the crater would post-date the initial formation of the dune field, but the deflation of fines which created the pedestal characteristics would postdate the impact event. Also in frame 733A14 (but not seen in Fig. 2) is a layer of smooth material that appears to overlie the dune field and has been eroded to reveal the dunes underneath.

Dune field "B" was imaged at moderate resolution by *Viking 2* on orbit 43 (see 043B40, 043B42) and later at high resolution on orbit 387 (Fig. 3). This dune field is located within the "Stealth" region discovered by *Muhleman et al.* [2]. The dunes occur in the topographically-low areas between lava flows that are hundreds of kilometers long (Fig. 3). Dune crests are oriented perpendicular to the regional slope, which is also perpendicular to regional winds that blow off the Tharsis Bulge [4]. These dunes cover about 1,700 km^2, making it the largest known dune field outside the martian polar regions. The dunes are spaced ~ 500 m apart. With the methods of *Lancaster and Greeley* [5], dune spacing is used to estimate dune height, equivalent sediment thickness (EST), and volume. The dune field is found to have heights ≈ 15–20 m, EST ≈ 2.5 m, and volume ≈ 4 km^3.

Medium and high resolution *Viking* infrared thermal mapper (IRTM) data indicate that neither dune field described here has a thermal inertia or albedo that is distinguished from the surrounding terrain. On Mars, most dune fields described to date have intermediate thermal inertias ($7–10 \times 10^3$ cal cm^{-2} sec$^{-0.5}$ °K^{-1}; 290–420 J m^{-2} sec$^{-0.5}$ °K^{-1}) and low albedos relative to the rest of Mars (≤ 0.09) [1]. These two dune fields have the same thermal inertias ($2–3 \times 10^3$ cal cm^{-2} sec$^{-0.5}$ °K^{-1}) as their surroundings. These thermal inertias are consistent with grain sizes << 60 µm [6].

INTERPRETATION AND DISCUSSION: The thermal inertia and albedo observations suggest that both dune fields are presently mantled by fine, bright dust. Indeed, in *Viking* image 043B40, bright wind streaks are seen crossing over the dune field of Fig. 3, suggesting that it is not active enough to remove the thin blanket of bright dust. The pedestal crater on top of the dunes northwest of Biblis Patera (Fig. 2), plus evidence in the same area that a smooth layer overlies the dunes, suggests that this dune field is not only inactive, it has been buried and has been partly re-exhumed by aeolian processes. In a hyper-arid setting, the best way to mantle a dune field and effectively stop the grains from saltating is to quickly bury it under a blanket of fine-grained (<< 60 µm) material that is too thick to be easily removed. For example, after the 1980 eruption of Mt. St. Helens in Washington, U.S.A., dunes near Moses Lake, Washington, were buried under 2–3 cm of ash [7]. For the active portions of the Moses Lake dune field, 2–3 cm of ash was not enough to shut down the dunes; however, on a planet with no rain, no animals, and no vegetation blowing in the wind to loosen the ash layer, a few centimeters would be sufficient to shut down saltation on these dune surfaces.

The two dune fields themselves constitute evidence for explosive volcanism in the Tharsis region of Mars. It is very common on Earth for wind to rework pyroclastic deposits, particularly in arid environments [*e.g.,* 8]. Pyroclasts that are sand-sized (or cm-size pumice) can be reworked into aeolian dunes [9]. Sand for building dunes on Earth is usually supplied by fluvial, lacustrine, or marine-littoral processes [*e.g.,* 10], but no evidence for these kinds of environments occur in the Tharsis region of Mars. Volcanoes and volcanic landforms are in abundance, however. Therefore it seems most likely that the sediment which comprises the dunes is made up of volcanic fragments. Pyroclastic fragments are the most likely sand source because of slow mechanical weathering rates and the fact that there are relatively few impact craters in Tharsis. The volcanic sources of these pyroclasts are probably within a few hundred kilometers of the dune field (*e.g.,* sand-sized grains of Mt. Mazama, Oregon, ash from its terminal eruption 6,800 years ago traveled a few hundred kilometers [11] and were reworked into dunes in Christmas Lake Valley, Oregon [*e.g.,* 12]). One possible source for sediment comprising the dunes at 2°S, 130°W (dune field "B" in Fig. 1) is a set of linear depressions on the west flank of Arsia Mons about 150–200 km upwind of the dunes which appear to have been the sources of lobate features that are interpreted to be possible pyroclastic flows [13].

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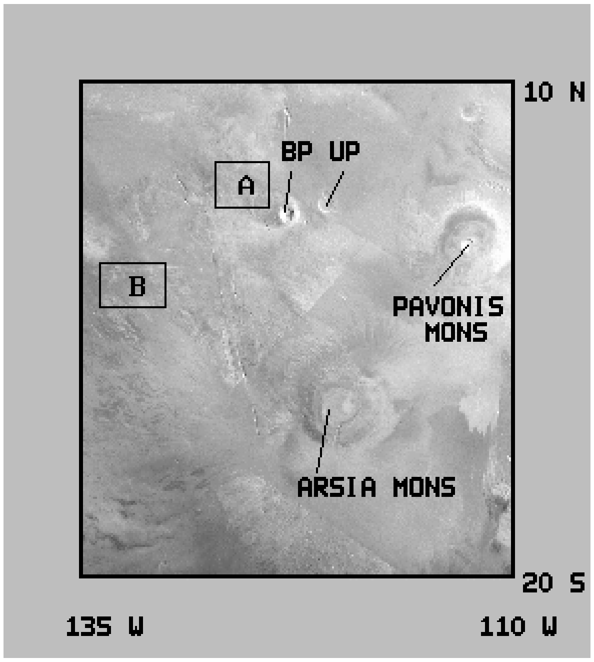

Figure 1. Context of two dune fields (in boxes **A**, **B**) in western Tharsis. **BP** is Biblis Patera, **UP** is Ulysses Patera.

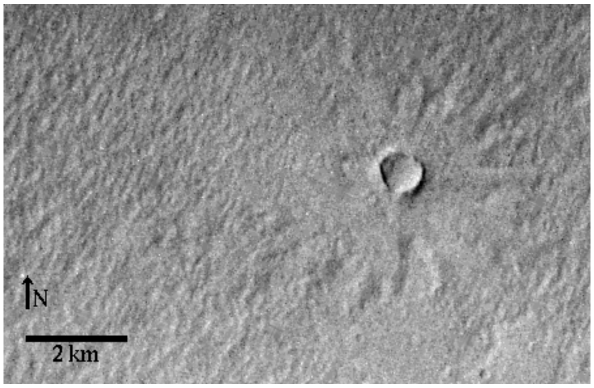

Figure 2. Impact crater superposed on dune field northwest of Biblis Patera (*i.e.,* **A** in Figure 1). This crater is one of the indicators that the dunes are old and have been subsequently modified. Not shown here, but visible in the same region, is a layer of smooth material that partly overlies the dune field. Figure is a portion of *Viking* orbiter image 733A14. Illumination is from the left. Image center is near 4°N, 126.4°W.

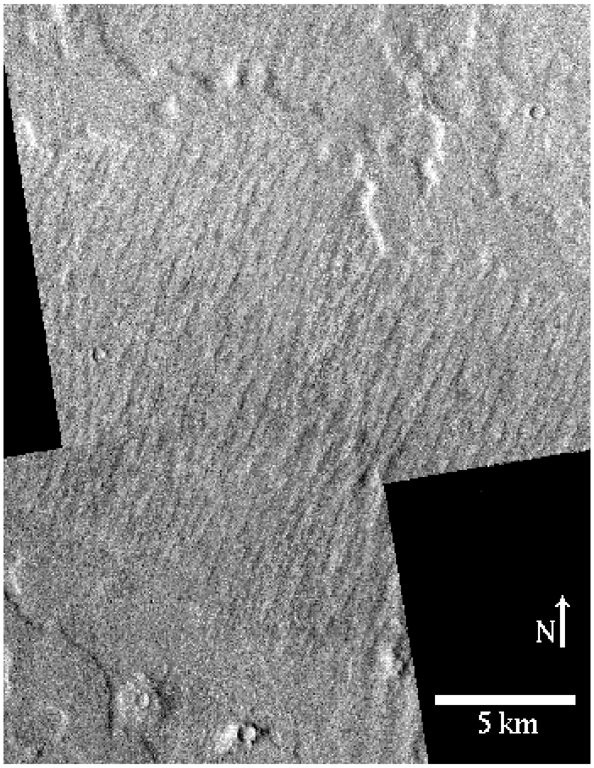

Figure 3. High resolution view of dune field northwest of Arsia Mons (*i.e.,* **B** in Figure 1). Note lava flow apparently superposed on dunes (upper frame) and pedestal craters (lower frame). Figure is mosaic of portions of *Viking* orbiter images 387B27 and 387B29. Illumination is from the left. Image center is near 1.7°S, 130.3°W.