DUST CLOUD OBSERVED IN VENERA 10 PANORAMA OF VENUSIAN SURFACE: INFERRED SURFACE PROCESSES. J. B. Garvin, Dept. of Geological Sciences, Brown University, Providence, R. I. 02912.

A zone of local darkening (ZD) extending for 25° azimuth is observed in the Venera 10 panorama of the surface of Venus. The darkened zone is interpreted to be due to the settling of a dust cloud through the field of view of the spacecraft camera minutes after touchdown. This point of view contradicts previous considerations of this feature [1,2] and is based on several different lines of evidence, both theoretical and observed. The ZD occurs in a 25° horizontal (azimuthal) and at least 25° vertical (elevation) region directly in front of the Venera 10 lander platform. It covers a 1 m^2 area at minimum based on camera viewing geometry and appears somewhat transparent in places (Fig. 1). Vertical dark streaks along with totally dark (opaque) sections nearest the lander best characterize the ZD. The streaks are reminiscent of those observed in the first image of the martian surface at the Viking Lander 1 site (Fig. 2) [8]. The darkening in the martian image (12A001/001) has been accepted as evidence for a dust cloud raised by the lander retrorockets that subsequently settled through the camera's field of view [8,9]. On Mars the feature lasted for only 66 seconds, but surface winds of around 7-10 m/sec could have dispersed the dust cloud in the thin martian atmosphere [8,9]. The ZD seen in the Venera 10 panorama from Venus persists for at least three minutes and is not recognized (from imagery) until 13 minutes after touchdown. The light venusian surface winds of 1 m/sec or less [1], combined with the high density of the atmosphere could permit a transient feature such as a dust cloud to remain relatively fixed for a significant period of time (i.e. for 20 min. within a few meters of the surface) until it had settled.

Stagnation pressures relative to local atmospheric pressure for Mars and Venus due to the landing of a spacecraft give some indication of the force transmitted to the surface on landing. For Mars a value of $\sim$ 0.3 dynes/cm^2 was calculated, whereas the value for Venus was computed to be 17150 dynes/cm^2 [10]. Based on these values alone, one might expect a venusian dust cloud to be larger and to persist long enough to be "seen" after 13 minutes following its formation. Stokes-Cunningham settling velocities for dust-sized particles on Mars and Venus are similar due to the large differences in surface gravities (g) and atmospheric viscosities (μ) for the two planets. The ratio g/μ controls the settling rate (V_f) if particles of similar diameter (d) and density (ρ) are considered: i.e.

$$V_f = \frac{(\rho-\rho_a)gd^2K}{18\mu}$$ where K = correction,

and ρ_a is atmospheric density. For Mars, g = 372 cm/sec^2, μ = 121 μP for CO_2 at martian pressure (7 mbar) and temperature ($\sim$ 240°K), so $g/\mu = 3.07 \times 10^6 cm^2/g\text{-}s$. For Venus, g = 887 cm/$sec^2$, μ= 310 μP for CO_2 at venusian pressure (90 bars) and temperature (740°K), so $g/\mu = 2.86 \times 10^6 cm^2/g\text{-}s$. From these simple calculations it is clear that Stokes settling velocities for dust-sized particles on Mars and Venus differ by less than a factor of two. This implies there are other factors contributing to the different behavior of fine particles in the martian and venusian atmospheres.

The following scenario is proposed for the formation of a dust cloud and its subsequent dispersion at the Venera 10 site. Photometric data suggest the dust cloud would not be carried above the spacecraft until at least 30 seconds after touchdown [1,2,3]. Turbulent effects brought about by wake turbulence from spacecraft descent can form eddies and vortices that, in combination with forces of impact (kinetic energy), would disturb the relatively

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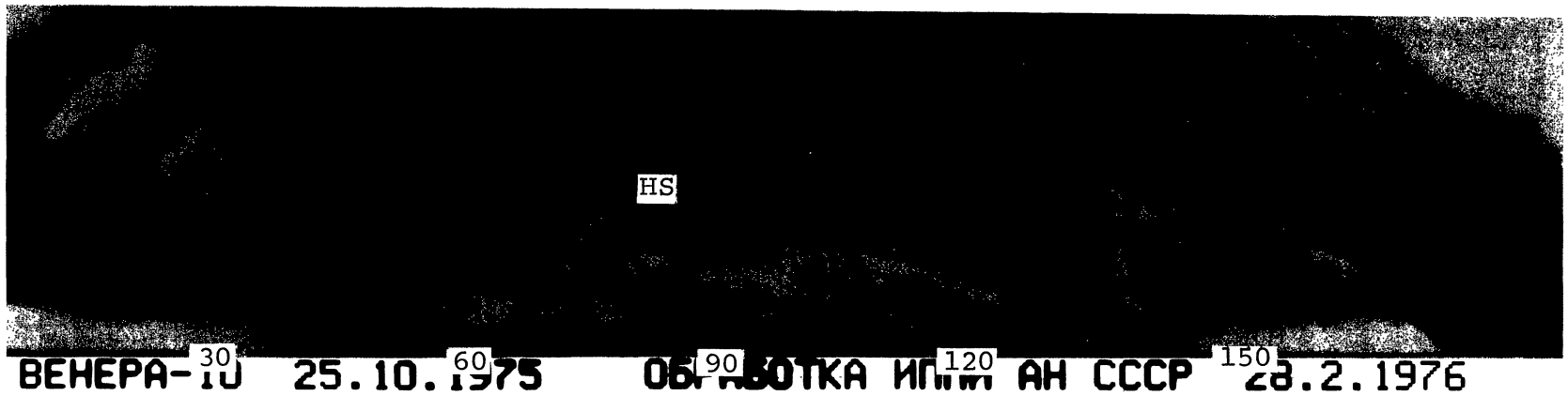
planar venusian surface at Venera 10 and raise dust particles. Camera resolution constrains the size of the raised particles to be less than 1 cm and likely much smaller (in the tens of μm range) due to settling velocities. The thickness of the laminar layer near the surface of Venus is defined to be $\delta = \mu / \rho_a V_{*t}$ where V_{*t} is the threshold wind velocity [5]. Thus $\delta = (310\mu P)/(0.069\ g/cm^3)(1.5\ cm/sec) = 0.0295$ cm or $\sim 30\mu m$. This suggests there might be a very thin layer of dust on the venusian surface, in contrast with Mars where $\delta \sim 590\ \mu m$. The threshold wind speeds for Mars, Venus, and Earth vary by orders of magnitude from ~ 2 cm/sec on Venus to 200 cm/sec for Mars [3,4]. If we assume dust particles on Venus are approximately the size of the laminar layer or 30 μm = 3×10^{-3} cm in diameter, then Stokes-Cunningham settling velocity $V_f = 3.9$ cm/sec. This means dust particles would settle 23.4 m in 10 minutes. If, however the particles were only 10 μm = 1×10^{-3} cm in diameter, they would settle only ~ 2.6 m in the same time. A 24 m dust cloud is not unreasonable for Venus given the spacecraft impact velocity of 7 m/sec and relative stagnation pressure of >17000 dyne/cm^2. On Mars it has been inferred the dust cloud at Viking lander 1 would have extended 200 m in elevation [8]. Therefore, it is concluded that a dust cloud of ~ 30 m in height could be formed during landing and could provide material to darken the Venera 10 scene ten minutes or more after its formation.

In summary, the key observations relevant to dust cloud formation at Venera 10 are: 1) The dust cloud was formed and raised by the combined effect of landing and wake turbulence (after landing) so it was still being raised 30 sec after touchdown; 2) The dust cloud rose over the lander to a height of at least 3 m (ht. of V10 spacecraft [3]) and probably 30 m; 3) The dust particles are in the 20-30 μm size range based on the height of the laminar layer [4,5]; 4) Wind velocities at V10 are ~ 1 m/s [1] which are too low to rapidly disperse a dust cloud; 5) The dust cloud settled into the field of view (50° inclined, 80 cm high) of the camera around 13 mins. after touchdown and its effect lasted at least three minutes (see Fig. 1, 65° to 100° azimuth); 6) The dust cloud effect was absent by the time the camera imaged the γ-ray densitometer (130° - 145° azimuth); 7) The ZD does not totally correspond to a region in front of the heat shield cover (HS in Fig. 1) where the automatic camera sensitivity system (ACS) operates, nor is it in a zone of artificial illumination (ZAI) as suggested in [1]; 8) There is evidence from photometry that there was a disturbance in the venusian atmosphere at the base of the V10 lander for ~ 30 sec after touchdown; a uniform decrease in the radiation from above the spacecraft was recorded after that time, suggesting a dust cloud overhead [3]; 9) Nephelometer data from the Pioneer Venus day probe that survived for 64 minutes on the venusian surface suggests a dust cloud lasting a few minutes was generated from probe impact [7].

References: 1) Keldysh (ed.) (1979) NASA-TM 75706, 193 p. 2) Ekonomov et al. (1980) Icarus 41, 65. 3) Moshkin et al. (1980) Cosmic Research 17, 232. 4) Hess (1975) J. Atmos. Sci. 32, 1073. 5) Sagan (1975) J. Atmos. Sci. 32, 1079. 6) Iversen et al. (1976) J. Atmos. Sci. 33, 2425. 7) Ragent et al. (1979) Science 203, 790. 8) Mutch et al. (1976) Science 193, 791. 9) Shorthill et al. (1976) Science 194, 91. 10) The stagnation pressure (p_s) relative to static atmospheric pressure (p_a) is: $p_s - p_a = \frac{1}{2} \rho_a V^2$, where ρ_a is the atmospheric density and V is the terminal spacecraft landing velocity. On Mars at VL-1, $\rho_a = 1.03 \times 10^{-5}$ g/cm^3 and $V \sim 240$ cm/sec, while on Venus $\rho_a = 0.07$ g/cm^3 and $V \sim 700$ cm/sec at Venera 10.



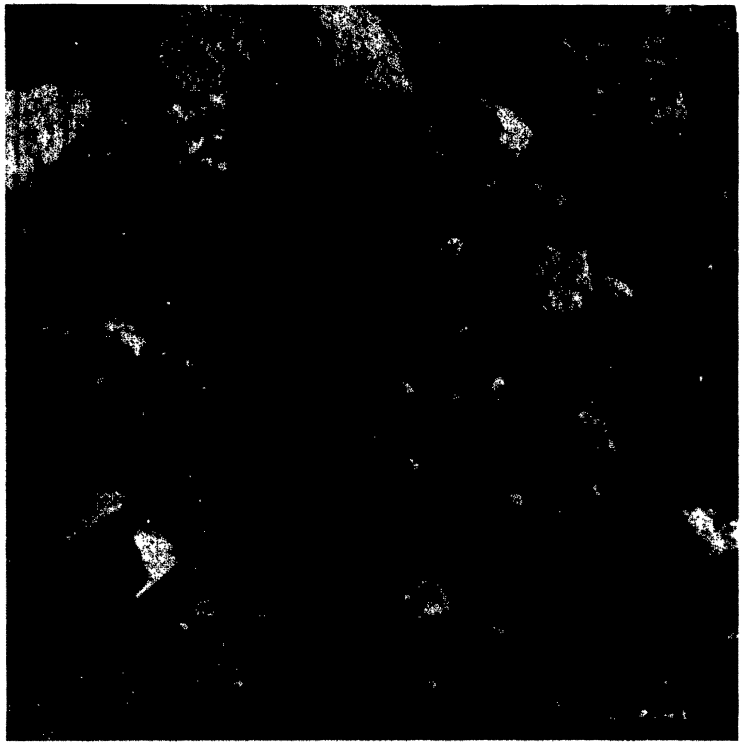


Fig.1 (above): Constrast enhanced Venera 10 panorama of the venusian surface initiated 2 min. 8 sec. after touchdown. HS is the 40 cm long heat shield cover that was discarded from the camera view-port after landing. ZD is the darkened region in the middle of the photograph, and extends from 65° to over 90° azimuth.

Fig.2 (left): First image of the martian surface initiated 25 sec. after touchdown of VL-1 (part of frame 12A001/000). Dark streaks at left are caused by dust cloud raised during landing and its subsequent settling between the camera and the surface. Rock in upper left is about 10 cm across.