

INITIATION OF SANDSTORMS DUE TO IMPACTS OF THE 1-10 M - IN DIAMETER METEOROIDS ONTO THE SURFACE OF MARS. I.V.Nemtchinov, O.P.Popova, V.A.Rybakov, V.V.Shuvalov (Institute for Dynamics of Geospheres Ras.Acad.Sci., 38 Leninsky prospekt, build. 6, 117979, Moscow, Russia (ivan@idg.chph.ras.ru).

Introduction: The least understood aspect of Martian aeolian cycles is the mechanism for setting particles into suspension. Because of the low-density atmosphere, extremely high winds are required to raise loose dust of the size inferred for Martian dust (approximately a few micrometers) [1].

The size of the small dust clouds being registered on Mars roughly coincides with the size of the clouds after the impact of bodies of approximately a few meters in size [2]. The cloud of debris and dust being formed after the impact may be a trigger-mechanism for famous Martian sandstorms (local, regional, or even global, under favorable conditions).

Mobilization of Dust: A hypothesis has been proposed [3,4] that the impacts of small cosmic bodies on the planet's surface may lead to formation of a heated layer over the ground due to absorption of the emitted thermal radiation. The interaction of the shock wave with the heated layer leads to initiation of large-scale vortex flow and high-speed jets moving along the surface. This flow may be responsible for the intense dust lifting even in the case when a small cosmic body does not directly hit the ground but disintegrates due to aerodynamic forces and creates an explosion in the atmosphere above the ground and an intense light flash.

Several factors of impact can facilitate a dust rising in addition to thermal layer effect, i.e.:

- outgassing of the porous surface layer under heating by the radiation impulse;
- intrusion of the shock-compressed gas into the regolith and subsequent blow-off in the rarefaction wave;
- steep erosion by blast-generated high-velocity winds;
- generation of large-scale vortex flows due to interaction of the blast wave with the ballistic wave and the wake behind a falling body [4].

Frequency of Impacts. A rate of impact on a planet is usually estimated by analyzing the frequency-size distribution of craters on a surface, taking into account some additional considerations on the age of the surface. However this method only allows for determination of the rate averaged over a large (in the geological sense) period of time. Erosion processes tend to conceal the scars caused by small impactors (in the case of Mars, aeolian processes leading to dust

transportation may be very effective).

In [5] it was considered that the impact mass flux at the Moon and Mars are identical based on comparison of Martian crater frequencies with those on the Moon and on correction for impact velocity differences. Authors of [6] used observational results of Mars crossing asteroids and came to the conclusion that Martian impact mass flux is a factor of 2 higher than that of the Moon as Mars is nearer to the origin of the impactors. Here we shall assume that frequency of the impacts on unit surface of Mars is within a factor of 2 the same as that on the surface of Earth.

The atmospheric entry processes in the case of large meteoroids are mainly governed by fragmentation, while ablation becomes less essential factor. The larger is the cosmic body the easier it is to find the fault in it. According to the statistical theory [7], the strength is falling with the increased mass. On the other hand, to open the large crack one needs to have at his disposal a large amount of energy proportionally to the square of the size. Potential elastic energy of the cosmic body under the aerodynamic loading is proportional to the cube of radius. Thus the fragmentation pressure is falling inversely proportional to radius [8]. These considerations are giving the general trend. It is impossible to predict beforehand the pressure at the blunt nose of a body which leads to its breakup as we do not know the structure and so on. One may use statistical data but they are absent for Mars as yet.

The aerodynamic forces depend mainly on the density of the atmosphere, shape, structure and other properties of the body and only slightly depend on the chemical composition of the atmosphere [4]. Thus for similar body with a similar velocity and angle of impact one may use the data for the case of the Earth and only the altitude of the flight would be changed.

In the Earth atmosphere a large number of bright light flashes of energies in light impulse of about 0.1-1 kt TNT and higher have been registered by USA DoD satellites equipped with photoelectric detectors [9-11]. Intense light impulses are created by impacts of meteoroids disrupted in the atmosphere (mainly at altitudes of about 30-45 km).

Several techniques for the assessment of meteoroid's characteristics from the light curves and heights of peak intensities have been developed [3,12]. Using these techniques the preatmospheric kinetic energy for

a number of events was determined.

The biggest event is the 1 February 1994 with initial energy as high as 30-40 kt TNT (or initial mass of about 400 t). The bright flash with light energy of about 4.5 kt TNT was caused by this meteoroid which deeply penetrated into the atmosphere (at an angle of 45° and velocity of 24 km/s) and disintegrated above at altitudes of about 34 km and 21 km [9,12].

Another famous impact event, the Sikhote-Alin meteor shower (12 February 1947 event), may be compared with the 1 February 1994 event. Initial masses of these meteoroids are probably the same, as well as the angle of trajectory inclination, but the initial velocity of the Sikhote-Alin is almost twice smaller. That caused fragmentation of 1 February 1994 meteoroid at higher altitudes and probably large fragments constitute a smaller part of the pre-breakdown mass in contrast to the Sikhote-Alin event.

In a rarefied atmosphere of Mars analogous impactors will penetrate into deeper layers of the atmosphere. They will disintegrate lower 15 km or even reach the planet surface, partially in disrupted form. Only the first disruption would occur if a meteoroid similar to that caused the 1 February 1994 will enter into the Martian atmosphere. And this body would reach the Mars surface as a tense swarm of fragments. The meteoroid similar to that caused the Sikhote-Alin event would hit the surface in a form of large fragments due to its low velocity. They will create crater with the size similar to that of the undisrupted meteoroid.

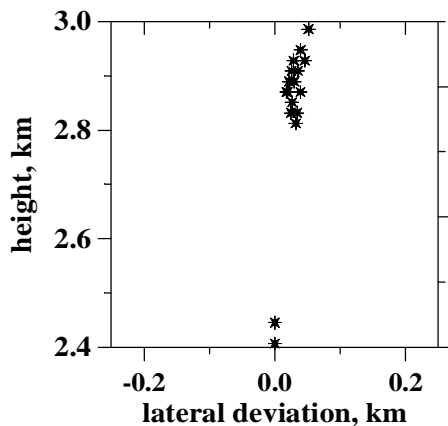


FIGURE 1. Modeling video-like picture on fragmentation meteoroid similar to Beneš ov into Mars's atmosphere. Positions of fragments are given versus altitude and lateral deviation from the leading fragment.

Many smaller bolides are registered by ground-based photographic European Network. One of the well documented bolides is the Beneš ov bolide [13].

It entered the atmosphere almost vertically with the velocity of about 21 km/s. Fragmentation has been confirmed by direct observation of fragments deviating from the main trajectory. Clouds of small fragments and vapor with common shock wave were formed but a number of fragments escaped from the cloud encompassed by the common shock wave and moved individually. The behavior of the Beneš ov meteoroid is probably typical for big stony meteoroids. Such meteoroids are fragmented in the Martian atmosphere at low heights causing bright flashes and hitting the surface as a swarm of fragments (Fig.1).

Mass of the Beneš ov meteoroid (2-4 t) is in the lower range of the masses of the satellite detected bolides. Its initial kinetic energy is about 0.1-0.2 kt TNT. About 20-60 meteoroids similar Beneš ov enter the Earth atmosphere each year. As a crude estimate we may assume that a number of impacts on Mars is smaller by a factor of 2-3 owing to the smaller area of the Red planet in comparison with the Earth, that is about 10-20. They cause light flashes bright enough to be detected by sensors similar to that used in [11], but on board of Martian Satellites. That may help to find fresh craters or modification of Martian surface. Mobilization of dust [4], due to the low-altitude blast in the Martian atmosphere is also an indication of impact.

In laboratory experiment [4] and numerical simulation efforts have been made to simulate the vortex flow and dust transport, resulting from the interaction of impact generated atmospheric blast wave with radiatively heated surface and atmospheric wake. In experiments with the dust coated surface, a large amount of the dust was carried away. All the dust was lifted from the central region around the point of energy release. This region has a sharp boundary: inside dust is absent, and outside practically all dust lies as before the explosion. The lifted mass was estimated as 1,000 times larger than the mass of the meteoroid.

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