MICROTEKTITES ON MARS. R. D. Lorenz, Lunar and Planetary Laboratory, University of Arizona, Tucson AZ 85721-0092, USA (rlorenz@lpl.arizona.edu).

Introduction: Energetic impact events produce a fireball large enough to punch through the atmosphere and distribute ejecta on ballistic trajectories, leading to large fields of microspheres. These particles, often called microtektites, are formed by condensation of rock vapor in the expanding fireball, and by melting of material on reentry. Mars' thin atmosphere means that this process can occur for smaller, and therefore more frequent, impact events. Such materials should therefore be widespread on Mars. Furthermore, the thermal history of such particles is very different from the steady sprinkling of micrometeorites entering the atmosphere on hyperbolic orbits. This will make deposits of microtektites easy to recognize with in-situ instrumentation, especially in the polar deposits [1].

Atmosphere-Piercing Impacts: Part of the energy of an impact event is deposited in a fireball of gas, whose volume relates to the energy [2]. This fireball will expand, nominally to a size at which its pressure will have fallen to the ambient surface pressure of the planet. However, if the fireball is large enough that its diameter is comparable to an atmospheric scale height, the fireball keeps expanding upwards. This 'blowout' has been observed in a high-altitude nuclear test ('Teak', 3.8MT) as well as in the SL-9 impact plumes on Jupiter. The phenomenon is also responsible for the distribution of microtektites on Earth (which are dispersed far too widely to have transported within the atmosphere) and is also believed to lead to the formation of the parabolic features around impact craters on Venus [3] – in these features (fig.1), the ejecta is dispersed with a circular symmetry by ballistic transport above the atmosphere, and then the material is winnowed by East-West winds in Venus' thick atmosphere.

On Earth, an event needs to be energetic enough to form a crater about 10 km in diameter (and the Ivory Coast microtektite field is associated with the 12km Bosumtwi crater, as an example). In Mars' thin atmosphere, the corresponding threshold size is only about 2.5 km (or a 150m diameter impactor, with a velocity of 10 km/s) : thus atmosphere-piercing events are relatively common on Mars compared with Earth or Venus.

Fig.1 Parabolic feature around crater Adivar on Venus : the parabola, formed by exo-atmospheric dispersal of material in the expanding ejecta plume is several hundred km across – intermediate in size between the north and south polar residual ice caps on Mars.

Global Ejecta Transport: On Earth, a velocity of around 10 km/s is needed to transport – material half-way around the planet. Mars is both smaller in diameter, and has a lower gravity, so the corresponding speeds are lower. Trajectory simulations (fig.2) show that particle trajectories are appreciably affected by planetary rotation, and only 4.5 km/s is needed to carry particles half-way around the planet. These low velocities imply that if the atmosphere is punctured, the particles will be dispersed globally. Typically microtektites are distributed with a surface number density that falls off to the nth power of distance (n~3 to 4.5) For Bosumtwi [4], there are around 100 particles (100 μm or larger) per square cm, at a distance of about 2000 km.

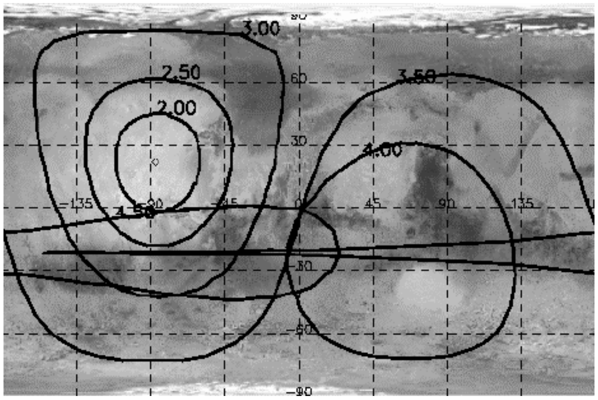

fig.2 Cylindrical projection of the Martian surface : diamond indicates example source crater (Fesenkov, 86km dia – same lat/long as Chicxulub on Earth) contours show regions reached by particles launched at 45º elevation with speed in km/s indicated by numbers. The poles are reached with about 3 km/s, and antipodes with 4.5 km/s. Note lateral displacement of contours, and stretched tadpole shape of 4.5km/s contour, due to planetary rotation.

Spherules and Heating: Material melted in or condensing from the vapor plume of an impact will tend to condense as small spheres whose size is limited by surface tension's ability to overcome aerodynamic stress [5] and the spherules can be deposited as thick, uniform beds. More energetic events (higher velocity impact) produce smaller spheres : for Mars, with lower escape velocity and further from the sun, such velocities are lower than for Earth, and so spherules are larger. For the 2.5km crater event discussed above, the corresponding particle diameter would be 300 μm [1].

The likely presence of abundant meteoric material on the Martian surface has been noted previously [6] Larger micrometeorites tend to melt since their lower area/mass ratio limits their ability to radiate the heat of entry. Simulations of entry heating suggest most meteorites on Mars less than 300 μm diameter will be unmelted.

Thus, a convenient distinction emerges – molten particles smaller than a few hundred μm (especially if found in a thick bed) are likely to be microtektites, whereas larger sporadically-distributed molten particles are most likely to be meteorites.

Future Prospects: The considerations above suggest that microspheres should be abundant and widespread, provided they are not destroyed by abrasion. Their preservation in the Martian environment is therefore crucial. Of immediate interest, therefore, is the Mars Polar Lander. First, this is landing in a region where microspherules might be effectively preserved in place. Secondly, the lander is equipped with a sampling arm, and a robotic arm camera with the ability to image the soil with ~20 μm pixels. With such a resolution, it should be possible to recognize 300 μm diameter particles as spherical and uniform.

The 2001 lander may have a similar opportunity to find spherules, especially if a preserving sedimentary deposit is accessible. Ultimately, the prospect of identifying and studying such particles in samples returned to Earth offers most potential. As well as morphological features (some terrestrial microtektites themselves bear tiny microcraters [7]) elemental abundances may give – clues as to the heating history of the particles by the depletion of volatile elements like zinc[1,8].

As well as yielding some insight into the impact process itself, layers of martian microtektites might prove useful as stratigraphic markers, much as volcanic horizons to in terrestrial ice-sheets.

References:

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