

ORGANIC MATTER ON THE EARLY SURFACE OF MARS: AN ASSESSMENT OF THE CONTRIBUTION BY INTERPLANETARY DUST; G. J. Flynn, Dept. of Physics, SUNY Plattsburgh, Plattsburgh, NY 12901

Calculations by Anders (1) and Chyba et al. (2) have recently revived interest in the suggestion that organic compounds important to the development of life were delivered to the primitive surface of the Earth by comets, asteroids or the interplanetary dust derived from these two sources. Anders (1) has shown that the major post-accretion contribution of extraterrestrial organic matter to the surface of the Earth is from interplanetary dust. Since Mars is a much more favorable site for the gentle deceleration of interplanetary dust particles (3) than is Earth, model calculations show that biologically important organic compounds are likely to have been delivered to the early surface of Mars by the interplanetary dust in an order-of-magnitude higher surface density than onto the early Earth.

Anders (1), in a detailed study of the accretion of organic-bearing extraterrestrial matter in various size ranges onto the Earth, concluded that, since organic matter cannot survive the high temperatures generated by large impacts, the major organic contribution comes from interplanetary dust particles (IDPs) small enough to survive atmospheric entry without reaching high temperatures. Mars is a much more favorable site for the deceleration of interplanetary dust than is Earth because of its lower surface gravity, giving rise to a lower average atmospheric entry velocity for IDPs, and its greater atmospheric scale height, resulting in a longer deceleration interval. In the terrestrial case, most IDPs larger than 100 μm in diameter melt or vaporize on atmospheric entry. Flynn and McKay (3) calculate that the fraction of 100 μm diameter IDPs surviving atmospheric entry at Earth is comparable to that for 700 μm diameter IDPs at Mars. The survival of these larger IDPs during atmospheric entry at Mars is particularly important to the rate of delivery of organic matter to the surface of Mars because the size-frequency distribution of IDPs in space is sharply peaked (see Figure 1), with 90% of the incident mass being between 10^{-7} and 10^{-2} grams (4), or about 60 to 2700 microns in diameter. Thus most IDPs near the peak of the mass-frequency distribution are destroyed on Earth atmospheric entry, but a large fraction of these particles survive Mars atmospheric entry without melting.

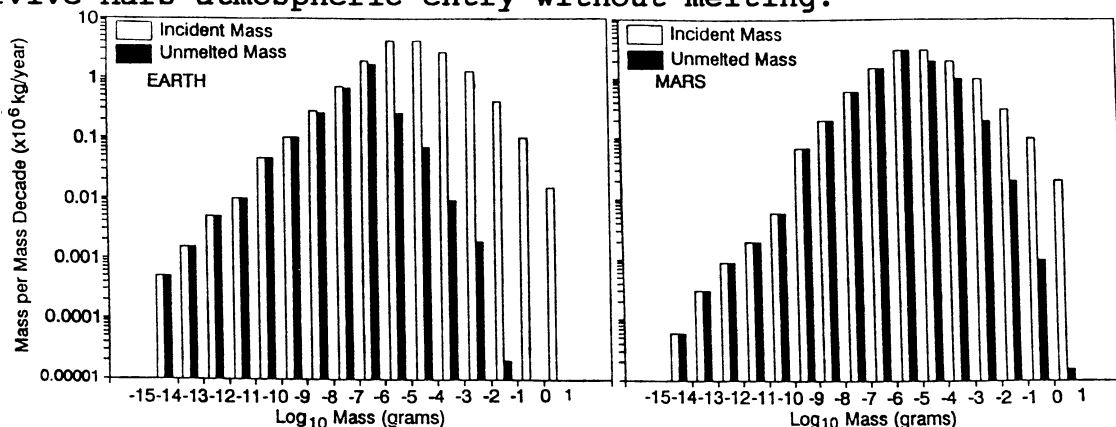


Figure 1: The micrometeorite size frequency distribution measured at Earth (6) and calculated for Mars are shown along with the mass surviving atmospheric entry without melting. The mass of micrometeorites arriving at Earth is greater than at Mars the mass surviving atmospheric entry is greater at Mars than at Earth because Mars is more favorable for micrometeorite deceleration.

Using the method described by Flynn and McKay (3) the size frequency distribution, and the atmospheric entry velocity distribution of IDPs at Mars have been calculated. The entry velocity distribution, coupled with the atmospheric entry heating model developed by Whipple (4) and extended by Fraundorf (5) was used to calculate the fraction of particles in each mass decade which survives atmospheric entry without melting (ie., those not heated above 1600 K). The incident mass and surviving mass in each mass decade are shown for both Earth and Mars in Figure 1. Integrating the areas under the incident and surviving mass frequency distributions gives a surviving mass of 8.6×10^6 kg/year out of an incident mass of 12.0×10^6 kg/year. This accretion rate for unmelted meteoritic material at Mars is almost three times the 3.2×10^6 kg/year of meteoritic material which Anders (1) calculates to survive Earth atmospheric entry without melting, even though the incident mass at Earth is higher, approximately 16.0×10^6 kg/year (6). Because Mars is a smaller planet than Earth, the surface density of meteoritic material which accretes onto Mars without melting is more than an order-of-magnitude higher than onto the Earth.

The average carbon content of IDPs $\leq 20 \mu\text{m}$ in diameter collected from the Earth's stratosphere is reported to be about 10% (7, 8), with one particle having 49% carbon (7). Organic molecules, including polycyclic aromatic hydrocarbons (9), have been detected in IDPs. However, the small masses of individual IDPs ($\sim 10^{-8}$ grams) has, thus far, precluded quantitative determination of the fraction of the carbon which is present in organic molecules. The carbon content of IDPs $> 100 \mu\text{m}$ in diameter is not well established because most of these particles melt or vaporize on Earth atmospheric entry, but Yates et al. (10) have extracted carbon with an isotopic composition consistent with that of the macromolecular organic material in carbonaceous chondrite meteorites from melted meteoritic spherules $> 100 \mu\text{m}$ in diameter recovered from Antarctic ices.

Repeating the entry heating calculations for IDPs not heated above 900 K, the pyrolysis temperature estimated by Anders (1) and Chyba et al. (2), indicates that approximately 2.4×10^6 kg/year of interplanetary dust accretes onto Mars with its carbonaceous matter unaltered. Assuming, following Anders (1) the average carbon content of IDPs is 10% then the present accretion rate of unaltered (not heated above 900 K) meteoritic carbon onto the surface of Mars is about 2.4×10^5 kg/year.

Anders (1) has suggested that the accretion of IDPs may have provided biologically important organic compounds to the primitive surface of the Earth. The more favorable conditions for low temperature accretion of interplanetary dust onto the surface of Mars provided even higher concentrations of these prebiotic organic compounds to the early surface of Mars. This source of organic matter coupled with the possibility of more favorable climatic conditions on the early Mars (11) may have implications for the biochemical evolution of the planet.

REFERENCES

- 1) Anders, E. (1989) *Nature*, **342**, 255-257.
- 2) Chyba, C. F. et al. (1990) *Science*, **249**, 366-373.
- 3) Flynn, G. J. and McKay, D. S. (1990) *J. Geophys. Res.*, **95**, B9, 14497-14509.
- 4) Whipple, F. L. (1950) *Proc. Nat. Acad. of Sci. USA*, **36**, 687-695.
- 5) Fraundorf, P. (1980) *Geophys. Res. Lett.*, **10**, 765-768.
- 6) Hughes, D. W. (1978) in *Cosmic Dust*, Wiley, New York, 123-185.
- 7) Blanford, G. E. et al. (1988) *Meteoritics*, **23**, 113-121.
- 8) Schramm, L. S. et al. (1989) *Meteoritics*, **24**, 99-112.
- 9) Allamandola, L. J. et al. (1987) *Science*, **237**, 56-59.
- 10) Yates, P. D. et al. (1991) *Meteoritics*, **26**, 412.
- 11) McKay, C. P. and Stoker, C. R. (1989) *Rev. Geophys.*, **27**, 189-214.