ENTRY CORRIDOR OF MICROMETEORITES CONTAINING ORGANIC MATERIAL

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A new ablation model of a composite micrometeorite containing both refractory and organic components was proposed in a previous paper[1] to explain such a transmission as the Greenland's and Antarctica's micrometeorites one.

Our first investigation was to use a computational code ("COKE") which simulates the entire process of ablation of a char forming composite material. At that time, the complexity of this code could'nt afford us to achieve a parametric study of micrometeorites entry. Thus, only partial results about this process were available.

Now, after a critical analysis of the conservative equations solved by COKE, the micrometeorites specific properties has allowed us to simplify the code in an efficient manner. Moreover, the pyrolysis process has been coupled with the fusion and vaporisation of the refractory component. Hence this code, including the equations of motions, simulates a complete ablation process of micrometeorites during an entry.

An interesting way to present the results for the whole domain of entry angle (γ_i) and velocity (V_i) of micrometeorites impacting the Earth, is to present them as "entry corridors". This is usually used in planetary entry of space vehicule modelisation . Then we have to calculate for a given body, the two boundary curves of overshoot and undershoot :

- the overshoot curve corresponds to a relation between V_i and γ_i for the body to be captured by the Earth's atmosphere.
- the undershoot curve corresponds to a similar relation for an heating limited entry, related to some specific thermal criterion. The entry corridor required belongs to the domain bounded by these two curves.The criterion could be a maximum allowed temperature T_c as does the traditional Whipple's law[2], for a non ablative one-dimensionnal trajectory in a plane atmosphere (ie no overshoot). But other thermal criterion could be used with this code. Particularly, we have considered a maximum allowed stage of carbonization for an organic component. Moreover the effects of the organic component pyrolysis on the maximum reached temperature has been studied.

The probability to be in a desired corridor is presented in the discussion of the entry statistic.

Entry corridor of micrometeorite - a comparison with previous model :

We have computed the entry corridor required for a 100 µm non ablative micrometeorite (density 2,5 ; begining of melting at : $T_f{}^b$ = 1500 K). The entry is supposed beginning at Z_i = 150 km. This altitude has been determined from conservation of kinetic momentum considerations. Any highest Z_i would yield to the same statistical results. The *figure 1* represents the two boundary curves determining the entry corridor. On the left of the overshoot boundary curve, the particule will be not captured by the Earth's atmosphere. On the right of the undershoot one the particule temperature will exceed 1500 K during the entry, involving a partial or a total melting or vaporization. The hatched zone is the entry corridor required for particle remaining unmelted.

The corresponding domain of the Whipple's law (on the left of the dotted curve in the *figure 1*) is slightly different. This discrepancy noticeable at low angle of entry is due to :

-(1) the assumption of an isothermal atmosphere which becomes wrong, since the altitudes of heating are greater than the isothermal portion of the Earth's atmosphere (Z > 100 km). Flynn[3] show the same result for the 10 µm micrometeorites which decelerate before entering the isothermal portion, whatever their angle of entry.

-(2) the approximation of a plane atmosphere which becomes also wrong. The curvature of the Earth yields an increase of the density scale height effectively encountered by the micrometeorite in comparison with a plane atmosphere. These two effects lead to an increase of the undershoot boundary curve towards highest entry velocity .

Entry corridor of a micrometeorite containing organic material :

The effect of the organic component pyrolysis on the corridor of entry (hatched zone) are presented on the *figure 2*. The undershoot boundary (T_{max} = 1500 K) upper curve correspond to a composite micrometeorite containing initially 30 % in mass of an organic component (here assumed to be equivalent to a phenolic resin) and 70 % of a silicate. The lower one shows the corresponding result for a 100 % silicate particule. As we said in 1, the effect of the pyrolysis of an organic component has a slight influence on the maximum temperature reached during the entry.

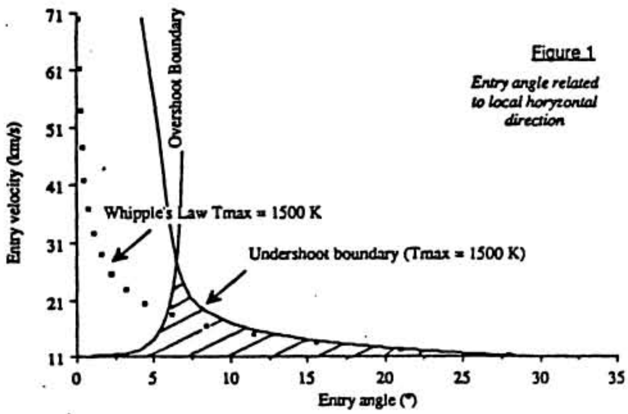
This comes from the high fraction Surface / Mass, of such body (size < 1 mm) which yields to an energetic predomination of the radiative reemission. This constatation could be extended to every other volatile component like ices, sulfides and hydrates silicates. The major contribution to the cooling process comes from the variation of density of the body during the entry which yields to a decrease of the maximum reached temperature of about 50 K for this organic matter mass content. We have reconsidered the screening effect of the emitted vapors . An evaluation has been done in assimilating this effect as a change in the aerodynamic flow from the free molecular regime to the transitional one. Then using Monte Carlo simulations results which modelize the transitional regime, an evaluation of the change in the heat transfert and drag coefficient was possible. The results show a negligible effect except for the highest size of the micrometeorites (≥ 1 mm) ; this overcomes the uncertainty about this process[4] for size greater than 100 µm.

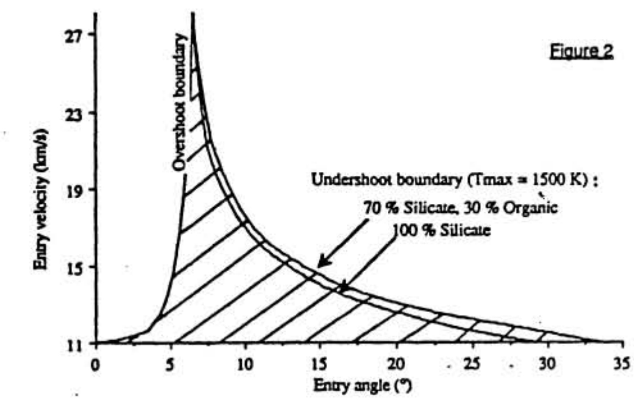
Entry corridor for the atmospheric transmission of a partly degraded organic component :

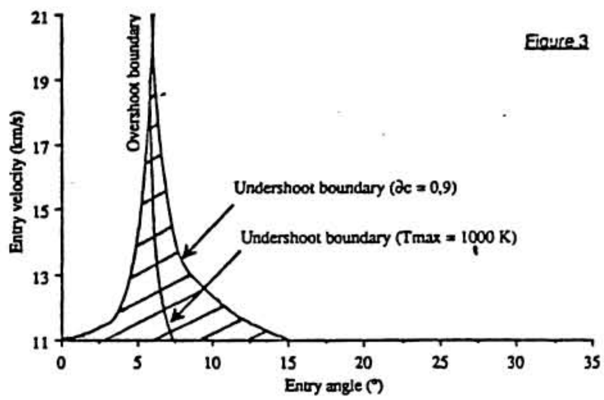
The transmission of organic matter not totally reduced to carbon is considered in the *figure 3*. The undershoot curve bounding the corridor corresponds to a maximum degree of carbonisation of the organic component : ∂_c = 0,9 (hatched zone). If we compare with the undershoot curve for a maximum temperature reached : $T_C = 1000$ K on the *figure 3*, we see that the curve is lower than the preceeding one. This result illustrates the dependance of the temperature domain of the pyrolysis processes on the rate of heating, effect that we have already discuss in 1 but now extended for all the domain of entry parameters.

Entry corridors statistic :

A second step of these calculations is to determine the statistical probability of beeing in the desired corridor. The classical assumption of an isotropic flux of micrometeorites on the Earth can be simply used for weighting the angle of entry[5]. For any entry velocity we can evaluate the probability for an incident micrometeorite to have an entry angle corresponding to the desired corridor : γ_i[overshoot boun-dary] < γ_i < γ_i[undershoot boundary]). The results are presented on the following table (size:100 µm, density : 2,5)







Entry Velocity (km/s)	Entry corridor requirement probability for a given thermal constraint				
	Tmax < 1500 K			Tmax < 1000 K	∂c < 0,9
VI	Whipple's Law	100 % Silicate	70 % Silicate 30 % Organic	70 % Silicate 30 % Organic	70 % Silicate 30 % Organic
11	24,25	24,25	30,46	1,65	6,70
12	14,03	14,53	19,48	0,95	3,05
13	8,79	9,19	11,36	0,57	1,57
14	5,65	6,16	7,31	0,38	0,94
15	3,81	4,22	5,02	0,26	0,70
20	0,69	0,84	1,09	0,00	0,00
25	0,19	0,20	0,30	0,00	0,00
28	0,07	0,00	0,00	0,00	0,00

Conclusion :

Our numerical code has been first used in the classical Whipple case and has shown that for statistical calculations the Whipple's law could be a good approximation.

Then a non classical case, which can not be described by the Whipple's Law, such as micrometeorite cointaining organic material has been considered. Our calculations reveal that all the pyrolysis thermal terms and the screening effect due to the emission of emitted vapor are negligible for size lower than ≈ 1 mm. The variation of the micrometeorite density during the entry is the unique contribution to a decrease of the heating.

Instead of a maximum temperature allowed during entry, we have used a different thermal constraint for entry, which is a maximum carbonization stage allowed for the organic component. Our results show that a significant fraction (~15 %) of unmelted micrometeorites could still present a partly degraded organic component at the end of their atmospheric entry, even for velocity corresponding to grains originally from short period comet.

This result due to the pyrolysis process can explain the possible presence of extraterrestrial organic molecules in the Greenland's and Antarctica's micrometeorites.

The weighted-corridor-model can be applied to compute other interesting effects as for example : loss of rare gases or dehydratation of micrometeorites.

References :

[1] *Bonny et al, LPSC XIX, 118-119,1988.* [2] *Whipple , F. L. Proc. Nat. Acad., 687, 695, 1950.* [3] *Flynn, G., L., LPSC XIX, 338, 339, 1988.* [4] *Allen et al, NASA TN D-2872,1965.* [5] *Fraundorf, P., Geophys. Res. Let., 10, 765-768, 1980.*