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1. Here we're going to investigate the effect of a thick atmosphere on impactors.

a) Venus has an atmospheric pressure of 9 MPa and a surface gravity of 9 ms^{-2} . What is the *column density* of the atmosphere, that is, the total mass of the atmosphere per unit area, in kg m^{-2} ? [1]

b) If a spherical impactor of radius R and traveling vertically downwards enters an atmosphere of column density σ , write down an expression for the total mass of atmosphere the projectile encounters assuming that it reaches the surface [1]

c) Theoretical calculations show that an impactor will break up if the mass of atmosphere it encounters equals the mass of the impactor itself. Assuming an impactor density ρ , write down an expression for the radius R at which an impactor will break up for a given column density σ . [3]

d) For the case of Venus, what is the impactor radius at which break-up occurs if the impactor density is 2500 kg m^{-3} ? [1]

e) Using the expression from your notes, calculate the smallest size of impact crater you would expect to see on the surface of Venus. Assume an impact velocity of 15 km/s . How does your answer compare to the actual observations? [4]

f) If the impactor came in at an oblique angle, rather than vertically, what would happen to the break-up radius and why? [1]

g) If the impactor was made of ice rather than rock, would the minimum crater size be bigger or smaller? [2]

[13 total]

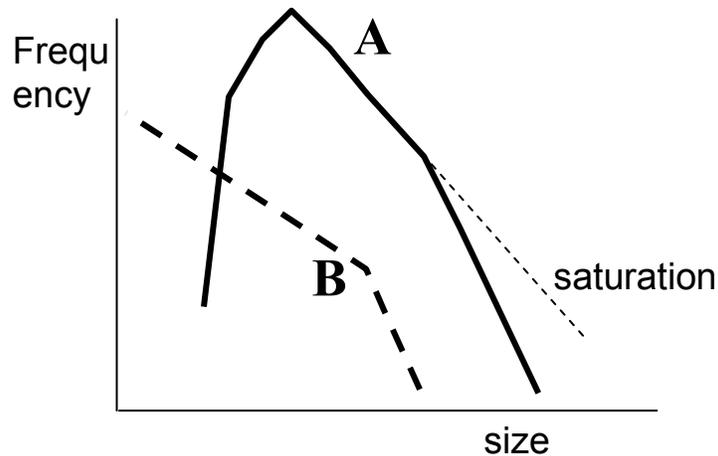


Figure 1. Hypothetical crater size-frequency distributions.

2) Figure 1 shows hypothetical crater size-frequency distributions (A and B) for two different planetary surfaces.

- a) Which surface is older and why? [1]
- b) Give 2 possible explanations for the deficit in small craters seen for population A [2]
- c) Why might A be saturated for small craters but not for large craters? [1]
- d) Large craters on B were probably produced by the same population of impactors which produced large craters on A. Do you think the small craters on B were produced by the same population? [1]
- e) Suggest one scenario in which a surface might experience two different populations of impactors [2].
- f) Say that one of A or B is from an inner solar system body, and one is from an outer solar system body, which do you think is which, and why? [2] [9 total]

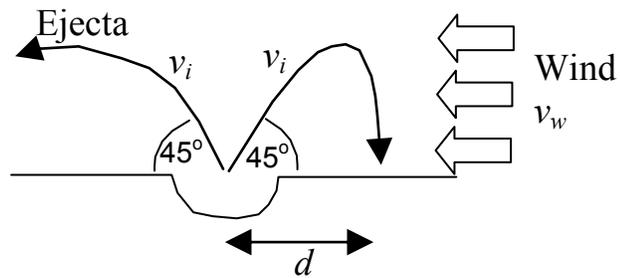
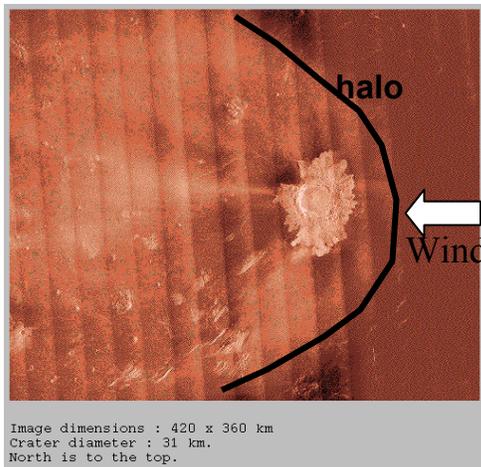


Figure 2. Parabolic ejecta halos on Venus.

3) Some craters on Venus have parabolic ejecta “halos”, presumably caused by wind blowing the ejecta downwind (see Figure 2).

a) If the ejecta exits the crater with velocity v_i at an angle of 45° and the gravity of Venus is g , write down an expression for the time taken before the ejecta hits the ground again. [2]

b) For ejecta traveling in an upwind direction, write down an expression for the net horizontal velocity of the ejecta if the horizontal wind velocity is v_w . [1]

c) Hence write down an expression for the upwind distance d the ejecta travels as a function of g , v_i and v_w . [2]

d) If initial velocity of the ejecta $v_i = 1 \text{ km/s}$, $g = 9 \text{ ms}^{-2}$ and $d = 75 \text{ km}$ (see Figure 2), what is the wind velocity? [3]

e) The wind speeds at the surface of Venus as measured by the Venera landers are only a few m/s. How do you reconcile this observation with your answer to d)? [2]

f) Why don't we get parabolic halos on Mars? [1]

[11 total]