THE VIKING IMAGERY, THE EARLY HISTORY OF THE MARTIAN SATELLITES, AND THE ACCRETIONARY TAIL. J.P. Duraud *,**, Y. Langevin*, M. Maurette*. *Laboratoire René Bernas - 91406, Orsay. **Service de Chimie-Physique du C.E.A. - 91120, Gif/Yvette.

I - INTRODUCTION

In reference 1 we presented an analytical model of regolith evolution for a martian satellite with a radius, R_s, which allows to compute 3 distinct types of regolith thickness, Δ: 1. $\Delta_f \sim R_s/50$ is an upper limit obtained by supposing that all material ejected upon impact is reaccreted and that the satellite has been bombarded with the maximum integrated flux of meteorites, beyond which its fragmentation occurs ; 2. the equilibrium thickness, $\Delta_e \lesssim 2$m, is evaluated just by assuming that the material ejected with the escape velocity is completely lost for the formation of the regolith ; 3. the "normal" value, $\Delta_o \sim 5$ to 10m, corresponds to a situation already observed on lunar maria, where both all the ejected material is reaccreted and the surface is exposed during $\sim$4 by to a meteoritic flux similar to the present day flux. As shown in the next sections these values of Δ_f, Δ_e, Δ_o help in interpreting important features observed on the pictures of Phobos, that both put severe constraints on any model of regolith evolution and help in deciphering the history of the martian satellites. In addition the evaluation of the Δ_f, Δ_e and Δ_o values expected for lunar highlands yields an interesting limit for the integrated intensity of the accretionary tail, i.e. the flux of debris, still not accreted into larger bodies, that pervaded the early solar system.

II - THE VIKING IMAGERY OF PHOBOS AND THE EARLY HISTORY OF THE MARTIAN SATELLITES.

The observation of the superb pictures of Phobos taken at a distance of 40km by the Viking imagery system reveals a flat bottomed crater, which indicates that the "experimental" thickness, Δ_{exp}, of the regolith of a martian satellite with a radius of $\sim$10km is about 100m. This value, when compared to both Δ_e and Δ_o gives the following clues concerning the early history of the martian satellites :

1 - Δ_{exp} is much larger than $\Delta_e \sim$2m. We thus conclude that Phobos (and probably Deimos) reaccreted a very large fraction of the ejected material.

2 - But Δ_{exp} also greatly exceeds $\Delta_o \sim$5 to 10m and this has the following implications : i. Phobos was in fact bombarded with an integrated meteoritic flux much larger (x 100) than that corresponding to a 4 by exposure of its surface in the present day meteoritic flux. This flux could possibly originate either from a swarm of small bodies first in orbit around Mars, and then subsequently accreted by Phobos, or from the accretionary tail. The large crater density observed on lunar highlands as well as the almost complete erasure of lunar geological features older than 4 by is also best interpreted by assuming a large increase in the meteoritic flux intensity during the early history of the Moon (2). The simultaneous observations of the effects of this very high meteoritic flux on the Moon and Phobos would rather support its filiation to the accretionary tail. This in turn strongly suggests that Phobos was already locked in orbit around Mars more than 4 by ago ; ii. As a result of being exposed to the accretionary tail the martian satellites should present a "megaregolith" similar to that observed on lunar highland. But since the cessation of the accretionary tail $\sim$4 by ago only the most superficial layer of the martian satellites, that we define as their "normal" regolith, should have been frequently gardened down to a depth $\Delta_o \sim$ 5 to 10m.

Such a regolith can be expected to be quite similar to that observed on lunar maria, with the exception that no stratified structure should be visible as a steady rain of well mixed material was responsible for the deposition of the satellite regolith. However, in our model one clear boundary should be observed between this normal regolith and the underlaying megaregolith. Indeed the normal regolith was worked out by a meteoritic flux characterized by a mass spectrum probably vastly different from that of the accretionary tail. Such a difference should be responsible for a marked change in the size distribution of the constituent grains of these two distinct types of regolith, with the grains of the megaregolith being much coarser than those of the normal regolith. In addition, as a result of the much higher intensity of the accretionary tail, the exposure time of the megaregolith grains on the top surface of the satellite was much shorter than that of the normal regolith grains. Consequently, a marked difference in the degree of space "weathering" of the two types of grains should be observed, which is related to their exposure to solar wind ions, micrometeorites, splashes of glassy materials, etc. We thus believe that the normal regolith should be more "mature" and thus darker than the underlaying megaregolith ; iii. As $\Delta_{exp} \sim \Delta_f$ Phobos has "almost" being exposed to the maximum integrated flux of meteorites beyond which fragmentation occurs.

Various other features in the pictures of Phobos are quite compatible with some of these conclusions. For example, the large crater Stickney (r $\sim$5km) is surrounded by an extensive network of lines extending up to a distance of $\sim$10km , and which have been interpreted as fracture lines (3). This clearly indicates that Phobos has almost been fragmented. Verveka has also reported the observation of a clear horizontal boundary at a depth $\sim$20m in one of the crater of Phobos (4), which is compatible with our limit of normal gardening. Such a limit, if confirmed by further work, should in turn give interesting clues about either the mass spectrum of the accretionary tail or the effects of space weathering on regolith evolution.

Finally the high resolution pictures of Phobos show both rock boulders and impact craters presenting a continuous range of degree of burial, which is well illustrated by the "filled up snowprint" appearance of the buried features. These features are thus well compatible with our steady rain model for the deposition of material on the surface of the small martian satellites.

III - LUNAR HIGHLAND AND THE ACCRETIONARY TAIL.

In the previous section we already argued for the general occurence of the accretionary tail in the early solar system, which has left prints on both the lunar highlands and the surface of the martian satellites. We now try to infer the value, ψ_{lh}, of the integrated flux of meteorites received by lunar highlands during the accretionary tail, by relying on estimates of the thickness of their corresponding megaregolith ($\Delta_{lh} \sim$a few km).

In reference 1 we evaluated the equilibrium thickness of the regolith of a small body, $\Delta_e \sim 0.05\ R_s^2/R_M$, where R_s and R_M are the radius of the small body and that of the Moon, respectively. For a large body like the Moon, exposed to a sufficiently high integrated flux of meteorites, the value, $\Delta_e \sim$ 40km, has to be considered as a lower limit of Δ_{lh}. Indeed, in the computation of Δ_e a large fraction of the ejected material is lost to space whereas 99,9% of this material is reaccreted by the Moon. But the estimated value of Δ_{lh} ($\sim$ a few km is in fact much smaller than Δ_e ! By using formula derived from our model of regolith evolution we thus conclude that the Moon has not been subjected during its early exposure to the accretionary tail to an integrated flux of meteorites, $\psi_e \sim 300{,}000\ \psi_o$, sufficiently high to trigger the formation of an equilibrium thickness (ψ_o corresponds to the bombardment of the lunar surface during 4 by in the present day meteoritic flux).

With more elaborated computations the values of Δ_{1h} can indeed be used to infer an estimate, $\psi_{1h} \sim 10{,}000\psi_o$, for this earlier flux of meteorites which was mostly active $\sim$4 by ago. If confirmed by further works this high value of ψ_{1h} will put on firmer grounds interesting speculations presented by others, and dealing for example with the various effects of the accretionary tail on the early Earth, and such as the formation of the ocean basins, the injection of extraterrestrial organic matter on the Earth, the evolution of the primitive Earth atmosphere, etc...)

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