IMPACT MELTING IN THE MERCURIAN REGOLITH: IMPLICATIONS FOR REMOTE-SENSING OBSERVATIONS; Mark J. Cintala, Code SN21, NASA JSC, Houston, TX 77058.

As summarized elsewhere in this volume,[1] the rate of impact melting in the mercurian regolith could be almost 14 times higher than on the Moon, due primarily to greater impact velocities coupled with the higher flux of impactors (about 5.5 times greater). Such a degree of fusion of surface materials implies that observable differences between the Moon and Mercury must exist. Some suggestions regarding the regolith of Mercury in light of its peculiar place in the solar system are summarized below.

Dynamical Aspects of Impact-Glass Production: While the bulk of small-scale impact glasses are formed in the near-surface layer of a regolith,[2] they are also mixed with deeper materials. As a first approximation, it can be assumed that the effects of mixing and blanketing are a function of the volume of the "average" crater formed in that regolith. The volume of such an average crater $\bar{V}_E$ formed on either the Moon or Mercury can be estimated from

$$\bar{V}_E = \int_{v_{min}}^{v_{max}} f(v)\, V_E\, dv \Big/ \int_{v_{min}}^{v_{max}} f(v)\, dv \qquad (1)$$

in which $f(v)$ is the velocity distribution of impacting objects for the planet in question,[1] V_E is the excavated volume of the crater (found by using the scaling relationship for dry quartz sand as given by Schmidt and Housen[3]), v_{min} is the escape velocity from the planet's surface, and v_{max} is the sum of the planet's orbital velocity around the Sun and the solar-escape velocity at the planet's average orbital radius. After evaluating this integral for *identical projectiles and assumed regolith characteristics*, it is found that the average crater on Mercury is only about 1.07 times more voluminous than its lunar counterpart, due to the fact that the higher mean impact-energies at Mercury are countered by the lower lunar gravitational acceleration. The quantity of impact melt produced, however, is also a function of the impact velocity. The volume of melt V_L created by an average impact can be found through an equation identical in form to eq. (1), in which V_E is replaced with a polynomial expression for V_L as a function of the impact velocity.[1] The average volume of melt produced per average volume excavated ($\bar{R} \equiv \bar{V}_L / \bar{V}_E$) can then be determined; the ratio of these values for Mercury and the Moon $\bar{R}_M / \bar{R}_m$ is found to be 2.47. These results are significant in two ways: first, the relative volumes excavated by these "average" impacts are almost equal, implying that the net magnitude of mixing per impact on the two planets is also very similar; second, the amount of impact melt that must be accommodated by this mixing process on Mercury is more than twice that on the Moon. When the high impact-flux (*i.e.*, impacts per unit area per unit time) at Mercury is considered, it is apparent that small-scale impact melts (agglutinates, ropy glasses, etc.) should be substantially more abundant in the planet's regolith. Because many lunar soils have agglutinate contents well above 50 weight percent,[4] however, the mercurian regolith clearly cannot possess 2.5 times more impact melt. Unless some mechanism unidentified here increases the efficiency of mixing on Mercury, mercurian glasses must routinely experience multiple "remelting" events.

Potential Characteristics of Mercurian Agglutinates: Agglutinates constitute the most pervasive glass-bearing component in lunar regoliths. It is assumed, by analogy, that agglutinates are also the dominant manifestation of small-scale impact melting on Mercury; although the planet's surface can attain much higher temperatures than those on the Moon,[5] it appears that it is not hot enough to induce devitrification significantly different from that of the lunar case.[6] Agglutinates are well known for their influence on lunar reflectance spectra;[7,8] such effects include increasing spectral slopes toward longer wavelengths,[7,8] decreasing the regolith's overall reflectivity,[8] and broadening an absorption feature near 1 μm while weakening the pyroxene absorption-feature in the same spectral region.[9] The principal contributors to these effects are glasses containing dissolved Fe^{2+}, Ti^{3+}, and Ti^{4+},[10,11] as well as abundant, submicrometer, metallic-Fe spherules.[7,8,11] Although both theoretical considerations[12,13] and observational evidence[14,15] point to little Fe in the mercurian crust, even small amounts dissolved in glasses are sufficient to induce notable effects in a regolith's optical properties.[8] While numerous suggestions have been made to account for the Fe spherules, perhaps the most enduring is that of Housley *et al.*,[16] in which Fe^{2+} is reduced to Fe^0 and agglomerated as a result of impact melting in the presence of implanted solar-wind H. It appears that the mercurian magnetic field generally prevents direct access to the planet's surface by solar-wind particles;[17] nevertheless, mechanisms that can implant H in the mercurian regolith have been identified.[17] On the basis of the calculated rates of supply to and loss from the planet's surface,[17] the net rate of hydrogen implantation is estimated to be between 6.7×10^5 and 3.6×10^6 protons/s, a rate that is 4.8×10^{-3} to 2.6×10^{-2} times the rate at the Moon.[18] Taking 100 years as the time required for H saturation of the lunar regolith,[16] the equivalent period for Mercury would be on the order of 4×10^3 to 3.6×10^4

years, which is still a rapid rate in the context of regolith evolution. Should hydrogen be a necessary ingredient for the formation of the metallic-Fe spherules, then, it is likely that it would exist in sufficient abundance in the mercurian regolith.

Spectral Consequences: Even early spectral observations of Mercury alluded strongly to the presence of abundant glass in the planet's regolith;[19] subsequent data provided evidence of a weak absorption near 1 μm, and have been used to place an upper limit on the FeO content of the mercurian regolith at about 5.5 weight percent.[14] Although lower abundances are permitted by the data -- the most recent and precise spectral measurements yielded no clear indication of such an absorption[15] -- a large fraction of Fe would induce albedos lower than those observed.[19] The lack of an unambiguous absorption due to Fe^{2+} in crystalline sites has been attributed[15] to the intensive impact-melting environment at the planet's surface, which is a reasonable suggestion in light of the calculations summarized above. With the high value of $\bar{R}_M/\bar{R}_m$ and with lunar regoliths routinely possessing agglutinate abundances above 50 weight percent, the prospects for survival of substantial fractions of crystalline material in the upper layers of Mercury's regolith are comparatively poor. Perhaps as important, however, is the effect that this impact environment would have on glasses that already exist. Whatever suggested process is involved -- all of which require impact melting and the consequent high temperatures -- reduction of residual dissolved Fe^{2+} by repeated "remelting" of the glasses might even remove the broad, charge-transfer absorption at 1 μm that is characteristic of otherwise normal agglutinates.[9] Thus, the lack of distinct absorption features due to Fe^{2+} in mineral or glass phases should not be surprising, particularly if little Fe^{2+} existed in the surface materials at the outset.

Effects on Albedo: Compared to the other terrestrial planets, both the Moon and Mercury have relatively low, disk-integrated normal albedos, at about 0.12 and 0.14, respectively.[20,21] The visible contrast across the mercurian surface, however, is somewhat lower than it is on the Moon,[22] with no regional differences comparable to the lunar mare-highland dichotomy. This lack of contrast might be due to the abundance of impact glass in the mercurian regolith, as well as to its low FeO-content, which appears to be similar that at the Apollo 16 site. Using soils derived from Apollo 16 light-matrix and dark-matrix breccias (1.5 and 4.9 weight percent FeO, respectively),[23] Adams and Charette[8] evaluated the 0.565-μm (visible) reflectance as a function of each soil's magnetic fraction, which they effectively equated to the agglutinate content. (It was subsequently determined that a substantial portion of the magnetic fraction of lunar soils is composed of nonagglutinitic materials, although the magnetic and agglutinitic fractions are well-correlated.[24] Thus, the actual agglutinate contents of the soils cited by Adams and Charette[8] are somewhat lower than plotted in their figures.) They found that the difference in reflectance between the soils derived from the light- and dark-matrix breccias becomes very small to nonexistent when the magnetic fractions exceed about 60 weight percent, a value corresponding to an agglutinate content of about 34$\pm$9 weight percent. As summarized above, a mercurian regolith with such a small fraction of agglutinates should be rare indeed. Thus, it is possible that the extensive impact metamorphism of the mercurian surface has significantly reduced any differences in visible contrast that might have existed between regional terranes, leading to the relatively bland appearance now presented by the planet.[22]

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