PROCESSES OF FORMATION AND DEGRADATION OF IMPACT CRATERS INFERRED FROM MESSENGER'S FIRST FLYBY OF MERCURY.

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Introduction: The morphologies of craters of various sizes on a planetary surface shed light on the processes that create them as well as on the various geologic processes that degrade and erase them. Both primary and secondary craters were recognized on Mariner 10 images of Mercury. For the first time in over 30 years, MESSENGER images will reveal some of these impact features again from different lighting geometries, at different resolutions, and in different wavelength bands while also revealing new features not imaged by Mariner 10 and/or too small to be depicted by Earthbased radar in longitudes west of Caloris. We will report some preliminary findings about craters from this first MESSENGER flyby.

Crater Formation and Initial Morphology: The crater size-frequency distributions (discussed in more detail by Strom et al. [1]) reflect both the impactor populations, as they have evolved during Mercury's observable geological history, and secondary craters formed by ejecta from primary impacts. Primary craters are formed by present-day populations of asteroids and comets (including Sun-grazers), which strike Mercury at generally higher velocities than for other terrestrial bodies. Earlier epochs of cratering may still be recorded from small-body populations that may or may not have evolved or become depleted by now, including projectiles responsible for the Late Heavy Bombardment, vulcanoids (orbiting interior to Mercury's orbit), and erstwhile satellites of Mercury. There may have been significant spikes in the bombardment rate, which would generally be expected to correlate with spikes in cratering rates on other terrestrial bodies. Primary craters generally form one at a time, hence are spatially random, but the possibility of chain craters being formed by impacts shortly after tidal disruption (by Mercury or the Sun) of an impacting body has been discussed [2]. (Such quasi-linear chains can be distinguished from endogenic crater chains by morphology studies.) Secondary craters, formed sporadically by ejecta from basins and larger primary craters, are generally recognizable from their two-dimensional spatial clustering; due to stronger gravity, their lateral dispersal is more constricted than on the Moon. There is always the possibility that craters or depressions may be formed by volcanic or other endogenic processes; such features may have been below the resolution limits of Mariner 10 images [3].

The initial morphological shapes of craters on Mercury are similar to those formed on other planets and satellites; the crater sizes at which simple craters change to complex craters, and to protobasins and finally to multi-ring basins, reflect both the higher impact velocities close to the Sun and Mercury's Mars-like surface gravity, and--to a lesser degree--surface rheology [4,5]. Unmodified fresh craters have depth/diameter relationships that differ from planet to planet; André and Watters [6] find that 30-200 km complex craters, when compared with lunar carters, are even shallower (i.e. more like Martian craters) than found earlier by Pike [4]. For unknown reasons, Mercury's polar craters may be shallower than those at lower latitudes [7,8]. Over 70 protobasins and multi-ring basins were identified on the Mariner 10 coverage. Differences between fresh-crater morphologies and observed crater morphologies reflect the variety of processes that may degrade craters gradually or instead may modify them (or erase them) suddenly or episodically. The percentages of craters of a particular size in different degradational states provide clues about the nature of the responsible processes and how they have evolved with time.

Crater Degradation: Various degradational processes, beyond those due to the cratering process itself, have been hypothesized to operate on Mercury, although many of them await MESSENGER's higher-resolution imaging. For instance, terrain has been modified at the antipode of the Caloris basin, either by convergence of seismic waves or ejecta; it is plausible that high-resolution imaging may reveal similar hilly and lineated textures antipodal to other basins. The presence/absence of antipodal disturbance as a function of basin size, as well as the morphology of the disturbances, now seen at higher resolution, may reveal clues as to which of these mechanisms is responsible for these terrains. Tectonism, revealed at Mariner 10 resolutions by lobate scarps, wrinkle ridges, and extensional troughs, may have expressions at smaller scales, as well; the extent to which initially circular craters are deformed by such features provides a direct measurement of the amount of extension/contraction that has occurred. Of special interest is the nature (e.g. volcanic or basin impact ejecta) of Mercury's widespread intercrater plains, which appear to be related to paucity of 10-30 km craters on Mercury relative to the Moon [9]. Studies of the morphologies of Mercury's craters of these sizes, and comparisons with Mars (which also shows a paucity of multi-ten-km craters, generally ascribed to processes that cannot have operated on Mercury) and with the Moon, can elucidate this puzzle.

Chronology: In general, stratigraphic relationships between craters and other geologic features (e.g. the degree to which scarps cut craters more frequently than craters are superposed on scarps [10]) can tie down the relative chronology of Mercury's geophysical and geological evolution. To the degree that the lunar chronology can be transferred to Mercury [11], we will also be able now to assign an absolute chronology to Mercury's geological units, allowing us to place them in the historical context of the evolution of the rest of the inner solar system. Dynamics of small-body populations in the Solar System require that the cratering flux on Mercury be approximately proportional to that on the Moon, unless Mercury were subjected to appreciable later, Mercury-specific cratering by vulcanoids [12, 13].

Secondary Cratering: The significance of secondary cratering in producing many/most craters <1 km diameter has recently been recognized on Europa and Mars [14] and deserves investigation on high resolution MESSENGER images of Mercury. Interpretations of secondary cratering from limited higher-resolution Mariner 10 images are contradictory: such craters are said to be both more well-preserved [15] or less prevalent [11] on Mercury than on the Moon. Of particular interest in the early, global-to-regional scale images to be acquired during the flybys is whether many or most craters up to 10-25 km diameter are actually secondaries from Mercury's numerous basins, as advocated for the Moon by Wilhelms [16], or truly primary craters, as is generally assumed. Studies of crater morphologies and spatial relationships to basins should clarify this largely forgotten question.

MESSENGER's First Flyby: MESSENGER's January 2008 flyby of Mercury will provide excellent views of major parts of Mercury never previously imaged by spacecraft, providing an opportunity to assess whether the general characteristics of craters observed by Mariner 10 are similar to those of craters on the other side of the planet. Moderately high-resolution images of portions of the planet will reveal features only a few hundred meters in size, permitting a preliminary assessment of the sub-km crater populations, and whether or not they are consistent with secondary craters observed on Mars and elsewhere. Certain studies of crater morphologies that begin with the first-flyby images will have to await complete global coverage and/or higher resolution images, which will be obtained during later flybys and during the orbital mission. Some of the scientific goals that can be illuminated by MESSENGER studies of crater statistics and morphologies are discussed by Head et al. [17].

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