SECTION 6: MERCURY

Mercury is the closest planet to the Sun, and still very little is known about this world. So far, only one spacecraft has visited the planet is a succession of three flybys in 1974. Only 45% of the planet was photographed, and the remaining half has yet to be investigated. With practically no atmosphere, Mercury can be compared to the Moon, except for it's density and hence gravity which is much greater than that of the Moon. The gravitational difference however, does give an excellent opportunity for comparative planetology to be undertaken.

From the little we have seen of Mercury, several different terrain units have been identified: cratered terrains; inter-crater plains; Caloris basin and the smooth plains. Mercury has suffered from impact cratering and tectonism and there is evidence for volcanism having occurred although there have been no volcanic landforms yet identified.

6.1 Comparison of Impact Craters on Mercury and the Moon

Mercurian craters follow the same morphological sequence as lunar craters with small diameters having a simple form and gradually becoming more complex as the diameter increases. They have ejecta blankets, secondary impact craters and the fresh craters have dark haloes and bright rays. Mercurian craters do undergo degradation through the process of subsequent impacts, and we can therefore see a range of degradation states of craters on Mercury. The erosive power of secondary impact craters is much greater on Mercury and can "age" an adjacent crater to a greater extent than on the Moon. This is due to the fact that Mercurian secondary impact craters tend to cluster in tighter groups, hence causing greater damage to that area. The higher gravity on Mercury also gives the projectiles higher velocities on landing which increases the degradation caused.

Many factors affect the form of impact craters, particularly the presence of an atmosphere and surface water. It is difficult to disentangle the effects of just one of those factors when so many can operate at one time. It is therefore important to be able to isolate just the one factor or have a significant difference between that factor on two worlds. This is the case for gravity on Mercury and the Moon. Mercury’s equatorial surface gravity is just 0.38 that of the Earth, but the Moon’s is even lower at 0.16 times the Earth. Neither body has an atmosphere to speak of, neither have they had a wet, watery past. In many ways they are similar, which means that we can easily pick out the role gravity plays in the impact cratering process.

One of the first comparisons of craters between these worlds was by Gault et al. (1975) shortly after the Mariner 10 mission. They found that whilst the same trend in crater morphology was found on both worlds, the crater diameters at which particular features were found differed significantly.

Table 6.1 Comparison of Terrace Frequency (Gault et al., 1975)

	Mercury	**Moon**
Rim diameter (km)	Percent Terraced	Percent Terraced
0-10	7	0
10-20	80	12
20-30	95	33
30-40	92	79
40-50	100	87
50-60	100	100
60-120	100	100

Table 6.2 Comparison of Central Peak Frequency (Gault et al., 1975)

	Mercury	**Moon**
Rim Diameter (km)	Percent Peaked	Percent Peaked
0-10	0	0
10-20	80	26
20-30	84	53
30-40	83	79
40-50	100	87
50-60	100	100
60-120	100	100

FIGURE 6.1

So, gravity clearly affects the size/morphology relationship of craters. As for the ejecta and secondary impact craters, differences were also obvious (see Figure 6.1). The continuous ejecta sheet for the lunar craters are systematically larger than those on Mercury. This being the case, Melosh is wrong to state that Equation 1.3 in your notes hold for bodies other than the Moon. Gault et al. Derived the following linear relationships for continuous ejecta extents:

Mercury: $(R_{CE}/D)_{Merc} = 0.44 - 10^{-3}D$ Equation 6.1

Moon: $(R_{CE}/D)_{Moon} = 0.68 - 1.5x10^{-3}D$ Equation 6.2

where: R_{CE} is the radial extent of continuous ejecta and D is the diameter of the crater in question. These equations hold for craters <300km in diameter. This means that, roughly, Mercurian continuous ejecta will have a radial extent approximately 0.65 that of lunar continuous ejecta (see Figure 6.2). Interestingly, if we map the Martian relationship between continuous ejecta and crater diameter, we find no linear relationship at all.

FIGURE 6.2

Secondary impact craters also show differences in that Mercurian secondaries fall much closer to the rim of the primary crater and are more densely packed (see Figure 6.3). Previous lectures have shown differences in impact cratering with features unique to a particular world, i.e. lobate fluidised ejecta flows on Mars and the ejecta outflows on Venus. Since these features occur only on one planet as far as we know, it is difficult to assess the effect of changing either the temperature, gravity, atmosphere or volatile content on them.

FIGURE 6.3

6.2 The Terrains of Mercury

6.2.1 Cratered Terrain and Inter-crater Plains.

As with the Moon and Mars, Mercury has been subjected to intense cratering in the past. Broadly, the surface of Mercury can be split into two provinces: the highlands and lowland plains (analogous to the lunar highlands and maria). The highland regions are heavily cratered, but are interspersed with large areas of gently rolling plains with craters of <15km diameter. These highland plains have been termed inter-crater plains. They occupy a remarkably large chunk of the surface viewed by Mariner(~45%) and yet the origin of these plains is still under debate.

Although the surface of Mercury is heavily cratered, the crater density is not as high as on the Moon. The most simplistic interpretation of this is that Mercury was somehow resurfaced early in its history. The apparent lack of very heavily cratered terrain could be explained by it being buried by the inter-crater plain material. 15 large, ancient impact basins, which predate the inter-crater plains have been identified on the basis of many criteria including circular patterns and alignments of features. The presence of these basins does suggest that heavily cratered terrain did exist, but that it was buried beneath the inter-crater plains material.

Many of the craters in the inter-crater plains are unusual in shape: elongate and shallow or open on one side. They are often found in clusters or chains which give them the appearance of being secondary impact craters. The origin of the inter-crater plains material is controversial. Some believe it to be old basin ejecta material. The evidence to support this is the apparent association of lineated terrain with the inter-crater plains. The form of the lineated terrain is similar to that seen around the Imbrium basin on the Moon and hence lends support to the basin ejecta interpretation. Others seem to suggest that a volcanic origin could account for the inter-crater plains, however very few volcanic landforms have been found on Mercury.

6.2.2 Smooth Plains

A substantial portion of the surface of Mercury is covered by relatively flat, young plains material. They are generally flat or gently rolling terrain and possess numerous wrinkle ridges (compressional tectonism), similar to those seen on lunar maria. Their origin is debated since not much information can be obtained from the Mariner data. In general, a volcanic origin is assumed for the plains (which also make up the Caloris annulus) even though no volcanic landform can be seen on the surface. This is based primarily on analogy with lunar basins and maria. However, it has been pointed out that the volcanic arguments put forward here are similar to those used for an area of the Moon which subsequently turned out to be wrong when samples were returned.

6.3 Basins

As well as those basins which predate the inter-crater plains, there are also several basins which are younger than the plains. Some of these basins are so degraded that only a single ring remains. In others, multiple rings can still be seen with well preserved ejecta blankets and secondary impact craters.

The largest basin on Mercury is the Caloris Basin, with a diameter of 1340km. Mariner could only image half of the basin as it was unfortunately situated on the terminator of Mercury at the time. Surrounding the basin is the Caloris mountain terrain (Caloris Montes Formation), which consist of large massifs several kilometres high. The Caloris Montes are approximately 30-50km wide across the rim. To the NE and SE is the Nervo Formation. This consists of hummocky and rolling terrain, interpreted to be fallback from ejecta and impact melt material. To the E and NE can be found the Odin Formation, extensive hummocky plains extending up to 800km from the rime of Caloris. The hills are approximately 1-2km across, and the whole formation is interpreted to be ejecta from Caloris. Then we see the Van Eyck Formation which is lineated terrain stretching to 1000km beyond the rim of the basin. Overlapping this unit is also the Odin Formation, hummocky deposits mantling pre-existing terrain. This unit extends from 700-1100km from the rim. Beyond all of these are the smooth plains, flat to gently rolling terrain, believed to be fluidised shock melt or post-Caloris volcanism. The floor of the basin has an extensive plains unit which may have a volcanic origin or is perhaps a thick sheet of impact melt.

6.4 Tectonism

Mercury exhibits four important tectonic features: a global grid system; lobate scarps; structures associated with the Caloris basin and local extensional features.

1. Global grid system. This system shows lineated features exhibiting well defined trends. They appear more in the inter-crater plains than in the smooth plains which indicates that the grid patterns are very old. The apparent global nature of the grid may suggest a planetary wide change in shape of the lithosphere of Mercury at some time in its past.
2. Lobate scarps. These are evidence for compressive tectonism on Mercury. They are long scarps with lobate outlines, varying in length and height from 20-500km long and a few hundred to a few thousand metres high. They often intersect and disrupt other features such as craters and smooth plains which means that they post-date most of the other activity on Mercury. Although they are seen at all latitudes, related graben (extensional tectonism) which could compensate for the compression are not seen (except locally). Because of this, the ridges are interpreted as being the result of planetary contraction by cooling of the core, although other factors imply that other stresses must have played a part too.
3. Caloris Basin. Outside of the Caloris Mountains there are many ridges and valleys. The linear ejecta formation exhibit many scarps, often radial to the basin. The interior of the basin shows abundant ridges, radial and concentric to the centre, located mainly in the outer regions of the basin interior. The origin of these ridges (and in basins on the Moon) is believed to be the result of compressive stresses produced by regional subsidence due to the weight of the volcanic/melt material filling the interior of the basin. Despite similarities with lunar basin ridges, there are important differences, one being that the Caloris ridges appear to be directly related to the impact, whereas the lunar ridges occurred some time after. If the ridges really were produced by loading stresses, we'd expect to see extensional graben outside the area of loading to compensate. Whilst such features are seen around lunar basins, they are not seen around Caloris, which again requires crustal compression to explain the absence of graben. Contrary to this however is the extensive fracturing pattern seen on the floor of Caloris. They are found only in the central area of the floor, in both radial and concentric patterns. A little further from the central floor area, fractures are observed to have modified the interior ridges, which implies that the fractures post-date the ridges, and are probably due to some kind of uplift mechanism.
4. Localised Tectonism. Evidence of localised tectonism on Mercury is not as abundant as that of the global tectonic features. However, there are some areas of uplift exhibiting linear grooves and scarps restricted to relatively small regions.

Reference List

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