THE GEOLOGICAL HISTORY OF MERCURY Paul D. Spudis, Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058; spudis@lpi.usra.edu

The Mariner 10 mission in 1974 mapped about half the surface of Mercury. On the basis of these data, we have a first-order understanding of the geology and history of the planet [1,2]. Mercury's surface shows intercrater plains, basins, smooth plains, craters, and tectonic features (Figure 1).

Intercrater plains Mercury's oldest surface is its intercrater plains [1,3], which are present (but much less extensive) on the Moon. The intercrater plains are level to gently rolling terrain that occur between and around large craters. The plains predate the heavily cratered terrain, and have obliterated many of the early craters and basins of Mercury [1,4]; they probably formed by widespread volcanism early in mercurian history.

Craters Mercurian craters have the morphological elements of lunar craters: the smaller craters are bowl-shaped, and with increasing size, they develop scalloped rims, central peaks, and terraces on the inner walls [3]. The ejecta sheets have a hilly, lineated texture and swarms of secondary impact craters. Fresh craters of all sizes have dark or bright halos and well developed ray systems. Although mercurian and lunar craters are superficially similar, they show subtle differences, especially in deposit extent. The continuous ejecta and fields of secondary craters on Mercury are far less extensive (by a factor of about 0.65) for a given rim diameter than those of comparable lunar craters. This difference results from the 2.5 times higher gravitational field on Mercury compared with the Moon [3]. As on the Moon, impact craters on Mercury are progressively degraded by subsequent impacts [1,4]. The freshest craters have ray systems and a crisp morphology. With further degradation, the craters lose their crisp morphology and rays and features on the continuous ejecta become more blurred until only the raised rim near the crater remains recognizable. Because craters become progressively degraded with time, the degree of degradation gives a rough indication of the crater's relative age [4]. On the assumption that craters of similar size and morphology are roughly the same age, it is possible to place constraints on the ages of other underlying or overlying units and thus to globally map the relative age of craters (Fig. 1).

Basins At least 15 ancient basins have been identified on Mercury [4]. Tolstoj is a true multi-ring basin, displaying at least two, and possibly as many as four, concentric rings [4,5]. It has a well-preserved ejecta blanket extending outward as much as 500 km from its rim. The basin interior is flooded with plains that clearly postdate the ejecta deposits. Beethoven has only one, subdued massif-like rim 625 km in diameter, but displays an impressive, well-lineated ejecta blanket that extends as far as 500 km. As at Tolstoj, Beethoven ejecta is asymmetric. The Caloris basin is defined by a ring of mountains 1300 km in diameter [4,6,7]. Individual massifs are typically 30 to 50 km long; the inner edge of the unit is marked by basin-facing scarps [7]. Lineated terrain extends for about 1,000 km out from the foot of a weak discontinuous scarp on the outer edge of the Caloris mountains; this terrain is similar to the "sculpture" surrounding the Imbrium basin on the Moon [4,7]. Hummocky material forms a broad annulus about 800 km from the Caloris mountains. It consists of low, closely spaced to scattered hills about 0.3 to 1 km across and from tens of meters to a few hundred meters high. The outer boundary of this unit is gradational with the (younger) smooth plains that occur in the same region. A hilly and furrowed terrain is found antipodal to the Caloris basin, probably created by antipodal convergence of intense seismic waves generated by the Caloris impact [8].

Smooth plains The floor of the Caloris basin is deformed by sinuous ridges and fractures, giving the basin fill a grossly polygonal pattern. These plains may be volcanic, formed by the release of magma as part of the impact event, or a thick sheet of impact melt. Widespread areas of Mercury are covered by relatively flat, sparsely cratered plains materials [4, 9]. They fill depressions that range in size from regional troughs to crater floors. The smooth plains are similar to the maria of the Moon, an obvious difference being that the smooth plains have the same albedo as the intercrater plains. Smooth plains are most strikingly exposed in a broad annulus around the Caloris basin (Fig 1). No unequivocal volcanic features, such as flow lobes, leveed channels, domes, or cones are visible. Crater densities indicate that the smooth plains are significantly younger than ejecta from the Caloris basin [4]. In addition, distinct color units, some of lobate shape, are observed in newly processed color data [10]. Such relations strongly support a volcanic origin for the mercurian smooth plains, even in the absence of diagnostic landforms [4,9,10].

Tectonic features Lobate scarps are widely distributed over Mercury [4,9,11] and consist of sinuous to arcuate scarps that transect preexisting plains and craters. They are most convincingly interpreted as thrust faults, indicating a period of global compression [11]. The lobate scarps typically transect smooth plains materials (early Calorian age) on the floors of craters, but post-Caloris craters are superposed on them. These observations suggest that lobate-scarp formation was confined to a relatively narrow interval of time, beginning in the late pre-Tolstojan period and ending in the middle to late Calorian Period. In addition to scarps, wrinkle ridges occur in the smooth plains materials. These ridges probably were formed by local to regional surface compression caused by lithospheric loading by dense stacks of volcanic lavas, as suggested for those of the lunar maria [4,11].

Geological history The earliest decipherable event in Mercury's history was the formation of its crust. By analogy with the Moon, Mercury may have experienced early global melting, similar to the lunar "magma ocean", whereby large-scale melting of at least the outer few hundred kilometers of the planet would concentrate low-density plagioclase into the uppermost part of the crust. If this process operated during early mercurian history, then its crust is probably composed largely of anorthositic rocks. Such a composition is consistent with full-disc spectra [12] and Mariner 10 color data for Mercury [13], which suggest that Mercury's surface is similar to the Apollo 16 site in the highlands of the Moon [10,12,13]. The early cratering record of Mercury has been largely destroyed by the deposition of the intercrater plains, but the largest multi-ring basins have been partly preserved. Sometime during the heavy bombardment, intercrater plains materials largely obliterated the older crater population (Fig. 1). The global distribution of the intercrater plains suggests that they may be at least partly volcanic in origin, although subsequent cratering has converted the original surface to breccia. The Tolstoj basin impact marked the beginning of the Tolstojan Period, still a time of high impact rates. The Caloris impact formed the largest well-preserved basin on Mercury's surface (Fig. 1) and provided an extensive stratigraphic datum on the planet. Catastrophic seismic vibrations from the Caloris impact probably formed the hilly and furrowed terrain on the opposite side of the planet. Shortly after the Caloris impact, massive extrusions of flood lavas formed the smooth plains. A rapidly declining cratering rate has produced minimal changes to Mercury's surface since the final emplacement of the smooth plains (Fig. 1). This low rate of cratering presently continues to produce regolith on all surface units.

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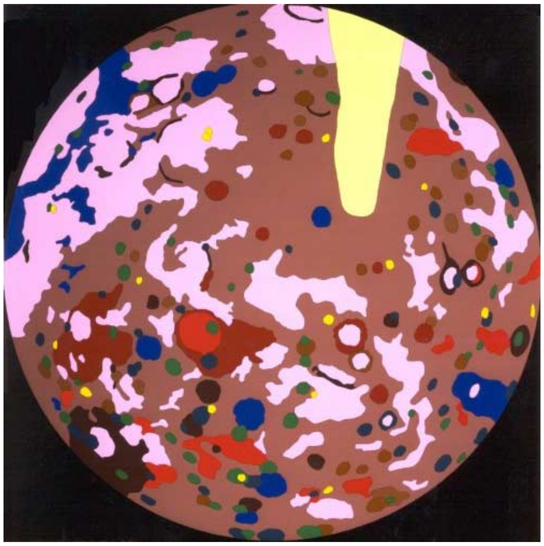

Figure 1 Geological map of the planet Mercury. Dark browns and tans – pre-Tolstojan craters, basins, and intercrater plains. Lighter browns and orange – Tolstojan craters and plains, respectively. Blues – units of the Caloris basin and craters of Calorian age. Pink – Calorian smooth plains. Greens and Yellows – Mansurian and Kuiperian age impact craters. After [4].