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The morphology of Mercury's Caloris basin as seen in MESSENGER stereo topographic models

Jürgen Oberst [a,*], Frank Preusker [a], Roger J. Phillips [b], Thomas R. Watters [c], James W. Head [d], Maria T. Zuber [e], Sean C. Solomon [f]

[a] German Aerospace Center, Institute of Planetary Research, D-12489 Berlin, Germany
[b] Planetary Science Directorate, Southwest Research Institute, Boulder, CO 80302, USA
[c] Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, USA
[d] Department of Geological Sciences, Brown University, Providence, RI 02912, USA
[e] Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139-4307, USA
[f] Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA

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ABSTRACT

A digital terrain model (1000-m effective spatial resolution) of the Caloris basin, the largest well-characterized impact basin on Mercury, was produced from 208 stereo images obtained by the MESSENGER narrow-angle camera. The basin rim is far from uniform and is characterized by rugged terrain or knobby plains, often disrupted by craters and radial troughs. In some sectors, the rim is represented by a single marked elevation step, where height levels drop from the surroundings toward the basin interior by approximately 2 km. Two concentric rings, with radii of 690 km and 850 km, can be discerned in the topography. Several pre-Caloris basins and craters can be identified from the terrain model, suggesting that rugged pre-impact topography may have contributed to the varying characteristics of the Caloris rim. The basin interior is relatively smooth and shallow, comparable to typical lunar mascon mare basins, supporting the idea that Caloris was partially filled with lava after formation. The model displays long-wavelength undulations in topography across the basin interior, but these undulations cannot readily be related to pre-impact topography, volcanic construction, or post-volcanic uplift. Because errors in the long-wavelength topography of the model cannot be excluded, confirmation of these undulations must await data from MESSENGER's orbital mission phase.

1. Introduction

The Caloris basin (centered at 30°N, 165°E) was discovered in images obtained by Mariner 10 during its three flybys of Mercury in 1974–1975. Owing to the orbital resonance of Mercury and the spacecraft, the same hemisphere of the planet was imaged under similar illumination conditions during each flyby, and the Mariner 10 cameras were able to view only the eastern portion of Caloris. Images obtained during the first flyby of Mercury by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft (Solomon et al., 2008) show the basin at its full extent (Murchie et al., 2008; Fassett et al., 2009; Watters et al., 2009). Because of high Sun (low incidence) angles in the basin area, however, the images do not give much indication of the topographic relief and surface morphology. Moreover, craters with bright ejecta rays are abundant in the area and mask some of the details of the basin morphology. MESSENGER's onboard laser altimeter collected two elevation profiles, one during each of the first two Mercury flybys, but these were in near-equatorial areas (Zuber et al., 2008) and did not transect the Caloris basin area.

In this paper, we use stereo images obtained during the first MESSENGER flyby of Mercury to derive a topographic model of the Caloris basin, from which we examine the basin morphology in detail. At a basin ring diameter of 1550 km (Murchie et al., 2008; Fassett et al., 2009), Caloris is one of the largest impact basins known in the Solar System and among the youngest of the large impact basins on Mercury. Its structure is relevant to the processes of basin formation and subsequent modification. Additionally, the morphology of the basin reflects its volcanic and tectonic evolution and provides important constraints on the thermal state and mechanical properties of Mercury's crust and lithosphere over time.

2. Image data

2.1. Camera

The Mercury Dual Imaging System (MDIS) (Hawkins et al., 2007, 2009) consists of a pair of wide- and narrow-angle cameras,

* Corresponding author at: German Aerospace Center (DLR), Rutherfordstr. 2, D-12489 Berlin, Germany.
E-mail address: Juergen.Oberst@dlr.de (J. Oberst).

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