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Mercury's Raditladi basin: A puzzling example of extensional tectonics in an unusually young impact feature

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Abstract

Recent imaging of Mercury by the MESSENGER spacecraft has revealed evidence of the planet's global tectonic history. While most of Mercury's surface has undergone contractional deformation, three large impact basins show evidence for extension within their floors. This paper discusses the geology of and unique tectonic pattern within the Raditladi basin and their implications for Mercury's surface evolution.

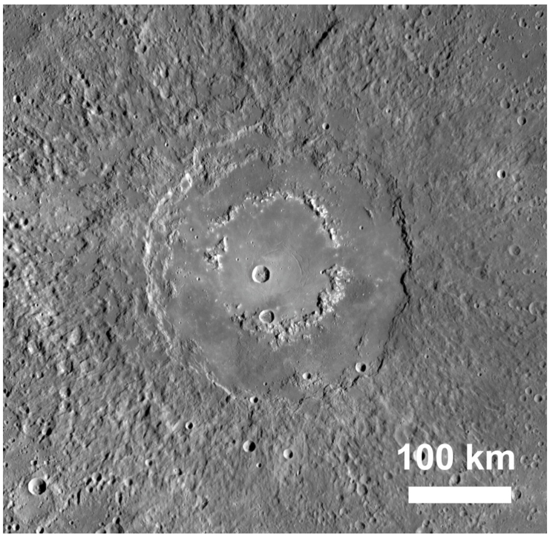

Figure 1: MESSENGER image of Raditladi crater, orthographically projected, showing peak ring complex and floor partially filled with smooth plains material.

The geology and age of Raditladi

The MESSENGER spacecraft imaged the Raditladi basin for the first time during its first flyby of Mercury in January 2008 [1]. Raditladi is a ~250-km-diameter impact feature located at 27ºN, 119ºE, west of the Caloris basin, and it closely resembles such lunar craters as Schroedinger as well as similar-sized craters on Mercury such as Mozart. Contained within the basin is a distinctive and slightly offset peak-ring structure ~125 km in diameter (Fig. 1). The basin walls have undergone modification and exhibit pronounced terraces to the north and west sides of the rim. Crater age-dating results [2, 3] suggest that Raditladi's interior smooth plains and ejecta blanket are of approximately the same age and that crater densities at Raditladi are an order of magnitude less than those at Caloris. This result implies that the Raditladi basin may be extremely young – perhaps less than 1 Ga.

The floor of the Raditladi basin is partially filled with smooth, bright reddish plains material that clearly embays the rim and central peak ring (Fig. 1). Smooth plains material with similar characteristics embays a number of craters and basins on Mercury and is interpreted to be primarily the result of volcanism [4, 5]. Portions of the basin floor to the north and south consist of dark, relatively blue hummocky plains material, similar to terrain identified around the Caloris and Tolstoj basins [5]. This hummocky material appears to be embayed by the smooth reddish plains material, which would be consistent with a

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volcanic origin for the smooth plains. However, evidence of impact melt exists in the form of numerous pockets of smooth reddish material found on top of the ejecta blanket, which, because of their location, cannot have a volcanic origin. The amount of impact melt expected to occur in Mercury's craters is not well understood, but it is expected that the melt fraction will increase significantly with increasing crater size [e.g., 6]. On the basis of available scaling relations, we estimate that Raditladi's floor contains at least 1 km of frozen impact melt. Because the basin is only ~3 km deep, this inference implies that most, if not all, of the smooth plains within the floor may have been emplaced as impact melt.

Extensional tectonics

Extensional tectonic features are extremely rare on Mercury and have thus far been found only in three locations. Radial trough complexes are found within Caloris [7] and a second large basin, Rembrandt [8], while the third occurrence of extension is found within Raditladi, where its form is different from those in the other basins. Here, a number of partially concentric, flat-floored troughs are arranged in a circular pattern ~70 km in diameter, close to the center of the basin. Most of the troughs are comprised of linear or curvilinear segments, arranged circumferentially around the basin center. To the south and west of the basin center, troughs are absent, possibly as a result of a superposed impact crater.

It has been suggested that the circular troughs in Raditladi are the surface manifestation of ring dikes or cone sheets [e.g., 9] formed above a magma reservoir [4]. This configuration would differ in geometry from the traditional sill formation thought to be responsible for lunar floor-fractured craters [e.g., 10] and, if correct, would extend the inferred duration of volcanism on Mercury. Alternative explanations for the extensional troughs involve the late-stage tectonic modification and uplift of the basin floor. One model that has been proposed to explain the polygonal troughs within the much larger and older Caloris basin invokes inward flow of the lowermost crust to produce uplift and near-surface extension in the basin interior [11]. This model may be less applicable to Raditladi, however, because it requires that Mercury's crust be sufficiently hot to undergo ductile flow at a comparatively recent time in Mercury's history, a conclusion at odds with thermal models that predict a thick, strong lithosphere. A second scenario proposed to account for troughs in Caloris is that annular loading by smooth plains exterior to the basin led to flexural uplift of the basin interior [12]. There are relatively young smooth plains to the north and east of the Raditladi basin that have overprinted all large craters in their areas. Most of the circumferential troughs within Raditladi are distributed to the northeast of the basin center, which could be consistent with loading by these smooth plains, although part of the trough system to the west of the basin center appears to have been obscured by a later impact crater, so a directional bias is possible. However, the thickness of these exterior smooth plains is not well constrained.

A third possibility is that isostatic uplift of an undercompensated basin yields near-surface extensional stress sufficient to produce faulting. A condition for this explanation is that the floor material be emplaced prior to most isostatic uplift. In the case of Raditladi, floor material could be dominated by rapidly cooled impact melt, possibly up to 1 km thick. One question for this explanation is why we do not see similar tectonic structures in other comparably sized basins on Mercury and the Moon. A possibility is that most other basins, because they are substantially older, have been modified by later volcanism, deformation, or impact, whereas the relatively young age of Raditladi may mean that it has escaped significant such modification.

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