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EJECTA FLOWS AND LANDSLIDES: ANALYSIS OF GLOBAL SURVEYS OF THE MOON AND MERCURY. A. Blance¹, D. A. Rothery¹, M. R. Balme¹, J. Wright², V. Galluzzi³ and S. J. Conway⁴. ¹The Open University, School of Physical Sciences ²European Space Agency, ESAC ³INAF, Institute for Space Astrophysics and Planetology (IAPS) ⁴University of Nantes, CNRS

Introduction: Flow features occur around impact craters across the Solar System. On Mars and Earth, ejecta deposits are often emplaced by ground-hugging flows, where volatiles may fluidize ejecta material [1,2,3]. In contrast, on dry airless bodies such as the Moon, ejecta deposits are mostly emplaced ballistically, with limited radial flow after emplacement [4, 5]. However, some impact craters on the Moon and Mercury do have flow features, whose layered morphologies, steep margins and lobate shapes contrast with ballistically emplaced deposits that thin continuously away from their source crater.

Xiao and Komatsu identify seven flow deposits around impact craters on Mercury [6], extending downslope into adjacent, older craters. Additionally, Tsiolkovskiy crater on the Moon has a flow extending into an adjacent impact basin [7]. These may be examples of ejecta flows, but could be mass movements of crater rim materials. Hokusai crater on Mercury also has an associated flow, extending around the whole crater on flat ground (Fig 1A), indicating an ejecta flow origin [8].

We undertook a global search of Mercury and the Moon to identify flow features around craters, which we believe to be the first comprehensive survey. Deciphering the origin of flows will aid in understanding how mass movements and the impact process modify planetary surfaces. Comparing Mercury and the Moon is particularly useful in assessing the role of volatiles, as Mercury has volatile-bearing materials at the surface [9, 10], which may fluidize ejecta. Mercury is thus an intermediary step between volatile-abundant Mars and the volatile-depleted Moon.

Method: Using grid squares to search by area, we surveyed Mercury and the Moon for flows around craters. We used global image mosaics, DEMs and additional images with varying illumination angles. For Mercury we used the ~166m/pix *MESSENGER* MDIS BDR Mosaic as a basemap [11], while for the Moon we used the *LRO* WAC Morphology Mosaic [12], resampled to match the Mercury basemap resolution.

Results: We found 89 craters with flow features on Mercury, and 84 on the Moon: a substantial increase on previously reported flow numbers [6]. Mercury is larger than the Moon, but the Moon has a higher crater density [13,14], so though the Moon has more of these features per unit area ($\sim 2.3 \times 10^{-6}$ per km² vs $\sim 1.1 \times 10^{-6}$ per km²), they have similar occurrence rates around craters ($\sim 0.005\%$ for craters over 10 km in diameter).

Almost all flows extend into adjacent craters or other topographic lows, suggesting pre-impact topography strongly influences flow development. Many features (Mercury 68, Moon 81) have recognizable source failure scarps (e.g. Fig 1C), indicating they are landslides. The landslides include flows with long runouts as well as smaller features that are likely slumps or rotational slides rather than true “flows”.

However, some features are not obviously landslides. 19 on Mercury and 3 on the Moon lack failure scarps, and seem to emanate directly from crater rims (Fig 1B). In several examples the crater rim and flow are on the same topographic level, without a clear topographic gradient from which a landslide could occur. On Mercury, flows around Hokusai crater and an additional unnamed crater occur over flat ground, not extending into an adjacent crater.

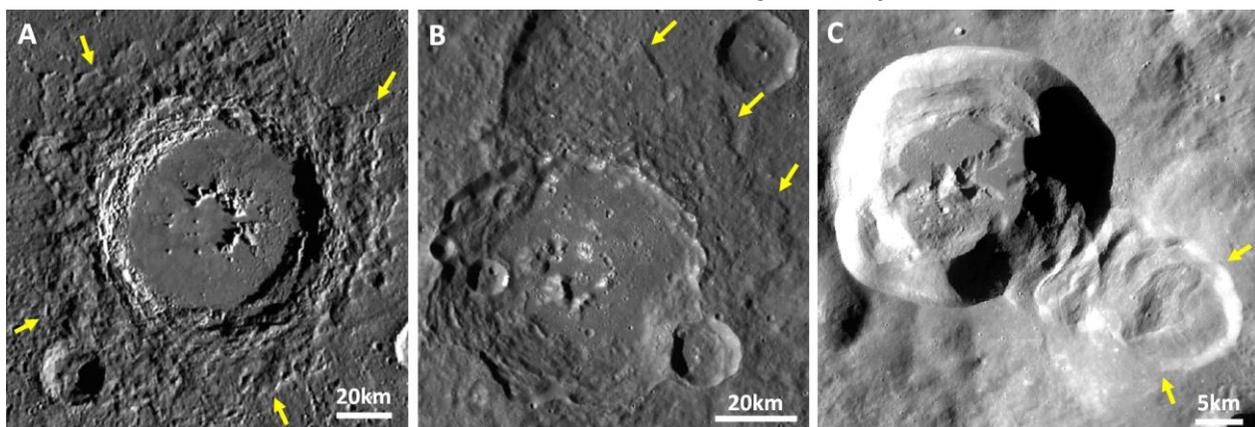


Figure 1 Flow examples. Flow margins indicated with yellow arrows. **A:** Hokusai crater on Mercury, with ejecta flow. **B:** Crater on Mercury with flow extending into adjacent basin. **C:** Klute W crater on the Moon, with associated landslide.

Discussion: For 2 examples on Mercury and 6 on the Moon we find impact melt deposits on top of the flow feature (see also [15]). This indicates these flows formed early in the impact process. Impact melt deposits are typically only identifiable around the freshest craters, and similar evidence may have been lost at more degraded examples. All flows identified in this work have degradation states indistinguishable from their source crater, further suggesting early formation. Boyce et al. [16] also showed that the Tsiolkovskiy crater flow has a crater counting modelling age equivalent to that of the crater's ejecta. We conclude that many flows occur during or soon after their source crater's formation.

The similar frequency of flows around craters on Mercury and the Moon indicates they are a fundamental feature of impact cratering on airless bodies with uneven topography. Landslides, where many appear to occur during the impact cratering process, could be considered along with interior slumping as part of the modification stage that produces the final crater.

Flows that are not obviously landslides may be initiated even earlier in the cratering process. The mercurian flows on flat ground around craters are likely ejecta flows. They are reminiscent of ejecta flows on Mars, with terminal ramparts and a ropey texture.

Other flows that lack failure scarps do extend downslope into adjacent craters. We estimated transient cavity diameters for source craters (after [17]), and found that their source cavity always intersects with the adjacent, older crater into which the flow extends (e.g. Fig 2A). This differs from examples with failure scarps, where there may be no intersection (e.g. Fig 2B). This could indicate these flows form during the excavation of the crater, where a void on one side of the impact site leads to flow, or where a transient cavity rim creates a steep gradient down into the older crater, causing material collapse. These scenarios require intersection between the transient cavity and the older crater. Flow at this early stage could explain the lack of failure scarp around the final crater rim.

Flows without obvious source failure scarps, though identified on both bodies, occur more frequently on Mercury (19) than the Moon (3), with the two flat ground ejecta flows exclusive to Mercury. This may be a result of volatiles on Mercury helping to fluidize material. Volatiles, however, don't appear to be a driving factor in the development of landslides around craters on Mercury, as these occur at a similar rate per crater as on the Moon. Alternatively, Mercury has a higher average impact speed, increasing melt production and fracturing intensity [18], which may aid flow. Mercury also has stronger gravity, encouraging transient crater collapse [17].

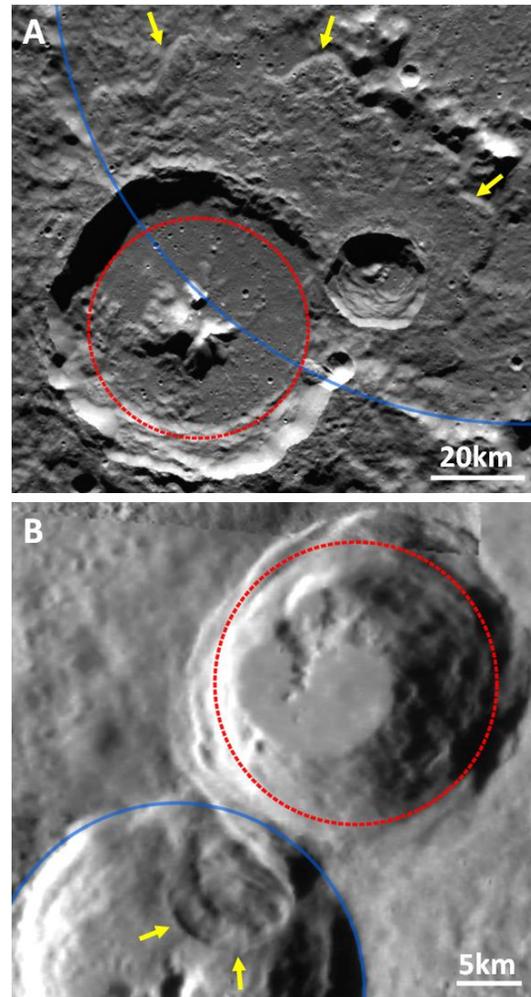


Figure 2 Red dashed line = Estimated transient cavity size. Blue line = Older crater original rim position. Both examples from Mercury.
A: Flow without clear failure scarp, source crater transient cavity intersects with older crater.
B: Landslide, source crater transient cavity does not intersect with older crater.

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