GLOBAL DISTRIBUTION OF LOW THERMAL INERTIA HALOS SURROUNDING SMALL YOUNG MARTIAN IMPACT CRATERS

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OVERVIEW

Using the THEMIS daytime and nighttime infrared global mosaics, a large population of small, young impact craters have been identified that are distinguished by the low thermal inertia halos surrounding them. A global survey identified 4,024 of these low thermal inertia halos, which are preferentially concentrated in the southern highlands and in other smaller regions across the planet. It is hypothesized that these halos are formed by a combination of fine grain impact ejecta falling to the surface after an impact and the existing regolith being disturbed by the impact itself. The global distribution pattern is hypothesized to either represent regions where the halos are preferentially formed, due to target surface material properties, and/or where the halos are preferentially preserved, due to low erosion rates of the fine grain material.

BACKGROUND & METHODS

The Thermal Emission Imaging System (THEMIS) onboard the 2001 Mars Odyssey spacecraft has acquired over 200,000 infrared images of the Martian surface over the first fourteen years of its mission, which were compiled into both daytime and nighttime infrared global mosaics by Edwards et al. (2011) [1,2]. Hill et al. (2014) [3] updated these mosaics using additional data and produced a combination global map by overlaying a colorized version of the nighttime global mosaic on top of the daytime global mosaic. The resulting “THEMIS Day IR with Night IR Color” global map can be used to easily identify surface features with unique thermal characteristics.

Using these global mosaics, Hill and Christensen (2014) [4] identified low thermal inertia halos surrounding small, young impact craters that were initially hypothesized to be well-preserved recent impact ejecta deposits. However, it is now thought that the halos may also be the result of existing surface regolith that has been disturbed by the impact process, which would increase porosity and decrease thermal inertia, similar to the lunar crater cold spots described by Bandfield et al. (2014) [5].

The low thermal inertia halos also appear to be related to, although much smaller than, the Martian ejecta halos described by Ghent et al. (2010) [6]. They also appear very similar to the Martian rayed craters described by Tornabene et al. (2006) [7]. In fact, the largest low thermal inertia halos that have been identified begin to develop a distinct rays as their sizes increase.

A visual search of the “THEMIS Day IR with Night IR Color” global map at full resolution between 60°N - 60°S was conducted and all craters with candidate low thermal inertia halos were marked. Nighttime temperatures were used as a proxy for thermal inertia for the purposes of this search. Each of the low thermal inertia halos were then classified according to their apparent degradation state.

GLOBAL DISTRIBUTION OF LOW THERMAL INERTIA HALOS

Mapping the locations of all 4,024 identified low thermal inertia halos (Figure 1) reveals a non-random pattern with significant concentrations in the mid-latitudes of the southern highlands, Solis Planum and southeast of Elysium Mons. This distribution pattern is thought to indicate that either:

a) the low thermal inertia halos are preferentially forming in these regions, possibly due to the surface material properties allowing for a larger amount of fine grain ejecta to be generated by an impact

b) the halos are being preferentially preserved in these regions, possibly due to calmer atmospheric conditions near the surface that do not redistribute the fine-grained material as quickly

The locations of the low thermal inertia halos in Figure 1 have been color-coded based on their classifications. Red represents degraded halos, orange represents modified halos, green represents preserved halos and blue represents well-preserved halos.

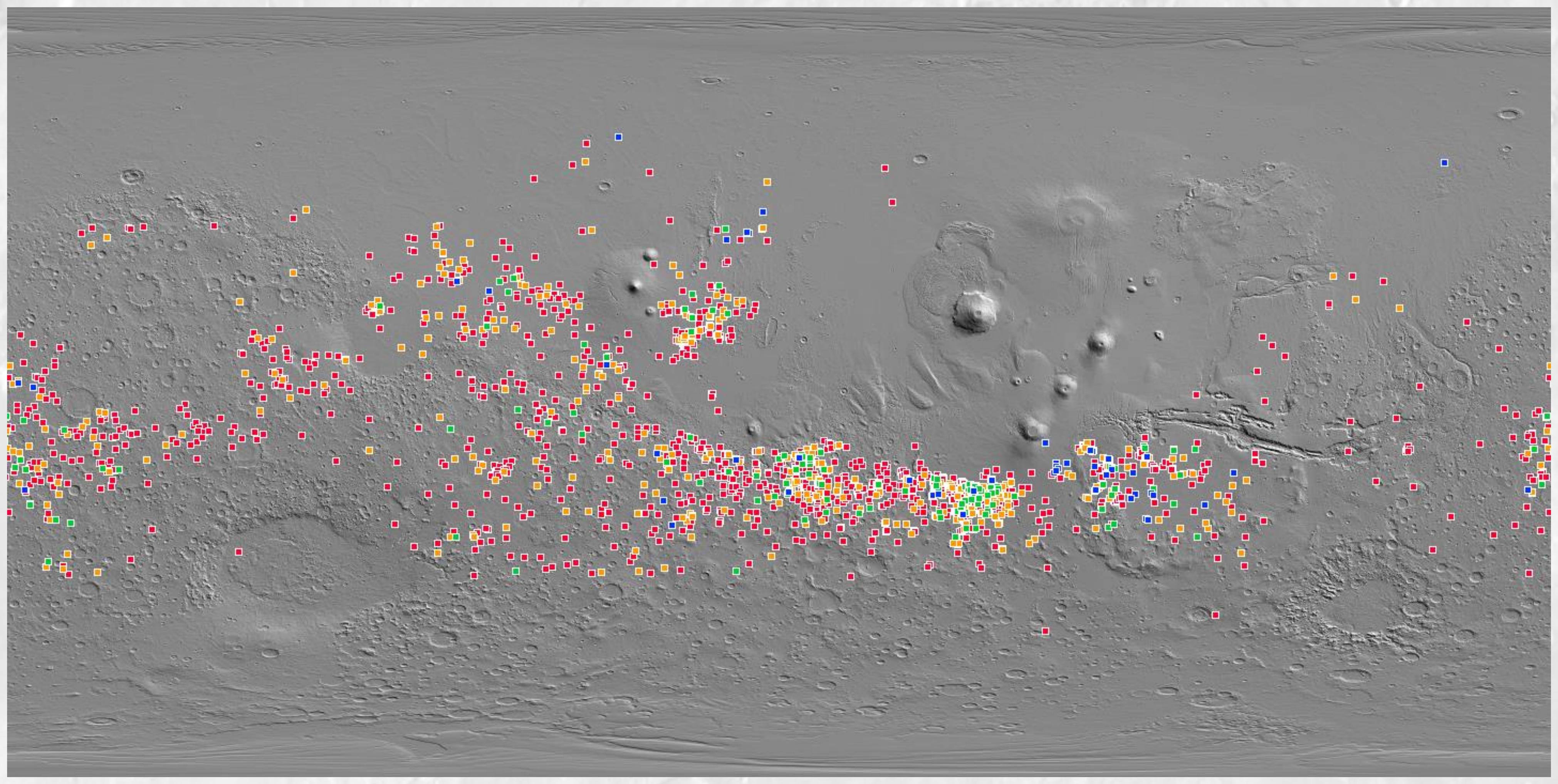
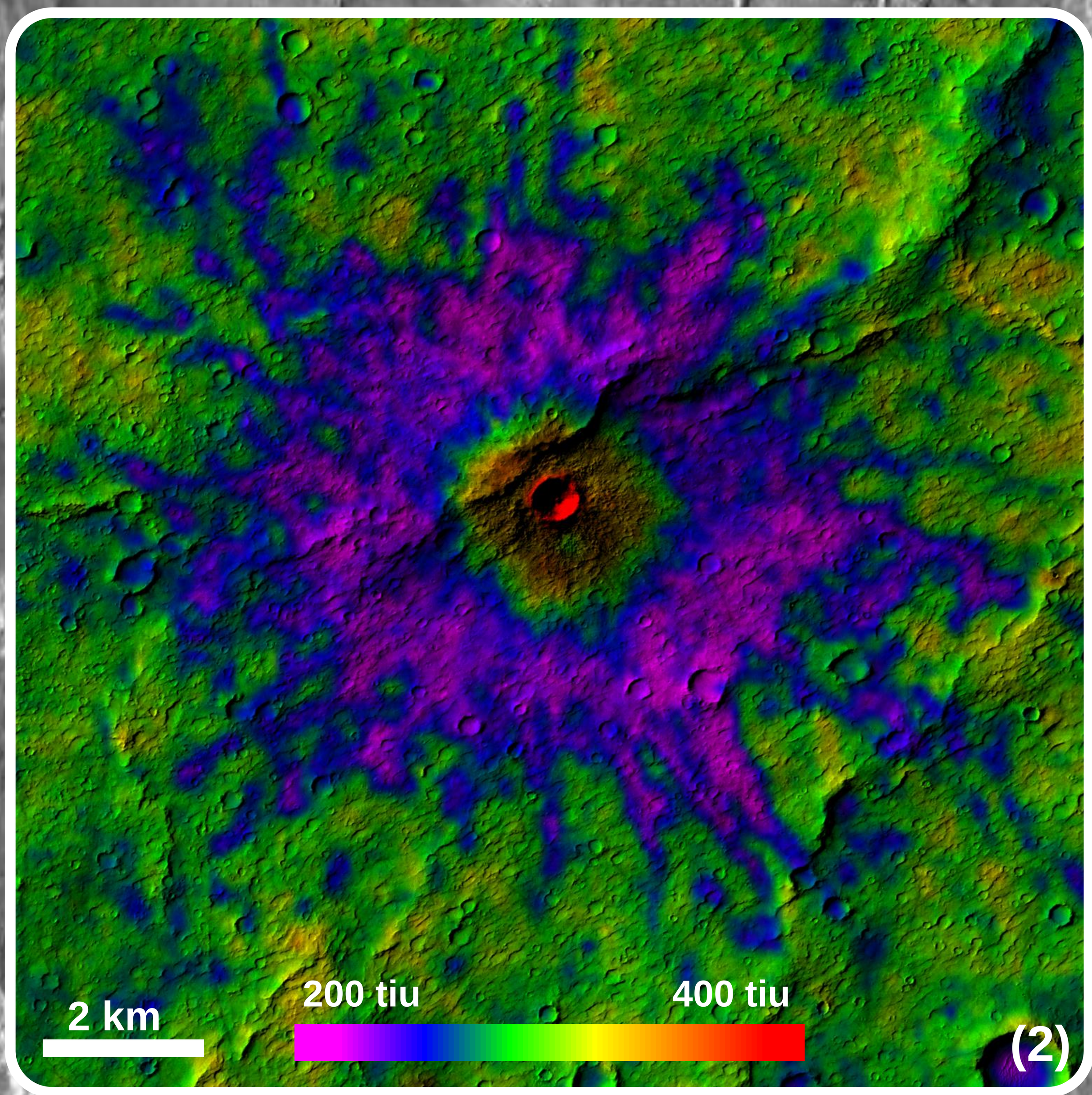


Figure 1: Global Distribution of Low Thermal Inertia Halos



LOW THERMAL INERTIA HALOS

Figure 2 shows an example of a preserved low thermal inertia halo surrounding an unnamed impact crater in northwestern Terra Sirenum, with colorized thermal inertia values [10] overlaid on a broadband CTX image (P17_007829_1571_XN_22S177W) [11] .

The thermal inertia values in the vicinity of the crater are relatively low, only varying between 200-400 tiu, which indicates that the surface is likely dominated by fine grain, loosely bound material. Even the surfaces immediately surrounding the crater, where exposed bedrock and blocky ejecta are present, must still contain a large percentage of low thermal inertia material in order to bring the average thermal inertia over the 100m pixels below the values expected of rocky surfaces.

EJECTA MORPHOLOGY

All of the preserved ejecta deposits that are covered by high resolution visible images also share a number of morphological characteristics. Exposures of bedrock are visible in the walls and rim of the craters, which explains the relatively high thermal inertia values in those areas. There is also blocky ejecta extending 1-2 crater diameters from the rim, with the block sizes decreasing with increasing distance from the crater. The area between the blocks appears smooth and likely contains fine-grained ejecta, which would lower the average thermal inertia of the area and result in the intermediate values seen between the crater rims and the halos.

LOW THERMAL INERTIA HALO CLASSIFICATIONS

Type 1: Below Data Resolution

These halos are small enough, usually below 3km diameter, that the 100m/pixel resolution of the THEMIS thermal inertia images made it difficult to classify them based on their state of degradation (Figure 3a).

Type 2: Heavily Degraded

Halos in this category are degraded to the point that they are nearly unrecognizable as halos. This category may include some low thermal inertia deposits that have been misidentified as halos (Figure 3b).

Type 3: Degraded

While the concentric nature of the halos are better preserved in this category, the contrast between the different concentric thermal inertia regions surrounding the crater is not very high or is inconsistent (Figure 3c).

Type 4: Modified

The contrast between the concentric thermal inertia regions of these halos is higher and the regions are more obviously concentric, with relatively minor variations (Figure 3d).

Type 5: Preserved

These halos represent the type examples that were initially identified. The thermal inertia contrast between the concentric regions of the halos is large and the outer ring contains very low thermal inertia material that is continuous around the entire halo (Figure 3e).

Type 6: Well-Preserved

These features resemble preserved halos that also have low thermal inertia material covering the young crater at the center. The current hypothesis is that these features are the youngest and/or best preserved examples in the evolution of the low thermal inertia halos, but other possible origins are still being investigated (Figure 3f).

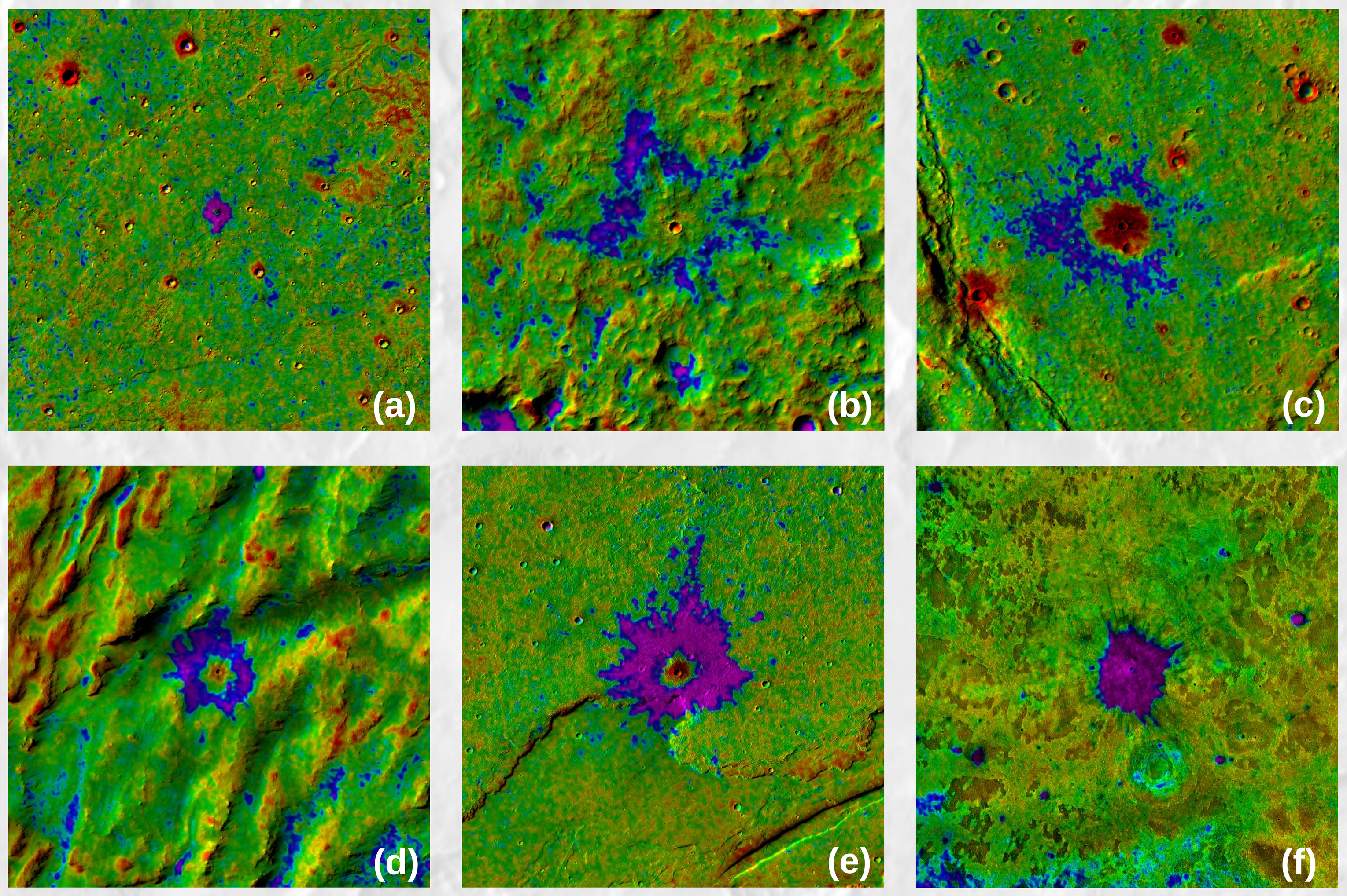


Figure 3: Examples of Low Thermal Inertia Halo Categories

CONCLUSIONS

The “THEMIS Day IR with Night IR Color” global mosaic has enabled the identification and characterization of 4,024 low thermal inertia crater halos across the Martian surface. They have characteristic thermal inertia patterns that clearly distinguish them from the surrounding terrain, surface morphologies consistent with young impact crater ejecta deposits and are concentrated in specific regions. Future efforts will focus on identifying the variables controlling where these halos are preferentially forming and/or being preserved.

References

[1] Edwards et al. (2011) JGR, 116, E10008. [2] Edwards et al. (2011) JGR, 116, E10005. [3] Hill et al. (2014) 8th International Conf. on Mars, Abstract #1141. [4] Hill and Christensen (2014) AGU, Abstract P33A-4028. [5] Bandfield et al. (2014) Icarus, 231, p221-231. [6] Ghent et al. (2010) Icarus, 209, p818-835. [7] Tornabene et al. (2006) JGR, 111, E10006. [8] Christensen et al. (2004) Space Sci Rev 110: 85-130. . [9] Smith et al. (2003) PDS. [10] Fergason et al. (2006) JGR, 111, E12004. [11] Malin et al. (2007) JGR, 112, E05S04.