EPSC Abstracts
Vol. 12, EPSC2018-603-1, 2018
European Planetary Science Congress 2018

The Distribution of Antipodal Ejecta from the Tycho Impact: Observations and Models

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Abstract

LRO Diviner and LROC observations have previously revealed a ~100 km region of anomalous rock abundance and melt features in the antipodal region of the Tycho impact crater. Analysis of LROC WAC multi-color data reveals a much more widespread ~600 km concentration of antipodal Tycho ejecta that we interpret to be melt spherules that converged near the antipode on ballistic trajectories from the Tycho impact.

1. Introduction

The distribution of distal ejecta from major impacts is of broad interest for the field of planetary science. On Earth, the Chicxulub impact crater produced a global layer of ejecta that resulted in intense heating when it re-entered the Earth's atmosphere that may have resulted in extinction of the dinosaurs at the K/T boundary 65 million years ago [1,2]. On the Moon, the extensive ray system associated with the 108 million year old Tycho impact suggests that it also deposited an ejecta blanket of global scale, although the nature and effects of the Tycho impact may be less extensive as those from Chicxulub due to the Moon's lower gravity and Tycho's smaller size. Fortunately, the Moon's slow resurfacing rates have resulted preservation of a significant fraction of Tycho's ejecta on the lunar surface, and its distribution can be recognized in the LRO data with the aid of ballistic models.

2. Datasets and Methods

We used photometrically corrected LROC WAC mosaics in bands 1 (321 nm), 3 (415 nm) and 4 (566 nm) to create a false color map of the Tycho antipodal region at a spatial resolution of 65 pixels per degree (~475 m) [3]. We also use a 3-body ballistic model that includes the effects of lunar and Earth gravity, as well as the rotational and orbital motions of the moon to calculate the trajectories of Tycho ejecta at a range of azimuth and elevation angles as well as initial velocities See [1] and [4] for descriptions of analogous 2-body ballistic models.

3. Results

3.1 WAC Colour

The WAC color map reveals the presence of an extensive region with distinct UV spectral properties characteristic of glass and shocked plagioclase in the vicinity of the Tycho antipode [5], shown in purple in Figure 1.

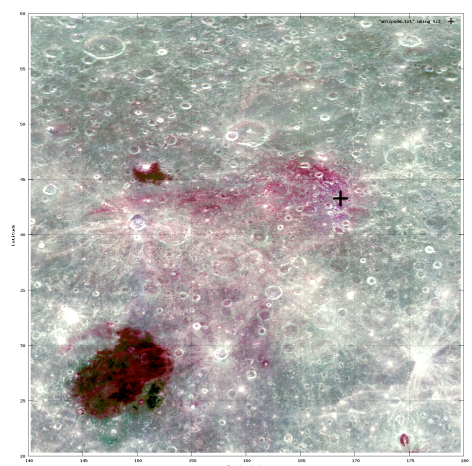

Figure 1. LROC WAC 3-band false color image of the Tycho antipodal region (extending from 140°E to 180°E and 20°N to 60°N). The location of the antipode is indicated by the black "+".

The purple areas in the false color map are concentrated to the south and to the east of the antipode. Areas with similar spectral features are also visible in the proximal rays of Tycho.

3.2 Ballistic Models

Ballistic model results predict a convergence of ejecta in the antipodal region for ejection angles of 0° to 45° relative to horizontal [6]. For increasingly higher ejection angles, the Moon's rotation results in the convergence of ejecta further to the west of the antipode point (Figures 2-4). The higher angle ejecta are distributed over a wider area to the west of the antipode with heating rates that are not sufficient to results in localized melting. Accumulations of small melt spherules, analogous to those that were deposited globally on Earth in association with Chicxulub, remain exposed on the surface and are responsible for the UV spectral features observed by LRO WAC. The convergence of low angle ejecta spherules just west of the antipode produces the most concentrated ejecta deposits, with re-impact heating rates sufficient to result in localized rubble formation, melting and flow features that are observed by LRO NAC and Diviner. [7-9].

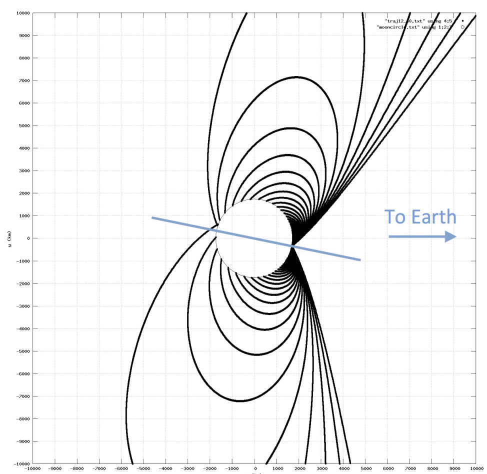

Figure 2. Ballistic models showing the trajectories of Tycho ejecta for ejection angles of 40°. The antipodal ejecta is concentrated to the west of the antipodal point due to the rotation of the Moon.

4. Conclusions

We conclude all the major observable global effects of the Tycho impact can be understood as a consequence of the ballistic emplacement of Tycho ejecta. Proximal rays, as well as widely distributed high-angle ejecta near the antipode are rich in spherules composed of glass and shocked plagioclase. Closer to the antipodal point, the convergence of low angle ejecta spherules became sufficiently intense as to initiate localized melting and flow. It is likely that antipodal deposits from major impacts are common on the Moon, but only the most recent deposits are detectable from orbit.

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