THE MARE IMBRIUM FLOW FIELD: REGIONAL GEOLOGIC CONTEXT OF THE CHANG'E 3 LANDING SITE.

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Introduction: On December 14, 2013, China's *Chang'e 3* lander and lunar rover *Yutu* landed in Mare Imbrium (44.1214°N, 340.4884°E). The spacecraft and rover landed at the northern boundary of one of the best preserved flow fields on the lunar surface. Lava flow margins on the Moon are scarce **[1,2]**, and the best preserved examples are observed in Mare Imbrium **[3-5]**. The Mare Imbrium lava flows are unique to the lunar surface in that they have well-defined flow margins, levees, and channels that are traceable from the source region to the flow front. These flows were initially mapped with Apollo data **[4,5]**, but the data sets did not provide complete coverage of the flow field at a consistent resolution. The overall goal of this study is to reevaluate the flow field with current data sets, create an updated morphologic map of the Mare Imbrium lava flows, and provide a qualitative and quantitative description of the emplacement of the flow field.

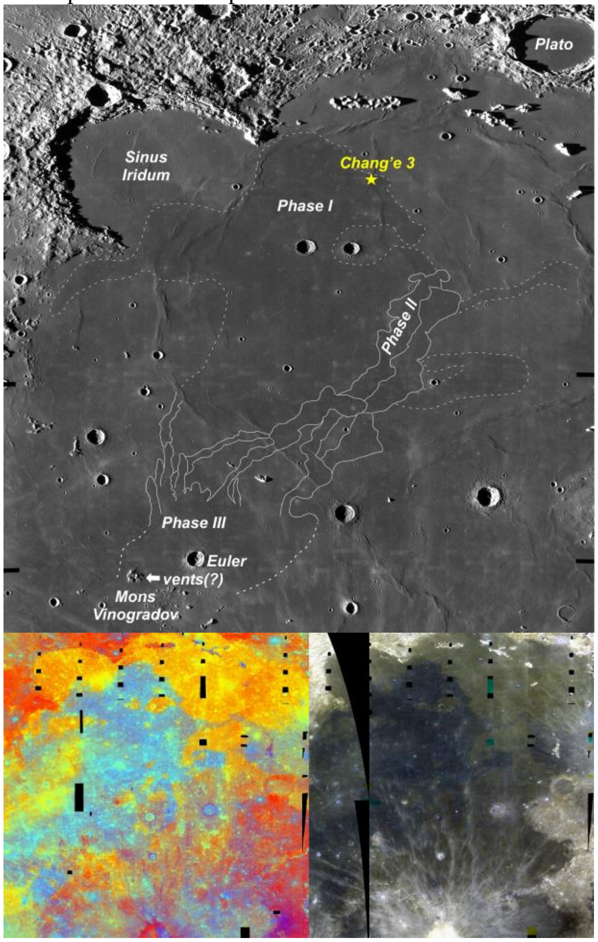

Figure 1. Chang'e 3 landed at at the northern edge of Mare Imbrium within the Phase I lava flows. LROC WAC mosaic (top). Clementine color-ratio & enhanced NIR (bottom).

Data and Methods: Recent missions have provided unprecedented data sets of the Moon with more consistent coverage and a variety of viewing angles and incidence angles. Here, we present an analysis of the Mare Imbrium lava flows based on new data sets from the Lunar Reconnaissance Orbiter (LRO) **[8]**, supplemented by data from Kaguya, Moon Mineralogy Mapper (M3), Clementine **[9]**, Lunar Orbiter, and Apollo. Mapping of the lava flows is being completed in ArcMap 10.2. The current basemaps are: *LRO Wide Angle Camera (WAC)* global mosaic (100 m/pixel) and a regional mosaic (50 m/pixel, incidence angle of ~70°), and *Kaguya Terrain Camera* mosaic of 3°x3° tiles (10 m/pixel). Topographic data sets include *LROC WAC 256 ppd* and *LOLA 1024 ppd* digital terrain models (DTMs), plus *LROC Narrow Angle Camera (NAC)* DTMs of Phase III lava flows. Field work was conducted at Askja volcano in Iceland (Aug., 2012), a potential terrestrial analog for the Phase III flows.

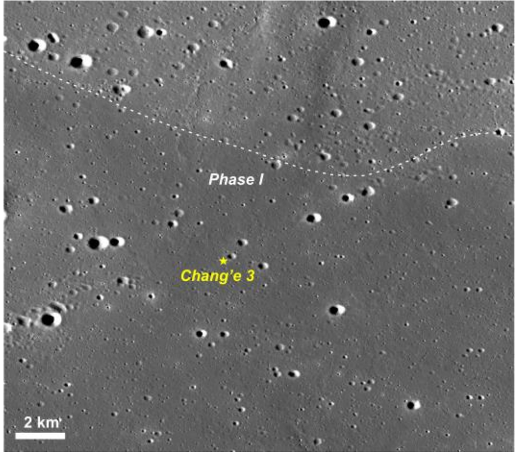

Figure 2. Location of Chang'e 3 landing site on Kaguya Terrain Camera image. Dashed line marks boundary between Phase I lava flows and olde mare units to the north.

Geologic Context of Chang'e 3: The Chinese spacecraft and rover landed within the mappable area of the higher Titanium, Phase I lava flows, ~7 km from the inferred flow margin, based on differences in color and multi-spectral color-ratio data from the surrounding, older mare. The flow field originates in the southwest part of the basin from a fissure or series of fissures and cones located in the vicinity of Euler crater and near *Mons Vinogradov*. The flow field is interpreted to have erupted in three phases (Phases I, II, III) over a period of 0.5 Billion years from 3.0±0.4 to 2.5±0.3 Ga with flow lengths of 300 km, 600 km, and

1200 km **[4,5]**. The flow field covers an area of 2.0 x 10^5 km^2 with an estimated eruptive volume of 4 x 10^4 km^3 **[4,5]**. Phase II and Phase III flows have well-defined flow margins (10 - 65 m thick) and channels (0.4 - 2.0 km wide, 40 - 70 m deep), but shorter flow lengths, 600 km and 400 km respectively. The older, Phase I flows, where *Chang'e 3* landed, extend 1200 km and have the largest flow volume, but interestingly do not exhibit any visible topographic margins and are instead defined by differences in color and multi-spectral signatures from the surrounding mare **[4-7]**. Flow margins are not apparent in LROC WAC or Kaguya images near the *Chang'e 3* landing site, but topographic profiles from LOLA and WAC DTMs reveal distinct increases in elevation of 10 to 30 m over distances of 5-20 km from the inferred flow margin towards the interior of the flow field. This area has been tectonically modified, so estimates are conservative, but the data does show that the flow is fairly thick in several locations in this area.

Discussion: Initial morphologic mapping reveals a different flow path for Phase I compared to the original mapping completed by **[4,5]** and the Phase I flows could be more extensive than initially mapped. The boundaries of the Phase I flow field have been revised based on M3 color ratio images **[11]**. This has implications for the area covered and volume erupted during this stage, as well as, the age of Phase I. Flow features and margins have been identified in the Phase I flow within the LROC WAC mosaic and in Narrow Angle Camera (NAC) images. These areas have a mottled appearance. LOLA profiles over the more prominent flow lobes in Phase I reveal these margins are less 10 m thick. Phase II and III morphology maps are similar to previous flow maps. Phase III lobes near Euler are 10-12 km wide and 20-30 m thick based on measurements of the LOLA 1024ppd Elevation Digital Terrain Model (DTM) in JMoon **(Fig. 3)**. One of the longer Phase III lobes varies between 15 to 50 km wide and 25 to 60 m thick, with the thickest section at the distal end of the lobe. The Phase II lobe is 15 to 25 m thick and up to 35 km wide. The eruptive volume of the Mare Imbrium lava flows has been compared to terrestrial flood basalts **[10]**, such as Laki (1783-1784), Iceland (Area:570 km^2, Vol.: 14 km^3) and Columbia River (Area: ~163,000 km^2, Vol.: 174,000 km^3) **[4,12]**. However these flows might not be representative of flow emplacement for the younger flows. The morphology of the lobes in Phase II and III, which includes levees, thick flow fronts, and lobate margins suggests these could be similar to terrestrial aa-style flows, as observed at Askja volcano in Iceland **(Fig. 4)**. The Phase I flows might be more representative of sheet flows, pahoehoe-style flows, or inflated flows **[12,13]**.

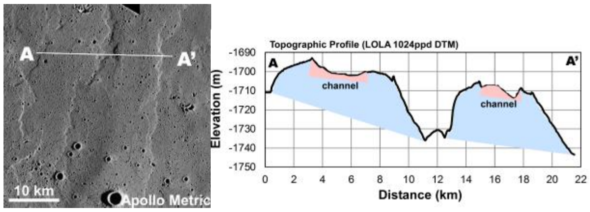

Figure 3. Topographic profiles of 2 different Phase III lava flows. Low-sun angle images show channels that are a few meters deep in the majority of the Phase III flows indicating preferred paths in many of these lobes.

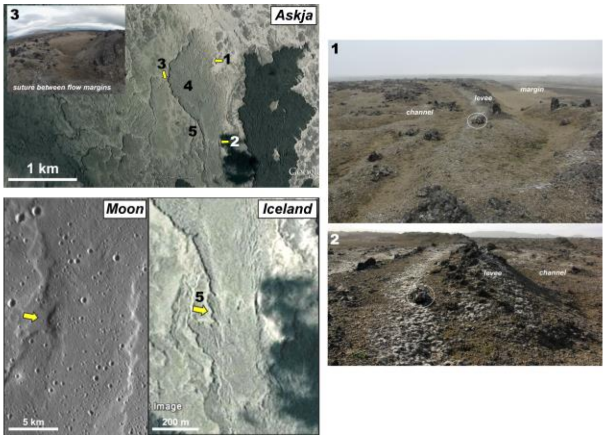

Figure 4. (top left)Context image of flow field at Askja volcano in Iceland. (1) Material in channel is only a few meters below the level of the levee. (2) Channels is ~5m deep. (3) Two flow margins meet and form a suture zone. (4) Flow line (or scar) is <1.5m deep. Similar features observed on the Moon. (5) Flow margins on the Moon and in Iceland have similar morphologic characteristics.

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