A NEW GLOBAL SEARCH FOR LUNAR PYROCLASTICS AND A REGIONAL STUDY OF LAVOISIER.

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Introduction: The lunar dark mantling deposits (DMDs) are mafic pyroclastics exhibiting a strong glass spectral signature in the near-IR and are the result of explosive volcanic eruptions [1,2]. The deposits are distinguished by their relatively low-albedos, smooth appearances, and high iron contents [1,3]. DMDs subdue the subjacent terrain and are thought to consist of ballistically emplaced volcanic glass, crystallized beads, and/or rock and mineral fragments [1,3-4]. DMDs present a range of compositions attributed to their eruptive style with glass-rich compositions trending towards a higher volatile content [5]. They are also thought to have mineralogies that reflect the deep lunar mantle owing to rapid ascent in dikes and conduits [6].

DMDs are often associated with the peripheries of large basins where crustal thinning from impactors, might have facilitated the rise of gas-rich magma and sill formation under crater floors [7-10]. The sills exerted an upward force resulting in either a doming or piston-like uplift of the crater floor [e.g., 7]. Doming is more typical for smaller craters (diameters < 40 km), while larger craters (diameters > 40 km) including Lavoisier crater, are uplifted and present flatter floor profiles and concentric fractures [2,11]. Localized DMDs such as those more central to Lavoisier crater are thought to have formed from a more explosive vulcanian-style eruption due to gas buildup away from the crater rim within the solidifying magma intrusion [2]. The composition and morphology of any volcanic materials such as pyroclastics and lava can reflect magmatic processes and dynamics prior to eruption [e.g., 6]. The characterization of these deposits is significant to understanding the magmatic history of the Moon as well as regional magmatic events [12]. Furthermore, pyroclastic materials also offer a potentially abundant source for the extraction of oxygen and other essential metals [e.g., 13].

In this study, we used recently available data to search for previously unrecognized DMDs as well as to update previous identifications. Then we focused on characterizing the DMDs within the region around Lavoisier crater to investigate the range in eruptive styles and compositions seen at one locality.

Methods: To locate potential DMDs, to determine their mantling extents, and to characterize their geologic settings, we utilized data in the NASA Planetary Data System (PDS), Annex, and Jaxa Archives, including the Lunar Reconnaissance (LRO) Wide Angle Camera (WAC), LRO's Narrow Angle Camera (NAC), the high resolution lunar topography (SLDEM2015), and Kaguya/SELENE's Terrain Camera (TC) image mosaics. The Kaguya/SELENE MI mineral abundance maps provided wt% estimates for FeO, pyroxenes, olivine, and plagioclase, as well as the derived optical maturity (OMAT) at a resolution of ~60 m/pixel [14]. Titanium (TiO_2) abundance maps were derived [15-16], and used along with Clementine UVVIS TiO_2 and WAC TiO_2 maps [16-17]. Data scales range from ~0.5 m/p (NAC) to ~200 m/p (Clementine UVVIS).

Global DMD Distribution: This work updates the database of known pyroclastic deposits [e.g., 18-23] to a total of 213 localities (**Fig. 1**). We mapped 34 previously unmarked deposits in areas of both unknown and recognized pyroclastics. Each was assigned a confidence factor, integers 1-5, with a value of 5 representing the highest confidence level.

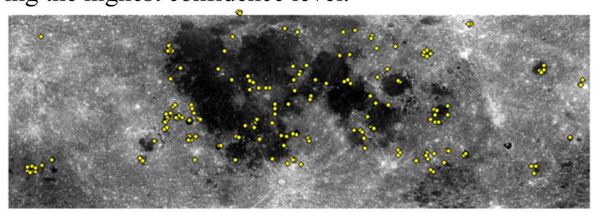

Fig. 1. Revised global distribution of DMDs (cylindrical projection -75°S to 75°N).

Lavoisier Region (centered at (39.0°,-80.0°), ~27800 km^2): Within the Lavoisier craters, 18 potential vent localities were identified and coupled with a confidence factor, updating previous maps [24]. The Lavoisier region pyroclastics are low-albedo, mantling, Fe-enriched deposits and are located within floor-fractured craters Lavoisier, and Lavoisier F, H, and E (**Fig. 2**). The floor-fractured craters have been dated as Nectarian to Pre-Nectarian in age and occur along the mare-highlands boundary [25]. Dating of the mare flow ~38 km east provides an age of ~2.9 Ga [26]. Regional stress trends in the maria display NE to SW compression, supported by the evidence of wrinkle ridges and gravity models [27,7].

Lavoisier: The fractures in Lavoisier crater manifest as two distinct concentric structures in relative proximity to the rim, similar to those in Oppenheimer [2]. Potential pyroclastic material close to the crater wall is mapped at a lower confidence due to its lack of clear mantling relationship. The volcanic deposits (mare and potential pyroclastics) associated with the outer fractures would have erupted during crater floor uplift [10-11]; however, Lavoisier crater exhibits negative topographic relief toward its center, which is not anticipated by models [11]. Current models of crater uplift by magmatic intrusions suggest that the outermost deposits would be less pyroclastic and dominated by lava and mare effusions. We also observed a possible spatter cone in Lavoisier, which suggests a range of lower volatility eruptions [28].

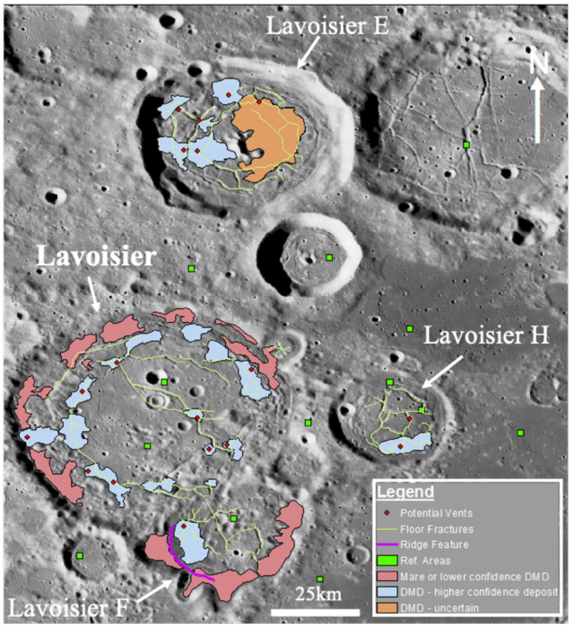

Fig. 2. Lavoisier regional map including features and pyroclastics (Kaguya MI TC Evening map).

Lavoisier E: DMDs lacks a notable titanium signature (~1 wt%) which is comparable to the regolith of the Lavoisier crater floors (**Fig. 3**). The unique chemical signature of the large (~230 km^2) deposit central to this crater (Fig. 2, orange polygon), along with a lack of distinct mantling, could suggest a phase of effusive volcanism. There is also a positive Bouguer gravity anomaly associated with the low-albedo deposits east of the central peak.

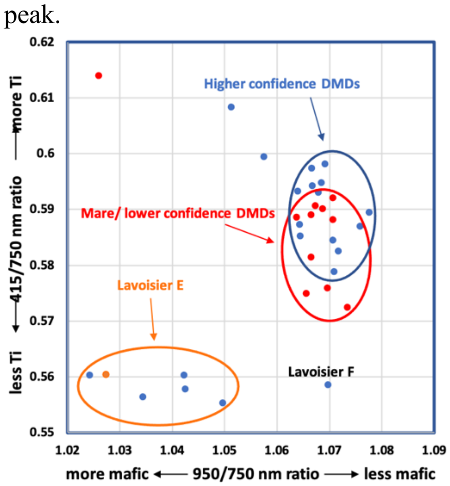

Fig. 3. The DMDs at Lavoisier E represent a compositionally distinct group among the Lavoisier craters (see Gaddis et al. Fig. 7.) [19].

Lavoisier F and H: There is a single identified pyroclastic deposit in Lavoisier F. The Lavoisier F and H DMDs are distinct in their TiO_2 signatures of ~6% in contrast to Lavoisier's deposit average of 3-4%. These variances are roughly correlated with the spatial relationship of the craters to the nearby maria in Oceanus Procellarum (avg. TiO_2 of 4.2%).

Summary: The Lavoisier DMDs are a result of volcanism associated with floor-fractured cratering. These deposits occur at irregular intervals along fractures produced during magmatic intrusion followed by crater floor uplift. Regional structures related to impact cratering causing crustal thinning facilitate these intrusions. This study characterizes deposits found within the Lavoisier craters in attempts to better understand eruptive styles ranging from more effusive mare-like deposits to presumably glass-rich explosive deposits.

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