Comparative study between local pyroclastic deposits at Atlas and Alphonsus crater. D. Misra1,2, C. Wöhler3, M. Arnaut4, and M. Bhatt5, 1Physical Research Laboratory, Ahmedabad, 380009, India (dibeyndu@prl.res.in, megsha@prl.res.in), 2Indian Institute of Technology Gandhinagar, Gandhinagar, 382055, India, 3Image Analysis Group, TU Dortmund University, 44227 Dortmund, Germany (christian.woehler@tu-dortmund.de).

Introduction: Lunar pyroclastic deposits (LPDs), associated with the dark mantle deposits (DMDs) within and around major mare-filled basins [1,2], are a key for understanding the early lunar mantle volatile composition and concentration [3]. The LPDs are mainly linked to morphological features like rilles, vents, fractures, and wrinkle ridges [4]. The amorphous volcanic glasses have spectral characteristics in the visible to near-infrared (VIS-NIR) wavelength range overlapping with those of other Fe-bearing common lunar minerals, such as olivine and pyroxenes [5]. Remote detection of volcanic glasses becomes feasible for 70 wt.% or more of volcanic glass mixed with minerals [6].

Considering the detection challenges of the volcanic glasses through remote sensing techniques, we focus on developing a methodology that can help us to understand the dominating mineralogy along with volcanic glass detection, an important input for understanding the source region of these eruptions. The study area considered comprises of two well-known local pyroclastic deposits (<1000 km²) [7] in the craters Atlas (46.3° N, 44.9° E) [8] and Alphonsus (13.4° S, 2.8° W) [9]. The spectral study is integrated with an analysis of relative grain size variations. This novel way of merging regolith physical information derived from telescopic observations with the compositional information of glasses provides us insights into the complex geological formation processes of the LPDs.

Data and methods: In this study, we constructed mosaics of the craters Atlas and Alphonsus using level-2 spectral reflectance data of the Moon Mineralogical Mapper (M³) onboard Chandrayaan-1 [10] for carrying out the mineralogical analysis (Fig. 1a and b). We calculated band center I (~1 μm) and II (~2 μm) and the average band depth (avg. BD) I at 0.9-1.05 μm, band depth II at 2-2.3 μm, and avg. glass BD at 1.1-1.2 μm wavelength range, respectively. We constructed a false color composite (FCC), where the avg. glass BD, avg. BD I, and avg. BD II are assigned to the red, green, and blue channel, respectively (Fig. 1c and d). We analyzed mineralogical variations within the local pyroclastic deposits (Fig. 1) through a density plot of band centers I and II of the associated minerals (Fig. 2).

For constructing maps of the relative grain size of the study areas, we acquired polarimetric data in the Johnson-Cousins R band, using an industrial polarization camera. The Imaging Source DZK 33GX250 combined with a Newton reflector of 200 mm aperture with an effective focal length of 3000 mm, located near Dortmund, Germany. This setup resulted in an image resolution of 0.9 km per pixel. We acquired a set of 3500 frames of the crater Atlas at 85° phase angle on February 27th, 2023, and of the crater Alphonsus at 52° phase angle on March 2nd, 2023, respectively. From each set of frames, the sharpest 10% were selected and stacked with the software Autostakkert3 [11]. From the stacked image data, we inferred the pixel-wise intensity and the degree of linear polarization (DoLP). We applied the method of [12] for estimating the relative regolith grain size, which exploits deviations from the negative correlation between surface albedo and DoLP. For the considered small surface areas with negligible variations in illumination and observation geometry, the measured pixel intensity was assumed to be proportional to the surface albedo. The resulting relative grain size distributions across the craters Atlas and Alphonsus are shown in Fig. 3.

Results and Discussion: The study regions (Fig. 1a and b) exhibit relatively high overall albedos, while the pyroclastic deposits display a distinct low albedo. It can be caused by the presence of Fe-rich volcanic glass in these deposits. The absorption in the 1.1-1.2 μm wavelength range can play an important role in identifying volcanic glass although its abundance is low [5]. Therefore, we calculated the avg. glass BD as well as
the avg. BD I and II to differentiate volcanic glasses from crystalline material of similar composition. In the FCC images (Fig. 1c and d), pixels in magenta-brown correspond to the pyroclastic deposits. Yellow-colored pixels denote mineralogical units where clinopyroxene (CPx) is predominant, coexisting with a mixture of orthopyroxene (OPx). Fresh craters are characterized by cyan color, indicating an OPx-enriched rock type. Red pixels at the central peak of Alphonsus (Fig. 1d) suggest a lithology dominated by the mineral plagioclase. The crater floors exhibit green and blue pixels, representing pyroxene-bearing and highly weathered mafic compositions, respectively.

The density plots (Fig. 2) showing the relation between the band center wavelengths I and II suggest that the signature of the volcanic glasses may be obscured due to OPx-rich ejecta from fresh craters within the pyroclastic deposits at Alphonsus. In the case of Atlas, volcanic glasses are associated with highly weathered pyroxene-mixed crater floor mineralogy.

![Figure 2](image2.png)

**Figure 2:** Density plots between band centers I and II for all pyroclastic deposits present in the study regions (marked with white dashed lines in Fig.1). Boxes with dashed lines indicate the characteristic parameter space identified for each material. The values for plotting pyroclastic and impact glasses are taken from [6].

The relative regolith grain size maps in Fig. 3 indicate a largely uniform grain size on the floors and outside the craters Atlas and Alphonsus, except for some topography-induced artifacts at the crater walls. The pyroclastic material in both craters, which appears dark in the intensity images, is associated with grain sizes larger than about 40-100% in comparison to the surrounding material. This observation suggests that the glass-rich pyroclastic material presumably erupted by fire-fountaining [7] is more resistant against destruction by micrometeoroid impacts than the surrounding crater floor material.

**Figure 3:** Telescopic intensity images of Atlas and Alphonsus (upper row, 16-bit DN) and corresponding images of the decadal logarithm of the relative grain size (bottom row).

**Ongoing work:** We plan to include elemental abundance analysis in our mineralogical and grain size analyses in order to understand the diversity of LPDs. We will also apply the developed method to regional scale LPDs and systematically study compositional and grain size variations. This integrated approach will eventually help us in understanding the geological complexities of the formation of LPDs.

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**References:**