Multispectral Assessment of Kovalevskaya Crater on the Lunar Farside

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Scientific Objectives:

- Assess the distribution of impact melt deposits around large (>100 km) complex craters.
- Determine the compositional characteristics of complex crater impactites to better understand the lunar farside crust.

About Kovalevskaya Crater:

- Complex crater with a well preserved outer rim, terraced walls, a flat crater floor, and a central uplift (Fig. 1). The central uplift comprises of two peaks with variable heights.
- Located ~ 30°N, 129°W (western lunar farside). ~85 km NW of the Cordillera mountains, Orientale basin (Fig. 1, inset).
- 113 km diameter (Fig. 1), 4–6 km crater rim - floor depth (Fig. 2).
- Eratosthenian in age [1].

Methods:

- Assessment made by combining spatial, spectral, radar and topographic details.

Topography: 1024ppd GDR data from the Lunar Reconnaissance Orbiter (LRO) Laser Altimeter Orbiter (*LOLA*) [2] to get elevation detail.
Spatial: Optical imagery from the LRO Wide Angle Camera (WAC) and Narrow Angle Camera (NAC) data to identify and map the extent of impactites (Figs. 1, 3).
Spectral: Reflectance spectroscopy (UV-VIS-NIR) from Clementine and Chandrayaan-1 M^3 missions to derive compositional detail (Fig. 4).
Radar: LRO Mini-RF instrument data used to detect presence of impact melt deposits optically eroded (following studies by [3, 4]).

- Data downloaded from ode.rsl.wustl.edu/moon. Integration of all datasets was possible using ISIS v.3 [5], Oasis Montaj®, JMars for Earth's Moon [6], and ArcGIS® software packages.

Spectral Sampling:

- Georeferenced Clementine 5-band UV-VIS data (120m/pix res.) used to characterize compositions at a regional scale.
False colour ratio composite map (Fig. 4A) provides level of surface optical maturity [7]. The iron weight % distribution map (Fig. 4B) used to determine iron rich areas [8].
- Level 2 M^3 reflectance data, with high spectral resolution (86 bands, 20–40 nm) [9], was used to compare integrated band depth (IBD) strengths at 1 µm, 1.3 µm, and 2 µm (Fig. 4C), and derive spectral profiles of mapped units (Fig. 4D-G). IBD values calculated using algorithms from [10,11]. Sampling was conducted on freshly exposed surfaces, with 5x5 pixel window sizes using ENVI v.4.8.

Results and Discussion:

The well-preserved nature of impactite materials at Kovalevskaya make it a great site to examine the distribution of impactite materials around complex craters.

The target materials at Kovalevskaya are mostly highland rocks, but also contain high iron rich content. While the distribution of mafic material is not ubiquitous, it alludes to the complexity of the target subsurface.

The extent of mafic-rich materials along the north east spanning the crater floor, terrace, and rim (Figs. 4C-G) suggest a mechanical mixing, i.e. the crater event may have tapped into a previously unknown buried mafic unit.

Summary:

Data fusion of spectral and spatial data provide new opportunities to better understand the formation and emplacement mechanisms of impactites such as impact melt deposits around large complex craters. The compositional information allows better understanding of the rock content of the lunar farside, and subsequently better estimates on the depths from which materials may be excavated.

Morphological Detail

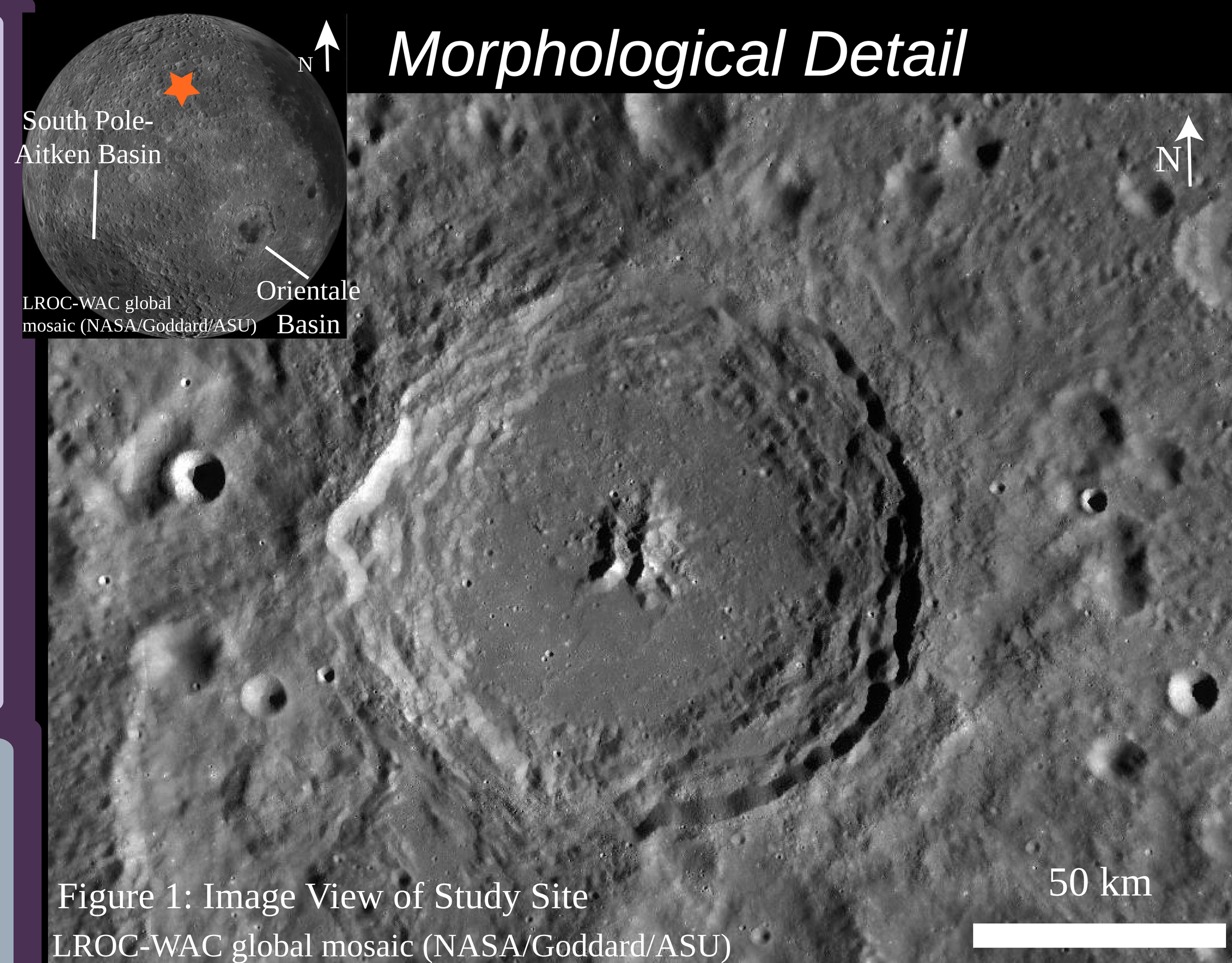
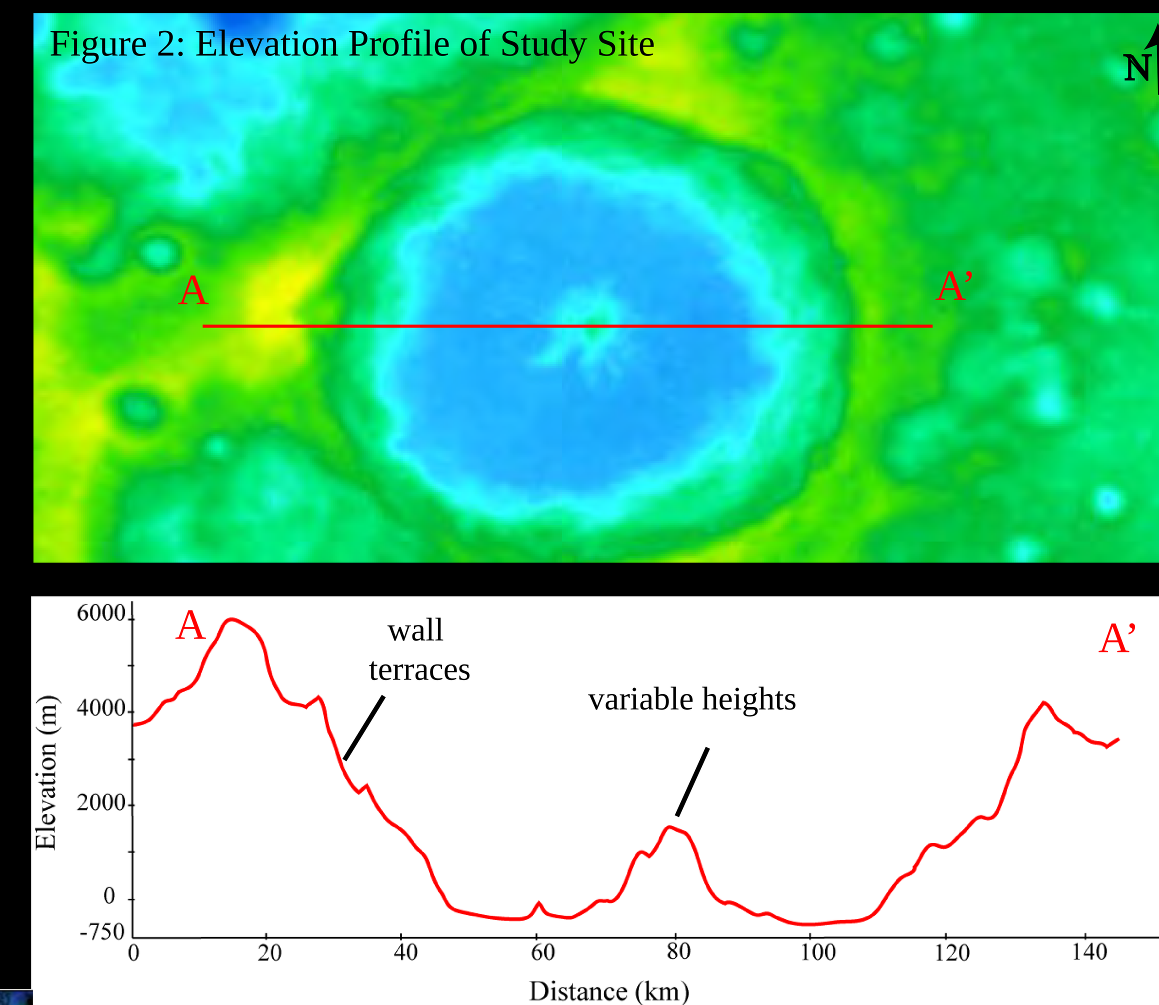


Figure 1: Image View of Study Site
LROC-WAC global mosaic (NASA/Goddard/ASU)

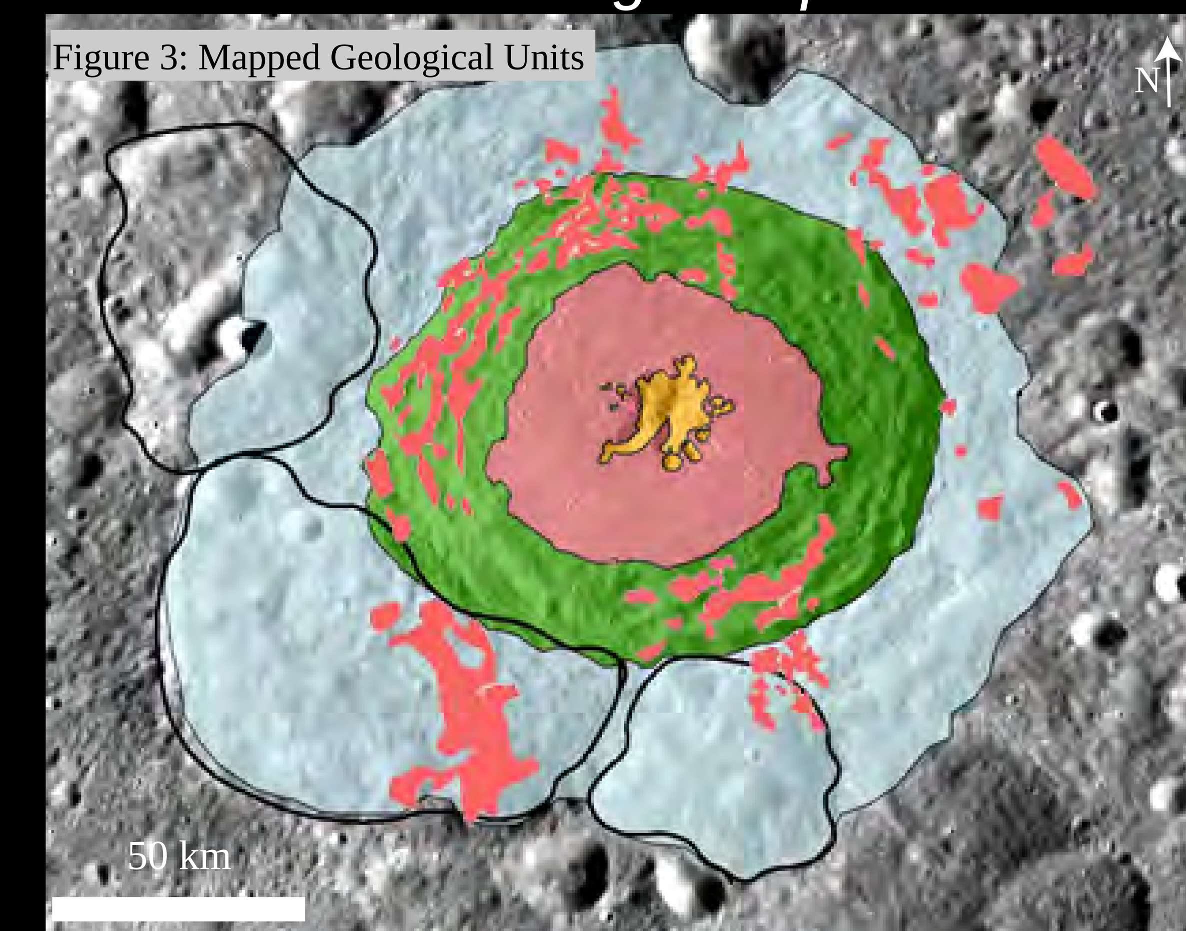
Topographic Expression

Figure 2: Elevation Profile of Study Site



Geologic Map

Figure 3: Mapped Geological Units



Continuous Ejecta Deposits
Terraced Crater Wall
Mapped Impact Melt Deposits
Crater Fill Deposits
Central Uplift
Impact Melt Lobe
Pre-Impact Crater Outlines

Compositional Characteristics

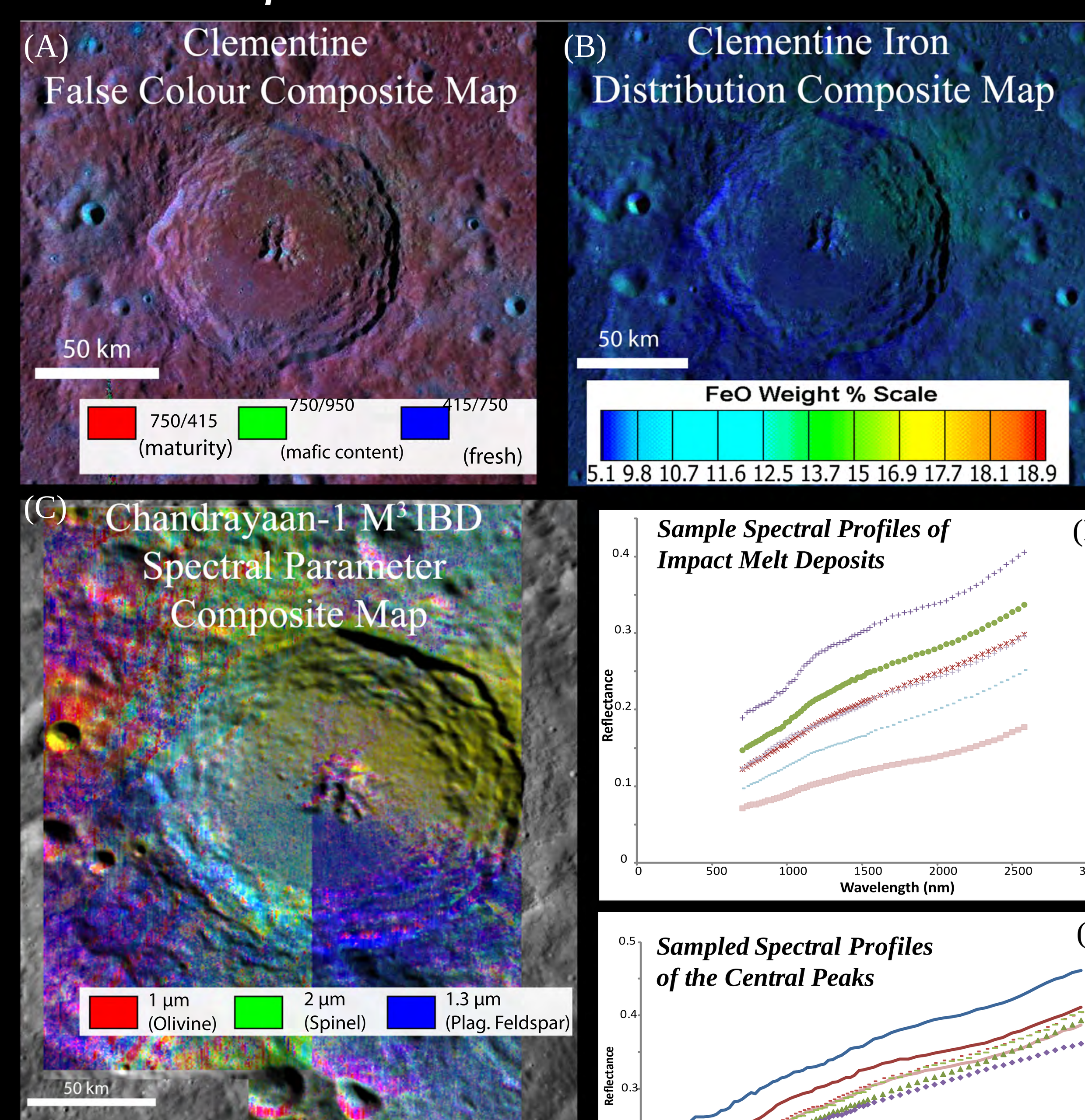
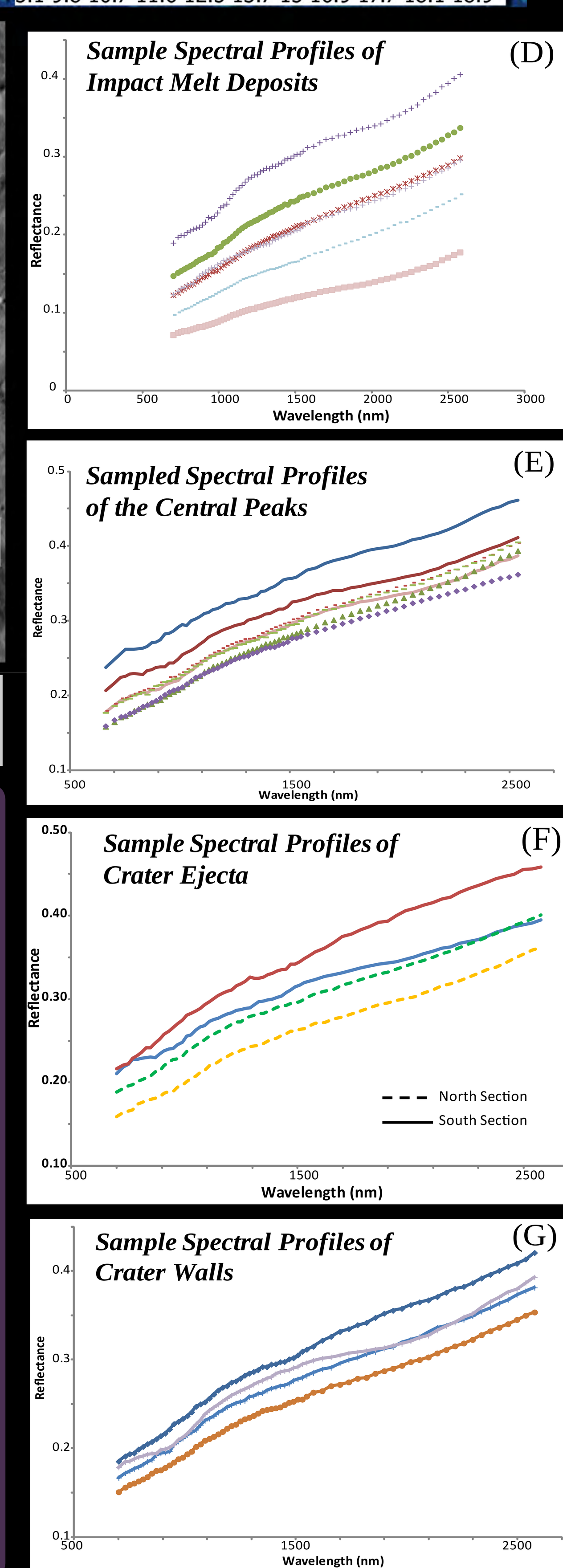


Figure 4: Spectral details of Kovalevskaya



Target Compostions:

* UV-VIS-NIR data is great for determining mineral compositions

* Clementine composite maps reveal a mature (red) terrain with mafic concentrations to the north-east (Fig. 4A, B).

* M^3 IBD parameter map (Fig. 4 C) and sampled spectral profiles (Fig. 4D-G) indicate a heterogeneous distribution of low and high-Ca pyroxenes, and plagioclase feldspar. Mafic rich minerals are concentrated along the north-east.

Impact Melt Deposits - A Closer Observation

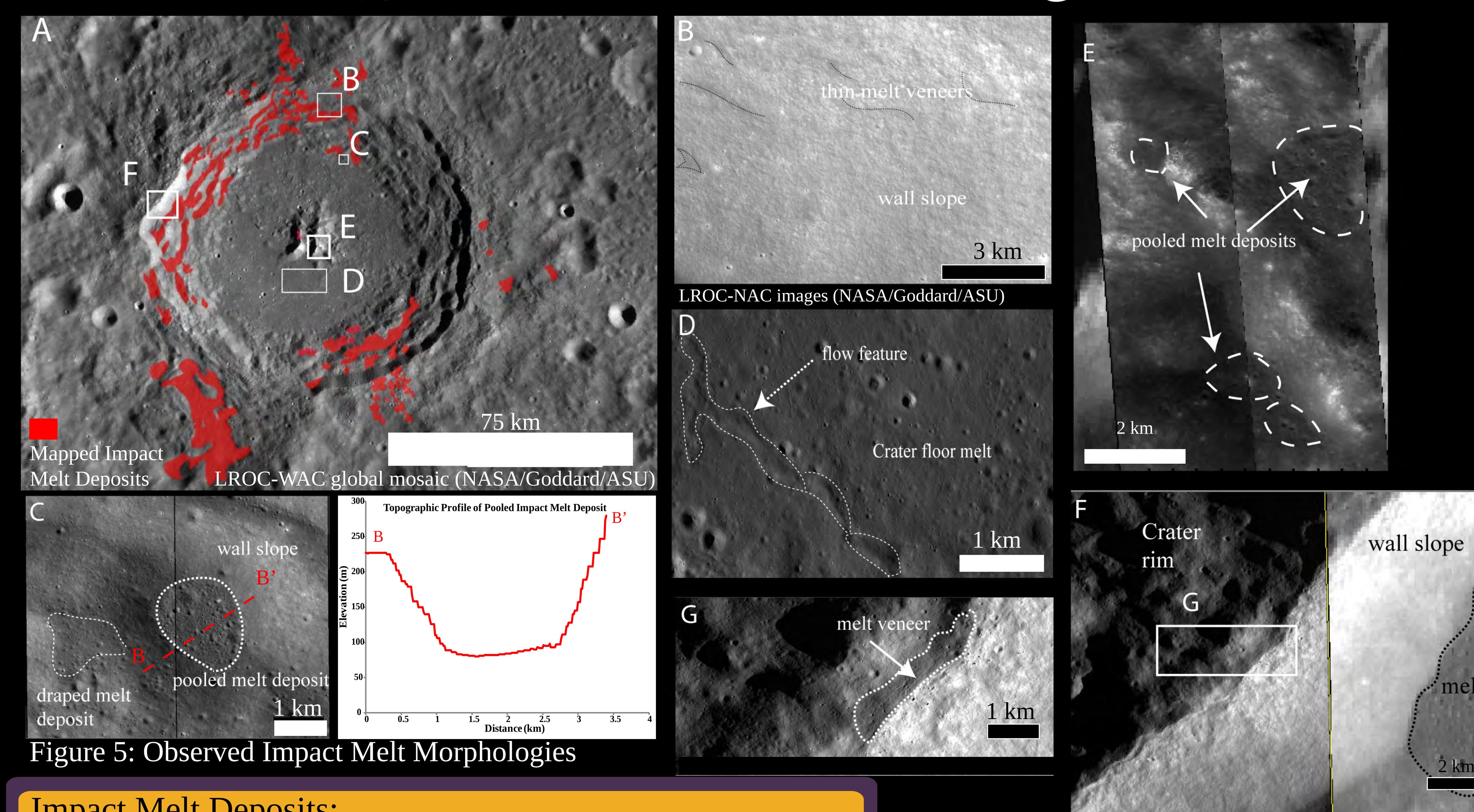


Figure 5: Observed Impact Melt Morphologies

Impact Melt Deposits:

* Recent high-resolution camera data provide improved techniques for identifying impact melt deposits (Fig. 5). Impact melt deposits are identified both within and beyond the crater floor (Fig. 5). These deposits are smooth, have low albedo. Morphologies range from melt lobe on the crater floor to thin veneers and pooled deposits in low-lying depressions (Fig. 5B-G).

* The maximum extent of mapped impact melt deposits is 97 km beyond the crater rim (~2 crater radii).

* Pre-existing topography near the crater area (Fig. 3) may have provided added momentum for impact melt deposits to emplace beyond the crater rim during the crater modification process[14].

* Radar data (Fig. 6) does not show any variations in the smoothness or roughness of the impact melt deposits when compared to the surrounding terrain (Fig. 6). This is likely due to long surface exposure (maturity) and subsequent cratering events.

Surface Roughness (Radar)

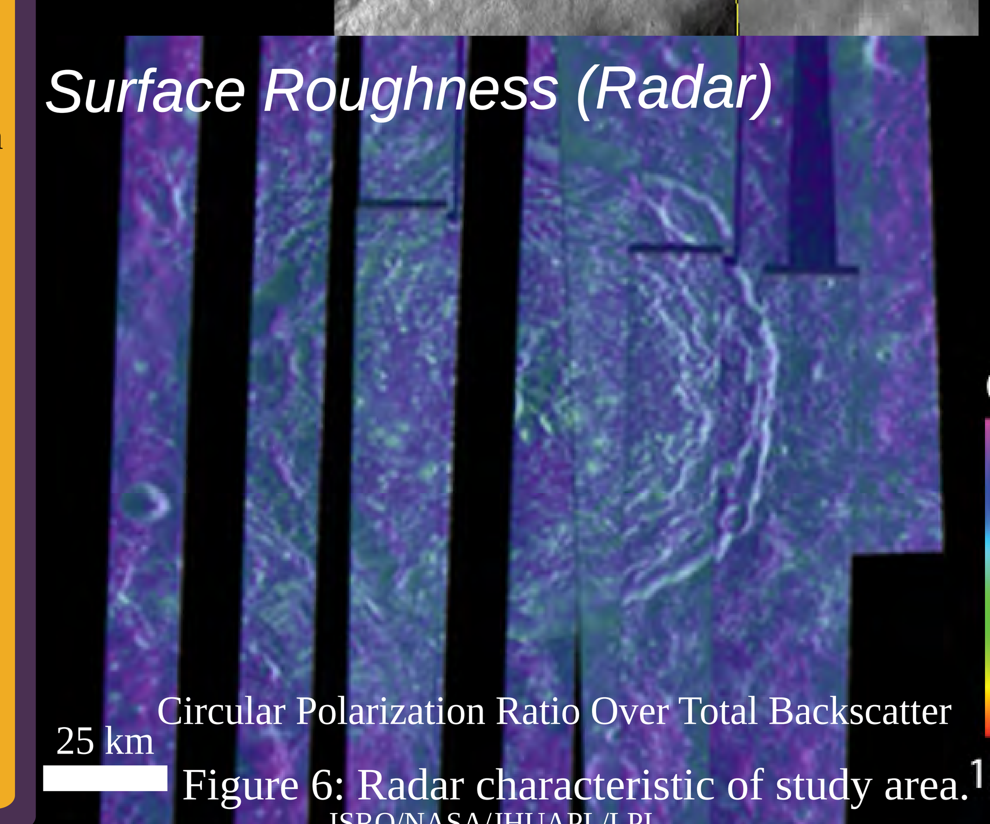


Figure 6: Radar characteristic of study area.

Acknowledgements: CSA ASC

References: [1] Scott et al. (1977) USGS Serv. Map I-1034. ; [2] Smith et al. (2010) Space Sci. Rev. 150, 1–4: 209–241; [3] Neish et al. (2011) 42nd LPSC. Abs. # 1881; [4] Carter et al. (2012) JGR, 117, E00H09. [5] Gaddis et al., (1997) 27th LPSC. Abs. # 1223 [6] Christensen et al. (2009) AGU Fall Meeting, IN22A-06. [7] Pieters et al. (1994) Science, 266: 1844-1848; [8] Lucey et al. (2000) JGR, 105:E8 20297-20306; [9] Green et al. (2010) 41st LPSC, Abs. 2331. [10] Mustard et al. (2011), JGR, 116:E00G12, [11] Donaldson Hanna et al. (2012) 43rd LPSC Abs. 1968. [12] Nozette et al. (2010) Space Sci. Rev. 150, 1–4: 285–302;[13] Melosh, (1989) Impact Craterig: Oxford Univ.245pp; [14] Osinski et al. (2011) EPSL, 310, 3:167-181.