Fire and Ice: Volcanic Domes and Remnant Ice in Western Arcadia Planitia

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Introduction: Domes in western Arcadia Planitia, just east of the Phlegra Montes (Fig. 1) were suggested in [1] as being felsic in composition based on observations of morphologic features resembling terrestrial felsic lava domes. However, examination of the composition of these features by [2] using CRISM Full Range Targeted (FRT) observations detected the presence of olivine suggesting a more mafic composition. This poster describes further work that has been conducted on these features using additional CRISM and HiRISE scenes as well as comprehensive MRO Context Imager (CTX) coverage.

Dome Features: The western Arcadia domes are recognized by several defining characteristics (Fig. 2). They consist of a central core, sometimes in a hemispherical dome shape, but also often in more irregular shapes, that are typically 1 to 2 km in approximate diameter. Surrounding the domes are shallowly sloping dark-toned aprons. The aprons sometimes are surrounded by light-toned aureoles, and sometimes with an outer concentric dark-toned aureole. The domes are typically high in thermal inertia relative to the plains (TI units on the order of 200 to 300 Jm-2K-1s-1) as determined using the (3MARS utility) while the dark-toned aprons are low in thermal inertia relative to the plains (TI units of approximately 150 to 300 Jm-2K-1s-1).

Compositional Characteristics from CRISM Spectroscopy:
Examination of spectra from the flanks of several domes covered by CRISM FRT scenes, using spectral parameter plots detailed in [3] for assessing ferrous silicate mineral mixtures, suggest that the flanks of these domes consist of a mixture of high-Ca pyroxene, basaltic glass, and olivine (Fig. 3).

We have also observed elevated values of the CRISM BD1300 parameter in association with the domes. This parameter indicates the presence of the 1.25 to 1.3 μm absorption feature (Fig. 4) of Fe-bearing plagioclase. In one scene, spectra extracted from the high BD1300 area also has a 2.2 μm band (Fig. 4) interpreted to be due to either an Si-OH or Al-OH overtone.

Additionally, a parameter indicating the possible presence of zeolites or sulfates, the difference of reflectance of 2240 nm less 2540 nm (R2240-R2540), is elevated in association with some of the aprons. Spectra from these regions (Fig. 5) have weak 1.92 and 2.53 μm absorptions- again consistent with either zeolites or sulfates. Also, the BD3000 parameter is elevated in association with light-toned aureoles.

New Observations from HiRISE and CTX:
A CTX mosaic was assembled for much of this region based on its nomination as a human exploration zone by [4]. Also, additional HiRISE scenes have been collected since the work carried out by [2]. The presence of "brain terrain"-like deposits in the light-toned aureoles was noted above. In the CTX mosaic we find multiple examples of domes with light-toned arcs immediately adjacent to the northern flanks of the domes (Fig. 6). While there is no HiRISE coverage over these north-facing light-toned arcs, the CTX imagery partially resolves what looks like "brain terrain" (5) composing these arcs; again suggesting the presence of ice. With ice-rich material on both the proximal and distal portions of the aprons, we conclude that the aprons are potentially cored by ice like the larger lobate debris aprons (LDAs) observed in multiple locations elsewhere on Mars [e.g., 6,7]. As noted by [1], a number of domes in the region have tongue-shaped extensions protruding from them (Fig. 8) that are suggestive of viscous lava flows. In the example shown in Fig. 8, the putative flow also is brighter in nighttime THEMIS IR imagery suggesting a coarser-grained, more blocky, or more indurated surface. We also have found at least one example of a putative cinder cone atop a dome (Fig. 9).

Discussion:
In CTX and HiRISE data we find multiple examples supporting the morphologic evidence described by [1] in which these domes display features consistent with terrestrial lava domes formed from viscous magmas. The presence of mafic magmas plus plagioclase in association with the domes suggests a largely mafic composition for these features although the possibility exists that they could be slightly more silica-rich than basalt- e.g., andesites or basaltic andesites. THEMIS spatial resolution is insufficient to make any confident conclusions regarding how silica-rich these domes are. As noted in [2], crystal-rich basaltic magmas are viscous and it could be that the domes formed from such crystal-rich magmas rather than forming expansive lava flows.

We have suggested that the aprons surrounding the domes are similar in nature to LDAs. As described by [8], LDAs could have formed through the collapse of regional ice sheets. Given the evidence in [11] for a regional ice sheet to the east of the dome field, we suggest that this ice sheet, or outliers of it, also covered the dome field (Fig. 10). Collapse of the ice sheet and dark-toned mantling material is hypothesized here as forming the aprons and their dark mantles (dark mantles extend over the tops of many domes as well).

References:

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Fig. 1. MOLA color topography from Google Mars (left) and zoom-in to area of interest in THEMIS daytime IR mosaic on right.

Fig. 2. CTX imagery of an Arcadia dome viewed in JMARS with defining characteristics labeled.

Fig. 3. A. 2 μm vs. 1 μm band center position for ferrous silicates and dome flanks. B. 1 μm band width vs. center for same materials.

Fig. 4. A. Composite of bands centered at 2.5, 1.5, and 1.08 μm of CRISM scene FRT00009A70. Yellow box indicates area from which pixels were extracted for the spectral average shown in Fig. 4B. B. Region of interest average showing both the 1.25 μm plagioclase band (dashed green arrow) and the 2.255 μm band (solid black arrow).

Fig. 5. A. FRT00017IF6 composite of 2.5, 1.5, and 1.08 μm bands with high R2240-R2540 region of interest location noted by rectangle. B. Spectral average from location noted in Fig. 5A with spline smoothed version in red and 1.92 and 2.53 μm bands marked with arrows.

Fig. 6. CTX imagery (from JMARS) of dome with arc of light-toned material to its north (indicated by arrows). It also has a dark-toned apron, but is surrounded by a light-toned and outer dark-toned aureole. Dome is centered at ~ 38.2°N, 171.7°E.

Fig. 7. Subsection of HiRISE scene ESP_013367_2190_COLOR over light-toned "brain terrain". A partial dark-toned mantle still exists over part of this unit.

Fig. 8. A. CTX imagery of dome (centered at 38.07°N, 174.07°E) with flow-like tongue extending out to the lower left in this view from the main core. B. THEMIS nighttime IR imagery of the same view showing that the putative flow tongue has a warmer temperature and thus a normally higher thermal inertia. Also noteworthy are the low values in the light-toned arc to the northeast (upper right in the image) of the dome.

Fig. 9. Subsection of CTX scene from JMARS of possible terminal cinder cone is circled in yellow. B. Corresponding coverage of dome in THEMIS nighttime IR imagery showing high values indicative of a high thermal inertia including over possible cinder cone.

Fig. 10: Possible sequence of events in formation of domes.