EVOLVED AND EXPLOSIVE VOLCANISM IN MEROE PATERA AND SYRTIS MAJOR CENTRAL CALDERA COMPLEX.

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Introduction: The Syrtis Major Planum Central Caldera Complex (SMCCC), hosting two calderas, Nili and Meroe Paterae, exhibits evidence for a diverse variety of volcanic processes [1] and mineralogical compositions [2, 3, 4] in a structural setting unlike that of most other volcanic edifices on Mars [5, 6]. To date, the geological context of these processes has been explored only in Nili Patera [1], the northernmost caldera, whilst Meroe Patera and the wider SMCCC have not been extensively studied. Consequently, the geological history of the caldera complex as a whole is poorly constrained and the implications for Hesperian magmatism remain unexplored.

Here, we describe the volcano-tectonic context of unusual materials and compositions within Meroe Patera and the broader SMCCC. We consider how these materials might have formed, how the SMCCC and Meroe Patera evolved, and the implications of this for magmatic evolution at Syrtis Major Planum.

Data and Methods: This study uses CTX images and MOLA topographic data, and uses THEMIS data to provide compositional and thermophysical information. Three CTX DTMs (20 m/pix) of Meroe Patera, produced in ‘SocetSet’ software following usual methods [7], provide high-resolution topographic data.

Meroe Patera: Meroe Patera is a circular caldera 45 km across, and has an asymmetric rim height ranging from 0 to 1 km. The caldera is defined by several concentric sets of normal faults, formed over at least three stages (fig 1), interspersed by several resurfacing events. The two outermost sets of arcuate normal faults are cross cut by wrinkle ridges associated with subsidence of the wider SMCCC. The central portion of the caldera floor is down-warped with numerous circumferential normal faults, while the center is crosscut by a sub-radial pattern of ridges.

The most striking features of the caldera floor are several arcuate light-toned features. These features, dark in daytime infrared THEMIS images but bright in nighttime infrared data, have two distinct surface textures: ‘diffuse’ and ‘crisp’. Towards the west and south, the more diffuse features (fig 1b) are bright patches 10-20 m across, which crop out at local topographic highs, fault scarps and crater rims. The crisply defined arcuate regions (fig 1c) towards the center of the caldera comprise blocky/rubbly material with wide flat bottomed pits exposing a bright surface cross cut by a pattern of polygonal fractures. Although the tonal change is sharp in CTX data, HiRISE reveals the contact at the break in slope of the pit scarp to be gradational.

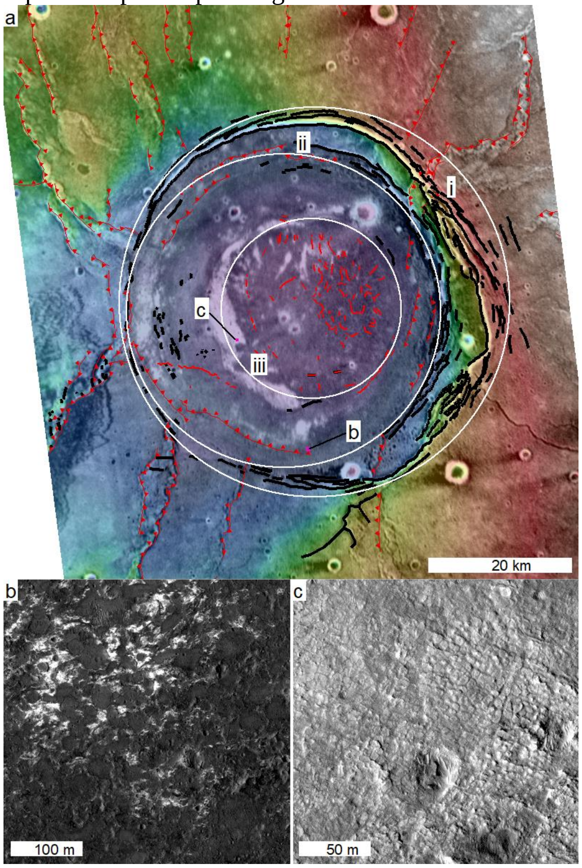

Fig 1: Meroe Patera caldera floor (a) Night THEMIS data overlain with a CTX DTM normal (black) and reverse (red) faults across 3 sections of the caldera floor. HiRISE examples of the arcuate bright regions (b) diffuse and (c) light toned material.

Central Caldera Complex: The SMCCC is a 400 × 200 km elliptical depression trending ~ NW-SE at the center of Syrtis Major Planum. The depression is controlled by reverse faults bounding wrinkle ridges with some minor normal faulting [5, 6].

In the axis of the SMCCC we identify a surface type with the same surface texture and thermal signature (fig 2) as a region interpreted to be dacitic in composition in Nili Patera [2]. This light-toned, axial lava unit, at the center of the caldera complex, abuts older volcanic terrains, but is overlain by an apparently thin layer of dark material to the east.

Throughout the SMCCC there are examples of light-toned materials exposed on topographic highs, ridge crests, fault scarps and crater rims. These light-toned inliers are the same as diffuse bright patches in Meroe Patera and similar to light-toned inliers in Nili Patera [1]. These light-toned inliers crop out in materials with a substantial mantle and where they have been exhumed by either tectonic or cratering processes, and are also overlain by a thin layer of dark-toned materials.

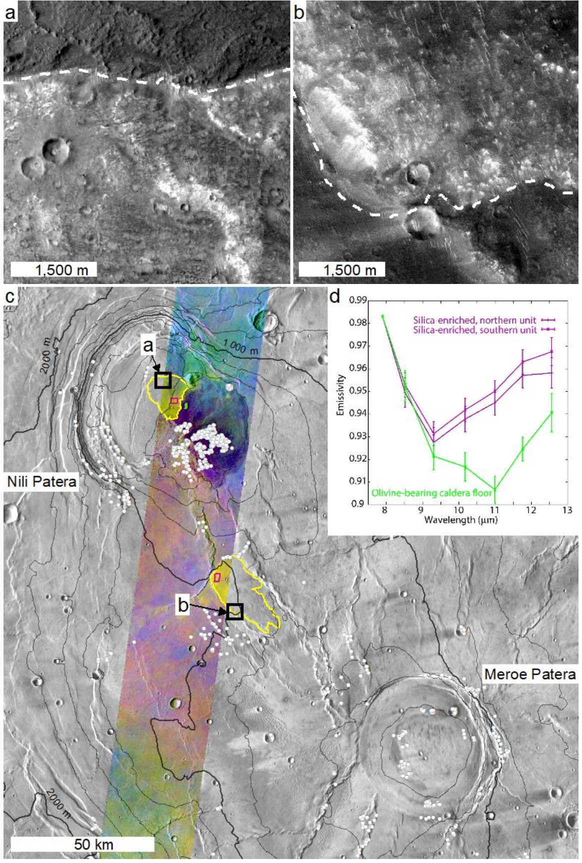

Fig 2: Comparison of surface textures between silica rich materials in (a) Nili Patera and (b) the SMCCC. (c) THEMIS DCS (bands 8 7 5) shows the location of these units separated by ~65 km and 800 m elevation. Also shown is the distribution of light-toned inliers (white dots) in the SMCCC. (d) THEMIS surface emissivity spectra show silica rich materials in Nili Patera and SMCCC to be spectrally indistinguishable. Olivine-bearing surfaces in Nili Patera provide reference.

Interpretations and discussion: There are striking similarities between the expression of light-toned materials in Nili Patera, Meroe Patera and the SMCCC. In Nili Patera these bright materials were proposed to have an ignimbrite origin [1], ponding on the nascent caldera floor and thinly draping more distal areas with more friable deposits. These were subsequently buried and exposed by later volcano-tectonic activity.

The observations at Meroe Patera and in the SMCCC support this hypothesis: the light-toned inliers only crop out in locations of uplift or erosion, consistent with being a thin layer, low in the stratigraphy, and their distribution (fig 2c) shows the possible elevation controlled extent of the ignimbrite deposits.

Spectrally-indistinct materials associated with the gradational boundary of these materials have resurfaced terraces down-thrown by caldera ring faults in the east of the caldera. This shows that emplacement of the materials hosting the light-toned inliers occurred after the initial stage of caldera collapse. However, none of the tectonic evidence at Meroe Patera supports catastrophic caldera collapse; cross-cutting relationships show that the resurfacing occurred before the second set of ring faults and the further subsidence of SMCCC. These lines of evidence argue against an endogenic origin of any ignimbrite deposits and suggest that the caldera was resurfaced part way through its development. We infer that the formation of Meroe Patera was contemporaneous with that of Nili Patera, contrary to the conclusions of some impact crater-based studies [8].

The texture and composition of the bright axial lava is consistent with a lava flow of high silica content, such as dacite. This material is spatially distinct (fig 2c) from the directly comparable material in Nili Patera [2]. However, unlike that, this material is not associated with a volcanic cone, perhaps suggesting that volatile content was less at this location and time.

Conclusions: Thermally-distinct materials in the SMCCC and Meroe Patera are light-toned materials cropping out in a range of styles, but are likely of an ignimbrite deposit, considering similar observations in Nili Patera. We find that Meroe Patera evolved through a simple piston like collapse pericontemperanously with the wider SMCCC.

Instead of an endogenic origin at Meroe Patera, we find evidence for resurfacing from outside the caldera during the course of its subsidence.

We identify a high-silica lava material in the central caldera complex, the second instance of such a material on Mars. Consequently, fractional crystallization leading to an extrusive eruption of a high silica magma reservoir was not unique to Nili Patera - adding to the growing body of evidence for evolved magmatic processes on Mars.

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