

**THE NILI PATEA CALDERA; EVOLVING MAGMAS, EXPLOSIVE ERUPTIONS AND HYDROTHERMAL DEPOSITS ON MARS.** P. Fawdon<sup>\*1</sup>, J. R. Skok<sup>2</sup>, M.R. Balme<sup>1</sup>, C. Vye-Brown<sup>3</sup>, D.A. Rothery<sup>1</sup>, C. J. Jordan<sup>4</sup> <sup>1</sup>Department of Physical Sciences, The Open University, Walton Hall, Milton Keynes, UK. MK7 6AA; peter.fawdon@open.ac.uk, <sup>2</sup>Department of Geology & Geophysics, Louisiana State University, Baton Rouge, LA 70803., <sup>3</sup>British Geological Survey, Murchison House, West Mains Road, Edinburgh, UK. EH9 3LA, <sup>4</sup>British Geological Survey, Nicker Hill Keyworth, Nottingham UK. NG12 5GG

**Introduction:** Nili Patera is a 45 km diameter caldera at the centre of the Syrtis Major Planum volcanic province [1]. Nili Patera is located at the northern end of a central caldera depression at Syrtis Major and is unique amongst martian volcanic terrains because it exhibits:

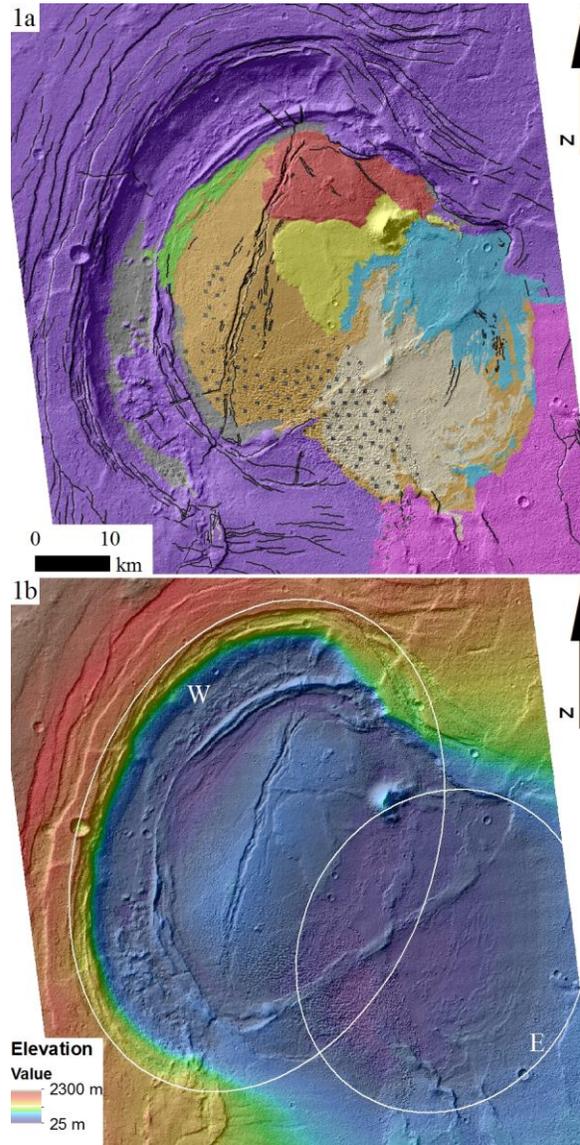
- Evidence of both effusive and explosive volcanism.
- Compositional diversity ranging from olivine rich basalts to dacite [2] and felsic units [3] at the lowest levels of the stratigraphy.
- Outcrops with spectral features indicative of hydrothermal silica [4].
- Asymmetric collapse with a maximum subsidence of 1800 m; dropping the caldera floor below the surrounding volcanic shield.
- A 300 m high resurgent dome in the western caldera floor.
- An active barcan dune system [5].

Our work addresses the stratigraphic and structural context of these discoveries and investigates Nili Patera's formation, magmatic evolution, caldera floor volcanism and the role of volatiles in the caldera. We present a geological map (figure 1) and history of Nili Patera to put these geological findings into context.

**Data and methods:** We used six 6 m/pixel Context Camera (CTX) images from Mars Reconnaissance Orbiter (MRO) to generate three 18 m/pixel Digital Elevation Models (DEMs) using SocetSet software. These DEMs were then used to orthorectify three CTX images as a base layer to produce the geologic map. Detail is provided, where available, from HiRISE (0.25 – 0.5 m/pixel) images, and mineralogical information is derived from all Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) visible-infrared spectrometer data available for the study area.

**Observations and discussion:** Figure 1 shows a simplified map summarising the geology and geomorphology of Nili Patera. Units are characterised at the highest resolution possible on a mineralogical and geomorphological basis, depending on the availability of derived mineralogy. The extents of units are mapped on to the CTX basemap. Units are then organised into

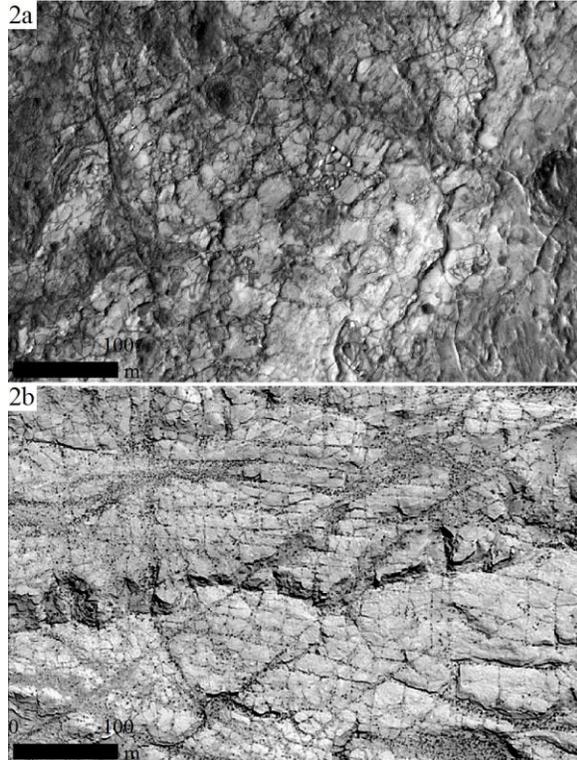
formations based on their spatial, temporal or genetic associations.



**Figure 1:** a. Simplified geological map of Nili Patera. Units and normal faults described in text, b. Topography from merged CTX DTMs over the hillshade.

*General physiography.* The caldera is subdivided into two parts. The western section (figure 1b; W), which formed first, is defined by normal and reverse faults systems (figure 1a; black lines), and has experienced the largest subsidence. The floor has a 300 m

high resurgent dome mirroring the tectonic boundaries of the western caldera floor. The eastern caldera section (figure 1b; E) is defined by subsidence associated with trapdoor collapse. Faulting at the margins cross-cuts faulting associated with the western caldera section. The eastern caldera floor is deformed by late-stage thrust-bounded wrinkle ridges and some minor normal faulting.



**Figure 2:** a. The bright fractured unit Nili Patera, b. Exposed ignimbrite in the Atacama, Lasca, Chili.

*Caldera-external lavas.* The oldest deposits are the pre-caldera lavas (figure 1; purple). Within this unit are large lava flows emplaced prior to caldera formation. This unit is crosscut by the normal fault forming the north-western caldera rim. To the south east are lavas emplaced after caldera formation in the central caldera complex (figure 1a; pink).

*Caldera-forming deposits.* Two units are associated with caldera formation. The lowest of these, exposed in the south east by 10-40 m of denudation, is a bright, fractured and layered unit with a characteristically felsic composition [3] (figures; 1a; white, 2a). Outcrops of this unit can be seen in ejecta from impacts within the caldera, in fault scarps of the resurgent dome and (possibly) as thin layers on parts of the interior caldera rim faults.

This unit has been considered an anorthosite pluton, supported by the compositional similarity to lunar anorthosites [6] and textural similarities to terrestrial

granite [3]. However the unit could instead be a welded felsic ignimbrite, associated with initial caldera formation in the west, and trapped in the topographic low in the east. This is consistent with the observed compositions, facilitates formation hypotheses for the western caldera, and is more consistent with detailed textural characteristics of the unit, especially considering terrestrial analogues (figure 2b).

Overlying these units is a rubbly basaltic pitted caldera floor unit which crops out across the south of the caldera floor and underlies later volcanism.

*Caldera floor volcanism.* Since caldera formation, there have been three phases of volcanism. In the north is an early basaltic flow field with associated effusive vents that has subsequently been dissected and uplifted by the resurgent dome in the western caldera floor (figure 1a; red). Following the formation of this unit, magma chemistry evolved, and the dacitic flow in the centre of the caldera was emplaced as was the 500 m high volcanic cone (figure 1a; yellow). Hydrothermal deposits [4] are found at the foot of the cone and on the dacite flow. The dacite flow now dips at  $2^\circ$ , tilted when the western caldera floor was uplifted to form the 300 m high resurgent dome.

Next, the northeast quadrant was resurfaced (figure 1a; blues) with rough and smooth textured volcanic material of uncertain origin. This unit onlaps the resurgent dome and is studded with ~ 15 low Cones, each 60 – 150 m wide.

A unit with a very strong olivine signature was also emplaced around this time (figure 1a; greens). The location on the western rim, the strength of the spectral response of the unit and late stage of emplacement suggest entrained crystal cumulates as opposed to natively high olivine content.

Finally, further subsidence resulted in a conjugate pair of wrinkle ridges bounded by thrust faults, cross-cutting and deforming units in the eastern caldera floor. This was probably a local response to shortening caused by regional subsidence of the caldera complex.

*Surficial units and erosion.* Since ~1.9 Ga [7] an aeolian processes have stripped back material in the south-eastern quadrant and formed the dune field, and which is active at the present day [5] (figure 1a; dots).

**References:** [1] Hiesinger, H. and J.W. Head, III, J. (2004) JGR 109(E1) E01004. [2] Christensen, P.R., et al., (2005) Nature, 436(7050) 504-509. [3] Wray, J.J., et al., (2013) Nature Geosci, 6(12): p. 1013-1017. [4] Skok, J.R., et al., (2010) Nature Geosci, 2010. 3(12): p. 838-841. [5] Silvestro, S., et al., (2010) GRL 37(20): p. L20203. [6] Cheek, L. C., et. al., (2013) JGR 118, 1805-1820. [7] Robbins, S.J., et. al., (2011) Icarus., 211(2): p. 1179-1203.