Icarus 302 (2018) 386–406

Contents lists available at ScienceDirect

Icarus

journal homepage: www.elsevier.com/locate/icarus

Clastic polygonal networks around Lyot crater, Mars: Possible formation mechanisms from morphometric analysis

L.M. Brooker[a,*], M.R. Balme[a], S.J. Conway[b], A. Hagermann[a], A.M. Barrett[a], G.S. Collins[c], R.J. Soare[d]

[a] Department of Physical Sciences, Open University, Walton Hall, Milton Keynes MK7 6AA, UK
[b] CNRS Laboratoire de Planétologie et Géodynamique de Nantes, Université de Nantes, 2 rue de la Houssiniére, 44322 Nantes, France
[c] Department of Earth Science and Engineering, Imperial College, Kensington, London SW7 2BP, UK
[d] Department of Geography, Dawson College, Montreal H3Z 1A4, Canada

ARTICLE INFO

Article history:
Received 6 March 2017
Revised 9 October 2017
Accepted 20 November 2017
Available online 21 November 2017

Keywords:
Mars, surface
Mars, climate
Geological processes

ABSTRACT

Polygonal networks of patterned ground are a common feature in cold-climate environments. They can form through the thermal contraction of ice-cemented sediment (i.e. formed from fractures), or the freezing and thawing of ground ice (i.e. formed by patterns of clasts, or ground deformation). The characteristics of these landforms provide information about environmental conditions. Analogous polygonal forms have been observed on Mars leading to inferences about environmental conditions. We have identified clastic polygonal features located around Lyot crater, Mars (50°N, 30°E). These polygons are unusually large (>100 m diameter) compared to terrestrial clastic polygons, and contain very large clasts, some of which are up to 15 metres in diameter. The polygons are distributed in a wide arc around the eastern side of Lyot crater, at a consistent distance from the crater rim. Using high-resolution imaging data, we digitised these features to extract morphological information. These data are compared to existing terrestrial and Martian polygon data to look for similarities and differences and to inform hypotheses concerning possible formation mechanisms. Our results show the clastic polygons do not have any morphometric features that indicate they are similar to terrestrial sorted, clastic polygons formed by freeze-thaw processes. They are too large, do not show the expected variation in form with slope, and have clasts that do not scale in size with polygon diameter. However, the clastic networks are similar in network morphology to thermal contraction cracks, and there is a potential direct Martian analogue in a sub-type of thermal contraction polygons located in Utopia Planitia. Based upon our observations, we reject the hypothesis that polygons located around Lyot formed as freeze-thaw polygons and instead an alternative mechanism is put forward: they result from the infilling of earlier thermal contraction cracks by wind-blown material, which then became compressed and/or cemented resulting in a resistant fill. Erosion then leads to preservation of these polygons in positive relief, while later weathering results in the fracturing of the fill material to form angular clasts. These results suggest that there was an extensive area of ice-rich terrain, the extent of which is linked to ejecta from Lyot crater.

1. Introduction

Terrestrial polygonal networks of centimetre- to decametre-scale patterned ground are common in cold-climate regions. They form by the thermal contraction of ice-cemented soils, in the case of fracture patterns, and/or the freezing and thawing of ground ice, in the case of patterned ground (e.g. Lachenbruch, 1962; Kessler and Werner, 2003). Patterned ground includes sorted patterned ground – frequently observed in periglacial environments, and thought to form through a combination of processes including frost heave and the upfreezing of clasts (Washburn, 1956; Feuillet et al., 2012) – and thermal contraction crack polygons, including various subtypes such as 'ice-wedge', 'sand-wedge', 'composite-wedge' and 'sublimation' (Marchant et al., 2002). Polygonal features have also been observed to form through the dehydration of volatile-rich material generally in arid conditions – termed desiccation polygons or desiccation cracks (Neal et al., 1968) – and through the polygonal weathering of exposed surfaces of boulders and rock outcrops (Williams and Robinson, 1989). Due to the large range of potential formation mechanisms it is important to pinpoint characteristics

* Corresponding author.
E-mail address: laura.brooker@open.ac.uk (L.M. Brooker).

https://doi.org/10.1016/j.icarus.2017.11.022
0019-1035/

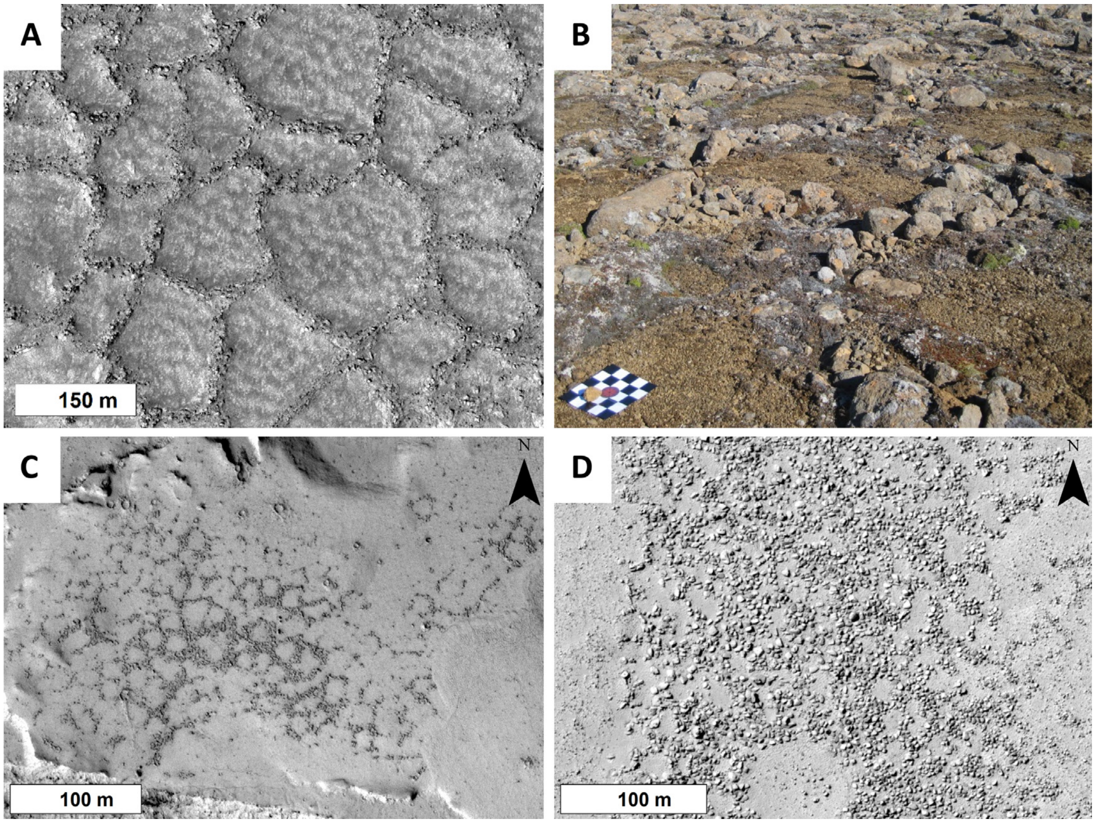

Fig. 1. **A)** HiRISE (ESP_016985_2315) image of part of a clastic polygonal network observed to the north-east of Lyot crater within the outer ejecta blanket. Image credit: NASA/JPL/University of Arizona. **B)** An example of morphologically similar terrestrial polygonal features found on Tindastóll Plateau, Northern Iceland. The scale is a 25 cm square with 5 cm markers. Image credit: Alex Barrett. **C)** HiRISE (PSP_004072_1845) image of possible sorted patterned ground located in the Elysium Planitia region of Mars (Balme et al., 2009). Image credit: NASA/JPL/University of Arizona. **D)** HiRISE (PSP_005597_1250) image of possible sorted patterned ground in the Argyre region of Mars (Soare et al., 2016). Image credit: NASA/JPL/University of Arizona.

unique to each polygon type to aid with identification, this is particularly key for their use as morphological (or perhaps process) analogues for features observed on Mars.

On Mars, polygonal surface features have been observed that range in diameter from metres to tens of kilometres (e.g. Pechmann, 1980; Seibert and Kargel, 2001; Mangold, 2005; Morgenstern et al., 2007; Soare et al., 2008; Lefort et al., 2009; Levy et al., 2011). Systematic study of these landforms and comparison with terrestrial analogues can help gain information into the mechanism by which they formed, and so gain insight into past and present environmental conditions. We have identified polygonal clast-bounded networks around Lyot crater, Mars. These polygons are enigmatic in that the clasts that demarcate the polygon sides are up to 15 metres across, with an average polygon diameter of 130 metres. This is significantly larger than morphologically similar polygons observed on Earth or on Mars (e.g., Fig. 1) which are found with maximum diameters of tens of metres (Washburn, 1956; Balme et al., 2009; Treml et al., 2010; Feuillet et al., 2012; Soare et al., 2016). Additionally, clastic polygons of this morphology and scale are – to our knowledge – unique to the ejecta blanket located around Lyot and so are of particular interest. Their distinctive morphology and location implies that there is a unique material and/or process leading to their formation. Thus, a better understanding of these features could provide useful information about the environment around Lyot, as well as the material that they are composed of.

The primary aim of this paper is to present the first in-depth study of these clastic polygonal features using both qualitative observations and quantitative morphometric measurements derived from high-resolution remote sensing data. Secondly, these data will be compared to both terrestrial and Martian polygon datasets collected from other studies in order to assess possible formation mechanisms and, finally, to infer a working hypothesis for their origin.

1.1. Lyot study area

Lyot crater (50°N, 30°E) is a ~215 km diameter, late-Hesperian-aged impact crater located north of Deuteronilus Mensae and immediately to the north of the dichotomy boundary. Lyot crater exhibits the lowest points of elevation in the northern hemisphere with a maximum depth of ~3 km in the crater interior (~7 km below datum). It has a central peak within an inner peak ring, and an extensive ejecta blanket composed of hummocky outer ejecta extending to ~2.5 crater radii from the crater rim, and smoother, more continuous inner ejecta with a marginal scarp which extends to ~1 crater radius from the crater rim (Fig. 2). The ejecta blanket is not well-preserved in the south and southwest due to superposition by deposits of the Deuteronilus Mensae region.

The impact event which formed Lyot crater is estimated to be late-Hesperian to early-Amazonian in age (~1.6 – 3.4 Ga; Greeley and Guest, 1987; Werner, 2008; Dickson et al., 2009). Large braided channels, extending > 300 km beyond the ejecta margins to the north, west and east of Lyot, are suggested to be the result of groundwater release during the impact event (Harrison et al., 2010). There are also numerous small channels present within the crater interior and inner ejecta blanket that are attributed to more recent fluvial activity, possibly associated with obliquity-driven climate cycles (Dickson et al., 2009; Fassett et al., 2010; Hobley et al., 2014).