Spatiotemporal development of two stepped fans in Xanthe Terra and Terra Sirenum, Mars

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INTRODUCTION

This study investigates stepped-fan deposits on Mars, focusing on their significance as indicators of past hydrological and climatological conditions. The research utilized advanced remote sensing techniques and landscape analysis to produce detailed geomorphological maps of two key sites: Picardi crater in Terra Sirenum and Dukhan crater in Xanthe Terra (Fig. 1). These sites showcase extremely well-preserved stepped-fan deposits, possibly have formed during groundwater sapping or short-lived groundice melting events in the late Hesperian or early Amazonian [1,2].

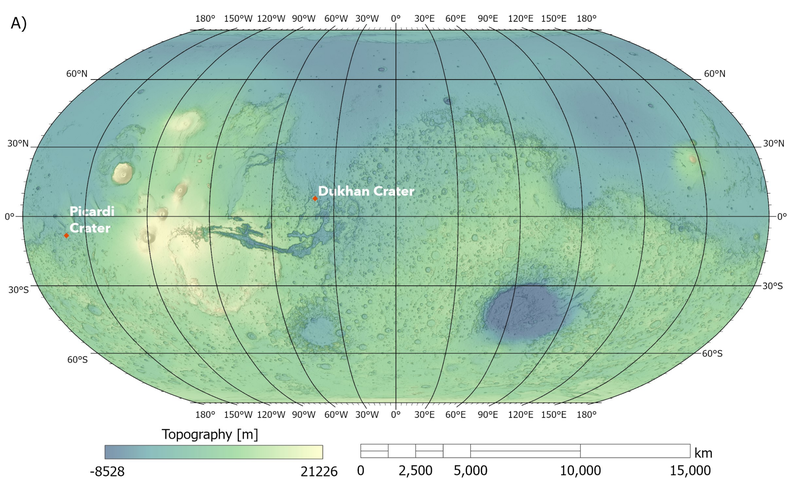


Figure 1: *A) Location of stepped-fan deposits in Picardi (Terra Sirenum) and Dukhan Crater (Xanthe Terra). B) Stepped-fan deposits in Picardi crater. C) Stepped-fan deposits in Dukhan crater.*

DATASETS AND METHODS

Utilizing data from NASA's Mars Reconnaissance Orbiter, including High Resolution Imaging Science Experiment (HiRISE) and Context Camera (CTX) imagery, alongside Digital Terrain Models derived of HiRISE and CTX stereo-pairs and HRSC DEMs for context, the study created high-resoluted and detailed geomorphological maps of the study sites. A synergistic mapping approach was adopted for the legend by combining the elements of the cartographic standard for planetary features by the USGS and integrating the symbology of the italian cartographic standard proposed by the Italian Geological Survey and the Italian Association of Physical Geography and Geomorphology [3].

RESULTS

The created maps are among the most detailed and high-resoluted maps featuring stepped-fan deposits on Mars. The map and the detailed landscape analysis provide insights into the complex origin of the fans and the landscape in which they are embedded. The geomorphological map showcasing the stepped fan deposits within Picardi crater was created at a scale of 1:70,000, while the map for the stepped fan deposits within Dukhan crater was created at a scale of 1:20,000.

Picardi crater, Terra Sirenum

- Showcases an exceptionally well-developed example of a stepped-fan deposit (see Figure 2)
- Seven distinct fan units originate from a single amphitheater-headed valley
- The units are deposited radially outward from the apex
- The fan is connected to a small, steep-walled valley

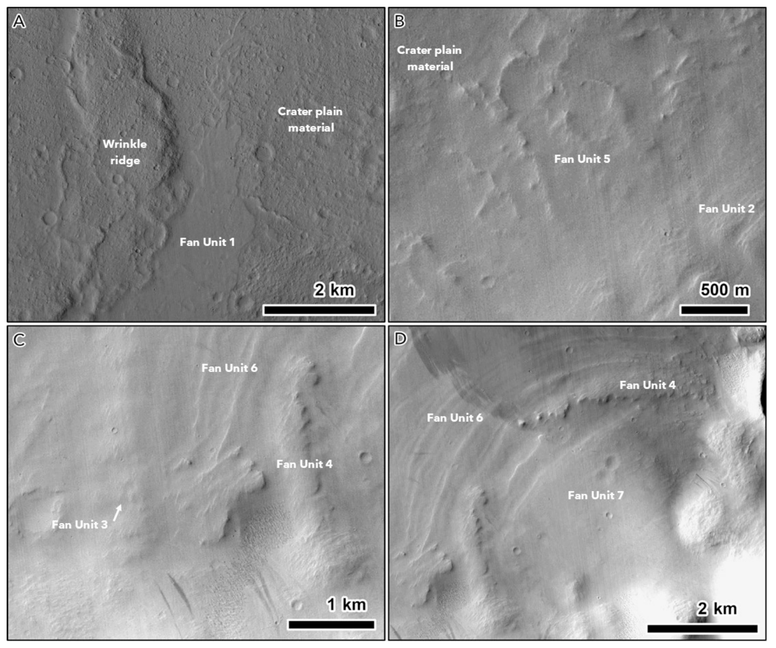


Figure 2: *Detailed HiRISE images of the Picardi crater fan deposit. A) Fan Unit 1. Wrinkle ridge and smooth, sparsely cratered sediments of Fan Unit 1 distal to the main fan-geological units. B) Fan Unit 5. Finger-like extensions at the topographically low, distal part of the main fan. C) Secondary, isolated fan deposit. D) Upper part of the fan deposits with Fan Units 6 and 7 covering the highly eroded, semicircular Fan Unit 4.*

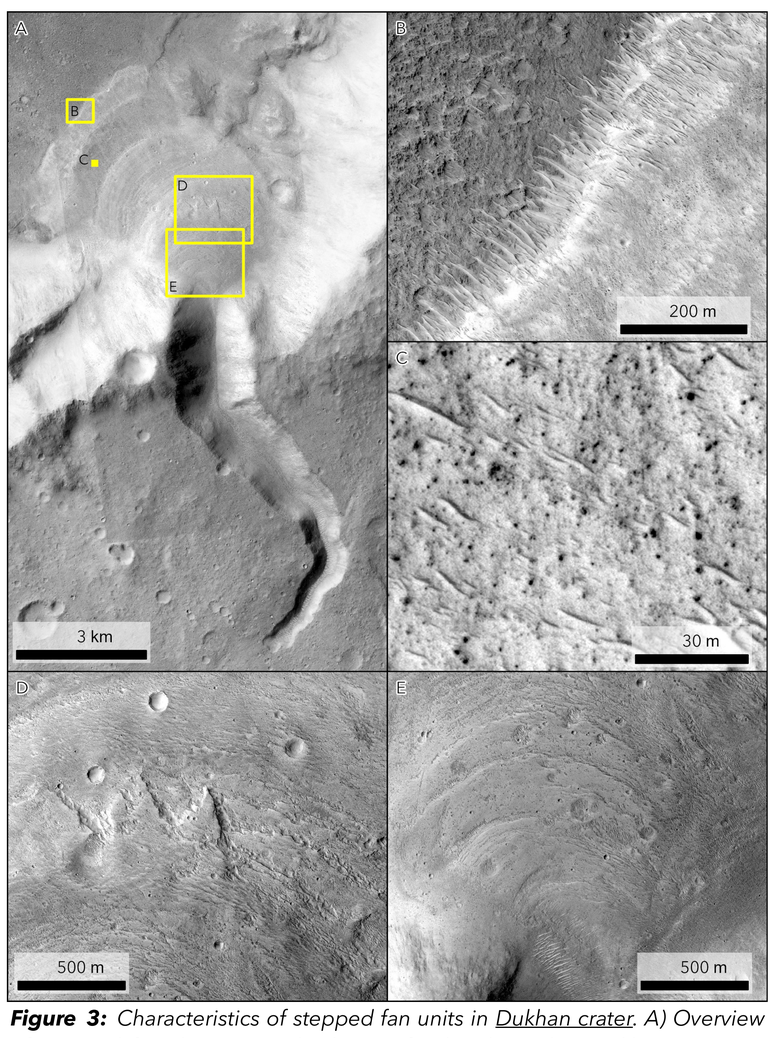


Figure 3: *Characteristics of stepped fan units in Dukhan crater. A) Overview of stepped fan deposits and adjacent feeder-channel in Dukhan crater. B) Distal transition zone between crater-plain material (NW) and the most distal Fan Unit 1 (SE). C) Coarse surface texture of flat-topped Fan Unit 1. Large boulders are visible, often several meters in diameter. D) Fan Unit 2, which is strongly eroded at its distal margin and superposed by Fan Unit 4. E) Fan Unit 4 showing flat-topped sub-units and substantial erosion on the eastern side. North is up in all panels.*

Dukhan crater, Xanthe Terra

Stepped-fan deposits in Dukhan crater consist of distinct units with varied characteristics:

- Fan Unit 1: Most distal, wedge-like shape, sparse cratering, large boulders on a flat top.
- Fan Unit 2: Partially covered by Unit 4, slightly higher albedo, erosion on its distal side.
- Fan Unit 3: Smooth surface with minor disruptions; forms the bulk of the fan.
- Fan Unit 4: Stratigraphically highest unit, erosion on its eastern side.

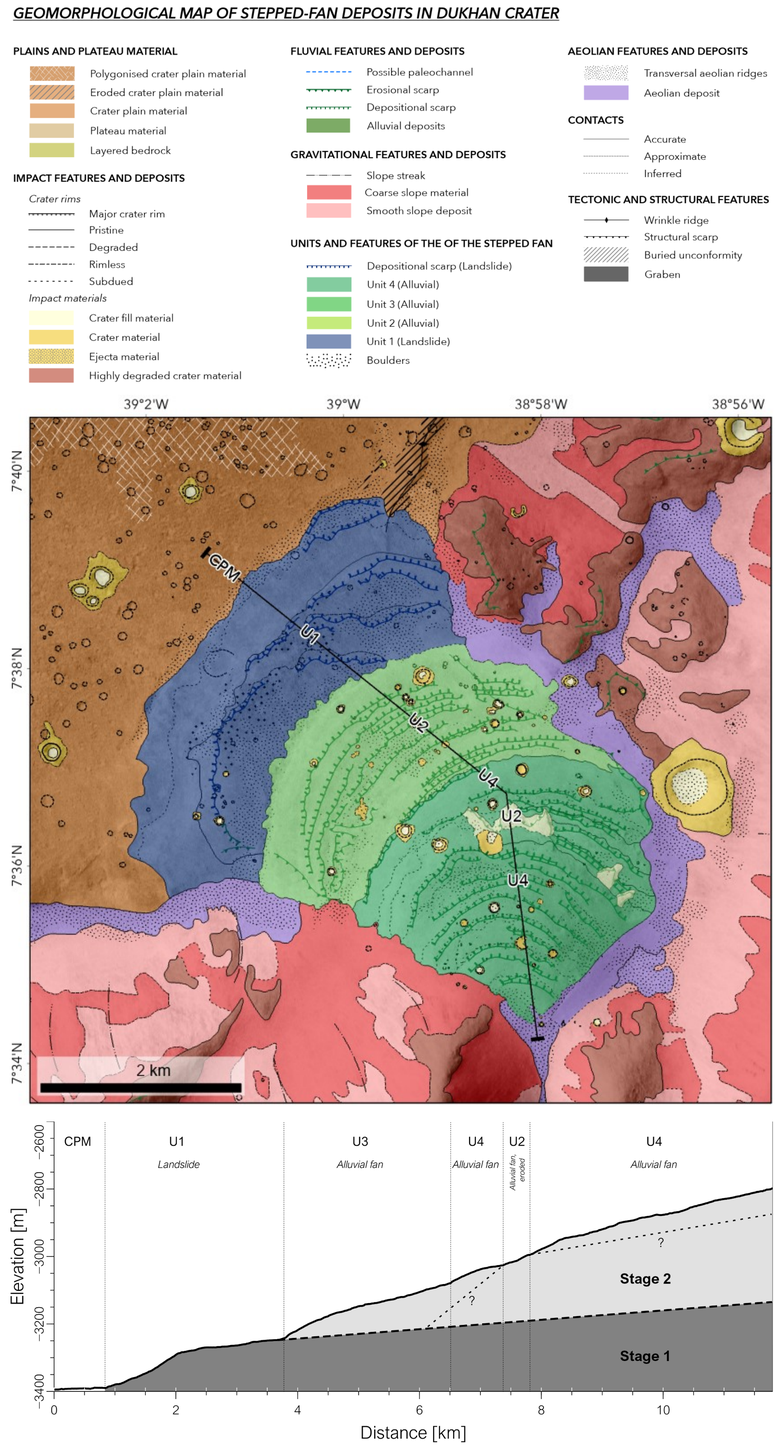
DISCUSSION

Picardi crater exhibits a complex evolution, transitioning from deltaic depositional in the lower fan to alluvial dominance in the upper fan. The formation mechanisms of these units suggest a dynamic interplay of environmental factors, including shifts in climate and hydrological activity.

In Dukhan crater, the stepped fan originated by different processes. The lowermost unit displays large boulders on its surface with diameters of >1 m and displays a massive sedimentary unit. It likely formed as a result of a landslide, and initiated the formation of the amphitheater-headed channel as a result of groundwater sapping [4, 5, 6]. The upper units, resembling conical, layered deposits, have characteristics of both alluvial fans and deltaic deposits, making their differentiation challenging.

CONCLUSION

The study reveals a more complex formation history for Martian stepped-fans than previously understood. Both Picardi and Dukhan craters show evidence of multiple processes, including deltaic, alluvial, and gravitational processes. These findings enhance our understanding of Mars' climatic and hydrological evolution, indicating shifts from water-rich to arid conditions over time.



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