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Inverted fluvial networks in the Antoniadi crater, Mars: A sedimentological and paleohydrological investigation

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Abstract

Valley networks are the main fluvial erosional landforms that document the extensive fluvial history of early Mars. Hundreds of examples of sinuous ridges are topographically inverted due to eolian deflation. The sedimentary structures of those landforms have the potential to record a rich history about their respective depositional environments. Therefore, herein, we briefly introduce the inverted channel forms which occur in Antoniadi crater and the mechanisms that led to the development of these landforms based on Saharan terrestrial analogues. Further work on the paleohydrological reconstructions for surface water hydrology and groundwater sapping processes could give us insights into the the evolution of the materials that partially filled Antoniadi crater and the associated paleoclimate records of Mars.

1. Introduction

Paleochannel systems preserved by inversion of relief have been identified on the Martian surface based on planimetric pattern at more than 200 sites. These form sinuous ridges that have been observed in spacecraft images, including MOC (0.5/12 m/pixel), THEMIS IR (100m/pixel), THEMIS VIS (18-36 m/pixel), CTX (~6 m/pixel), HiRISE (~0.3 m/pixel), CASSIS and the list continues to grow [1], [2]. These sites are interpreted to be relics of ancient fluvial activity, but there is less agreement on the source of water, the mechanisms of flow, and the histories of sedimentary deposit inversion [1]. The different geomorphic characteristics of inverted drainage networks on Mars indicate a range of paleofluvial environments that provide clues to the complicated fluvial history of the Martian surface [1].

Antoniadi is a 400 km diameter impact crater that formed an open-basin lake fed by valley networks [3]. It is estimated that Antoniadi crater lake needed around 30,000 km^3 of water for feeding it [3]. Inverted valley networks occur over the central part of Antoniadi crater. Therefore, investigating these landforms will provides key insights on the paleoenvironmental conditions on this region.

2. Morphology and Sedimentology

Based on our observations from HiRISE and CTX images, there are evidences of sediment induration and sediment lithification for the evolution of inverted channels in Antoniadi; existing of yardangs and recent geological formations indicates to sediment lithification (Fig. 1c), and fracture networks around examples (Fig. 1a and b) provide the sediment induration pathway. Sediment induration occurs when materials on valley floors are more resistant to erosion than the adjacent valley slopes due to cementation via formations of ferreicrete, silcrete, and calcrete with no burial [1], [2]. But fluvial sediments which followed a lithification pathway become more resistant to erosion due to burial and compaction. To address the problem of formative processes, we have been examining analogs in the eastern Sahara. In particular, we are investigating sediment induration at sites in southern Egypt and comparing them with examples of sediment lithification in the Dakhla Depression of Egypt (Fig. 2). Inverted stream channels in the southern part of the Egyptian Sahara show dendritic pattern, but in a few parts, the pattern is controlled by Nubia Formation to be sinuous linear ridges. In the Dakhla Depression, the exhumed meanders influenced the yardangs shape (Fig. 2b). Sediment induration pathway in the southern part of the Egyptian Sahara are densely cemented with iron oxide in the form of fibrous, crystalline hematite.

Also, cements of $CaCO_3$ and SiO_2 have been observed. For the exhumed meanders that developed by lithification in the Dakhla Depression, the sediments were compacted due to burial with a limited role of cementation. Samples for petrographic, geochemistry, and mineralogy were collected from both sites.

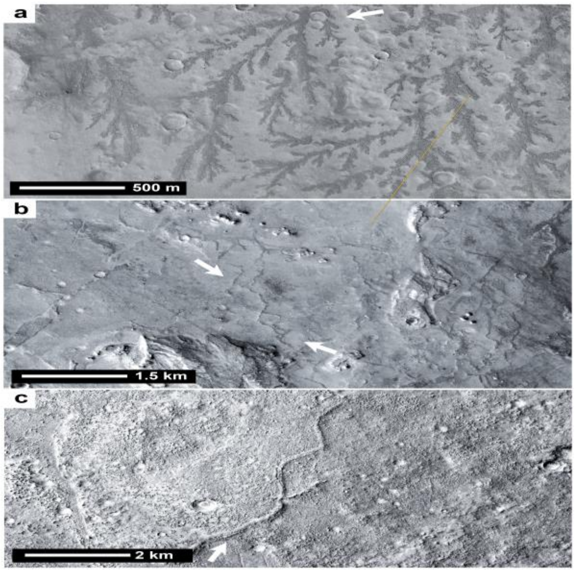

Figure 1. (**a**) Portion of a HiRISE image showing inverted short, stubby branches (ESP_012725_2015), (**b**) CTX image showing an inverted, anabranching stream system (P12_005816_2017_XI_21N298W), and (**c**) a lithified and exhumed channel surrounded by yardangs (CTX: K06_055528_2029_XI_22).

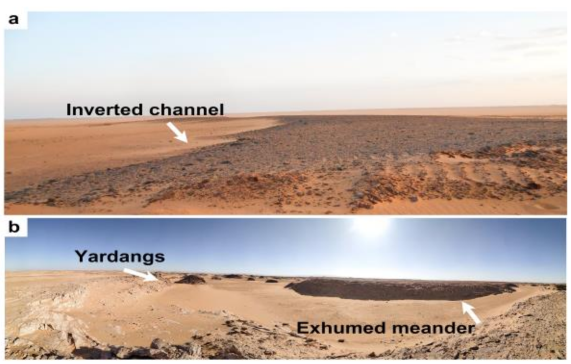

Figure 2. Field photographs showing; **(a)** an inverted channel on the Egyptian-Sudanese border, and **(b)** an exhumed meander in the Dakhla Depression, Egypt.

3. Paleohydrology

Based on the HiRISE and CTX images, the crater-fill materials exposed at the present surface in central Antoniadi exhibit at least three generations of inverted topographic features (Fig. 1). One of those generations, we interpret, was developed by groundwater sapping based on preliminary geomorphology (Figs. 1a), where the channels have short, stubby branches with growing headward. The other two generations seem to have developed by surface water hydrology (Fig. 1b, c). Estimating the paleohydraulics of those generations based on the geometry of those channels could give us new insights into the nature of the surface water-hydrology and groundwater sapping. Comparing inverted channel geometries in Antoniadi with modern terrestrial analogues may provide insights on paleoenvironmental conditions.

2. Summary and Conclusions

Inverted channels occur in the central part of Antoniadi crater. At least three generations have been identified based on investigation of CTX and HiRISE images. Incision of these channels appears to have resulted from surface water-hydrology and groundwater sapping. Sediment induration and sediment lithification are the main processes of the development of those features based on the geomorphic evidences. We are engaged in further work on the geomorphology, sedimentology, and paleohydrology of these features to reconstruct the paleoclimatic and tectonic conditions in the Antoniadi crater.

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