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Subsurface volume loss and collapse due to surface infiltration of Osuga Valles' catastrophic floods, Mars

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Abstract

Osuga Valles form a distinctive catastrophic system in which the flood events can be tracked from its chaotic origin down to its sink at terminal depressions or cavi (Fig. 1). We have begun analyzing Osuga's terminal cavi, centered around 14°50'S and 37°25'W, to understand the possible formation mechanism(s) of these depressions. The cavi's association with the outflow channels implies that there may be a link between the inflowing floodwater and the formation of the cavi, and hence the possibility of formation by surface collapse from subsurface dissolution processes, if such subsurface mineralogy existed.

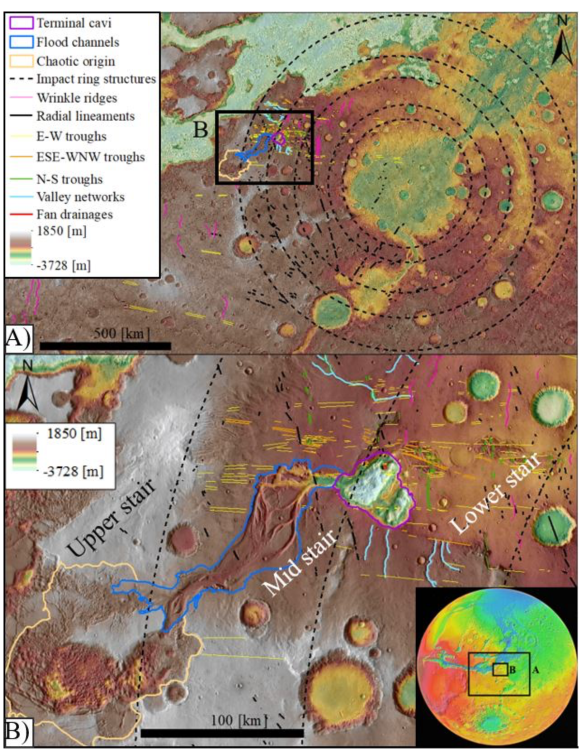

Figure 1: Structures around (a) and in the study area (b). THEMIS Day IR underlying MOLA DTM.

1. Introduction

The surface of Mars contains many types of depressions that are suggested to be the surface expression of volume loss resulting from magmatism [2], tectonic processes [4], cryosphere withdrawal and aquifer breach [3]. However, geochemical void-forming processes (e.g., karst dissolution), have not been similarly explored, although some depressions may be associated with buried salt deposits [3]. Chaotic terrains form depressions, which are generally located at outflow channel sources. It is assumed that their volume was lost as released groundwater and excavated load [3]. In the case of Osuga Valles, this volume seems to potentially contribute to the formation of its sink at the terminal cavi. Hence, our chaos-channels-cavi association study may contribute to understanding the possible depression formation mechanisms on Mars and add constraints to subsurface stratigraphy, past climate, and hydrology, with implications to astrobiology.

2. Surface Analysis

In this study, we mapped the cavi, the channels, and the chaotic source terrains in ArcGIS using CTX, HiRISE, and THEMIS data. MOLA tracks and HRSC DTMs were used to measure the depressions and channel system geometries. Impact ring structures divide the study area into three main elevation levels or stairs (Fig. 1), prior to the onset of catastrophic events. Our mapping showed that some structures served as hydraulic conduits. Through these topographic settings, some valley networks, which predate the catastrophic events, eroded into the steeper mid stair slopes and dissipated at the transition to the lower plateau stair. The main terminal channel - cavi transition in Osuga Valles is at this topographic stair. The cavi are situated within the lower plateau and are bordered to the south and west by the valley networks' higher terrains. The catastrophic channels cut through the ancient basin of the mid stair and head in two separate chaotic terrains at the upper stair (Fig. 1). The spatial association between these two chaotic terrains implies that the last outflow from the southern terrains postdates outflows from the northern terrains and produced higher discharges. Other sources were identified within and around the flood channels. The convoluted drainages of the valles, at the mid stair, are morphologically distinct and are linked by their spatial association, width, and depth, to different flood events. Shallower channels are cut by much deeper and wider channels and can be linked to fluvial morphologies that were identified on top of remnant collapsed blocks within the Cavi. These morphologies are interpreted to be alluvial fan segments that are associated with these earlier events. Before the system terminates at the cavi, the deeper channels merge at a cataract-like form. The fluvial morphology of this merged channel is at a much lower elevation. It continues inside the main cavus, but terminates where the depression's floor is cut by a secondary internal depression that postdates the collapse of the main cavus. The rims of this secondary depression are higher than the channel that they cut. The higher rims divert a mass flow, overlaying the flood channel. However, this mass flow is not necessarily related to the floods that formed the channel, as there are inverted landforms at this transition. Their existence suggests the flood channel was originally at the secondary depression's rim level and later on continued to erode while the rim remained high. At the lowest part of the internal secondary depression, there is a distinct outcrop of peculiar low albedo material in CTX. This outcrop appears relatively dark in THEMIS Night IR and is surrounded by relatively bright outcrops that fill the bottom of the secondary depression. The catastrophic channels erode into relatively low albedo terrains in CTX. The channels' upper segment has high albedo in CTX and is bright in THEMIS Night IR. There are no significant changes in thermal properties around the channels or depressions in THEMIS Day IR. Most of the main cavus' floor exhibits chaotic morphology, except for layering in its northern slope.

3. Summary and Conclusions

Our initial mapping suggests that preliminary volume loss and collapse resulted from lower discharges of infiltrating flood waters prior to the onset of collapse. Subsequent collapse was likely due to additional higher discharge flood events that drained directly into the forming depressions.

A terrestrial analog to Osuga's terminal cavi may be the Ze'elim Fan Sinkholes near the Dead Sea, Israel. These sinkholes are located at the termini of flood channels. Formation of these sinkholes was documented following flash flood drainage to pre-existing sinkholes. A suggested model for their formation is that groundwater dissolution of subsurface salt layer formed preliminary surface collapse, subsequently floodwater draining through the collapsed region became the dominant subsurface salt dissolution agent and induced farther surface collapse [1]. However, for the Osuga Valles terminal depressions, it is not clear whether the infiltrating flood waters removed the substrate volume by dissolving subsurface salt deposits, or by simply physically excavating subsurface fractures from rocks and melting ground ice. However, the region includes numerous older valley networks which terminate in this potential sedimentary basin, which implies that an evaporite-rich sedimentary basin previously existed at this site. We plan to estimate flood discharges using sediment transport equations and to assess the total subsurface volume loss by measuring and comparing the volumes of the cavi, channels, and chaotic sources. These calculations will help us to investigate the possible subsurface volume-changing geochemical processes that may have formed Osuga Valles' cavi and possibly other Martian depressions.

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