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Braided alluvial fan in the Terra Sirenum region, Mars

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1. Introduction

Amazonian-aged outflow channels on Mars have been recently identified using high resolution orbital data [e.g. 1, 2]. They display morphological evidence of fluvial erosion, including streamlined forms, scour marks, and erosional islands. In most cases, the source of water is interpreted as either a groundwater aquifer, melting of glacial deposits or ground ice (e.g., by impacts), or lake overflow. Irrelevant of the source, the presence of liquid water during the Amazonian has significantly increased our knowledge about the recent history of the Martian climate.

Here we report the presence of an Amazonian-aged outflow channel located on the rim of the Ariadnes Colles basin (37°S/178°E) that has an alluvial fan on its downstream part. The study area is located in the Noachian highlands of Terra Sirenum, the site of a large hypothesized paleolake [3]. This so-called Eridania lake existed during the Late Noachian-Early Hesperian and drained into Ma'adim Vallis, one of the largest valleys on Mars. The Ariadnes Colles basin was part of the Eridania paleolake and hosted later a closed lake.

2. Data and methods

We used HRSC and CTX images as well as CTX and MOLA topographic data (DTM) to analyze the morphological and hydrological characteristics of the Ariadnes outflow channel. We performed crater size frequency distribution (CSFD) analysis on CTX images to determine the absolute model ages of the fluvial events using CraterTools [4] and CraterStat 2 software [5], based on the chronology function of [6] and the production function of [7].

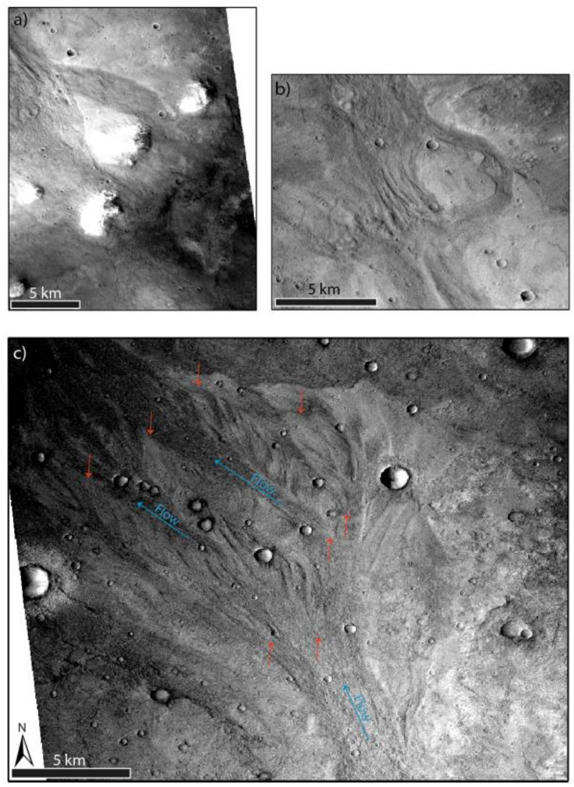

Fig.1: Morphological details of the Ariadnes outflow channel. a) Channel head. The water flowed through the gaps between the bright mounds, but the source of the water is unclear. b) Deep scour marks and erosional islands on the upstream section of the channel bed. c) Braided alluvial fan. The main channels are marked by blue arrows, and the beginning and ending of the major bar systems by red arrows.

3. Geomorphological investigation

The Ariadnes outflow channel is about 50 km long. It is incised into the ejecta blanket of a relatively fresh impact crater, and partly removed the ejected material. Besides the Ariadnes channel, the ejecta blanket has not been visibly modified by another erosional process and the crater has a sharp and steep rim. Crater counting of the ejecta suggests an absolute model age of around 1.7 Ga (Early Amazonian) for the impact event. We assume the crater age as the maximum age of the fluvial activity that formed the Ariadnes outflow channel.

The channel head is located at NE and SW sides of a 500 m height mound (Fig.1-a). The SW channel cuts the NE one, and therefore it formed later than the NE channel. Alternatively, both channel heads may have been active earlier but the last or few last outflow events occurred only through the left channel, which may as well reveal a change in the morphology of the source of water.

The channel has an average width of about 3 km and its depth varies between 30 m at its maximum and 10 m at its minimum. On the channel bed, we can observe deep grooves that are indicative of scouring of bedrock by catastrophic and high pressure flood flows [8] (Fig.1-b). Remnants of the ejecta blanket are visible as erosional islands (Fig.1-b). Whether the channel was carved by one continuous event or multiple events is unclear.

The downstream part of the channel is marked by a wide braided alluvial fan (Fig.1-c). An alluvial fan, by definition, forms when a confined feeder channel deposits most of its sediments load in an unconfined area [9]. This is the case for the Ariadnes outflow channel, as the feeder channel incised the ejecta blanket and, as soon as it reached the unconfined area downslope of the ejecta blanket, the deposition started. The absolute model age of the alluvial fan suggests an age of 470 Ma for the last fluvial event.

The alluvial fan, at its widest place, is about 15 km wide, and is composed of bars that are partly separated by multiple channels. These bars, deposited in the direction of the water flow, represent ever-changing patterns of migration and collision into each other (Fig. 1-c).

There is no clear morphological evidence of the source of the water. However, at the head of the channel, there is a closed depression that fits to the 400 m contour line (MOLA DTM). It may have hosted a lake, the overflow of which possibly carved the outflow channel.

4. Hydrological modelling

In order to better understand the formation mechanism of the Ariadnes outflow channel, we analyzed the channel hydrological parameter using the methods described in [10]. The alluvial fan volume of 2.4 km^3 is comparable with the volume of the eroded ejecta (2.52 km^3) on the upstream part of the channel. This suggests that no or very few sediments had been added to the system from the source area of water.

The discharge rate (Qw) has been estimated as 34 km^3/day for 30 m of channel depth and 6.9 km^3/day for 10 m. The volumetric sediment transport rate (Qs) is ~0.3 km^3/day and ~0.02 km^3/day respectively. We chose a grain size of 2 mm for the above calculation, which is the mean value measured by [11] using in-situ data of the MSL rover. The water to sediment ratio would be 130 to 370, which is a relatively high value compared to terrestrial examples of catastrophic flows. We have to note that due to the data resolution constraint and lack of some basic information e.g. precise grain size, these values may be overestimated.

5. Conclusions

The Ariadnes outflow channel represents clear evidence of one or several fluvial events in Terra Sirenum during the Amazonian. Based on the analysis of CSFD, we were able to narrow the channel formation time window from 1.7 Ga to 470 Ma.

The hydrologic modeling would provide important insights, e.g. the amount of water, flow duration, and source of water, into the understanding of the formation mechanism of this channel, as well as the climatic evolution of Mars.

References

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