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Possible glacio-fluvial landforms in southern Argyre Planitia, Mars: Implications for glacier thickness and depositional settings

H. Bernhardt[1], H. Hiesinger[1], D. Reiss[1], M. Ivanov[2], G. Erkeling[1], [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (h.bernhardt@uni-muenster.de), [2] Vernadsky Institute, Russian Academy of Sciences, Kosygin St. 19, 119991 Moscow, Russia.

Abstract

Our study presents new insights into possible formation mechanisms and glacio-fluvial implications of previously identified esker-like sinuous ridges on layered terrain in southern Argyre Planitia [1,2,3,4,5]. Based on detailed morphologic analyses and comparisons with terrestrial analogs, we interpret the ridges and their surroundings to be eskers on glacio-fluvial sediments. We propose the formation of northward trending degraded ridges to have involved back- and downwasting ice near the glacier rim comparable to the Piedmont-style Malaspina Glacier, Alaska [6]. Computational reconstruction suggests the eastward trending, more pristine ridges to have formed beneath a ~2 km thick ice sheet before its stagnant retreat. Fluvial landforms on top of or etched into possible glacial deposits also point to a distinct period of fluvial activity after glacial activity ceased.

1. Introduction

The southern rim of the Argyre basin on Mars between -52°S/-59°S and 310°E/322°E shows several landforms of likely glacio-fluvial origin [e.g., 1,2,3]. We compiled a new detailed geomorphologic map of the study area (Fig. 1), whose southern half consists of the heterogeneous Charitum Montes highland terrain (blocky, mountainous, or smooth upland terrain: UTb; UTm; UTs), representing the southern rim of the Argyre basin. The northern half represents the southern basin floor consisting mostly of rough, layered terrain (BFlr), slowly changing to intermediate and smooth terrain (BFli, BFls) within a ~100 km wide zone circumferential to the Charitum Montes. Sinuous, layered and branching ridges, up to 300 km in length and 160 m in height can be seen on the basin floor with their apparent vertices being located close to the mouth of Surius Vallis (Channel: Cha).

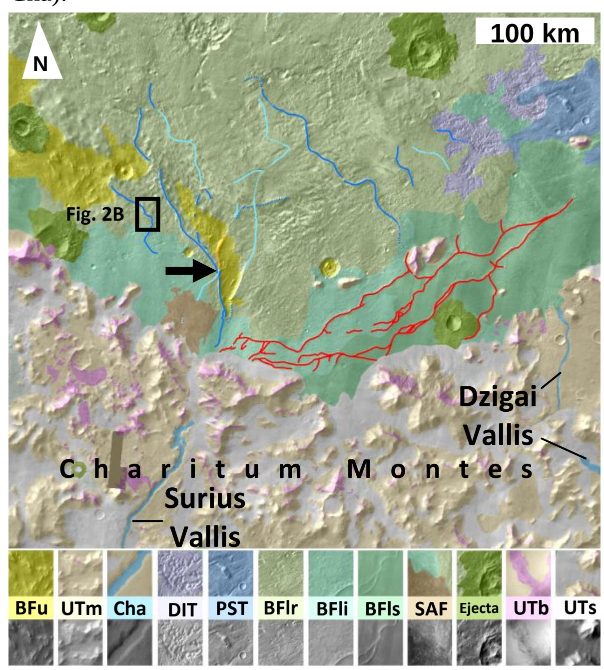

Figure 1: Geomorphologic map of southern Argyre Planitia (background THEMIS-IR Day). Units are explained in the text.

2. Morphology and stratigraphy

Absolute model ages based on crater counts on unit BFl suggest a formation of the esker-like ridges along with a suite of layered sediments on the floor of the Argyre basin ~3.7 – 3.5 Gyr ago. Unstratified parts of the basin floor are exposed in a ~1 km deep V-shaped depression ~70 km north of the mouth of Surius Vallis implying a sediment thickness of at least ~340 m. On the basis of the braided pattern and state of degradation of the sinuous ridges, we subdivided them into two populations, which could in turn reflect changing conditions of glacial retreat:

- Population I (Fig. 1, red lines) consists of northeast trending ridges that show patterns of multiple branching and braiding and appear less degraded
- Population II (Fig. 1, blue lines) consists of northward trending, solitary, and more degraded ridges, with layers extending into the adjacent terrain

Based on the analysis of crest shapes of the more pristine ridges of population I and their surrounding surface gradients, we used the transition method and the oblique path method [7,8] to compute four ice surface gradients of the glacier under which they might have formed. According to this reconstruction, the ice sheet reached a thickness of ~2 km if a conservative glacial terminus near the end of the easternmost ridge is applied. This would imply at least ~100,000-150,000 km³ of ice on the southern floor of the Argyre basin during the time the population I-ridges were deposited.

3. Discussion

In order to explain the transition of layers from the ridges into their surroundings, subglacial cavities in contact with subice channels have previously been proposed [3] as depositional environments. However, due to the vast extent of the population II-ridges on terrain with visible layering (over 40.000 km²), such a scenario has significant uncertainties, as subglacial cavities are spatially limited features. A more suitable scenario can be observed at the Piedmont-style Malaspina Glacier, Alaska [6], and was also proposed for terraced landscapes around Pleistocene eskers in Canada [10]: A glacial retreat involving backwasting of stagnant ice lying beneath fresh outwash sediments (Fig. 2), thereby creating a degraded and layered lag around the emerging eskers. If outwash sediments were fed by the same drainage source as an esker, sections of layers can extend from the ridge into the surrounding deposits. Therefore, we propose that the difference between the two ridge-populations represents a change of the subglacial drainage direction coupled with diminished downwasting, possibly due to a decreased deposition of outwash sediments.

After sedimentation during this proposed glacial period had ceased, a distinct period of fluvial activity

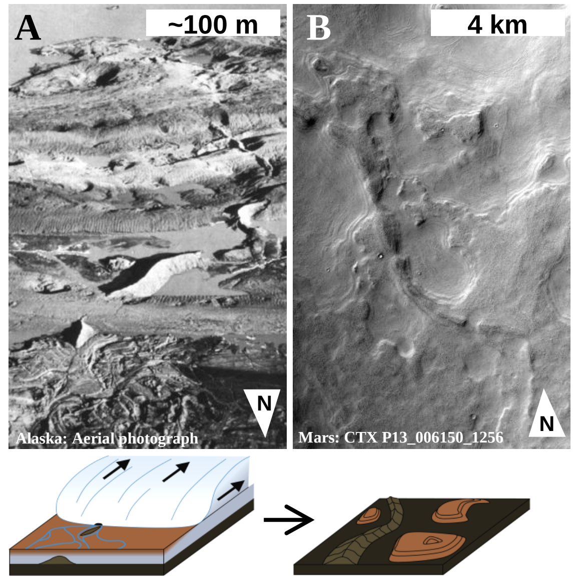

Figure 2: (A) Degraded esker at the margin of Malaspina Glacier, Alaska, sitting on ~100 m thick ice. The outwash-fan in the foreground was fed by the same drainage tunnel that formed the esker [9,10]. (B) Population II-ridge among degraded, terraced terrain in Argyre Planitia, Mars (shown on Fig. 1).

is indicated by a large alluvial fan (unit SAF), a channel-like trough (Fig. 1, black arrow) and vast streamlined terrain (PST) overlying or being etched into possible glacial deposits.

4. Summary and Conclusions

Two morphologically distinct esker-like ridge populations in southern Argyre Planitia likely reflect the transition between two modi of glacial retreat in the Hesperian: Wet-based - involving down- and backwasting of ice and outwash sediments similar to Piedmont-style glaciers like Malaspina Glacier, Alaska; and stagnant (possibly later cold-based) - preserving more pristine ridges, which enabled the computational reconstruction of a ~2 km-thick ice sheet. During a distinct period of fluvial activity, streamlined landforms were emplaced on top of the glacial deposits.

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