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Pilot investigation of reported volcanic flow sequences in the Syria-Sinai-Solis province

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Abstract

Geologic investigations point to a dynamic history for the evolution of the Tharsis rise, including major stages of activity, which includes distinct flow sequences. Furthermore, such putative stages of activity have been proposed to contribute significantly to transient environmental change, including major volatile release, flooding, ponding in the northern plains to form large bodies of water, and climatic perturbations. Our primary objective is to investigate these possible stages through delineating and crater counting individual lava flows within a candidate flow sequence and comparing their crater-retention ages with flows of an adjacent candidate flow sequence. We report preliminary findings of our first target, the southeastern flank of shield complex of Syria Planum, including parts of Sinai and Solis Plana.

1. Introduction

The Tharsis rise displays a variety of geologic characteristics, including: 1) distinct episodes of intensive magmatic/tectonic activity that declines with time, including development of local and regional centers of tectonic activity of varying age, size, and duration of formation, 2) fault and rift systems of varying extent and relative age of formation, including vast canyon systems of Valles Marineris, 3) a suite of diagnostic landforms, including volcanic constructs of diverse sizes and shapes and extensive lava flow fields, large igneous plateaus, canyon systems, and systems of radial faults and circumferential systems of wrinkle ridges and fold belts, and 4) early explosive activity transitioning into more concentrated volcano and fissure-fed eruptions [1].

In particular, the Tharsis rise records extensive volcanism as manifested by multiple large shield volcanoes and associated extensive lava plains such as observed for the shield complex of Syria Planum (Fig. 1). In addition to magmatic-driven activity, which includes plume manifestation [2], the massive load of kilometer-thick volcanic deposits and edifices induced stress onto the upper crust at regional scale resulting in numerous fault systems. These systems were formed during at least five tectonic phases [3,4]. Those mostly extensional phases were likely accompanied by major magmatic activity. Such magmatic pulses would have had a sustained impact on climate and atmospheric composition due to the release of large quantities of volatiles and ash [e.g., 5].

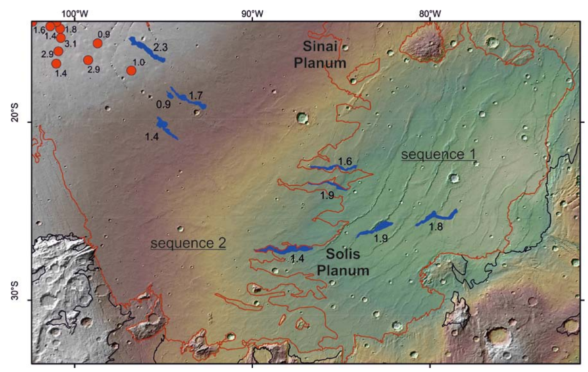

Fig. 1. Study area of the SE flank of the shield complex of Syria Planum, extending into Sinai and Solis Plana. Tentative sequence boundaries (red lines) and mapped lava flows (blue) are shown. Other units are outlined in black [e.g., 8]. Dots represent low-shield volcanoes [11]. Numbers refer to the formational age of lava flows/shields.

Individual rock units mapped in various parts of Tharsis have been already distinguished and related to magmatic/tectonic sequences [6-8], however, detailed analysis of those surface units and sequences are lacking. In a pilot study, we analyze two proposed major flow sequences along the southeastern flank of the Syria Planum shield complex, which includes Sinai and Solis Plana. Here, individual lava flows were mapped and their formational ages determined using crater size-frequency distributions.

2. Background: Syria, Sinai, and Solis Plana

Syria Planum is a complex shield volcano with at least three major flow sequences identified and mapped [8]. Sheet lavas were emplaced in the Syria-Solis province from the crustal areas and flanks of Syria Planum. Younger ridged plains material (unit Hr) of Sinai province appear to be partly buried by lava flows mapped as three major flow sequences, identified as older flows of lower member, younger flows of lower member, and upper member of the Syria Planum Formation (units Hsl_1, Hsl_2, and Hsu, respectively) [6, 8]. Lava flow materials show an age progression from the southeast (older) to the northwest (younger). In the southeast, subdued, individual lava flows and their flow fronts of unit Hsl_1 are scarce whereas in the northwest, pristine lava flows and flow fronts of the upper member are numerous; an extended period of wind erosion may have contributed to the subdued appearance of the older flows of the lower member.

3. Methods

Lava flows of two possible flow sequences were mapped using THEMIS IR day and night image data. Contacts and the traceable extents of lava flows were verified using HRSC data. Crater counts of representative areas were performed using CTX images, and ages were modeled following [9,10].

4. Results

For each flow sequence, we mapped 4 to 5 lava flows. The full extent of older sequence-1 lava flows (mapped as unit Hr in [8]) cannot be mapped. Margins and contacts are often subdued, buried, or mantled. Lava flows of sequence 1 are marked by wrinkle ridges, suggesting that the materials were deformed by tectonism. On the other hand, it is possible that several of the wrinkle ridges were embayed and partly buried by lavas, as several of the wrinkle ridges only display ridge crests.

In contrast, lava flows of sequence 2 (younger; mapped as units Hsl_1 and Hsl_2 by [8]) have rather well-defined margins and contacts. Their distal flow fronts are exposed and can be traced to medial to proximal reaches. Sequence-2 lava flows also appear thicker than sequence-1 flows. In addition, the area is also characterized by faults, pit chains, and low shield volcanoes.

Preliminary emplacement ages of individual lava flows vary from 0.9-2.3 Ga (Early/Middle Amazonian, Fig. 1). Lava flows of sequence 1 appear to have formed between 1.4-1.9 Ga whereas sequence-2 lava flows show a broader variation in formation ages ranging from 0.9-1.7 Ga (Middle Amazonian) with one lava flow formed at 2.3 Ga.

5. Discussion

Geologic mapping of the Syria Planum shield complex, which includes Sinai-Solis Plana revealed lava flow sequences based primarily on the presence/ absence of wrinkle ridges, lava flow morphologies, and crosscutting relations among rock materials and structures [8]. Emplacement ages of nine individual lava flows (0.9-2.3 Ga), however, do not directly reflect the inferred hiatus between sequence formations. Though further work is necessary, there are several considerations: (1) the preliminary results may not be unusual, since most low shield volcanoes near the summit of Syria Planum were formed between 0.8 to >1.6 Ga with some shields being as young as 0.3 Ga [11]; (2) fissure-fed eruptions sourcing from faults and lava tubes which transect older and younger apparent flow sequences likely dilute the crater retention ages, as flows of a younger sequence could be emplaced among older flow sequences; and (3) there may not be distinct volcanic flow sequences or it may not be possible to identify, map, and determine the extent of volcanic flow sequences from orbital-based assets. Such considerations have a major bearing on geologic mapping efforts of volcanic flow materials.

5. Future work and implications

We will continue to map and crater count individual lava flows in mapped sequences of Syria Planum and other parts of Tharsis. Continued lava flow mapping and dating will help constrain whether Tharsis recorded major volcanic flow emplacement phases, ultimately having a direct bearing on geologic mapping efforts and the assessment of the possible contribution of Tharsis to environmental and climatic changes.

References

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