ASCRAEUS MONS FAN-SHAPED DEPOSIT, MARS: GEOLOGICAL HISTORY AND VOLCANO-ICE INTERACTIONS OF A COLD-BASED GLACIER. R.L. Parsons and J.W. Head III, Department of Geological Sciences, Brown University, Providence, Rhode Island 02912, USA (Rebecca_Parsons@Brown.edu).

Introduction: Ascraeus Mons is the northernmost of the three Tharsis Montes shield volcanoes (Arsia Mons, Pavonis Mons, and Ascraeus Mons), which are aligned along a N40°E trend on the crest of the broad Tharsis Rise. These three volcanoes, by virtue of their great size and apparent similarity to terrestrial shield volcanoes such as Mauna Loa, Hawaii, have attracted considerable attention in the study of the geologic history of Mars. Previous studies have included investigations into their caldera morphologies as an indicator of late-stage summit activity [1,2,3], investigations into the evolutionary history of the volcanoes based on analyses of structural and morphologic features on and around them [4,5,6], and combined morphologic studies and crater counting to improve understanding of the overall stratigraphies of the volcanoes and the surrounding terrains [5,7]. Several of these studies provide evidence to show that although Arsia, Pavonis, and Ascraeus Mons have had similar structural histories; differences between the three imply that each has a unique variation on the theme.

One particularly interesting commonality between the three Tharsis Montes shield volcanoes is the occurrence of a distinctive and unusual fan-shaped feature, extending approximately northwest, on their western flank. Based on crater counts, these deposits are thought to be among the youngest in the region, forming during the Upper Amazonian concurrent with late-stage, minor volcanism, most likely in the form of fissure eruptions on the flanks of the volcanoes [7]. Three major facies, a ridged, a knobby and a smooth facies, are generally contained within the fan-shaped deposits [6-12].

For some years there has been a debate over the emplacement of these fan-shaped features. The problem is important because it contributes to an understanding of the environmental history of the Tharsis region, Mars' most prominent tectonic and volcanic region [13]. Based on Mariner 9 and Viking Orbiter images various interpretations of the origin of these features have been proposed including gravity-driven sliding [4,7,15,18], glaciation [16, 17], a combination of a catastrophic sliding and subsequent pyroclastic activity [6,18], and a combination of sliding, volcanism and ground-ice activity [10].

More recently, various authors [9,12] have used newly available MOLA data combined with MOC and THEMIS images to build on early comparisons of the fan-shaped features with terrestrial glacial deposits, such as the recessional moraines of Malaspina glacier in southeastern Alaska [17]. These later studies have used depositional frameworks of polar glaciers in the Antarctic Dry Valleys to demonstrate the consistency of the fan-shaped features with cold-based glacial deposits [9,12]. In this scenario, the ridged facies are interpreted as drop moraines formed from lateral retreat of cold-based ice, the knobby facies forms from in-situ downwasting of the ice in a process analogous to sublimation till formation, and the smooth terrain represents relict features of debris-covered ice or rock glaciers.

The work presented here focuses on Ascraeus Mons (Figure 1), which is the tallest of the three Tharsis Montes, rising 17 km above the surrounding plains to attain an elevation of 18.5 km above the Mars mean datum. Our purpose is a re-examination of the Ascraeus Mons fan-shaped deposit using higher resolution data than has previously been available, namely MOC and THEMIS images coupled with MOLA data, in order to assess the plausibility of a cold-based glacial origin and other possible processes of origin for the deposit.

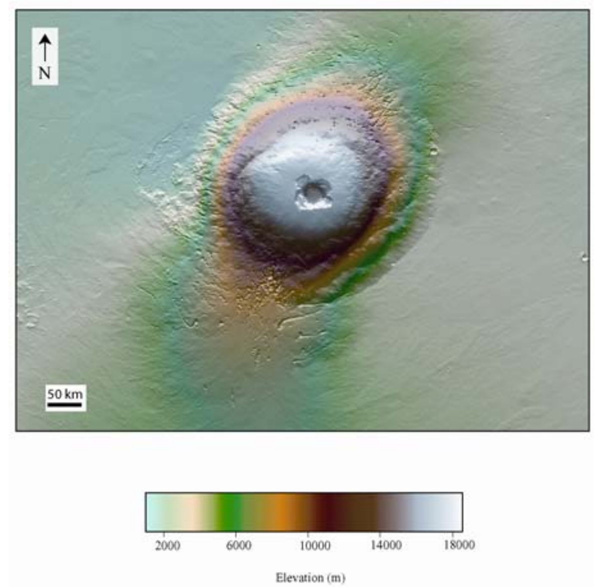

Figure 1: MOLA topography of Ascraeus Mons superposed over a shaded relief map.

Characterisation of the fan-shaped deposit: The Ascraeus fan-shaped deposit (Figure 2) is ~180 km at its widest point, and extends ~100 km from the shield base along a N82°W trend. The deposit is emplaced on the Tharsis Plains unit (At_5 in [7,10]), which consists of Amazonian sheet-like flows from Ascraeus Mons. Overall, the deposit covers a surface area of 14,000 km^2, which is significantly smaller than its counterparts at Arsia and Pavonis Mons (Table 1). The Ascraeus Mons deposit covers an elevation range of 1.5-2.5 km above the Mars mean datum, with a large portion being located within a topographic depression adjacent to the western flank of the volcano. This lower section is separated from the distal margins of the deposit by an arcuate scarp with a relief of ~180 to 300 m. The southern end of this scarp appears to have been disrupted by a lobate lava flow that can be traced from a source near the SW flank of Ascraeus Mons (Figure 2). Interestingly, this flow appears to trace the rim of the depression that contains a large portion of the deposit, rather than flowing into it like earlier lava flows.

Table 1: Morphometric data for the Tharsis Montes fan-shaped features.

	Arsia	Pavonis	Ascraeus
Surface area (km^2)	180,000	75,000	14,000
Trend	N62°W	N27°W	N82°W
Elevation range (km)	2.7-5.5	2.9-4.5	1.5-2.5
Length (from shield)	450	235	100

Previous studies of the Ascraeus Mons fan-shaped deposit have reported fewer interior deposits compared to the fan-shaped deposits of Arsia and Pavonis Mons [6,19]. Zimbelman and Edgett [6] reported observations of ridged and knobby facies within this deposit, but noted an apparent lack of any unit equivalent to the smooth facies observed at the other Tharsis Montes. Current geomorphic mapping based on a wider suite of image data has enabled us to identify three morphologically distinct units:

Ridged Terrain. This consists of at least seven near-continuous, concentric ridges that trace the distal edge of the deposit over a distance of ~180 km. Ridges have a mean spacing of ~800 m, but tend to converge towards the northern and southern portions of the deposit. MOLA data reveal general ridge heights of 10-40 m except for the outermost ridge, which is the most prominent reaching heights of up to 80 m. Additional smaller ridges (<10 m high) can be observed ~20 km east of the outer ridge. Ridges appear to cross-cut each other without disruption, which is consistent with the "blanket-like nature" [9] of ridges of the Arsia and Pavonis fan-shaped deposits.

Hummocky Terrain. This forms an almost continuous deposit covering an area of ~1800 km^2. Hummocks contained within this unit can be subdivided into two distinct types: (1) numerous rounded to sub-rounded hummocks, several km in diameter and tens of km in height ('knobby facies' in Figure 2), and (2) arcuate, ridge-like hummocks ~800 m long and ~60 m wide aligned approximately N60°E ('complex hummocks' in Figure 2). The former hummock type is consistent with the knobby terrains observed in the Arsia and Pavonis fan-shaped deposits, which have been interpreted as analogous to sublimation till in terrestrial glacial environments. The latter hummock type appears consistent with thumbprint terrain observed elsewhere on Mars, and interpreted as glacial in origin [e.g. 17,20].

Flow-like Feature. A relatively flat-topped, elevated plateau can be observed ~7 km west of the shield base in the central portion of the deposit. This mesa-like feature is 34 km long, 19 km wide, and is elongated north-south. Morphologically similar features have been described from the Pavonis fan-shaped deposit [12] and from central Acidalia Planitia [21], where they have been compared to terrestrial subglacial lava flows and table mountains, respectively. Other interpretations from studies of the Tharsis fan-shaped deposits include eskers formed by sedimentary deposition beneath or within a wasting ice sheet [10], unique lava flows [10], and shield base remnants [6].

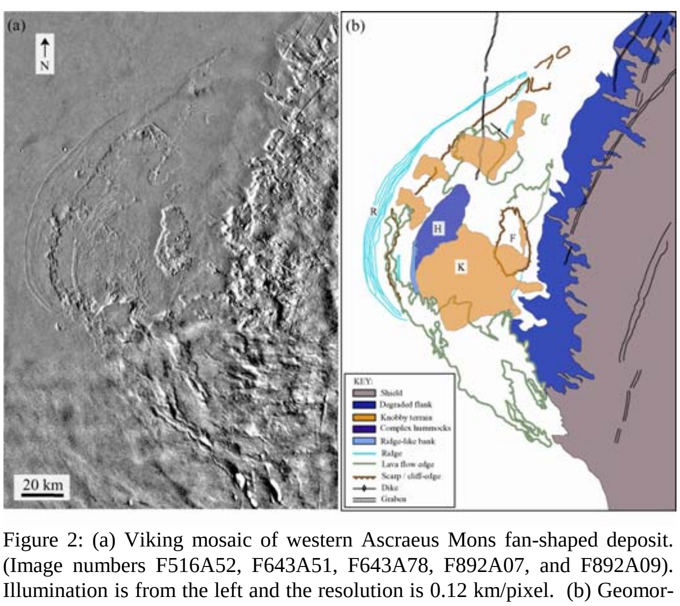

Figure 2: (a) Viking mosaic of western Ascraeus Mons fan-shaped deposit. (Image numbers F516A52, F643A51, F643A78, F892A07, and F892A09). Illumination is from the left and the resolution is 0.12 km/pixel. (b) Geomorphic sketch map of the deposit superposed on Viking mosaic (fan-shaped feature units highlighted: 'R' ridged facies, 'K' and 'H' hummocky terrain, and 'F' flow-like feature).

Glacial history of the area: Based on stratigraphic relations and our interpretations of each facies, we envision two end-members for the glacial history of the area: (1) the area represents a relict landscape that has subsequently been covered by cold-based ice resulting in the passive emplacement of glacial deposits, and (2) ice has been more instrumental in carving the landscape with intimate volcano-ice interactions.

1. Relict landscape and subsequent glacial deposition. In this scenario, the landscape was predominantly modified prior to the accumulation of ice. The scarp formed from faulting accompanying the tectonic development of the Ascraeus shield volcano, perhaps becoming more pronounced due to the affects of aeolian erosion. The degraded western flank, the mesa-like remnant of the shield base, and exposure of a dike at the surface in the northern part of the deposit could all be used to suggest that long-term aeolian erosion has exhumed a relatively old surface. Similar to the Antarctic Dry Valleys environment [e.g. 22], this relict surface would have been preserved beneath cold-based glacial ice. Hence, ice had only a minor impact on the landscape with the deposition of ridged and hummocky terrains during its recession.

2. Intimate volcano-ice interactions. In this alternative scenario, glacial deposition occurred concurrent with volcanic activity. The position of the scarp represents a stable margin of a relict glacier, and formed when one or more lava flow(s) cooled and solidified against its margin. As the lava accumulates against the ice, it will rapidly form a chilled margin that insulates the hot flow interior and prevents extensive melting of ice [23]. Following scarp formation, ice advanced to the position marked by the distal edge of the ridged facies. The formation of the ridged facies is a result of step-wise retreat of the glacier. A lava flow that can be traced within the depression adjacent to the western flank was then emplaced after the ice retreated completely. Subsequent re-advance and down-wasting of the ice resulted in the superposition of knobby terrain over the underlying landscape.

Conclusions: Geomorphic mapping of the Ascraeus Mons fan-shaped deposit implies a more complex history for this volcano than has previously been thought. The fan-shaped deposit on the western flank of Ascraeus Mons does provide significant evidence in support of a cold-based glacial origin. However, volcanism also appears to have been a factor in the evolution of these deposits.

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