

**THE AGE AND MORPHOLOGY OF THE ASCRAEUS MONS FAN-SHAPED DEPOSIT.** S. J. Kadish<sup>1</sup>, J. W. Head<sup>1</sup>, and D. R. Marchant<sup>2</sup>. <sup>1</sup>Dept. Geol. Sci., Brown University, Providence, Rhode Island 02912 USA (Seth\_Kadish@Brown.edu), <sup>2</sup>Dept. of Earth Sci., Boston University, Boston, Massachusetts 02215 USA.

**Introduction:** Fan-shaped deposits (FSD) extending to the NW of each of the Tharsis Montes have been interpreted to be a series of glacial deposits [1-4]. Geomorphological observations, supported by atmospheric and glacial modeling, suggest that the accumulation and sublimation of snow and ice produced the cold-based glaciers responsible for the deposits. The glaciers formed during periods of high obliquity [5], when increased polar insolation caused sublimation of the icecaps [4]; volatiles were transported to lower latitudes and deposited via precipitation of ice and snow, in this case on the NW flanks of the Tharsis Montes [4].

Although the FSDs at each of the Tharsis Montes show a number of similarities, the character of the facies and the significantly smaller size of the Ascræus Mons FSD make it distinct from that of Arsia and Pavonis Mons. Classification of the units at Ascræus reveals at least one unique facies and the absence of a smooth facies seen in the FSDs at Arsia and Pavonis. In addition, the Ascræus FSD covers an area of only 14,000 km<sup>2</sup>, compared to 180,000 km<sup>2</sup> (Arsia) and 75,000 km<sup>2</sup> (Pavonis) [2]. Here we present morphological and crater count analysis of MOC, HRSC and THEMIS data, and outline new insights for formation of FSD facies.

**Ridged Facies:** The ridged facies, consisting of at least seven elongate arcuate ridges, defines the western boundary of the FSD (Fig 1a). The ridges are relatively continuous in their ~180 km along-strike extent and run parallel to each other at the distal western edge of the FSD before converging to the north and south. No cross-cutting of ridges is apparent, but some convergence between ridges does occur. In areas where parallelism is preserved, ridges at Ascræus are 600-1,000 m apart and have widths of 300-400 m. Previous studies have measured heights of the ridges and determined that the outermost ridge is the tallest, reaching up to 80 m, whereas the neighboring ridges are 10-40 m in height [6].

A second set of subdued ridges begins ~20 km from the outermost ridge. A well-defined scarp, nearly parallel to the ridges, separates these sets (Fig. 1b). The inner set is significantly less pronounced than the outer set of ridges. Although parallel, they are not laterally continuous; the inner ridges are narrower (~100 m) and less tall (<10 m) than the outer ridges, but show similar horizontal spacing.

Both sets of ridges have been interpreted to be drop moraines, formed by debris deposited at the distal edge of glacial ice during a period of glacial margin stability. Subsequent periods of recession, restabilization, and continued deposition led to the series of parallel ridges [1]. Various physical attributes of the ridges can be used to explore glacial conditions. The lateral continuity of the ridges is a function of the availability and distribution of debris in the glacier. Although segmentation could be the result of post-modification by eolian or tectonic processes, the lateral continuity of the outer ridges suggests that the Ascræus glacier had a significant source of debris that was evenly distributed. The thickness, spacing, and height of the ridges are all related to the length of time the glacier can

remain at standstill, as well as how quickly it recedes. A longer period of equilibrium will allow for increased build-up of ridges, creating higher, broader features. This is also affected by the quantity of debris supplied, and the location of its source. Spacing is then determined by how rapidly the glacier retreats, and how long it is stabilized.

**Arcuate Scarp:** The arcuate scarp that separates the two sets of ridges faces inward, toward Ascræus Mons (Fig 1b). Measurements of the topography reveal that the height of the scarp varies from 180-300 m. The feature runs almost parallel to both sets of ridges. The curvature of the scarp and the inward-facing orientation suggest that it was created at the distal glacier edge. Following [6], this orientation could represent impounded lava flows from the Ascræus Mons SW flank traveling around glacier ice and banking up against the ice sheet, cooling in the process. On the basis of stratigraphic relationships, it appears that the glacier then advanced, emplacing drop moraines and debris outside the scarp; subsequent retreat and standstill inside the scarp then appears to have formed the second set of ridges. A similar process was originally proposed for three arcuate scarps at the Pavonis FSD [2].

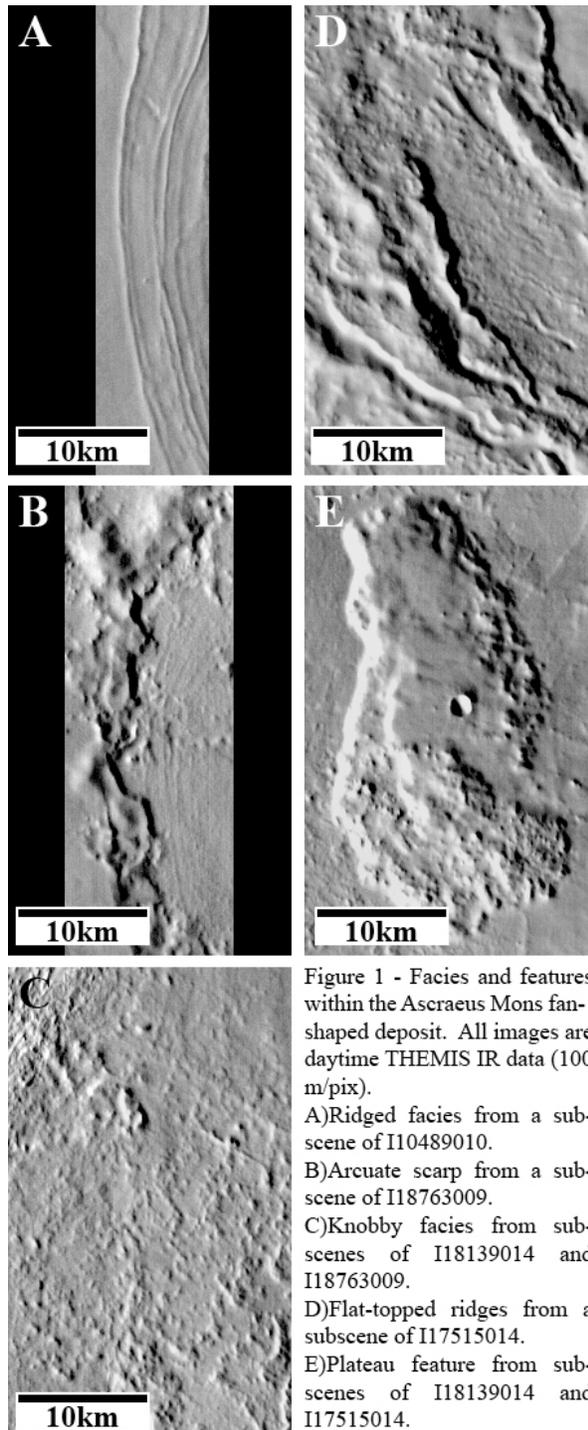
**Knobby Facies:** The knobby facies consists of numerous rounded hummocks, covering an area of ~1,800 km<sup>2</sup> [6]. The facies exists in at least four distinct regions, with the largest section extending over the southern part of the FSD from the Ascræus shield base to the arcuate scarp (Fig 1c). The northern patches are emplaced farther west, just inside the outer ridges. Hummocks in the northern half of the FSD tend to be less dense, but nowhere in the Ascræus FSD are hummocks as dense as they are at Pavonis or Arsia. The knobby terrain at Ascræus shows very few dunes; dunes are common between hummocks at Pavonis and Arsia. The knobby facies is interpreted to represent a type of sublimation till [1]. The relative sparseness of the Ascræus knobby facies suggests a smaller debris supply, and/or partial burial from subsequent Ascræus lava flows.

**Flat-topped Ridge Region:** Perhaps the best evidence that ties the arcuate scarp to lava flows is a flat-topped ridge region south of the FSD (Fig 1d). These flat-topped ridges have been interpreted to be lava flows [8], and form a significant scarp along the southern boundary of the FSD.

**Plateau Feature:** A large plateau exists near the center of the FSD, ~7 km west of the shield base (Fig 1e). The feature measures 34 km (N-S) by 19 km (E-W), with an elevation of >750 m [8]. It has been proposed that this elevated plateau formed via subglacial volcanism, and a similar morphology is seen at the Pavonis FSD [2]. The southern end of the plateau has rough topography, which appears to be part of the knobby facies. The presence of sublimation till on top of the feature is consistent with a subglacial origin.

**Deposit Age:** Crater counts were performed for the Ascræus FSD using a mosaic of THEMIS daytime IR and VIS images. Craters between 0.4 km and 2.0 km in diameter are in production. Using the Hartmann isochrons, an age of ~100

Myr is derived [9] (Fig 2). Craters <0.4 km in diameter were counted, but are being modified and eroded at a rate comparable to their production rate, creating a rollover of the data for points less than 0.4 km. Additionally, because the resolution of the mosaic was 100 m/pixel, craters of this size are often poorly resolvable. As such, 100 Myr should be considered a lower limit for the age; thus, this FSD is assuredly Late Amazonian in age. This result is in strong agreement with crater counting of the Pavonis FSD, which revealed an age of ~10-



200 Myr [2], and with previous dating of the Tharsis Montes using stratigraphic relationships and crater counting [10]. Between 5-20 Myr ago, the mean Martian obliquity was around 35° and surpassed 45° on multiple occasions, providing sufficient conditions for the formation of the Tharsis Montes glaciers [4]. As such, multiple phases of glaciation may have occurred over the past tens to several hundreds of millions of years [2,5].

**Conclusions:** The FSD extending to the NW of Ascræus Mons is consistent with a cold-based glacier model of origin. From observations of these FSDs and other related data, we can conclude: (1) Two sets of ridged-facies exist, separated by a scarp, near the outer edge of the FSD. These ridges are interpreted to be drop moraines with physical attributes depending predominantly on debris supply and glacial stability and recession. (2) The arcuate scarp that separates the sets of ridges is interpreted to have formed from lava flows circumventing the glacier. Its curvature, which is parallel to the ridges, and location in line with the flat-topped flow features protruding from the SW flank of Ascræus Mons support this interpretation. (3) The knobby facies formed from a sublimation till. The sparse distribution, absence of dunes, and separation of fields of hummocks could have resulted from a relatively small debris supply or partial burial by subsequent lava flows. (4) Based on new crater counts, the FSD is at least 100 Myr, confirming that it is Late Amazonian in age.

**References:** [1] Head J. W. and Marchant D. R. (2003) *Geology*, 31, 641-644. [2] Shean D. R. and Head J. W. (2005) *JGR*, 110, E05001. [3] Milkovich S. M. et al. (2005) *Icarus*, 181, 388-407. [4] Forget F. et al. (2006) *Science*, 311, 368-371. [5] Laskar J. et al. (2004) *Icarus*, 170, 343-364. [6] Parsons R. L. and Head J. W. (2004) *LPS XXXV* #1776. [7] Fastook, J. L. et al. (2005) *LPS XXXVI* #1212. [8] Parsons R. L. and Head J. W. (2005) *LPS XXXVI* #1139. [9] Hartmann W. K. (2005) *Icarus*, 174, 294-320. [10] Tanaka K. L. (1986) *JGR*, 91, 139-158.

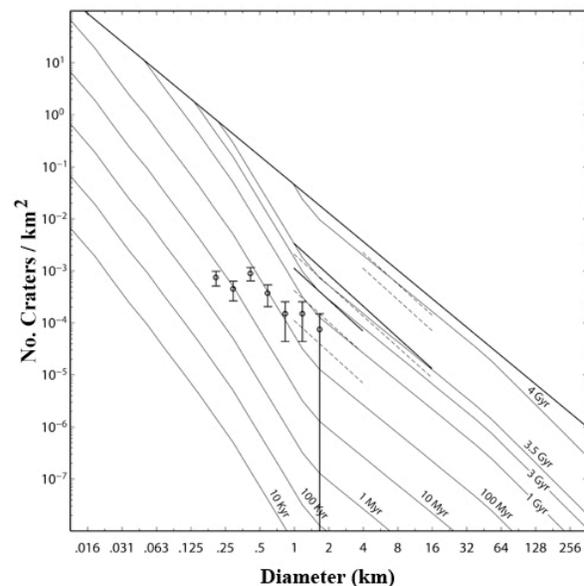


Figure 2 - Crater diameter distribution for craters superimposed on the Ascræus fan-shaped deposit. The isochrons from Hartmann show an age for the deposit of  $\geq 100$  Myr.