INSIGHTS INTO THE LATE NOACHIAN-EARLY HESPERIAN MARTIAN CLIMATE CHANGE FROM FLUVIAL FEATURES IN THE DORSA ARGENTEA FORMATION. K. E. Scanlon and J. W. Head, Department of Geological Sciences, Brown University, Providence, RI, USA. <kathleen_scanlon@brown.edu>

Introduction: The Noachian and Hesperian-aged geomorphological units mapped [1-2] as the Dorsa Argentea Formation (DAF) and the Hesperian-Noachian undivided unit cover a combined area of ~1.5 · 10^6 km^2 [3] surrounding and offset from the south pole of Mars. The units are characterized by sinuous and braided ridges, including the Dorsa Argentea for which the formation is named [e.g. 4-10], several regions of pitted terrain, the Cavi Angusti and Sisyphi Cavi [e.g. 11-13]; and steep-sided mountains, the Sisyphi Montes [e.g. 14]. A radar reflector closely correlated with the outline of the deposit is consistent with high concentrations of volatiles in and underlying the deposit [15]. Based on this evidence for remnant volatiles, the robust tendency of climate models to form a large ice sheet over the South Pole when total atmospheric pressure is increased from modern values [16], and the appearance and spatial relationships of numerous landforms resembling glacial, glaciovolcanic, and glaciofluvial features (**Figure 1**), the deposit has been interpreted as glacial [e.g. 3, 4, 17-20].

The Dorsa Argentea Formation represents a potential key to the Noachian-Hesperian climate transition on Mars. The presence of features associated with glacial melting has been used to constrain global temperatures at the time of its formation [21], and it has been hypothesized that basal melt flowing through the large channels emerging from the deposit [e.g. 3, 13] flowed through Argyre basin and the ULM valley system to the northern plains [22]. Understanding the nature of ice sheet growth and meltback recorded by the glacial landforms within the DAF will therefore provide insight into the nature of the Noachian-Hesperian climate transition. We seek to answer the questions: Are the type and distribution of glaciofluvial landforms within the DAF more consistent with temperatures decreasing monotonically from a globally warmer climate where seasonal melting may have been possible near the equator, or with episodic, global warming of a typically cold early Mars [e.g. 16]? What were the relative contributions of volcanism and climate to the melting that carved fluvial landforms in the DAF?

Flow characteristics recorded by eskers: Sinuous ridges within the Dorsa Argentea Formation have been interpreted as eskers due to their scale, morphology, spatial associations, and relationship to the underlying topography [e.g. 8, 9]. The eskers within the Dorsa Argentea formation have cratering exposure ages of ~3.4 – 3.8 Ga [23]. They are continuous over many tens of kilometers, likely reflecting stagnant ice margins and minimal glacial erosion after their deposition [e.g. 23, 24]. In HiRISE images, the eskers appear to contain meter-scale boulders. This may reflect either extremely high discharges in the former subglacial channels or, more likely, that the eskers are composed of indurated material which has fractured in the time since their formation [cf. 25].

Several subsets of the ridges within the DAF have an anabranching plan view morphology and are associated with broad, hummocky deposits (**Figure 2**). In terrestrial glacial environments, it has been suggested [26] that eskers of this type are emplaced in high-magnitude, low-frequency flood events, when existing subglacial conduits may be unable to expand by melting rapidly enough to accommodate sudden flux increases. The tunnel walls are breached, and the resulting connection between multiple channels and subglacial cavities decreases flow speed and causes the rapid deposition of sediment in the cavities. In-depth sedimentological studies have supported the catastrophic flood hypothesis for several esker systems of this type [e.g. 27-29]. An alternative hypothesis, that anastomosing eskers with hummocky deposits form as supraglacial outwash fans at ice margins, also identifies these landforms as diagnostic of flood events [e.g. 30].

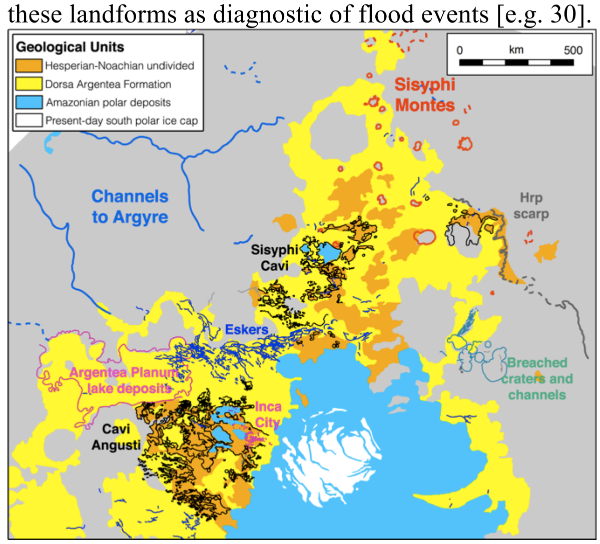

Fig. 1. Features interpreted to be of glacial origin in the Dorsa Argentea formation include cavi interpreted as melt-out terrains [e.g. 4, 13], lake deposits in Argentea Planum [3, 20], mountains whose morphology suggests a glaciovolcanic origin [e.g. 14], and fluvial channels connecting several craters [19]. The boundaries of the Dorsa Argentea formation, Hesperian-Noachian undivided terrain, Amazonian polar deposits, and present-day south polar cap are shown as mapped by Tanaka and Scott [1].

Sinuous ridges in the nearby Argyre basin are also thought to be eskers. Banks et al. [25] estimated the lower limits of water fluxes in the subglacial conduits that left these ridges. They used a simplified form of the Darcy-Weisbach equation to calculate velocity in a filled channel, assuming a triangular channel cross-section with a flow depth of 1 or 10 m and a medium sand or coarse gravel channel bed. The assumption of full flow is justified by upslope inferred flow in some Argyre eskers, which is also observed in the DAF [e.g. 8, 9] and which requires the water in the conduits to have been pressurized.

Following their methodology, and using measurements of channel bottom slope and channel width from a population of large, single-crested, non-anabranching eskers within the DAF, we estimate flow speeds of ~0.3 – 3 ms^{-1} and discharge on the order of $1{\cdot}10^3$ – $1{\cdot}10^5$ m^3s^{-1} through typical main-trunk DAF eskers. These are comparable to the values Banks et al. derived for the Argyre eskers, as might be expected if both developed under similar climate conditions. We are working to synthesize these inferred flow rates through subglacial tunnels with inferred discharges and paleolake levels in Argentea Planum and the channels and open-basin lakes leading out of the DAF.

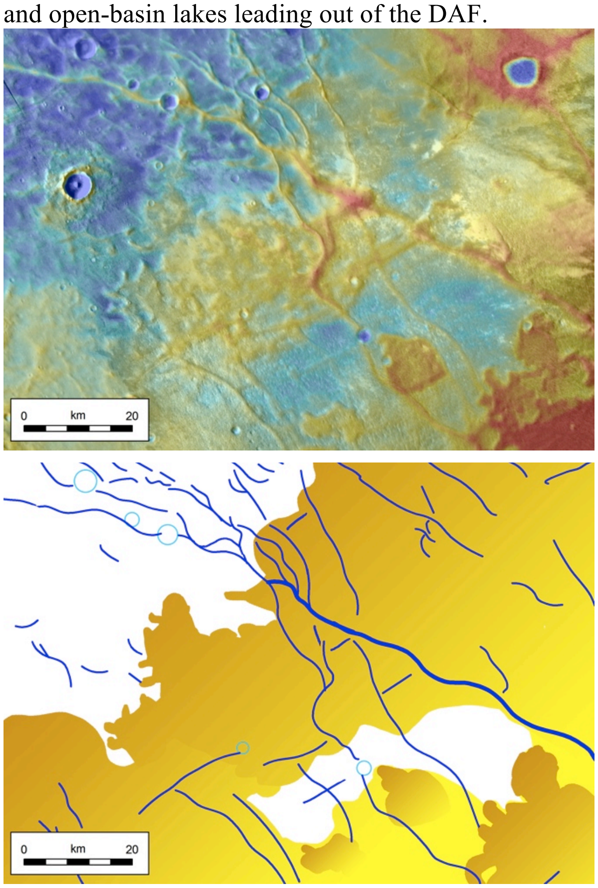

Fig. 2. *Top:* Anabranching eskers and associated hummocky deposits in the Dorsa Argentea Formation. High-resolution MOLA elevation shaded on THEMIS daytime IR image mosaic. *Bottom:* Sketch map of the region depicted above, with eskers shown in blue, hummocky deposits in gold, and superposed craters in cyan.

The role of volcanism: Glaciovolcanism in the deposit has been suggested as a potential heat source for melting ice to create the fluvial features and cavi (hypothesized melt-out terrain) in and emerging from the DAF [e.g. 13]. Unlike in other areas of Mars where volcano-ice interactions are hypothesized to have resulted in esker construction [31], we find no clear spatial association between the sinuous ridges and the candidate subglacial edifices within the DAF and the associated units. Cavi are frequently incised into material that embays the Sisyphi Montes, but in only one case does a possibly-glaciovolcanic edifice occur *within* one of the cavi, as would be expected if ice melt around the growing edifice directly induced cavi to develop. We therefore infer that melting of the DAF ice sheet may not have been directly related to the extrusive volcanism that built the Sisyphi Montes and related landforms, though elevated geothermal heat due to intrusive volcanism below the deposit may have played a role.

Conclusions and ongoing work: A more detailed investigation of the morphology of sinuous ridges in the DAF reaffirms their interpretation as eskers. Esker morphology in part of the deposit is consistent with formation in a high-magnitude, low-frequency flood event. Estimated fluvial discharge through the former subglacial tunnels is comparable to that estimated by other workers for the eskers in nearby Argyre basin. For the majority of fluvial features in the Dorsa Argentea Formation, we have yet to find evidence that glaciovolcanism (rather than climate) was the primary force driving melting. We are working to synthesize the stratigraphy and implied flow regimes from glaciofluvial features throughout the deposit in order to gain insight into the Noachian-Hesperian climate transition.

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