BOULDER-LAYER PAVEMENT ACROSS THE SOUTHERN HIGHLANDS AND COLD-BASED CONTINENTAL-SCALE GLACIATION. An Yin (yin@epss.ucla.edu) and Kobe Y. Wang, Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, California 90095-156702, USA

Introduction: A first-order question in the studies of Mars is whether most or the entire southern hemisphere highlands were once occupied by a single ice sheet ([1], [2], [3]). A related question is whether the inferred glaciation occurred only in the Noachian ([1], [4]) or extended into the Hesperian-early Amazonian ([5], [6]) and even the late Amazonian ([7]). Additionally, debate has also been centered on whether the proposed ice sheet was moving through wet-based ([8]) or cold-based ([9], [10], [11]) processes. The two end-member ice-transport models make specific predictions that are testable by photogeologic mapping. The wet-based transport model predicts (1) water-assisted soft-sediment deformation, and (2) presence of eskers, kames, subglacial lacustrine deposits, and drumlins ([16]). The cold-based transport model predicts (1) the absence of the aforementioned features ([16], (2) basal debris entrainment and pavement-like deposition ([12], [13], [14], (3) a lack of frontal and lateral moraine ridges ([14], [15]), (4) a bimodal sand-boulder size distribution ([14], [16]), and (5) partial preservation of pre-glaciation landforms (e.g., [17]). The goal of this study is to test the two end-member ice-transport models. By doing so we address the fundamental question of whether the southern highlands were once occupied by a single ice sheet.

Data and Methods: MOLA topographic data are used for locating possible glacial flow paths (Fig. 1). HiRISE images are then used to examine the landforms and textures of layered deposits exposed on the steep walls of younger craters and cliffs of irregularly shaped cookie-cutter-like depressions. Similar analysis was also conducted along ridges bounding the hypothesized glacier flow paths.

Preliminary Results: Observations Our reconnaissance work reveals the widespread occurrence of a boulder-pavement unit across the southern highlands. This unit occurs preferentially in linear troughs and irregularly shaped basins outlined in Fig. 1. The boulder-bearing unit filled up older craters and is exposed on the steep walls of younger craters and irregularly shaped depressions (Fig. 2A). The surface of the boulder-bearing unit is mostly flat except near the headwater regions of the major outflow channels; the boulder-unit surface is traceable for 10s-100s km and displays much lower densities of craters than those on the surfaces of the bounding high-elevation regions. The boulder-unit surface is commonly associated with irregularly shaped “cookie-cutter-like” depressions (Fig. 2A) covered in most sites by a layer of fine-textured and light-toned mantling material; the mantling layer displays polygonal patterns in the south (Figs. 2B and 2C) but occurs as a dust layer obscuring bedrocks below in the north near the dichotomy boundary. The boulder-bearing unit is crudely layered and exhibits matrix-support texture (Fig. 2D). The clast size of the boulders is ca. 2-5 m, with the percentage and size decreasing northward. The grain size of the supporting matrix is smaller than the pixel size (25-35 cm) of the HiRISE images. The boulder unit locally occurs as piles with outward radiating ridges close to the heads of the major outflow channels; the piles have undulating surfaces and exhibit lobate debris flow/apron features (Fig. 3). The higher-elevation regions bounding the boulder-bearing troughs are generally absent of the boulder-bearing units; their surfaces exhibit ostensibly higher densities of craters. Our preliminary survey of the Thaumasia plateau does not reveal a regionally extensive boulder unit associated with irregular depression, filled craters, and lobate flow features.

Interpretations. The parallel layering at scales of > a few km to a few tens of km suggests that the boulder material was laid down through a blanketing process, either by deposition of impact ejecta or a high-energy-transported sediments. However, the generally absence of the boulder pavement unit along the trough-bounding ridges in the southern highlands suggests that the boulders were laid down preferentially in topographically low regions, which is not consistent with the impact-ejecta interpretation. In addition, the close association of boulder deposits with lobate-flow features and irregularly shaped cookie-cutter-like depressions also does not support the impact-deposition interpretation. Here, we suggest that the boulder-pavement unit has a glacial origin; lobate features are ice-bearing debris and irregularly shaped depressions were sites of ice blocks removed by sublimation. The absence of (1) lateral and frontal moraine ridges, (2) drumlins, and (3) water-assisted soft-sediment-deformation features rule out wet-based ice-transport processes. The lack of boulder pavement in the Thaumasia plateau suggests that the interpreted glaciation predates the latest Noachian and early Hesperian. Thus, our preliminary results favor the cold-based – ice-transport mechanism and the Noachian icy-highlands hypothesis [4]. The lack of boulder deposits along the ridges bounding the linear troughs and irregularly shaped basins in Fig. 1 is also consistent with a cold-based ice-transport mechanism [14]. Rather than a single ice sheet as suggested in the earlier studies (e.g.,
[1], [4]), we envision that the southern highlands were occupied mostly by numerous valley glaciers (Fig. 1). Outbursts of supra-glacial lakes and breakthrough of large englacial reservoirs may have created episodic flooding along the outflow channels. The cold valley ice was mostly sublimated away in situ without creating large liquid-water lakes.

Figure 1. Hypothesized pathways of valley glaciers across southern highlands (white dashed lobes) and glaciated topographic depressions (gray regions).


Figure 2. (A) “Cookie-cutter-like” depression. (B) and (C) Polygonal mantling surface. (D) Matrix-supported boulder unit. All from HiRISE image ESP_013651_1075.

Figure 3. A boulder-bearing pile with lobate debris aprons and undulating surface (HiRISE image PSP_003279_1585).