EVIDENCE OF RECENT GLACIATION IN ELYSIUM PLANITIA, MARS. J. Nussbaumer[1], E. Hauber[2], and R. Jaumann[2], [1]Department of Mineralogy, Natural History Museum, London, UK, [2]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany.

Introduction: We present evidence for recent glaciation in southeastern Elysium Planitia, near the Martian equator. The surface features indicating glacial processes include eskers, ground moraines, and boulder trains. They are located next to wind-eroded, layered materials, that are part of the Medusae Fossae Formation. The characteristics of the esker-like features (concertina eskers) suggest that they were formed by a surging ice-sheet. The identification of equatorial glaciation in the recent past might confirm theories about climatic changes on Mars due to variations of the planet´s orbital parameters.

Background: Calculations of spin axis precession, nutation, and orbit inclination reveal, that the obliquity and eccentricity of Mars have experienced dramatic variations over time [e.g. 1, 2, 3]. Surface ice will be preferentially deposited at locations with the lowest average annual temperatures and the highest saturation state of the atmosphere. In periods of very high obliquity (~45°), ice may sublimate from the poles [4] and may be stable in equatorial regions [5]. Obliquity changes may be responsible for the observed stratigraphy of the polar layered deposits [6]. The mapping of very young exogenic surface features like gullies [7, 8], polygonal ground [9], viscous flow features [10], dissection of an ice-rich mantle deposit [11, 12] shows that they are constricted to a latitude belt between ±30° and ±60°, indicating climatic control. In addition, evidence of recent cold-based glaciation has been found on the northwestern flanks of the shield volcanoes of Tharsis (Arsia, Pavonis, and Ascraeus Montes) and Olympus Mons [13, 14, 15]. The neutron measurements by Mars Odyssey suggest a high hydrogen content in the high latitudes that may indicate a water-rich shallow subsurface in polar regions [e.g., 16, 17]. Towards the equator, the depth to the ice-rich substrate increases, in agreement with the theory that at present time (obliquity ~25°) the low and mid-latitudes experience an epoch of ice sublimation, dessication, and surface degradation [18].

Glacial morphology in Elysium Planitia: In this section we describe the morphologic characteristics of the surface features that we interpret as evidence for glacial processes. They include ground moraines, eskers, and boulder trains. The units are located in southeastern Elysium Planitia (Fig. 1) and were previously mapped as members of the Medusae Fossae Formation (MFF) (units *Amm* and *Aml* of 19]. The MFF is an Amazonian-aged deposit, the origin of which is enigmatic. It is widely eroded by wind and consist of volcanic air-fall deposits [20].

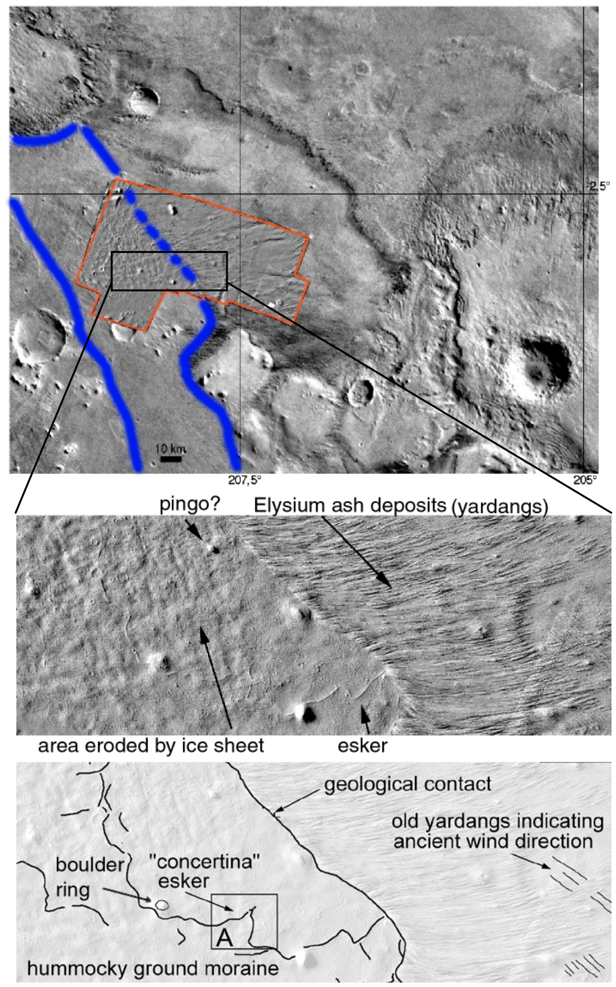

Figure 1. General context map from Viking MDIM (250m/pxl), includes a high-resolution viking mosaic (14 m/pxl, marked by red line), ancient ice sheet is marked by a blue line. Lower two images resemble a part of the image mosaic of Viking orbit 724A (14m/pixel; image width 60km, North is up, center at 207W, -3S) and geomorphological sketch map. Hummocky ground-moraines, eskers, and possibly pingos are evidence for former glaciation. The outlined box A marks the location of eskers deformed into a zigzag pattern typical for terrestrial concertina eskers.

Detailed geomorphological mapping of high-resolution Viking Orbiter images (orbit 724A, 14 m pixel^{-1}) reveals a hummocky deposit, which resembles terrestrial ground moraines. Hummocky ground moraines form by moving ice, whereas one side of the hummock is eroded by the ice. The debris is deposited on the leeward side of the hummocks. The average height of the glacial hummocks in Elysium Planitia is 30-40 m as observed in MOLA data. It is bordered to the northeast by a topographical scarp. The high-standing deposits beyond that scarp is wind-eroded, i.e., it is clearly marked by yardangs. Its morphology indicates that it is part of the MFF. The hummocky, ground moraine-like material is superposed by long and narrow ridges. We interpret these ridges as eskers. Eskers are sinuous ridges of stratified glaciofluvial sand or gravel formed as infillings of ice-walled rivers and deposited in tunnels in the ice [21, 22]. Locally, the sinuous pattern of the eskers (as seen in plan view) is changed into a jagged or zig-zag path. Icelandic eskers have been shortened and crumpled into such a zig-zag pattern by an advancing glacier snout [23; 24]. These so-called concertina eskers are associated with surging glaciers, characterized by periodic changes in flow velocities over various timescales [25]. Increasing flow velocities due to basal sliding occur only in wet-based glaciers. It is important to note that the surges are not triggered by climatic oscillations but by oscillations in the internal working of the glacier [26]. Although it is tempting to to ascribe the former existence of a surging glacier on Mars to previous climatic changes, this assumption is not supported by terrestrial analogy. Terrestrial surging glaciers are usually longer, broader, and less steep than normal glaciers. They rather form on sedimentary than on crystalline ground (note that this would also apply to the Elysium glaciers, since they are superposed on the MFF). Boulder trains are widespread on the ground moraine. While they also occur in the lee of obstacles in large floods or downslope from outcrops on steep slopes, they can also be associated with glacial deposits [27]. Boulder trains in glacial environments indicate ice movement during the last stage of glaciation [28]. Some boulders are concentrically deposited around hills as a result of decreasing ice thickness (boulder rings, Fig. 1).

Conclusion: Several landforms in southeastern Elysium Planitia suggest a recent local or regional wet-based glaciation. The geographic location near the equator of Mars require, that they formed under different climatic conditions than today. A possible explanation is that they were formed during a period of very high obliquity, when surface ice was stable at the Martian equator [29]. A similar conclusion was drawn by Head and Marchant [30] for equatorial cold-based glaciers in Tharsis. The difference between cold-based glaciation in Tharsis and wet-based glaciation in Elysium Planitia might be explained by the higher elevation and, therefore, colder temperatures under which the Tharsis glaciers formed. Our notion of ice in Elysium Planitia is in agreement with previous reports of glaciation in Elysium [31]. It also supports observations of shallow equatorial ground ice on Mars in recent times as inferred from young rootless cones interpreted as pseudo-volcanoes [32].

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