NEW EVIDENCE FOR THE FORMATION OF LARGE LANDSLIDES ON MARS.

M. H. Bulmer[1] and B. A. Zimermann[1], [1]JCET, UMBC, 1450 Rolling Road, Baltimore, MD 21227 (mbulmer@jcet.umbc.edu).

Introduction: Landslides in the Valles Marineris were first examined using Viking Orbiter (VO) images. They were interpreted to be large volume (>10^6 m^3) catastrophic failures with long runouts [1-5] and a range of emplacement models have been proposed to explain their apparent high mobility. However, the limited resolution of VO data meant that no models could be conclusively validated. The resolutions of MOC images (9 to 1.4 m/pixel), and THEMIS images (100 m/pixel infrared and 19 m/pixel visible), plus the MOLA dataset (<1m horizontal and vertical resolution at 300 m horizontal spacing) show new details of the slope forming materials and the processes that govern the triggering, failure, and deposition of landslides. Here we report on analysis of a landside site on the southern wall of Gangis Chasma (Figure 1) in the Valles Marineris [1,4] using MOC, THEMIS and MOLA data.

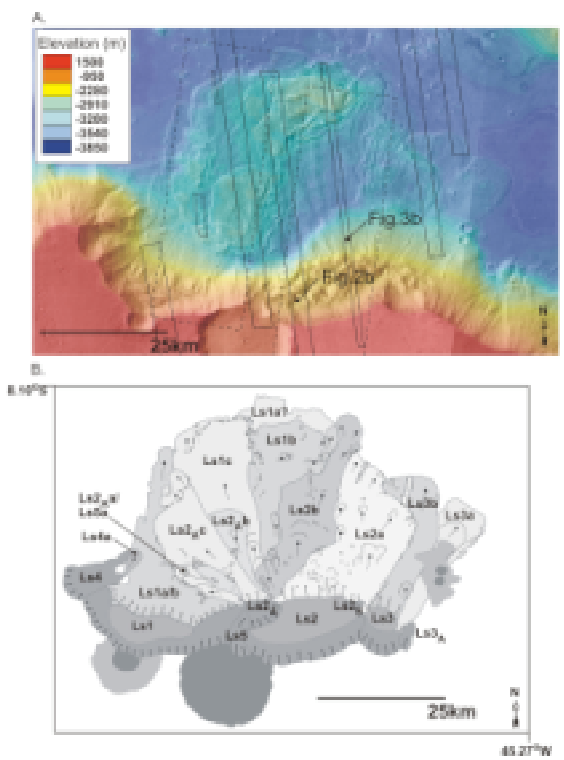

Fig.1 and 2. (1) Mosaic of THEMIS daytime IR images of the landslide site at Gangis Chasma with MOLA topography (color). (2) Geomorphic sketch map. Black arrows show the direction of travel.

Features observed in these data are at odds with models of large catastrophic high mobility landslides. However, they can be explained by deep seated gravitational creep on the canyon walls over billions of years and successions of small volume slides and flows from multiple source regions that build up numerous aprons over time. This evolutionally model represents a paradigm shift away from high rate deformation and mobility in landslides on Mars.

Observations: Large arcuate headscarps exist at the top of the 5 km high southern wall of the Chasma (Figure 1). At each headscarp layered rocks are visible. Failures of the layered rocks, through topples, falls, and slides have created smaller arcuate scarps and rock chutes within each headscarp. The strength characteristics of the wallrock in the Valles Marineris are consistent with terrestrial basaltic rock masses with a Rock Mass Rating of <50 RMR <65 [6]. Spectral observations from TES also suggest basaltic compositions [7]. These RMR values are weaker than intact rock (RMR 100), requiring fracturing, weathering, and/or pore fluid pressure. Fracturing is the most likely [6] and the extensive talus provides no evidence for pore fluid draining. Large talus cones can be related to individual rock chutes down which failed rocks were channeled.

At the base of the headscarps are surfaces that collectively form a topographic bench (–2300 m elevation). This is characterized by terraces, ridges, double ridges, ridge depressions, troughs, and counter-sloping scarplets. The topographic bench appears similar to terrestrial sakungs (deep-seated gravitational creep features). The lower portions of the deforming slope can display compressional features such as bulging [8]. In the basaltic wallrock on Mars, displacements are likely along discontinuities in the fractured rockmass. Individual terraces may have moved with a rotational or translational component. Deformations may have been at constant slow rates of creep. The Upper Noachian age [9] along with the 30º, 5 km high slopes of fractured basaltic wallrock favor gravitational creep. External effects such as a seismic shock associated with an impact, may alter the slow slope deformation into a catastrophic phase causing slides and flows. The scarps of terraces are mantled in talus from numerous shallow topples, slides, and flows.

At the base of the topographic bench (–3300 m elevation) the regional slope changes to 20°. Here talus deposits transition into lobes and sheets (Fig. 3a,b). Individual lobes and sheets can be traced to local talus accumulation zones below rock chutes on the sag terraces. This indicates talus is the source for these sheets and lobes. The variable dimensions of these lobes reflect the size of the accumulations zones from which they were fed. They travel on average < 5 km and the tracks of lobes can be traced using their linear margins, which show levees and lateral shear (Fig. 3b).

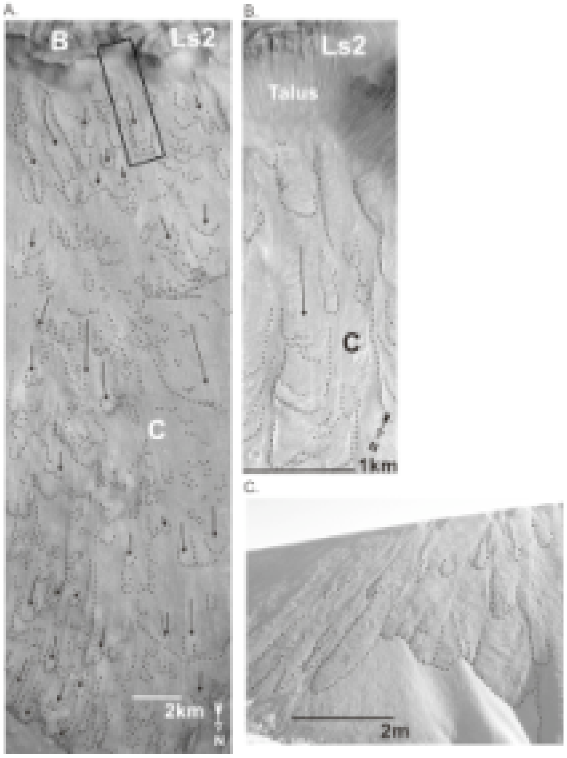

Figure 3. (**A**). THEMIS visible image of the slopes labeled C, below the topographic bench B, showing sheets and lobes extending to the canyon floor, V01001002 (**B**) Scarps on a terrace, talus and lobes, subscene MOC-M0703026. One lobe is 3 km long, 30 m thick on average with a volume of 0.03 km^3). (**C**) Terrestrial sandflows showing individual lobes and sheets, levees and transverse structures.

It is these margins that give the appearance of extensive longitudinal structures [1] on aprons. The lobes display characteristics of flow, having sinuous pathways that follow topographic lows. Multiple lobe fronts can often be identified within the same track (Fig. 3b). This argues for pulses during emplacement or episodes of remobilization of the materials. Overlapping and coalescing tracks indicate that successions of lobes produced from multiple source regions have moved down the regional slope. Individual lobes and sheets extend only short distances (<5 km) but the successions of pulses and remobilizations causes materials to be pushed further downslope. Over time aprons are built (Fig. 1b). It is these aprons that have previously been interpreted to be the result of single failures with high mobility [1-5]. The complexity of lobe interactions increases down the regional slope. Tracks can be identified by discrete sets of transverse en-echelon structures visible in MOC images (Fig. 3b). These can also be used to infer the movement direction.

The morphological structures on the lobes and sheets are most similar to terrestrial rock glaciers, rock avalanches and sandflows. Periglacial rock glaciers originate by the deformation of the lower parts of talus slopes, forming a bulging lobe at the base [10]. Recorded velocities on rock glaciers are 0.20 + 0.11 m/yr (25), 0.3 m/sec on sandflow lobes (Fig 3c) and <10 m/sec on individual rock avalanche lobes [11]. These are considerably less than those calculated (70-125 m/sec) in long runout models [2].

Discussion: Based on our observations, we propose a new evolutionary model for landslides in the Valles Marineris. It begins with deep-seated gravitational deformation of the 5 km high canyon rockwall. Displacements occur along discontinuities in the fractured basaltic rockmass, which create terraces that creep downslope forming a topographic bench and cause the lower slopes to bulge. In conjunction with the large-scale slow gravitational deformation, weathering and mechanical breakdown of the rockmass results in smaller-scale rock falls, topples and slides. Over time scarps enlarge and rock chutes develop down which fragments are channeled and accumulate at the base forming talus cones. Deformation of these talus slopes can result in rock glaciers. Periodically, parts of the rockwall and localized accumulation zones fail and material moves downslope under gravity. Rockfalls, topples and slides may be triggered by external effects such as seismic shocks from impacts. Movements of slope materials occur as slides and/or flows producing lobes or sheets. Sheets can transition to lobes as a function of different velocity profiles and local topography. These new movements find pathways down local topographic lows or can override older deposits causing them to be remobilized. Complex networks of lobes and sheets are emplaced through this cycle of accumulation at source areas and periodic failures. In this way, with sufficient material supply from source areas, slope materials are gradually pushed further downslope eventually reaching the canyon floors.

References: [1] Luchitta, B.K., (1978) *Geol. Soc. Amer. Bull.,* 89, 1601-1609. [2] (1979) *J. Geophys. Res.,* 84, 8097-8113.[3] *Icarus,* 72, 411-429. [4] McEwen, A.S. (1989) *Geology,* 17, 1111-1114. [5] Shaller, P.J., (1991). PhD thesis, Calif. Inst. Tech., pp586. [6] Schultz, R. A., (2002) *Geophys. Res. Letts., 29,* 19, 1932. [7] Banfield, J., et al. (2000) *Science, 287,* 1626-1630. [8] Bisci, C., et al. (1996) in *Landslide Recognition,* pp. 150-160. [9] McEwen, et al. (1999) *Nature, 397,* 584-586. [10] Benn, D I. and D.J.A., Evans, (1997) Glaciers and Glaciation. Oxford University Press Inc. [11] Bulmer, M.H. and Zimmerman, B.A. (2004) *GRL submitted.*