ACTIVE BOULDER MOVEMENT ASSOCIATED WITH MARTIAN LOBATE LANDFORMS. C. M. Dundas[1] and M. T. Mellon[2], [1]Astrogeology Science Center, U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ, 86001, USA (cdundas@usgs.gov), [2]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD, 20723, USA.

Introduction: High-latitude lobate features have been identified at several locations on Mars [1-4]. Based on terrestrial analogs, these features have been described as candidate solifluction lobes and taken as evidence for thaw and recent liquid in the shallow subsurface [1-4]. As such, they are expected to be inactive or at most evolving very slowly under current Martian surface conditions, since widespread melting under current conditions is implausible [5-7].

Some of the lobate features concentrate rocks into lobate and arcuate patterns on steep slopes (Fig. 1), typically convex downslope. These boulders act as markers that enable change detection studies: rock movement may be episodic in response to slower changes in the subsurface, thus making such effects visible. This makes it practical to look for evidence of changes in features suggestive of creep.

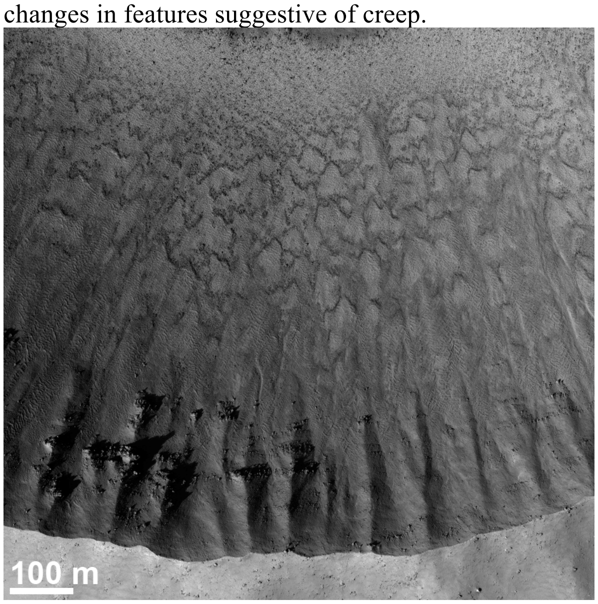

Figure 1: Lobate patterns formed by boulders on a steep slope near 60°N (HiRISE image ESP_027553_2405; downhill towards the top).

Observations: We examined HiRISE repeat images of several boulder-lobe slopes between 60–72°N and observed multiple instances of rocks shifting downhill. We have inspected four sites to date and observed at least one definite or probable rock movement at three of them. Typical movement distances are meters, suggesting a low-energy process. However, the movement occurs in the interval between single HiRISE images, and to date individual rocks have only been observed to move once. Based on even this admittedly small sample, we infer that boulder movement is not the product of rare or unusual events. Movements appear to be discrete one-off events as opposed to a general shift of many boulders along a lobe. Most of the changes observed to date are not well-constrained in season (confident detection of boulder movement is only possible with favorable illumination) but one case can be constrained to mid-summer (Fig. 2).

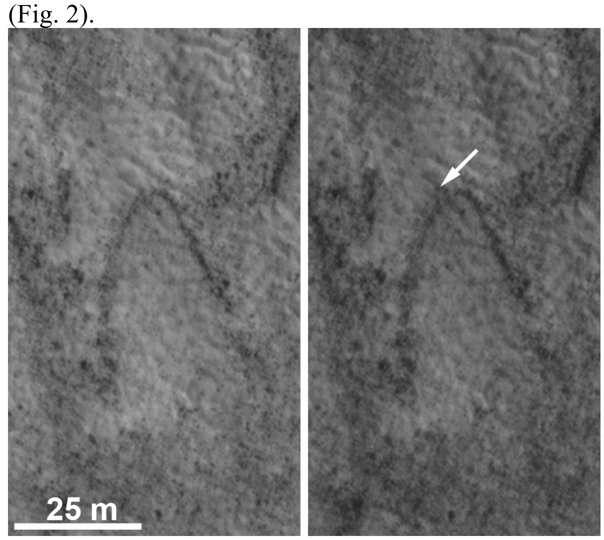

Figure 2: ~2-meter shift of a boulder between HiRISE images ESP_027553_2405 (left; L_S=124°) and ESP_028186_2405 (right; L_S=148°). Downhill is to the top and light from the left; movement is approximately downhill.

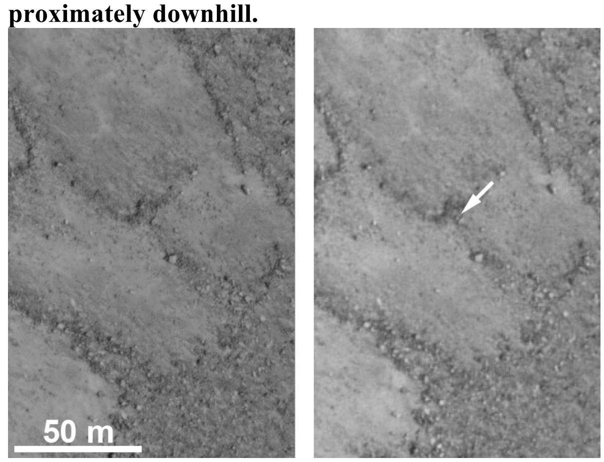

Figure 3: ~5-meter shift of a boulder between ESP_027768_2525 (left) and ESP_046216_2525 (right). Downhill is to the lower right and light from the right; movement is approximately downhill.

As the boulders are near the limit of HiRISE resolution, these are challenging observations and we have been conservative in our interpretation. Observational difficulties can include differences in lighting as well as viewing angles; orthorectified images were not available. It is possible that additional, subtle (below the detection threshold) boulder movement occurs on these slopes.

Discussion: These observations are consistent with expectations for boulders gently dislodged from previously stable positions by a gradual (unresolvable) downslope creep of regolith. This is a previously unobserved style and setting of active slope evolution on Mars. The short transport distances and lack of association with outcrops are distinctly different from known rockfall events. These observations suggest the occurrence of a previously unknown active process or processes at high latitudes.

What is this active process? One possibility is solifluction-type creep driven by freeze-thaw of low-temperature brines [1, 4]. However, it is unlikely that such brines would sufficiently saturate the soil and produce a sufficiently wet active layer; observations of perchlorate salts at the Phoenix landing site at similar latitude suggest thin films instead [8]. Unfrozen water at the interface between soil grains and pore ice is thought to induce ice-lens growth on Mars [9], and sufficient lens growth capable of causing surface heave may also drive lateral creep if this process occurs on steep slopes; indeed, ice lens growth is sometimes a component of solifluction on Earth [10], although Martian ice-lens growth timescales are probably much longer than the annual cycles associated with terrestrial solifluction. It is also possible that creep could be induced by liquid-free processes. Lobate creep landforms have been reported on the Moon (e.g., [11] and references therein) and are not diagnostic of solifluction. Given sufficient time and a lack of liquid, processes that are insignificant on Earth may play major roles in Martian geomorphic evolution and could potentially mimic solifluction, which itself is a combination of multiple processes [10]. Some liquid-free mechanisms that may move material on Martian slopes include: i) CO_2 loading and gas pressurization [12] or CO_2 frost locking/unlocking of boulders [13] (both implausible for the case of boulder movement constrained to summer); ii) mineral hydration-dehydration driven expansion-contraction cycles; iii) seasonal thermal expansion and contraction of ice (the presence of which is supported by the occurrence of patterned ground); iv) diffusive creep of ice-free surface soil driven by wind or seismic activity; or v) the disruption of the local ice table, which previously cemented a boulder to the ground ice [14], caused by small climate shifts or changes in the ground surface. It is possible that multiple processes contribute to downslope movement on Martian slopes.

Current observations are not sufficient to definitively show whether the active rock movement is associated with the formation or maintenance of the boulder lobes. However, there is reason to suspect that this is the case. If frequent boulder movement were disrupting older lobate features, then the significant frequency of events observed would have degraded and dispersed these landforms (which often appear fresh) in a geologically short interval. Several examples of rocks moving to rest on the upslope side of other boulders show that a concentrating effect is possible, which could develop landforms. If the observed movement is an active contributor to the development of boulder lobes, then they are consistent with the present climate and do not require greatly different conditions in the geologically recent past.

These observations add to a growing body of evidence that middle and high Martian latitudes experience geomorphic evolution today [e.g., 15-18]. This finding suggests that significant parts of the present surface are shaped by currently-active processes in the cold, dry modern climate.

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