ACTIVE LAYER ON MARS: WHEN AND WHERE? *M. A. Kreslavsky*[1], *J W. Head*[2], [1]Earth and Planetary Sciences, University of California – Santa Cruz, 1156 High, Santa Cruz, CA, 95064, USA, mkreslav@ucsc.edu; [2]Department of Geological Sciences, Brown University, Providence, RI, 02912, USA, james_head@brown.edu.

Active layer sorting cannot explain rock circles in Elysium Planitia. Soliflucion lobes in several high north craters can result from a recent active layer episode.

Introduction: The year-average surface temperature on Mars is well below 0ºC everywhere, therefore permafrost covers the whole planet. By definition, the active layer is the uppermost layer of the permafrost that undergoes a seasonal freezing and thawing cycle. According to the current knowledge, the day-average surface temperature on Mars never exceeds 0ºC, thus, no active layer exists on Mars under the present climate conditions. We analyzed [1] the possibilities for the existence of a pervasive active layer in the geologically recent past in response to climate evolution driven by changes of spin and orbit parameters. In brief, we found [1] that the active layer could form only at high latitudes and only under high obliquity, and not later than a few Ma ago. That prediction relied on a reliable assumption that in the Late Amazonian the climate system was of the same type as today, meaning that the atmosphere was thin, thermal coupling between the atmosphere and the surface was weak, and insolation was the major factor controlling the surface temperature.

Recently, a number of authors described small-scale morphologies that are similar to those typical for the terrestrial active layer and formed on Mars well outside the space-time domain of our prediction. Thus, there is a problem of how to reconcile these morphological observations with our understanding of the martian climate system, which is quite reliable. Philosophically there are two possibilities: (1) More detailed consideration of the climate system can allow for active layer formation in some local and specific circumstances. (2) Formation of the active layer is impossible, and the features of interest were formed by other processes, despite their morphological similarity (so-called "equifinality"). Here we present two brief case studies that demonstrate these two situations.

Present-day climate system: The presence of an active layer requires the year-maximum daily-average surface temperature T_M to exceed 0ºC. As we discussed in [1], while the atmosphere is thin, the temperature is primarily controlled by insolation. In **Fig. 1b** we plot T_M against the year-maximum daily-average top-of-the-atmosphere insolation I_M. The latter is measured in parts of the solar constant at the mean Mars distance from the Sun. Each point on the plot corresponds to a single spatial cell in the Mars Climate Database [http://www-mars.lmd.jussieu.fr/]. The database represents the results of the global climate model that is tuned to best reproduce all available measurements of the surface temperature; thus it represents the actual climate well, although a few K errors in T_M are possible. The correlation between T_M and I_M is obvious (Fig. 1b). The scattering is mostly controlled by surface albedo. In the left, lower- I_M half of the plot, we see two parallel trends. The lower (colder) trend represents bright areas, the upper (warmer) one representing darker regions. The warmest outliers in the lowest I_M are the darkest cells in Acidalia. The right, higher I_M part of the plot is populated by southern high-latitude areas that have rather uniform intermediate albedo and thus form a single trend. The gray shade represents the domain, where we expect to find possible conditions, with obvious extrapolation to slightly higher I_M.

"Sorted circles" in Elysium Planitia at 4.50ºN 155.94ºE (**Fig. 2a**) has been reported in [2]. Their morphological similarity to the largest known terrestrial sorted circles is great, and sorted circle formation in terrestrial permafrost is a typical active layer process that requires repeating seasonal thawing [2]. The red curve in **Fig.1a** shows the last 1 Ma history of I_M for this site. The vertical red line shows the maximal I_M for the last 20 Ma, which was reached 62 ka ago. The spin/orbit history prior 20 Ma ago is essentially unknown. The peak heights of I_M for this equatorial site are primarily controlled by orbit eccentricity *e*. The terrain is young, its age is 10s to first 100s Ma; according to [3], e>0.14 is highly improbable for this time span, which corresponds to I_M < 0.43, an insignificant increase in comparison to the plotted value. Thus, the highest possible I_M is well in the domain sampled by the present-day insolation conditions. The maximum T_M we would expect in the last 20 Ma is ~220 K. If the present-day bright veneer was absent, and the surface could be dark, it would make T_M higher, but it would not exceed ~250 K, still far from the water melting point.

Highly concentrated brines capable of significant (10s K) reduction of the melting point have often been cited as a possible means to reconcile "warm" morphologies with a cold climate. The solutes that can produce such brines are chlorides and perchlorates. The low-resolution global data [4] give Cl abundance in the upper meter of the surface much lower (a factor of 20 – 50) than needed to saturate the active layer with highly concentrated brine. It is quite possible that small amounts of segregated low-temperature brines are responsible for some observed morphologies formed by specifically martian processes. However, brines cannot help in reproducing terrestrial active-layer processes at lower temperatures.

We conclude that an active layer formation in Elysium is highly improbable, and we would tend to think about other mechanism of formation of these features.

Solifluction lobes in an unnamed crater at 71.9ºN 344.5ºE (**Fig. 2b**) have been described in [5] and [6]. Their morphological similarity to terrestrial solifluciotn lobes is striking. Their formation on the Earth is essentially an active layer process [6]. Their morphological freshness suggests a very young age at odds with our general predictions [1]. It is interesting, that the lobes occur on all walls of the crater, including the N wall. If formation of the lobes occurred at very high obliquity, we would expect them to avoid the colder N wall. We calculated the history of I_M for all walls of this crater, taking into account their 20º slope, and chose the coldest wall for each epoch (the N wall is always the coldest when obliquity is higher than 26º). The thick blue curve in **Fig.1a** shows the result. The peak seen at 632 ka ago is actually the 20-Ma maximum. For this peak, T_M=273 K is inside the extrapolated permissible domain (Fig. 1b), in its upper, low-albedo part. The present-day albedo of the walls is moderate, however, there are dark dunes on the crater floor. It is quite possible that strong winds at this high-obliquity epoch spread that material on the walls and "painted" them black, which allowed for high temperatures and formation of an active layer. Thermal IR radiation from the opposite very warm wall could also help.

Nineteen (19) craters in the Northern plains with similar lobes were identified in [6]. We found that 16 of them contain dark dunes on their floor, 2 do not have dunes, but still have some dark material, and only 1 has no dark material inside; however, for this crater we also did not find well-expressed lobe morphology. Although these statistics are biased by preferential targeting of HiRISE, it seems that the presence of dark material is essential. This also explains why the lobes are observed only in a small proportion of craters.

The age of 632 ka seems too old according to [6] and [5]. A peak 74 ka ago (Fig. 1a) seems to better fit the observed morphological freshness and the absence of small superposed craters. I_M is significantly lower, but formation of an active layer cannot be ruled out with certainty. The most recent I_M peak 21 ka ago is certainly too low and cannot produce an active layer.

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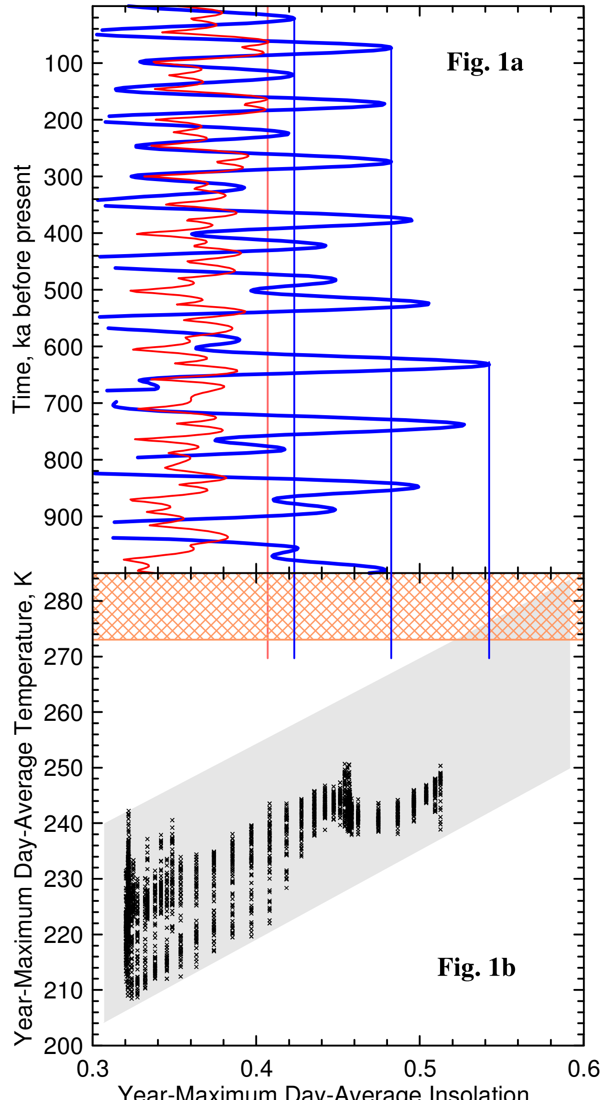

Fig. 2a

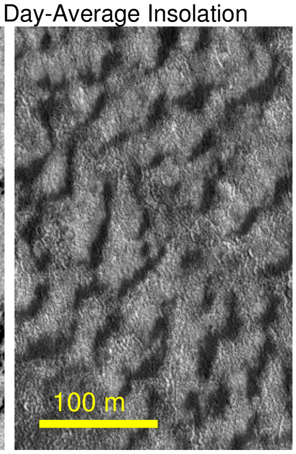

Fig. 2b