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High latitude patterned grounds on Mars: Classification, distribution and climatic control

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Abstract

Patterned grounds such as polygonal features and slope stripes are the signature of the presence of ground ice and of temperature variations in cold regions on Earth. Identifying similar features on Mars is important to understand its past climate as well as the ground ice distribution. In this study, young patterned grounds are classed and mapped from the systematical analysis of Mars Observer Camera high resolution images. These features are located poleward of 55° latitude which fits the distribution of ground ice found by the Neutron Spectrometer onboard Mars Odyssey. Thermal contraction due to seasonal temperature variations is the predominant process of formation of polygons formed by cracks which sizes vary from 15 to 300 m. The small (<40 m) widespread polygons are very recent and degraded by the desiccation of ground ice from the cracks which enhances the effect of ice sublimation. The large polygons (50 to 300 m) located only around the south CO_2 polar cap indicate the presence of ground ice and thus outline the limit of the CO_2 ice cap. They could be due to the blanketing of water ice deposits by the advances and retreats of the residual CO_2 ice cap during the last thousand years. Large (50–250 m) and homogeneous polygons similar to ice wedge polygons, hillslope stripes and solifluction lobes may indicate that specific environments such as crater floors and hillslopes could have been submitted to freeze–thaw cycles, possibly related to higher summer temperatures in periods of obliquity higher than 35°. These interpretations must be strengthened by higher resolution images such as those of the HiRise mission of the Mars Reconnaissance Orbiter because locations with past seasonal thaw could be of major interest as potential landing sites for the Phoenix mission.

Keywords: Mars; Geological processes; Ice; Water

1. Introduction

The occurrence of polygons on Mars similar to those found on Earth in periglacial regions has been the subject of debates for three decades. Large polygonal systems were identified on Viking images of the Northern plains (Pechmann, 1980; Lucchitta, 1983). These polygons, 2–10 km across with bounding through widths of 200 to 800 m, are too large to be compared to terrestrial periglacial polygons and could be better related to tectonic stresses, maybe in relation with a past ocean (Hiesinger and Head, 2000). New high resolution images of the Mars Observer Camera (MOC) of MGS show small-scale polygons much more similar in size to terrestrial patterned ground (Baker, 2001; Malin and Edgett, 2001; Masson et al., 2001; Yoshikawa, 2002; Mangold et al., 2002a, 2003; Kuzmin et al., 2002, 2003; Leverington, 2003). Polygons found in the Utopia and Elysium regions are several hundreds of meters large and could correspond to Late Amazonian events of thermal cracking and a possible control by thawed ground ice (Seibert and Kargel, 2001). Nevertheless, the preferred orientation of cracks suggests a control by tectonic stresses (Yoshikawa, 2002). Such interpretations question the origin of small scale polygons as due to periglacial processes created by the temperature variations in ice rich layers. Identifying polygons related to periglacial processes is important in order to study recent modifications of ice distribution and climate on Mars.

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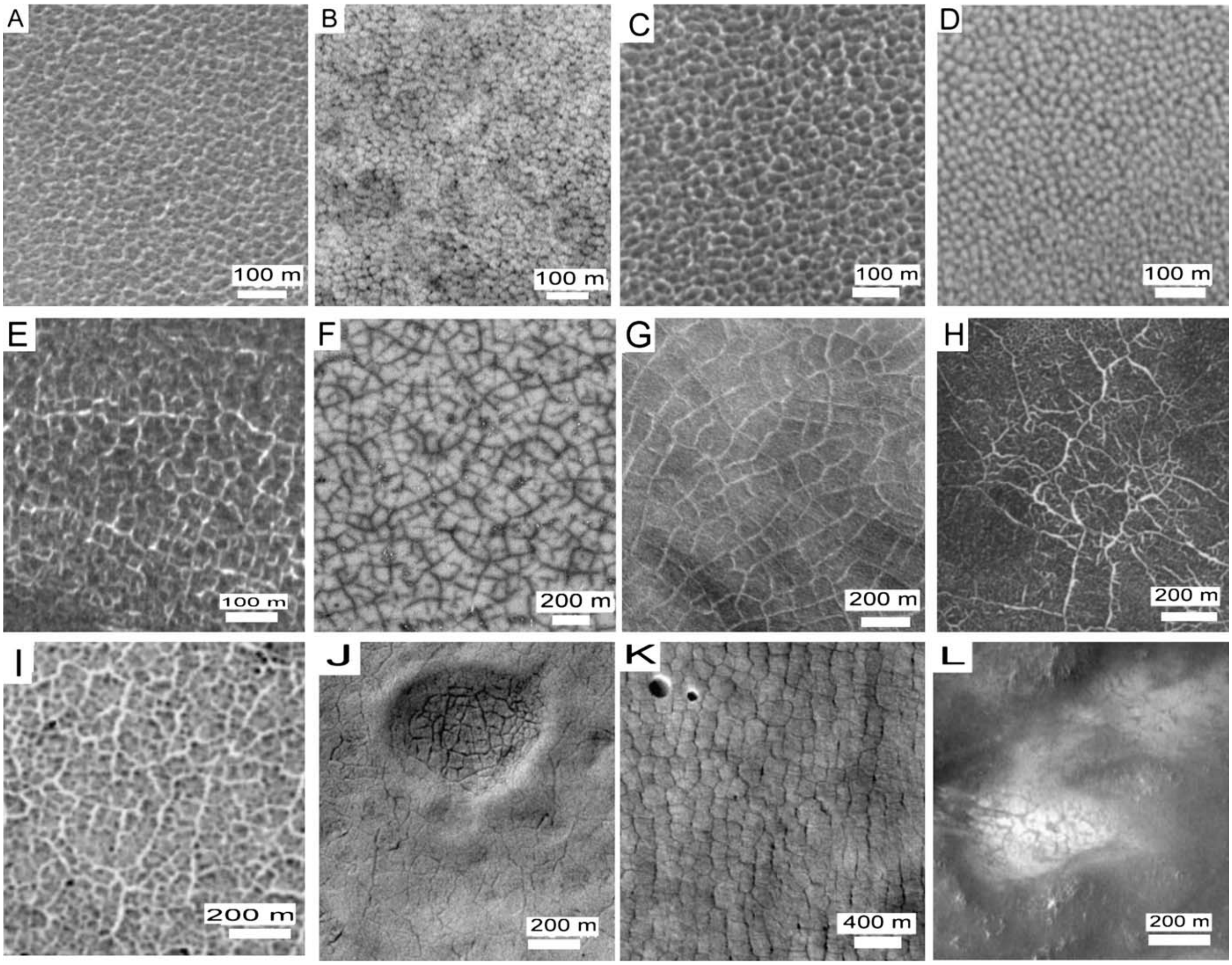

Fig. 1. Different types of small scale patterned grounds on Mars. (A) Homogeneous small polygons without apparent cracks. MOC image #M02-04505, 65.7° S, 176.8° W, $L_s = 162°$ (L_s = solar longitude). (B) Regular hexagonal patterns. MOC image #M04-02503, 63.2° S, 275.4° W, $L_s = 192.5°$. (C) Similar to (A) in the northern hemisphere. MOC image #M14-00154, 60.6° N, 2.9° W, $L_s = 329.1°$. (D) Hummocky terrains. MOC image #M03-04266, 54.1° S, 229.5° W, $L_s = 174.9°$. (E) Small cracks visible from the presence of CO_2 ice inside. MOC image #M08-03679, 69° S, 98.4° W, $L_s = 225.9°$. (F) Straight cracks close to south polar cap. MOC image #M09-01292, 84.9° S, 103.6° W, $L_s = 238.4°$. (G) Ice wedge like polygons on the floor a 20 km diameter crater in the northern hemisphere. MOC image #E03-00299, 64.7° N, 292.9° S, $L_s = 140.6°$. (H) Complex networks of cracks defining polygons of different sizes. MOC image #M08-05725, 67.7° S, 347.7° W, $L_s = 230.2°$. (I) Polygons of variable size with fractal like geometry. MOC image #M09-04469, 74.4° S, 98.9° W, $L_s = 246°$. (J) Cracks after complete defrosting of CO_2 ice. MOC image #M12-00012, 69.6° S, 271.4° W, $L_s = 293.2°$. (K) 300 m large polygons of Utopia Planitia. MOC image #M04-01631, 44.3° N, 272,7° W, $L_s = 190°$. (L) Polygons localized inside bright areas in depression patch in the equatorial region near Schiapparelli basin. MOC image #AB102306, 5.4° S, 340.7° W, $L_s = 201°$.

In this study, polygons 15 to 300 m large (Fig. 1) found at high latitudes of Mars are described and classified. The classification uses criteria such as the size of the polygons, their homogeneity of their size, the occurrence of cracks and the control by local topography. The results show that most patterned grounds can be classified into nine types. Four types are restricted to high latitudes of the southern hemisphere. Clearly associated with climatic variations are the four types of polygons found at the same latitudes on both hemispheres. Scenarios of their formation is proposed, invoking as a major process seasonal thermal contraction. The role of a potential freeze–thaw cycles is finally discussed for some of these landforms.

2. Classification, distribution and age of patterned grounds on Mars

2.1. Description of martian patterned grounds and terrestrial analogs

Small-scale patterned grounds on Mars display a large variety of geometry and size. A common kind of patterned ground consists of very regularly spaced polygons, typically 30 m large, apparently devoid of straight cracks (Figs. 1A, 1C). Similar patterns can be found in both hemispheres (Fig. 1C). Such small patterns were identified by Malin and Edgett (2000) (Fig. 9b at 54,8° S) in the vicinity of recent