

DEVELOPMENT OF POLYGONAL THERMAL CONTRACTION PATTERNS IN A SOUTH POLAR TROUGH, MARS - 3-YEARS OF OBSERVATIONS. S. van Gasselt¹, D. Reiss², A. Thorpe¹, G. Neukum¹, ¹Freie Universitaet Berlin, Institute for Geosciences, D-12249 Berlin, Germany, ²German Aerospace Center, Institute of Planetary Research, D-12489 Berlin, Germany (vgasselt@zedat.fu-berlin.de).

Introduction: As part of our mapping and classification work focused on Martian south polar polygonal patterns [1-2], we have taken special interest in areas that have been imaged two or more times by the Mars Orbiter Camera (MOC) instrument in order to identify seasonal variations. We present multi-temporal observations of variations in polygonal patterns and a qualitative discussion regarding their formation. The region of interest covers a south polar trough (SPT) at about 281° E and 87° S (fig. 1) that is incised into the south polar residual cap (SPRC), exposing underlying dark-lane deposits.

Observations: MOC-NA images M07/02129 ($L_s=204^\circ$), M12/00730 and E11/03905 (both $L_s=297^\circ$) cover the SPT. The rims of the northeast-southwest trending SPT have a mean topographic elevation of approximately 3100 meters (Figure 1). At its center, the elevation of the trough is approximately 2750 meters. Based upon spring-time observations (1999) the seasonal ice cap is still receding. The trough is filled with CO₂-snow, which blankets all underlying surface features. In summer-time data (2000/2001) several dark polygonal shapes become faintly visible. The polygonal pattern, however, has changed significantly in both summer-time images (fig. 2a-c).

Pattern Characterisation: The diameters of the individual polygons range from 10 meters to about 140 meters (fig. 3). This size distribution compares closely to that described by [3,4,5]. The data show an almost identical relative frequency of 3-ray and 4-ray conjunctions in both images. The conjunction angles between individual polygonal troughs range from 80° to 140° with two maxima at 90° to 100° (orthogonal) and at about 120° (hexagonal).

Layers: The sequence of layers in the SPT is characterised by at least three units. The top layer is a

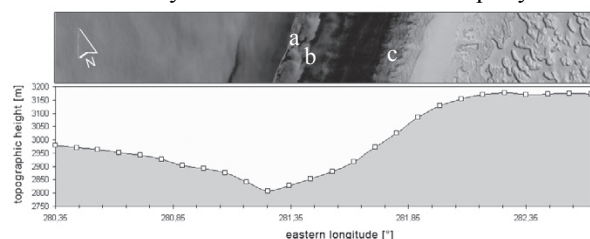


Figure 1. Topographic profile obtained by the MOLA instrument for MOC-NA image M12/00730. The polygonal crack pattern is predominantly distributed on the southeastern and sun-lit flank below 3050 metres. The cross-section of the trough is highly asymmetrical with a steeper slope angle of about 4-5 on the sun-lit flank and a more gentle slope angle of about 3 at the northwestern wall.

seasonal CO₂-frost layer that is present in the spring, but also appears to exist in the fall and winter. The (cracked) middle unit becomes exposed at the latest by early summer and vanishes by mid-summer. On this layer polygonal fractures are visible. The bottom unit consists of dark material of the trough deposits.

Frost Fissures or Ice Wedges ? The polygonal shapes are relatively smooth, upturned trough-edges and central troughs are missing. Upturning occurs as a

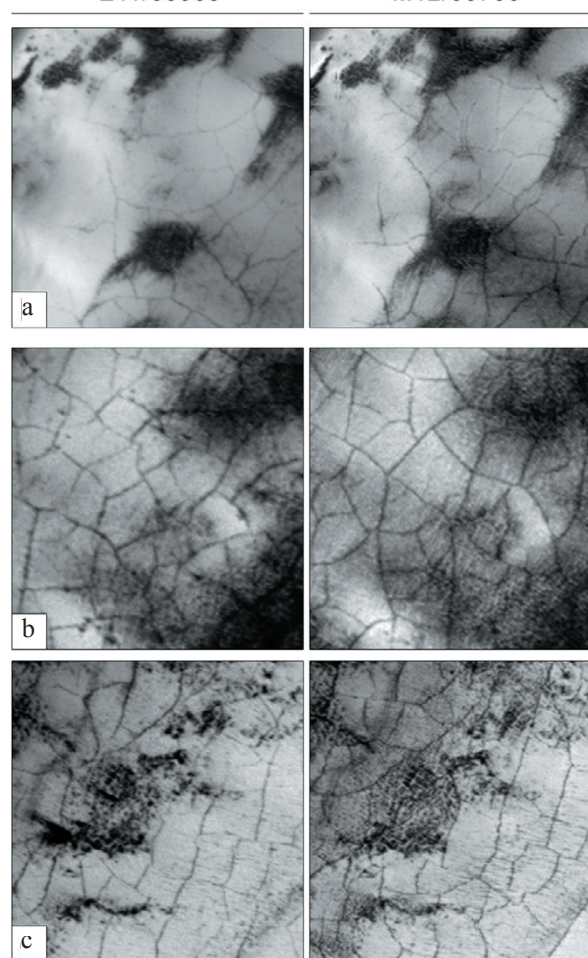


Figure 2. Comparison of high-resolution scenes taken from summer-time MOC-NA images M12/00730 and E11/03905. Lower-case letters in the scenes refer to locations marked in Figure 1. (a) Northwestern part of trough, remnants of seasonal CO₂-ice cover the lower-elevation areas. Higher elevated areas are defined by characteristic dark outcrops of the trough infill underneath. Oriented orthogonal polygon pattern occur at the southern outcrop. Image width is 4 km. (b) Highly modified polygonal pattern at the trough center, image width is 3.1 km. (d) South-eastern rim near the transition to a thick CO₂-layer. The dark patches have a fine-scaled checkerboard texture. Image width is to 4.4 km. North-direction is always up.

result of re-expansion during several freeze-thaw cycles [6]. The fractured surface disappears in mid-summer. The fact that the contraction-fissures are filled with dark material would lead to the conclusion that sand-wedges could grow if the cracked surface remained stable over many years. Because of the instability of the surface, ice- or sand-wedge polygons could not have formed; therefore, the observed features are identified as seasonal sediment-filled fissures. Orthogonal polygon networks are probably subject to formation in inhomogeneous materials. This type of polygon pattern occurs where earlier cracks, which tend to follow random sinuous courses, are intersected by later fractures [6]. As the orientation of orthogonal fissures occurs in the vicinity of outcrops of dark sediment, it seems likely that this underlying dark material has a major influence on the horizontal temperature gradient and therefore causes a concentric fracture pattern around these dark-material patches. We applied a technique devised by [7] on the basis of [6] to determine the linear expansion coefficient [$1/^{\circ}\text{C}$]. We obtained rough estimates for that in a range from $110 \cdot 10^{-6}/\text{K}$ to $320 \cdot 10^{-6}/\text{K}$ which is one order larger than those provided by [8] but still in the range of laboratory experiments ($350 \cdot 10^{-6}/^{\circ}\text{C}$) and measurements at Illisarvik ($50\text{--}400 \cdot 10^{-6}/^{\circ}\text{C}$) [7].

Model for Polygon Formation: (1) In early summer (fig. 4) seasonal CO_2 blankets the polar trough rims. Most of the CO_2 inside the trough sublimates, revealing a thin veneer of the less volatile H_2O -ice mixed with dust. (2) In mid-summer, the central SPT surface is free of cracked layers and only the dark trough infill is exposed. (3) During early fall, first H_2O then CO_2 is deposited on the trough surface. In this case, CO_2 insulates underlying layers in a similar fashion as the so-called 'active layer' on Earth. (4) In early spring, the trough is covered by a thick veneer of CO_2 frost. (5). During mid spring, CO_2 is sublimating and a diffuse polygonal pattern can be seen through the CO_2 cover. The dust, which

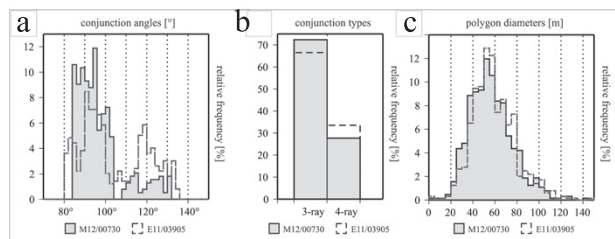


Figure 3. Polygon statistics for conjunction angles (a), conjunction types (b), and diameters (c) in MOC-NA image M12/00730 and E11/03905.

is incorporated into the sublimating CO_2 layer, is now redistributed on the H_2O layer and fills the polygonal troughs the following summer.

Conclusions: 1. We see that geologic processes are active on Mars which shows that the south polar cap (and its neighbouring units) must be considered as an individual geologically active unit [10]. 2. We found strong indications that a layer of H_2O underlies the seasonal CO_2 frost cover. This layer cracks due to thermal contraction and sublimates during summer. This thin layer plays a significant role in the development of thermal contraction cracks. 3. At this SPT, due to the instability, ice-wedging can be ruled out. 4. Each year, dark sedimentary material in the SPT accumulates after the cracked surface layer disappears and the fissure infill remains. 5. Based upon three-years of observation, polygonal patterns change annually in regions where conditions are favourable. 8. In this context, climatic change plays no role in the evolution of polygonal cracks.

References: [1] van Gasselt et al., 3rd Conf Mars P. Sci., #8088, 2003; [2] van Gasselt et al., Lun. Planet. Sci. Conf. 35, #1891, 2004; [3] Lucchitta, B., 4th Int. Conf. Proc. Permafrost, 1983; [4] Seibert, N. and Kargel, J., Geophys. Res. Lett., 28, 2001; [5] Kuzmin, R. et al., Lun. Planet. Sci. Conf. #2030, 2002; [6] Lachenbruch, A., Spec. Geol. Soc. America Pap., 70 1962; [7] MacKay, J. R., Can. J. Earth Sci., 23, 1986; [8] Mellon, M., J. Geophys. Res., 102, 1997; [9] Smith, D. et al., Science, 2001; [10] Thomas, P. et al., Nature 404, 2000.

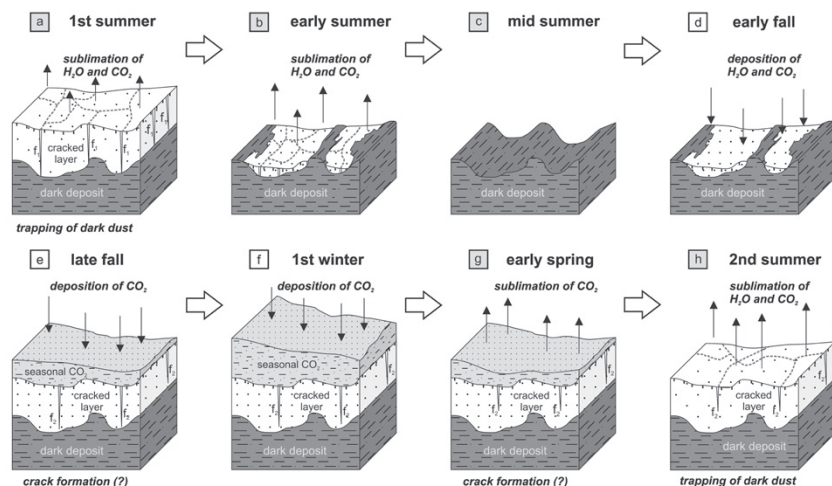


Figure 4. Three-layer-model for seasonal changes in the SPT during one Martian year starting in summer. Top layer is seasonal CO_2 snow and -ice with a thickness of several centimeters [e.g., 9]. The second layer represents a thin veneer of cracked material which might be H_2O ice. The third (bottom) layer is the SPT infill of dark material. Thicknesses of individual layers are highly exaggerated for display purposes. Gray boxes with letters represent scenarios which are covered by image observations. The time and time-span for formation of contraction cracks is uncertain. The letters f1 and f2 are first-generation and second-generation fissures, respectively.