POLYGONS IN SOUTHERN UTOPIA PLANITIA: INITIAL RESULTS FROM THE MARS ORBITER LASER ALTIMETER (MOLA). Harald Hiesinger, James W. Head III, Dept. of Geological Sciences, Brown University, Providence RI 02912, USA (Harald_Hiesinger@dlr.de).

Abstract

New data obtained by the Mars Orbiter Laser Altimeter (MOLA) allow us to analyse the topography and morphology of the polygonal terrain in southern Utopia Planitia. MOLA data show that: 1) polygonal terrain in Utopia Planitia is located at the slopes of the Utopia basin; 2) the onset of polygonal terrain in Utopia occurs nearly at the same elevation in several profiles and lies at about the same elevation as a terrace, which is interpreted as a shoreline of an ancient body of standing water within the Utopia basin; 3) polygonal terrain occurs over a wide range of elevations below the terrace, i.e. on regional slopes of ~0.1˚ and this is consistent with observations on Earth for the formation of polygons in a permafrost environment; 4) the depth of the troughs is on the order of 30 m and tends to be greater towards the center of the Utopia basin; 5) the widths of polygonal troughs are on the order of 2 km and are considerably larger than previously published; 6) the morphology of the troughs was modified by eolian and/or mass wasting processes; 7) the formation of polygonal terrain is likely due to a combination of desiccation, thermal contraction, and bending of a wet sediment layer over preexisting topography. These observations are consistent with the formation of polygonal terrain in the area of a former standing body of water.

Characteristics of Polygons: The pre-MOLA view

Polygons are relatively common on the northern plains of Mars. Most of them are located in southeastern Acidalia Planitia (45°N, 15°W), northwestern Elysium Planitia (36°N, 256°W), and Utopia Planitia (49°N, 233°W) [Pechmann, 1980]. Lucchitta [1986] noted that polygonal terrain generally occurs in close proximity to the major outflow channels and in low reentrants of the northern lowlands, which project into the southern highlands. These reentrants may have served as bays to accumulate wet sediments from the southern highlands. The giant martian polygons are 2-32 km across [McGill, 1986, 1987; Pechmann, 1980; Lucchitta, 1983; Helfenstein and Mouginis-Mark, 1980, Borrello, 1987]. Helfenstein and Mouginis-Mark [1980] measured the sizes of 383 polygons in Utopia, Acidalia and the polar regions and found that the largest polygons tend to occur in Utopia (mean size 7.4 km), while the smallest occur in the polar regions (mean size 3.5 km). The width of the fractures which form the polygons is about 200-1000 m [Pechmann, 1980; McGill, 1986]. According to Morris and Underwood [1978] the fracture width can vary up to 2 km. Based on shadow length measurements on Viking images from D.W.G. Arthur, Pechmann [1980] noted that the depth of four representative troughs varies between 30±10 m and 107±10 m. Morris and Underwood [1978] mention that polygonal troughs are typically a few hundred meters deep. McGill [1987] proposed a thickness of the polygonal terrain of 500 m. In a more recent paper McGill and Hills [1992] suggested a regional thickness of 600 m.

Characteristics of Polygons: The MOLA view

We investigated the geometry of 169 troughs within the polygonal terrain of southern Utopia Planitia. We focused on polygonal terrain between 27˚N and 47.5˚N latitude and 247.5˚W and 270˚ W longitude, an area which is mostly covered by the USGS maps I-1427 and I-1432 (1:2M). For our investigation we used of MOLA data (version of revision: m) obtained during aerobraking (hiatus-orbits) and from the science phasing orbits (SPO1&2). Seven orbits were investigated in detail; 27, 417, 251, 453, 232, 213, and 361 (sorted by increasing longitude).

Location, geologic context, and relation to regional topography: The geologic map [Greeley and Guest, 1987] shows that polygonal terrain in Utopia Planitia mainly consists of material of the Hesperian Vastitas Borealis units. The Vastitas Borealis formation is of volcanic, alluvial or eolian origin and shows evidence of tectonism, compaction, or periglacial and erosional processes [Greeley and Guest, 1987]. The channel deposits of the Ael_3 unit which are Amazonian in age are interpreted as lahar streams [Christiansen, 1989], which have flooded the basin center from the southeast and have partly covered the polygonal terrain. Interpolating between all available MOLA orbits in order to generate a global topographic map [Smith, 1999] and combining this map with the map of Lucchitta [1986] we see that the polygonal terrain in Utopia Planitia is located on the slopes of the Utopia basin [McGill, 1989; Frey and Schultz, 1990; Schultz and Frey, 1990; Thomson and Head, 1999]. The USGS topographic map [Eliason et al., 1992], which was available before MOLA, does not reveal the important relationship between polygonal terrain and topographic position within local basins. Going northward along the 5 profiles that start south of the polygonal terrain, the onset of polygons occurs at about the same elevation level within a narrow range of ~70 m (-4339 m to -4410 m). In addition, the onset of polygonal troughs occurs close to the same elevation of a terrace at -4350 m which is interpreted by Thomson and Head [1999] as the shoreline of a paleolake, which once filled the Utopia basin. Five MOLA passes cross this terrace and in all passes the onset of polygonal troughs is within 60 m of the elevation of the terrace. Both the terrace and the onset of polygonal terrain occur at an elevation where a hypothetical water fill of the Utopia basin would spill over into the adjacent northpolar basin. These observations argue for a formation of polygonal terrain in a recessional environment like a drying lake or ocean.

Slopes: Polygonal terrain in southern Utopia Planitia slopes to the north and therefore following the global trend observed in all MOLA profiles, independent from the geologic unit.. Therefore, polygons occur at different topographic levels along the general north-facing slope and do not mark a single horizontal topographic level. The slopes along the MOLA ground tracks in the investigated region are less than 0.1˚ over baselines from tens to hundreds of kilometers and appear to be very similar to all investigated MOLA orbits. Orbit 417 shows the smallest slope (0.0184˚), orbit 251 the largest slope (0.0626˚), and orbit 27

(0.0484˚), orbit 213 (0.0474˚), orbit 232 (0.0611˚), orbit 361 (0.0597˚), and orbit 453 (0.0461˚) exhibit intermediate slopes. The mean slope of polygonal terrain in southern Utopia Planitia is 0.0491˚. These slopes are in excellent agreement with slopes measured by Head et al. [1998] who point out that the systematic slope from the equator to the pole is on the order of 0.056˚. All slopes were calculated as linear least square fits of all data points.

Width, depth, and dip angles: MOLA profiles usually do not cross the polygon troughs perpendicularly. Therefore, the width measured in the profiles is corrected for widening due to oblique cross-cutting. Even after this correction, our widths are considerably larger than previously published trough widths of polygonal terrain, between 200-1000 m [Pechman, 1980, McGill, 1986]. However, our data are in good agreement with trough widths of up to 2 km, as suggested by Morris and Underwood [1978]. We determined the width for 169 troughs from the MOLA profiles and found that the width varies between 0.5 km and 7.5 km. 36% of all fractures show a width of <1.5 km and 72% of all troughs exhibit a width of <2.5 km. Only 17% of the investigated troughs are smaller than 1 km in width. The mean fracture width is about 2 km with a standard deviation of 1.14. The depths derived from the MOLA profiles are in excellent agreement with the previously published data [Pechmann, 1980] and vary between 5 m and 110 m. The mean depth of the investigated troughs is 32 m with a standard deviation of 22. 62% of all measured troughs are shallower than 30 m. When depth and width of the polygonal troughs are plotted versus the distance from the basin center (45˚N, 248˚W), the depth increases towards the basin center. The determination of acurate dip angles causes problems because MOLA data usually do not cross the polygonal troughs perpendicularly. In addition, most of the troughs exhibit convex or rounded rims which yield systematically smaller dip angles if they are included in the measurements. At the base of the troughs concave debris aprons may have accumulated, thus decreasing the dip angle. For these reasons, we calculated dip angles based on the depth of a trough and the width which was corrected for oblique crossing of the MOLA pass. Therefore our dip angles are only estimates as we do not know the exact morphology perpendicular to the trough orientation but only along the MOLA ground track. In general, we see that the dip angles of the trough walls are usually small with a mean dip angle of less than 3˚ and a variation from 0.5˚ to 15˚.

Morphology: Investigating the morphology of individual troughs, we see a broad variety ranging from simple v-shaped troughs to more complex u-shaped and w-shaped fractures. However, it should be kept in mind that small, simple v-shaped troughs may simply be the result of limited spatial resolution when the trough is defined by only a small number of data points. Another point to keep in mind is that the shape of the trough in a MOLA profile is strongly influenced by the angle between the profile track and trough orientation. With these limitations in mind, troughs may be symmetric or asymmetric in shape and can either show convex or concave walls. In our data, a large number of the troughs appear more or less symmetrical with convex upper trough walls and concave bottoms. In addition a number of troughs show a morphology which could be interpreted as raised rims. Such raised rims may indicate that ice wedging was an important process to form polygonal terrain.

Conclusion

Results from MOLA data are consistent with a formation of polygonal terrain in the area of a paleolake which once filled the Utopia basin. As major parts of polygonal terrain north of the Chryse area [Lucchitta, 1986] are also found in a topographic depression, we suggest that the formation of polygonal terrain is closely related to isolated basins, which may have accumulated water, ice, mud, or slush in order to form at least temporarilly lakes. We conclude that bending of a wet sediment layer over preexisting topography in combination with shrinkage due to desiccation and/or thermal contraction of the wet sediments can explain most of the MOLA observations.

References

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