MARTIAN OCEANS: OLD DEBATE - NEW INSIGHTS. Dorothy Z. Oehler[1] and Carlton C. Allen[2], [1]LZ Technology/Jacobs JETS Contract, Johnson Space Center, Houston TX 77058; dorothy.z.oehler@nasa.gov. [2]NASA, Johnson Space Center, Houston, TX 77058; carlton.c.allen@nasa.gov.

Introduction: The possibility of an ancient ocean in the northern lowlands of Mars has been discussed for decades [1-14], but the subject remains controversial [15-20]. Among the many unique features of the northern lowlands is the extensive development of "giant polygons" - polygonal landforms that range from 1 to 20 km across. The kilometer-scale size of these features distinguishes them from a variety of smaller polygons (usually < 250 m) on Mars that have been compared to terrestrial analogs such as ice-wedge and desiccation features. However, until recently, geologists were aware of no examples of polygons on Earth comparable in scale to the giant polygons of Mars, so there were no good analogs from which to draw interpretations.

That picture has changed with 3D seismic data acquired by the petroleum industry in exploration of offshore basins. The new data reveal kilometer-scale polygonal features in more than 50 offshore basins on Earth (Fig. 1) [21-26]. These features provide a credible analog for the giant polygons of Mars.

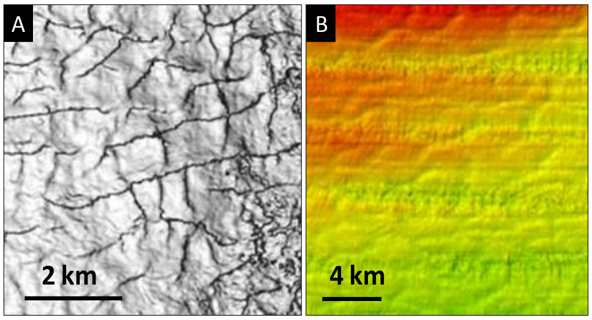

Fig. 1. **Giant polygons - Earth. A.** 3D seismic map of subsurface polygons, offshore Norway [26]. **B**. Seabed polygons imaged by multibeam acoustic data, offshore Ireland (Irish Geological Survey); colors = water depths.

Giant polygons on Earth and Mars: On Earth, large-scale polygons (LSPs) occur exclusively in offshore accumulations of fine-grained sediments (*e.g.*, shales, mudstones). These polygons are bounded by normal faults and range in size from about 0.5 km to 4 km. Moreover, the LSPs only occur in sediments deposited on passive margins (basins lacking significant horizontal stress) [21-26]. These polygons are thought to result from compaction, 3D contraction, and dewatering that occurs with shallow burial (20 m-700 m). Recent work suggests further that the genesis of the bounding faults may involve diagenesis of clay-rich sediments leading to shear failure under low confining stress [21]. Polygon fields can span millions of km^2 and may be associated with fluid expulsion structures such as mud volcanoes and gas-release depressions.

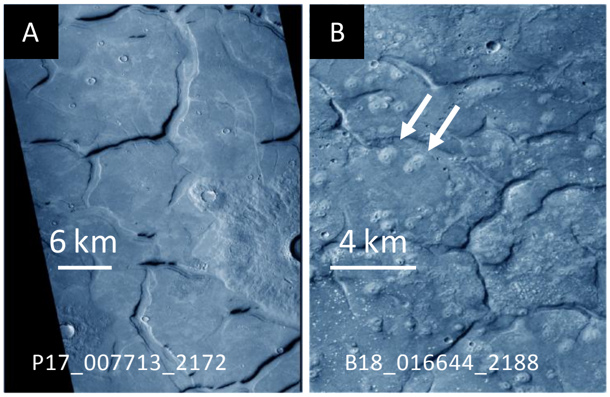

Fig. 2. Giant polygons - Mars. A. S. Utopia. **B**. Acidalia showing associated mounds (arrows).

On Mars, giant polygons are common in Acidalia and Utopia [27-28] (Fig. 2). In Acidalia, they are 1-10 km across, and fields of them span more than 10^6 km^2 [29]. In Utopia, giant polygons are developed in the SW and in the N, separated by Amazonian volcanics [30]. The largest polygons (~3-20 km) are in the SW. In the N, sizes are smaller (~ 2-10 km). Together, the two areas cover more than 3 x 10^6 km^2. In both Acidalia and Utopia, giant polygons occur within the Vastitas Borealis Formation [31], a unit thought to have formed from late Hesperian outflow sediments or their periglacially modified residues [10].

Comparison of Size and Geologic Context:

***Size*:** Both the terrestrial and martian features are kilometer-scale and 1-2 orders of magnitude larger than other types of polygons on Earth and Mars. Terrestrial LSPs scale with burial depth, such that the largest features occur in areas with least burial. On Earth, when burial exceeds ~300 m, LSPs divide into smaller 2^{nd} order polygons [32]. This is thought to be a consequence of increasing compaction with greater depth. The generally large sizes of martian giant polygons may reflect, in part, relatively low compaction due to shallow burial and/or low planetary gravity. Recent work also suggests that basement topography may play a role in polygon size by localizing stresses around buried features and thereby influencing positioning of polygon faults [33]. Thus, more widely spaced irregularities in basement topography may promote the development of larger polygons.

Geologic Context: *Tectonic Setting*. Terrestrial LSPs form only in sediments deposited on passive margins. The lack of strong horizontal compressive stress in such settings appears to promote radial contraction that leads to polygon formation. Since plate tectonics on Mars has been minimal, many martian settings may be similar to terrestrial passive margins in lacking strong horizontal stresses. *Sediment Type and Rate of Deposition*. On Earth, LSPs occur exclusively in fine-grained sediments, and rapid deposition has been implicated in their formation. Studies of Mars suggest that distal-facies, fine-grained sediments would have been deposited in Acidalia by the late Hesperian outflow floods [34-35]. Utopia also may have received sediments from the Hesperian floods [30], and possibly very fine-grained deposits and limited burial may have contributed to the large size of polygons in SW Utopia. *Mud Volcanoes*. On Earth, some LSPs are associated with mud volcanoes (MVs), though other LSPs lack this association [29]. In Acidalia, mounds interpreted as MVs occur with giant polygons (Fig. 2) [29]. In Utopia, giant polygons in the SW lack MV-like mounds, but possible mounds occur in the N. *Elevation*. The distribution of martian giant polygons appears to be restricted by elevation. In Acidalia, they only occur below -3900 m [29]. In Utopia, they appear to have a slightly deeper upper limit of -4050 m.

Discussion: The general similarities in size and geologic context between the martian and the terrestrial polygons support the possibility that the martian features formed in sub-aqueous settings. The relationship between the martian giant polygons and elevation might suggest that their formation was related to an equipotential surface (level of water or sediment). The upper elevation limits of the giant polygons are similar to geomorphic levels mapped and recently reassessed by Parker and colleagues as the Deuteronilus and Acidalia Levels, with one interpretation being that those Levels might correspond to short-lived transgressions caused by floods into a frozen ocean [36-37].

The late Hesperian outflow floods may have been the triggering event for such a transgression and for the rapid deposition and burial required for giant polygon formation. Consistent with this is new evidence, from exposures in crater walls, for widespread aqueous sedimentation in Chryse and Acidalia resulting from the Hesperian floods and involving "immense volumes of water and sediment" [38]. Similarly, a former ocean or ponded, frozen outflow discharge is suggested by evidence for a residual cryosphere from recent work correlating high mobility, fluidized crater ejecta with low radar surface permittivities [39].

Summary and Conclusions: The terrestrial analog of LSPs in subsea passive margins can explain features of martian giant polygons including their size, occurrence in lowland areas where fine-grained sediments are predicted, elevation restriction, and association of some with mud volcano-like mounds. This analog implies that the giant polygons on Mars reflect burial of water-wet sediments to depths of at least 20-300 m. Burial could have occurred below a frozen ocean or major body of liquid water. The late Hesperian outflows may account for the liquid and sediment volume that produced both the water-wet conditions and burial required for giant polygon formation. This interpretation joins recent studies suggesting the existence of an ancient martian ocean - one possibly ice-covered for much of its history, but with transient episodes of liquid water. The giant polygons of Mars may reflect one or more of these aqueous episodes.

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