SORTED STONE CIRCLES ON SVALBARD: A MARS ANALOG? H. Hiesinger[1], V. Jungheim[1], D. Reiss[1], E. Hauber[2], A. Johnsson[3], [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (hiesinger@uni-muenster.de), [2]DLR-Institut für Planetenforschung, Rutherfordstr. 2, 12489 Berlin, Germany, [3]Univ. of Gothenburg, Box 100 SE-405 30 Gothenburg, Sweden.

Introduction: Patterned ground is abundant on the surface of Mars and is found across a wide range of latitudes [1-4]. Generally, patterned ground is common at latitudes above 55° North and South and becomes patchier closer to the equator in both hemispheres [e.g., 1,5,6]. Regions with abundant patterned ground are commonly correlated with high amounts of hydrogen in the near-surface [7,8]. The latitude-dependent occurence in both hemispheres indicates that patterned ground formation is controlled by climate and the presence of near-surface ice [1,5,9-11].

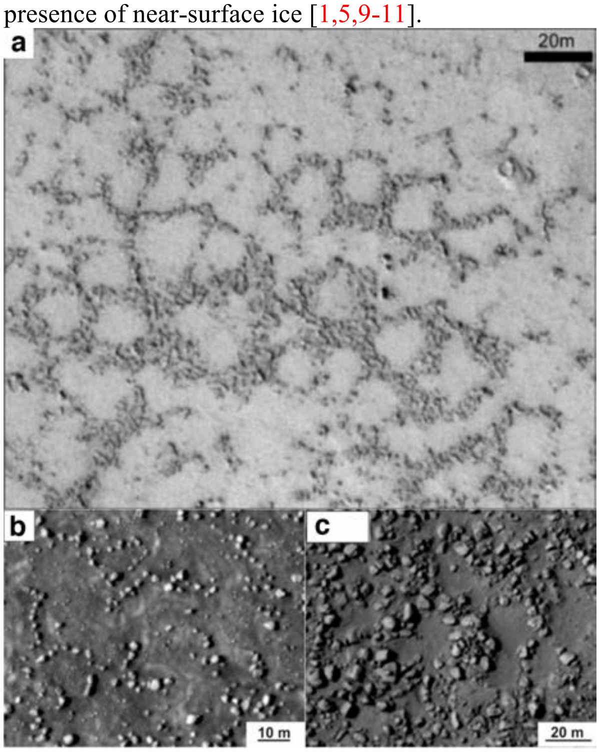

Fig. 1: Stone circles on Mars. (a) circles in Elysium Planitia [12]; (b) boulder clustering at 66°N [13]; (c) boulder clustering in the circum-Argyre Planitia highlands [14]

One particular type of patterned ground on Mars are sorted stone circles (SSCs) [e.g., 12]. These SSCs are located in Lethe Vallis, an erosional channel in the downstream area of the Athabasca catastrophic flood deposits [12]. Over 200 almost circular polygons with average diameters of 13.7 m were identified by [12]. The observed minimum diameter is 6 m and the maximum diameter is 23 m [12]. These SSCs have a flat interior and are bordered by clastic margins with rocks from the pixel scale minimum (0.25 m) up to 2 m. The walls are between the width of one rock up to 5 m [12]. These SSCs are arranged in a network pattern (Fig. 1). They appear in an assemblage of landforms including domed polygons, polygons with high relief, and ring-mound landforms [12]. These surrounding features and the presence of SSCs suggests a periglacial environment [12]. Boulders of patterned ground elsewhere on Mars seem to have moved over geologically short timescales of ~1 Ma or shorter, suggesting that these features are geologically young [13].

To assess the possible periglacial origin of the martian SSCs, we performed detailed multi-year (2009-2016) studies of periglacial analog SSCs on the high-arctic archipelago of Svalbard. The field studies were performed during July/August of 2012-2014 in Western Spitsbergen on the peninsula Brøggerhalvøya, located west of the research station Ny Ålesund. The study area at the tip of the peninsula is called Kvadehuksletta, which is a coastal strand flat with several beach ridges and intermittent swales, representing ancient shorelines caused by isostatic rebound after the last glacial maximum (26,500-20,000 years ago) [15].

Methods: We applied a wide variety of field techniques to study SSCs in Svalbard, including morphometric measurements, digging, trenching, sampling, topographic measurements, measurements of the active layer thickness, color marking to determine possible areas of frost heave activity, stereo imaging as well as vertical imaging from a kite and a ~3 m high pole. These field measurements were augmented by laboratory analyses of the grain size distribution, the soil moisture, and the soil organic carbon (SOC).

Results: The 22 studied SSCs vary widely in morphology and sizes. Some are near-perfectly circular, others are elliptic or even asymmetrical with no complete outer ring or sorted nets. There are also circular inner domains with irregular outer walls. The diameters of the SSCs range from 1.8 m to 10 m with an average diameter of 3.2 m, hence being about one order of magnitude smaller than their martian analogs. The width of the wall varies between 0.3 m and 1.2 m and the average width is 0.7 m, again being significantly smaller than the martian SSCs. The height of the wall is generally a few centimeters to decimeters. The ratios of the wall widths to the SSC diameters are between 0.11 and 0.44 with a mean value of 0.22. Some SSCs are well sorted and the boundary between the inner domain and the outer wall is distinct. Others have large amounts of coarser material located on the surface of the inner domain so that the distinction by grain size or material properties is difficult. The rocks can be well rounded or angular (Fig. 2), sometimes both shapes are present at the same sites.

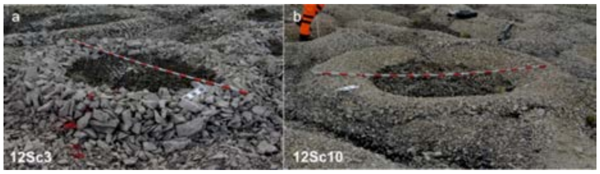

Fig. 2: Two examples of sorted stone circles on Svalbard consisting of angular clasts (left) and rounded gravel (right) 2014 (red scale = 10 cm)

All excavated SSCs showed a very well defined steep-walled pedestal (sometimes with a ridge) underneath the inner part of the rock wall consisting of more consolidated material (Fig. 3).

Fig. 3: Excavated SSC showing the steep-walled pedestal (left) and the two perpendicular trenches dug in 2014 (red scale = 10 cm)

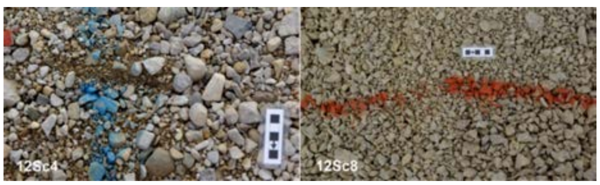

Fig. 4: Field images from 2013 (right) and 2014 (left) of the color markings done in 2012 (scalebar = 5 cm).

Some images taken in 2013 and 2014 show changes that have occurred since the marking of the SSCs in 2012. In Fig. 4 (left), the blue marking on SSC 12Sc4 is interrupted by a zone of finer grained material in the center of the rock wall in 2014. In 2013, we observed an interruption of the red line in the wall center of SSC 12Sc8 (Fig. 4, right). This indicates that SSC formation is still active and surpasses the estimateed velocity of boulder movement of >1-10 µm/a on Mars [13].

All together, 96 samples were retrieved from various depth from two trenches across SSC 14Sc1 in 2014 and from several SSCs in 2012 and 2013. The moisture of the samples varies between 0 and 16%. As expected, the soil moisture is higher in the swales than on the slopes or ridges. However, low soil moisture values were also recorded in some swales. The grain size distributions of all samples show that gravel dominates in most of the samples (69 out of 96) meaning that gravel is the most common size fraction. In some samples silt is the dominant grain size (23/96); in one case the sand and gravel content were the same. Only very few samples were predominantly sand (3/96) and none was dominantly clay. Samples from the inner domain are generally finer grained than samples from the wall. The samples show four types of grain size distributions (Fig. 5). They can be distinguished by the proportion of grain size fractions of the total sample. Type 1 occurred in 27 of the 96 samples, Type 2 in 44 samples. Type 3 encompasses 18 samples and type 4 occurred in 7 samples.

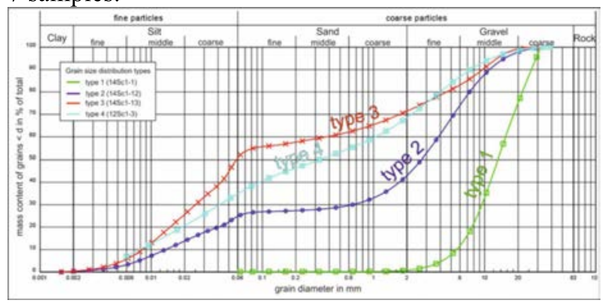

Fig. 5: Grain size distribution types identified in samples from Svalbard

The samples contained between 0 % and 1.97 % SOC with an average content of 0.71 %. The SOC content seems to be independent of the vertical distribution of the samples. Most samples have a SOC-content between 0.3 % and 1.4 % with some samples from the surface containing almost no SOC and one near-surface sample containing the highest SOC-content of 1.97 %. For comparison, SOC values between 0.1% and 3.9% in a SSC at Kvadehuksletta with a distribution suggesting convective soil motion have been published by [16]. Our SOC-data are generally similar, although we do not observe the same distribution. Thus, we can not confirm the proposed convective soil motion as a formation mechanism for SSCs.

Conclusions/Discussion: On the basis of our analog terrestrial study results, we raise the following question. Provided a long-lived, geologically recent, active cryoturbation layer of ground ice existed on Mars within the last few million years of SSC formation [12], it is still questionable if this layer would have been sufficiently thick to produce SSCs with boulder sizes found on Mars. At Kvadehuksletta the active layer is about 0.5-1.0 m thick, forming SSCs with diameters of 3-6 m. On the basis of our Svalbard results, an active layer capable to form SSCs of the observed diameters of 6-23 m on Mars would have to be at least 2-6 m thick. At a minimum, the active layer should be thicker than the size of the diameter of the largest transported grain size or the boulders would stick in the frozen ground beneath and could not take part in the sorting process. Thus, currently the formation model of [17] appears more plausible.

References: [1] Mangold, 2005, Icarus, 174; [2] Mellon et al., 2007, Proc. 7th Int. Conf. on Mars, 3285; [3] Mellon et al., 2008, JGR, 114; [4] Balme and Gallagher, 2009, EPSL, 285; [5] Kostama et al., 2006, Geophys. Res. Lett., 33; [6] Marchant and Head, 2007, Icarus, 192; [7] Boynton et al., 2002, Science, 297; [8] Feldman et al., 2002, Science, 297; [9] Head et al., 2003, Nature, 426; [10] Mellon et al., 2009, JGR, 114; [11] Soare et al., 2016, Icarus, 264; [12] Balme et al. 2009, Icarus, 200; [13] Orloff et al., 2011, JGR, 116; [14] Banks et al., 2008, JGR, 113[15] Clark et al., 2009, Science, 325; [16] Hallet and Prestrud, 1986, Quat. Res., 26; [17] Orloff et al., 2013, Icarus, 225