INVESTIGATING MARTIAN RIPPLE FORMATION IN THE AARHUS MARS SIMULATION WIND TUNNEL.

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Introduction: Two scales of aeolian sand ripples have been observed on Mars in images from the NASA Mars Exploration Rover (MER) Spirit [1] and Mars Science Laboratory (MSL) Curiosity [2] (Fig. 1). Such a pattern consists of dm-scale ripples superimposed over larger m-scale bedforms [1, 2]. In Gale Crater, both ripple sets are observed over dark sand dunes of the informally named Bagnold dune field forming a three-order bedform hierarchy [2, 3]. Interestingly, according to [1], both ripple sets formed on unimodally-distributed sand. The origin of this complex ripple pattern has been debated in the scientific community [4-7]. According to [1] the m-scale ripples are analogue to dm-scale impact ripples forming on Earth. Their larger size is attributed to the low-density Martian atmosphere, and in particular to the lower wind dynamic pressure, allowing these bedforms to protrude higher in the boundary layer [4]. Thus, in the view proposed by [4], both Martian ripple scales are formed by the same impact mechanism. Conversely, [2] suggested that the m-scale ripples are different, and form due to the lower kinematic viscosity of the Martian atmosphere [1]. In this view, while the dm-scale ripples are analogue to their terrestrial counterparts, the larger m-scale ripples arise from another type of instability and are similar to current ripples forming in water on Earth [1]. While the scaling relationship between m-scale ripple wavelength and atmospheric density [8] seems to support the view of [1], a re-examination of sand grain size in the Bagnold dune field done by [7] shown that the grain size distribution is not unimodal as suggested by [1], thus favoring the formation model proposed by [1, 4].

Here we expand and complement previous experiments that shown the co-existence of two ripple scales on monodisperse 90 µm glass beads [8], by analyzing ripple formation in unimodally distributed 125 µm natural sand and on monodisperse (170 µm) glass beads at different pressures in the Aarhus Mars wind simulation tunnel (AWSTII) (Fig. 2).

Preliminary results: The experiments, funded by two Europlanet grants (20-EPN-054 & 22-EPN3-076), were conducted at different pressures: 1013 mb (terrestrial pressure), 500, 250, 125 and 16 mb (Martian pressure), for both glass and natural sand. In addition, for the natural sand, we performed additional runs below the Martian pressure for the first time, at 8 and 4 mb. *Glass beads.* Two scales of ripples formed at terrestrial pressure (Fig. 1a) and at 500 mb. The larger (hydrodynamic) pattern is lost at 250 mb. Results for finer glass beads obtained in 2022 in the same facility [8] show that hydrodynamic ripples were still visible at 250 mb. but lost at lower pressures. Thus, for the coarser fraction analyzed here (170 µm), the hydrodynamic ripple pattern is lost at higher pressures suggesting a relationship between grain size and ripple pattern [8]. *Natural sand.* For the natural sand the presence of two patterns is not as clear as for the glass beads suggesting that, together with the size, even the shape of the grains is playing a role in dictating the development of two ripple sets (Fig. 1b). It is possible that less regular sand grains will initiate a coarsening process e.g. small megaripples that will interfere and even block the formation of the hydrodynamic ripples. A preliminary qualitative analysis of impact ripple formation in natural sand, seems to point toward an inverse relationship between ripple size and pressure (Fig. 1b, c). We are currently investigating this interesting behaviour (also hypothesized for the Martian impact ripples by [1]) quantitatively by computing how the wavelength of the bedforms and other pattern parameters (crest orientation and dispersion) change with time (Fig. 3).

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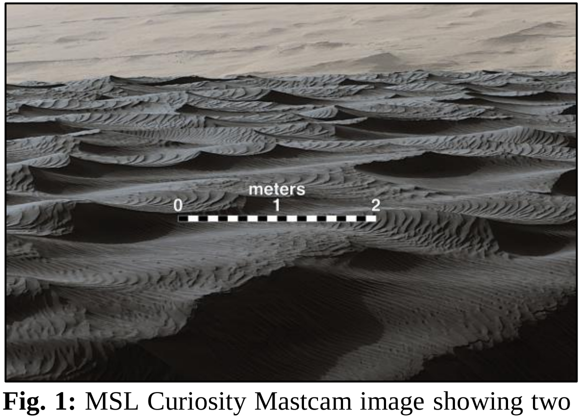

Fig. 1: MSL Curiosity Mastcam image showing two ripple sets on the stoss side of the Namib dune in Gale Crater on Mars. NASA/JPL-Caltech/MSSS.

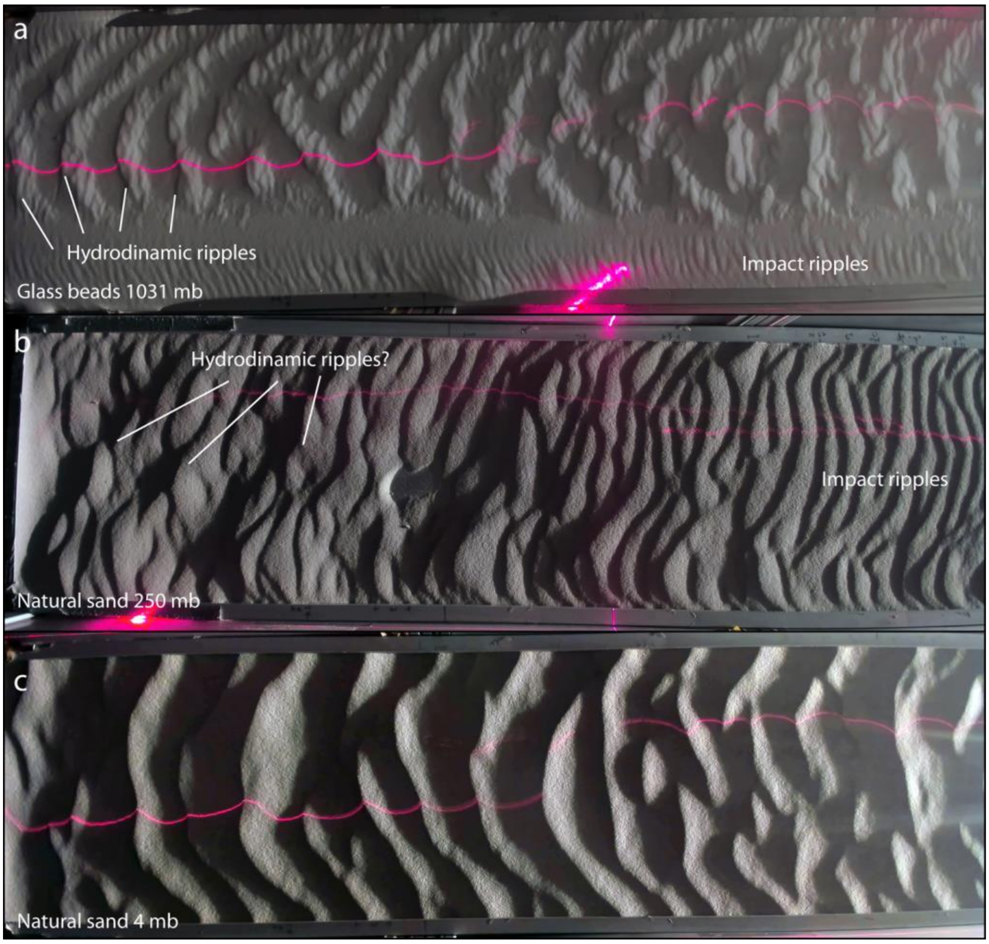

Fig. 2: Ripple pattern obtained in the low pressure wind tunnel. a) two ripple sizes formed in glass beads (170 µm) at 1031 mb. b) ripples in natural 125µm-sand at 250 mb. Two scales might be distinguished but they are not as evident as in the glass beads. c) ripples at 4 mb in natural sand. Only one pattern can be distinguished.

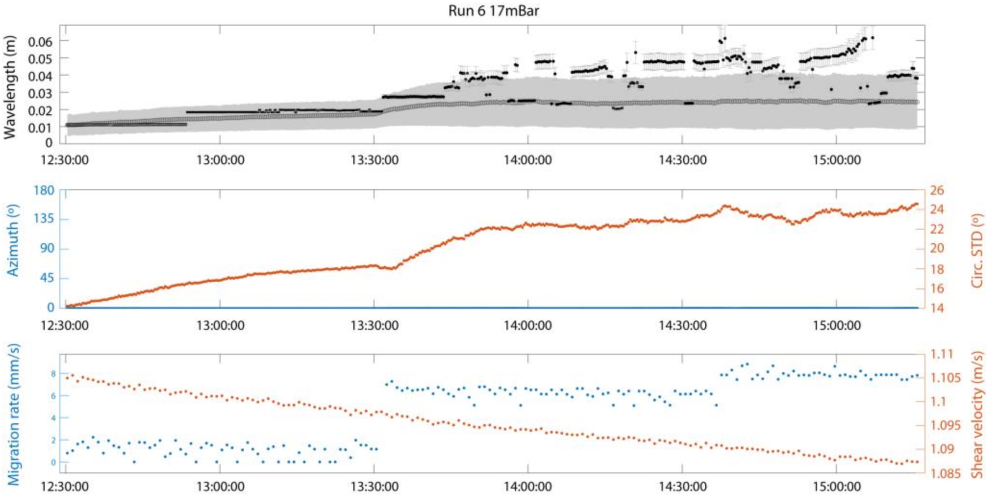

Fig. 3: Ripple pattern analysis for the 170 µm-glass beads at Martian pressure. Note how the wavelength stabilizes with time.