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Unique ventifacts and related aeolian conditions at Zhurong landing site, Utopia Planitia, Mars

Zhaopeng Chen^{1,2}, Qing Zhang², Lin Guo², Sylvestre Maurice¹, Agnès Cousin¹, Gwénaél Caravaca¹, Matteo Loche¹, Wangli Chen², Dawei Liu², Xin Ren², Jianjun Liu², and Chunlai Li²

¹ Institut de Recherche en Astrophysique et Planétologie, Université de Toulouse, UPS, CNRS, Toulouse, France

² National Astronomical Observatories, CAS, Beijing, China

Introduction. On 14 May 2021 (UTC), China's first Mars rover, Zhurong, has opened a new frontier of in-situ Mars exploration when it landed in the vast terrain of southern Utopia Planitia [1]. The first year of Zhurong's journey has provided close-up views of the landscape. Traversing south, the rover was able to visit several bright dunes and witness several ventifacts [2]. For the ventifacts, [2] described some being pitted and layered with flaky structures, while [3] has inferred that some of the low-lying ventifacts were exposed sulfate duricrusts, suggesting possible underground aqueous activity. Here, we have identified that the flaky features are aeolian and their formation relates to certain aeolian conditions.

Ventifacts. The Multispectral Camera (MSCam) onboard Zhurong was able to capture 29 high-resolution images of blocks exhibiting abraded features interpreted as ventifacts during the first 300 Martian solar days (sols). Common abraded features like linear features (Fig. 1acdf) and scallops (Fig. 1bef) [4] were identified at 10-50 mm scales. Curiously, a unique kind of smaller (generally < 10 mm, most at 3-5 mm), flak/scale-like morphology was also discovered (concentrated and scaly in Fig. 1adf and flaky in Fig. 1be, see also Fig. 2 central image). Both the common and unique features showed consistent general orientations (Fig. 1g) correlating with the highest velocity wind that occurred during local winter (given by Mars Climate Database (MCD) [5][6]), suggesting an aeolian origin. In addition, Zhurong's MarSCoDe microscopic images [7] of the ventifact surface before and after MarSCoDe laser ablation [7]

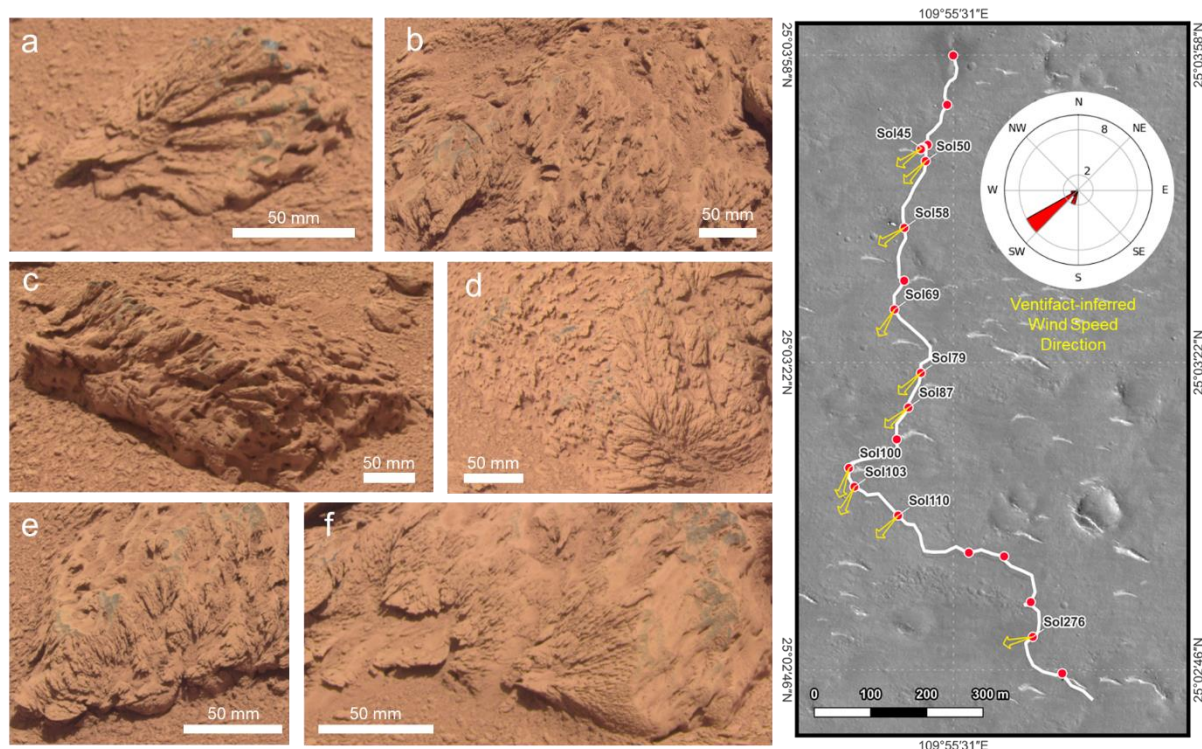


Fig. 1 (a-f) Example of ventifacts observed by MSCam on Sol 79 (af), 87(be), 110(c), and 276(d). Note that pits also presented on the ventifacts but they have no preferred orientation, presumably igneous. (g) Track of Zhurong during its first 300 sols and dotted sites with MSCam imaging. Sites where a general orientation of the abraded features can be clearly inferred with visual inspection are marked with their Sols and arrows indicate the inferred wind velocity directions. Base map by the High Resolution Imaging Camera (HiRIC) onboard the Tianwen-1 orbiter.

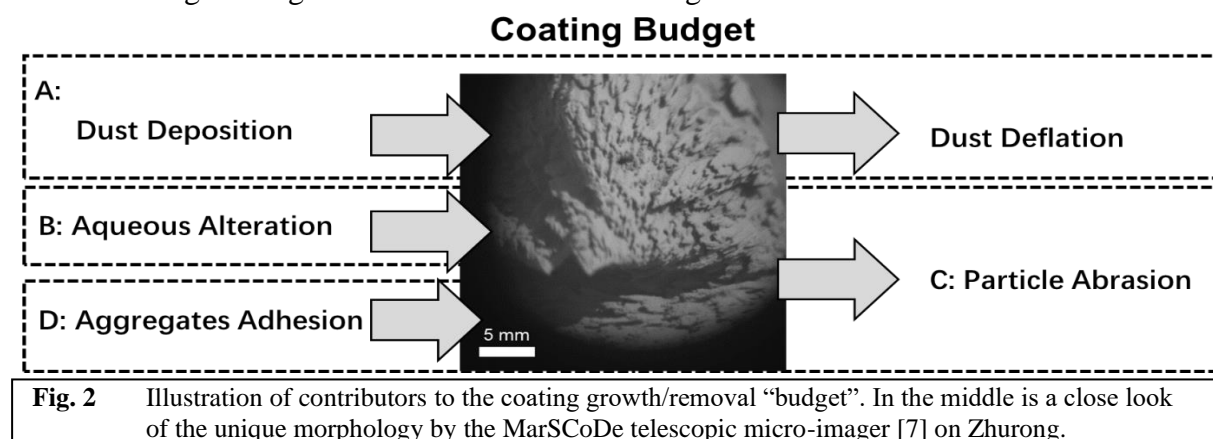
revealed that the flak/scale-like morphology has a similar low hardness as the ventifact coating rather than the harder interior. To our current knowledge, the unique small and flak/scale-like morphology on ventifacts has not been observed in previous Mars missions. Combining the evidence for scale and hardness, we argue that the uniqueness of the morphology is induced by the presence of an extensive coating, which provides material of low hardness to be abraded into current forms.

Aeolian conditions. We then looked into what local aeolian conditions might dominate the coating growth/removal (Fig. 2):

- (A) Atmospheric dust deposition/deflation balance was biased toward to net removal according to previous studies ([8], estimated by [9]: about $-10 \mu\text{m}/\text{yr}$);
- (B) Erosion rind / dust cementation induced by transient water ice may not exceed several μm per year, due to the thickest annual ice deposition being $\sim 0.2 \mu\text{m}$, predicted by MCD [10];
- (C) Coating abrasion by saltation of sand-sized particles could reach $500 \mu\text{m}/\text{yr}$ with an abundant sand supply (our calculation, following [11][12][13][14]);
- (D) Coating growth by adhesion of saltated sand-sized silt-clay aggregates [15][16] may reach a magnitude similar to C.

Thus, considering the magnitude of the contributions, we hypothesized C and D as the major balancing factors concerning the current coating formation. Further comparative investigation discovered that, unlike for example Ares Vallis [17] and Gale [18], there is no significant abrasive sand supply around the Zhurong site as local dunes were inactive [19], which may enable D, supplied by the aggregation local particles, to accumulate sufficient coating. The coating can be further maintained by electrostatic force or cementation by concurrent atmospheric moisture [20] (MCD result [10]).

While our investigation does not yet find a past habitable environment, we suggest that the adhesion of aggregates may pose a threat to future in-situ missions, as they may require some abrasion to be removed. A stationary spacecraft, within the height of aggregates saltation (generally $< 1 \text{ m}$ [21]), may be covered by Martian material faster than expected if little removal mechanism (such as C) is present. The source of the aggregates and the exact extent of adhesion at the Zhurong landing site are still under our investigation.



[1] J. Liu et al., *Nat. Astron.*, **6** (2021). [2] L. Ding et al., *Nat. Geoscience*, **15** (2022). [3] Y. Liu et al., *Science Adv.*, **8**, 19 (2022). [4] J. Laity and N. Bridges, *Treaties on Geomorphology*, **11.14** (2013). [5] F. Forget et al., *JGR:Planets*, **104**, E10 (1999). [6] E. Millour et al THE MARS CLIMATE DATABASE (VERSION 5.3) (2018). [7] W. Xu et al., *Space Sci. Rev.*, **217** (2021). [8] M. Kahre et al., *JGR:Planets*, **111**, E6 (2006). [9] C. Gebhardt et al., *JGR:Planets*, **125**, 9 (2020). [10] T. Navarro et al., *JGR:Planets*, **119**, 7 (2014). [11] L. Sutton et al., *J. Atmo. Sci.*, **35**, 12 (1978). [12] R. Greeley et al., *JGR*, **87**, B12 (1982). [13] B. White, *JGR*, **84**, B9 (1979). [14] M. Chojnacki, *JGR:Planets*, **123** (2018). [15] R. Greeley, *JGR*, **84**, B11 (1979). [16] R. Greeley and S. Williams, *Icarus*, **110** (1994). [17] N. Bridges et al., *JGR*, **104**, E4 (1999). [18] R. Sullivan et al., *JGR:Planets*, **127** (2022). [19] J. Liu et al., *Nature*, under review. [20] D. Kinsley and R. Leach, *Precambrian Research*, **14** (1981). [21] B. White et al., *JGR*, **81** (1976).