Assessment of Forty Dune Sites on Mars Using CTX Images

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Introduction

Mars has a large number of sand dune fields that reflect both past and present wind patterns [1]. Here we study Martian sand dunes and the wind flow involved using Context Imager with 6 m/pixel (CTX [2]) images and document the types, orientations and the distribution of sand dunes on Mars at 40 locations widely distributed around the planet [3]. The diverse dune types indicate 'long term' wind patterns that produced the distinctive dune shapes observed at each site, expanding our comprehension of the evolution of sand dunes and recent aeolian processes active on Mars. This work was in support of NASA MDAP grant NNX12AJ38G.

Wind Pattern

Large dune patterns provide documentation of recent transport-capable wind directions, shown in red arrows. Star dunes indicate at least three wind directions (Fig 2). Barchans with 'tails' provide evidence for a bi-modal wind regime, reflecting seasonally varying winds (pink arrow as combined wind) with respective angles as defined by [3]. Winds directions derived from Martian sand dunes vary due to topographic influence (e.g., in crater or valley), but the regional trends are consistent between ripples and dunes [5]. Wind patterns overall are consistent with slipface orientation predictions [1].

Data and Methology

Dune identification and mapping were carried out at 40 sites [4] using CTX images (Fig. 1b) in the JMARS (Java Mission planning and Analysis for Remote Sensing) software package with the assistance of THEMIS (THermal EMission Imaging System) images (Fig 1c, 1d) obtained during both day and night, and selected HiRISE images [1] (Fig 1a).

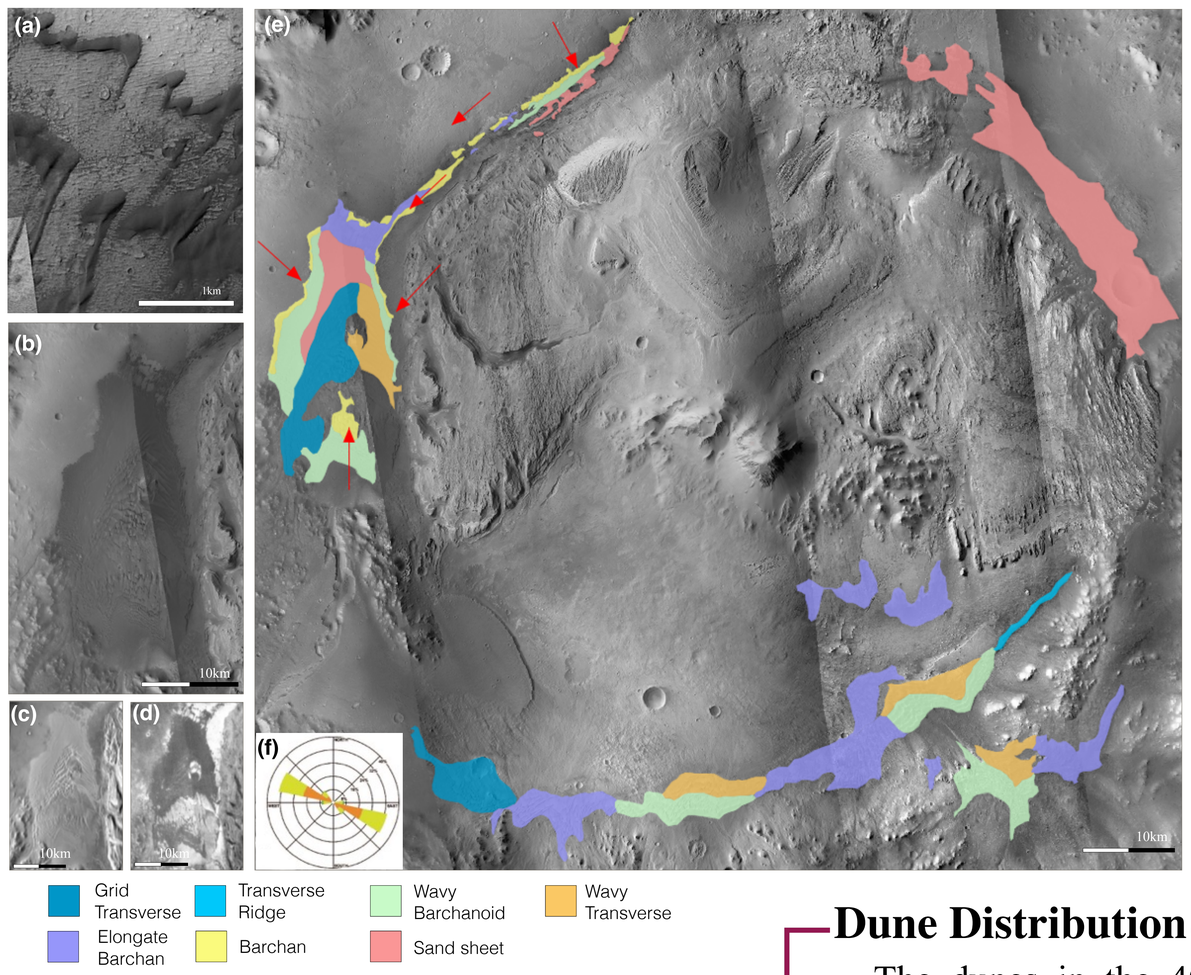

Figure 1.
Gale Crater (137.50E, 4.46S) with sand covering 860.6 km^2 of the crater floor. (a) HiRISE image of elongate barchans. (b) CTX images of an enlarged view of northwest part of Gale Crater. (c) THEMIS image during day time (d) THEMIS image during night time. (e) Map of dunes within Gale crater (f) Ripple rose diagram [3].

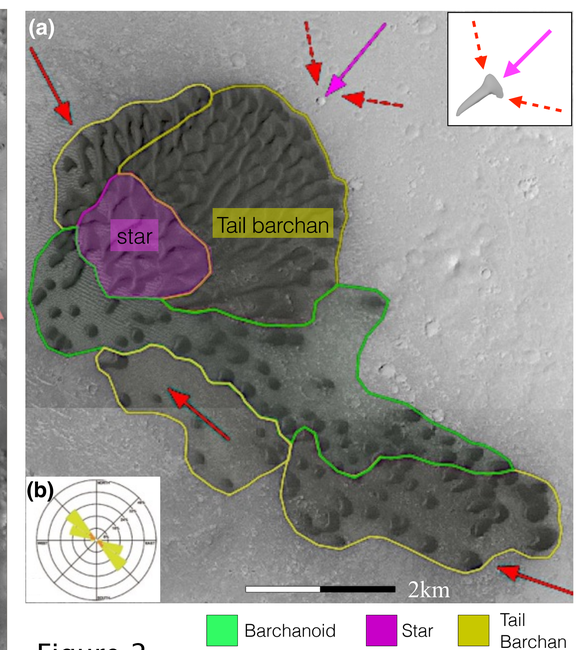

Figure 2.
(a) Three different winds inferred from barchans and tail barchans contribute to star dune (purple) pattern formed in central part of dune field near Cerberus Fossae (169.19E, 8.57N) (b) Ripple rose diagram [3].

Table 1. Summary of each type of dune.

Dune Type	Classification criteria	Mapped Areas (km^2)	Occupation (Area)	# Sites observed (out of 40)
Barchan	Clear crescent-shape dunes Limited sand supply Dominant wind direction observed	1551.7	13.5%	28
Barchanoid	Arc-shaped dunes connected Without a single continuous crest line	3492.5	30.4%	28
Transverse	A linear dune structure observed Sand filled in between the main crests Wind flows perpendicular to the crest line	3126.3	27.2%	21
Sand sheet	Not a clear shape or slip face Widely scattered distribution Sand sheet, if larger than 250 km^2	3144.5	27.4%	27
Star	Dunes with three prominent arms Three directions for sand-moving winds	1.2	<0.1%	1
Linear	A straight crest line shown Lacking sand filled in between the crests Wind inferred parallel to the straight crests	119.3	1.0%	1
Unknown		41.2	0.4%	1

Dune Distribution

The dunes in the 40 study areas are scattered within crater, valley, ridge, plains, polar and caldera settings. The percentages of dominant dune types within craters (covering documented 7229 km^2 at 23 sites) are barchan (14.9%), barchnoid ridge (35.4%), transverse (28.5%), sand patch (17.7%), and linear (1.7%). Thirteen dune types observed in the southern hemisphere cover 8937 km^2 (from 23 sites) are more abundant than in the northern hemisphere, where nine dune types were observed at 17 sites with a total area of 2540 km^2. No correlation among the main four types of sand dunes (barchan, barchnoid ridge, transverse, sand patch) from PCA suggests Martian sand dunes evolved independently.

Summary

Our research recognises both short term ('recent') sand-driving formative aeolian processes and long term (time scale not known) winds that have generated and modified the shape of the sand dunes, consistent with a previous study of ripples and dunes on Mars [5]. Dune shape likely affected some ripple orientations, but this tentative inference is under further study.

Reference: *[1] Hayward et al. (2014) Ica- rus, 230, 38-46. [2] Malin et al. (2007) J. Geophys. Res., 112(E05S04). [3] Johnson and Zimbelman (2015) Fall AGU, Abs. EP43A-0968. [4] Johnson and Zimbelman (2015) LPSC XLVI, Abstract #1539. [5] Liu et al. (2016) Fall AGU, Abs. EP21A-0853.*