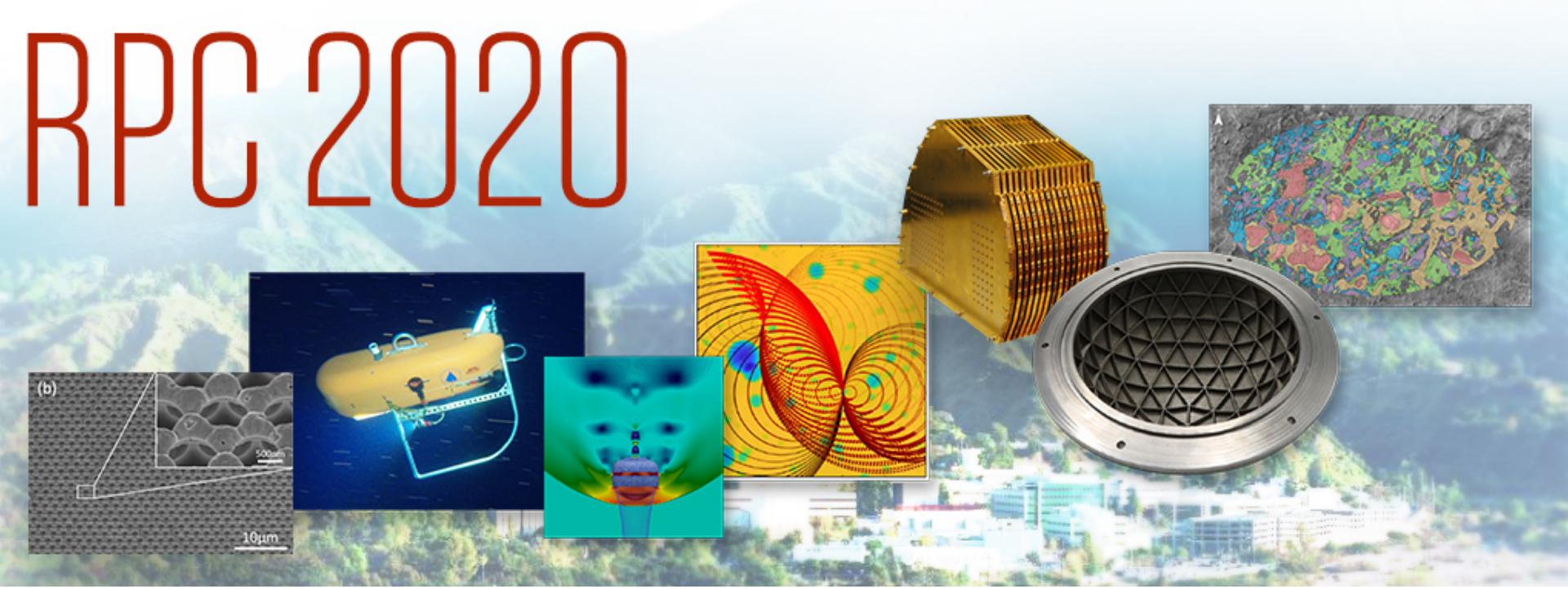
RPC 2020



Virtual Research Presentation Conference

Aeolian processes on Mars: Hypothesis testing with experiments and remote sensing

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Program: SURP

Jet Propulsion Laboratory
California Institute of Technology

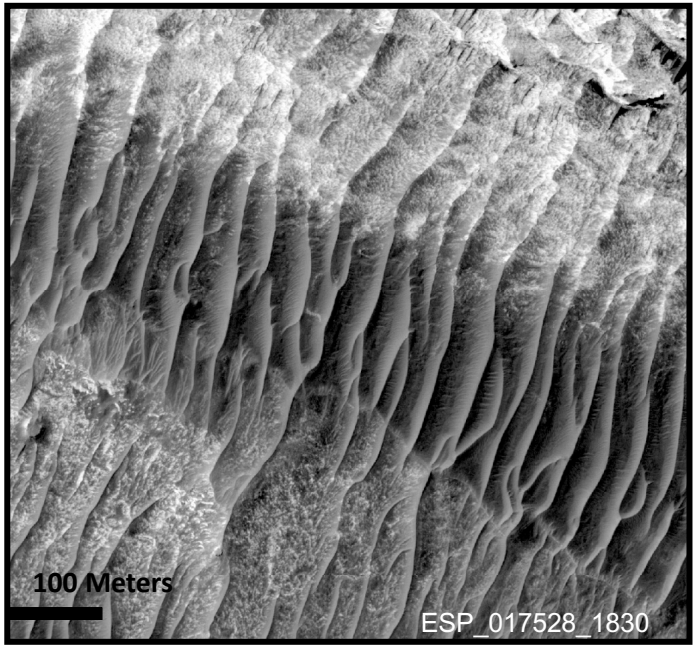
Presentation #RPC-075

Introduction

Abstract

Wind dominates the surface of Mars and is a primary agent of both ancient and modern surface changes. Martian sediments deposited by wind record critical information about the timing and nature of past Martian climate. Aeolian abrasion has dominated landscape evolution on Mars for the last several billion years, and wind-carved features may hold clues to climate evolution and landscape modification. Despite the dominance and importance of aeolian activity, the workings of wind on Mars remain poorly understood, and recent rover and orbiter image observations have highlighted gaps in our understanding of aeolian processes.

This research project focuses on two enigmatic and uniquely Martian aeolian sedimentary features: transverse aeolian ridges (TARs) and periodic bedrock ridges (PBRs). Shared attributes between PBRs and TARs motivate the hypothesis that formation mechanisms for the two are related, but this potential genetic relationship is, as yet, untested. Replication of TAR and PBR abrasion patterns in the UCLA wind tunnel, coupled with a global survey and characterization of candidate PBR occurrences on Mars offers the potential for important insights into the environmental conditions and mechanics necessary to create a class of aeolian features that occurs across the surface of Mars but only in very rare circumstances on Earth.



Problem Description

Context

- TARs and PBRs are common on the surface of Mars and occur within Gale crater, the field site for Curiosity, and in Jezero crater, the future landing site of the Mars 2020 rover. But our understanding of how these features form, and under what conditions, is limited due to the lack of Earth analogs
- Aeolian science is one of the few remaining disciplines where tabletop experiments are actively making significant advances and can address fundamental questions of aeolian transport, accumulation, and preservation in the Martian rock record. We can use wind tunnel experiments to simulate the formation and modification of aeolian features not readily found on Earth
- Shared attributes between PBRs and TARs motivate the hypothesis that formation mechanisms for the two are related, but this potential genetic relationship is, as yet, untested.

Comparison or advancement over current state-of-the-art

- The proposed experimental work conducted at UCLA will innovate on the current state of the art by using 3D-printing to create bespoke topography and to control the density of artificial sediments. In contrast, previous research has been limited by discrete densities of natural materials (e.g., quartz, walnut shells; Greeley and Iversen, 1987).
- PBRs are an understudied and underrecognized aeolian feature on the surface of Mars; our research represents the first global to regional characterization of these features

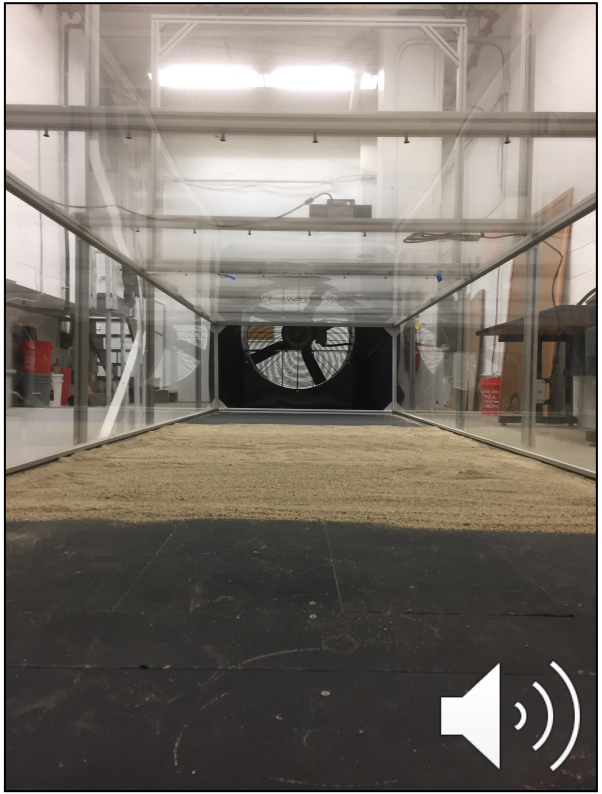
Relevance to NASA and JPL

- TARs occur throughout the MSL Curiosity field site in Gale crater, and cover ~20% of the area of Jezero crater, the landing site of the Mars 2020 Perseverance rover. Understanding the origin, characteristics, and internal structure of TARs, including grain size and grain size distributions, will provide important information that can be brought to bear in assessing the traversability of these potential rover hazards.
- Although many other wind tunnels exist in the southern California area, the UCLA wind tunnel is the only one dedicated to the study of aeolian sediment transport, and this project enables JPL's future involvement in aeolian research using these unique facilities.
- This work provides the basis for a continuing and lasting collaboration between JPL's Mars research and UCLA's GALE lab, enabling future collaborations between JPL and UCLA researchers on mission concept proposals and ROSES proposals in the field of aeolian research.

Methodology

Experimental Hypothesis Testing of the Origins of PBRs

- Using the wind tunnel at UCLA, we tested both bare-rock and periodically armored PBR formation environments. We used seven 1080p visual cameras for views of cm-scale bedform development or sediment accumulation. Two time-flight camera and infrared laser Kinect stations produced digital elevation models with millimeter-scale vertical resolution, quantifying any topographic changes.
- An erosional substrate was constructed from a polyurethane foam with a density of 16 kg/m^3 and maximum thickness of 5 cm. Sand was graded to a range of 1.1-1.45 mm (very coarse) rounded to subrounded quartz and feldspar grains, supplied to the system at a fixed rate of ~ 30 cm^3 per minute.
- We tested the validity of the 2 endmember hypotheses for PBR formation separately. The bare-rock transverse erosion hypothesis was simulated using a horizontal polyurethane base with dimensions of 1.5 m x 3 m at the tunnel floor, exposing the substrate to coarse grain saltation. Separately, the investigation of TAR-mediated abrasion incorporated transverse shielding with a symmetric triangular cross section. We used 3D-printed rigid plastic with a symmetric wave height of ~2 cm and a periodicity of 10 cm, overlying horizontal 1.5 m x 3 m foam flooring.
- In both arrangements, digital elevation models were captured at 30 minute intervals during the experiment, and imported to Matlab for visualization. Difference maps between images establish mm-scale losses due to abrasion, or net sediment accumulation where ridges trap saltating grains.

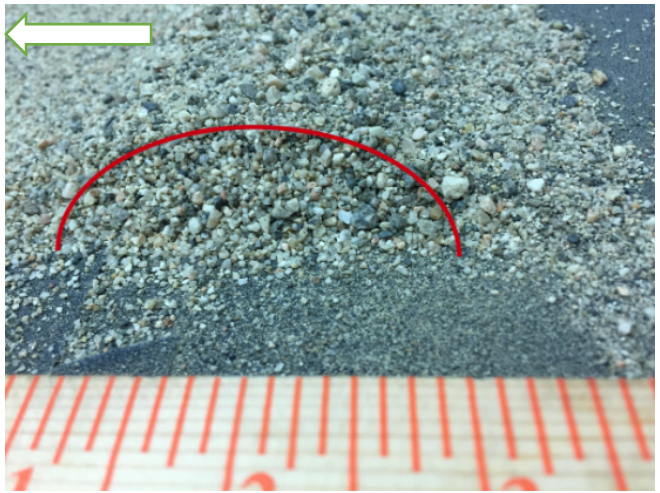


Methodology

Global to Regional Survey and Characterization of PBRs on Mars

- Equatorial Survey
  - We searched 1419 orthorectified HiRISE stereopairs with associated CRISM coverage between a -15° and +15° latitude band. This subset of data was surveyed to maximize the information (geological and mineralogical) for each site while sampling all longitudes and a variety of geologic settings.
  - Within each HIRISE stereopair, the presence of PBRs, TARs, and TAR-mantled PBRs was noted.
- Ius Chasma, Valles Marineris Survey
  - Each HiRISE image (n = 881) within the bounds of Ius Chasma in Valles Marineris was examined for the presence of PBRs, TARs, and sites where PBRs and TARs co-occur
  - A geologic map of Ius Chasma was constructed using CTX/HiRISE at a scale of 1:5M with six units identified. This geologic map provided context for the sites at which PBRs and TARs were identified
- Other Sites
  - HiRISE images (n = 217) for 3 sites outside the equatorial survey and the Ius Chasma survey areas known to contains PBRs and TARs in close proximity were identified and characterized
- At each location where PBRs were identified in either the equatorial or Ius Chasma surveys, the following measurements were made:
  - Wavelength of PBRs and nearby TARs, if present
  - Along-ridge length for both PBRs and TARs
  - Orientation of both TARs and PBRs (including presumed wind direction)
  - Local MOLA elevation
  - THEMIS temperature and TES thermal inertia of the bedrock in which PBRs were located

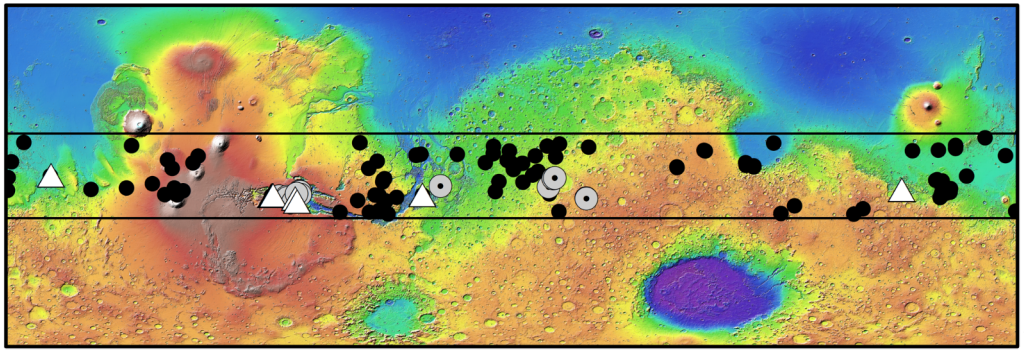
Results

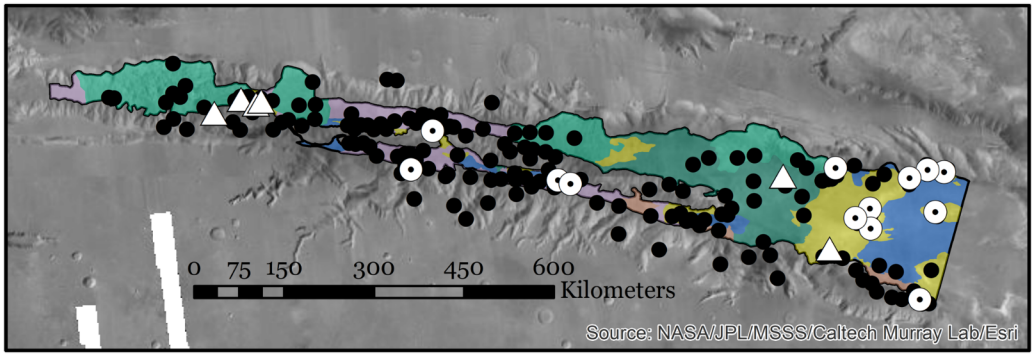


Arrows indicate wind direction. Early wind tunnel experiments incorporate both medium-fine mobile sediments (including ripple bedforms at intermediate wind speeds) and coarse immobile sediments. When transverse coarse-grained bedforms are exposed to mobile fines, smaller grains are incorporated into the ridge structure by kinetic sieving, a possible method for the growth of symmetric TAR bedforms.

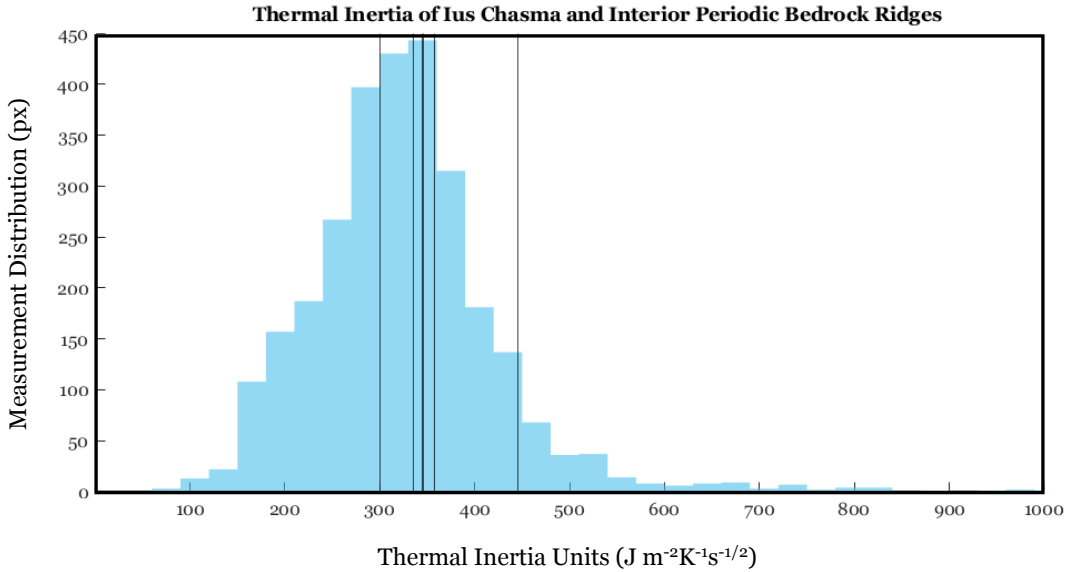
Experiment work was cut short due to COVID-19 pandemic. Wind tunnel experiments will resume as labs reopen.

Results


Legend
PBR Only, n=3
PBR + TAR Interactions, Equatorial Survey, n=15
TAR Only, n=118
-15 to +15 Latitude

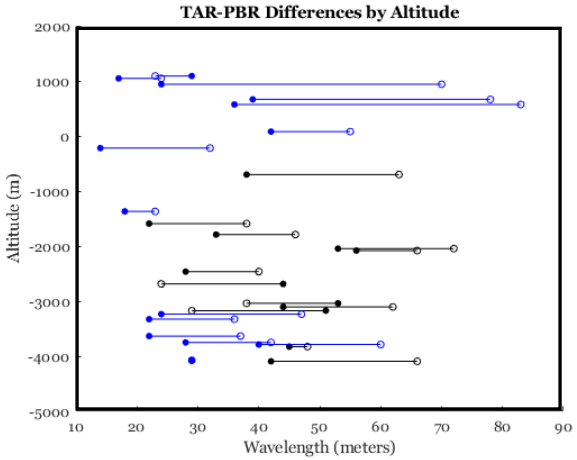

0 75 150 300 450 600
Kilometers
Source: NASA/JPL/MSSS/Caltech Murray Lab/Esri
Legend
TAR Only, n=163
PBR Only, n=6
PBR + TAR Interactions, Regional Survey, n=13
dust / undifferentiated
lobate terrain
blocky terrain
banded sedimentary
light toned bedrock
sedimentary bedforms

Results

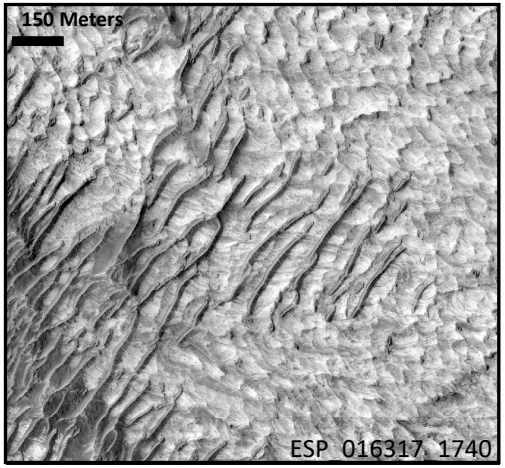


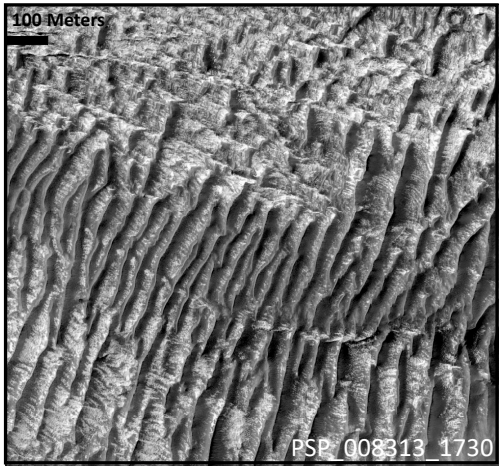
Periodic bedrock ridges (vertical lines) occur in low thermal inertia bedrock within Ius Chasma. For comparison, bedrock exposures on Mars typically have TI values ranging from ~450 to greater than 1200 tiu. Blue histogram shows the distribution of TES pixels in Ius Chasma. Low TI values for the bedrock containing PBRs are interpreted to suggest that this bedrock is soft and easily erodable.

Results



- PBRs (open circles) and TARs (closed circles) occur at a wide range of elevations. At sites where PBRs and TARs occur together, PBRs typically exhibit larger wavelengths than co-occurring TARs. Equatorial survey sites are shown in blue; Ius Chasma sites shown in black.





- Where TARs mantle PBR-bearing bedrock, PBR extent (light toned ridges) and TAR extent (dark toned ridges) are often highly correlated. TARs consistently occur on elevated ridgelines rather than occupying topographic lows.

We conclude that PBR formation, at least in some cases, is related to the occurrence of TARs, although the causal relationship between the two features is not yet fully constrained

Publications

J. W. Sneed, M. D. Day, K. M. Stack, A. A. Fraeman, Experimental Hypothesis Testing of the Origins of Periodic Bedrock Ridges, Abstract 3040, presented at Sixth International Planetary Dunes Workshop, May 12-13 2020

J. W. Sneed, K. M. Stack, A. A. Fraeman, M.D. Day, Large-Scale HiRISE Survey Demonstrates a Genetic Relationship Between Periodic Bedrock Ridges and Transverse Aeolian Ridges, Abstract 747668, to be presented at 2020 Fall Meeting AGU, December 1-17