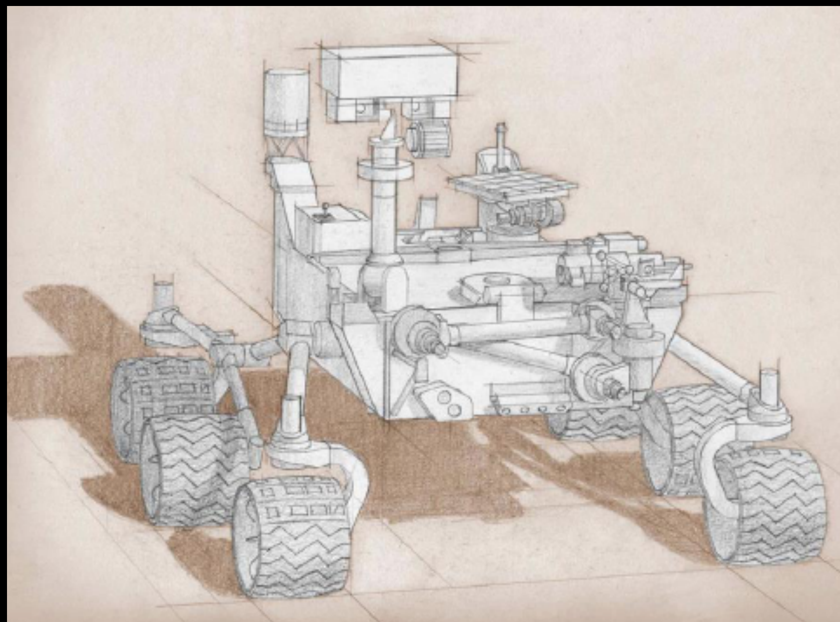

Sediment Flux Results for Aeolian Bedforms at Candidate Landing Sites for the Mars 2020 Rover

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2020 Mars Rover 3rd Landing Site Workshop
February 8-10, 2017

Introduction and Motivation

- It is now known that wind-driven bedform (e.g., dunes and sand ripples) activity is occurring across Mars today [e.g., Sullivan et al. 2008; Bridges et al. 2011, 2013; Chojnacki et al. 2011, 2014, 2015, 2017].
- Current and candidate landing sites often have aeolian bedforms, some of which may be migrating and eroding the surface.
- It is also thought the rapid aeolian abrasion of sedimentary deposits which potentially host ancient habitable environments may provide the best mechanism for exposing samples containing relatively undegraded organics [Farley et al. 2014; Grotzinger et al. 2014; Williams and Rice, 2017, 2020 Workshop].

Introduction and Motivation

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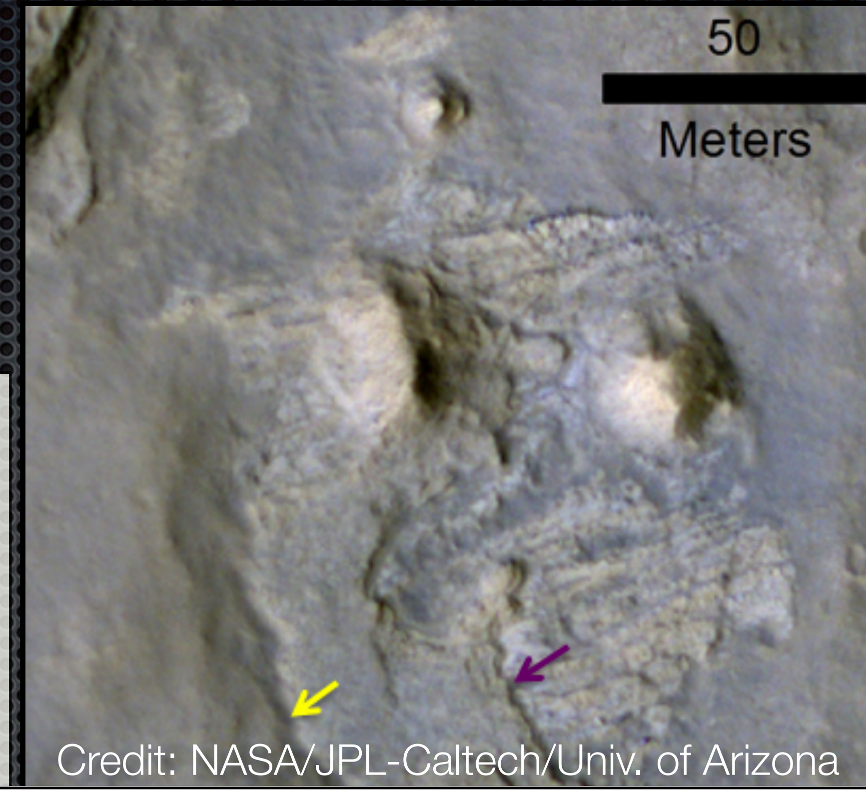
Our goal here is to use HiRISE-derived topography and images to:

1. Estimate **regional sand fluxes** (as a proxy for abrasion rates) for candidate-landing sites.
2. Assess **local conditions** of candidate-landing site ellipses for possible contemporary aeolian bedforms and sand movement.

Background

- Exposure ages of wind eroded strata were determined isotopically by the Curiosity rover team [Farley et al. 2014].
- Sand blasting there has rapidly exposed (~80 Myr) sedimentary layers during scarp retreat, minimizing (potential) organic degradation due to cosmic rays [Rice, 2nd 2020 Workshop; Grotzinger et al. 2014].
- Thus, estimating sand fluxes and abrasion rates is highly relevant to surface missions aimed at sampling materials with minimal organic degradation and possible signs of ancient life.



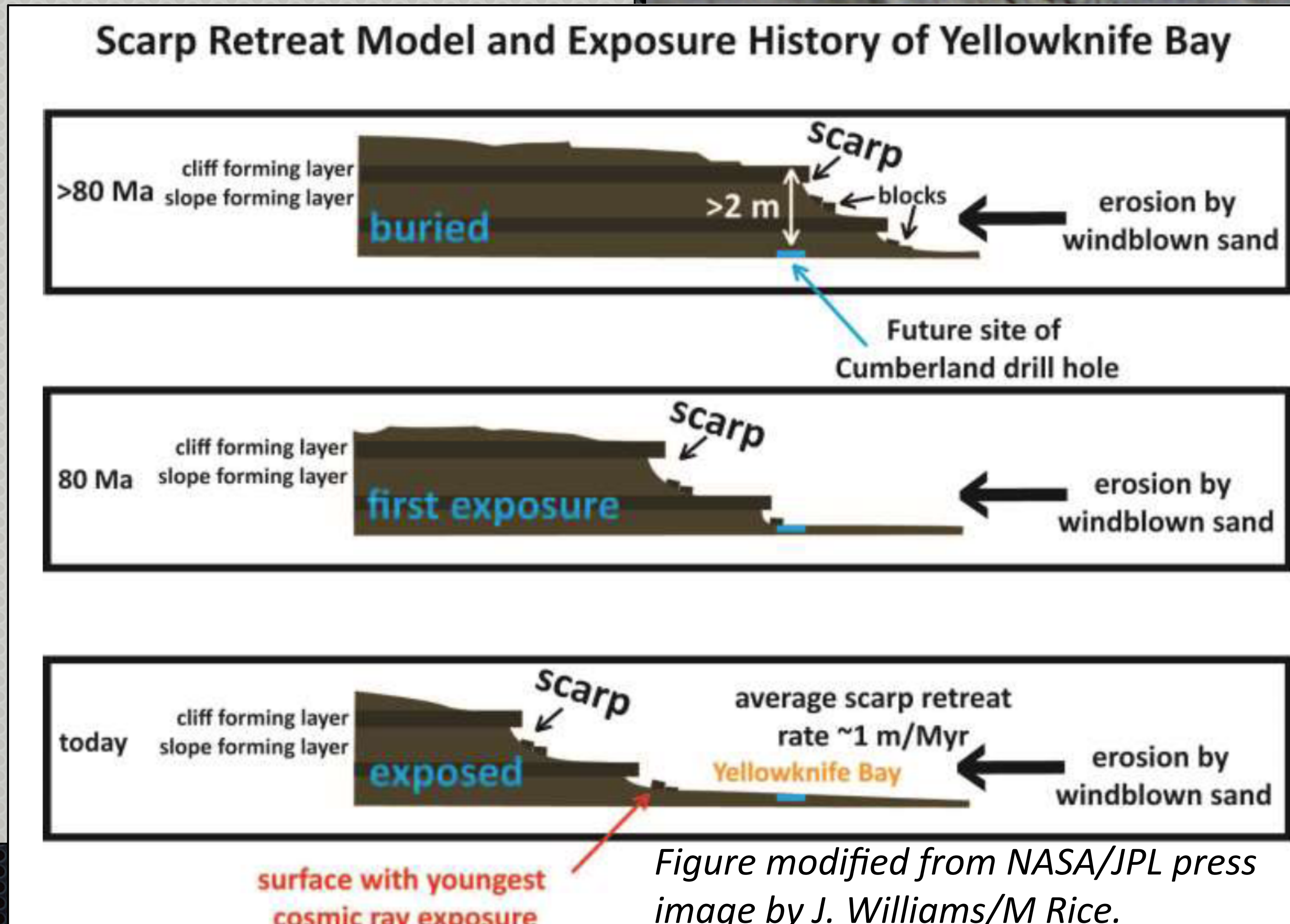
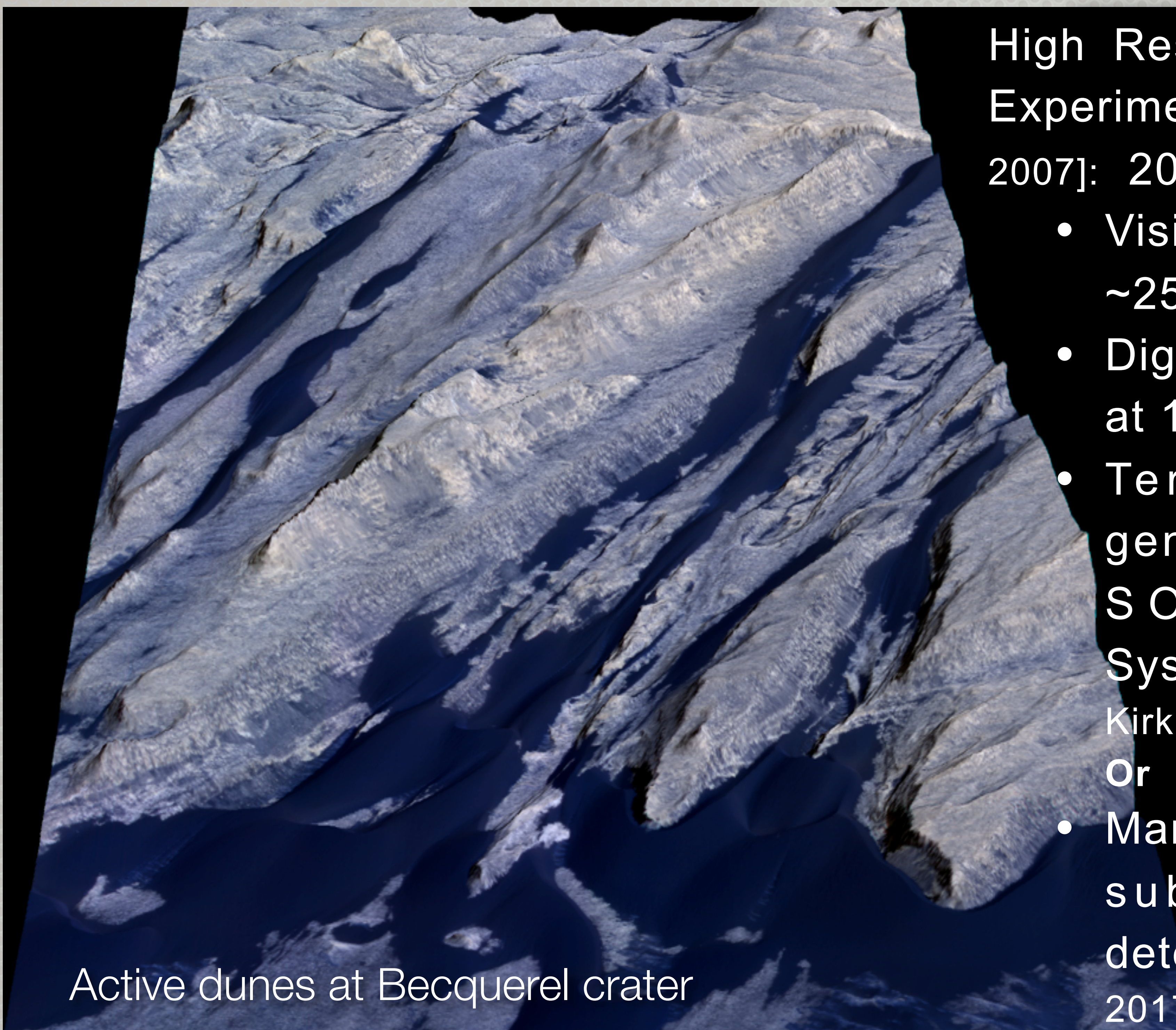


Figure modified from NASA/JPL press image by J. Williams/M Rice.

Chojnacki

Methodology - Sediment Fluxes



Active dunes at Becquerel crater

High Resolution Imaging Science Experiment (HiRISE) [McEwen et al. 2007]: 2006- present

- Visible wavelength images at ~25 cm/pixel
- Digital Terrain Model (DTM) at 1 m/post
- Terrain and orthophoto generation creation using SOCET SET (© BAE Systems, Inc.) software [see Kirk et al. 2008]

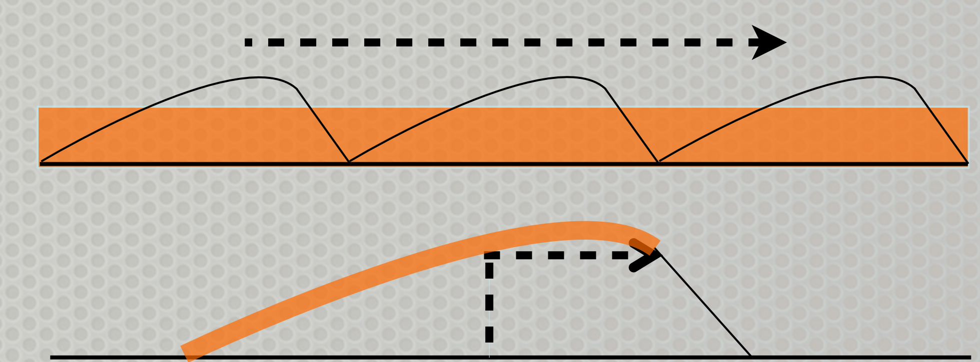
Or

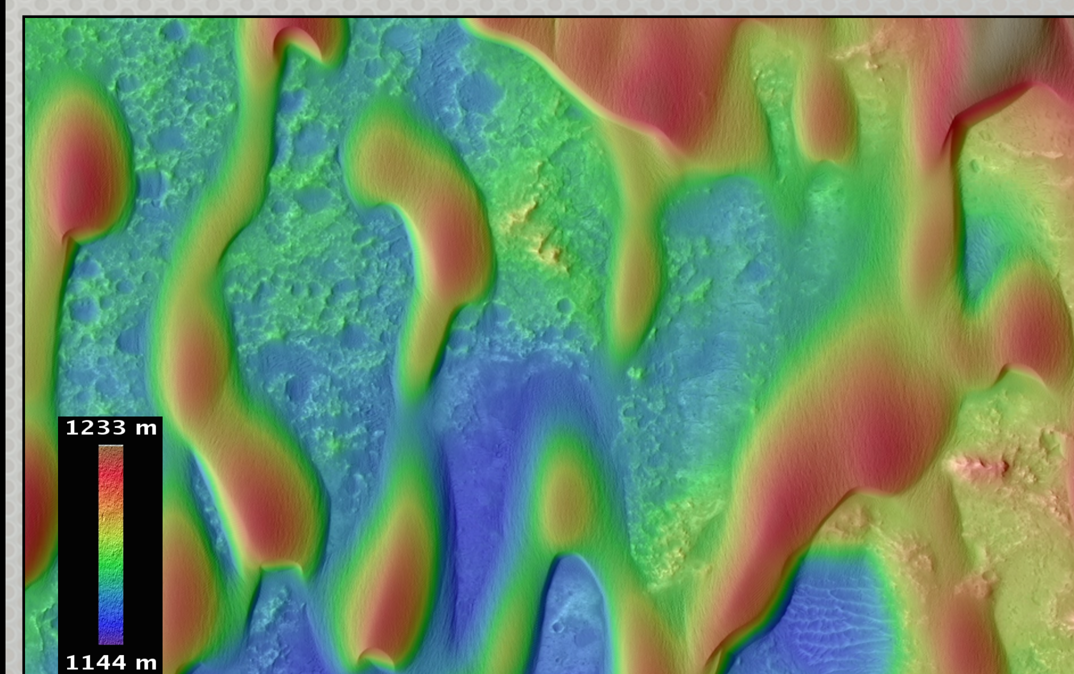
- Manual registration of image sub-regions for change detection [see Chojnacki et al. 2017]

Methodology - Sediment Fluxes

Sand Flux $Q_c = (L_s \times d)/t$ ($m^3\ m^{-1}\ yr^{-1}$)

- L_s = dune height
- d = displacement (m)
- t = time (Earth yr)





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Methodology - Sediment Fluxes

Sand Flux $Q_c = (L_s \times d)/t$ ($m^3\ m^{-1}\ yr^{-1}$)

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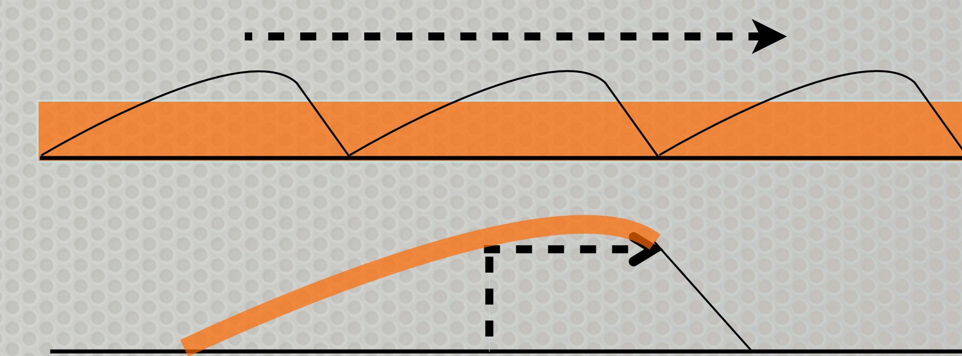

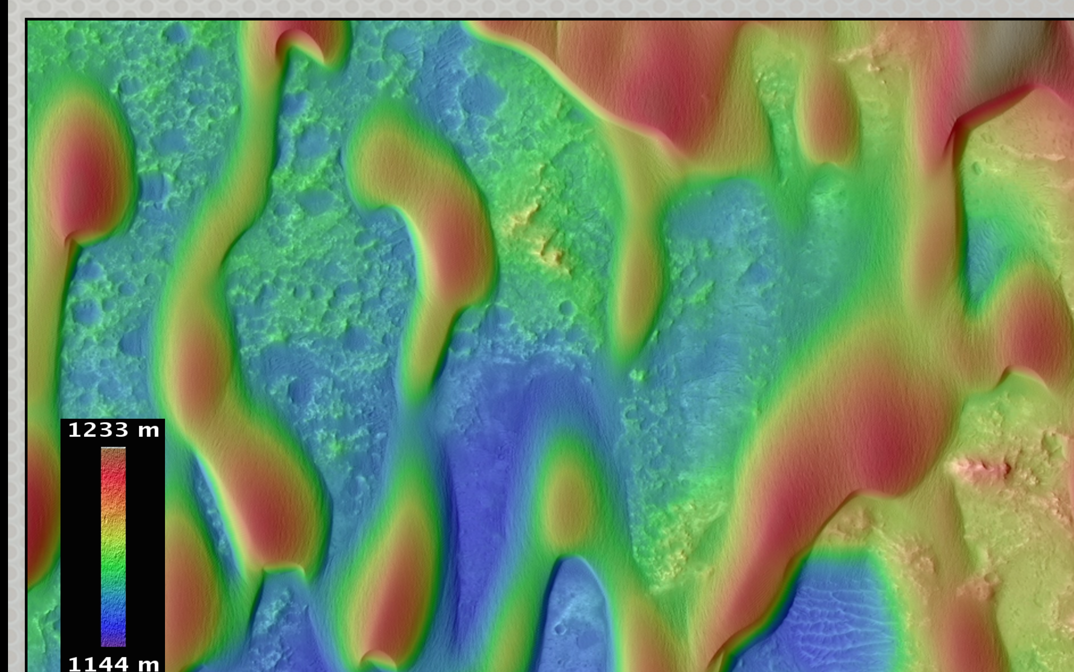

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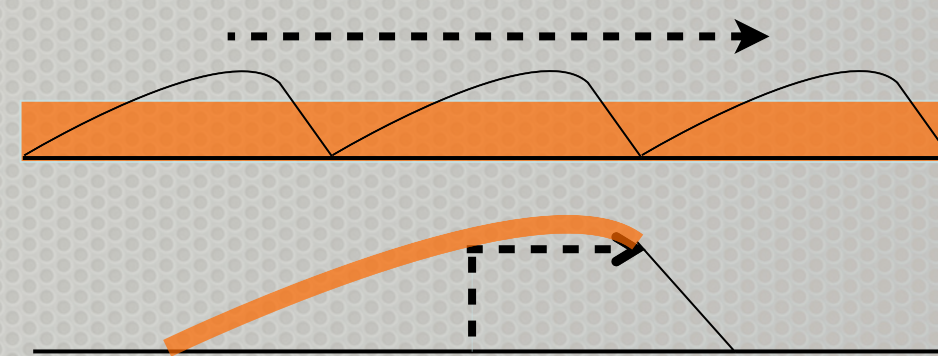
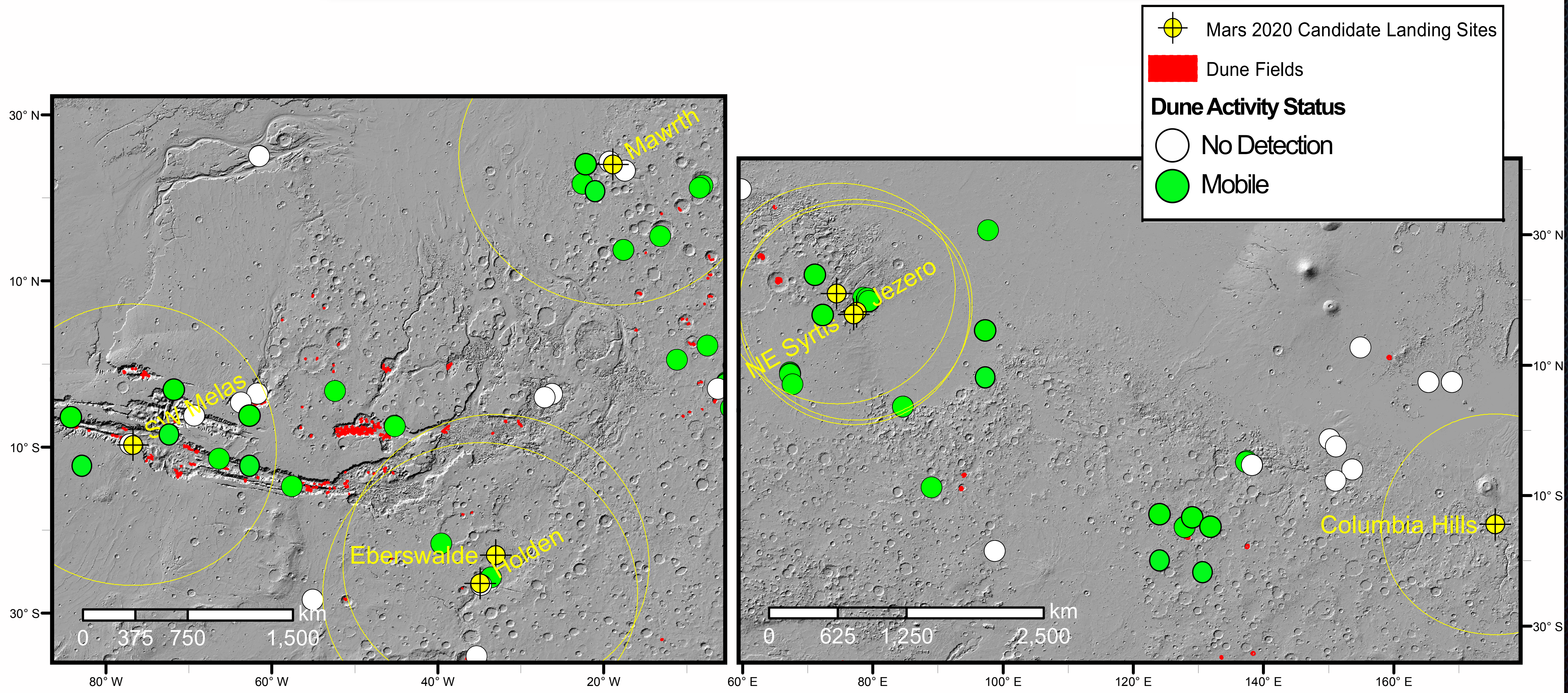


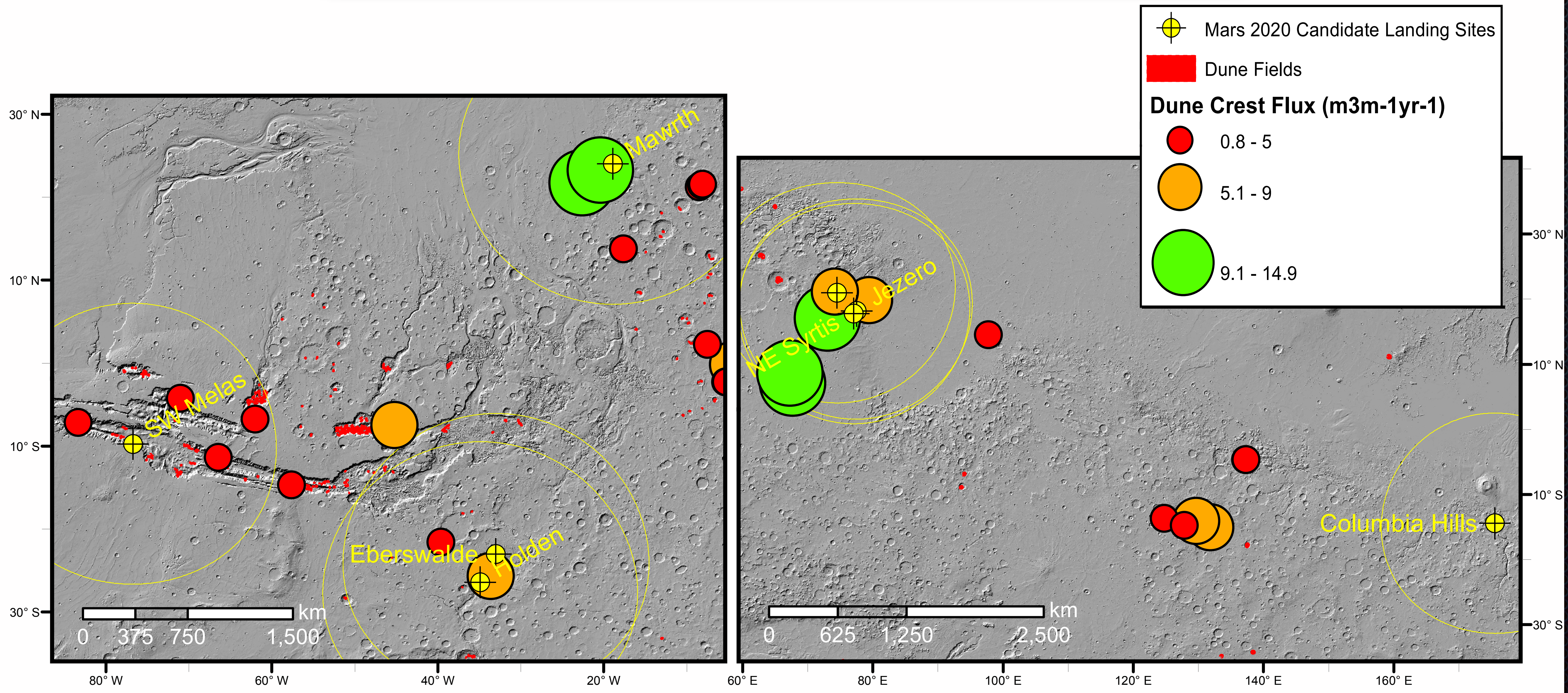
Aeolian abrasion scales with inter-dune sediment fluxes (Q_i) and can be estimated given some basic assumptions (e.g., target material, impact threshold etc.) [Bridges et al. 2012; Chojnacki et al. 2017, LPSC].

Regional Results for Mars 2020 Candidate Sites



- Dune activity status provide context for locations with active bedforms or no detections [see Banks et. al., LPSC, 2017; Chojnacki et al. 2017, LPSC].
- 1000-km radius ellipses centered on candidate landing sites provide scale.

Regional Results for Mars 2020 Candidate Sites



- Regional sand fluxes include monitoring sites with 1000-km radius ellipses
- Nili Fossae/Jezero/NE Syrtis sites had the highest regional sediment fluxes.
- Mawrth, Eberswalde, Holden, and SW Melas had moderate fluxes.
- Gusev/Columbia Hills site lacks any regional dune monitoring sites (~1500 km).

Regional Results for Mars 2020 Candidate Sites

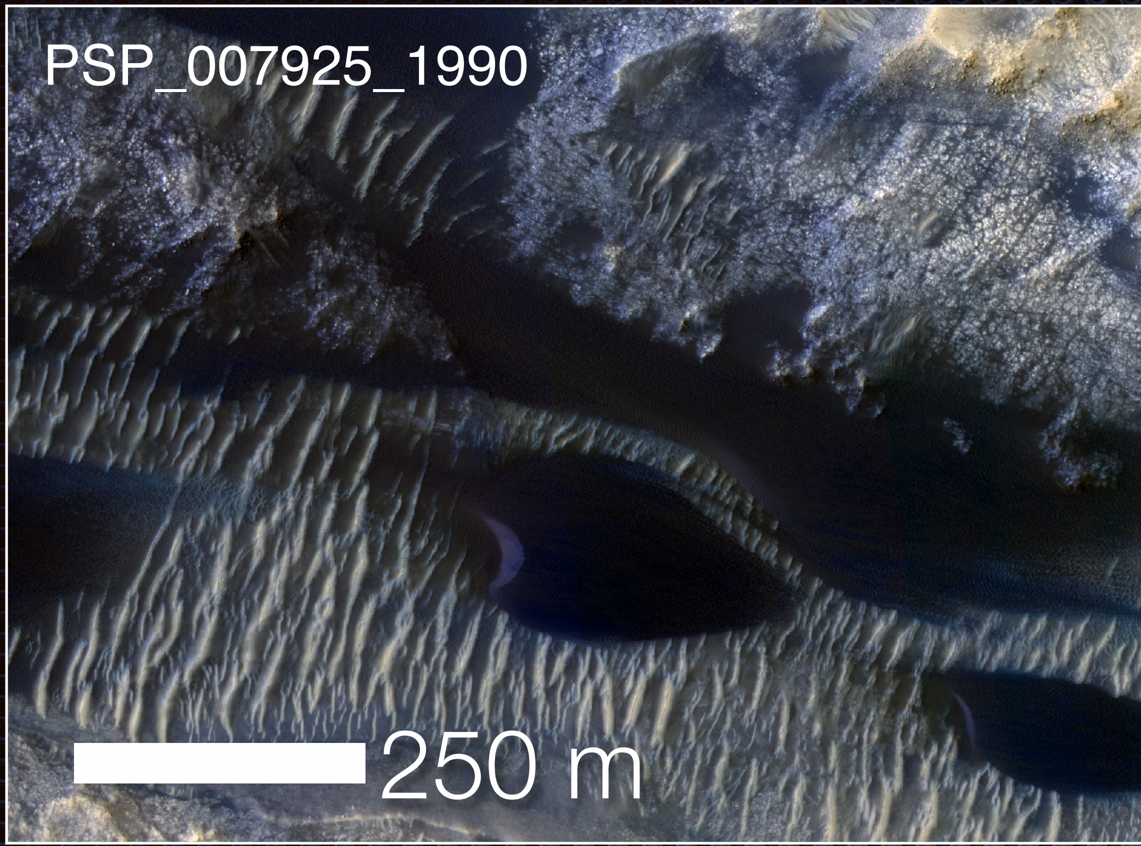
Location	# Dune Sites	Fluxes		
Mawrth Vallis*	6 sites	Moderate fluxes: 5 m3/m/y	min	**1.2**
			max	**11.5**
			avg	**4.9**
			std	**4.8**
Nili Fossae* / Jezero Crater / NE Syrtis Major	5 sites	High fluxes: 12 m3/m/y	min	**7.2**
			max	**16.9**
			avg	**11.6**
			std	**4.5**
Melas	4 sites	Moderate fluxes: 4 m3/m/y	min	**2.7**
			max	**5.0**
			avg	**4.0**
			std	**1.0**
Columbia Hills	0 sites	-	min	-
			max	-
			avg	-
			std	-
Eberswalde Crater* / Holden Crater*	2 sites	Moderate fluxes: 5 m3/m/y	min	**4.3**
			max	**6.2**
			avg	**5.3**
			std	**1.3**

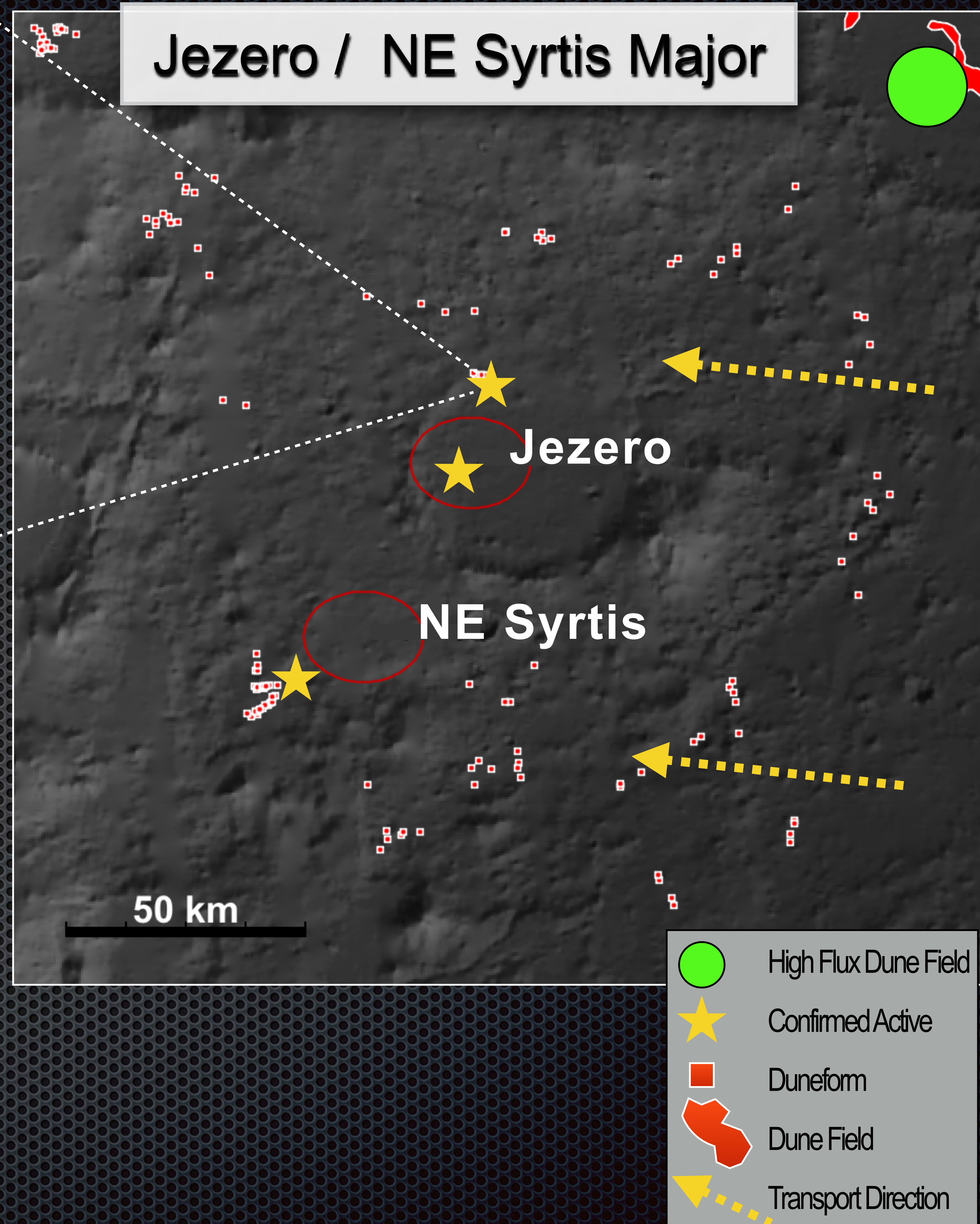
*Includes active dune monitoring sites within 100 km of landing ellipse.

Discussion and Caveats

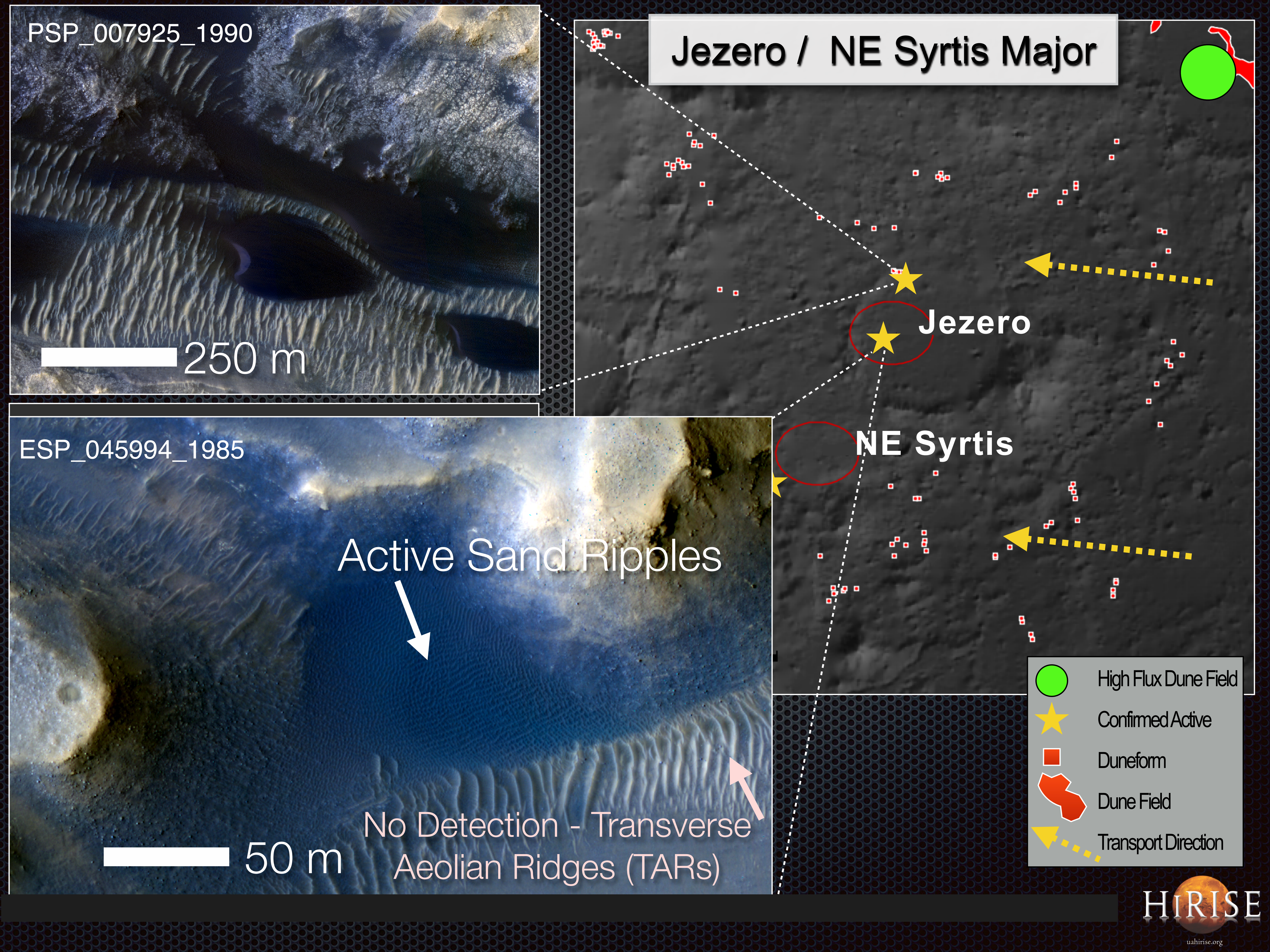
- HiRISE analysis of Meridiani dune fields surrounding Endeavour crater, a crater previously documented to have very active bedforms [Chojnacki et al. 2011, 2015], found they are also active and part of region-wide sediment migration [Chojnacki et al. 2016].
- However, estimated “Regional Fluxes” may not be appropriate for the candidate landing sites, especially when spatially removed from the proposed landing site ellipse.
- Environmental boundary conditions such as wind regime, topography, sediment supply, and sediment state can vary widely.
- Local conditions of candidate-landing site ellipses should be assessed for possible contemporary aeolian bedforms and sand movement.

Jezero / NE Syrtis Major

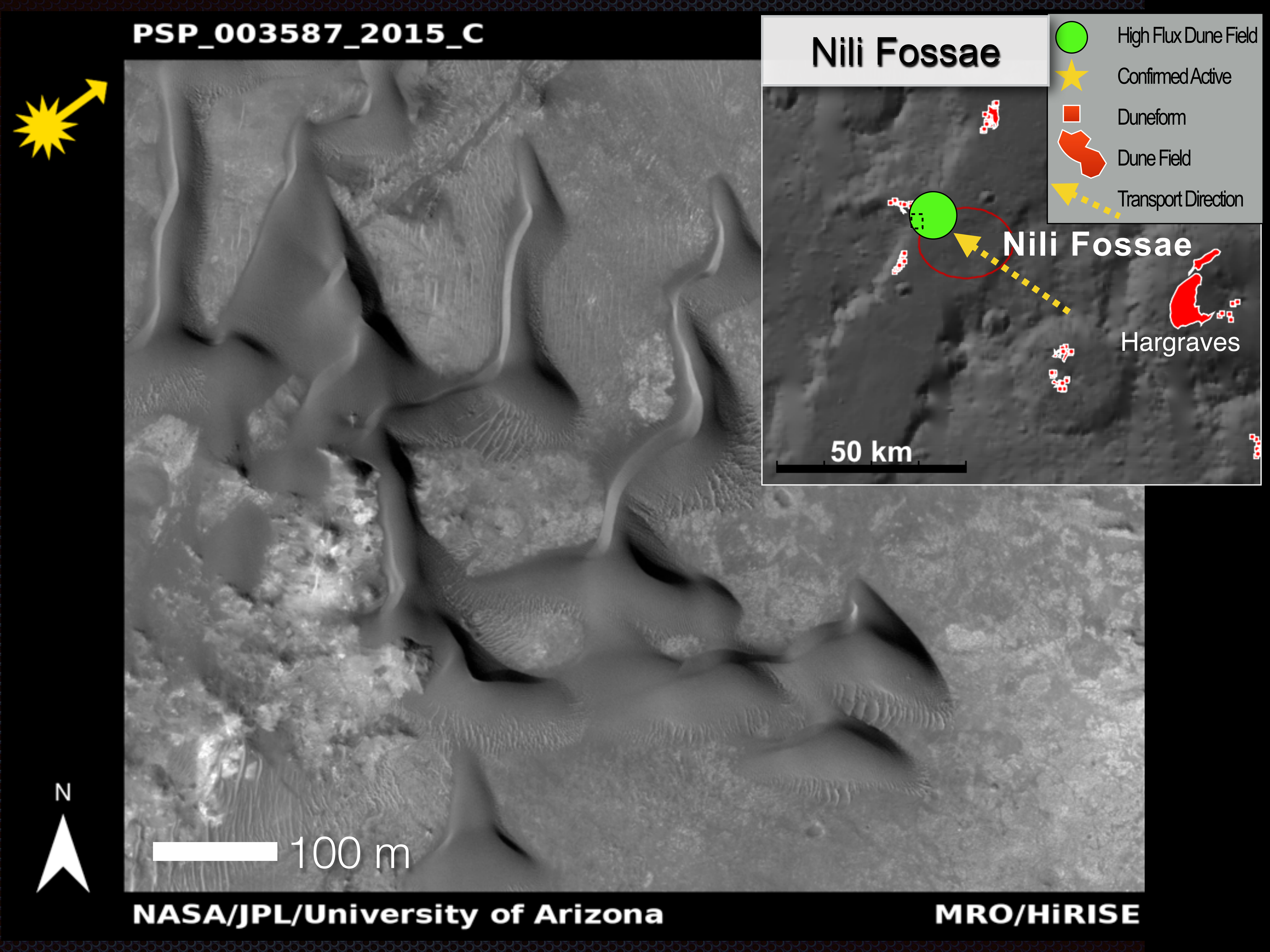




All sites were mapped using CTX and HiRISE in a search for possible contemporary bedforms using criteria from prior detections (e.g., low albedo, sharp brinks [e.g., Bridges et al. 2013]) and tested (where available) using overlapping HiRISE data.

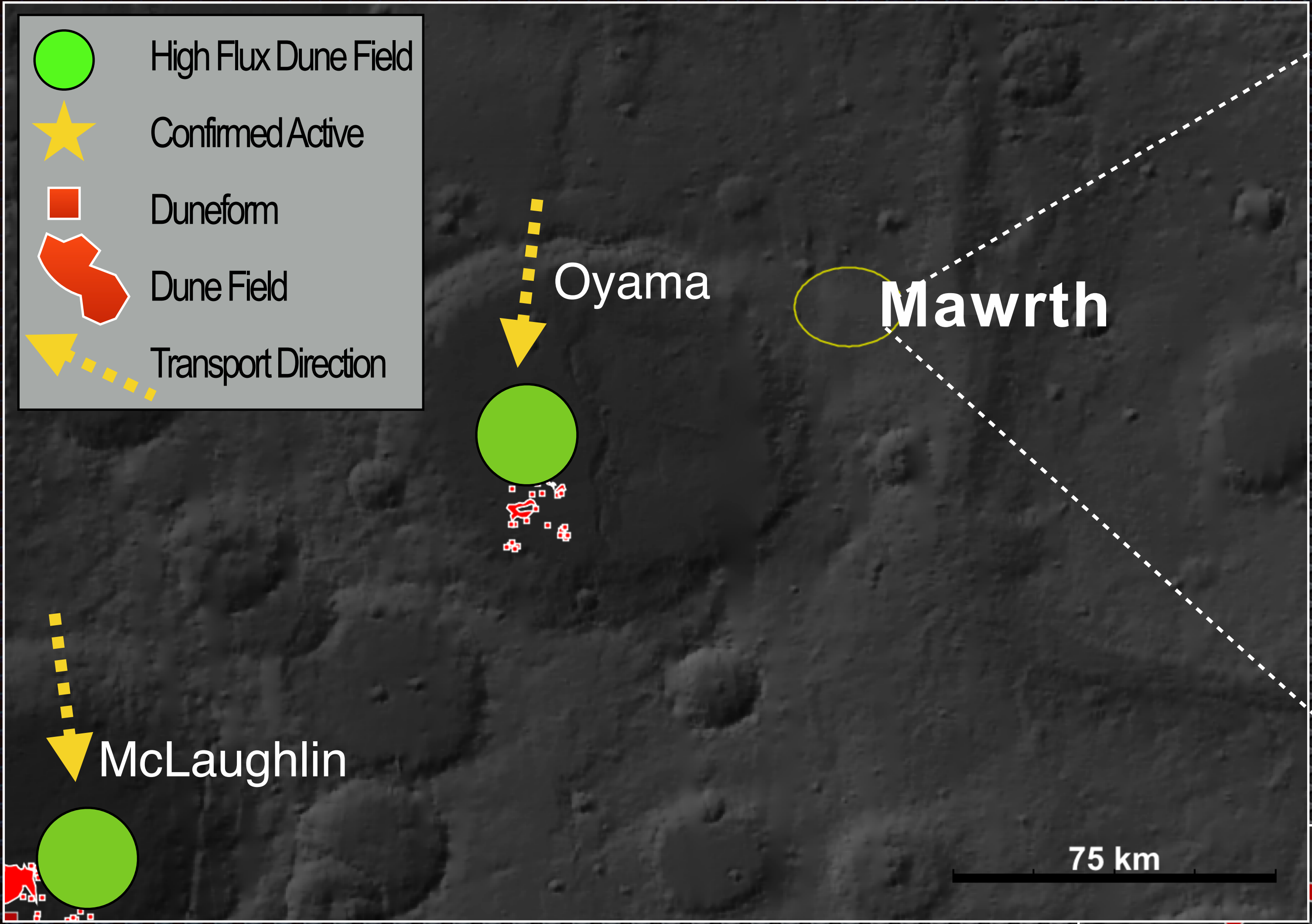


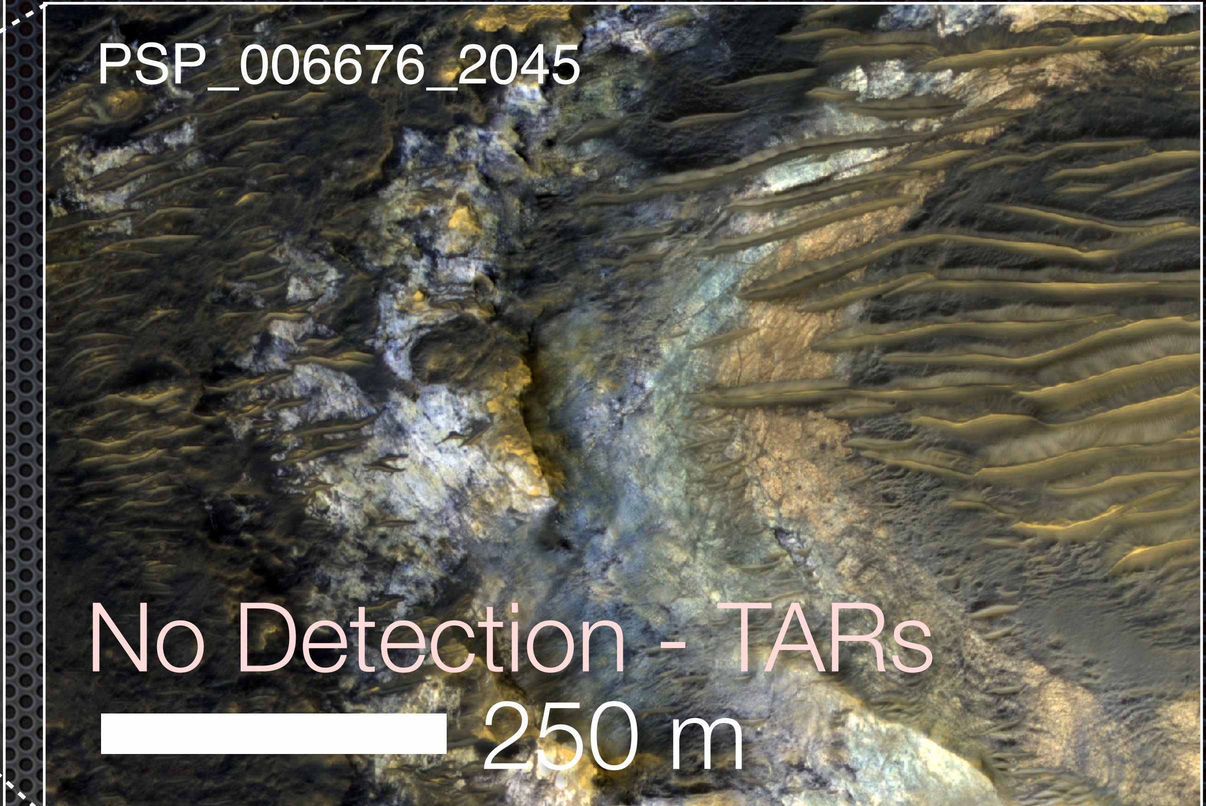
Jezero / NE Syrtis Major
PSP_007925_1990
250 m
ESP_045994_1985
Active Sand Ripples
No Detection - Transverse Aeolian Ridges (TARs)
50 m
Jezero
NE Syrtis
High Flux Dune Field
Confirmed Active
Duneform
Dune Field
Transport Direction
HiRISE
uahirise.org

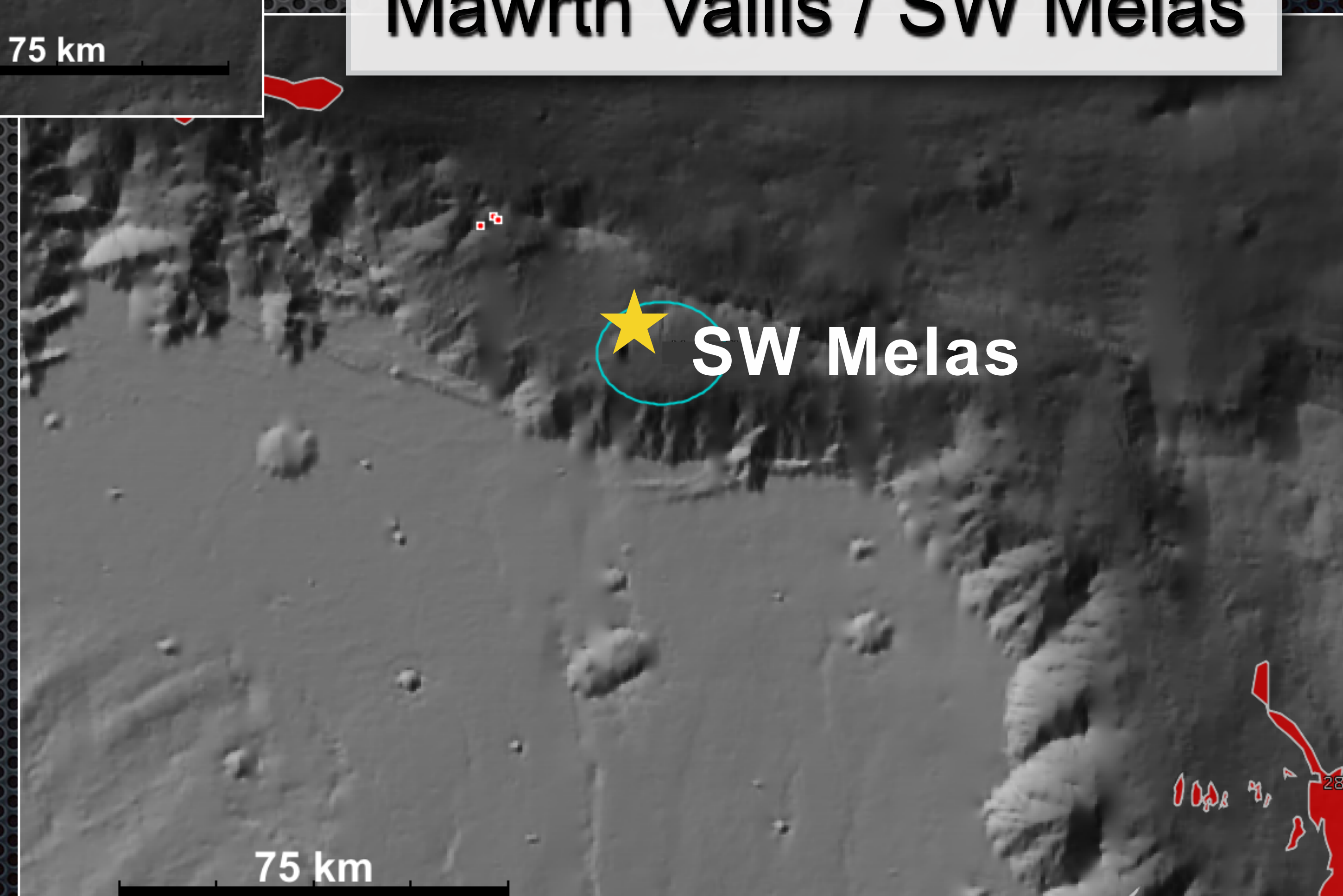

PSP_003587_2015_C
Nili Fossae
High Flux Dune Field
Confirmed Active
Duneform
Dune Field
Transport Direction
Nili Fossae
Hargraves
50 km
N
100 m
NASA/JPL/University of Arizona
MRO/HiRISE

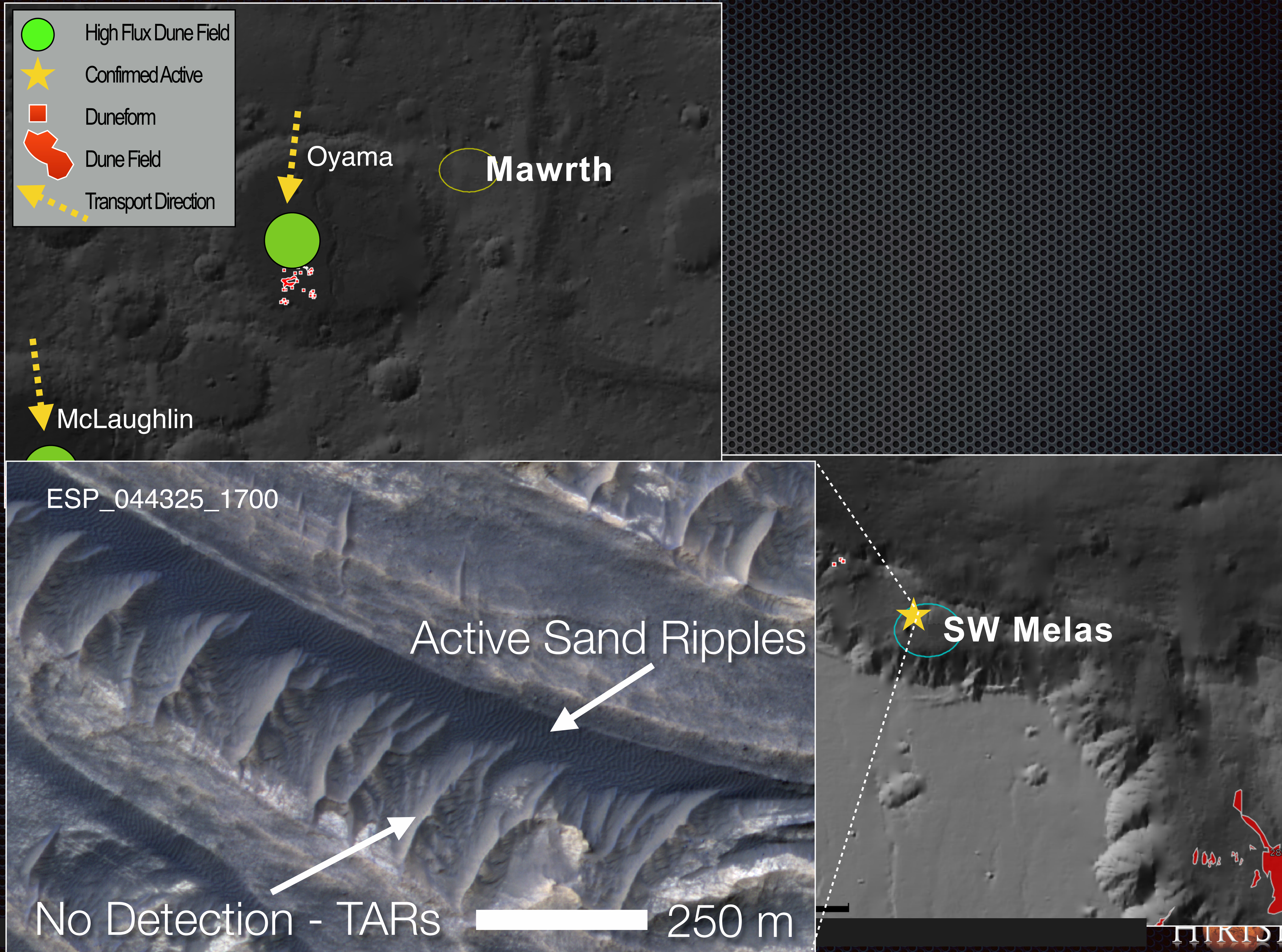

ESP_047049_2015_C
Nili Fossae
High Flux Dune Field
Confirmed Active
Duneform
Dune Field
Transport Direction
Nili Fossae
Hargraves
50 km
N
100 m
NASA/JPL/University of Arizona
MRO/HiRISE

Mawrth Vallis / SW Melas



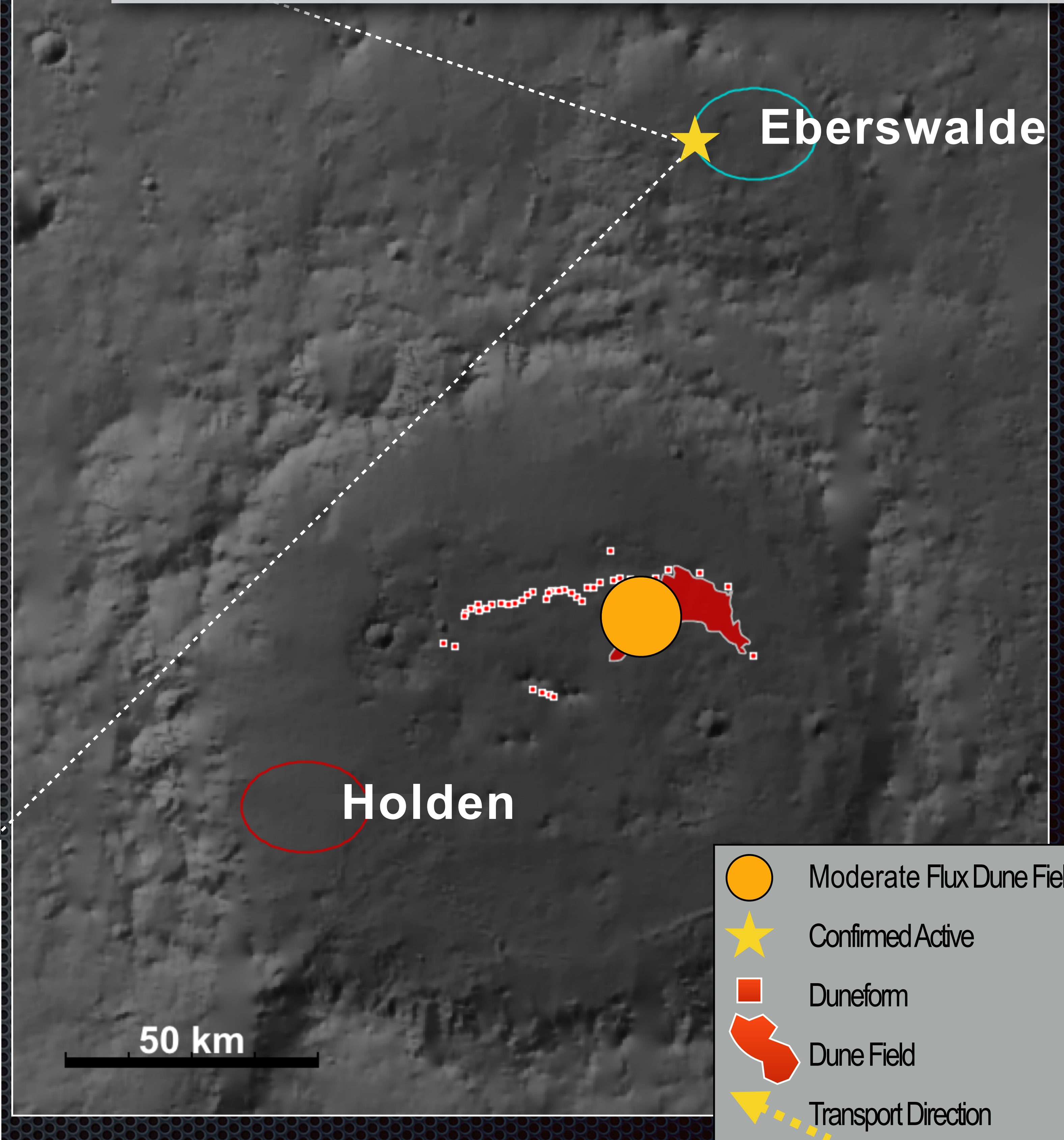




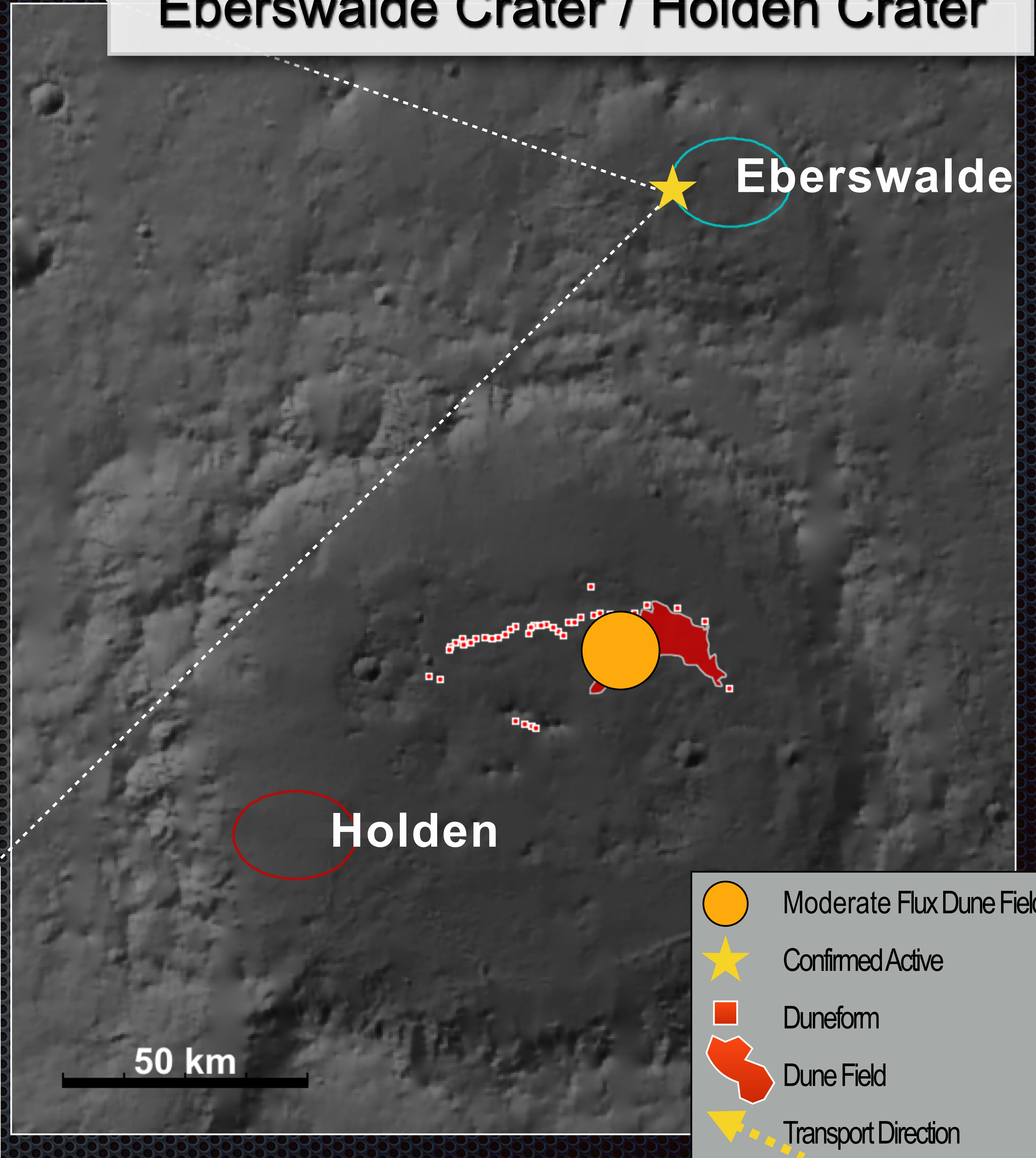

High Flux Dune Field
Confirmed Active
Duneform
Dune Field
Transport Direction
Oyama
Mawrth
McLaughlin
ESP_044325_1700
Active Sand Ripples
No Detection - TARs
250 m
SW Melas
uahirise.org

Eberswalde Crater / Holden Crater

Dark-toned bedform unit mapped by Rice et al. [2013] found to be active, but spatially-limited.



Eberswalde Crater / Holden Crater



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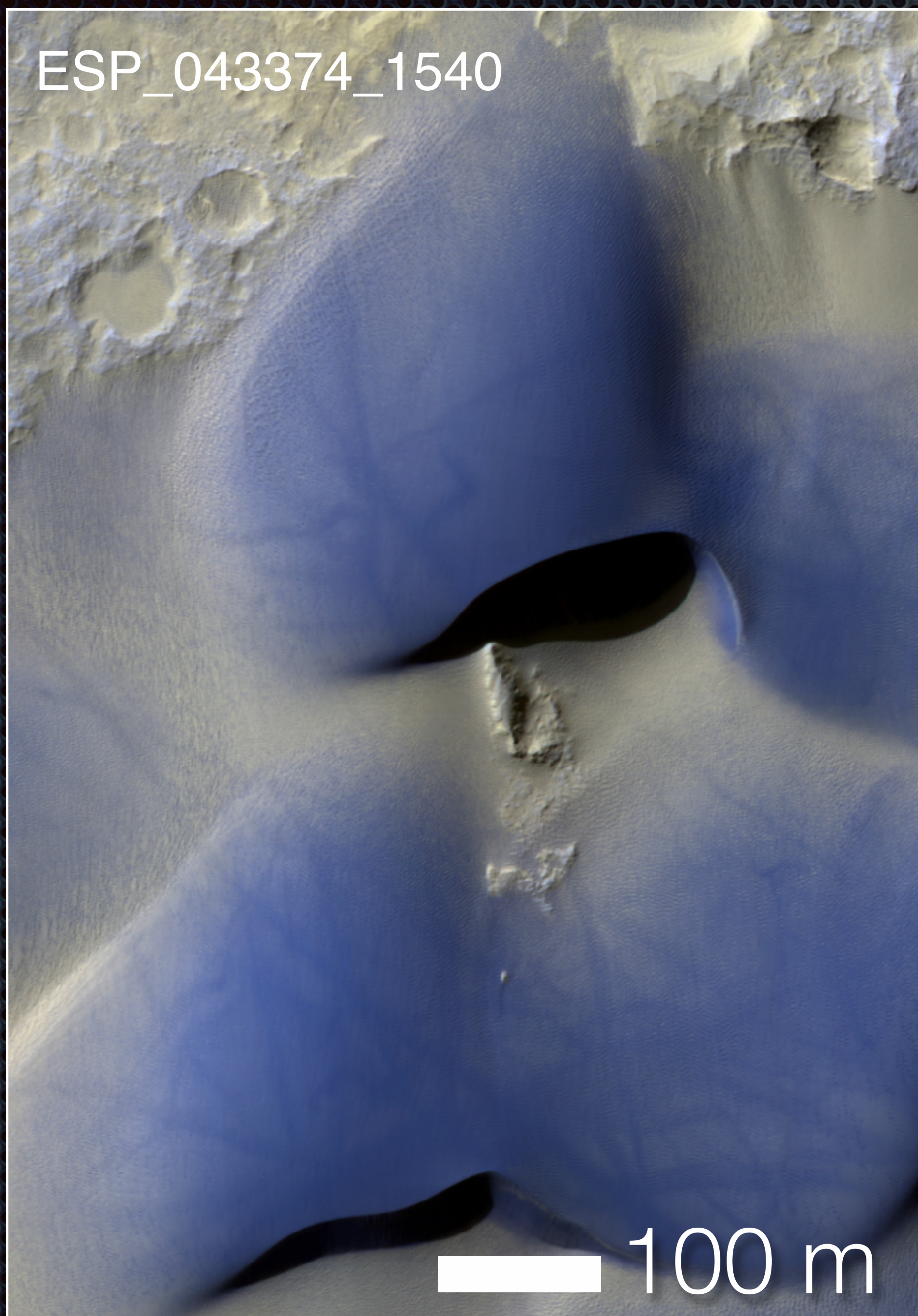
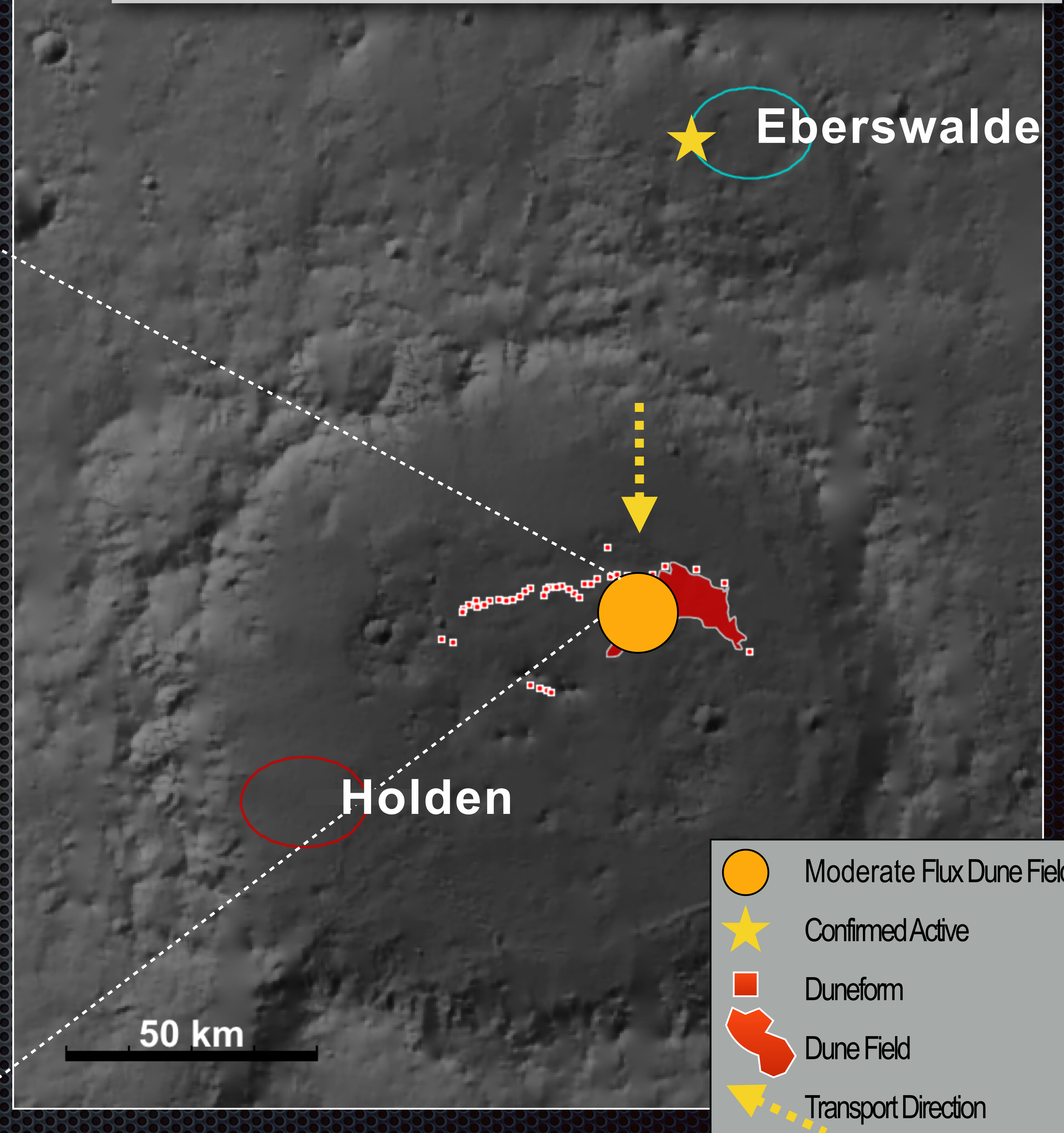
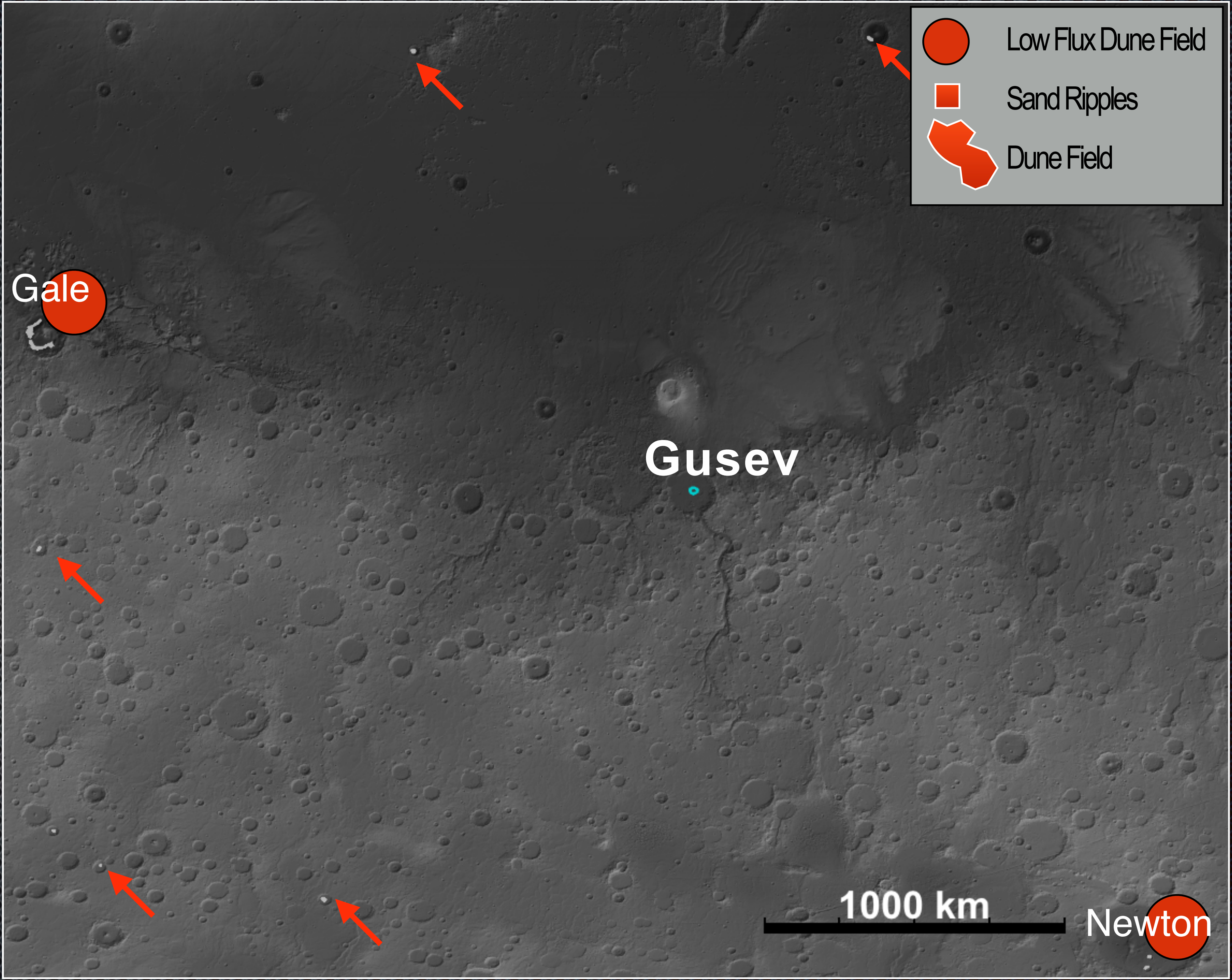
Eberswalde Crater / Holden Crater



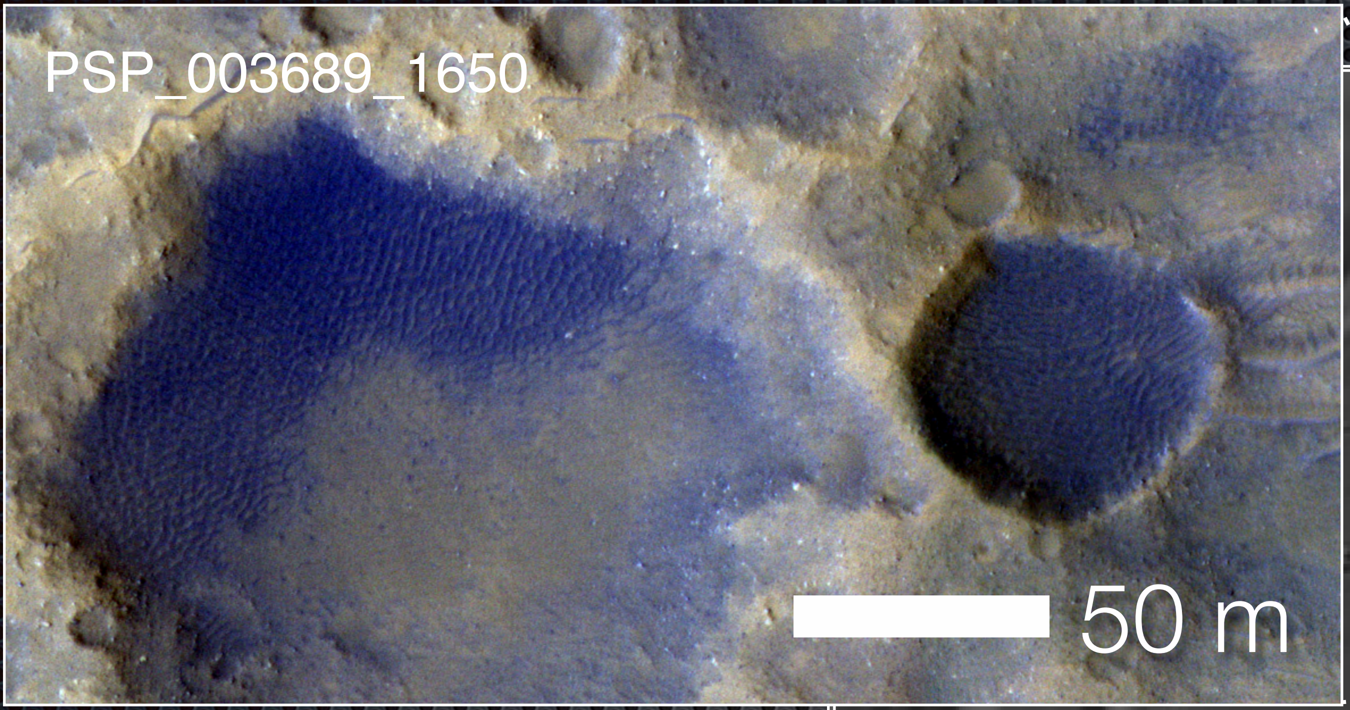


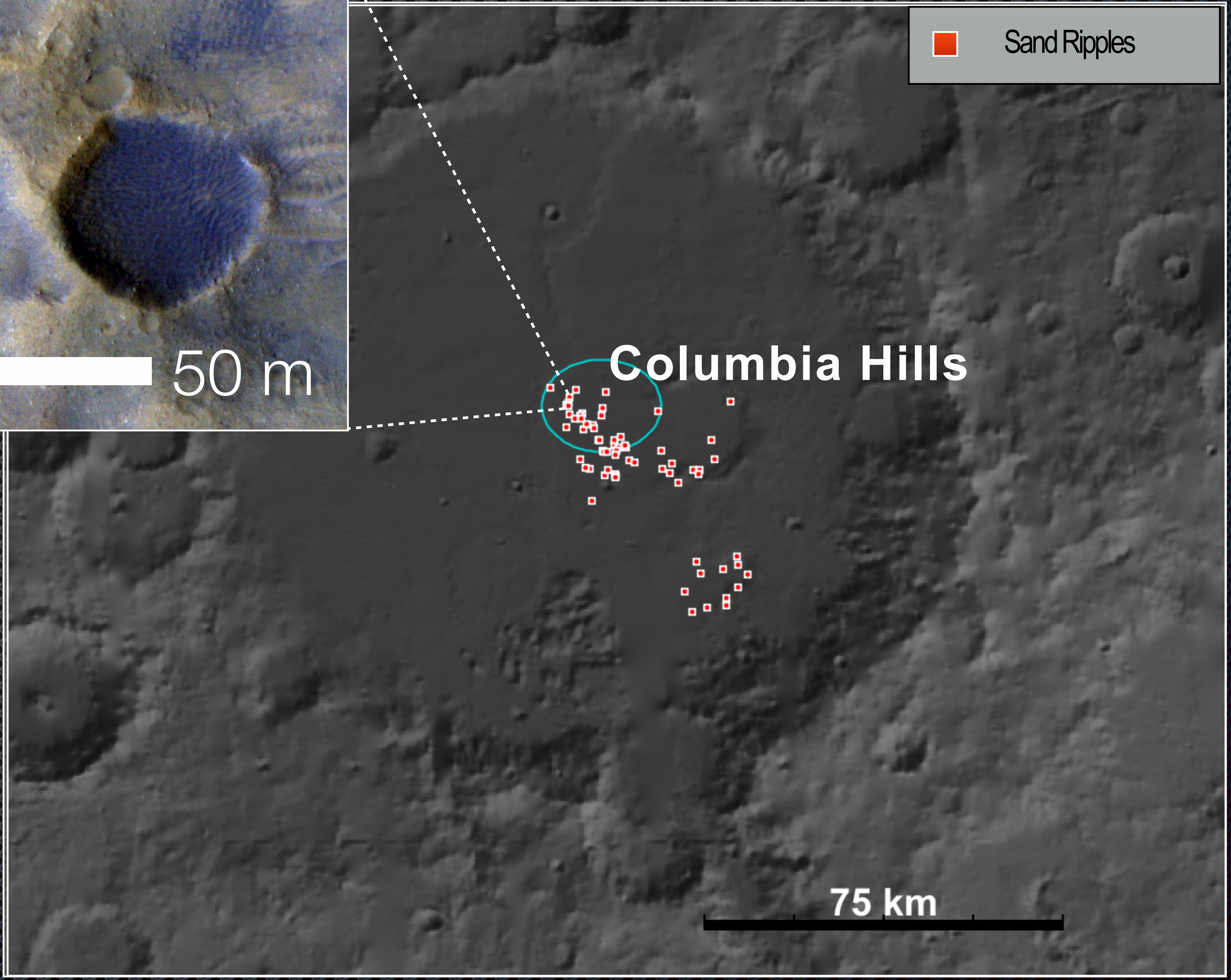
Columbia Hills



Columbia Hills site lacks nearby dune monitoring site (~1500 km) or even regional dune fields (~1000 km) based on global mapping efforts [Hayward et al. 2007; 2014].

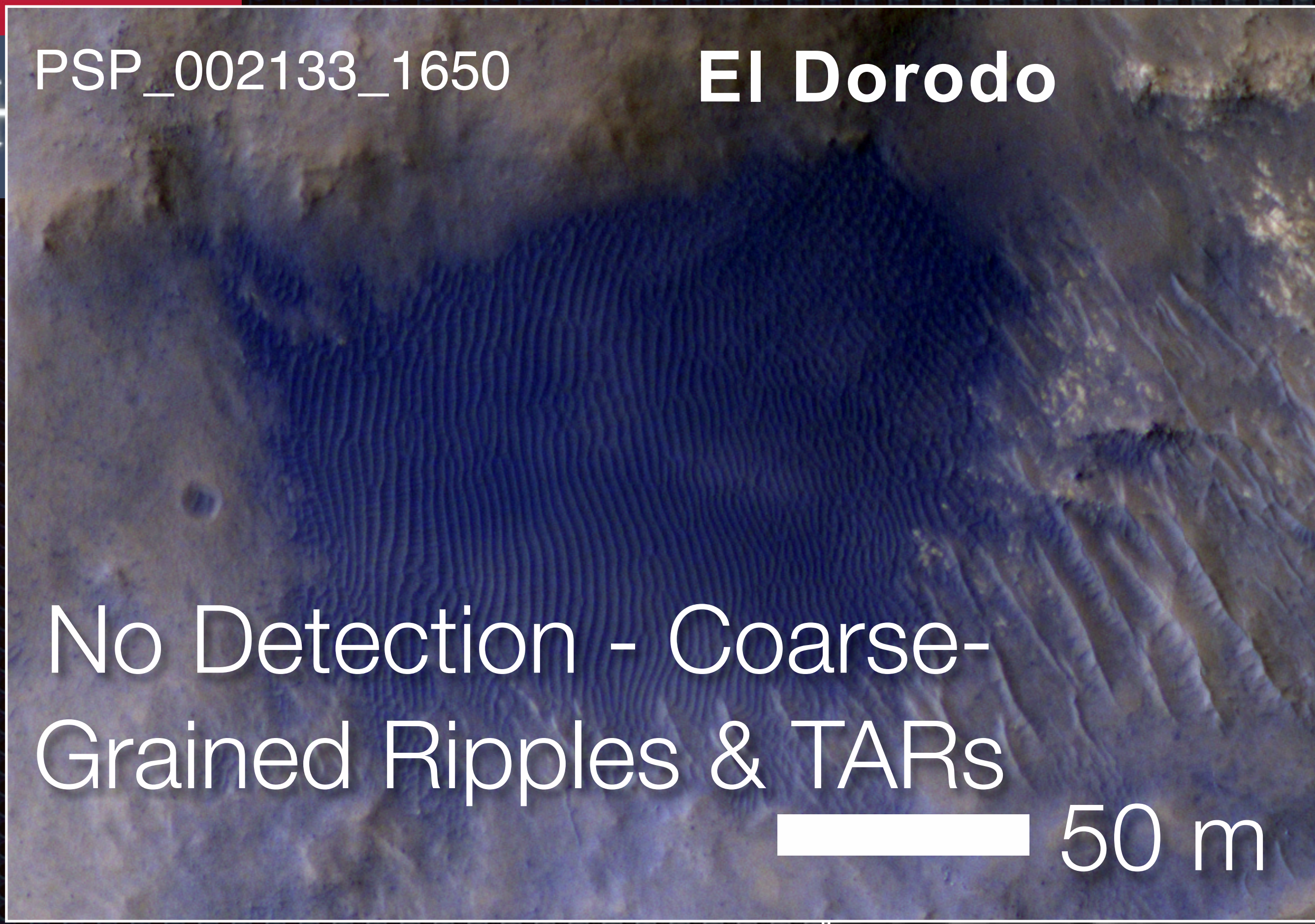
Columbia Hills

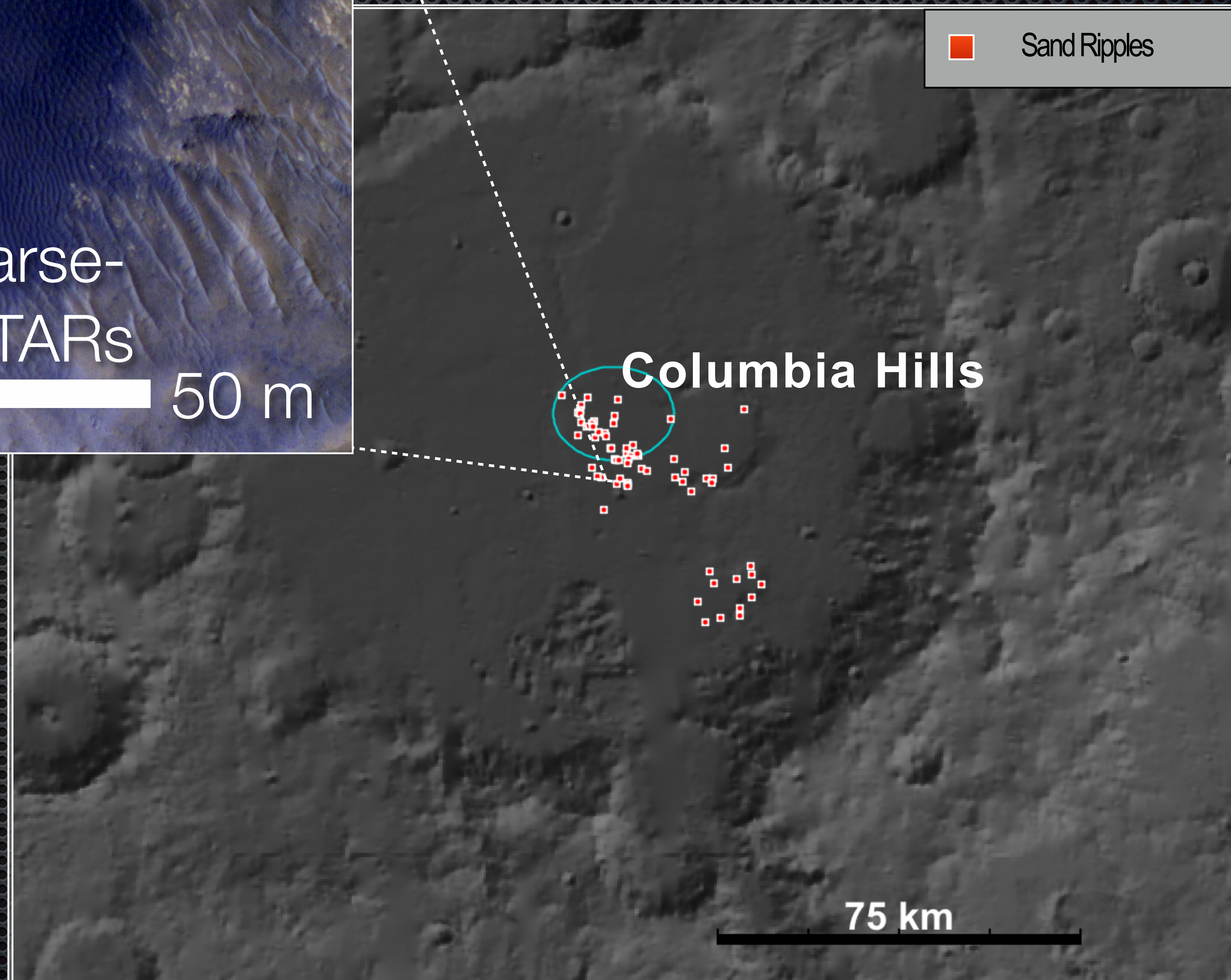


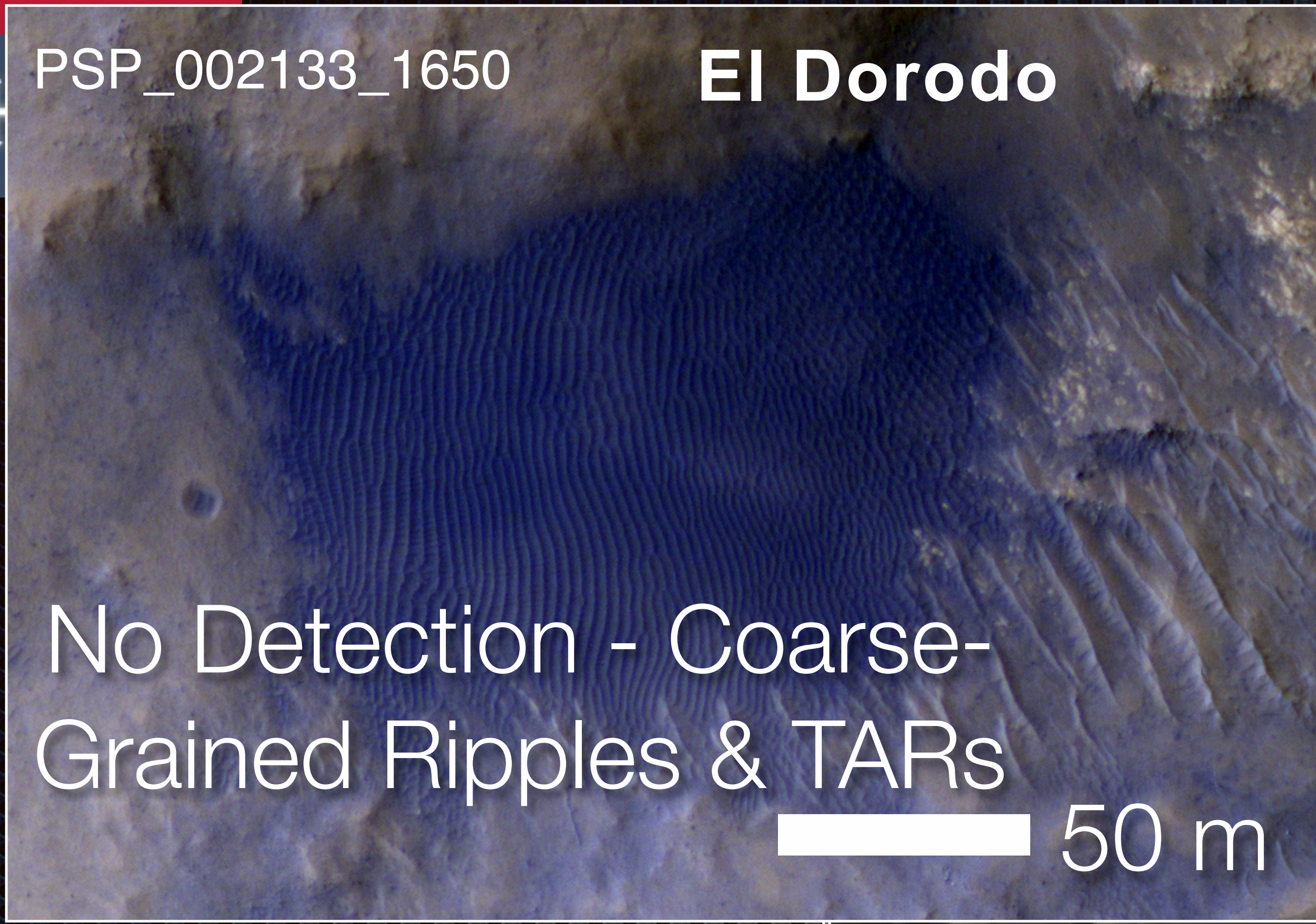


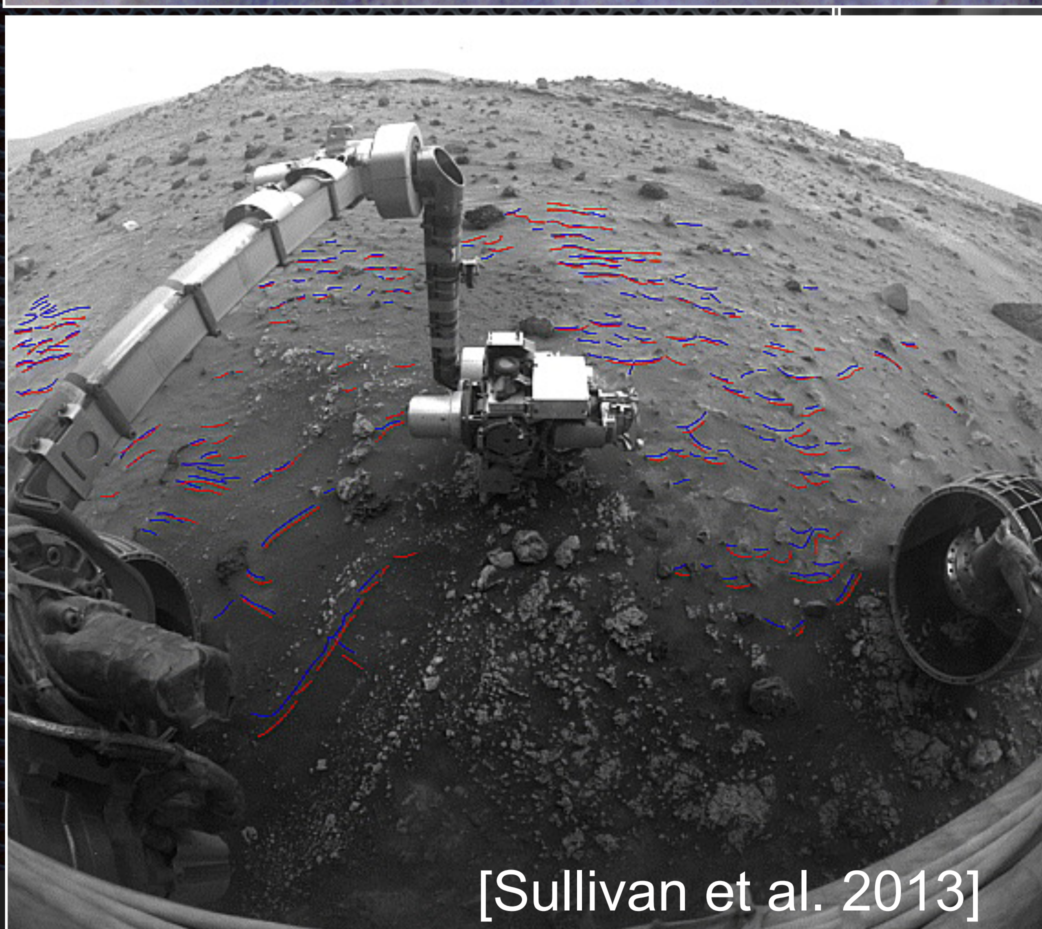
Gusev crater has numerous, isolated sand ripple patches, typically within or adjacent to small craters. No major bedforms.

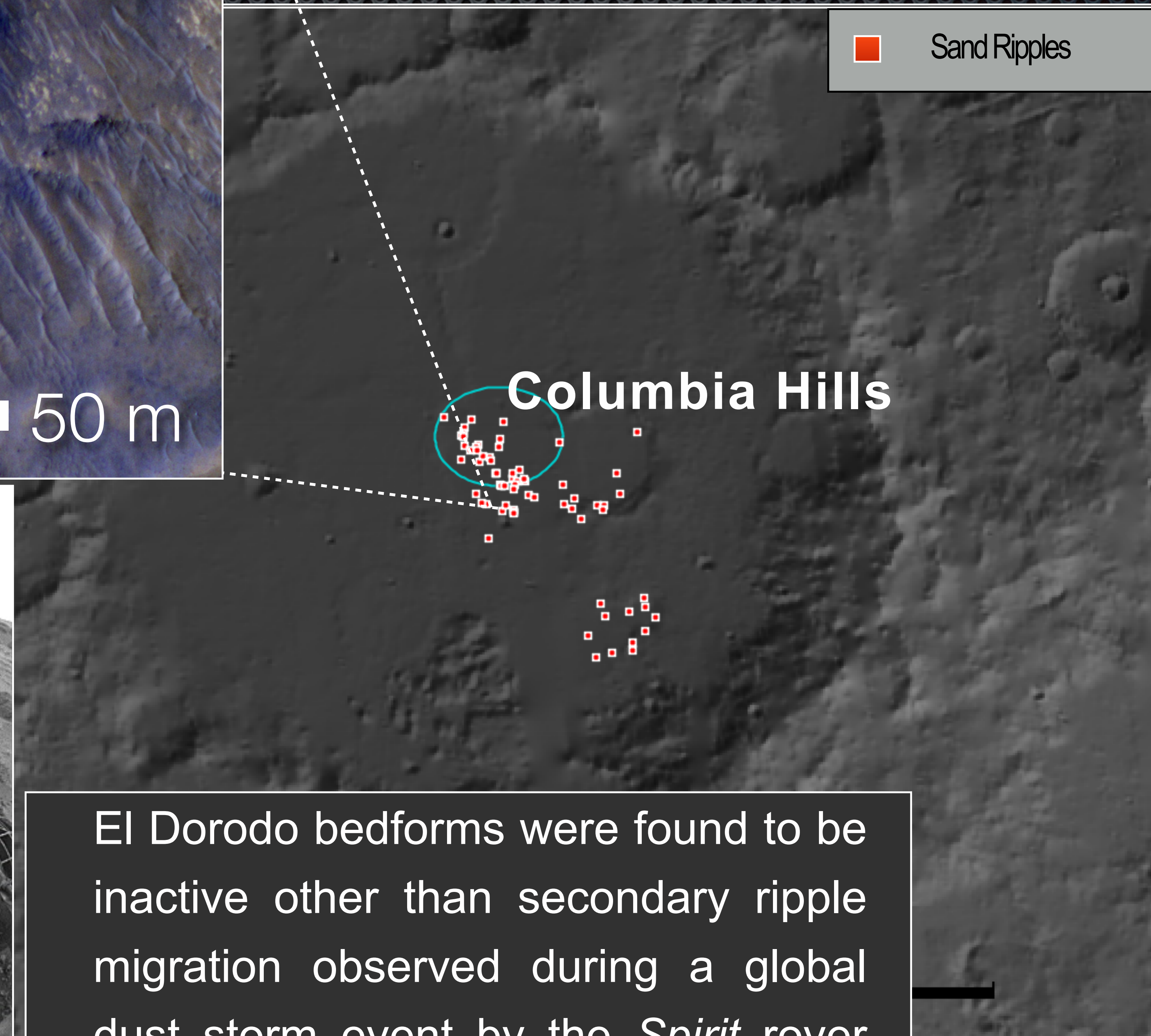
Columbia Hills











El Dorodo bedforms were found to be inactive other than secondary ripple migration observed during a global dust storm event by the *Spirit* rover [Sullivan et al. 2008].

THE UNIVERSITY OF ARIZONA.
HiRISE

Local Results for Mars 2020 Candidate Sites

Location*	Sand Dunes Within 10km of Ellipse?	Bedform Change Within 10km of Ellipse?	Notes:
Jezero Crater	YES	YES$^{\Psi}$	Numerous dunes on the plateau to N, W, & E (upwind), some of which are active. Minor sand ripples adjacent to fan. Large high-flux dune fields in crater to the NE.
Columbia Hills	NO	NO	Numerous patches of sand ripples, mostly within small craters, including within the ellipse. No detections of bedform change other than secondary ripples described by *Sullivan et al*. [2008].
NE Syrtis Major	YES	YES	Numerous dunes on the plains to N, W, & E (upwind), some of which are active. Large high-flux dune fields in crater to the NE. Some evidence for sediment pathways across the proposed ellipse.
Eberswalde Crater	NO	YES	Ripple movement of "dark-toned bedform" unit [*Rice et al.,* 2013] on west edge of ellipse. No other likely mobile bedforms in the vicinity.
SW Melas Basin	NO	YES$^{\Psi}$	Minor (active) sand patches within the ellipse. Numerous regional (active) dune fields, but none local.
Nili Fossae	YES	YES$^{\Psi}$	Numerous dune fields SW-NW and generally downwind of ellipse. Scattered dunes on plateau to E (upwind) and Hargraves crater dune field. Good evidence for sediment pathways across the proposed ellipse.
Mawrth Vallis	NO	NO	High flux dune fields in craters to the W (Oyama & McLaughlin). Sparse evidence of contemporary bedforms on plateau surrounding or within ellipse.
Holden Crater	NO	NO	Large high-flux dune field in Holden to N (upwind). Sparse evidence of contemporary sand movement in ellipse.

*All sites have aeolian bedforms (Transverse Aeolian Ridges (TARs), wind ripples) within the proposed landing ellipse, but non have sand dunes.

$^{\Psi}$Sites where change detection confirmed active bedforms within the proposed ellipse.

Regional and Local Results for Mars 2020 Candidate Sites

Site	Landing Site Scientific Selection Criteria: CHARACTERIZABLE GEOLOGIC SETTING & HISTORY		ANCIENT HABITABLE ENVIRONMENT		HIGH BIOSIGNATURE PRESERVATION POTENTIAL		ASTROBIOLOGICAL QUALITY OF RETURNED SAMPLES		PETROLOGICAL QUALITY OF RETURNED SAMPLES		REGIONAL SAND FLUX RESULTS	LOCAL INDICATORS OF SAND MOVEMENT AND POTENTIAL AEOLIAN ABRASION
	mode	average	mode	average	mode	average	mode	average	mode	average		
Jezero	5	4.9	5	4.7	5	4.4	5	4.4	5	4.3	HIGH	HIGH
Columbia Hills	5	4.7	5	4.3	5	4.3	3	3.8	5	4.1	LOW	LOW
NE Syrtis	5	4.7	5	3.8	3	3.3	5	3.8	5	4.8	HIGH	HIGH
Eberswalde	5	5.0	5	4.5	5	4.3	3	3.4	3	3.0	MODERATE	MODERATE
SW Melas	5	4.5	5	4.1	5	3.9	3	3.6	3	3.1	MODERATE	MODERATE
Nili Fossae Trough	5	4.4	3	3.4	3	3.2	3	3.4	5	4.7	HIGH	HIGH
Mawrth	5	4.3	3	3.7	3	2.9	3	3.4	5	3.9	HIGH	LOW
Holden Crater	5	4.4	3	3.4	3	3.2	3	3.2	3	3.4	MODERATE	MODERATE

[Golombek and Grant, 2015] [*This Study*]

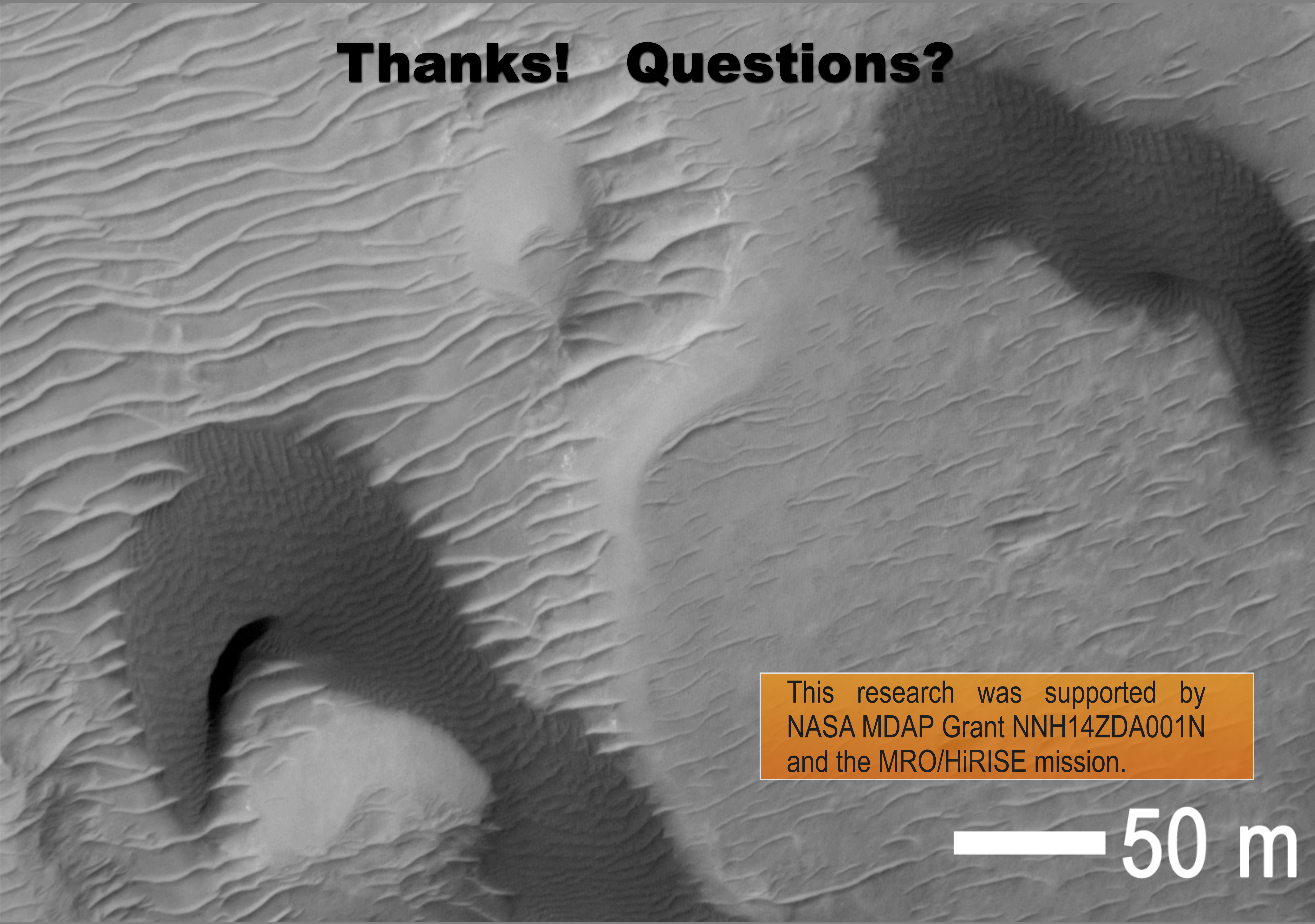
Regional and Local Results for Mars 2020 Candidate Sites

Site	Landing Site Scientific Selection Criteria: Characterizable Geologic Setting & History (mode)	(average)	Ancient Habitable Environment (mode)	(average)	High Biosignature Preservation Potential (mode)	(average)	Astrobiological Quality of Returned Samples (mode)	(average)	Petrological Quality of Returned Samples (mode)	(average)	Regional Sand Flux Results	Local Indicators of Sand Movement and Potential Aeolian Abrasion
Jezero	5	4.9	5	4.7	5	4.4	5	4.4	5	4.3	HIGH	HIGH
Columbia Hills	5	4.7	5	4.3	5	4.3	3	3.8	5	4.1	LOW	LOW
NE Syrtis	5	4.7	5	3.8	3	3.3	5	3.8	5	4.8	HIGH	HIGH
Eberswalde	5	5.0	5	4.5	5	4.3	3	3.4	3	3.0	MODERATE	MODERATE
SW Melas	5	4.5	5	4.1	5	3.9	3	3.6	3	3.1	MODERATE	MODERATE
Nili Fossae Trough	5	4.4	3	3.4	3	3.2	3	3.4	5	4.7	HIGH	HIGH
Mawrth	5	4.3	3	3.7	3	2.9	3	3.4	5	3.9	HIGH	LOW
Holden Crater	5	4.4	3	3.4	3	3.2	3	3.2	3	3.4	MODERATE	MODERATE

[Golombek and Grant, 2015]

[*This Study*]

Thanks! Questions?



This research was supported by NASA MDAP Grant NNH14ZDA001N and the MRO/HiRISE mission.

Summary

- Regional sand flux results for Mars 2020 candidates suggest:
  - The Nili Fossae/Jezero/NE Syrtis sites had the highest regional sediment fluxes.
  - The Mawrth, Eberswalde, Holden, and SW Melas sites had moderate regional fluxes.
  - The Columbia Hills site lacks a nearby dune monitoring site (~1500 km) or even regional dune fields (~1000 km) [Hayward et al. 2014].
- Local conditions of candidate-landing sites suggest:
  - The Nili Fossae/Jezero/NE Syrtis sites likely had sediment pathways across their ellipses.
  - Eberswalde, Holden, and SW Melas sites show minor sandy ripple deposits (some detected mobile).
  - Mawrth appears to lack sandy deposits forming bedforms.
  - Ripples examined at Columbia Hills were not detected to be active and local abrasion rates are assumed to be relatively low.

Discussion

- The abrasion susceptibility (S_a) of local basaltic rocks can be estimated to assess how sand fluxes modify the landscape. Using the methodology and assumptions (S_a for basalt, mean trajectory height etc.) from Bridges et al. [2012].
  - Sand blasting at McLaughlin crater is estimated to erode 2–8 μm/yr for flat ground and 15–75 μm/yr for a vertical rock face.
  - These erosion rates would be even higher for the clay-rich units that have been previously documented there.
  - Erosion rates will increase with the greater atmospheric pressure during higher obliquities [Chojnacki et al. 2017, LPSC].
- Erosion of local sedimentary deposits by active sand dunes has the potential to expose samples with relatively undegraded organics and should be considered [Grotzinger et al. 2014].

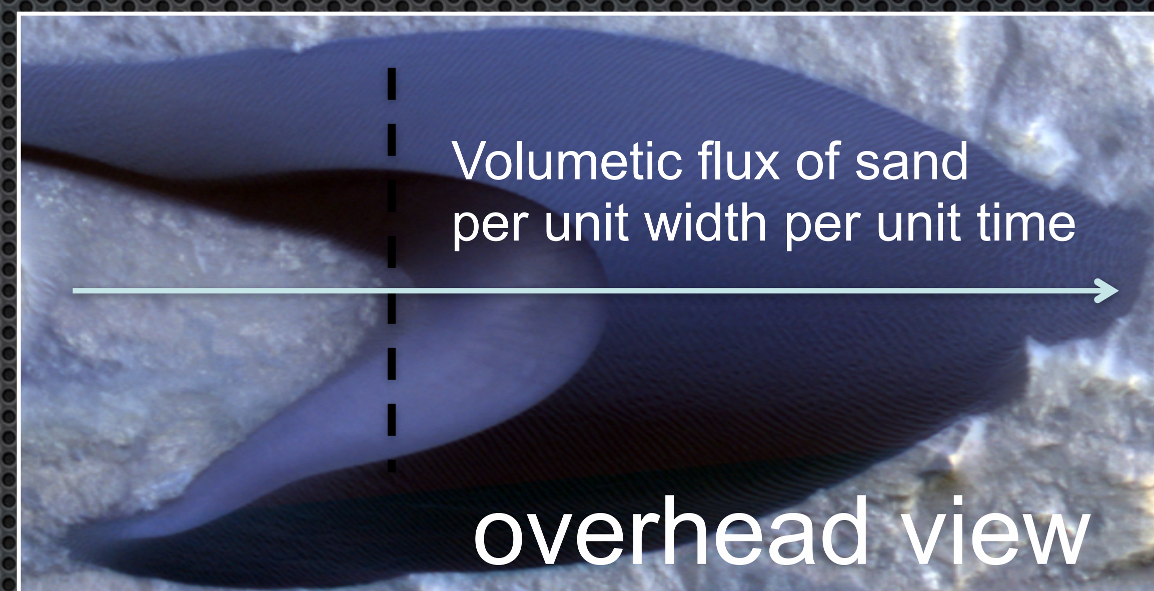
Abrasion Rates

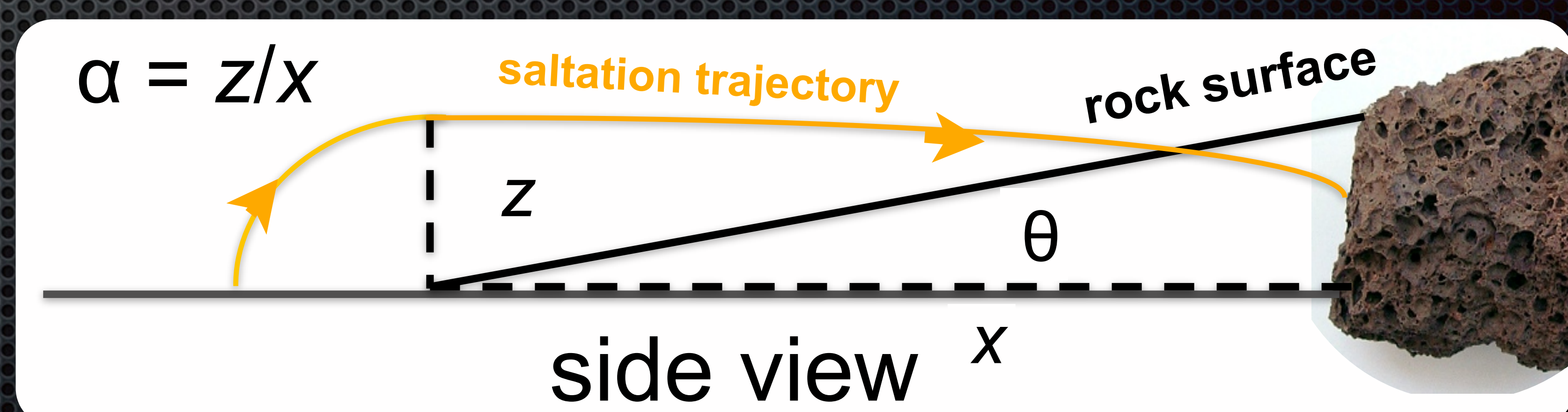
- The abrasion susceptibility (S_a) or the mass loss from impacting sand on rocks is relevant to erosion rates and landscape modification.
- The S_a for basaltic sand grains impact basaltic rocks at the impact threshold for Mars is S_a ~2x10^{-6}, based on laboratory measurements [Greeley et al. 1982].
- Abrasion rates for a range of sloping surfaces (i.e., flat ground to a vertical rock face) were estimated using the approach described by Bridges et al. [2012a] and the following equation.

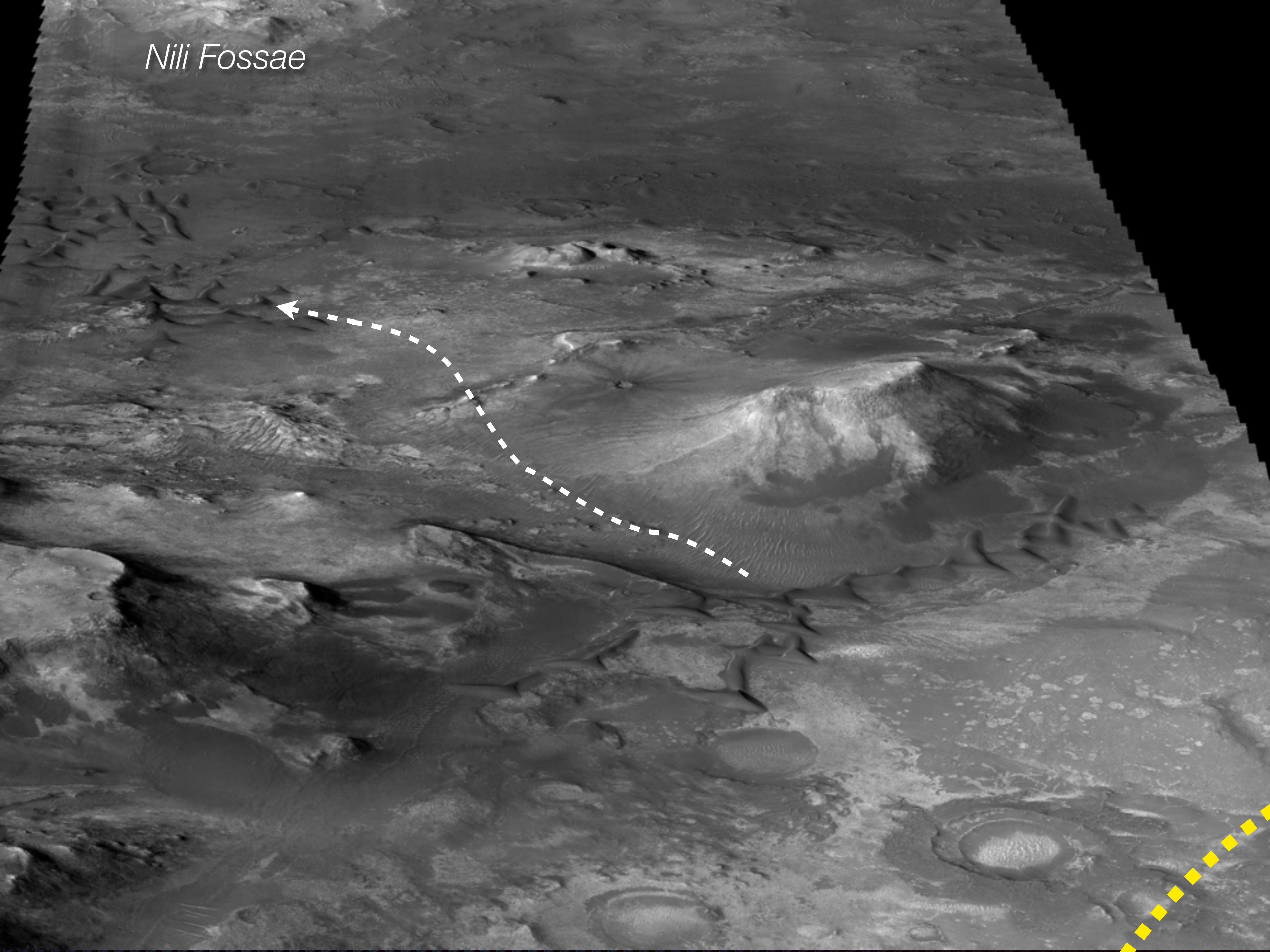
Abrasion Rate = $S_a Q_i / z(\alpha\cos\theta + \sin\theta)$

- Estimated abrasion rates* for basalt are 0.1–16 μm/yr for flat ground and 4–80 μm/yr for vertical rock surfaces.

*Does do not include wind deflation or wind abrasion.



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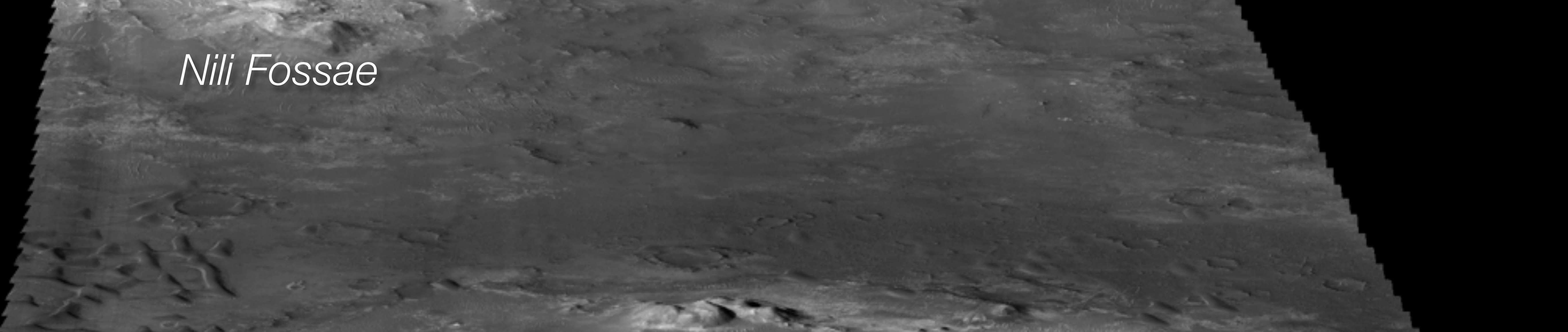

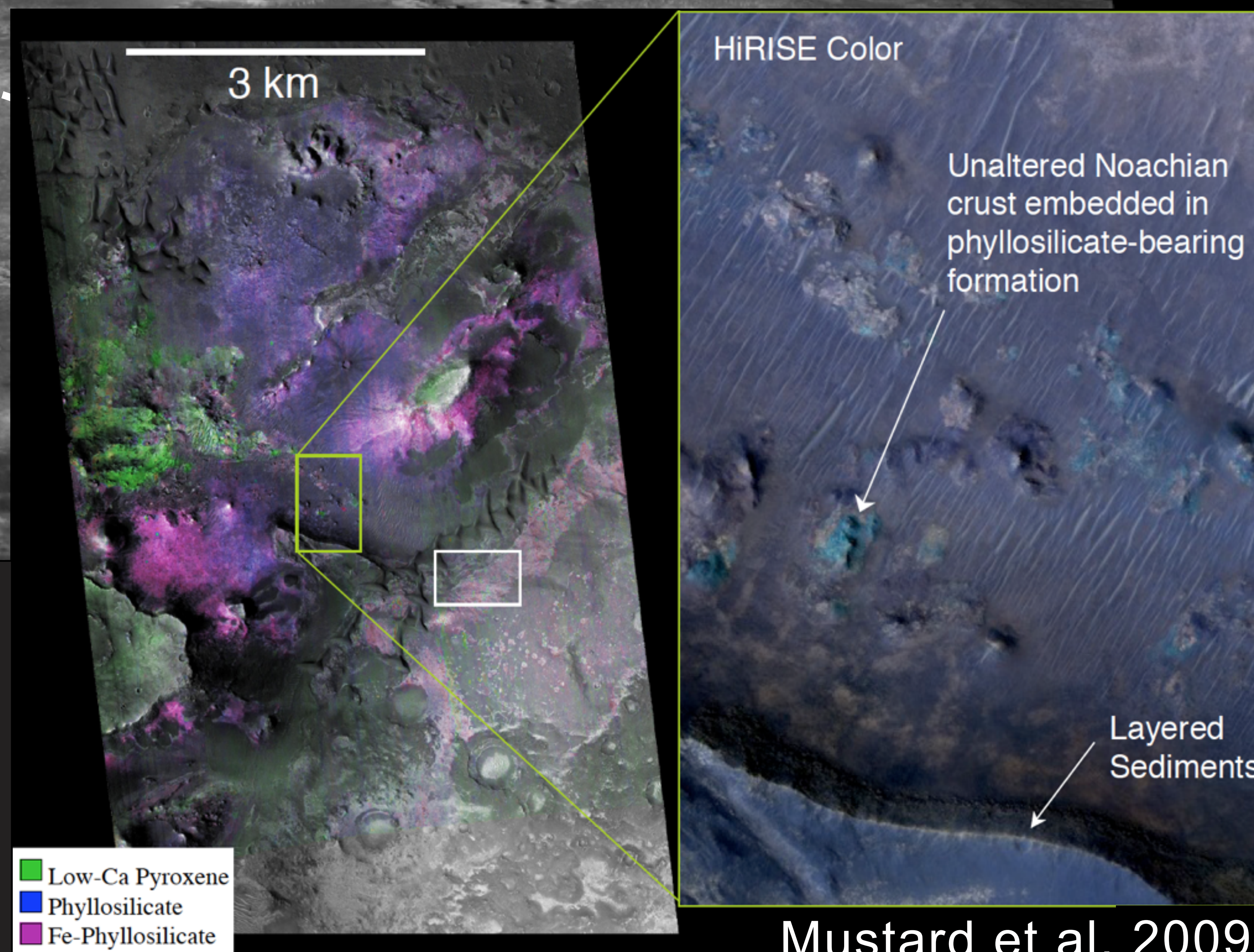

- Aeolian erosion removes spectrally-obscuring dust that would otherwise mask mafic rocks and phyllosilicate-bearing materials.

Mustard et al. 2009