Remote Sensing of Mars

Focus on Relevance to Terramechanics

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KISS xTerramechanics Workshop
6/20/11

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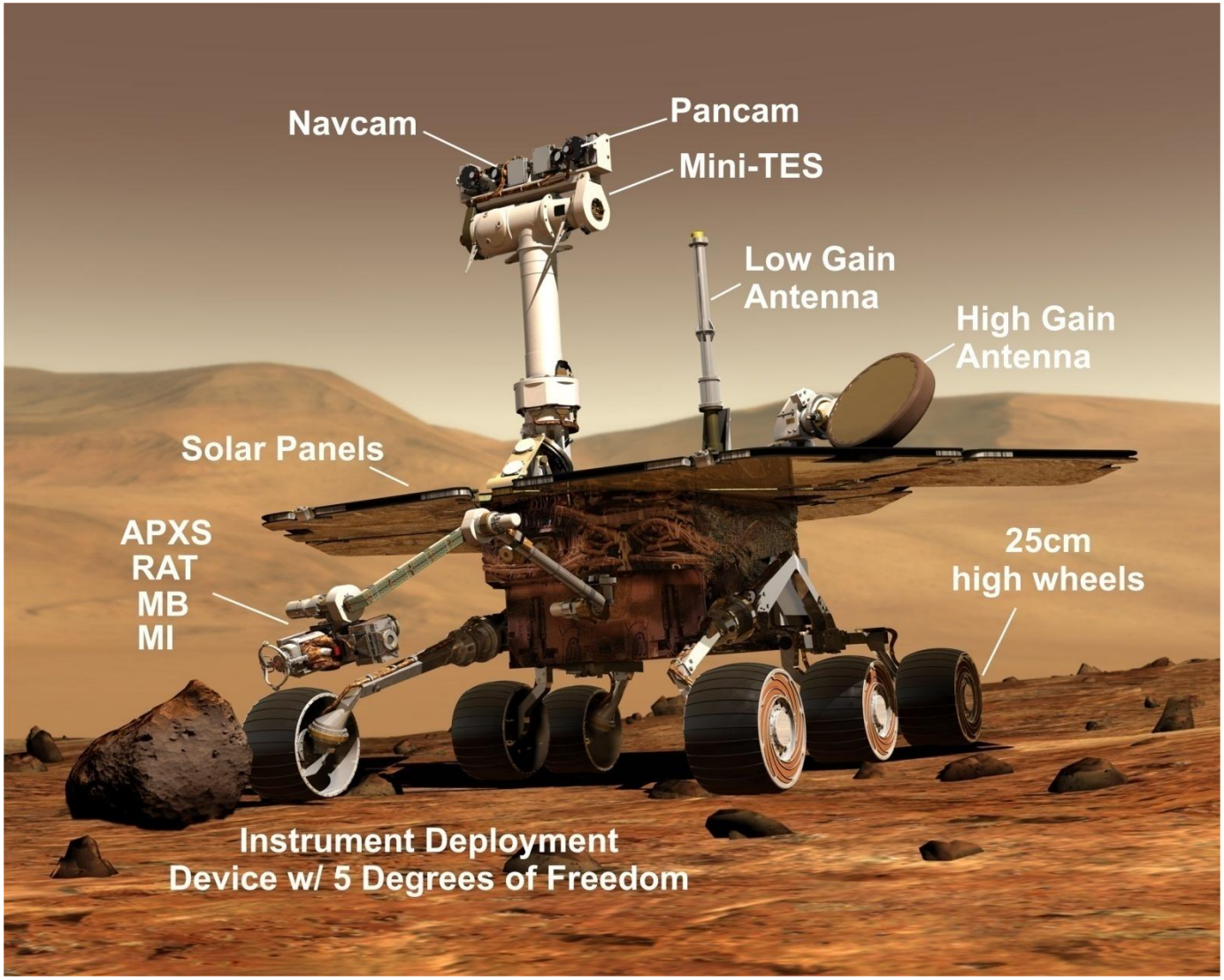
MER Athena Science Team

Coordinated Orbital and Opportunity Rover Observations

- Opportunity has traversed ~30 km mainly NS over past 7 ½ years, a “calibration alley” for coordinated rover and orbital observations and analyses
  - Extends retrieval of rock & soil properties and environmental history reconstructions beyond traverse sites
  - Allows better understanding of mobility issues and path planning to minimize sinkage and slip

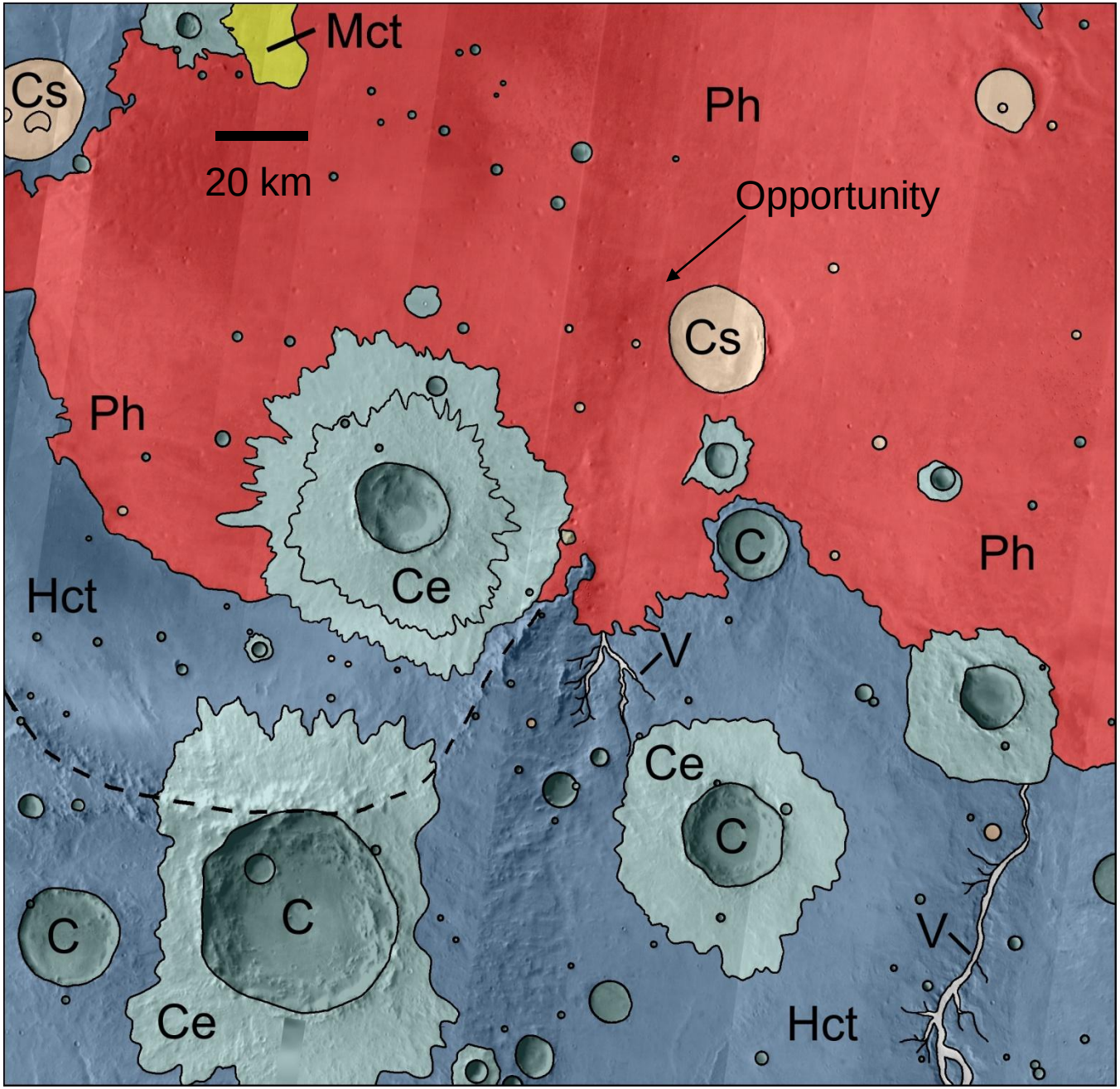
Opportunity Rover



- Right front wheel left rotated ~8 deg inward when azimuthal actuator failed
- Shoulder IDD actuator failed so driving uses "fishing stow" and have limited deployment work space
- Mini-TES no longer responding

Key Orbital Instruments

- Odyssey
  - Thermal Emission Imaging System (THEMIS) with 5 multispectral visible (5 bands, 0.43-0.86 μm, 18 m/pixel) and thermal coverage (10 bands, 6.78-14.88 μm , 100 m/pixel)
- Mars Reconnaissance Orbiter (MRO)
  - Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) 544 band (0.362 to 3.920 μm) hyperspectral imager with 18 m/pixel (and other modes)
  - Context Imager (CTX) 6 m/pixel (0.5-0.8 μm)
  - HiRISE with 0.25 m/pixel 3 bands (0.55-0.85 μm)
  - Coordinated and nested observations
  - Stereo for CTX and HiRISE using data from two or more orbits

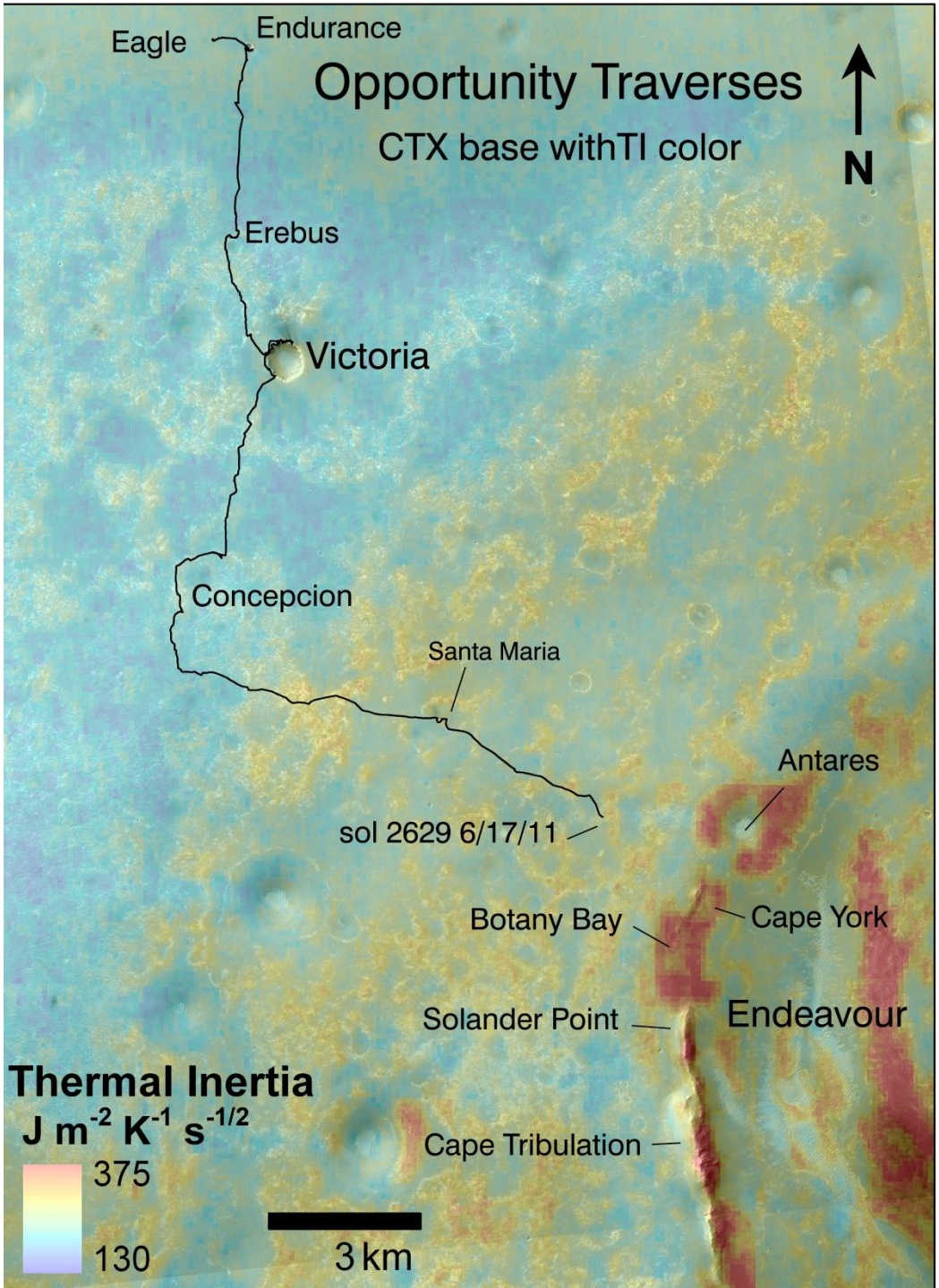


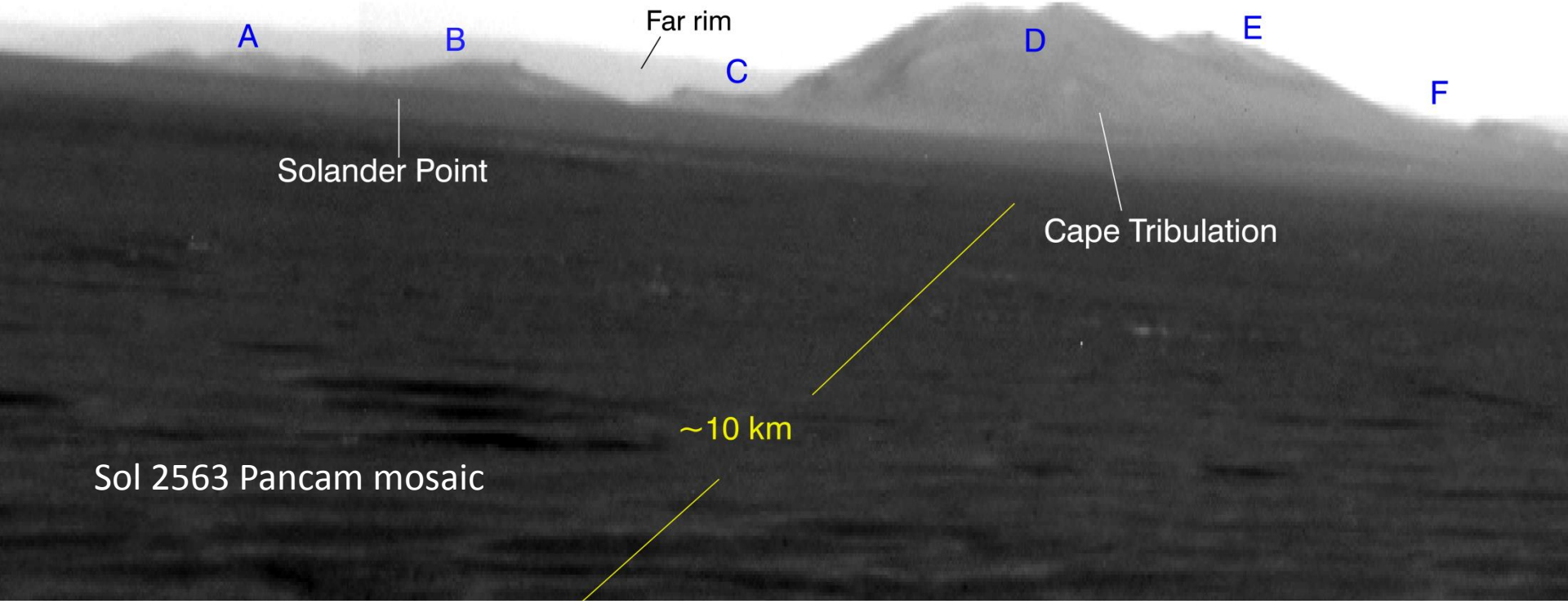
Units & Symbols

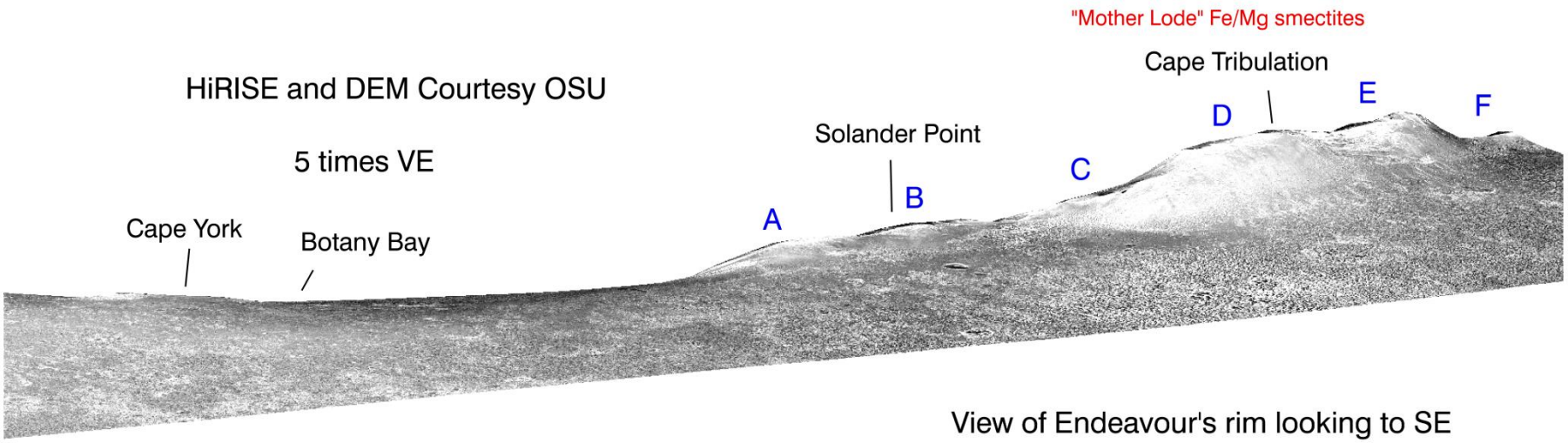
- C — Crater
- Ce — Crater ejecta
- Cs — Crater, subdued
- Ph — Hematite-bearing Plains
- V — Valley
- Hct — Cratered Highlands
- Mct — Mantled Terrain
- – – – Ridgeline trace

Thermal Inertia

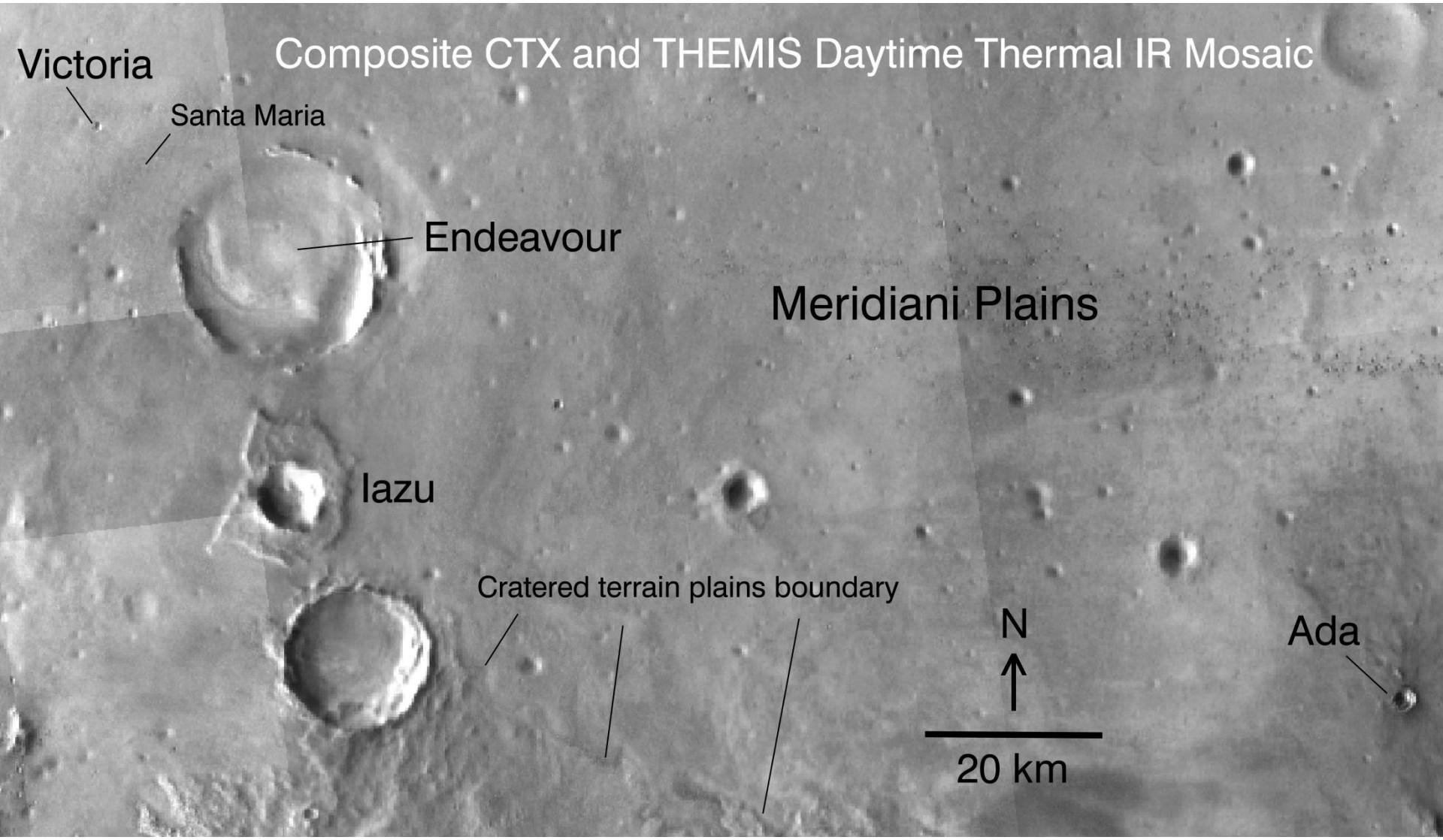
- Predawn THEMIS thermal IR observations used to derive thermal inertia:
  - $TI=(K\rho c)^{1/2}$
  - K=thermal conductivity
  - ρc = heat capacity
  - Values indicate dominance by soil cover for Mars
- Integrated effect over thermal skin depth (cm's)
  - Skin depth=$K/\rho c\ (P/\pi)^{1/2}$
  - P=period of observation, typically diurnal

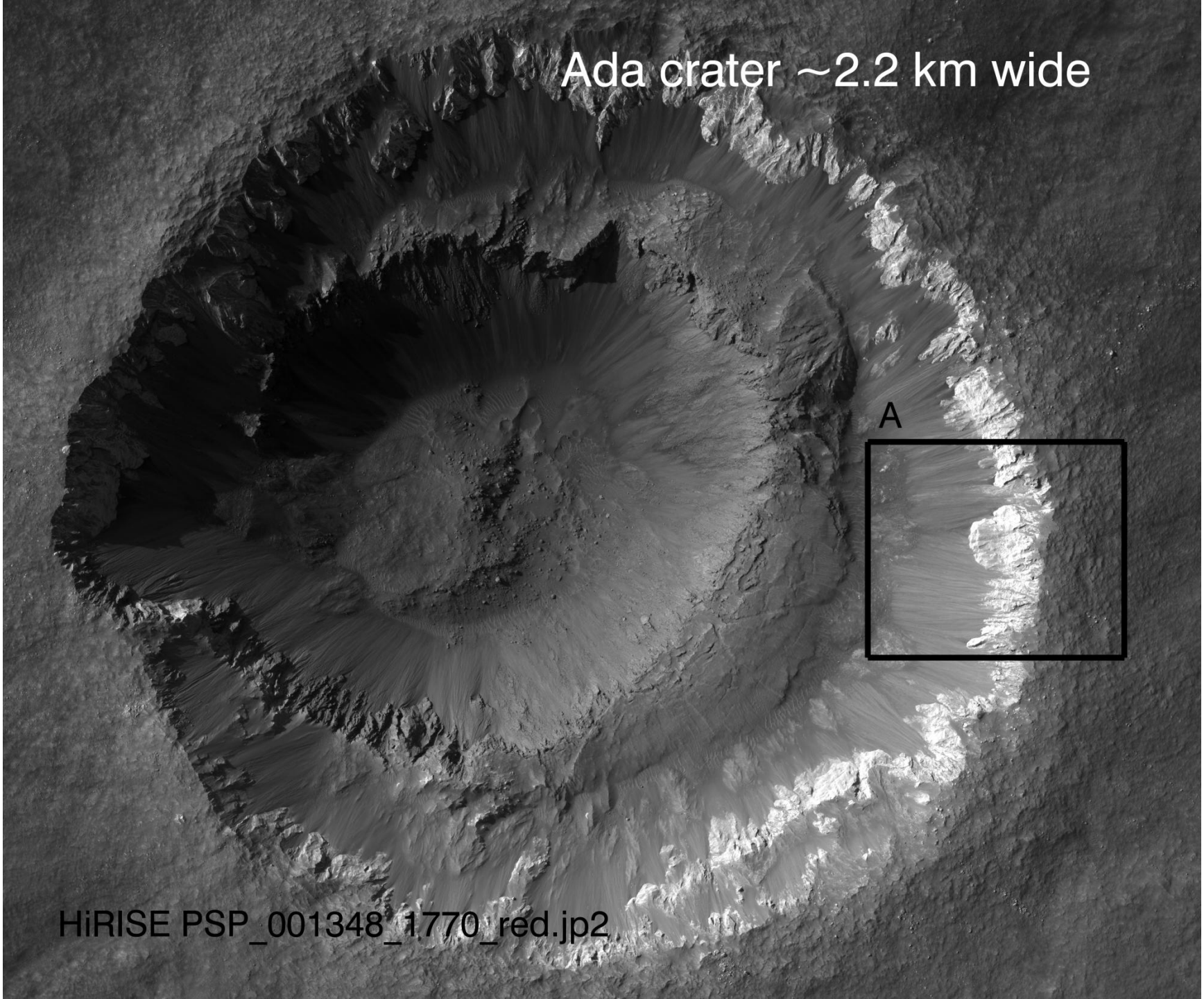

Eagle
Endurance
Opportunity Traverses
CTX base withTI color
N
Erebus
Victoria
Concepcion
Santa Maria
Antares
sol 2629 6/17/11
Botany Bay
Cape York
Solander Point
Endeavour
Cape Tribulation
Thermal Inertia
J m-2 K-1 s-1/2
375
130
3 km



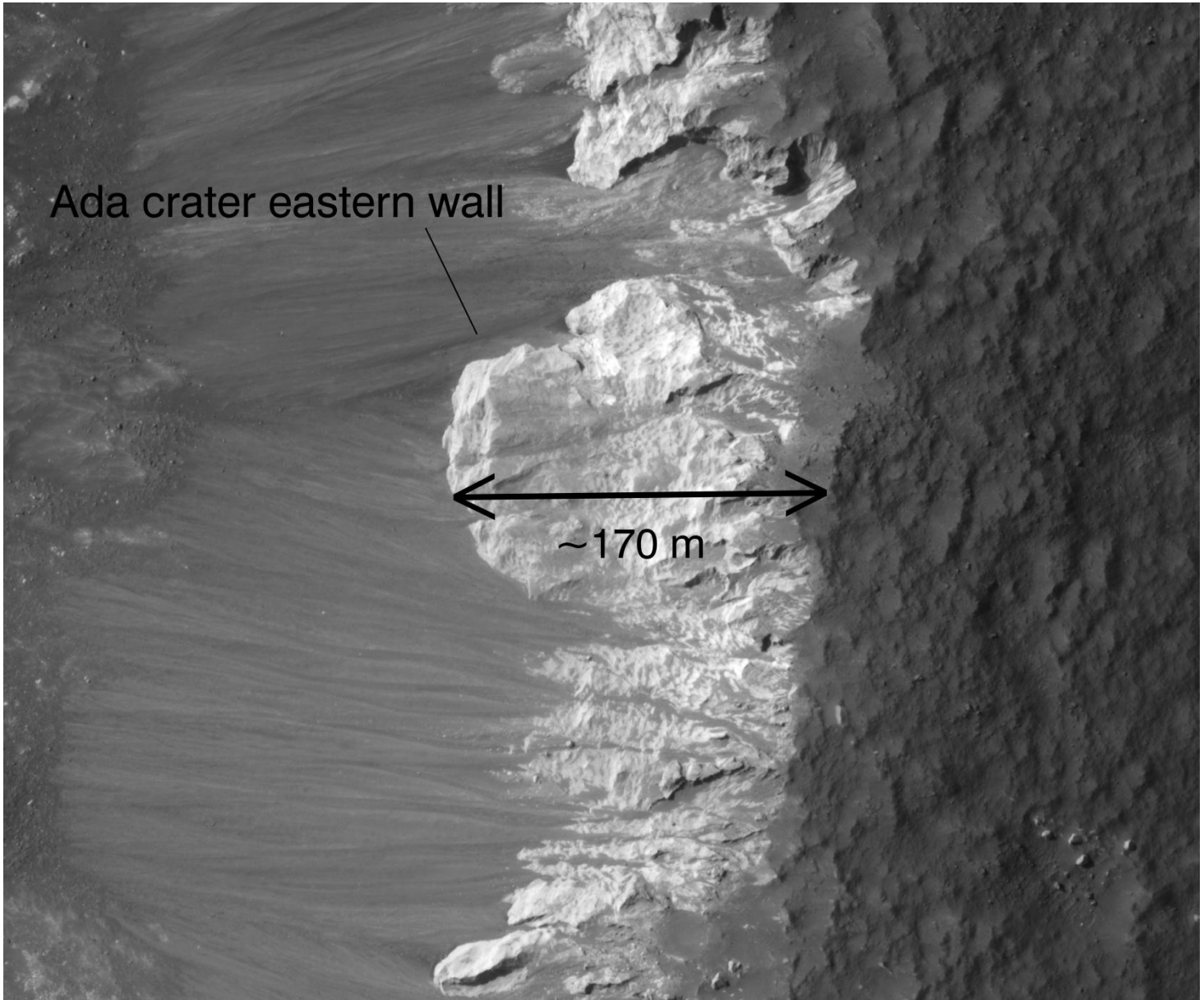


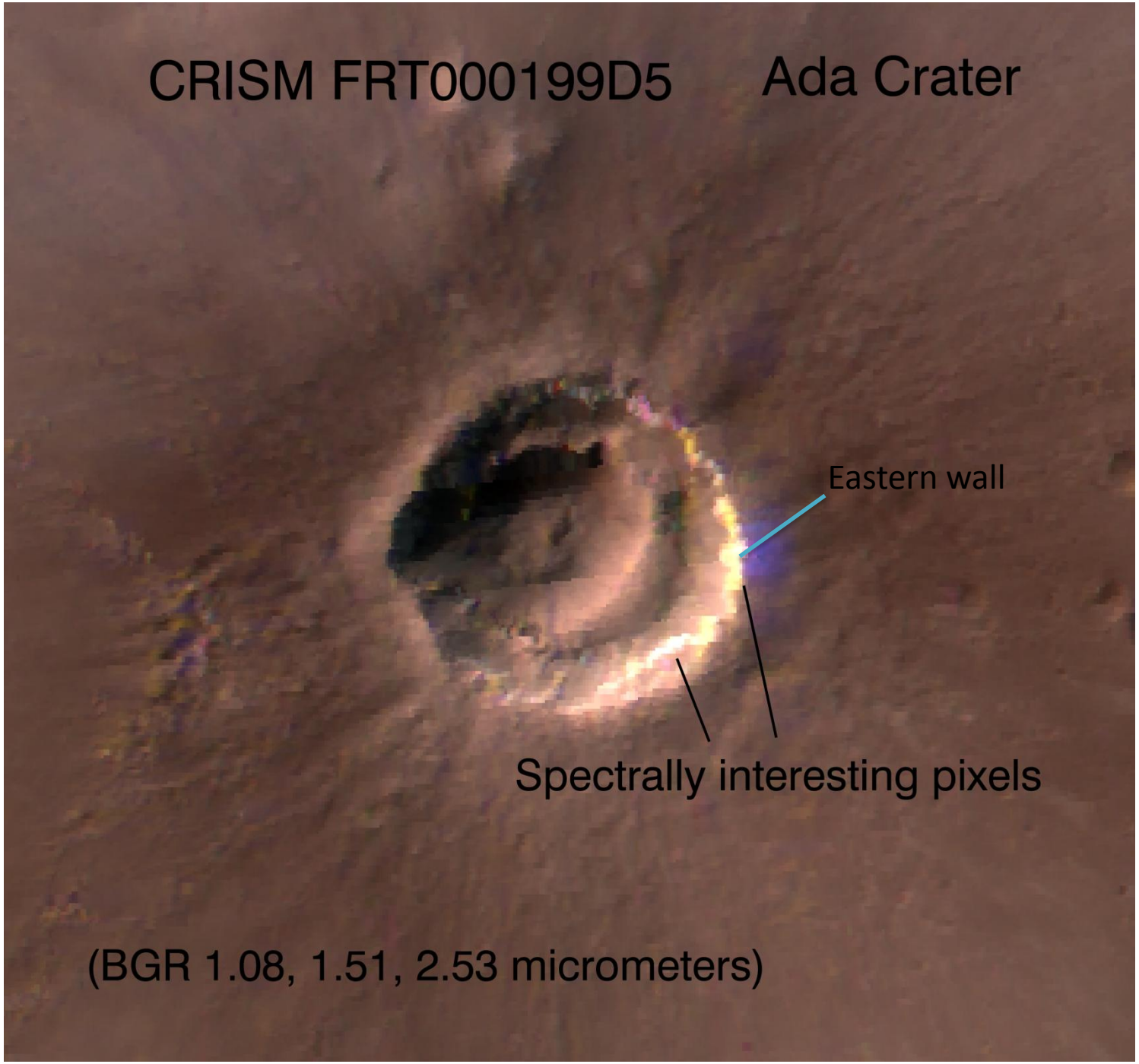
View of Endeavour's rim looking to SE


Composite CTX and THEMIS Daytime Thermal IR Mosaic
Victoria
Santa Maria
Endeavour
Meridiani Plains
Iazu
Cratered terrain plains boundary
N
Ada
20 km

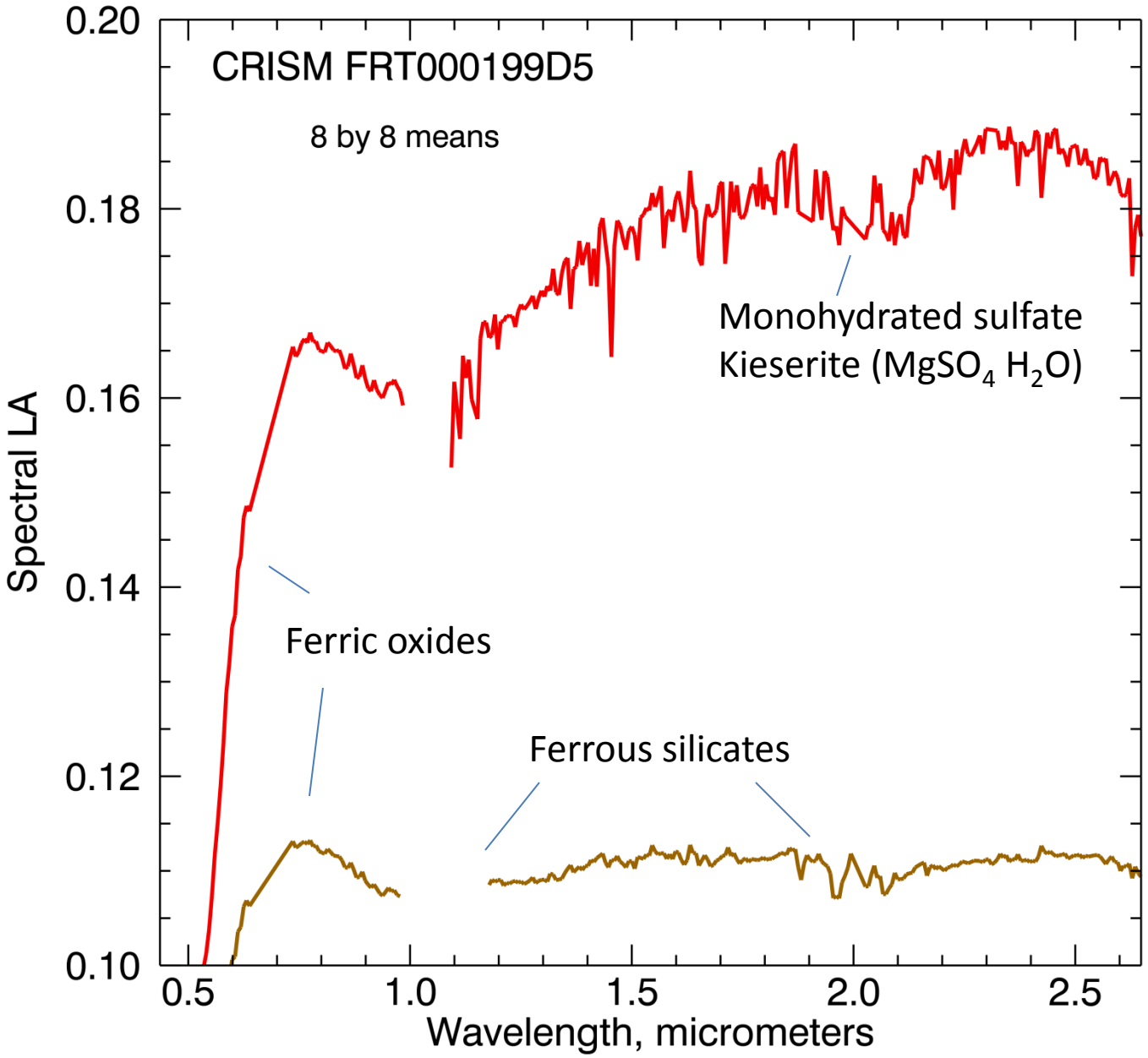

Ada crater ~2.2 km wide
A
HiRISE PSP_001348_1770_red.jp2

Ada area A




CRISM FRT000199D5
Ada Crater
Eastern wall
Spectrally interesting pixels
(BGR 1.08, 1.51, 2.53 micrometers)

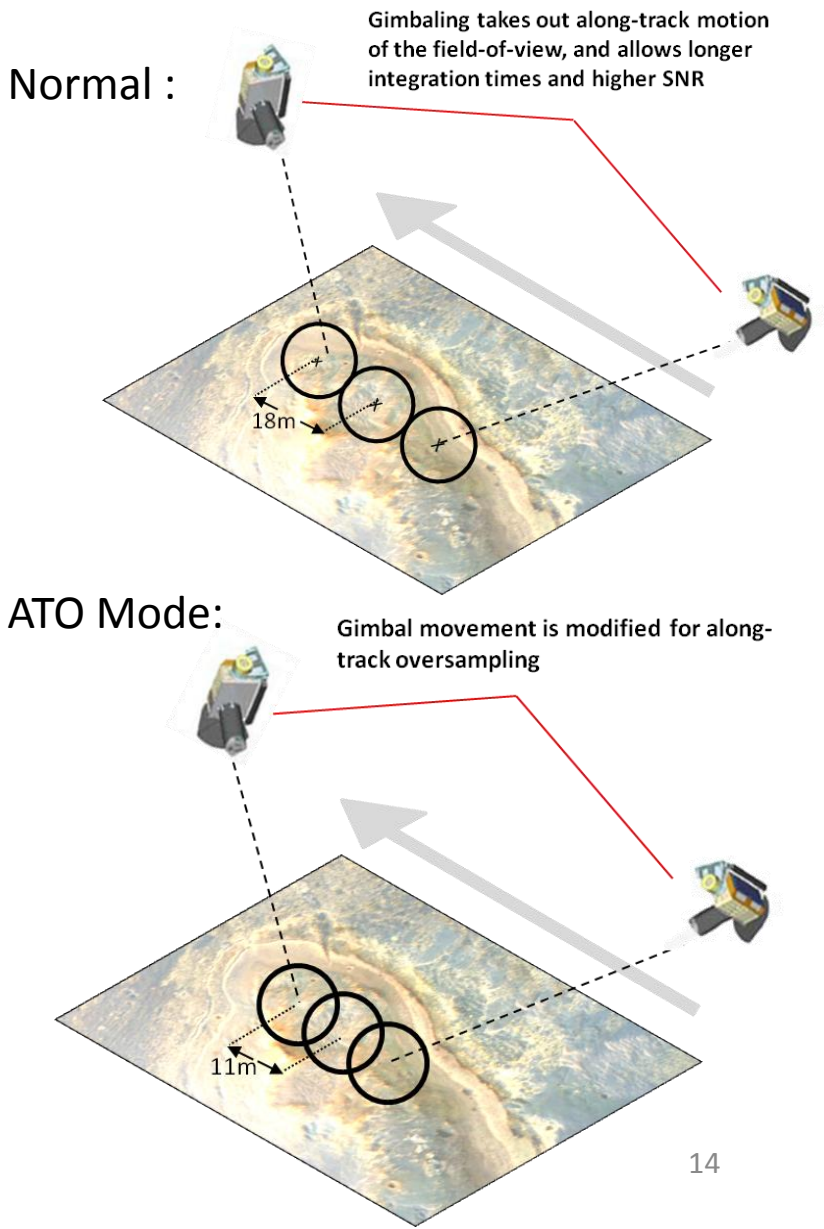
Ada crater red=bright wall brown=plains



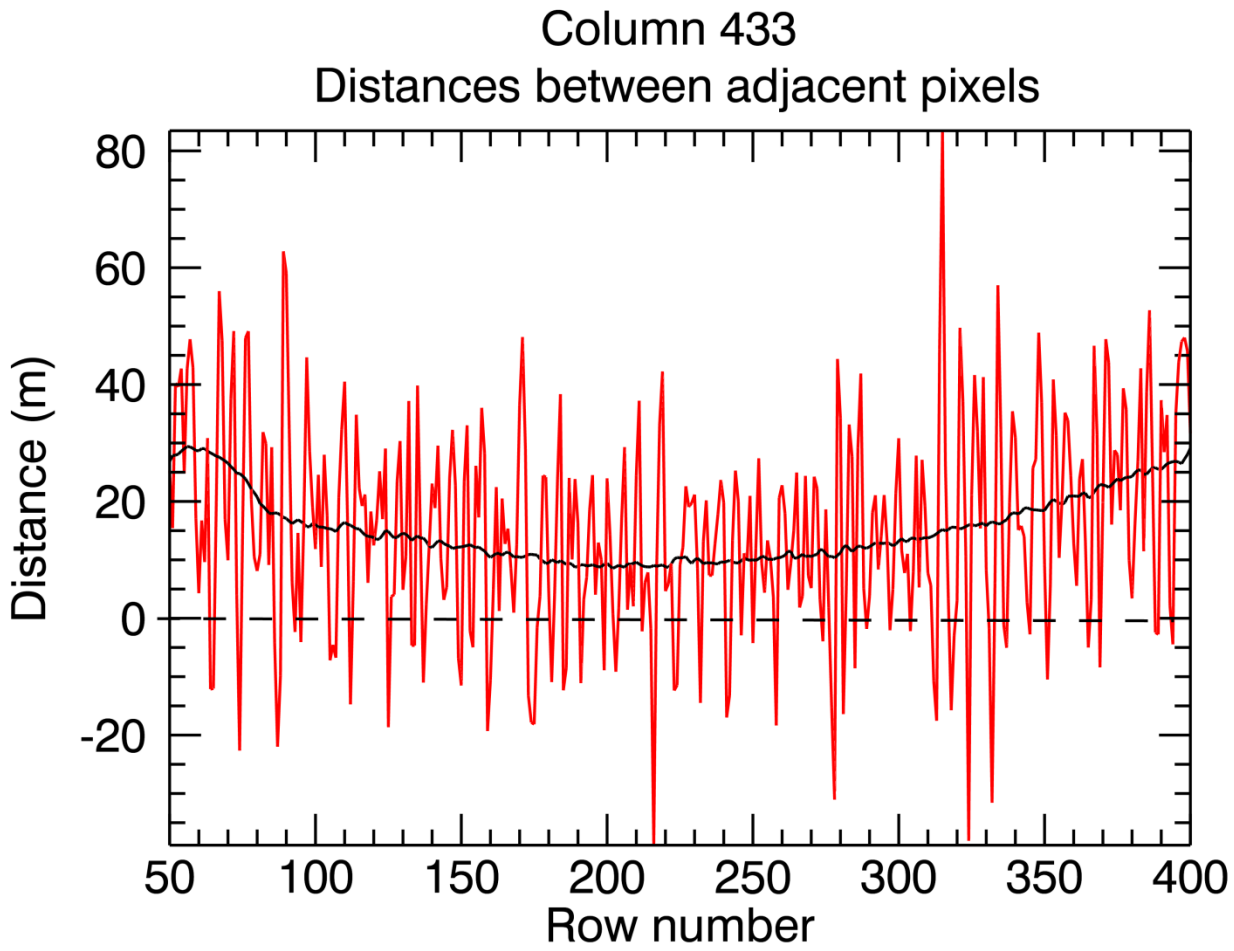
Processed using DISORT to model atmosphere and surface together

CRISM Along Track Oversampled (ATO) Observations

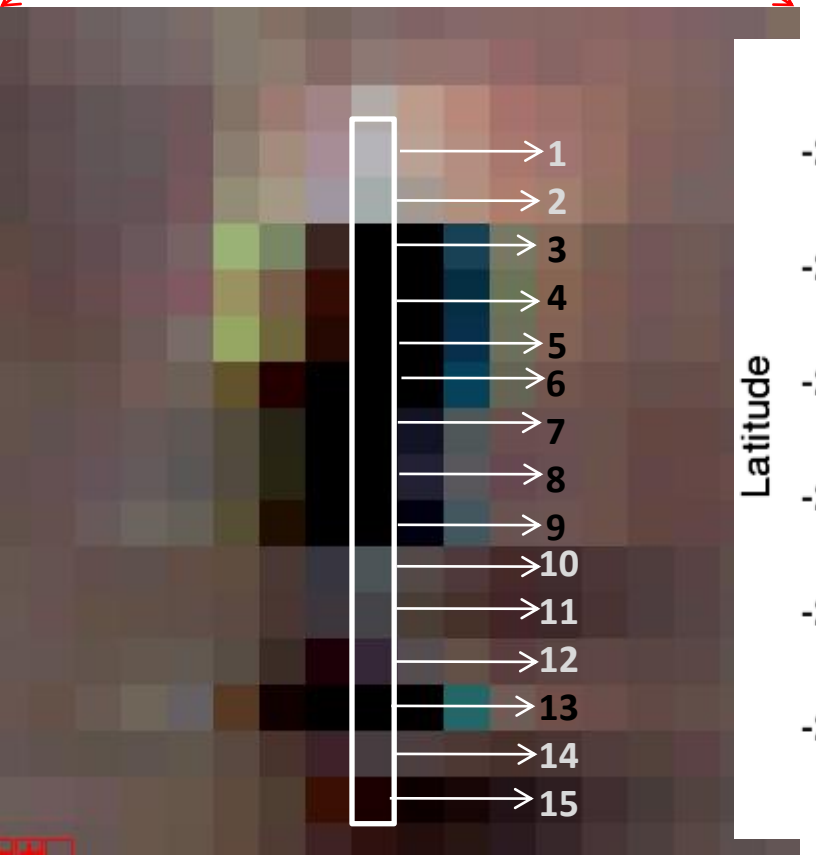
- New observing scheme where pixels overlap in the along track direction (see figures)
- Allows detection of small scale features (<18 m/pixel)
- Pixel size and noise trades

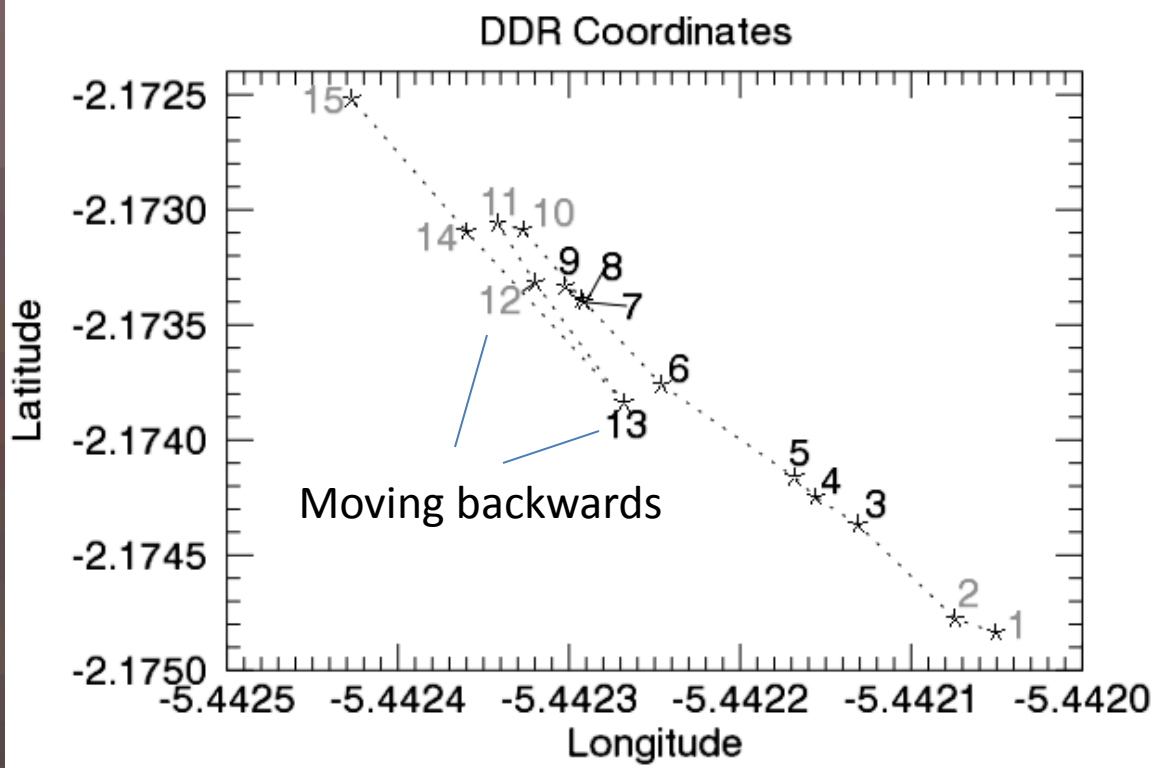


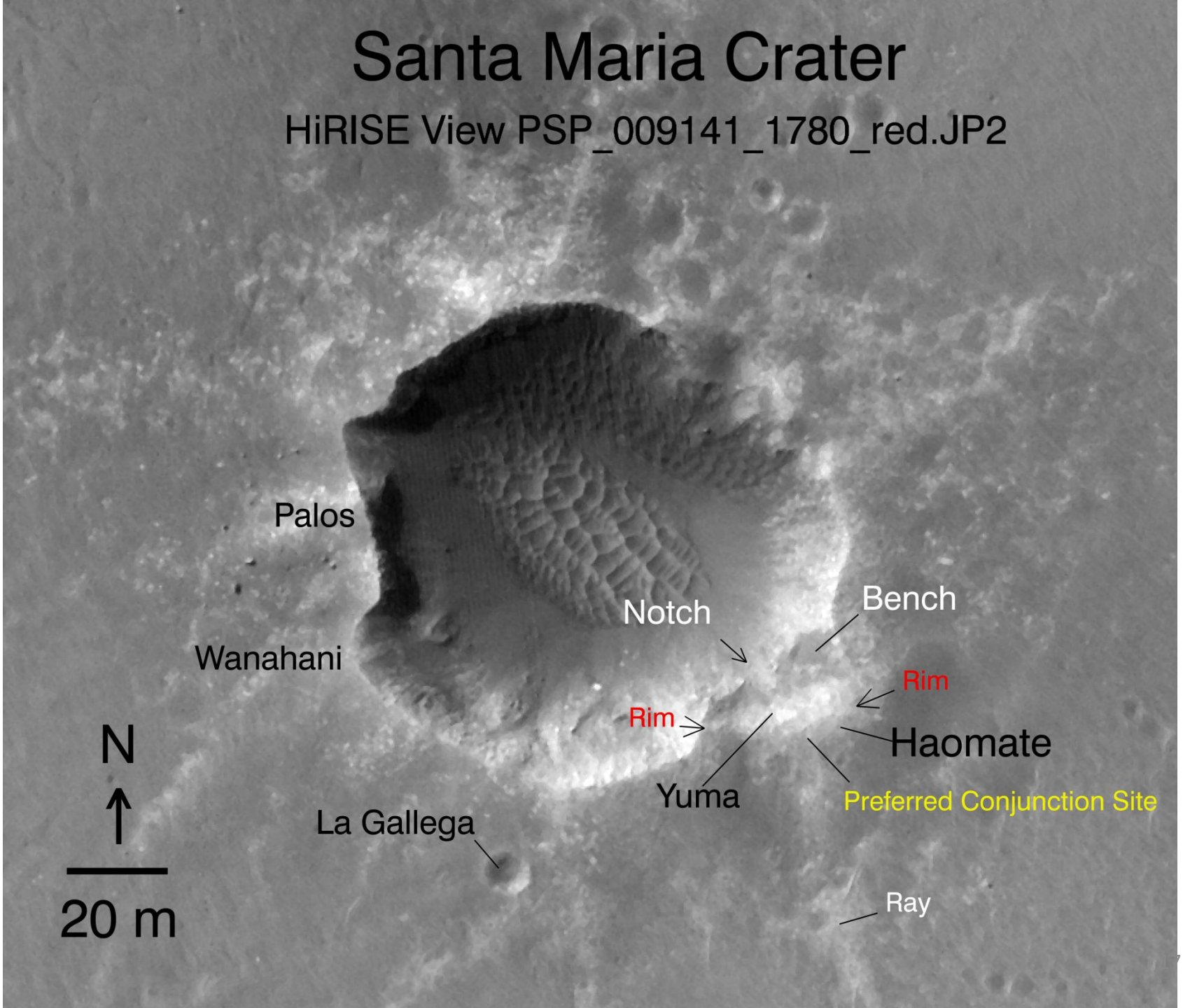
FRT001B8A4 oversampling



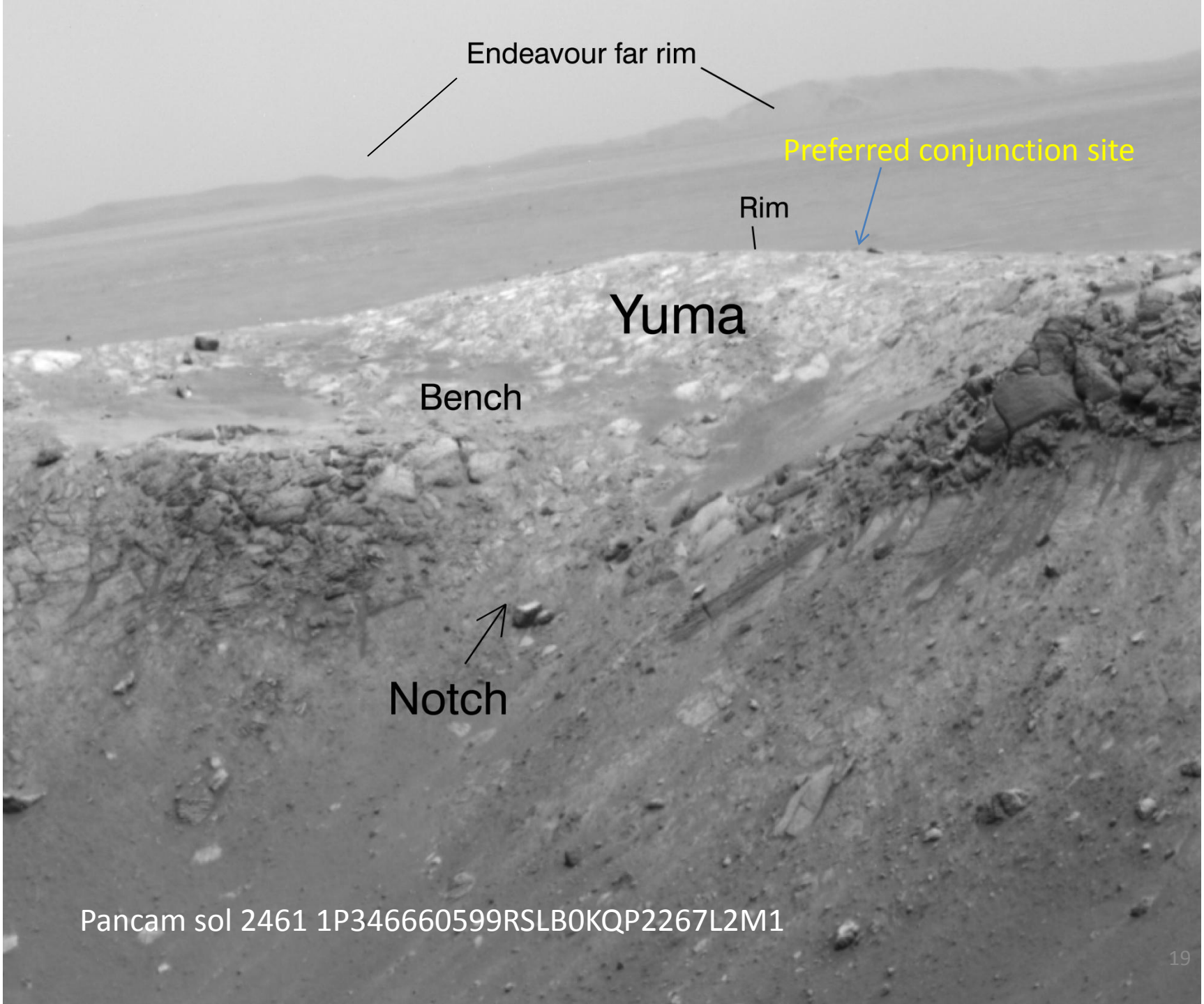
FRT001B8A4 oversampling





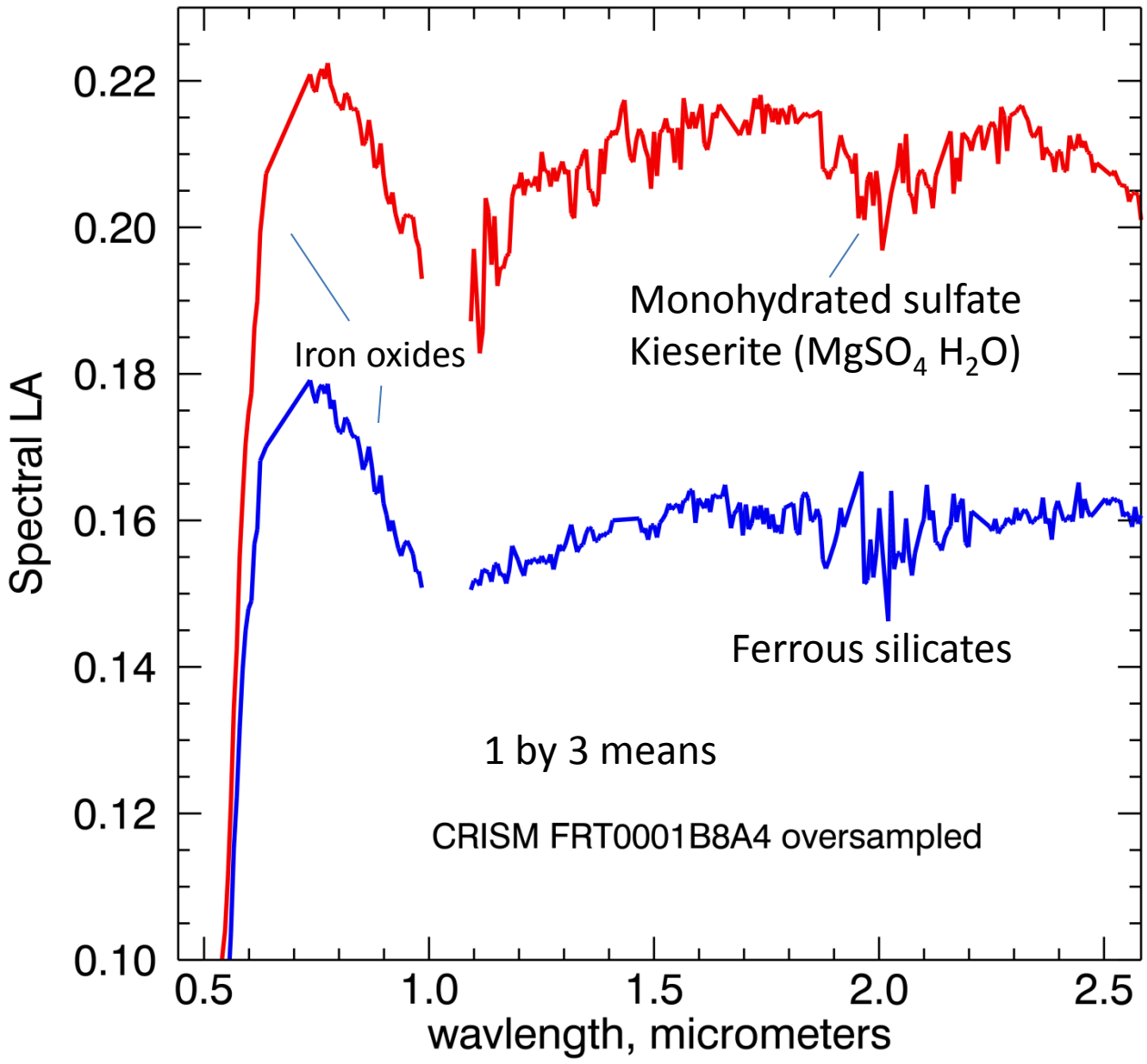

Santa Maria Crater
HiRISE View PSP_009141_1780_red.JP2
Palos
Wanahani
Notch
Bench
Rim
Rim
Haomate
Yuma
Preferred Conjunction Site
La Gallega
Ray
N
20 m

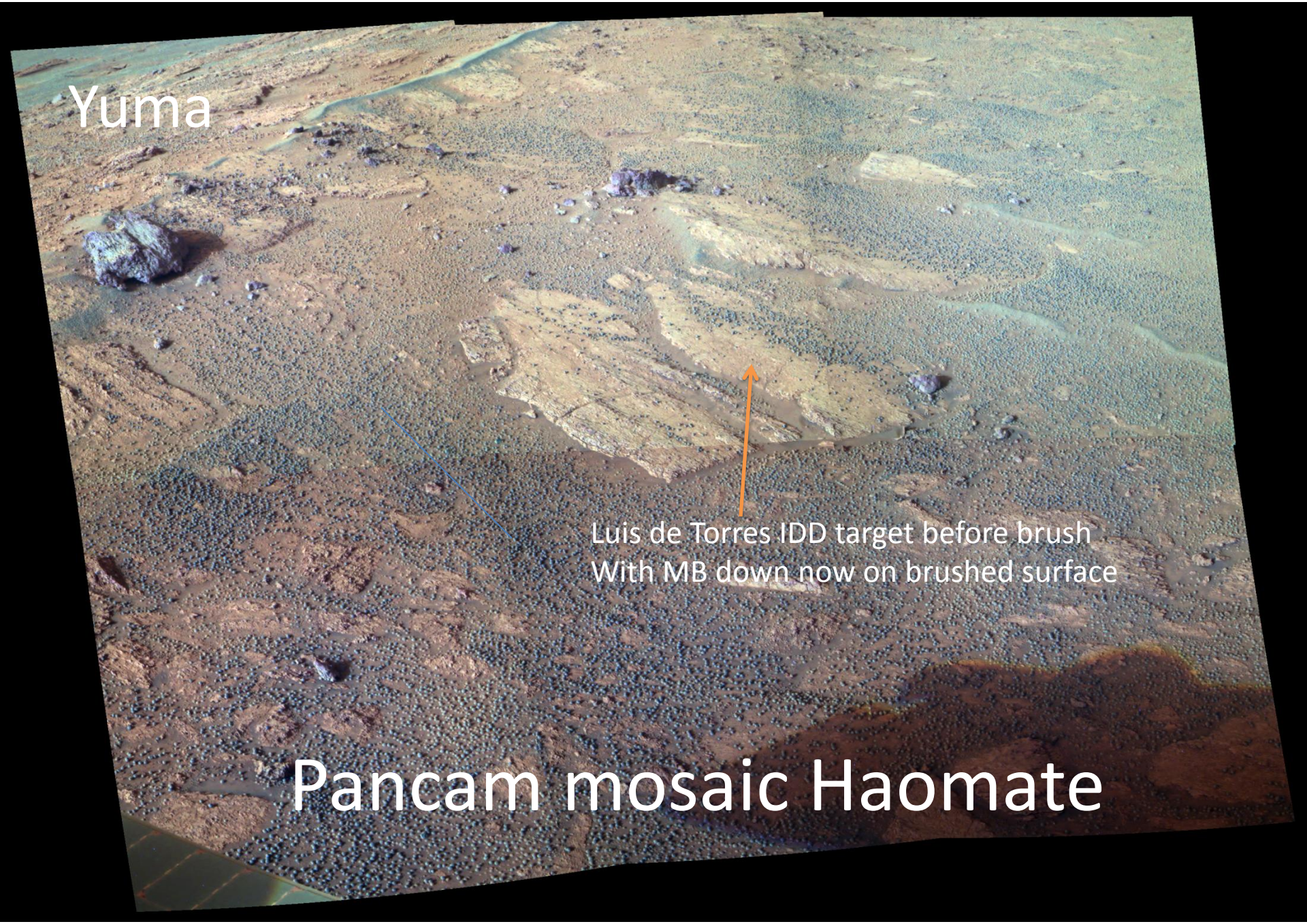

CRISM FRT0001B8A4 over CTX Santa Maria crater
RGB 0.7097, 0.5989, 0.5337 micrometers
S datashow
interesting color properties for
same location that L data indicate
hydrated sulfate is exposed in
5 to 6 pixels aligned NS
Ray
Preferred solar conjunction site
Rim near Yuma
Data processing courtesy
Abby Fraeman, WUSTL

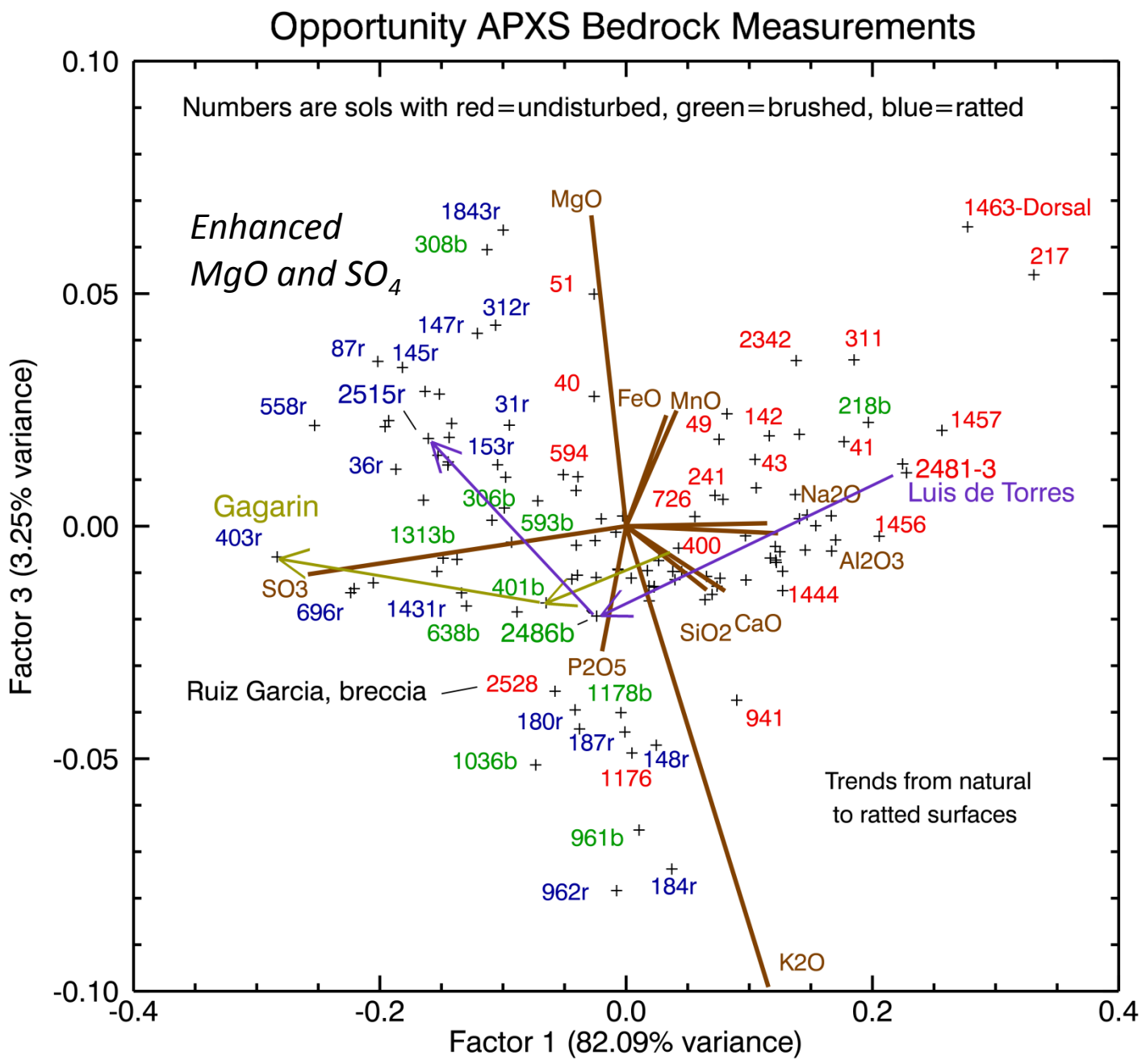


Pancam sol 2461 1P346660599RSLB0KQP2267L2M1

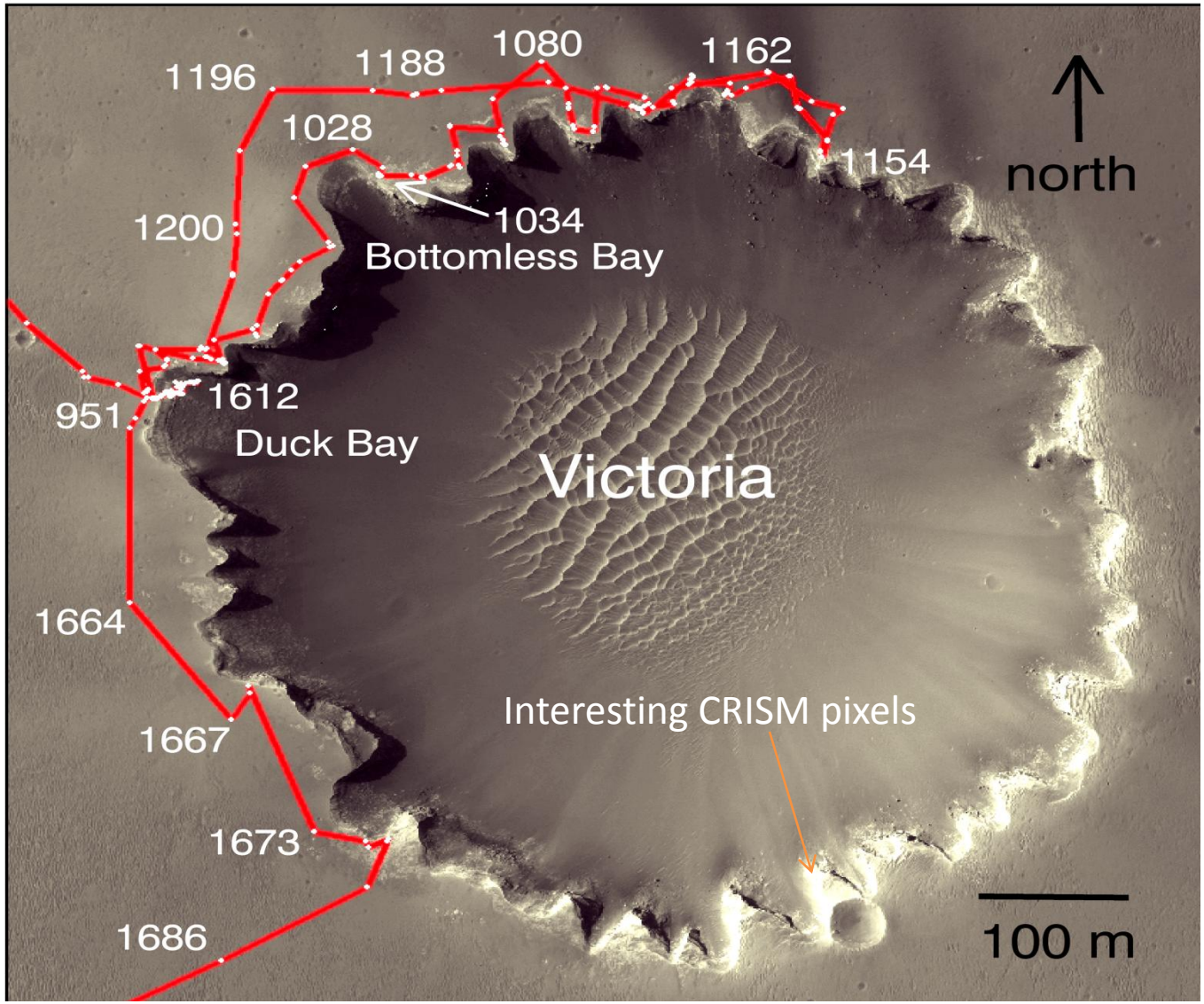
Santa Maria red=Yuma and Haomate, blue=floor

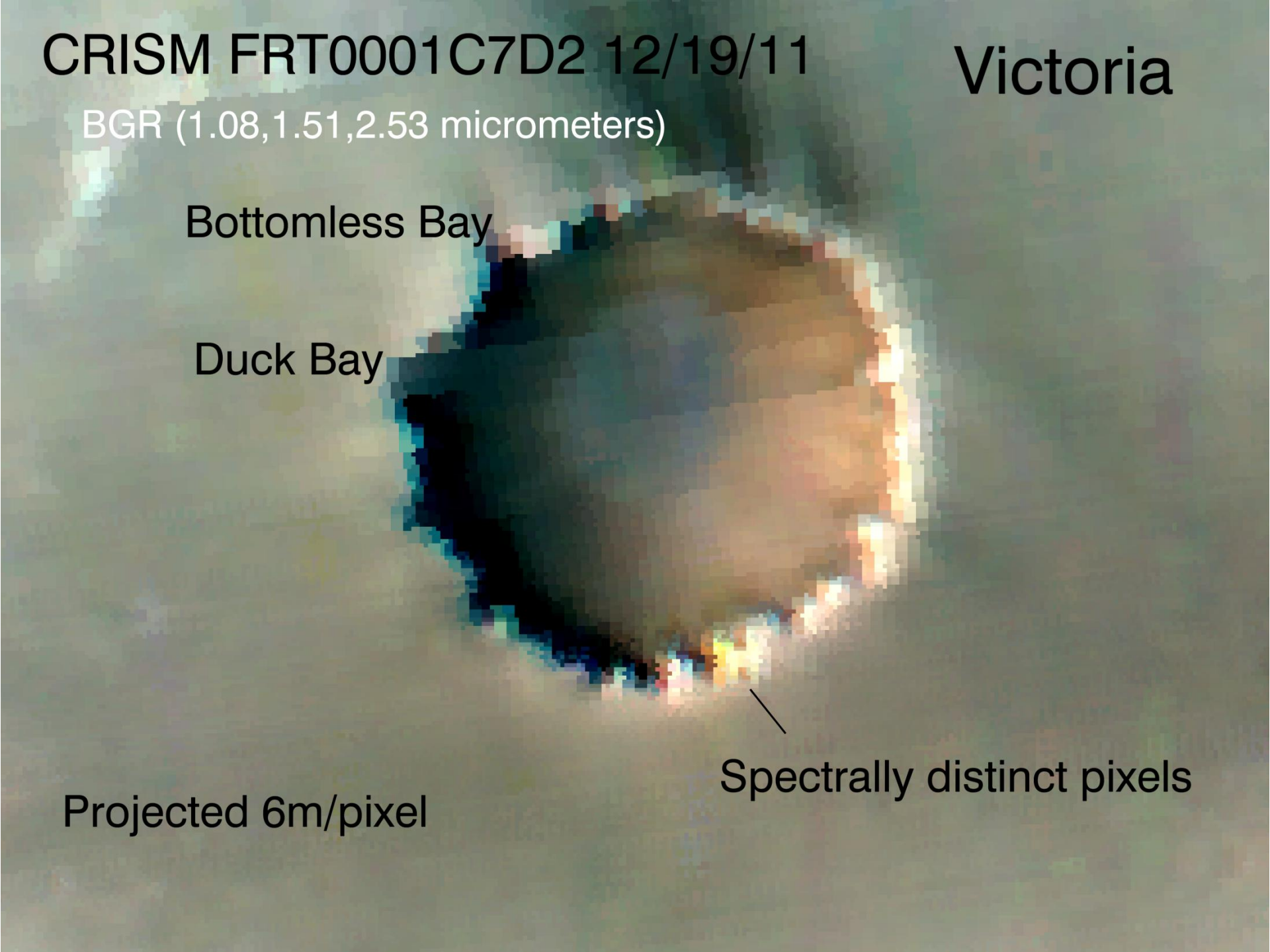


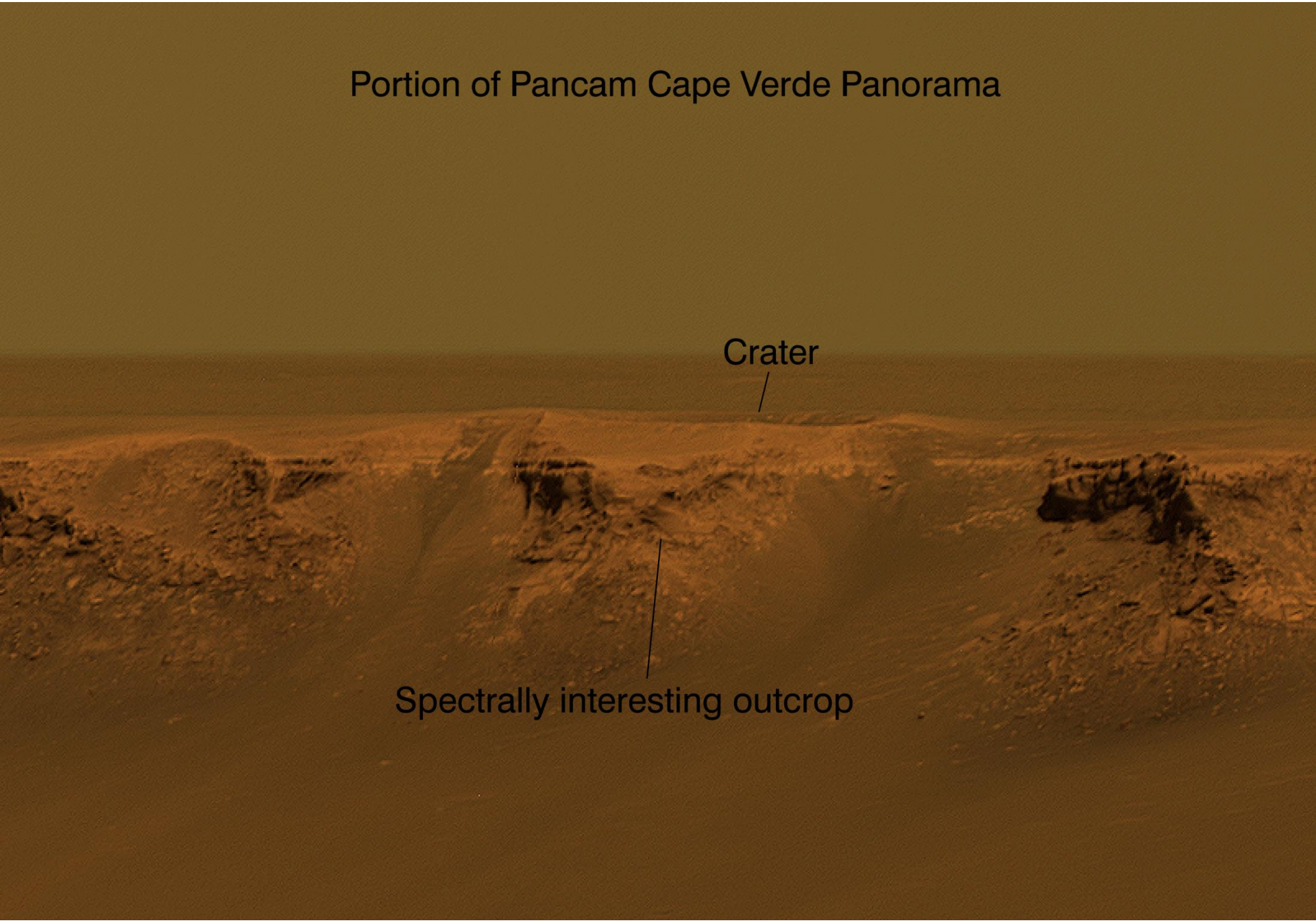

Yuma
Luis de Torres IDD target before brush
With MB down now on brushed surface
Pancam mosaic Haomate

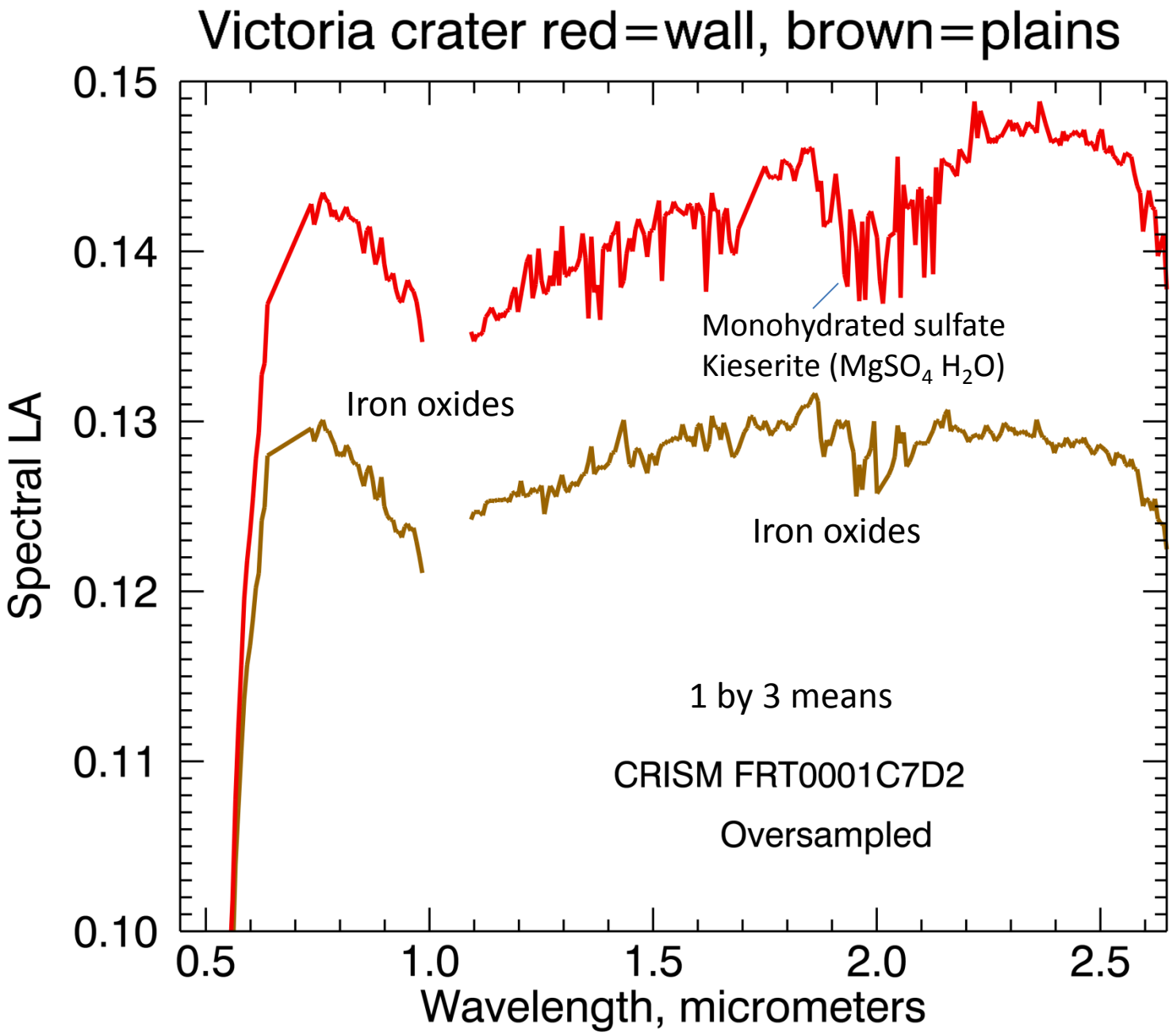

Opportunity APXS Bedrock Measurements
Numbers are sols with red=undisturbed, green=brushed, blue=ratted
Enhanced
MgO and SO4
Factor 3 (3.25% variance)
Factor 1 (82.09% variance)
0.10
0.05
0.00
-0.05
-0.10
-0.4
-0.2
0.0
0.2
0.4
MgO
FeO
MnO
SiO2
CaO
Na2O
Al2O3
P2O5
K2O
SO3
Gagarin
Luis de Torres
Ruiz Garcia, breccia
Trends from natural
to ratted surfaces
1843r
308b
51
312r
147r
87r
145r
2515r
558r
31r
153r
36r
40
49
142
2342
311
218b
1457
41
43
2481-3
241
726
306b
593b
1313b
403r
696r
1431r
638b
2486b
401b
400
1456
1444
2528
1178b
180r
187r
148r
1176
1036b
941
961b
962r
184r
1463-Dorsal
217
594

HiRISE ESP_016644_1780_red.jp2




CRISM FRT0001C7D2 12/19/11
Victoria
BGR (1.08,1.51,2.53 micrometers)
Bottomless Bay
Duck Bay
Spectrally distinct pixels
Projected 6m/pixel

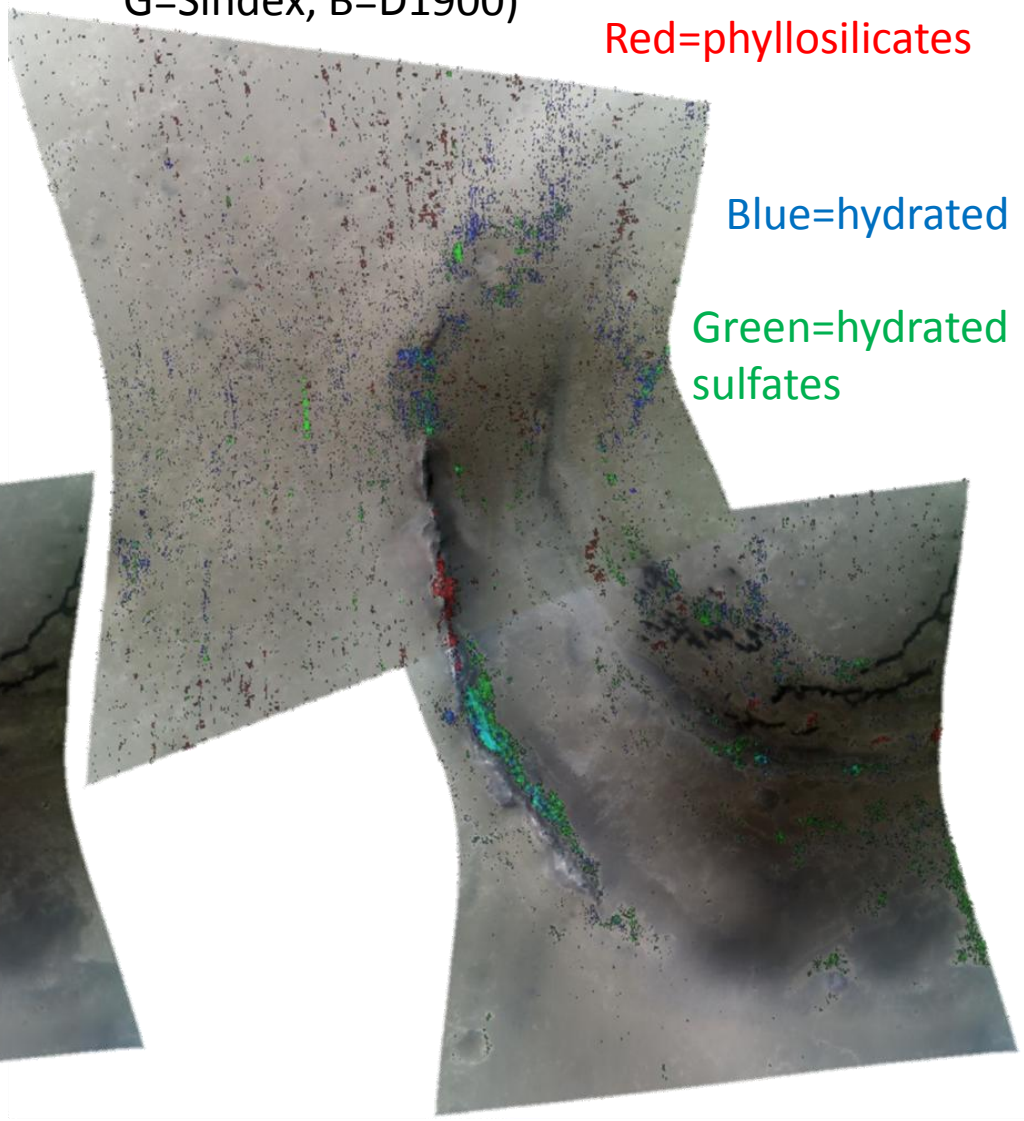

Portion of Pancam Cape Verde Panorama
Crater
Spectrally interesting outcrop


Victoria crater red=wall, brown=plains
0.15
0.14
0.13
0.12
0.11
0.10
Spectral LA
0.5
1.0
1.5
2.0
2.5
Wavelength, micrometers
Monohydrated sulfate
Kieserite ($MgSO_4$ H_2O)
Iron oxides
Iron oxides
1 by 3 means
CRISM FRT0001C7D2
Oversampled

Previous Results:

False color composite:
R = 2.3, G = 1.5, B = 1.08 µm

Parameter maps overlain (R=D2300, G=Sindex, B=D1900)



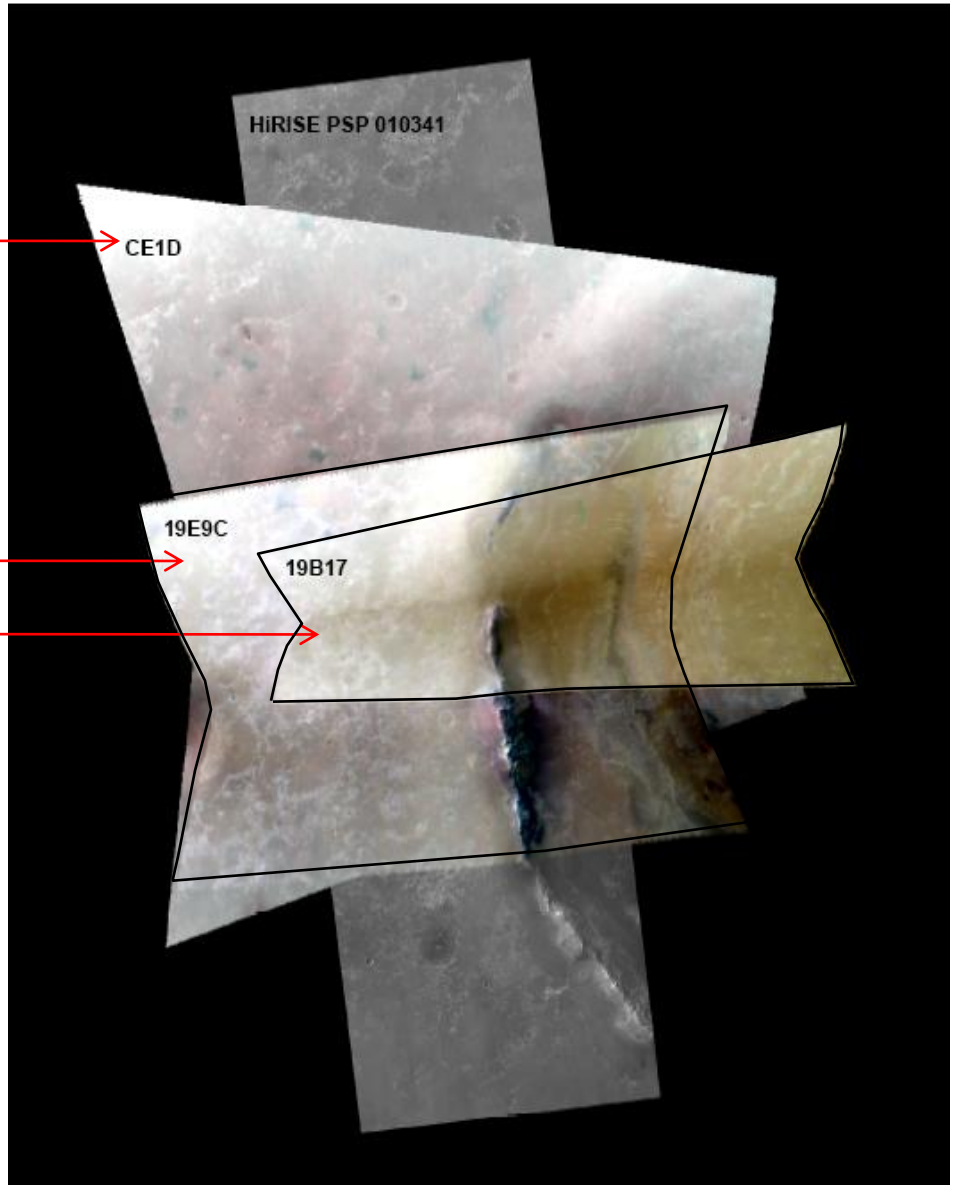
Red=phyllosilicates

Blue=hydrated

Green=hydrated sulfates

Similar to results of
Wray et al. 2009 GRL 36 L21201

ATO Observations Over Endeavour's Rim



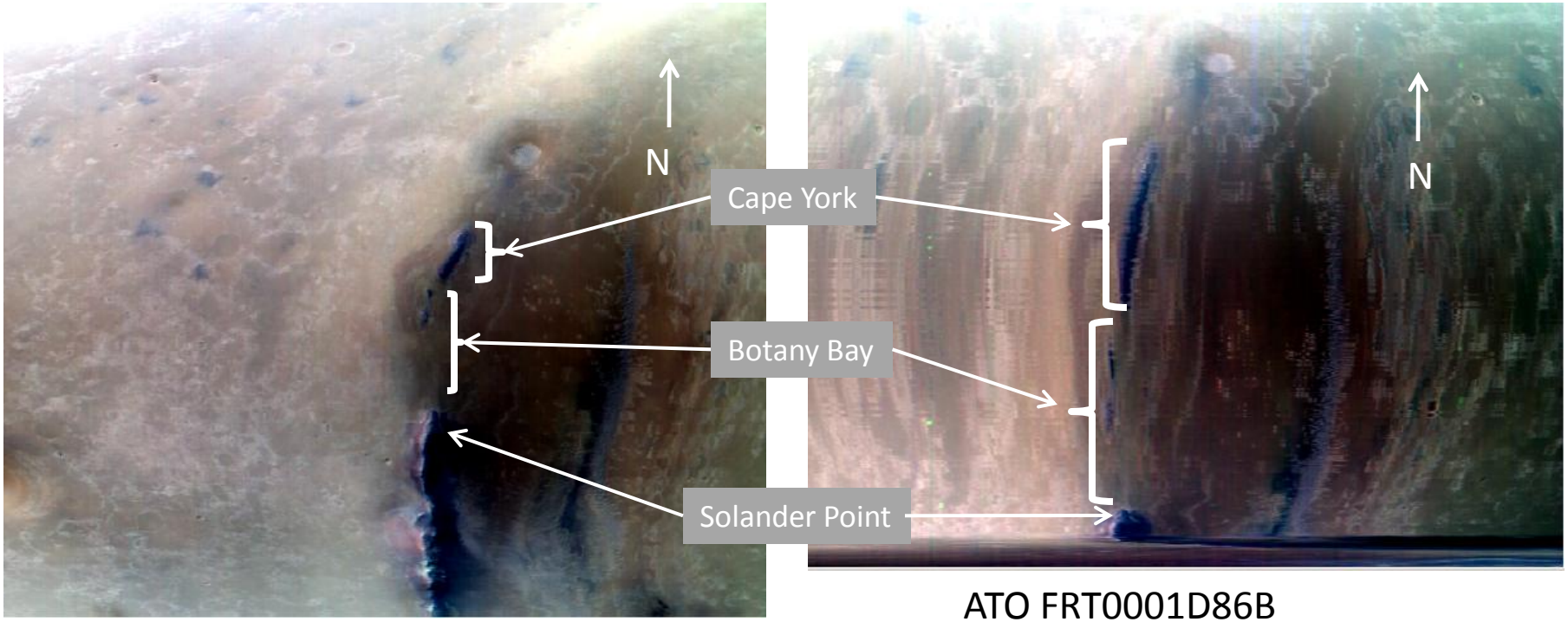
Original →

ATO →

1st ATO Test →

ATO Observations are shorter in the along-track direction due to overlap of pixels

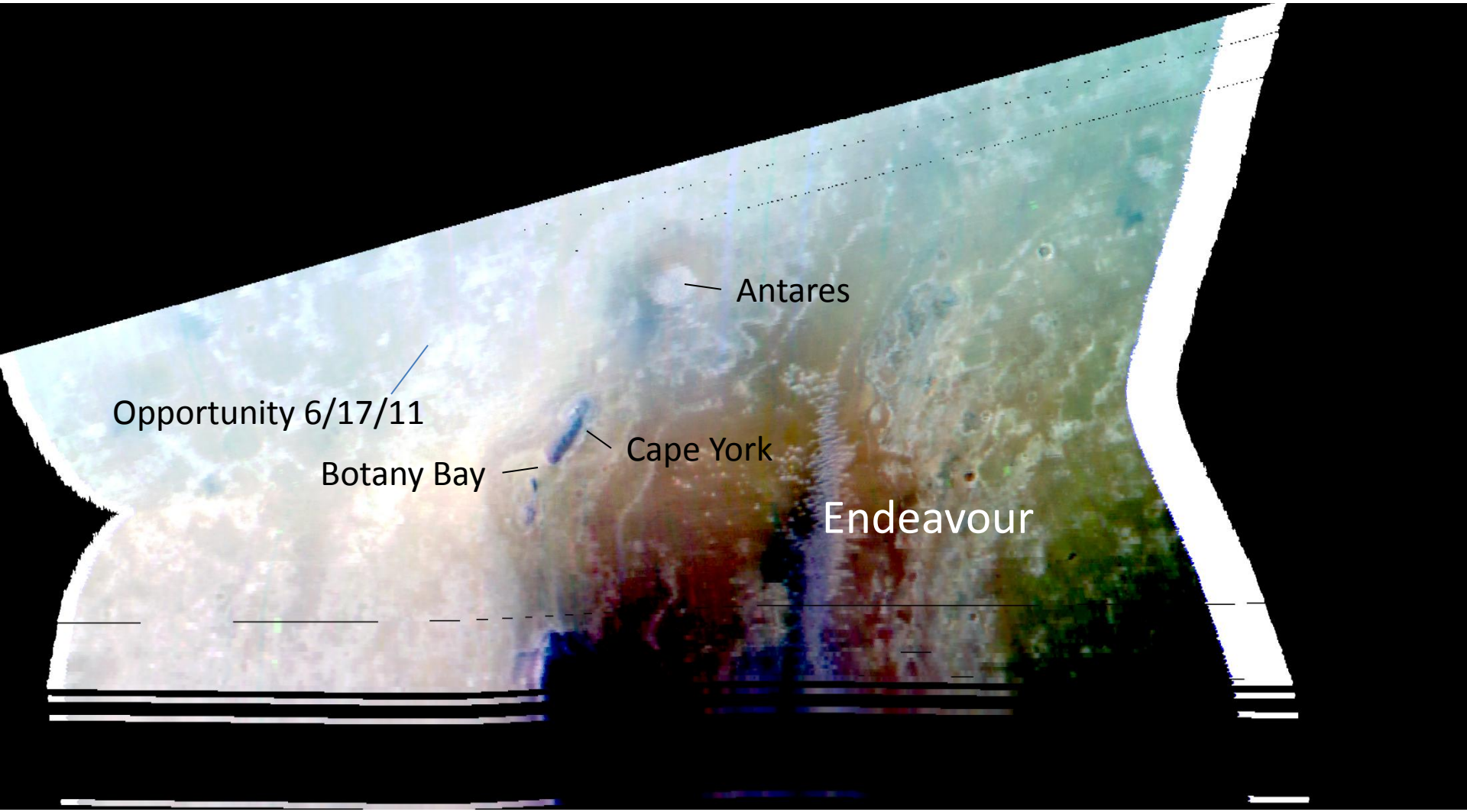
CRISM ATO Image Centered Over Cape York

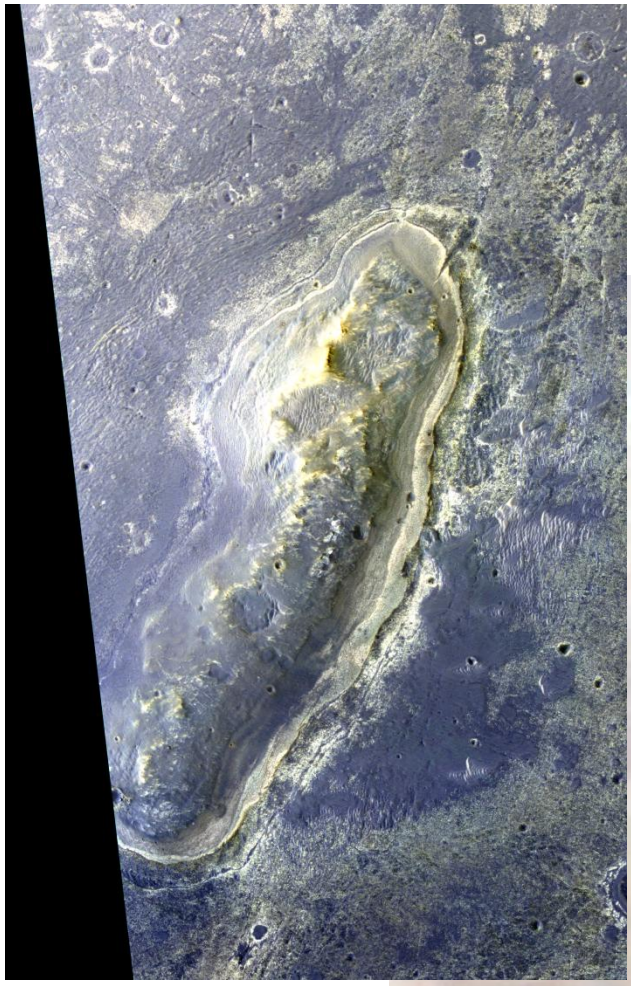


Normal FRT000CE1D

ATO FRT0001D86B

CRISM ATO FRT0001D86B False Color IR Using 3, 6, 12 m/pixel



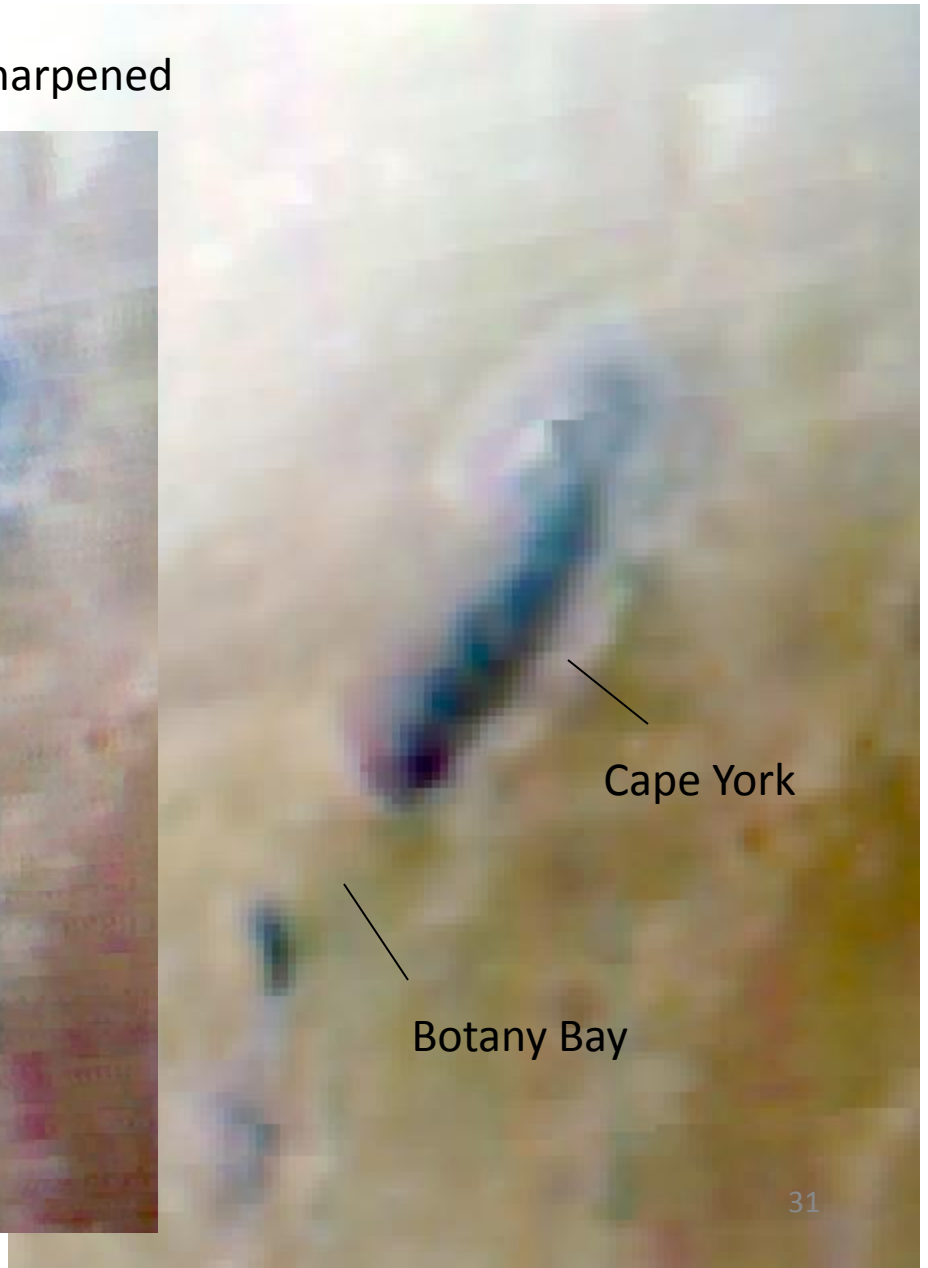


HiRISE color
ESP_021892_1775

CRISM ATO FRT0001D86B

12 m/pixel projection

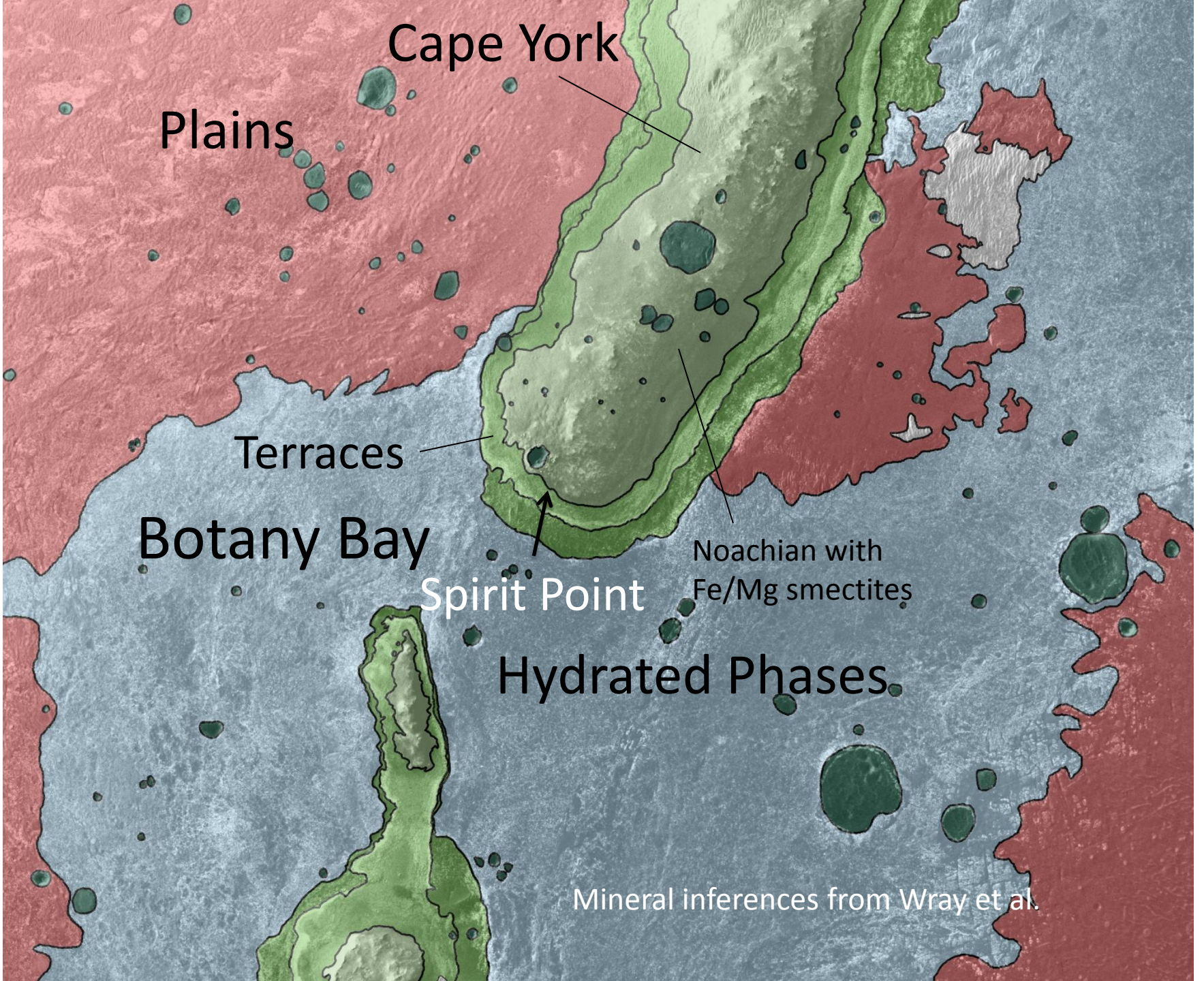
3,6,12 m/pixel sharpened

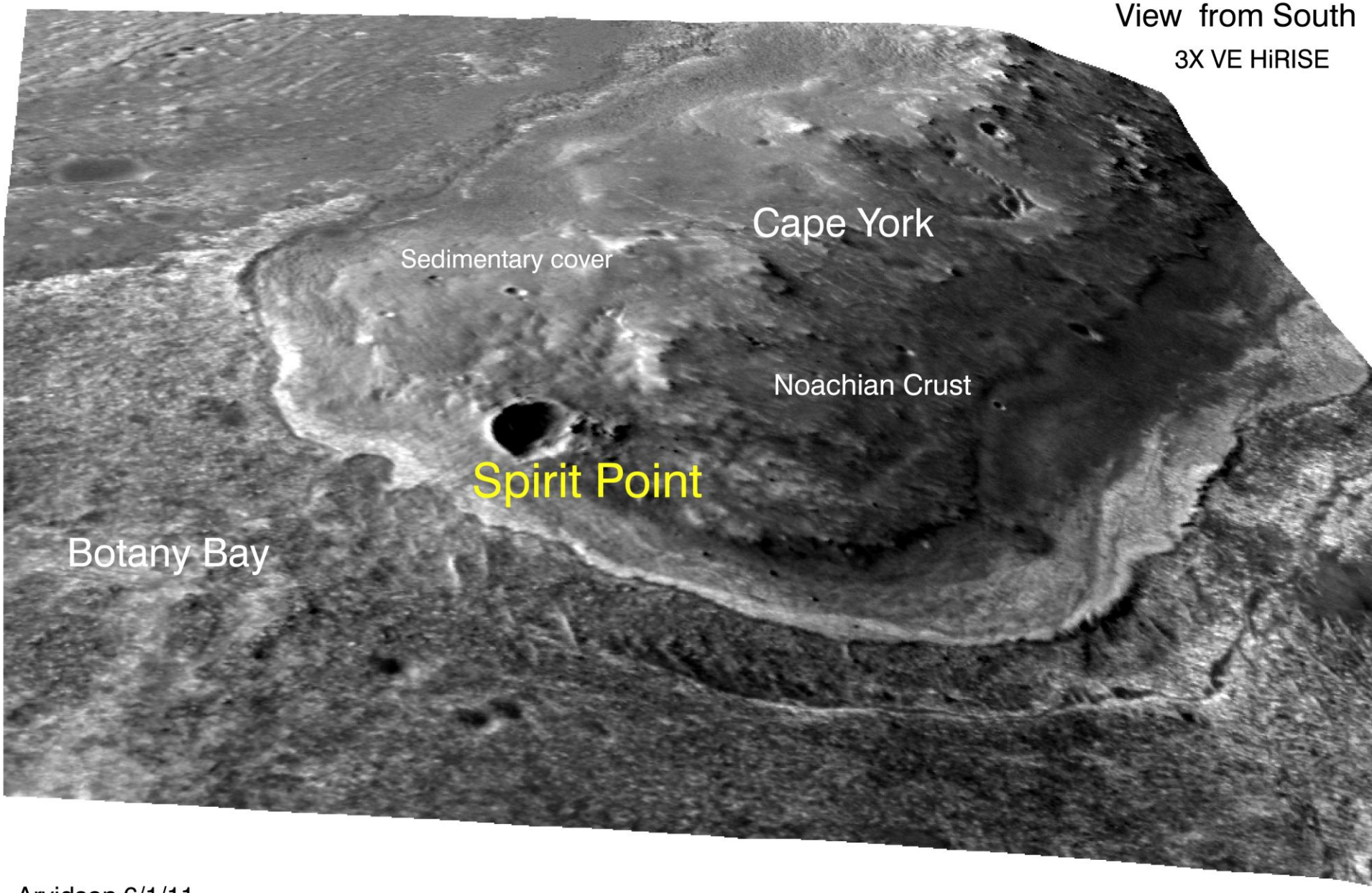


Surface Spectral Reflectance Retrievals

- ATO FRT0001B8A4 spectral retrievals require:
  - Understanding of trade-off between sharpened pixel size and decrease in S/N of retrieved spectra
  - High fidelity radiative modeling of the atmosphere and surface
  - Validation using ability to model sharp CO_2 bands
  - Parameter mapping and mineral inferences

WORK IN PROGRESS


Cape York
Plains
Terraces
Botany Bay
Spirit Point
Noachian with
Fe/Mg smectites
Hydrated Phases
Mineral inferences from Wray et al.



Arvidson 6/1/11

HiRISE image and associated DEM with OSU processing