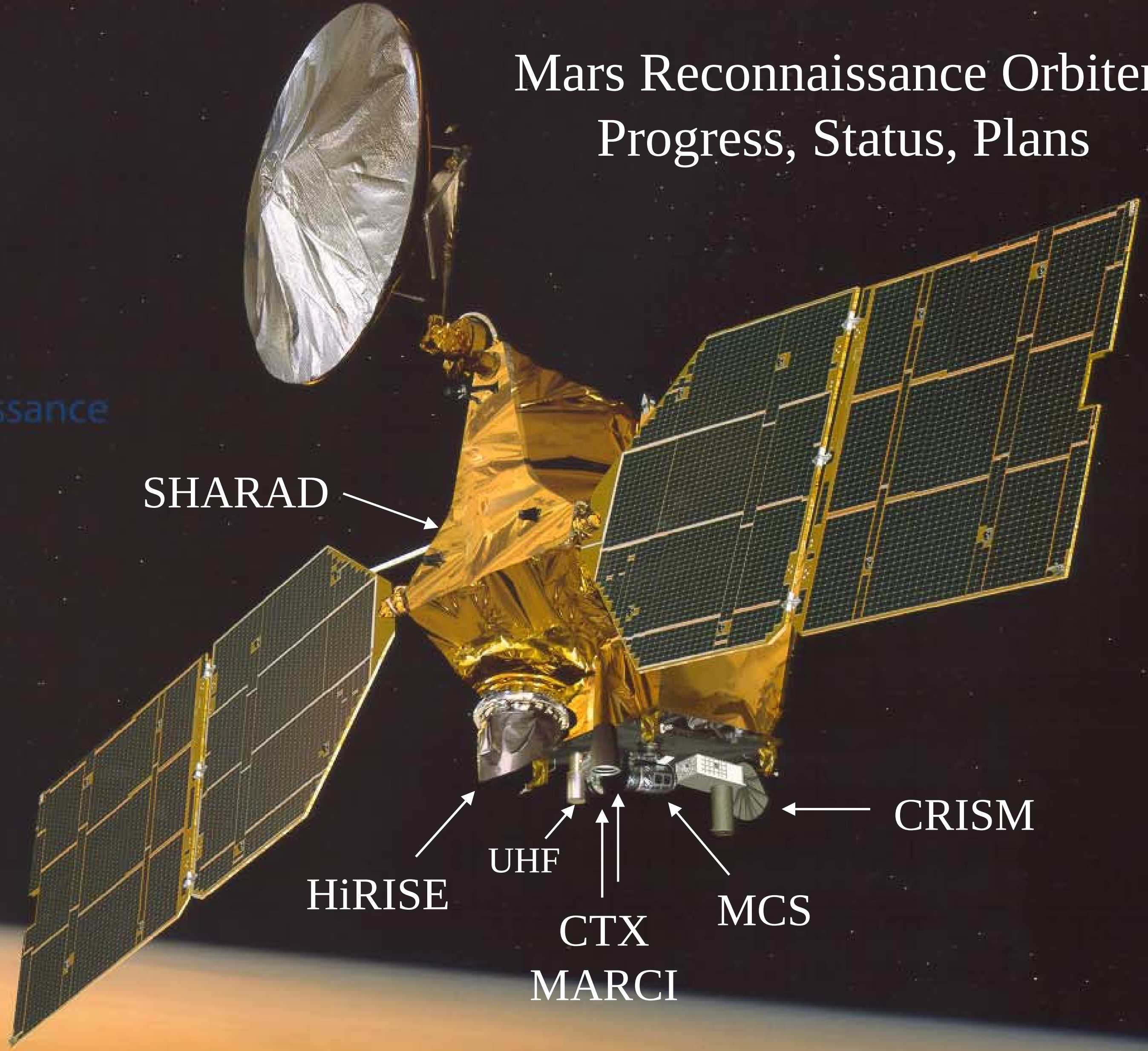
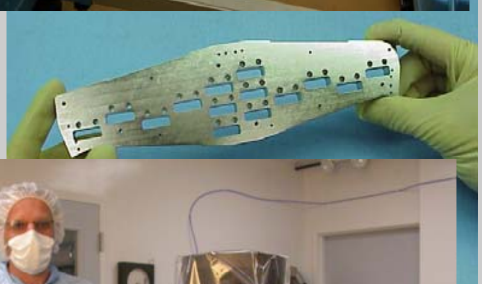
Mars Reconnaissance Orbiter: Progress, Status, Plans



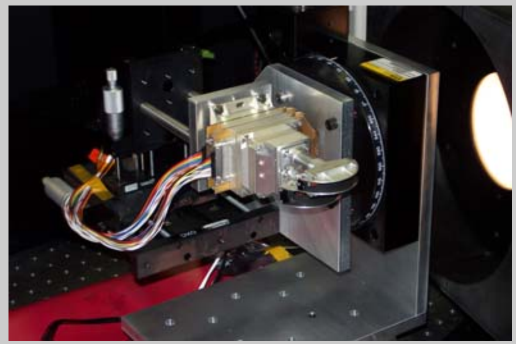
Presented by:
J. Plaut, S. Smrekar
R. Zurek
on behalf of the
MRO Team

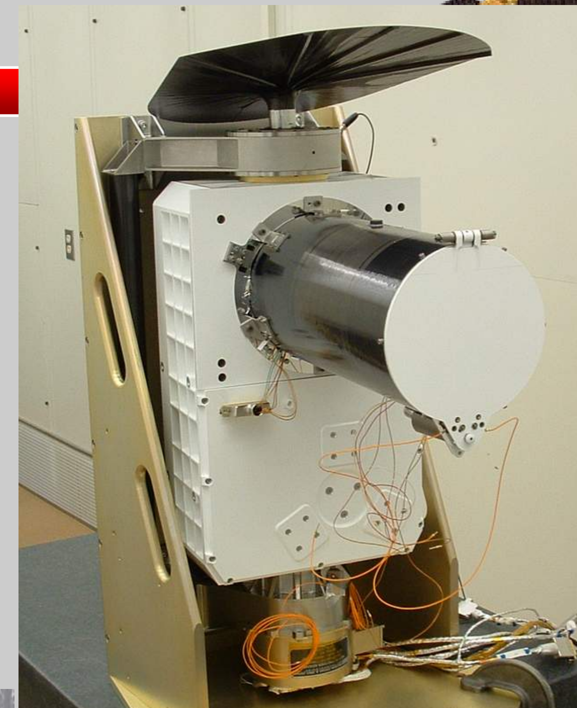
MRO Science Instruments

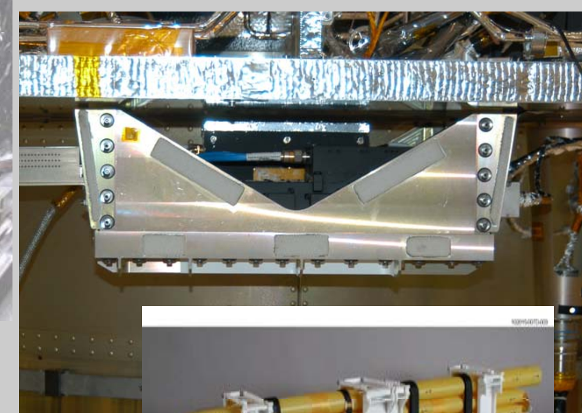


HiRISE ***CRISM***

MARCI







MCS

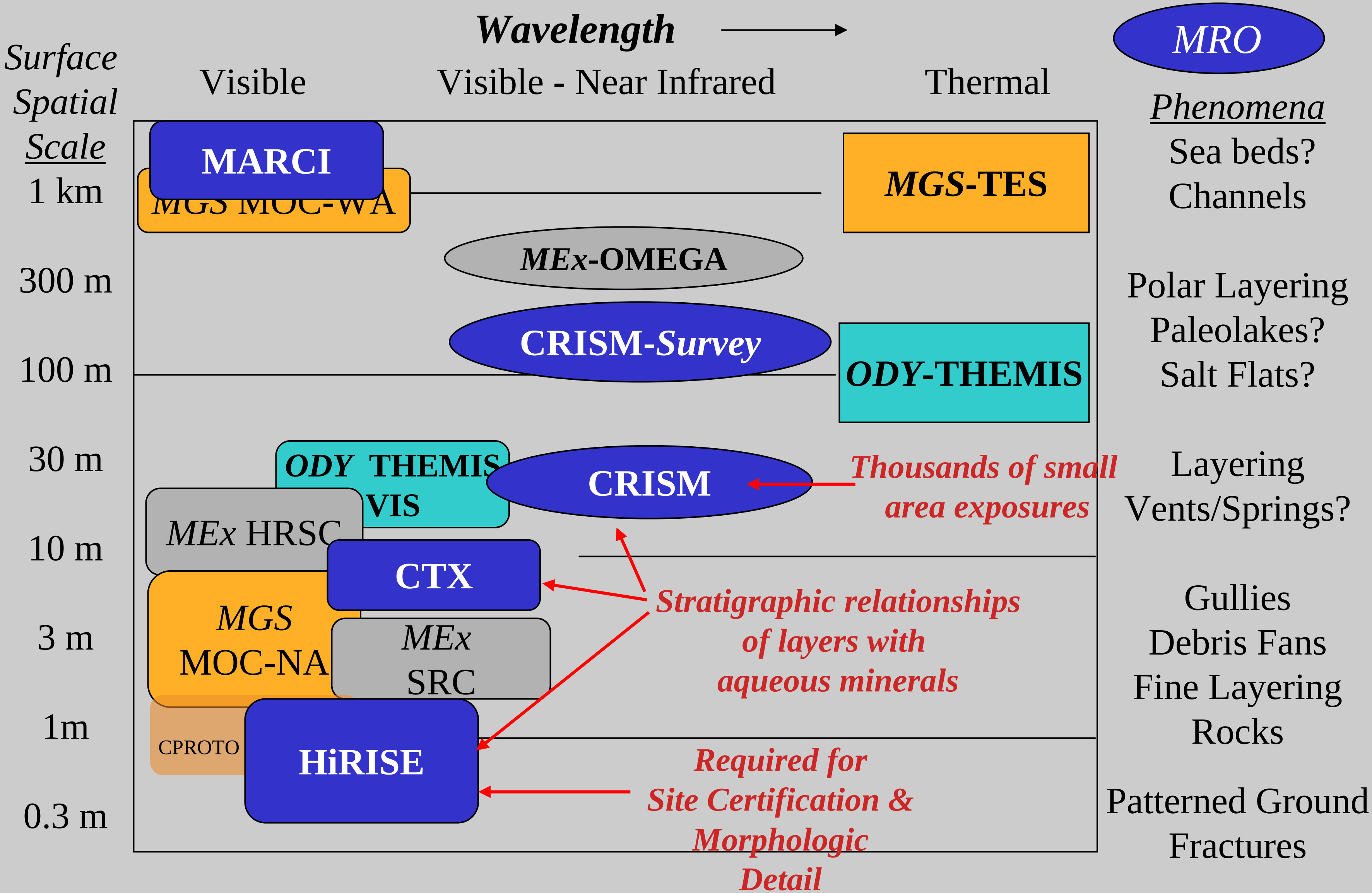
CTX

SHARAD

MRO/JPL/NASA

MRO Builds on Earlier Missions

Mars Reconnaissance Orbiter



Coordinated Observing

<u>Example: Nili Fossae</u>

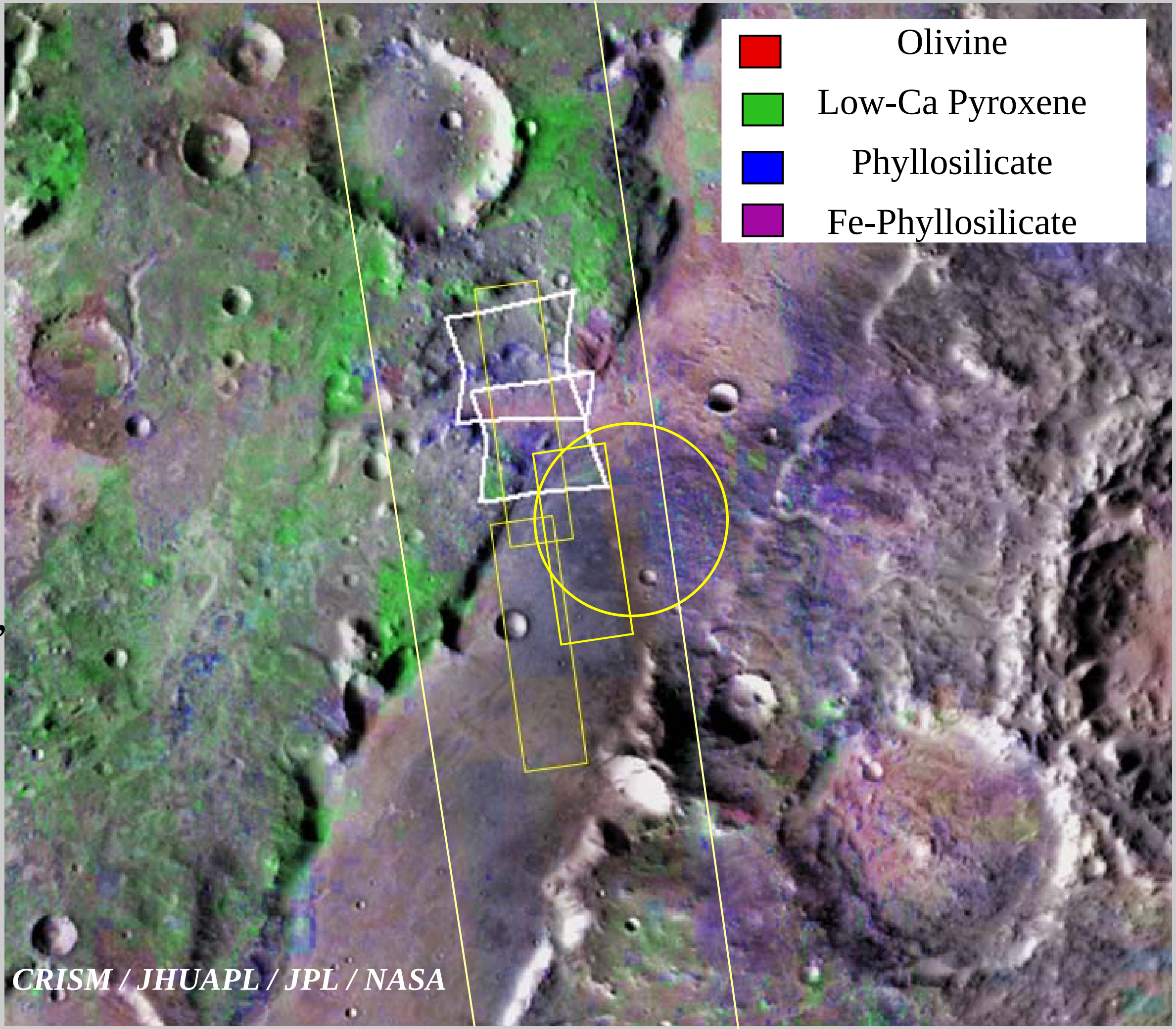
Background: CRISM/ OMEGA survey data indicating mineralogy

CTX: Wide track (30 km)

HiRISE: Yellow rectangles (6 km width)

CRISM: White "butterfly" patterns

MSL Landing Ellipse: 20-km diameter circle (yellow)



MRO Science Metrics: PSP + ESP Plans

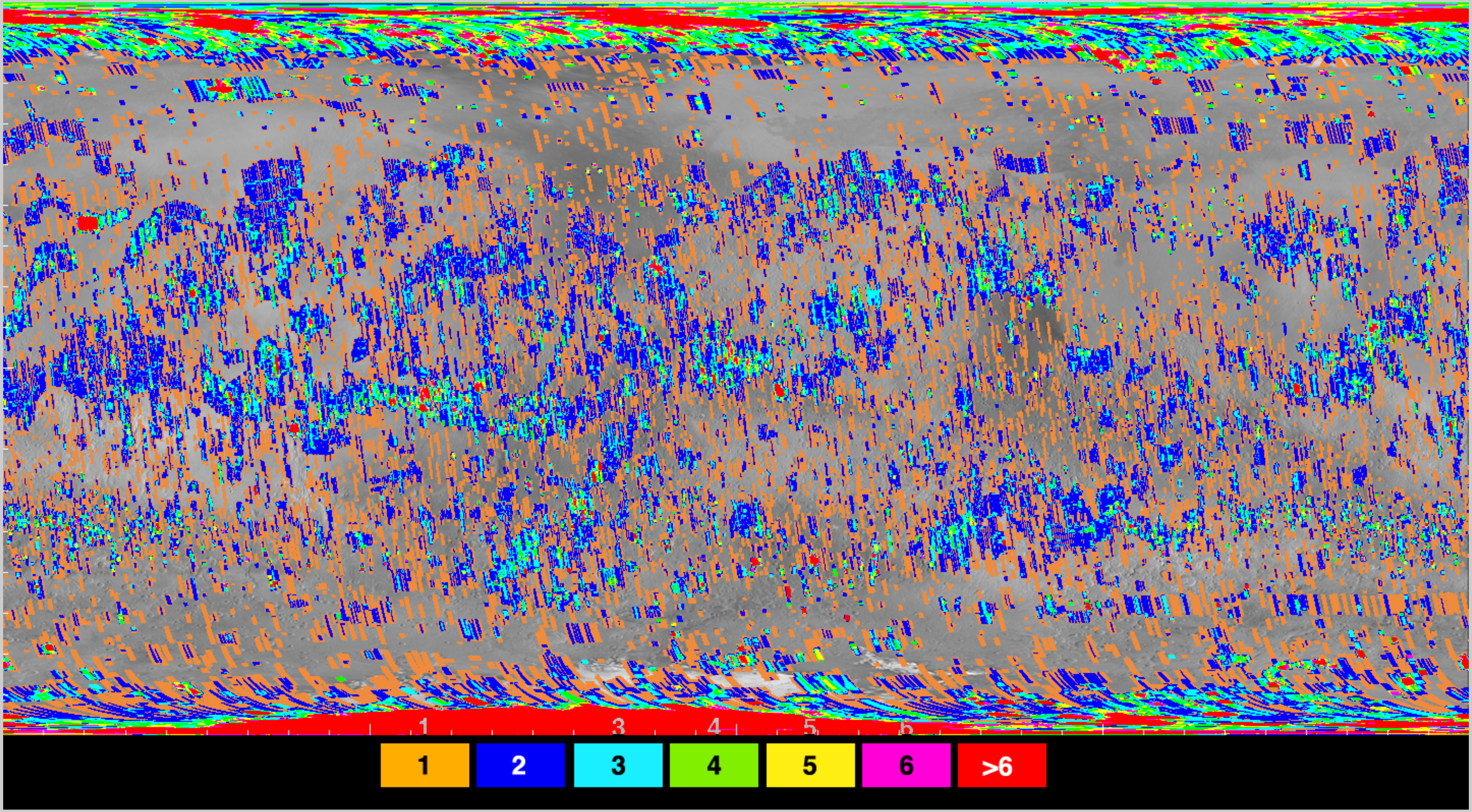
Investigation	Science Measurement Goals	Progress thru end of PSP	By end of ESP
HiRISE	Targeted high resolution imaging of high-priority locales, typically at 25-30 cm/pixel resolution and with a central color stripe; Stereo for digital terrain mapping (DTMs)	~ 0.6 % of Mars; ~ 964 stereo pairs; ~ 9,550 images	~ 1%; ~ 1500 stereo; ~ 15,000 images
CRISM	Multi-spectral regional survey coverage followed up by high-resolution hyperspectral (h/s: ~18 m/pixel in up to 544 channels). Atmosphere surveys of the globe at 9° of L_S; Emission Phase Functions (EPFs)	~ 64% multi-spectral survey 9,514 h/s observations; 18,610 total observations; 1 Mars Year monitored	~ 80% m/s survey ~ 13,000 h/s obs. 2 Mars years of atmos. survey
CTX	Context Imaging at ~ 6 m/pixel over large regions; repeat coverage for surface change detection and stereo, including DTMs	18,020 images with ~ 38.5% unique coverage (~8% repeat coverage)	~60% regional coverage
SHARAD	Subsurface radar profiling of high-priority areas, especially polar caps and mid-latitude ice deposits	~45% of Mars sampled via 5,100 observing strips	~70% regional sampling
MARCI	Daily monitoring of atmospheric state, dust events (DE) & surface; daily global maps	1 Full Mars year,global DE; 9,670 MARCI images;	2 Mars years
MCS	Daily, globally distributed MCS vertical soundings from ~ 0-80 km with ~5 km resolution	1 Full Mars year, with GDE >30 x10^6 MCS soundings	2 Mars years
Gravity:	Increase in resolution of the Mars gravity field; improved estimates of (seasonal) polar cap mass	~35% increase in gravity field resolution	Seasonal mass variation
Accelerometer	Derived density profiles from ~105 to 170 km on ingress and egress from each of ~450 periapses spanning southern hemisphere latitudes	Data taken during Aero-braking phase; archived during PSP	Completed
Science Data Return	26 Terabits (full mission success) returned October 9, 2007	~73.4 Tb	~120 Tb

MRO Metrics: Status (3/2010)

- **Science Data Volume Returned: 105 Terabits**
  - Compressed and not counting headers
  - 73.4 Tb (PSP) + 31.6 Tb (ESP) [March 23, 2010]
- **Capability enables extended coverage at highest ever spatial resolution for many observing modes, whether of the surface, subsurface or atmosphere**
  - 50% of Mars now covered at 6 m/pixel (panchromatic) [CTX]
  - ~0.9% of Mars imaged at 30 cm/pixel, including ~1300 stereo image pairs [HiRISE]
  - 66% of Mars covered in 72 bands for compositional mapping @ ~200 m/pixel [CRISM]
    - CRISM now using 262 bands when in survey mode
  - 6500 subsurface sounding segments [SHARAD]
  - > 1000 days of daily global maps [MARCI] and atmospheric sounding [MCS]
- **Orbiter Status**
  - 290 kg of fuel (120 kg reserved for MSL support) using ~15 kg/year
  - CRISM 2 (of 3) coolers working (for NIR); HiRISE focal plane stable
  - S/C suffered 4 safe mode entries in 2009; essentially single string in telecom

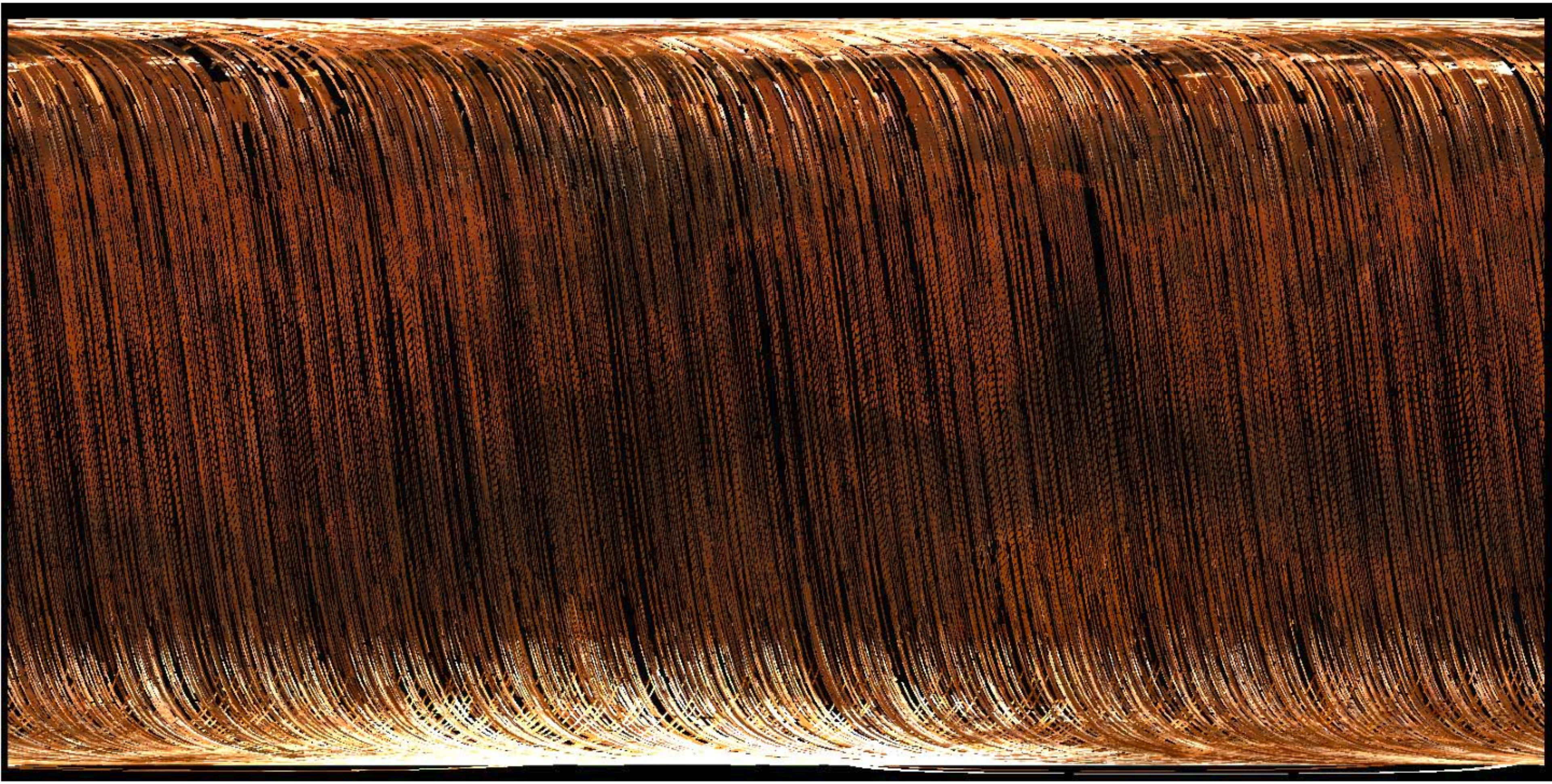
CTX Coverage Map as of 31 January 2010

Mars Reconnaissance Orbiter



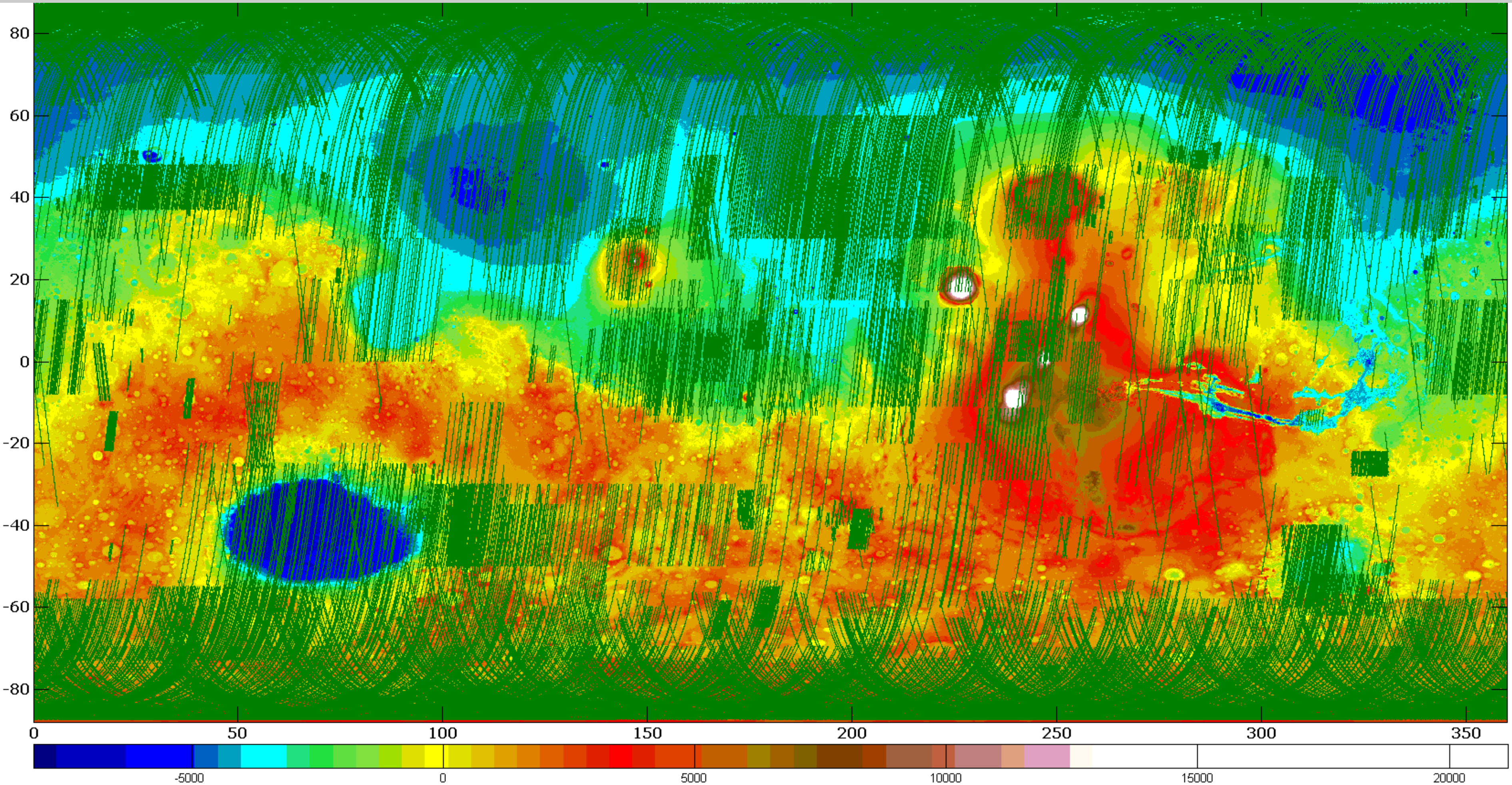
MRO/JPL/NASA

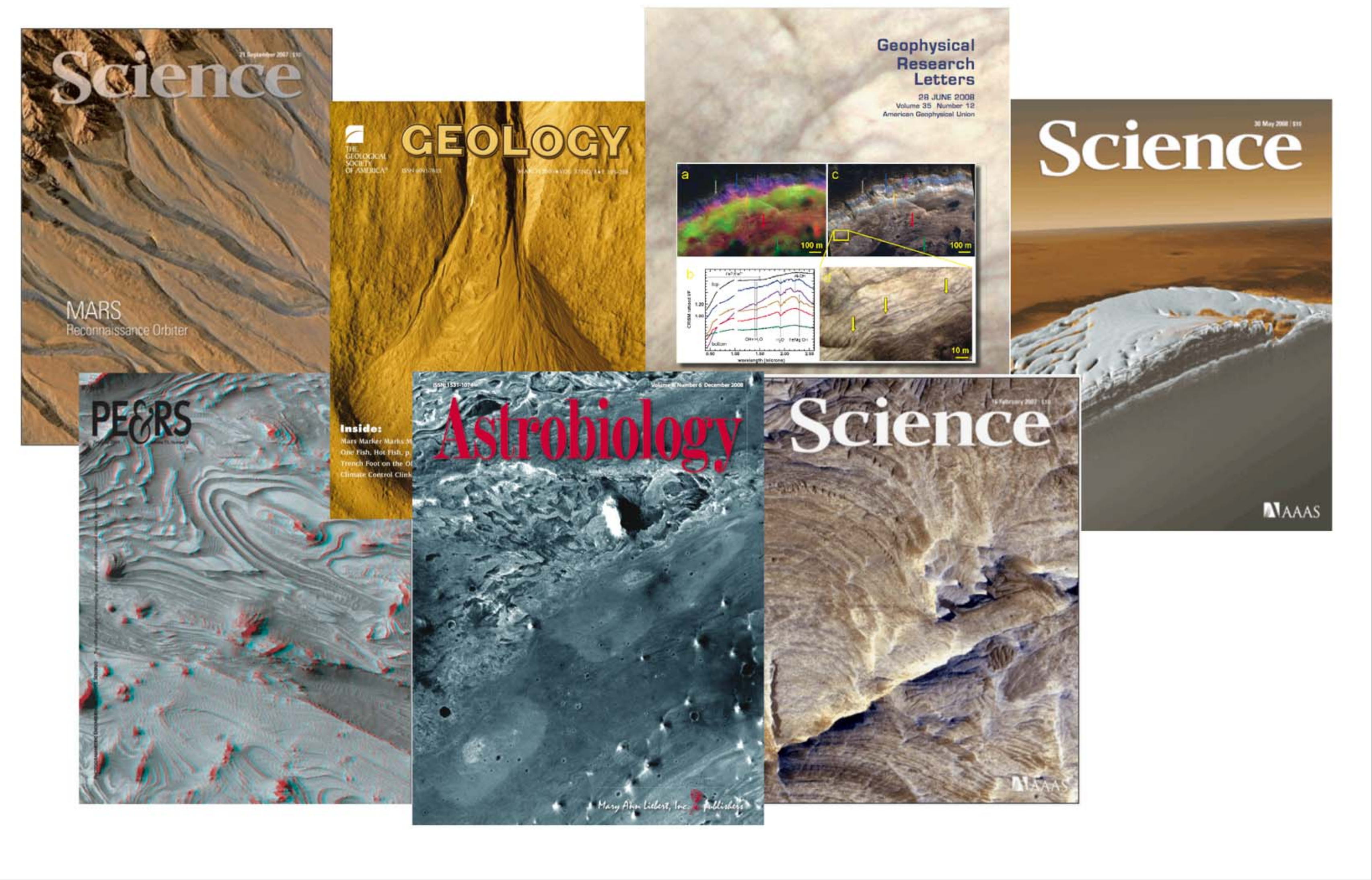
AL / SU MRDRs Delivered Thru Release 11



MRO SHARAD Track Locations

Mars Reconnaissance Orbiter




Science
MARS
Reconnaissance Orbiter
GEOLOGY
Inside:
Geophysical
Research
Letters
28 JUNE 2008
Volume 35 Number 12
American Geophysical Union
Science
AAAS
PE&RS
Astrobiology
Science

MRO PSP Science Highlights

Mars Reconnaissance Orbiter

Science Highlights: Surface Climate Change and Habitability

High resolution gravity data support impact hypothesis for crustal dichotomy

=> Role of early large-body impacts

Coordinated observations showing distinct layers with aqueous minerals

=> Episodic history of water action

Thousands of localized areas with aqueous minerals exposed in Noachian terrain

=> Regional & global processes involving water

Light-toned Hesperian-age hydrated silica deposits near Valles Marineris

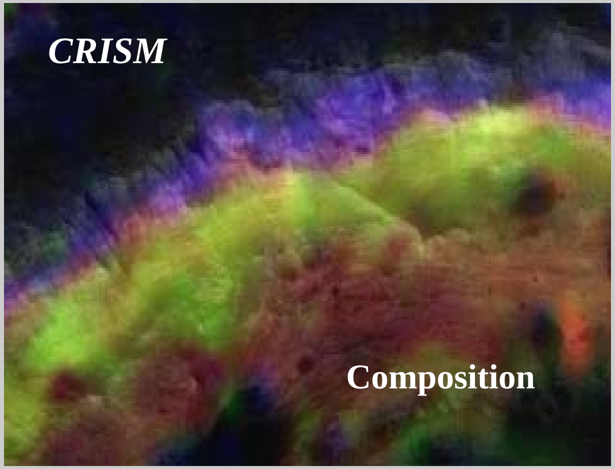
=> Extended period of water activity

Indurated fractures in sedimentary bedrock

=> Ground water action through much of Mars history

Localized carbonate deposits

=> Preservation potential for biosignatures



SHARAD

MRO PSP Science Highlights

Mars Reconnaissance Orbiter

Science Highlights: Recent and Present Climate

Systematic layering within north polar ice cap

=> *Physical record of obliquity cycles*

⇒ *Geologically very young N. polar cap*

Active polar margins, seasonal change & cap erosion

=> *Regional ice-gas transitions in Mars climate*

Highly structured atmosphere above regional topography (e.g., Hellas)

=> *Local circulations and their effect on trace gases*

Observations of a warm polar night

=> *More vigorous global (Hadley) circulations*

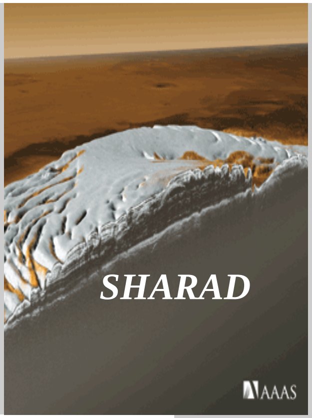
Extending the climate record

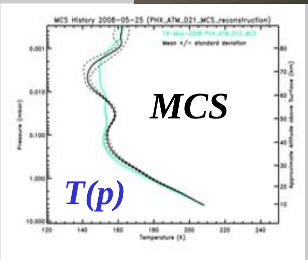
⇒ *Water vapor column measured for 4th Mars year*

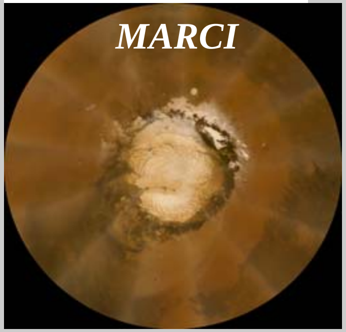
⇒ *First annual climatology of CO*

Detailed morphology of gullies and channels, some (not all) formed by water

=> *Geologically recent water activity*

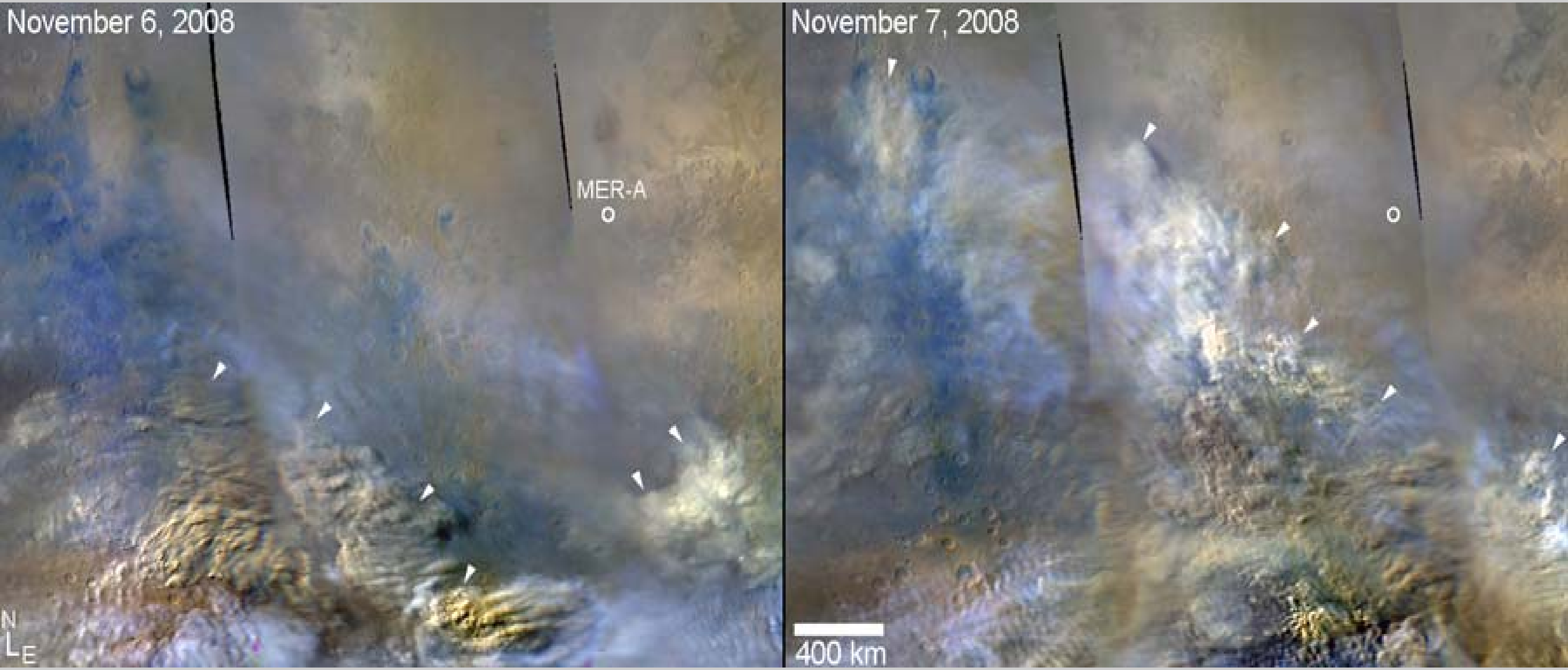






Dust Storm Activity Near Spirit (MER-A) Site

November 2008



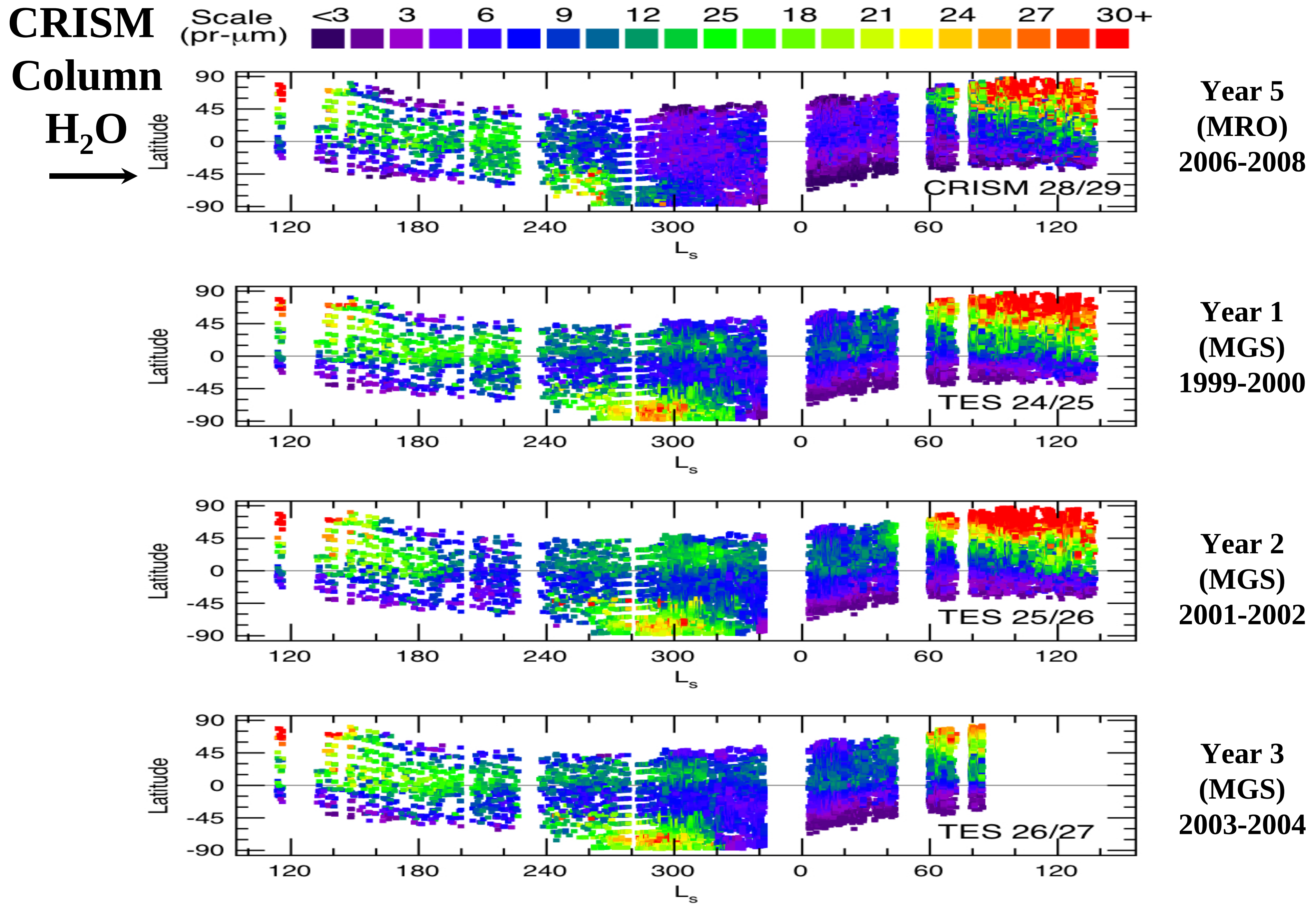
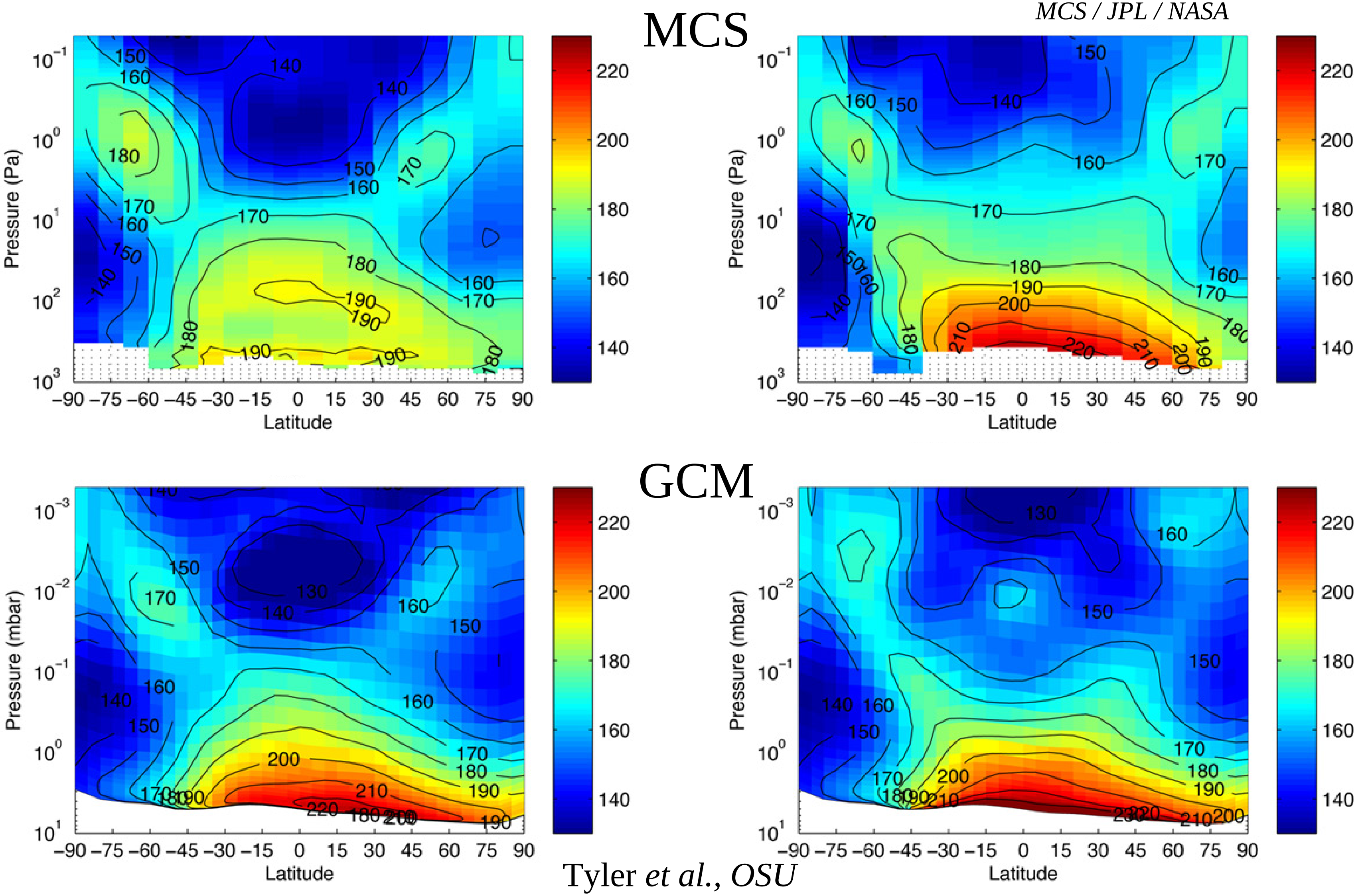


Figure 12. Smith et al., CRISM Water Vapor and CO

GCM Comparison with MCS (L_s 160°)

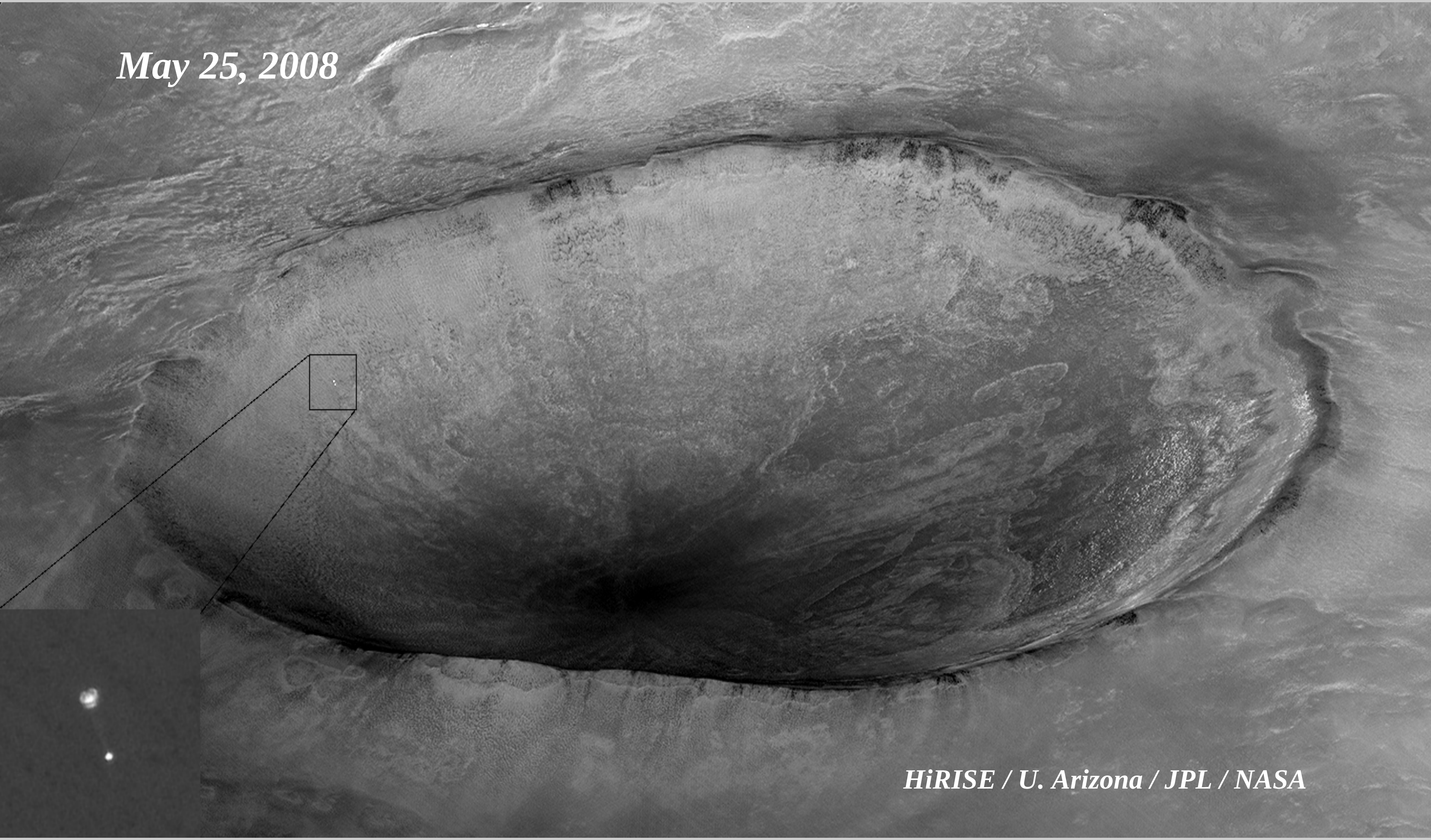
Mars Reconnaissance Orbiter



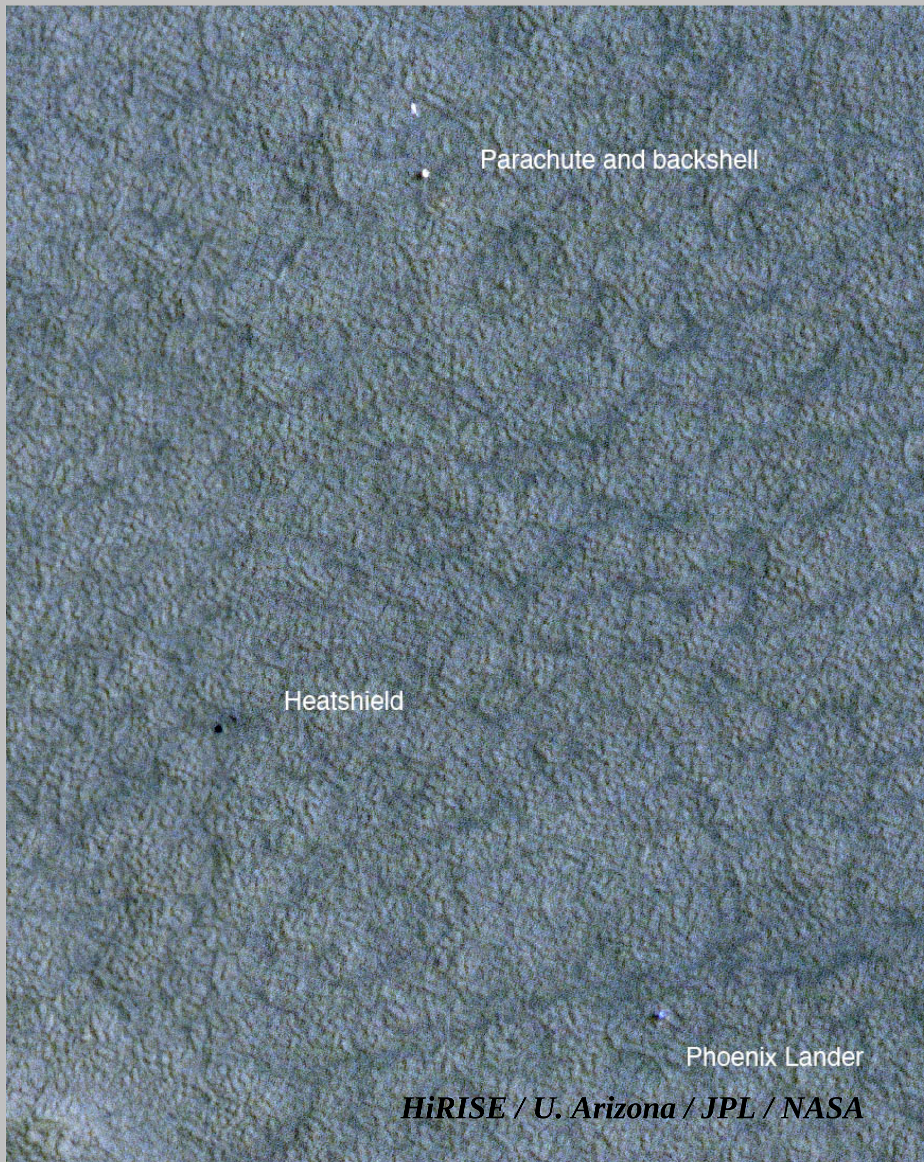
Tyler *et al., OSU*

MRO/JPL/NASA

• MRO HiRISE Views PHX Descent

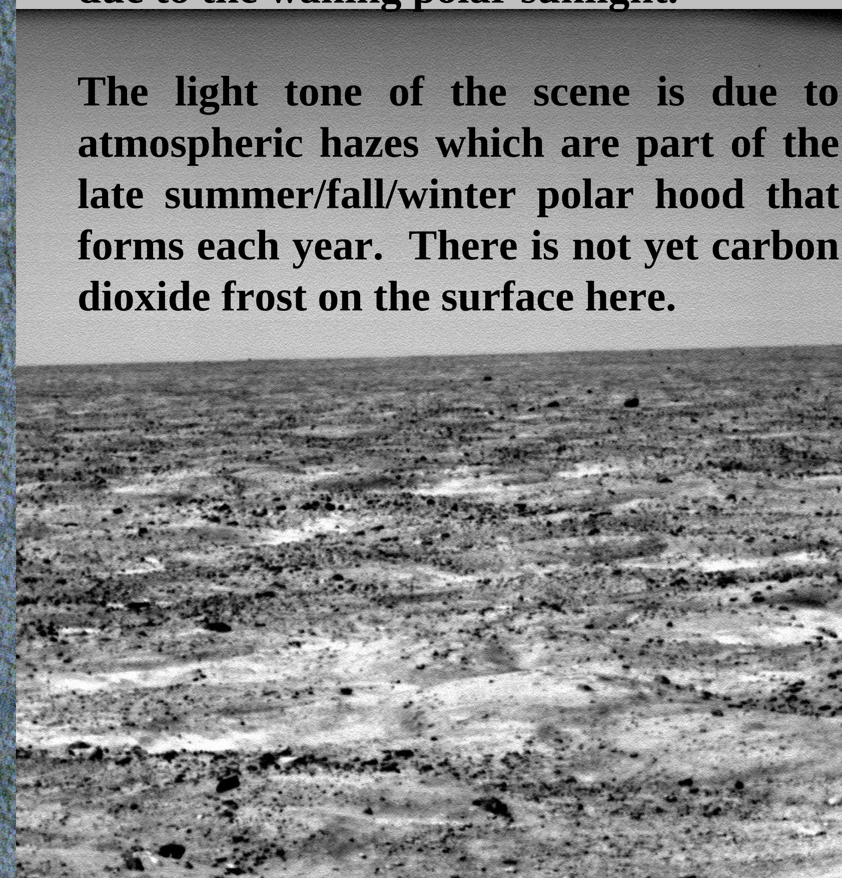


Phoenix on the Martian Surface



HiRISE / U. Arizona / JPL / NASA

This HiRISE image of the Phoenix surface hardware was taken after the PHX mission had ended, bereft of power due to the waning polar sunlight.



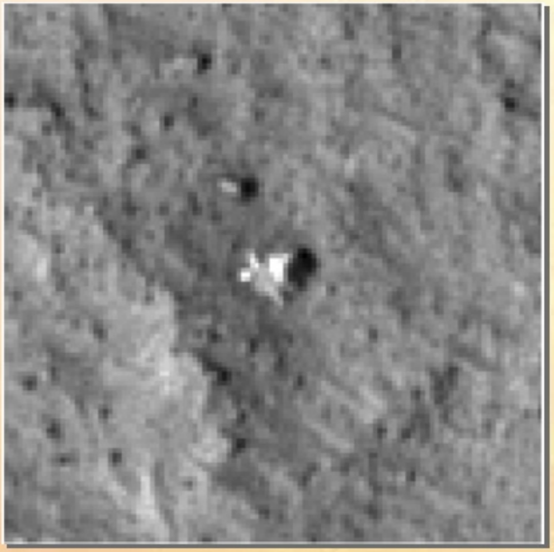
The light tone of the scene is due to atmospheric hazes which are part of the late summer/fall/winter polar hood that forms each year. There is not yet carbon dioxide frost on the surface here.

Victoria Crater viewed from above by MRO HiRISE

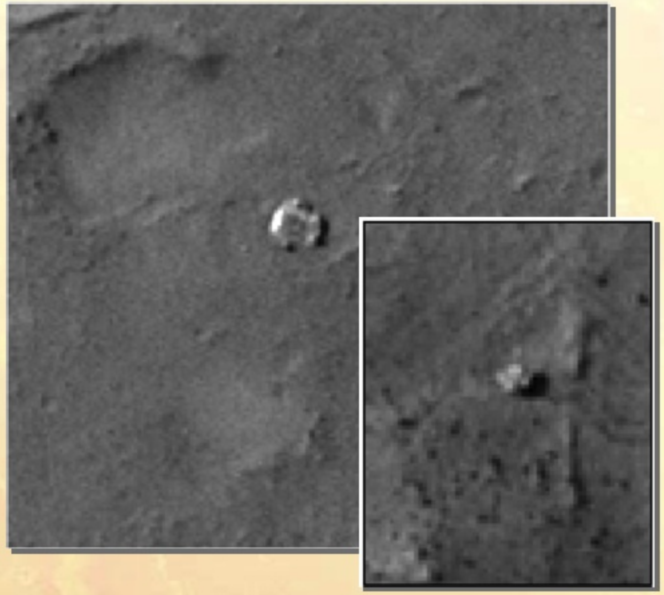
Victoria Crater viewed from its rim by MER Opportunity

Landers & Rovers as seen by HiRISE

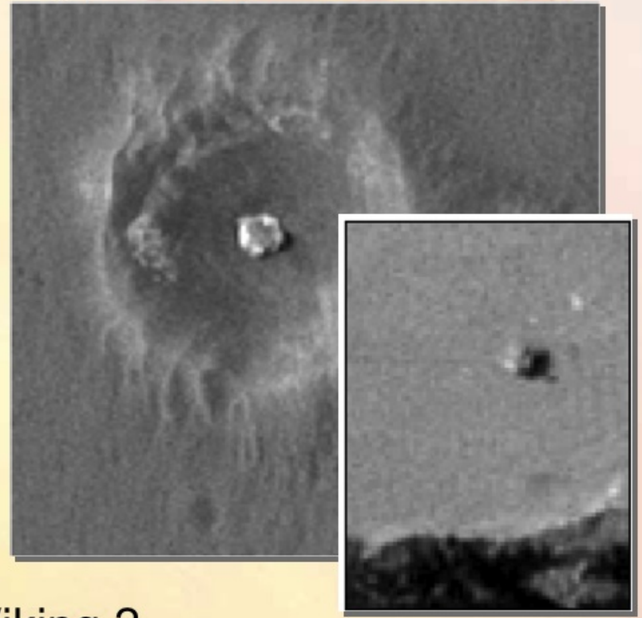
MPF



Spirit Lander & Rover

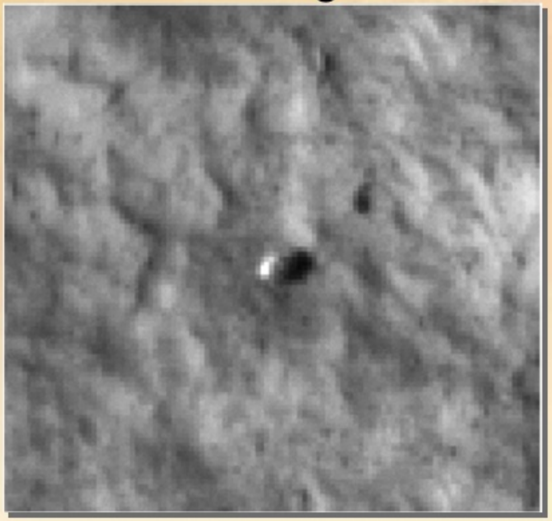


Opportunity Lander & Rover

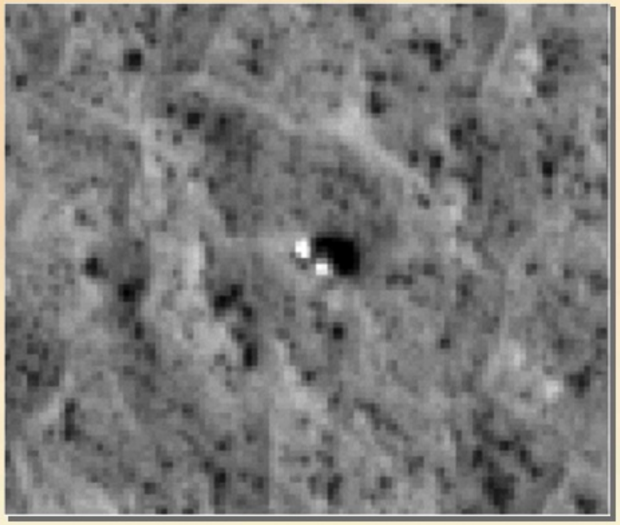


LPL / U. Arizona / JPL / NASA

Viking 1

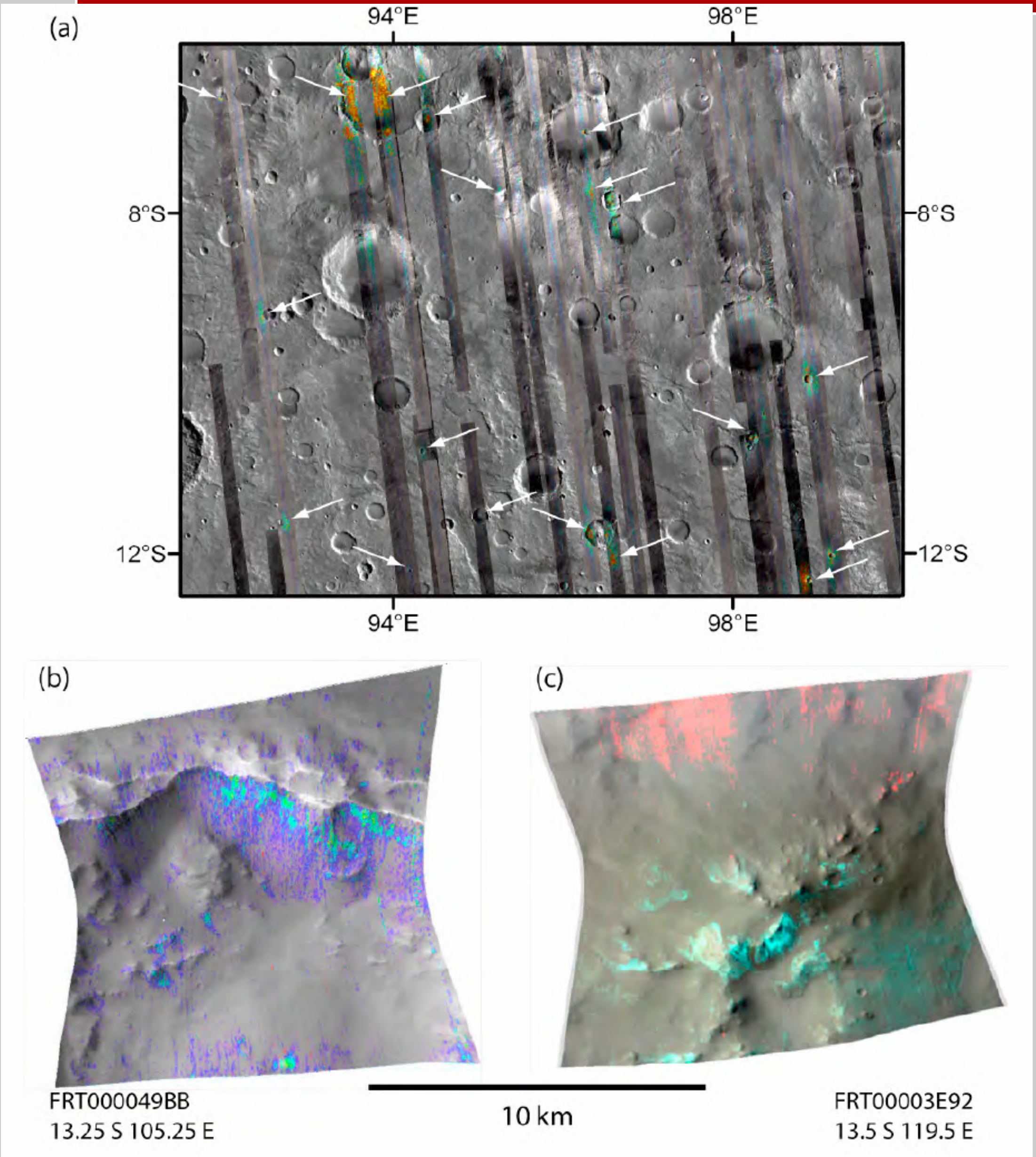


Viking 2



Thousands of Exposures of Aqueous Environments

Mars Reconnaissance Orbiter



CRISM Multi-spectral Survey reveals:

~10,000 outcrops of significant phyllosilicate (clay) deposits

Most of these are relatively small exposures readily identified only at the CRISM survey spatial resolution (< 300 m/pixel)

Most are in the Noachian terrain, the oldest part of the Martian surface

CRISM / JHUAPL / JPL / NASA

MRO Has Advanced Understanding of Mars Aqueous Deposits

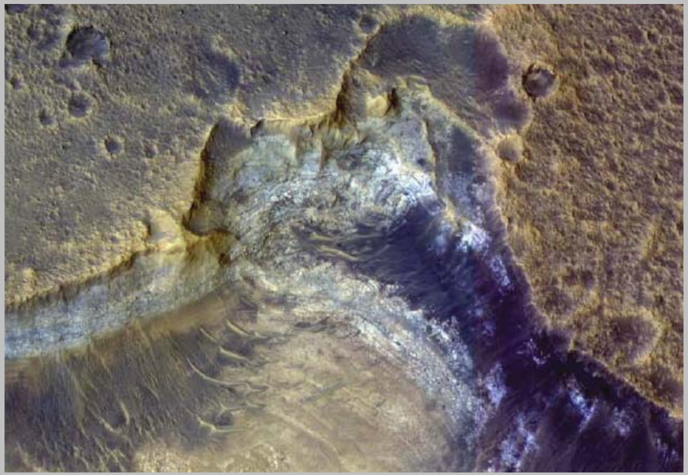
Mars Reconnaissance Orbiter

Deposits Having Both Morphologic and Mineralogic Evidence for Persistent Water

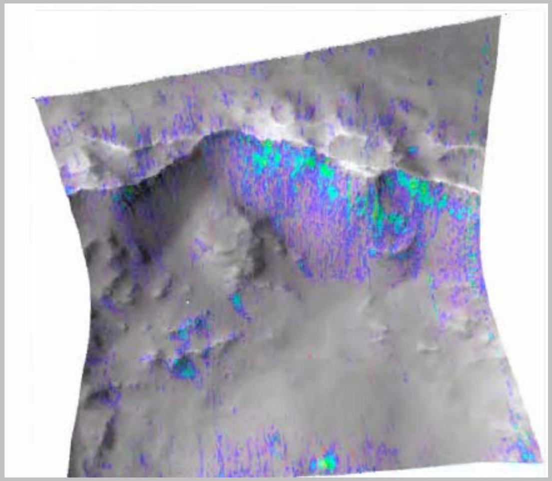
Short name	MGS/TES	Mex/OMEGA	Odyssey/ THEMIS	MRO/CRISM MRO/HiRISE	In situ investigation
Meridiani-type layered deposits	Deposits of gray hematite	Adjacent occurrences of mono- and polyhydrated sulfates	-	Improved resolution of vertical stratification; little internal deformation	Opportunity
Valles-type layered deposits				Intricate vertical layering of sulfate types; folding; alteration zones	-
Gypsum plains	-	Gypsum-rich optical surface	-	Role of eolian reworking; relationship to basal unit	-
Layered phyllosilicates	-	Al- and Fe/Mg-clays at Nili and Mawrth	-	Thin interbedding of clay units; detailed stratigraphy	-
Massive phyllosilicates	-	Unknown hydrated mineral associated with dozens highland craters	-	~10K highland outcrops in craters, chasmata; chlorite + other phyllosilicates	-
Phyllosilicates in fans	-	-	-	Highland crater fans/deltas contain phyllosilicate-rich layers	-
Glowing terrain	-	-	Detection of chloride	Polygonal fracturing, lack of sulfates	-
Siliceous layered deposits	-	-	-	Widespread hydrated silica in layered deposits on Hesperian plains	Spirit (?)

2004

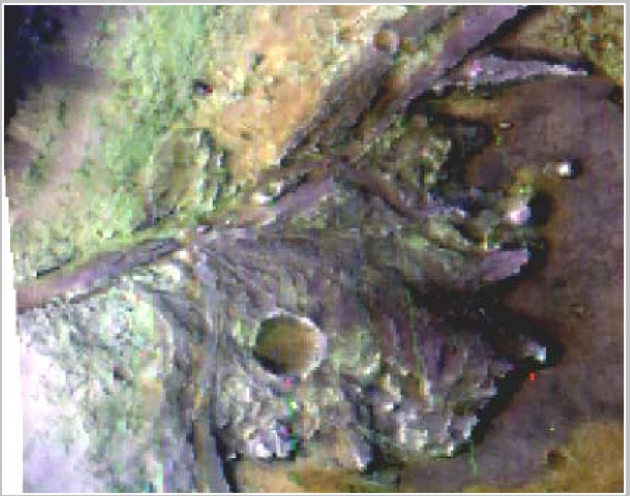
Summary of Deposit Types (1-4)



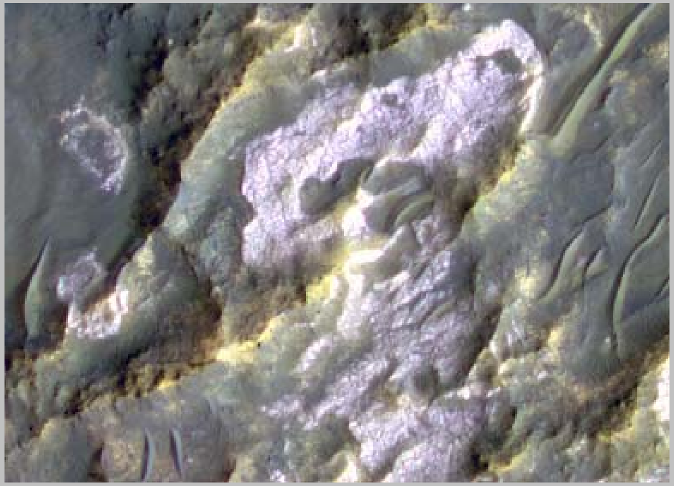
1. Noachian layered phyllosilicates



2. Noachian deep phyllosilicates exposed in highland craters, chasma walls



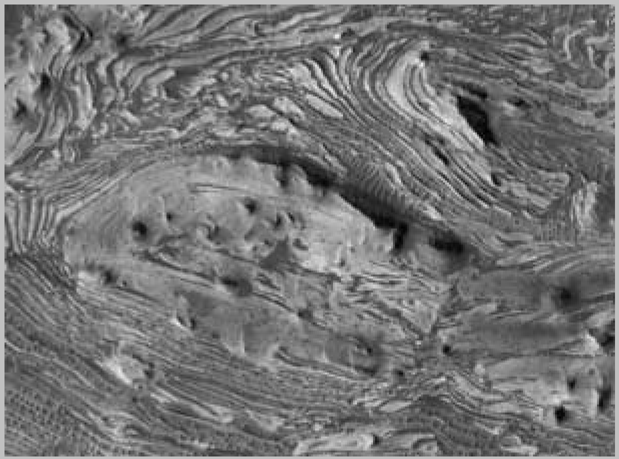
3. Noachian intra-crater fans with phyllosilicate-rich layers



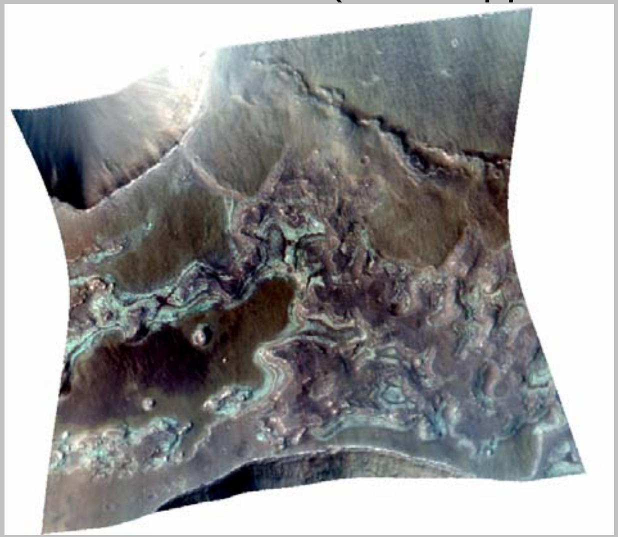
4. Noachian "glowing terrain" thought to be rich in chlorides

Summary of Deposit Types (5-8)

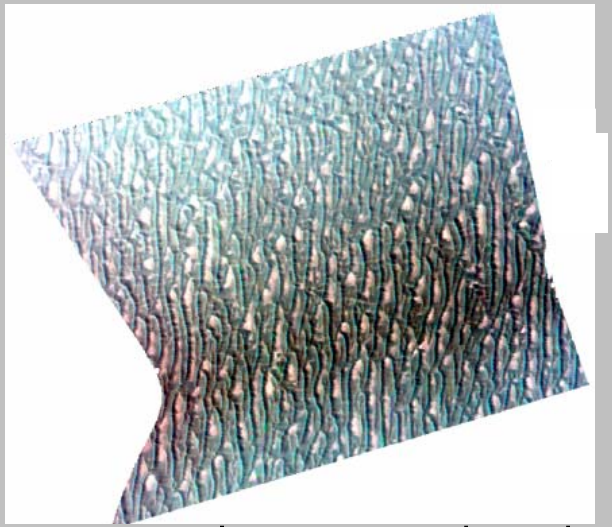
5. Noachian Meridiani-type layered deposits with sulfates + hematite (MER/Opportunity)



6. Hesperian Valles-type layered deposits with diverse layered sulfates + Fe oxide



7. Thin Hesperian layered deposits with hydrated silica



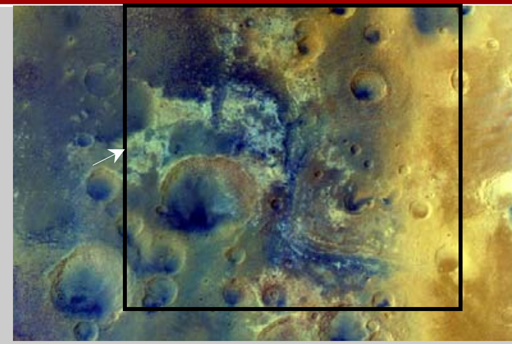
8. Amazonian gypsum deposits surrounding north polar layered deposits

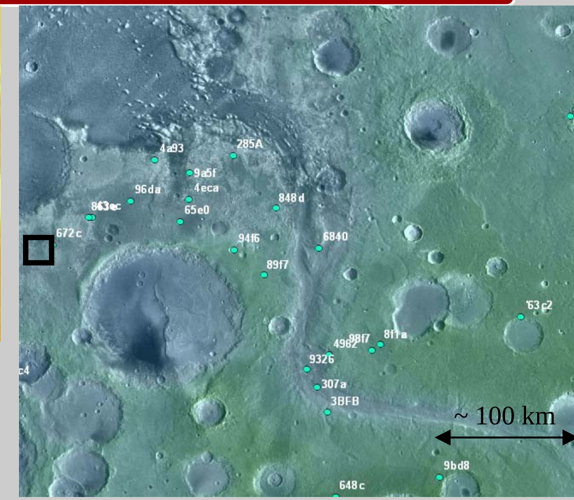
Layering in Mawrth Vallis

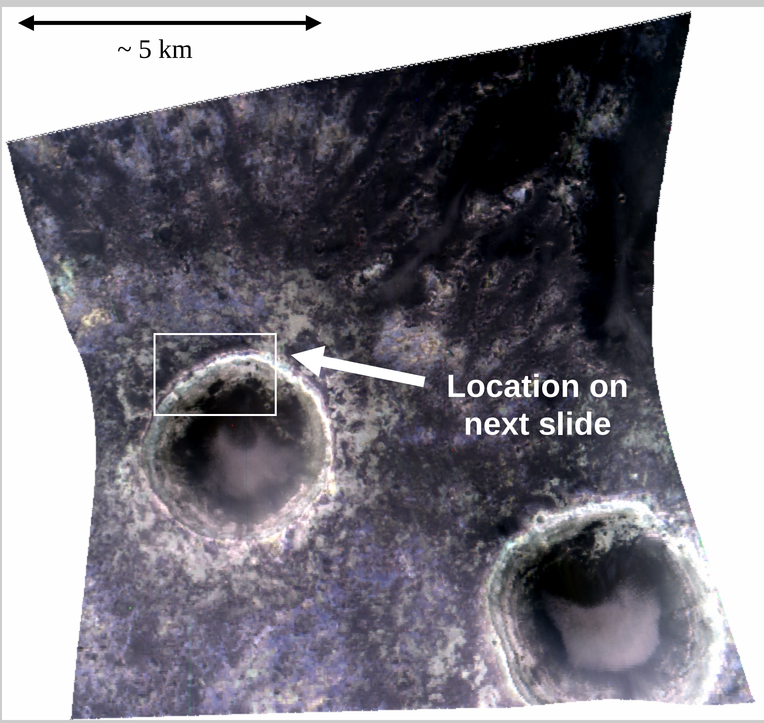
Mars Reconnaissance Orbiter

Mawrth Vallis exhibits layering that includes aqueously altered iron oxides and clays

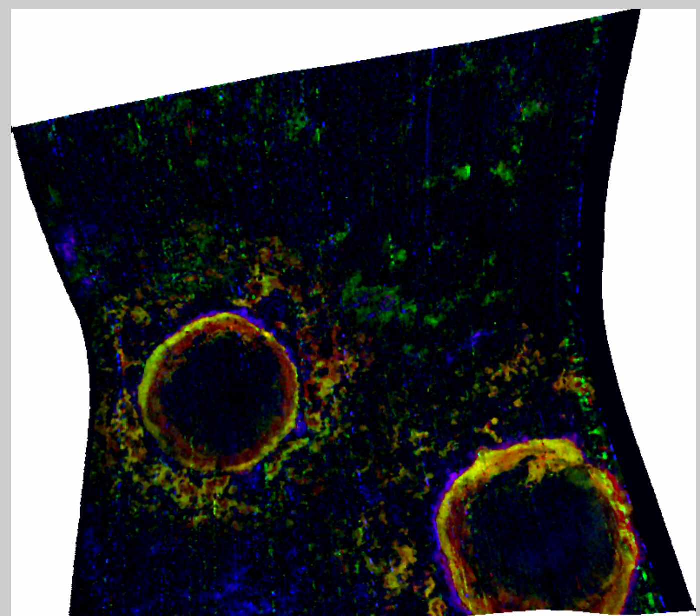
A pattern of mafic rocks -> Al-rich clays -> Fe-rich clays is repeated across the region







R=bound water
G=Fe/Mg clay
B=Al clay



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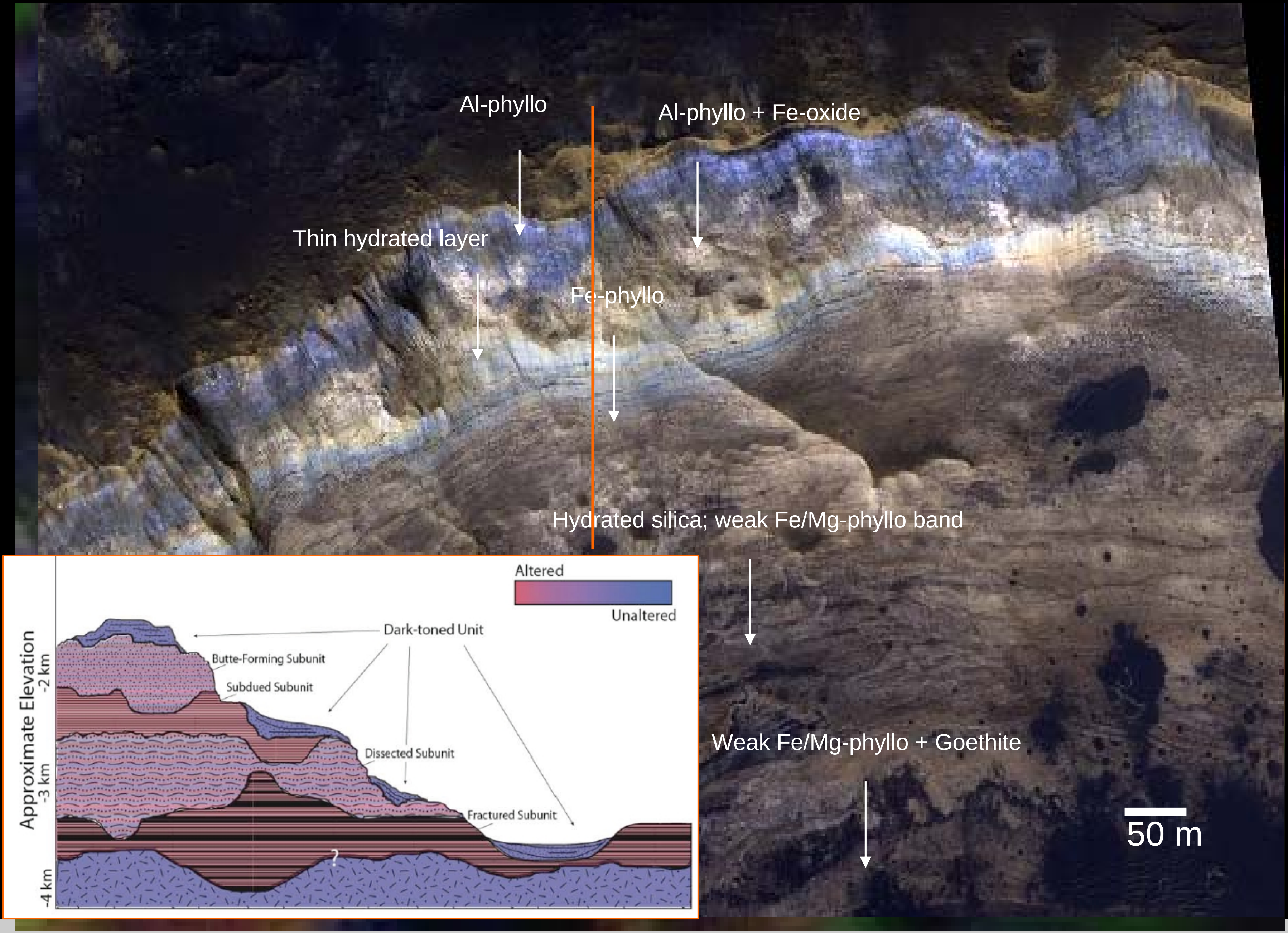


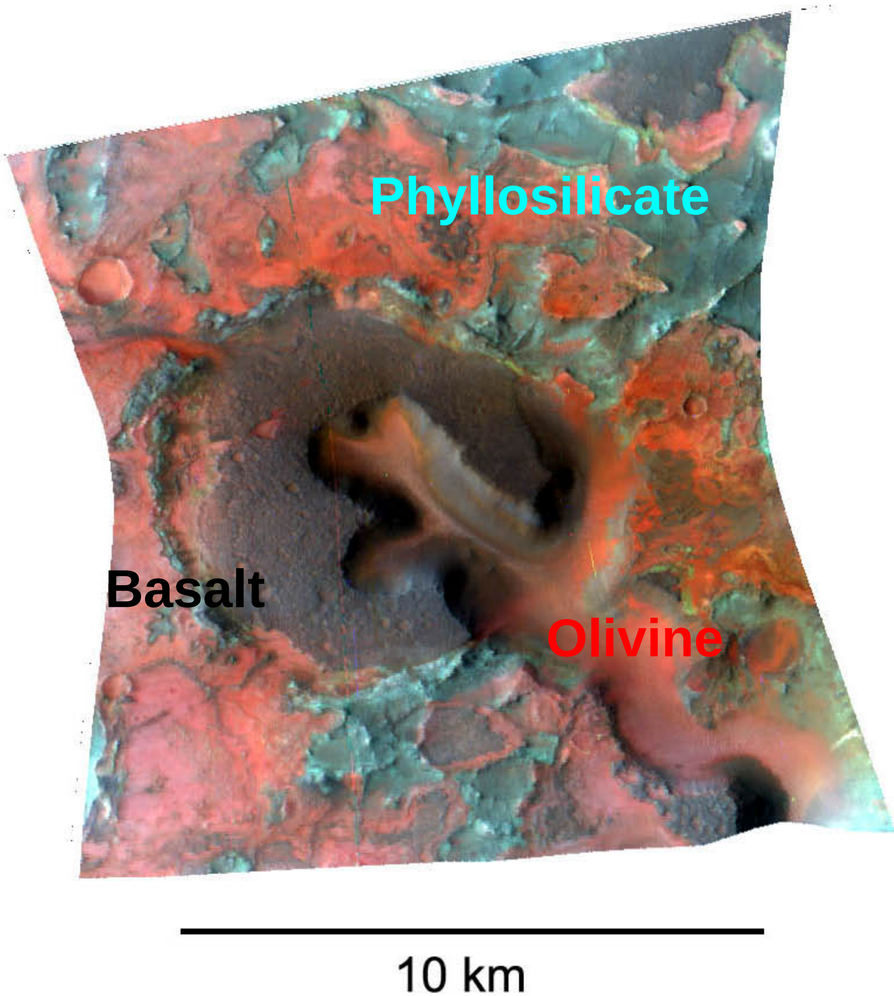
Al-phyllo
Al-phyllo + Fe-oxide
Thin hydrated layer
Fe-phyllo
Hydrated silica; weak Fe/Mg-phyllo band
Weak Fe/Mg-phyllo + Goethite
50 m
Altered
Unaltered
Dark-toned Unit
Butte-Forming Subunit
Subdued Subunit
Dissected Subunit
Fractured Subunit
Approximate Elevation
-2 km
-3 km
-4 km
?

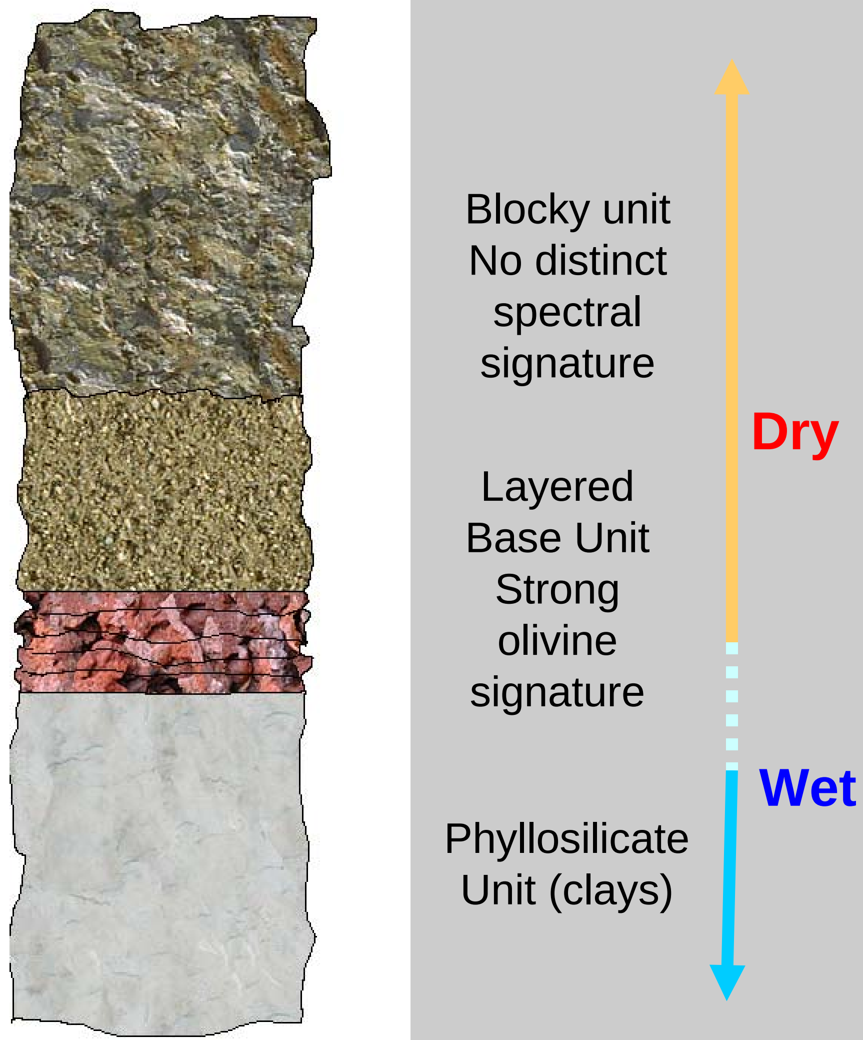
MRO/JPL/NASA

Noachian Crust Compositional Layering

Mars Reconnaissance Orbiter

IR False Color (2528, 1505, 1078 nm)





MRO/JPL/NASA

Ancient Crust

Mars Reconnaissance Orbiter

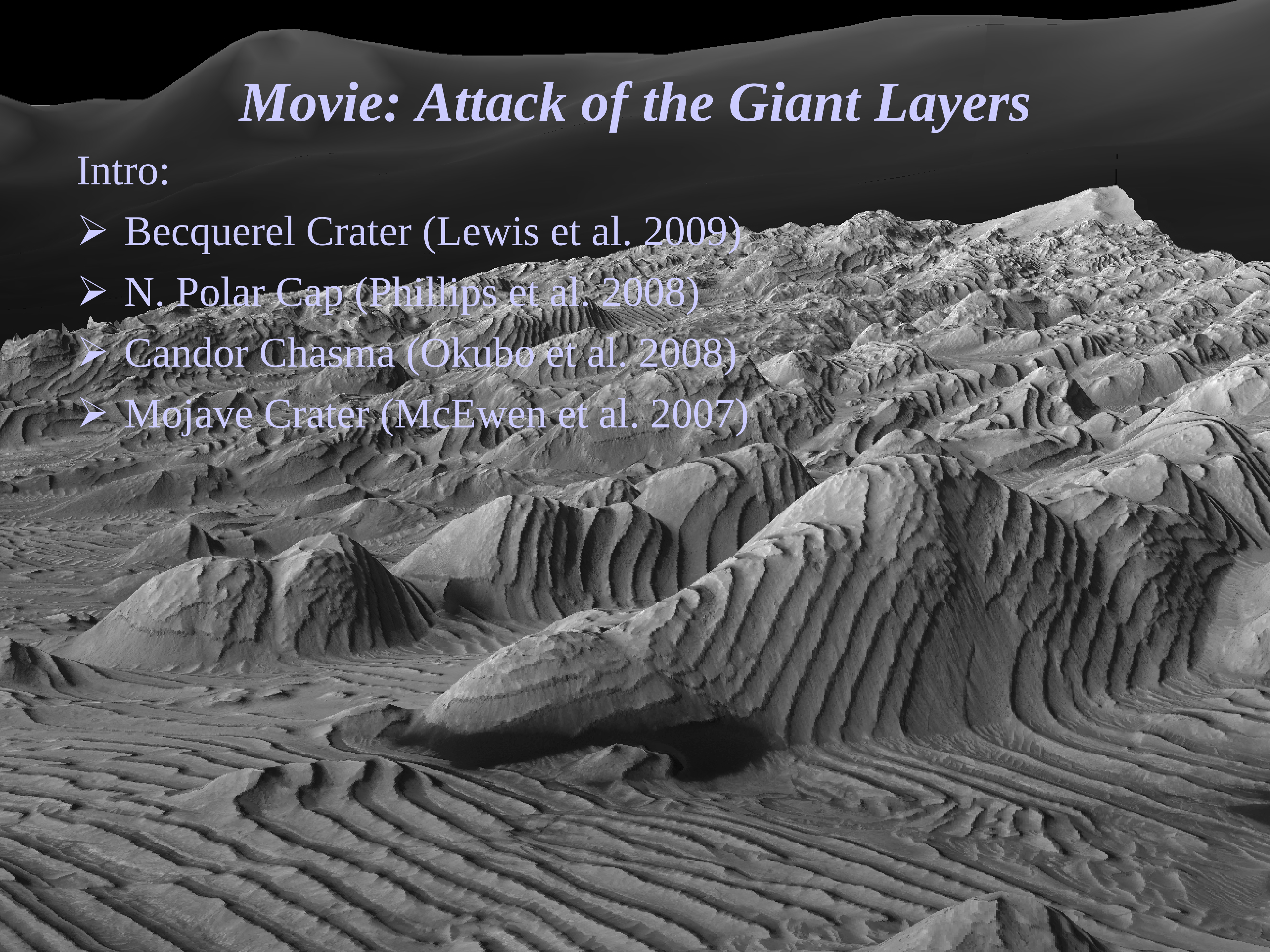
Branched Features on the Floor of Antoniadi Crater
(PSP_012435_2015)

Noachian crust in Syrtis Major
ESP_012962_1955

Movie: Attack of the Giant Layers

Intro:

- Becquerel Crater (Lewis et al. 2009)
- N. Polar Cap (Phillips et al. 2008)
- Candor Chasma (Okubo et al. 2008)
- Mojave Crater (McEwen et al. 2007)



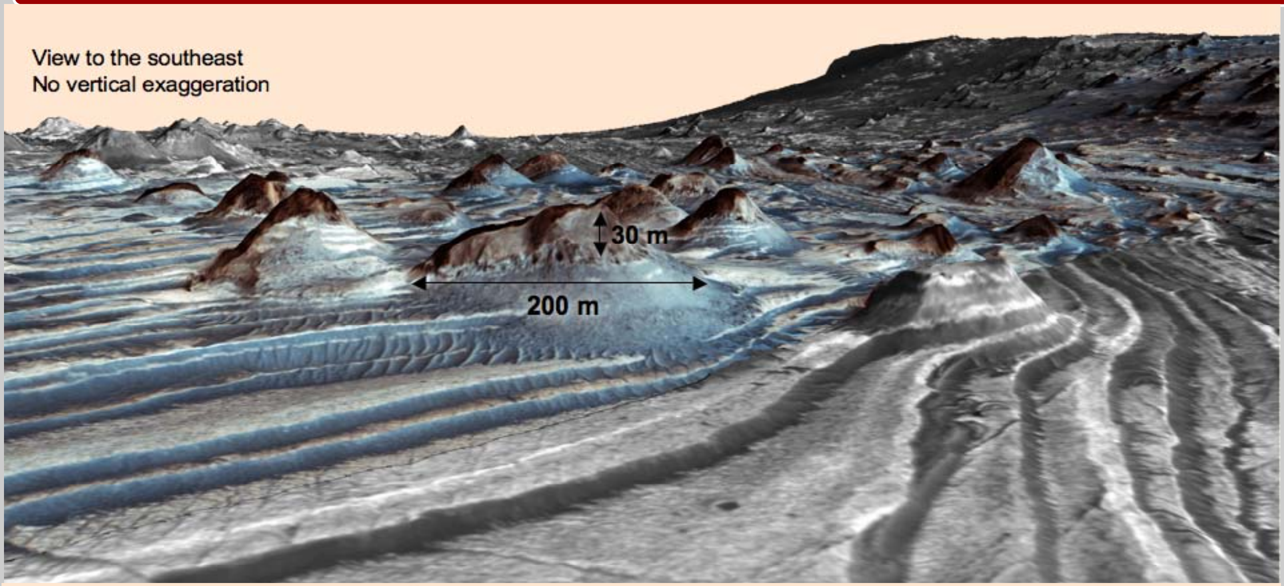
Non-Polar Layered Terrains

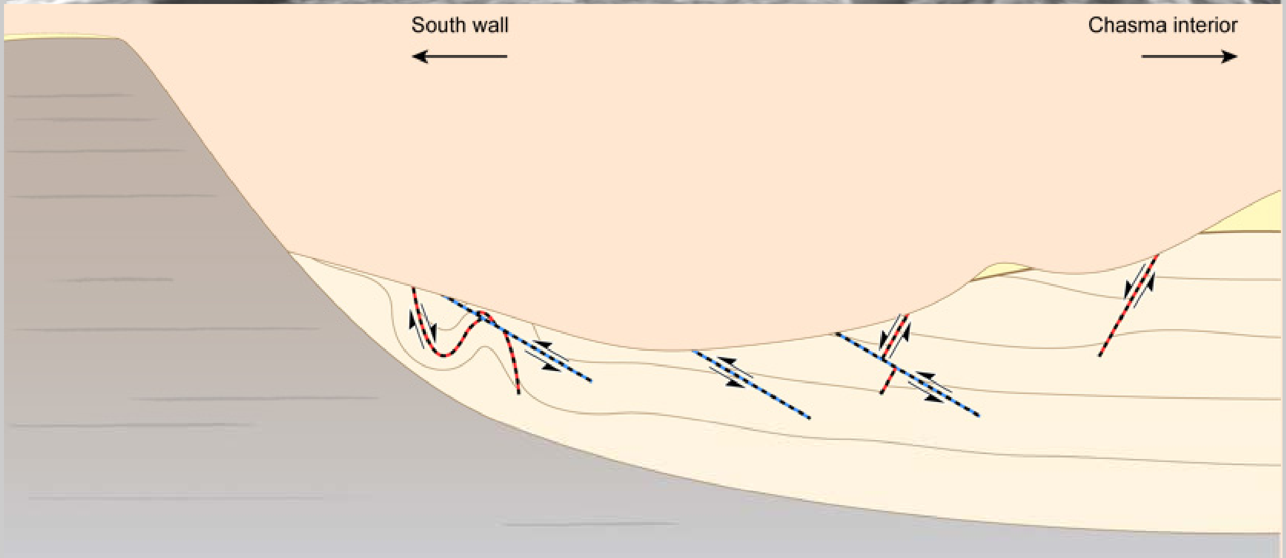
Mars Reconnaissance Orbiter

- ***Layered Rocks in Arabia***
- Sedimentary rocks are widespread across the surface of Mars, and represent an archive of past climate activity.
- ~30 cm/pixel HiRISE stereo images allow 1 m/pixel topography
- Topographic data are used to reconstruct accurate stratigraphic columns from orbit, even where tectonism has deformed the rocks
- Stratigraphy can shed light on formation environments and depositional mechanisms
- *Lewis et al., 2009*
- ***HiRISE / U. Arizona / JPL / NASA***

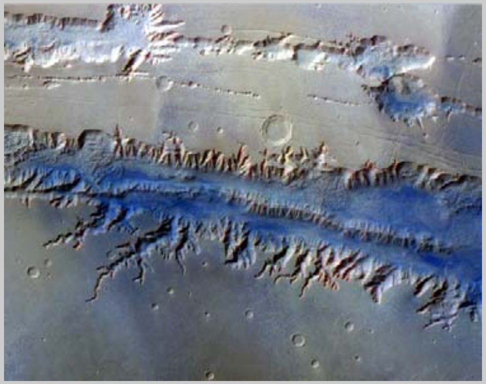
MRO/JPL/NASA

Complex Topography in Candor Chasma

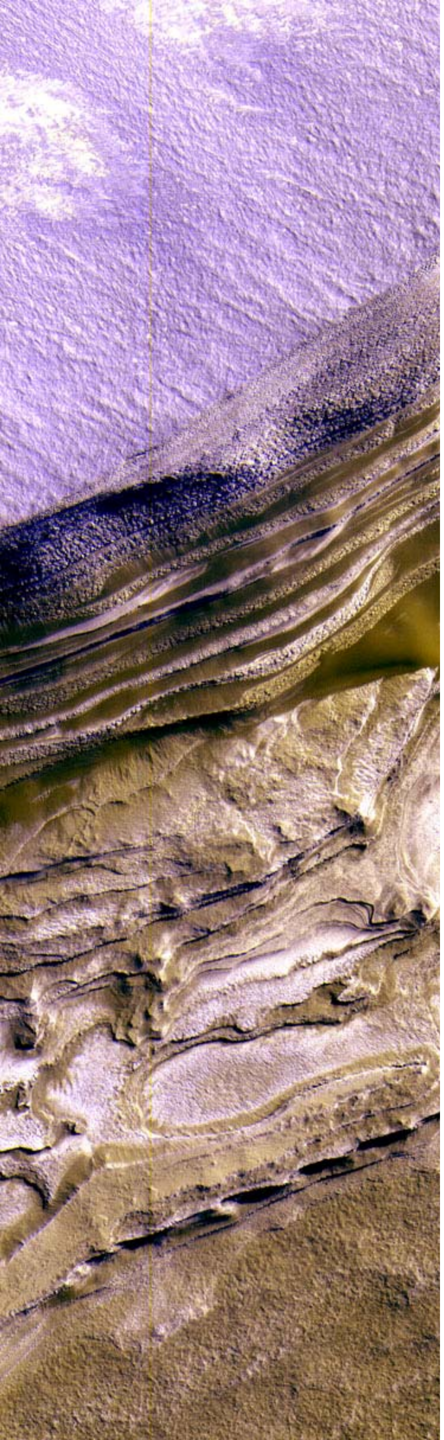


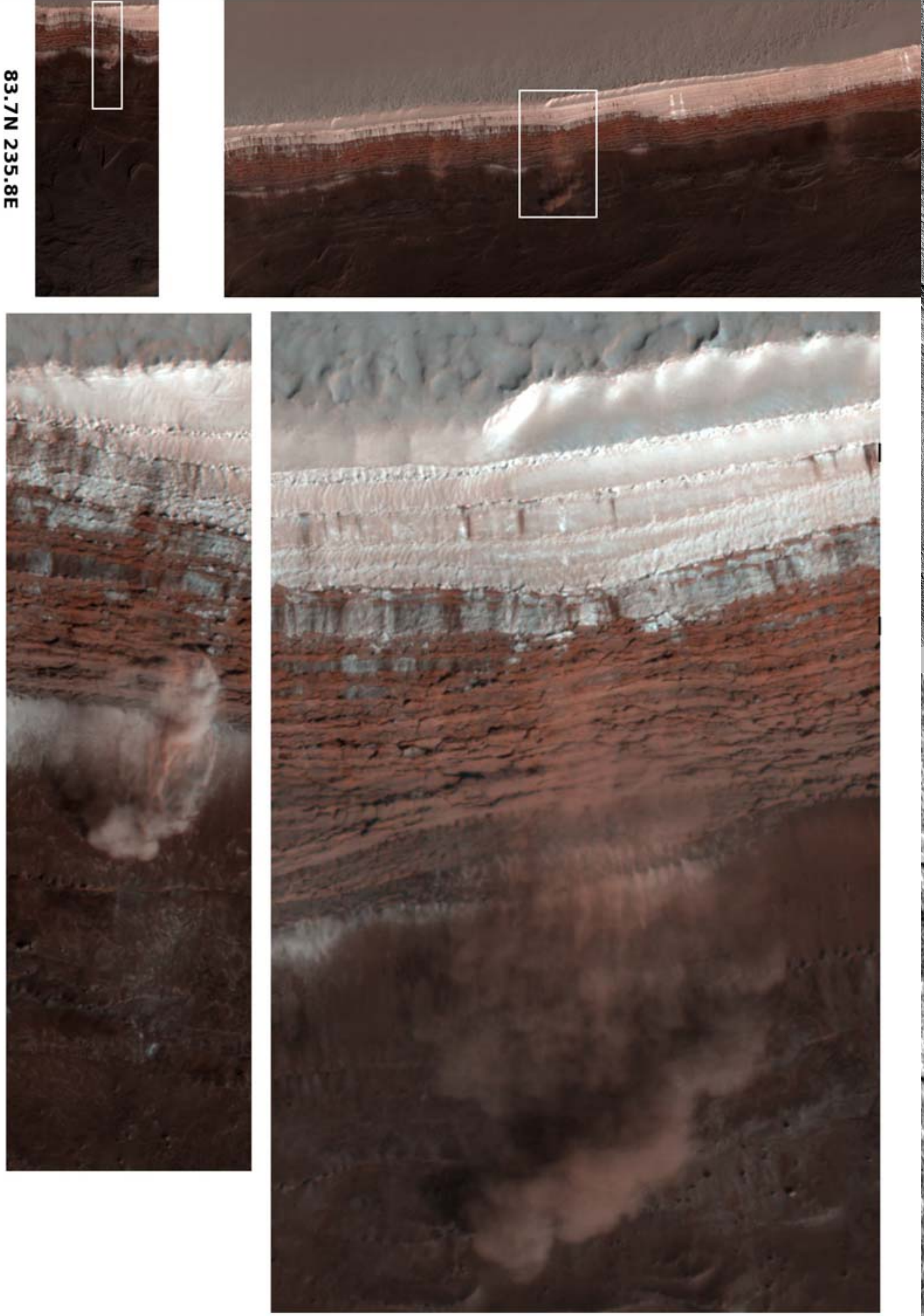


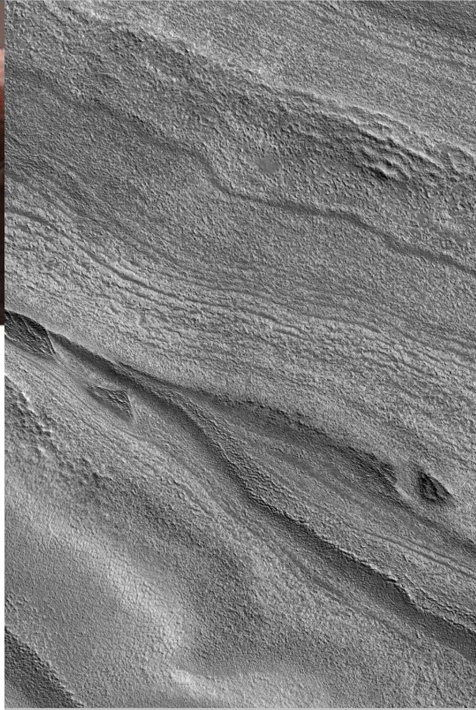
HiRISE color draped over a terrain model of southwest Candor Chasma, Hesperian age layered deposits.

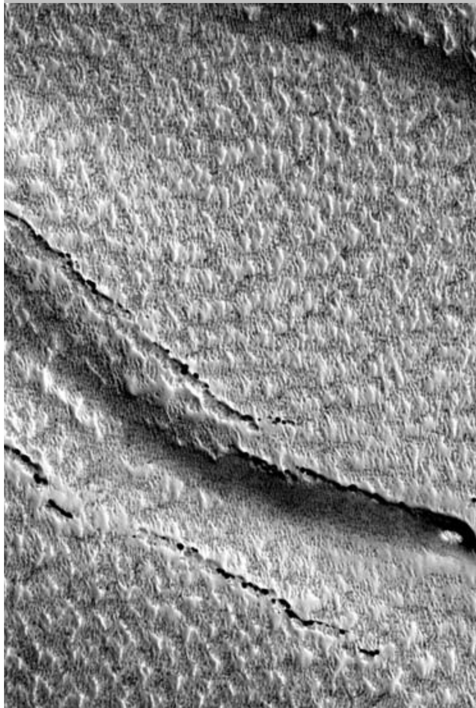


Interpreted cross-section showing fault/folding history of the interior layered deposits.

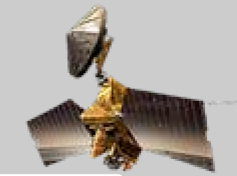



83.7N 235.8E





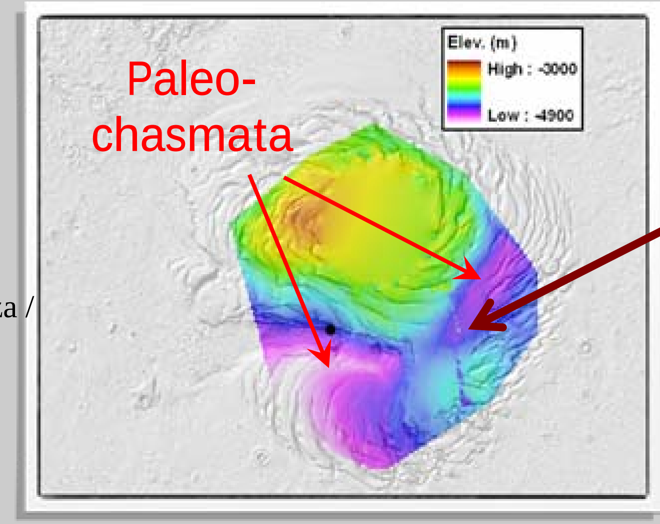
MRO SHARAD: Science Highlights

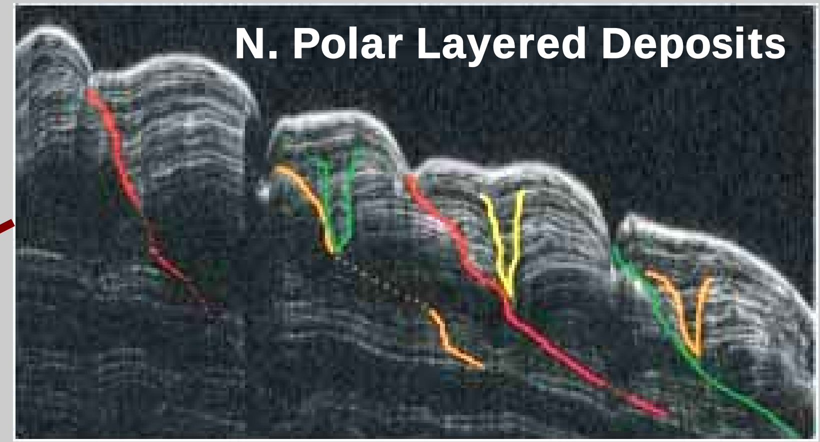


Mars Reconnaissance Orbiter

Credits

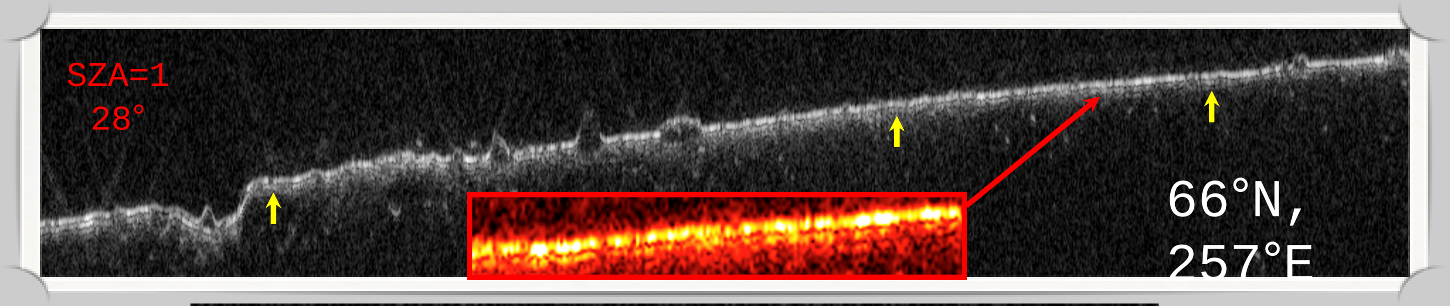
NASA
JPL
ASI
***SHARAD*:**
U. Roma-Sapienza /
TAS-I /
SWRI /
U. Texas /
JPL



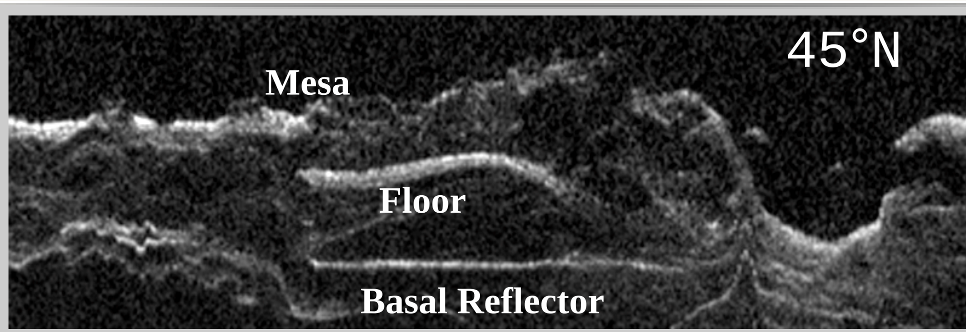


Trough migration paths in the North Polar Layered Ice Deposits

High-Latitude Subsurface Ice: *Vastitas Boralis*

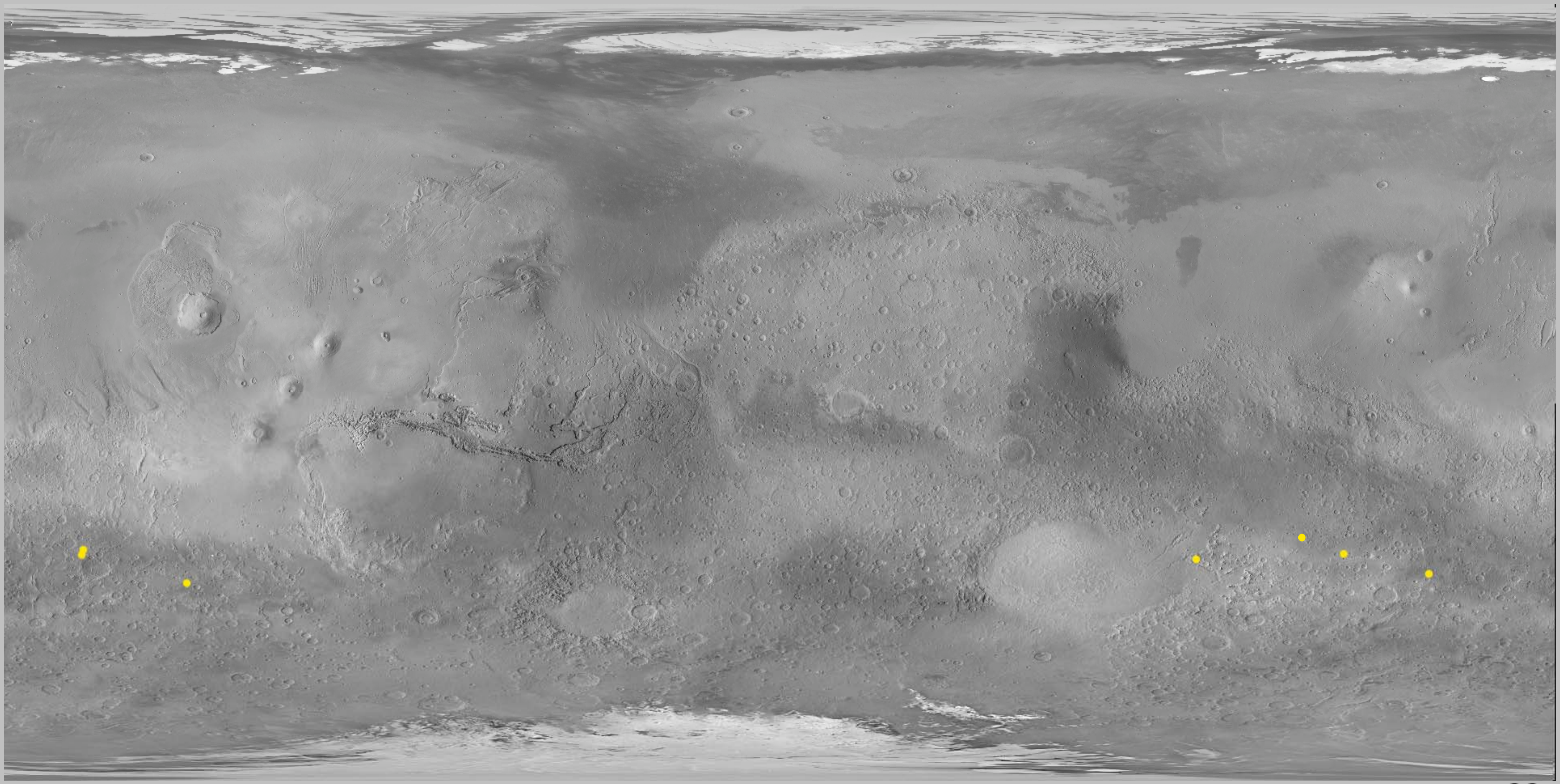


Mid-Latitude Subsurface Ice: *Deuteronilus Mensae*



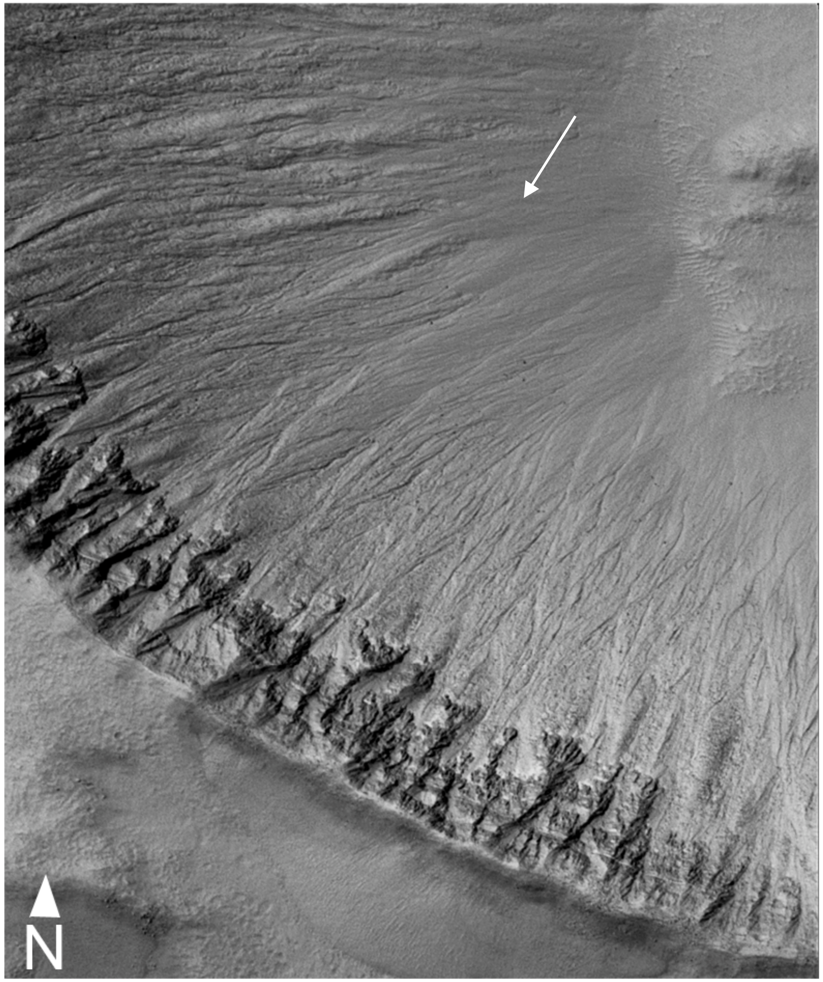
Are gullies formed by present-day water?

Locations of Recent Gully Activity

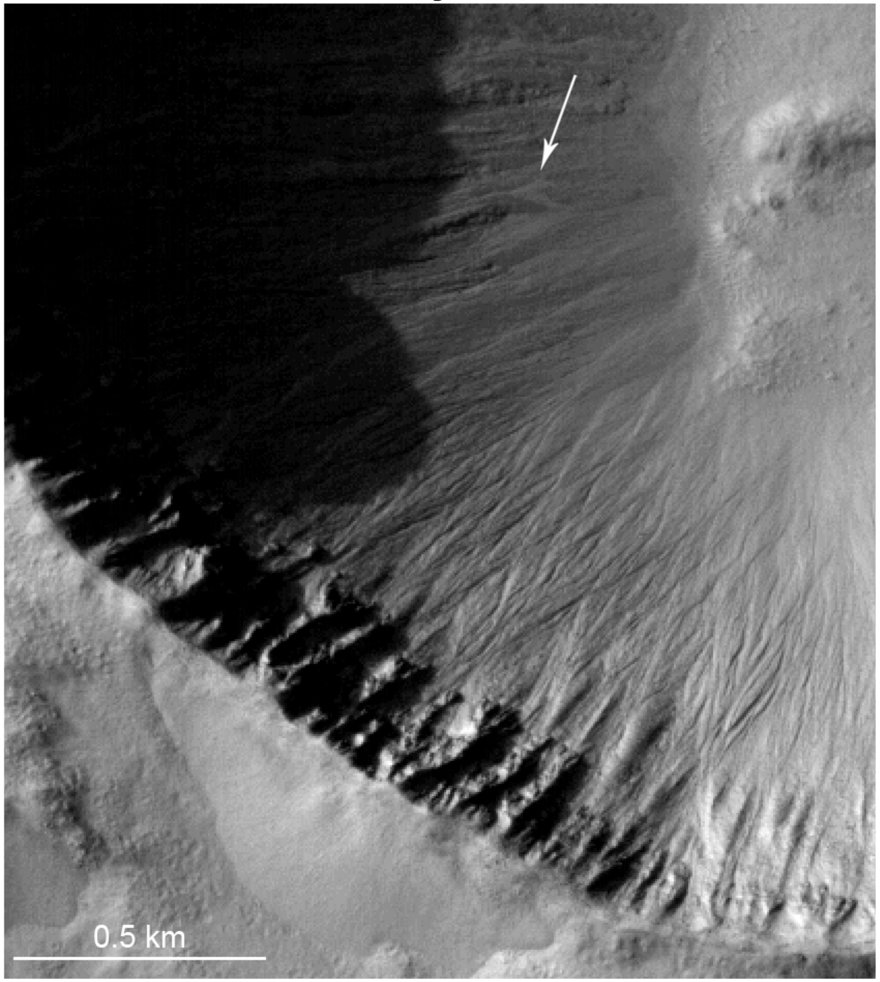


Terra Cimmeria, 42.0ºS 209.5ºW

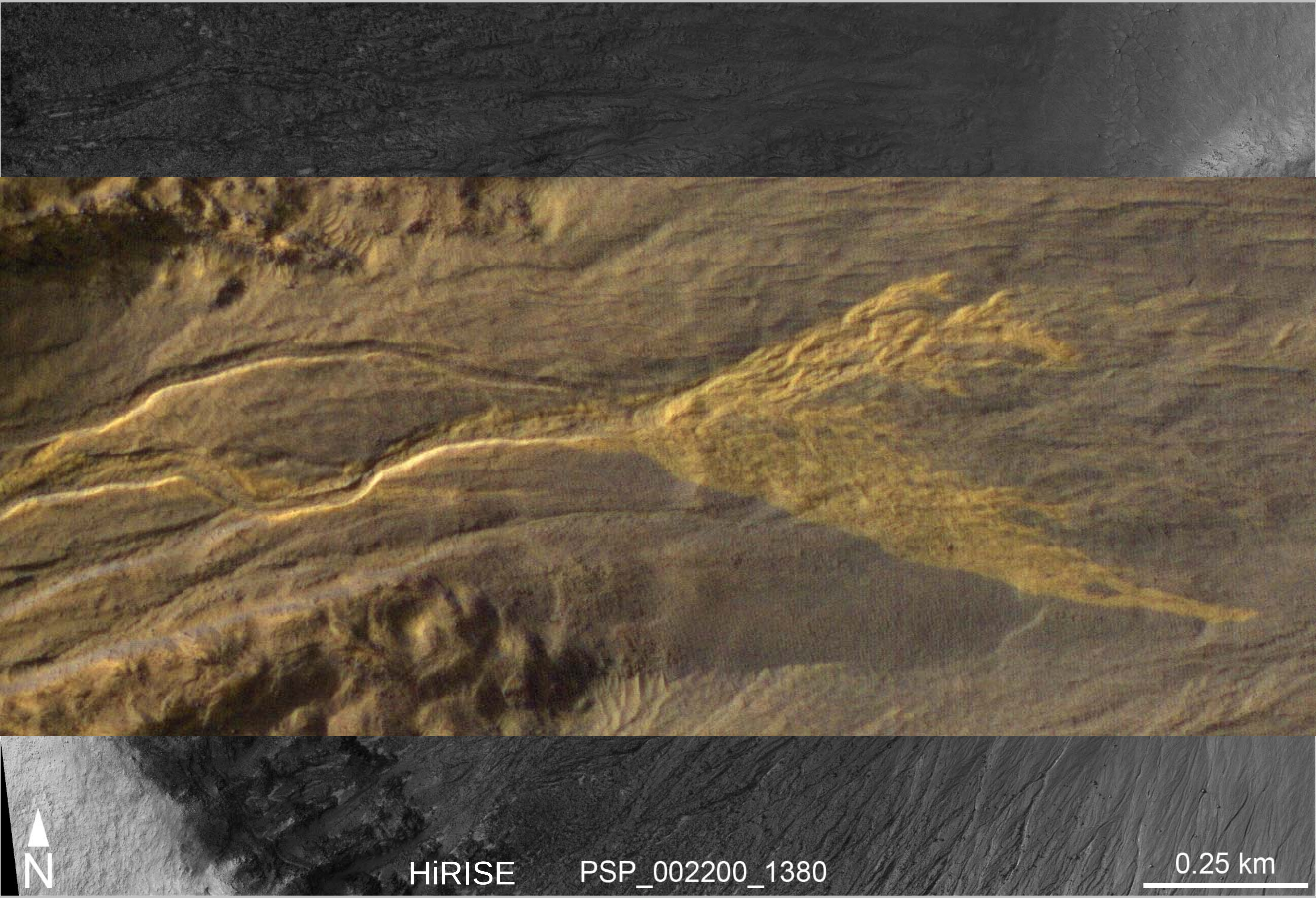
Formed between 9 January 2006 and 14 January 2007



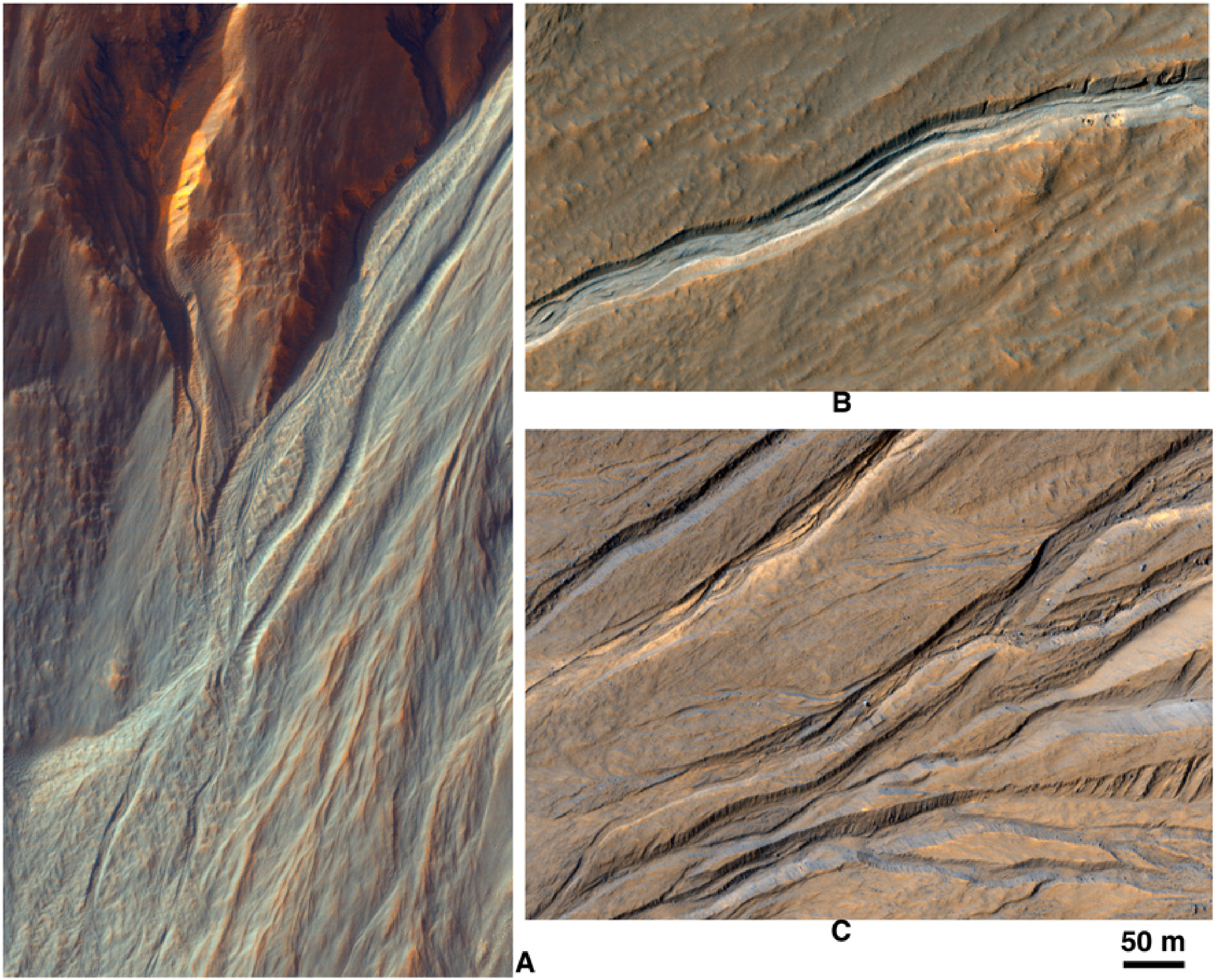
MOC NA S14-00995 (9 January 2006)



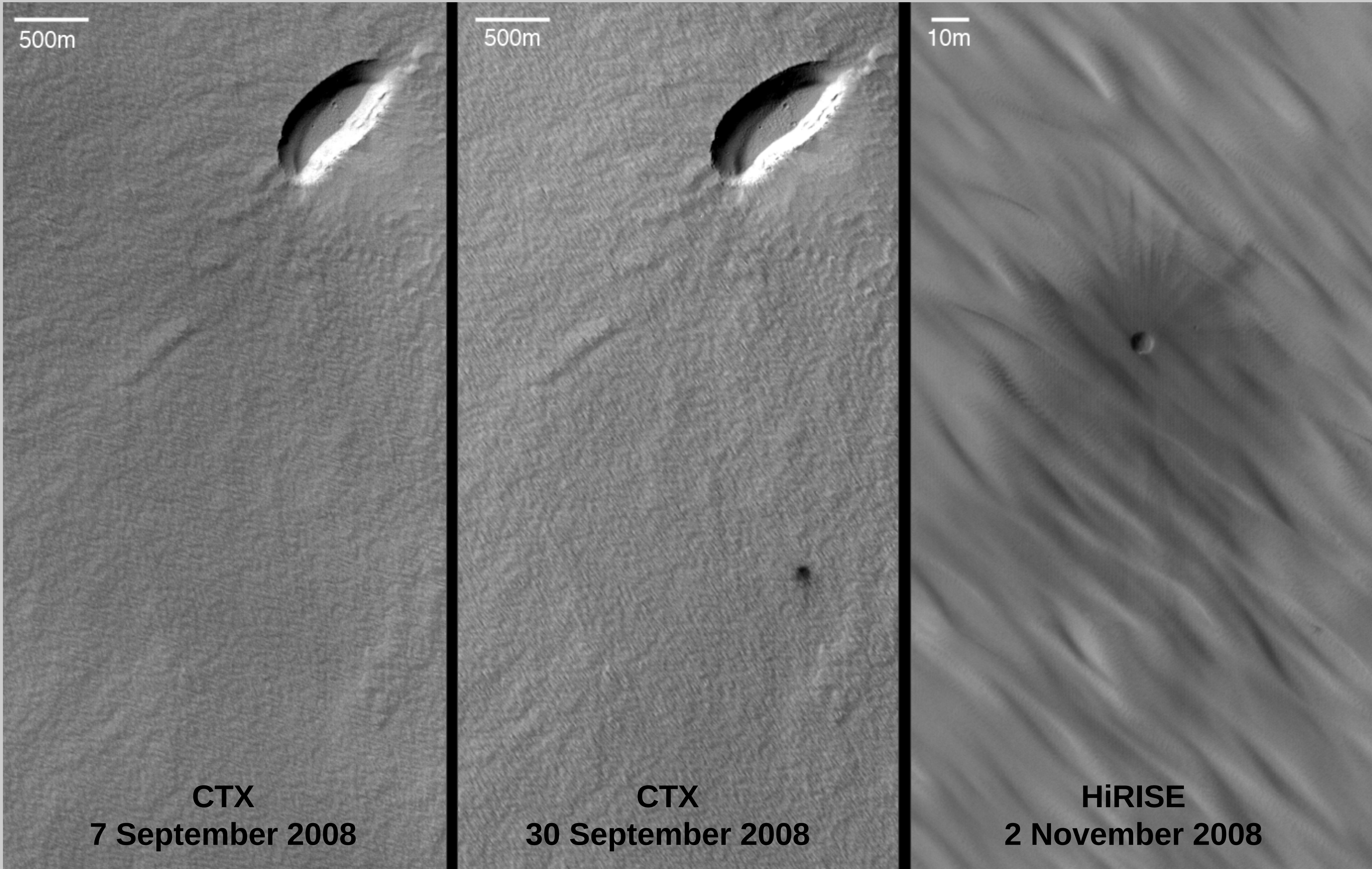
CTX B05_011443_1380_XI_42S209W_090104
(4 January 2009)

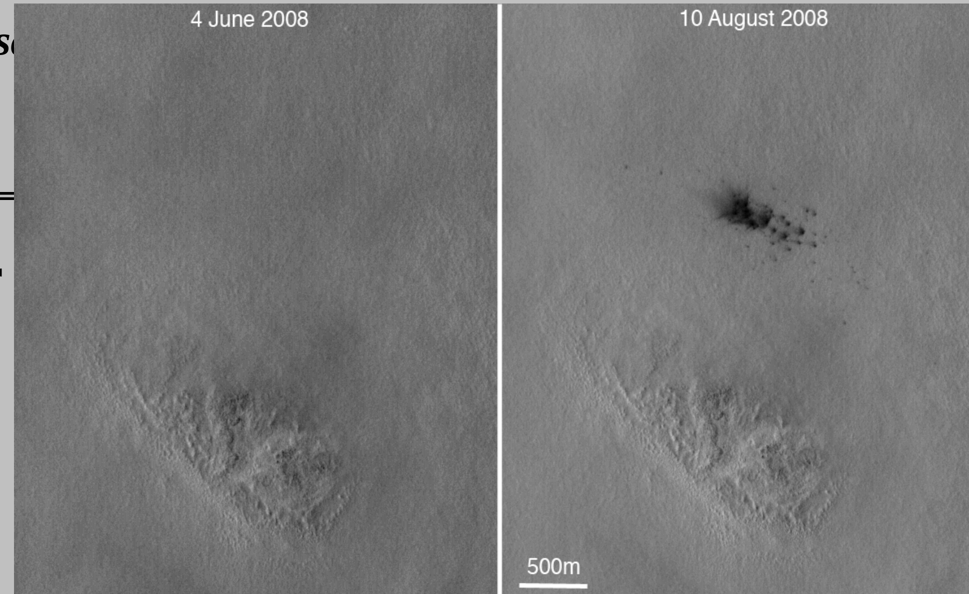

N
HiRISE
PSP_002200_1380
0.25 km

Gully channels on shallow slopes (<20º) cannot be explained with dry flows (Pelletier et al., Geology, 2008)



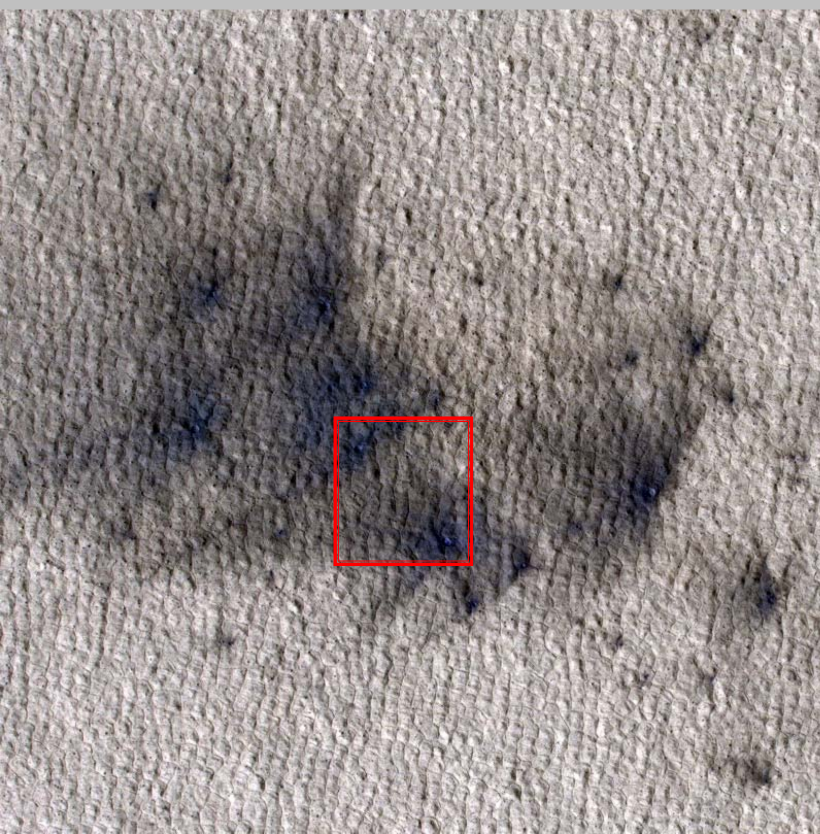
Mars Reconnaissance Orbiter

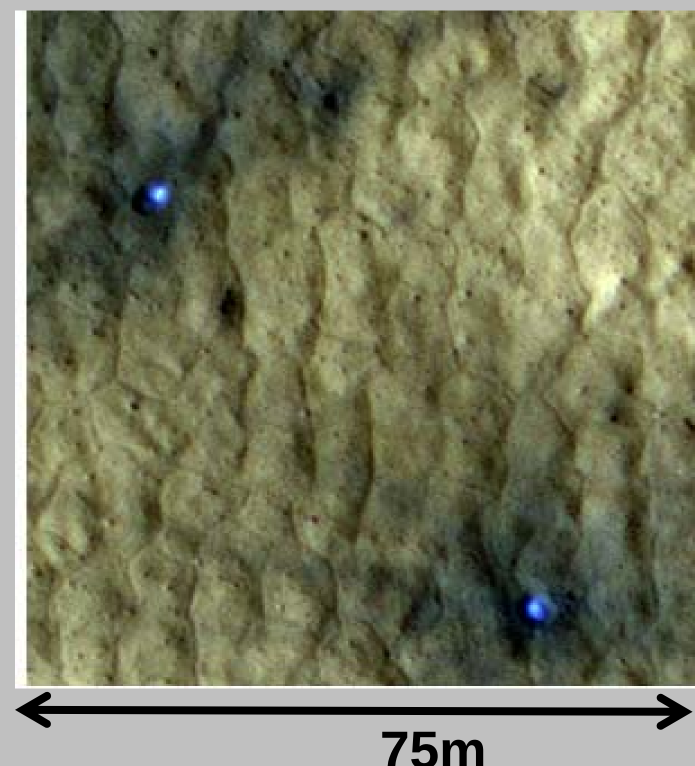


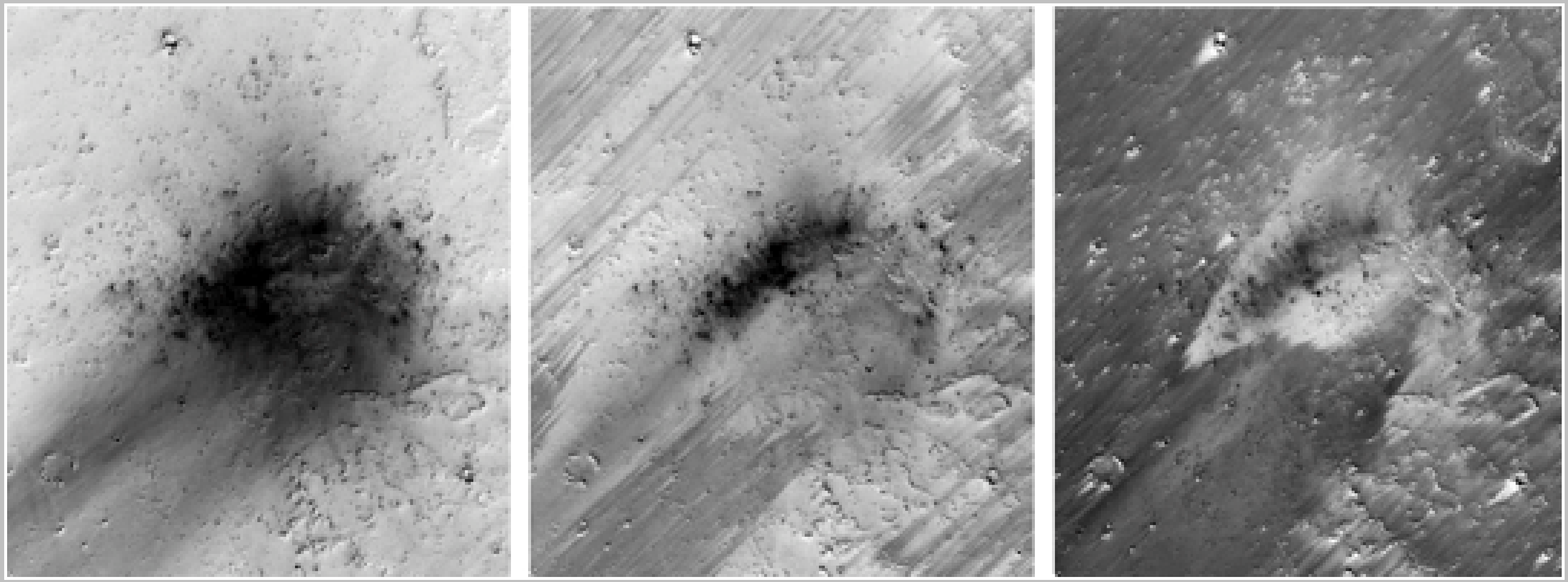


CTX discovers newly formed crater

- 46.3 N
- HiRISE follow-up showed something unusual
- Color and Brightness suggest ice

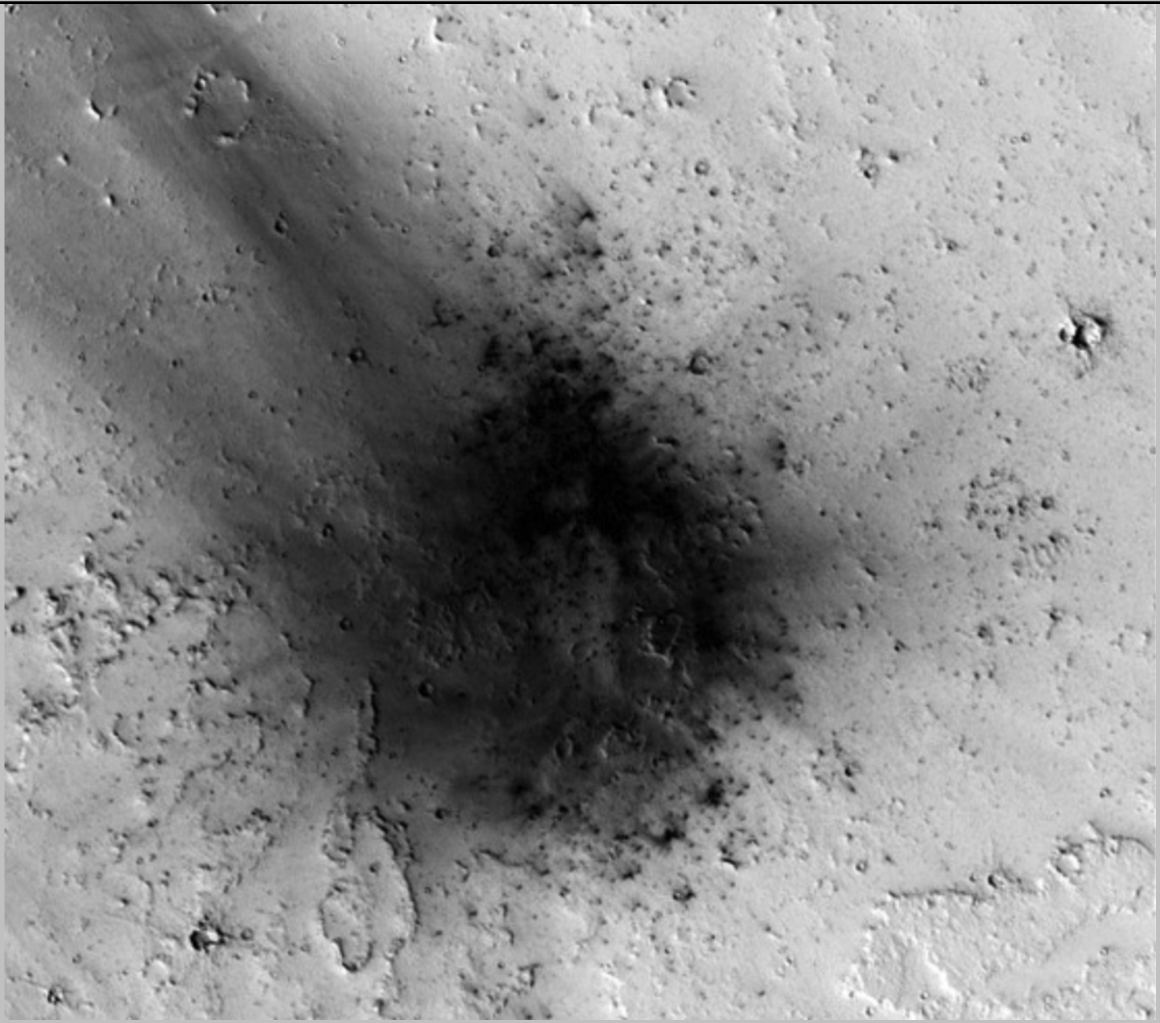


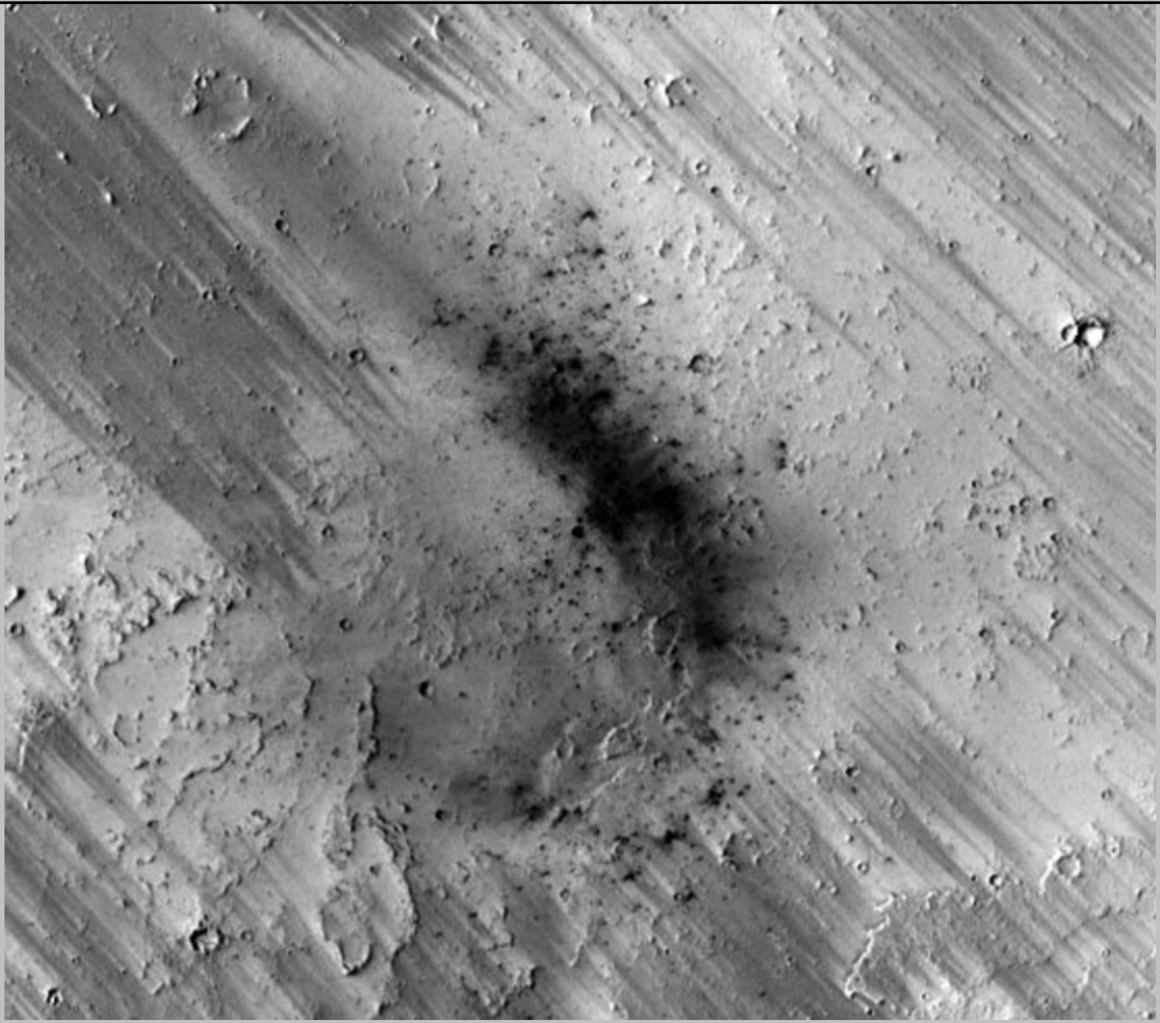


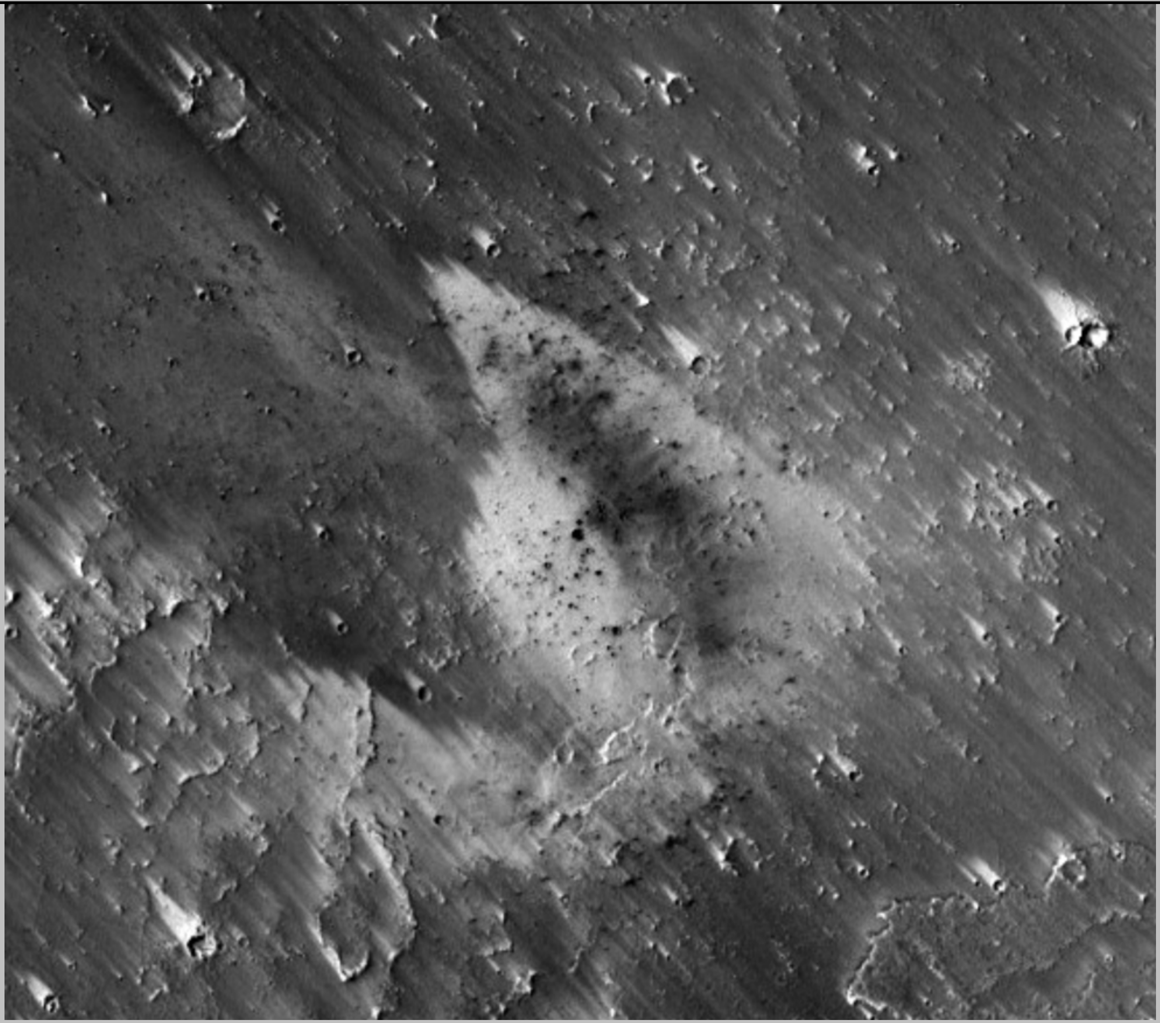


Rapid modification of recent impact feature – HiRISE.

[Sorry – no scale bar or lat/lon!]





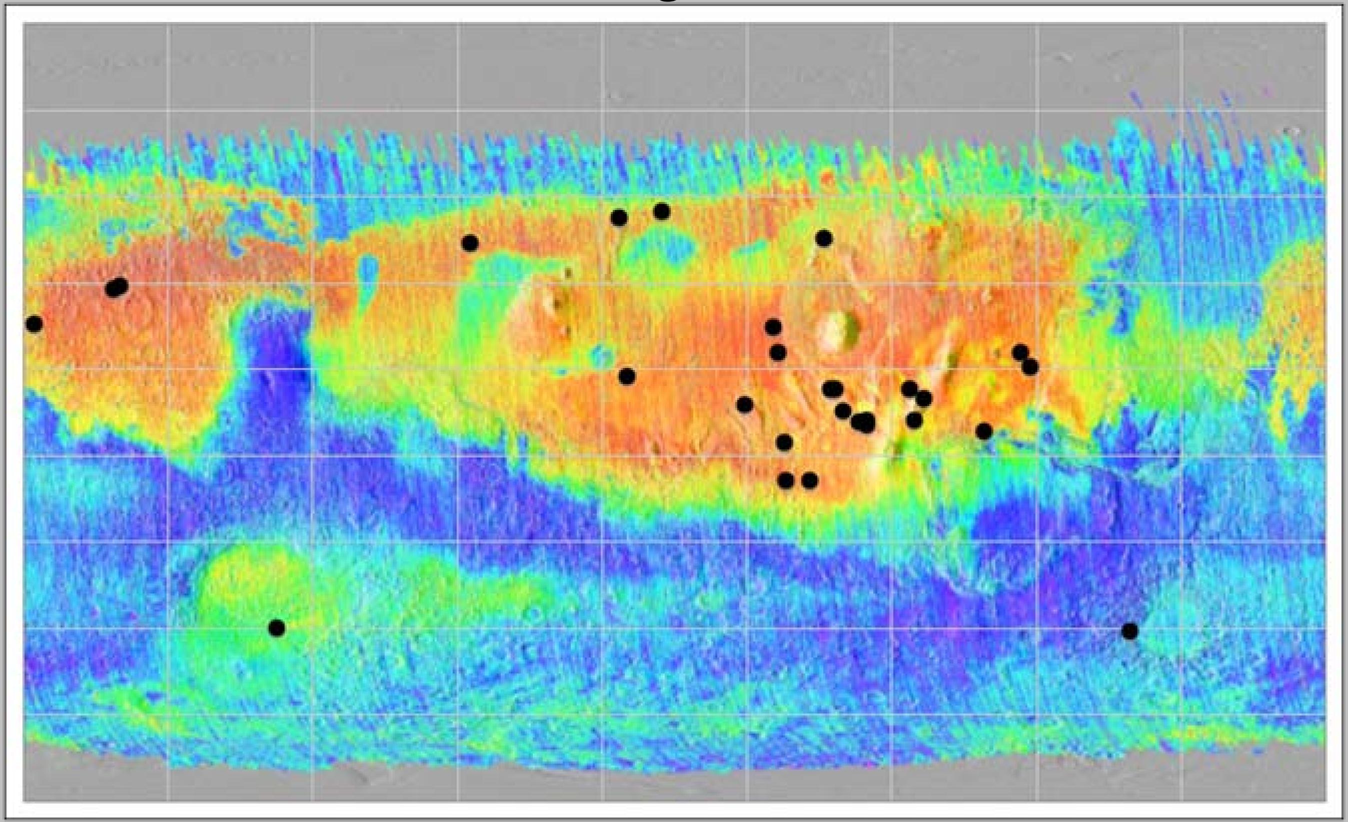


~75 New small craters

Huge bias in crater discovery locations

- Dusty areas
- Good weather

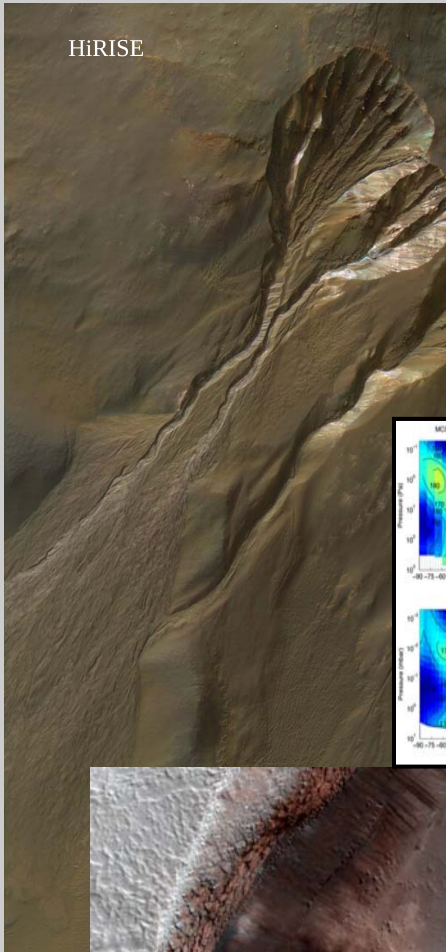
~2/3 of known craters in one region

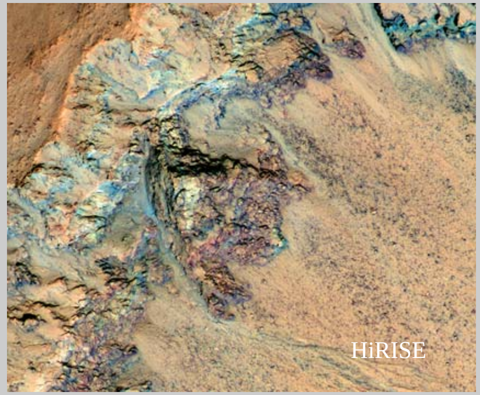


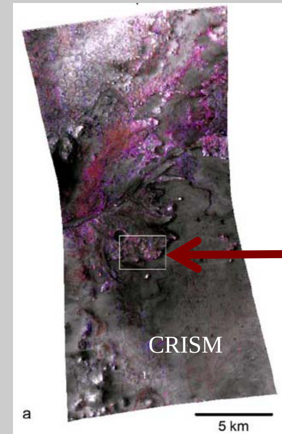
Craters with TES dust index (Ruff & Christensen, 2002)
Daubar and McEwen, LPSC 2009

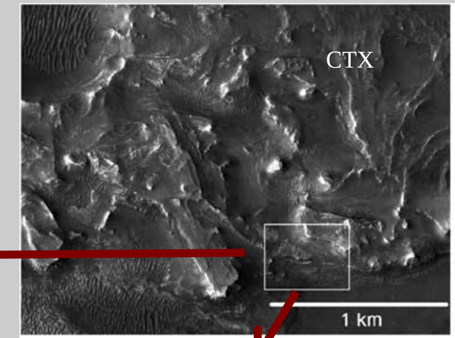
MRO Science Highlights

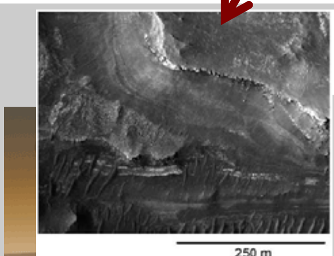
Mars Reconnaissance Orbiter

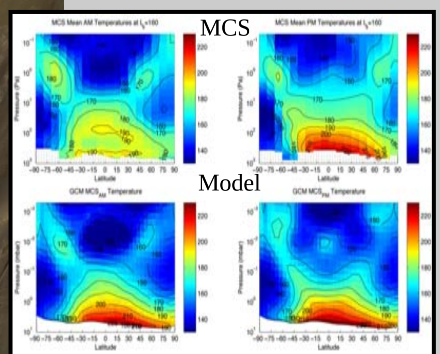


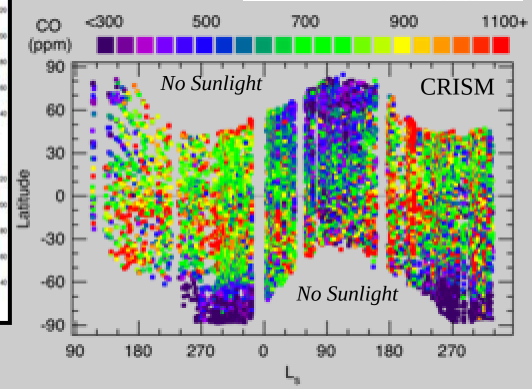


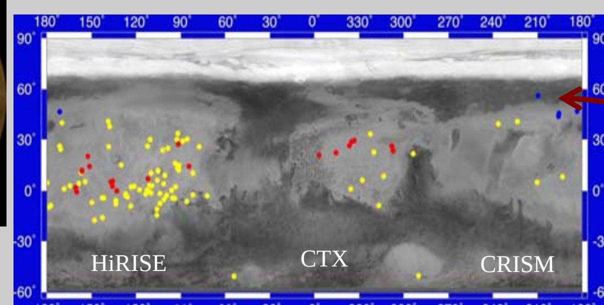












MRO/JPL/NASA

MRO Summary

Mars Reconnaissance Orbiter

- **MRO continues to be a very productive mission**
- **The spatial resolution of the MRO instruments, in nearly all modes, and the ability of the spacecraft to return the resulting large volume of data are superior to any deep space orbital missions flown to date or planned for the foreseeable future**
  - These capabilities are also needed for the support of future missions (MSL, 2016 ESA EDL Demo, 2018 MAX-C/ExoMars) through these functions:
    - Landing site selection: Identification, Characterization, Certification
    - Environmental monitoring for EDL and surface operations
    - Near-real time coverage for EDL
- **The science plan going forward:**
  - Continue to work with MER, MEX, ODY and MSL teams to identify key targets and coordinate observations
  - Continue to expand coverage in space and time of the surface and atmosphere
  - Expand high resolution coverage (mosaics) of interesting locales (e.g., in Valles Marineris)
  - Capture seasonal, interannual and long-term change