# The Mars Exploration Rovers and Water on Mars

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CLEO Lunch Talk

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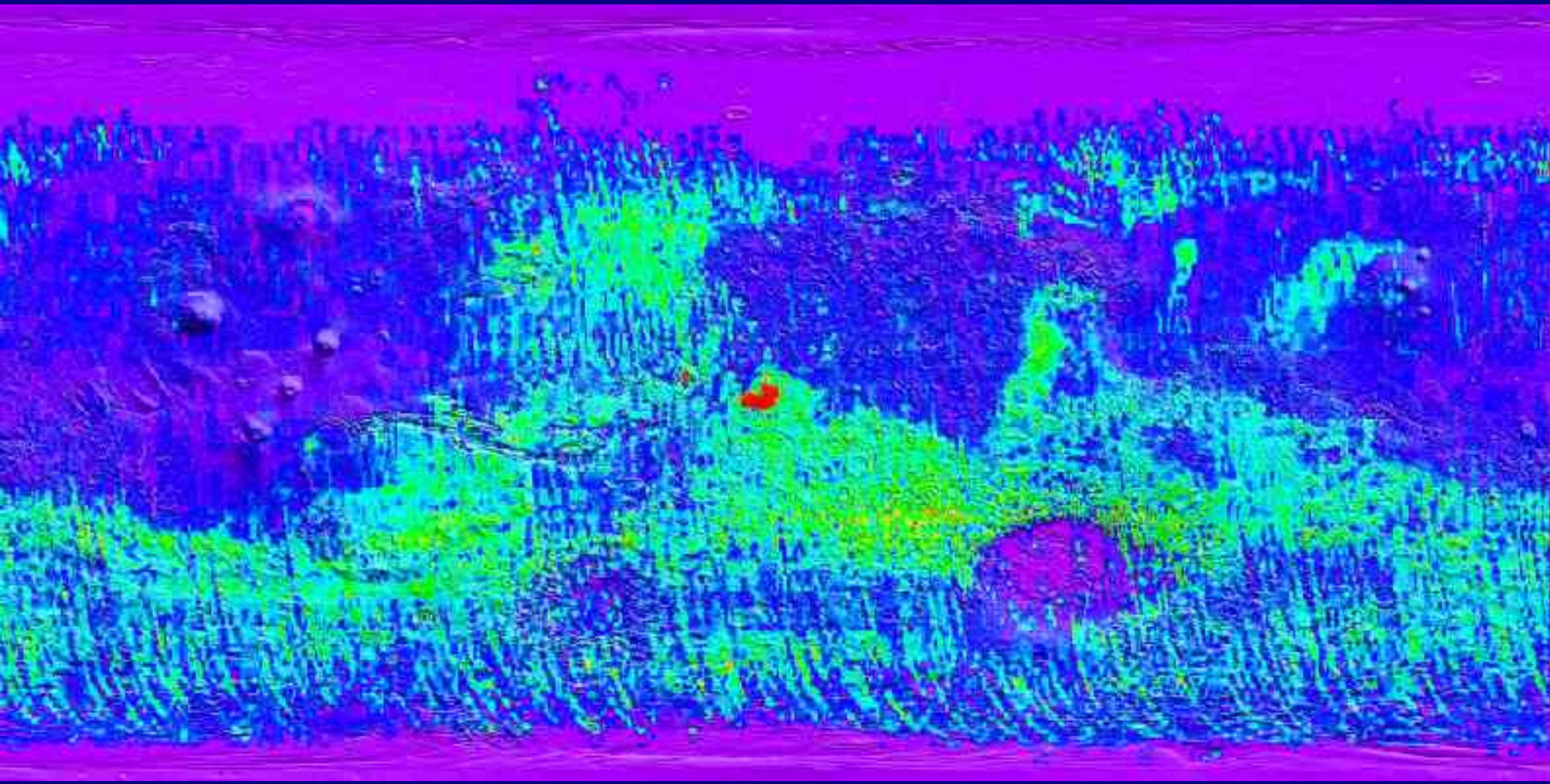
# Mars Global Surveyor (MGS)

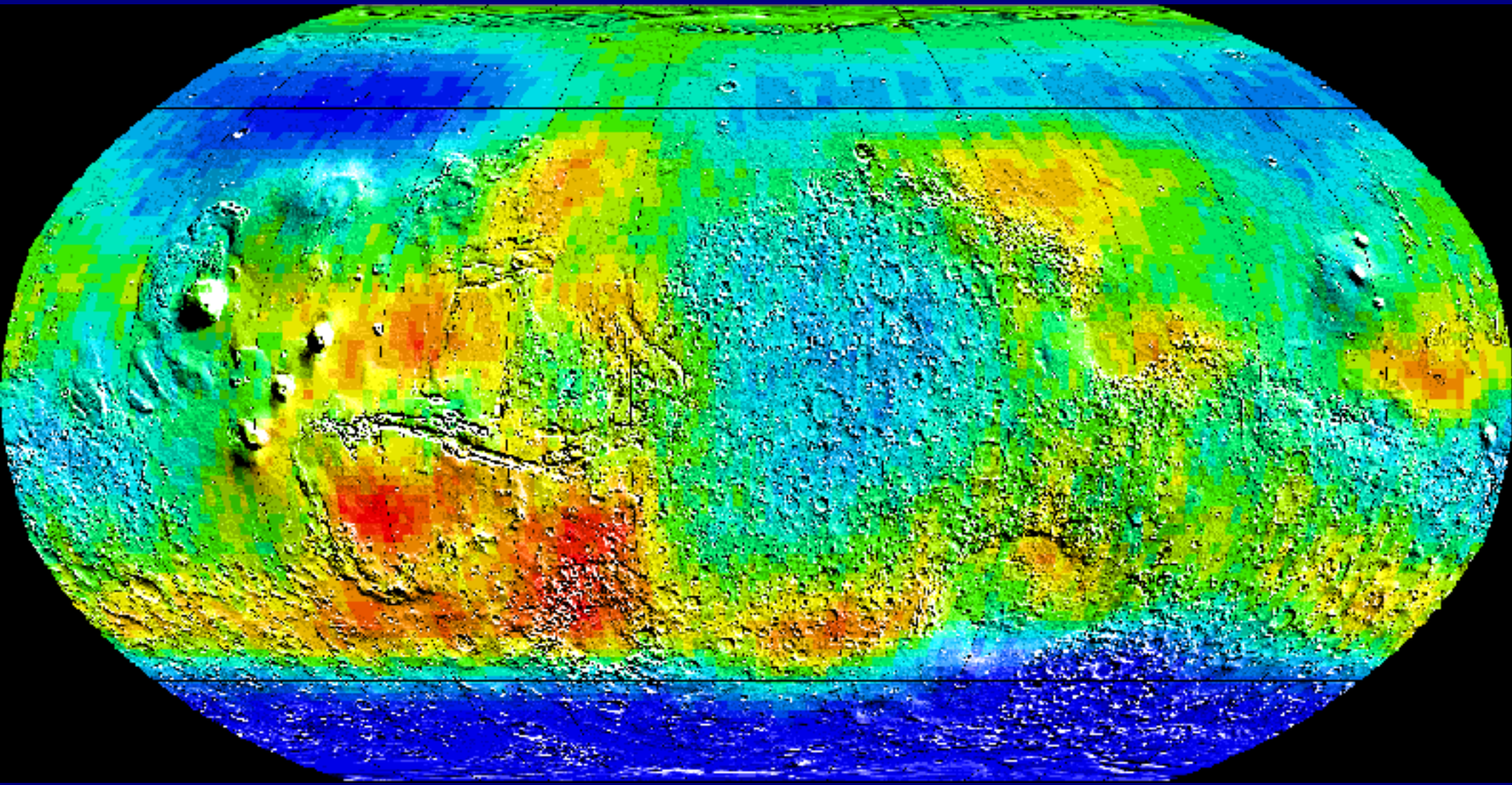
- Entered orbit in 1997
- Responsible for some recent evidence of water
  - Gullies
    - Appear to be water outflow channels
    - Appear to be recent
    - Weird distribution with latitude
  - Thermal Emission Spectrometer (TES):
    - Low resolution spectrometer, designed to classify minerals
    - Hematite!



Hematite density (red is higher)

# Mars Odyssey

- Entered orbit in 2001
- Neutron spectrometer has provided clear evidence for water ice
  - Enormous amounts of polar hydrogen (thought to be water ice)
  - Some hydrogen at lower latitudes (locked up in rocks?)



Hydrogen density (blue is higher)

# Mars Exploration Rovers

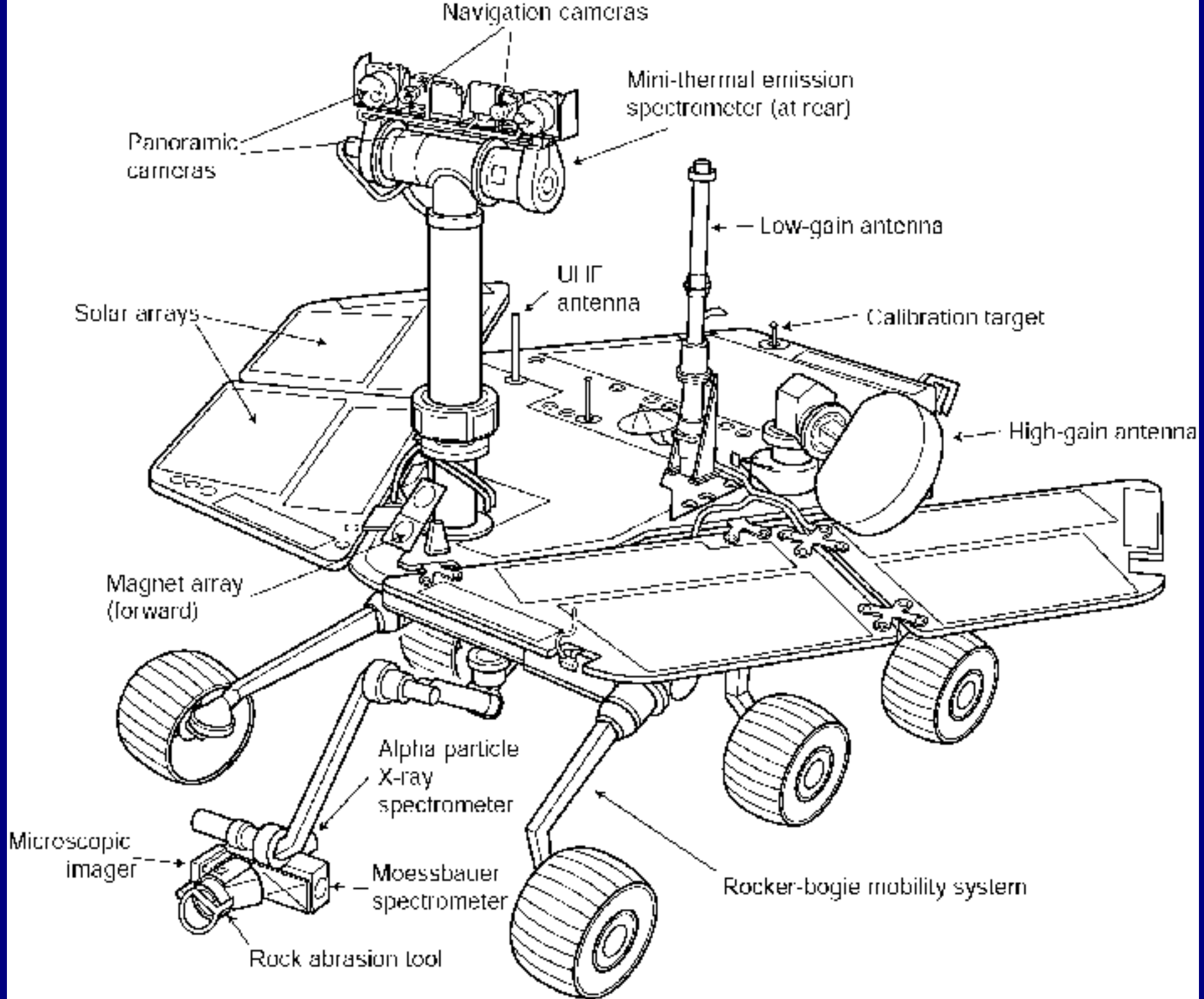
- Roughly 50 m / day top speed
  - Not yet achieved, but probably soon
- Very autonomous:
  - Joysticking them isn't practice given the current ~10 minute light travel round trip time

# Mast-mounted instruments

- Pancam
  - Pretty pictures
  - Fourteen visual and near-IR filters
  - Stereo vision, w/ camera spacing and height roughly equivalent to human eyes
- Mini-TES
  - Similar to MGS-TES (Christensen is the lead on both)

# IDD (Arm) mounted instruments

- Microscopic imager
  - 3 cm x 3 cm field
  - 1024x1024 pixels
- Alpha-particle X-ray Spectrometer
  - Atomic abundances
- Moessbauer Spectrometer
  - Chemical composition & oxidation states of Fe bearing minerals
- The RAT (not exactly an instrument)


Navigation cameras
Mini-thermal emission spectrometer (at rear)
Panoramic cameras
Low-gain antenna
UHF antenna
Solar arrays
Calibration target
High-gain antenna
Magnet array (forward)
Alpha particle X-ray spectrometer
Microscopic imager
Moessbauer spectrometer
Rock abrasion tool
Rocker-bogie mobility system

# Landing sites

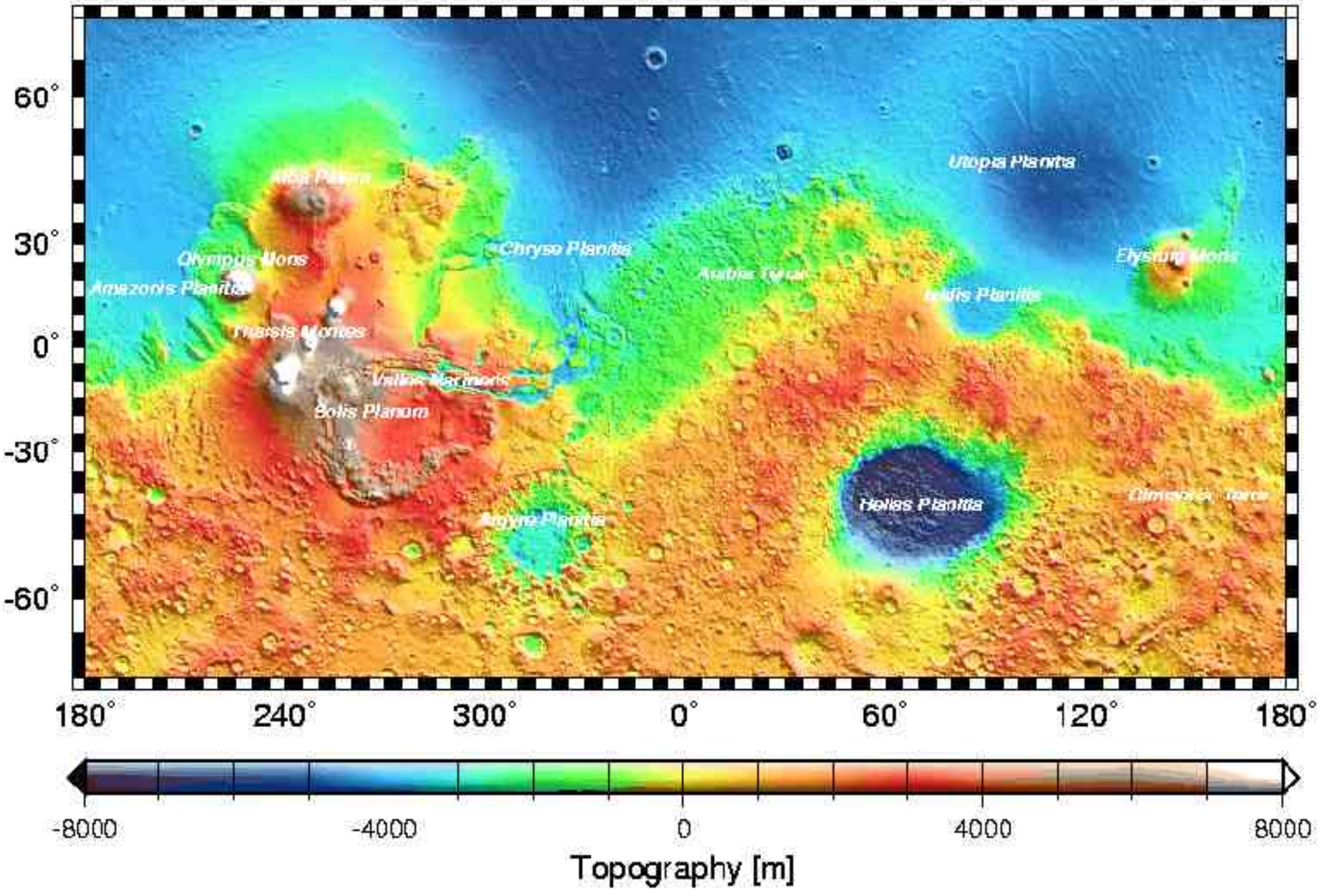
- Little of Mars' surface safe for landing!
- Gusev Crater
  - Crater with what seems like an obvious flow channel in, and no channel out
    - Standing water seems like an obvious conclusion! Is it correct?
  - Problem: High winds
- Meridiani Planum / Terra Meridiani
  - Hematite

# Gusev Crater

- Crater with what seems like an obvious flow channel in, and no channel out
  - Standing water seems like an obvious conclusion! Is it correct?
- Problem: High winds
  - Engineers weren't happy... motivated a decent imager to measure wind-induced ground speed and cross-range rockets on the backshell.

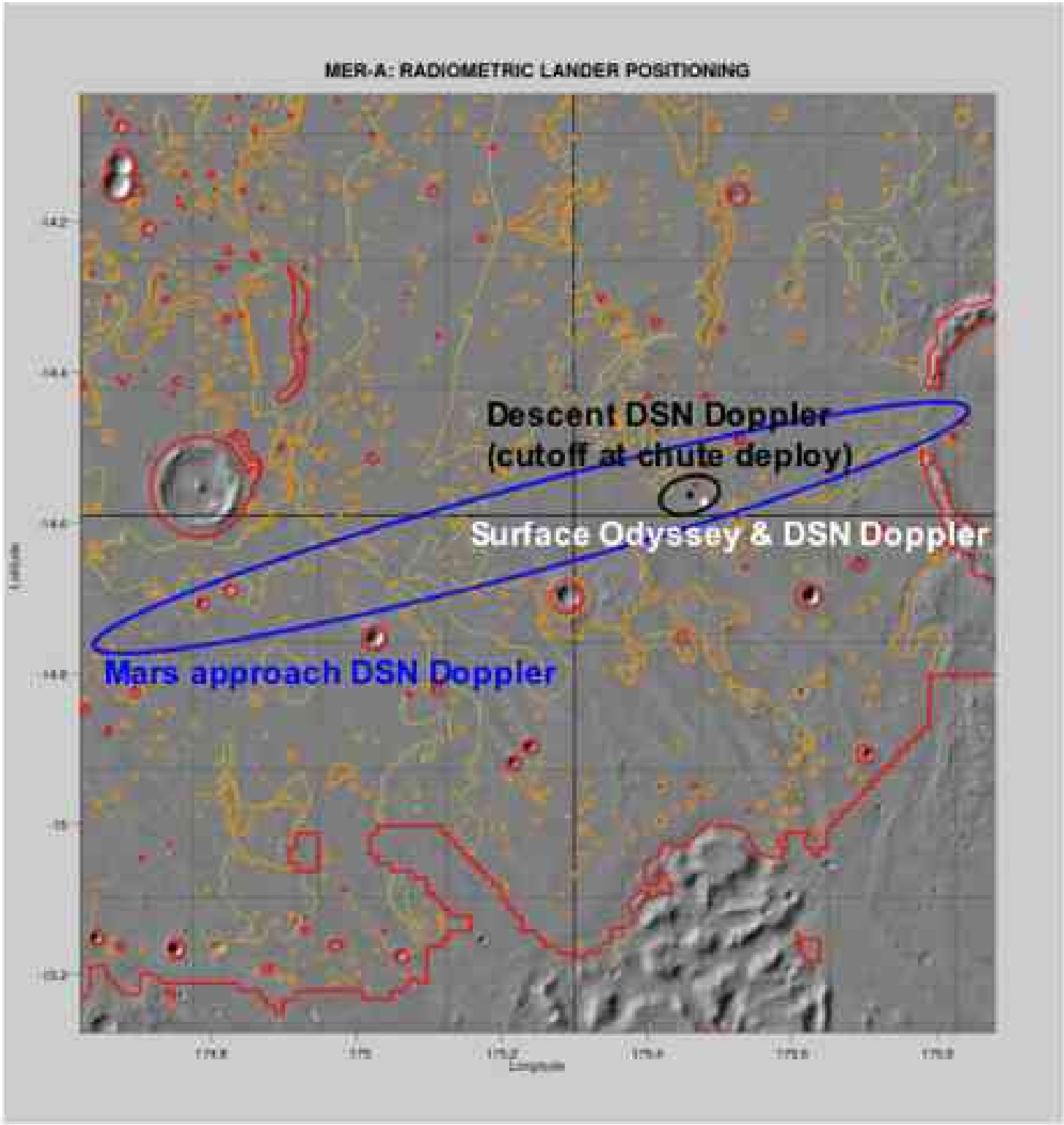
# Meridiani Planum / Terra Meridiani

- Hematite


60°
30°
0°
-30°
-60°
180°
240°
300°
0°
60°
120°
180°
Utopia Planitia
Olympus Mons
Amazonis Planitia
Chryse Planitia
Arabia Terra
Elysium Mons
Tharsis Montes
Valles Marineris
Solis Planum
Hellas Planitia
Argyre Planitia
-8000
-4000
0
4000
8000
Topography [m]

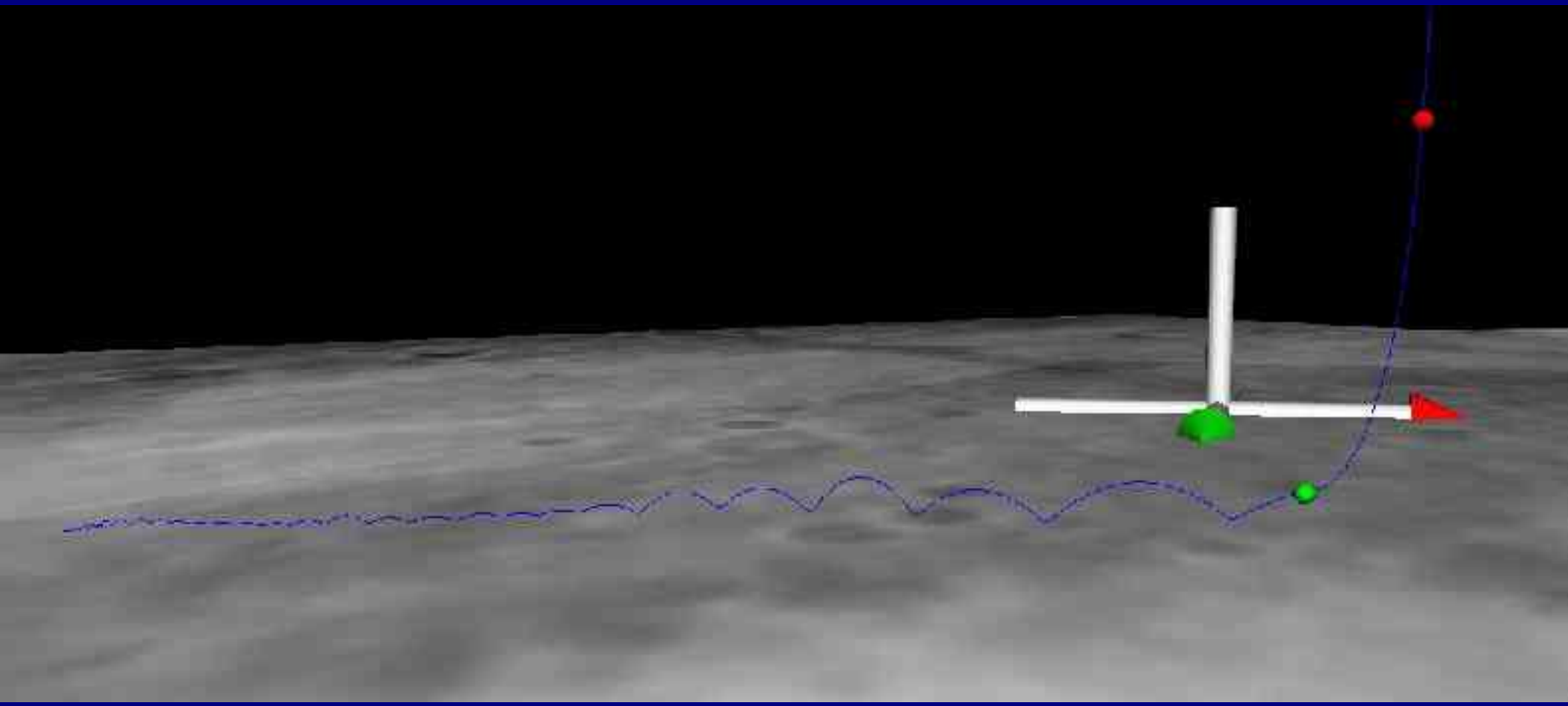
# MER-A: Spirit

- Critical questions:
  - Did standing water ever exist in Gusev Crater?
  - If it did, where is the lake bed? Near the current surface, or deep below?
  - What other aqueous processing may have occurred?
- So, some things to look for...
  - Sedimentary rocks
  - Evidence of water processing of other rocks & soil

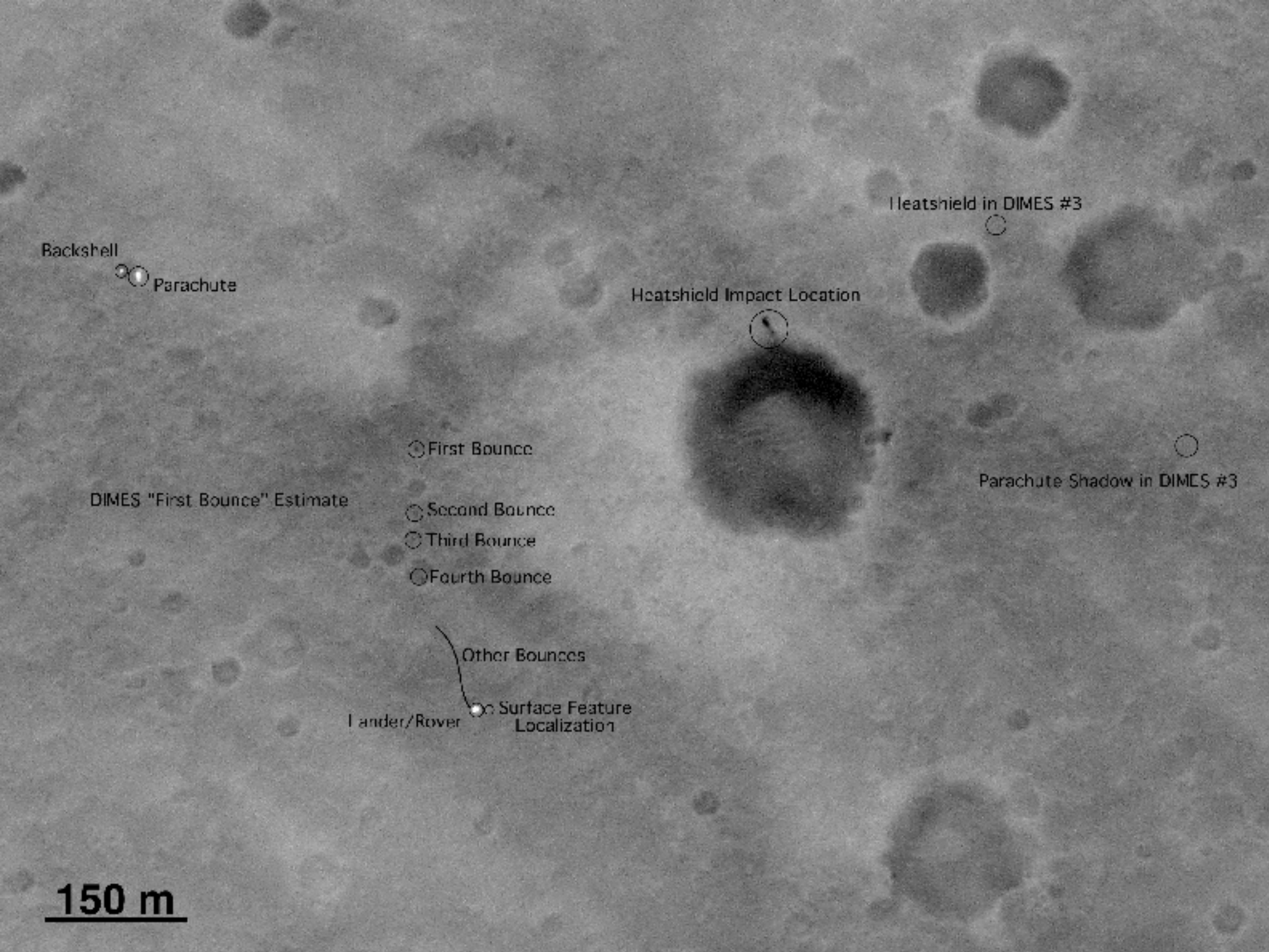

MER-A: RADIOMETRIC LANDER POSITIONING
Descent DSN Doppler
(cutoff at chute deploy)
Surface Odyssey & DSN Doppler
Mars approach DSN Doppler

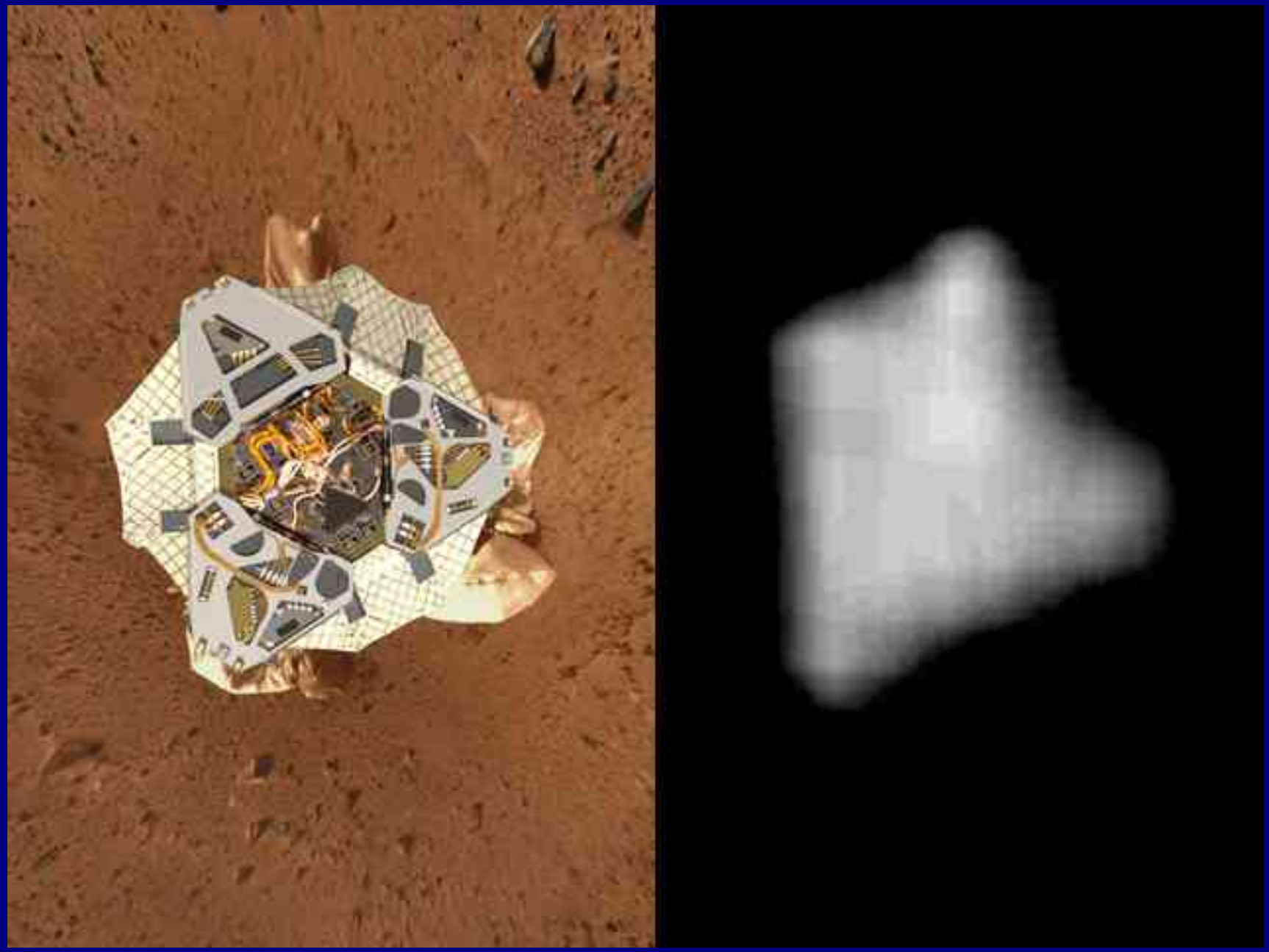
# Spirit immediate vicinity

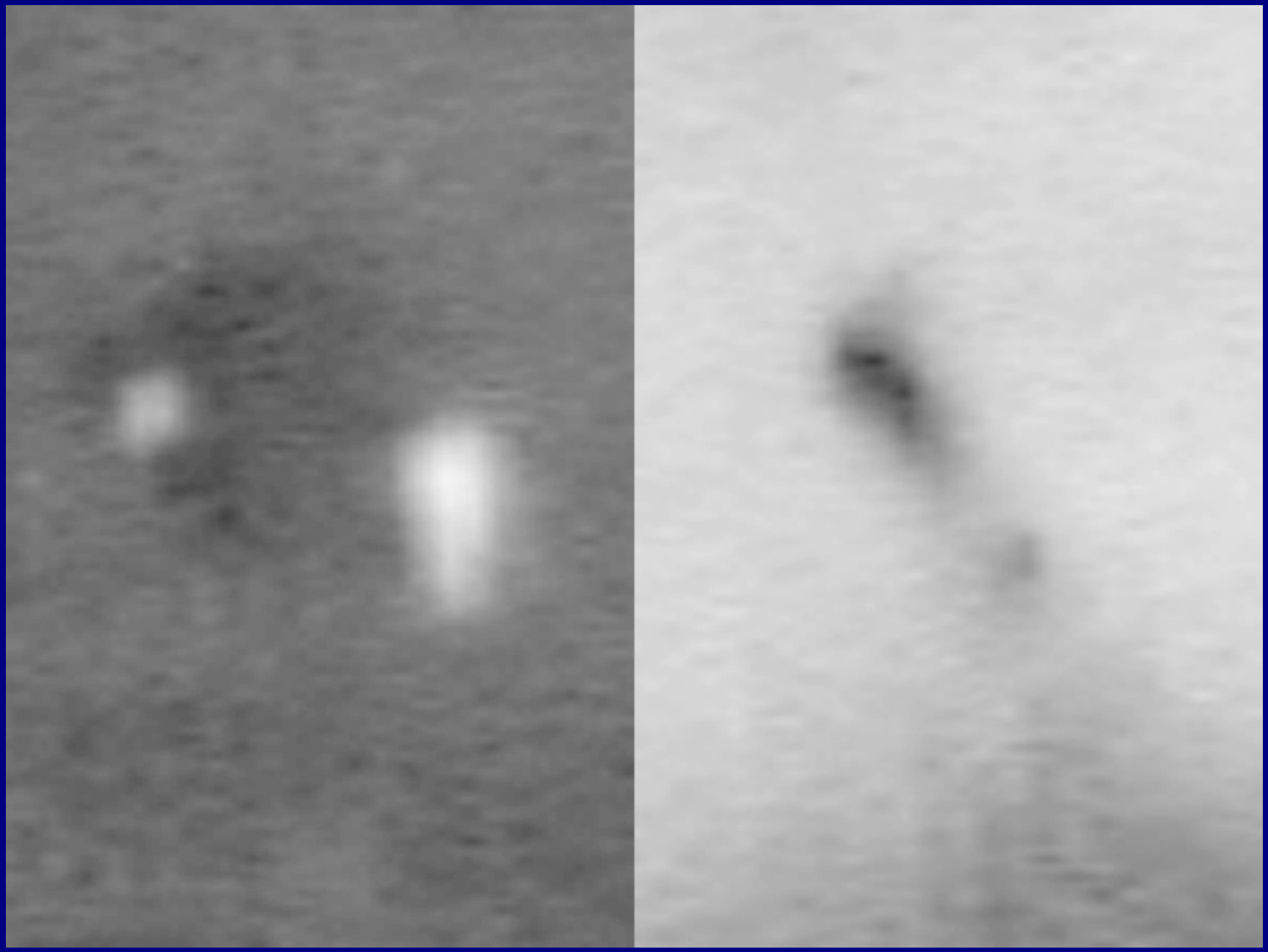
- Fewer and smaller rocks than Viking and Pathfinder sites... much safer to drive on
- Big crater near by
  - ~ 200 m diameter
  - 250 m away
- Hill complex 2-3 km to the east




Spirit took this image of the martian surface right before it landed.


Heatshield in DIMES #3
Backshell
Parachute
Heatshield Impact Location
First Bounce
Parachute Shadow in DIMES #3
DIMES "First Bounce" Estimate
Second Bounce
Third Bounce
Fourth Bounce
Other Bounces
Surface Feature Localization
Lander/Rover
150 m





Backshell and Parachute

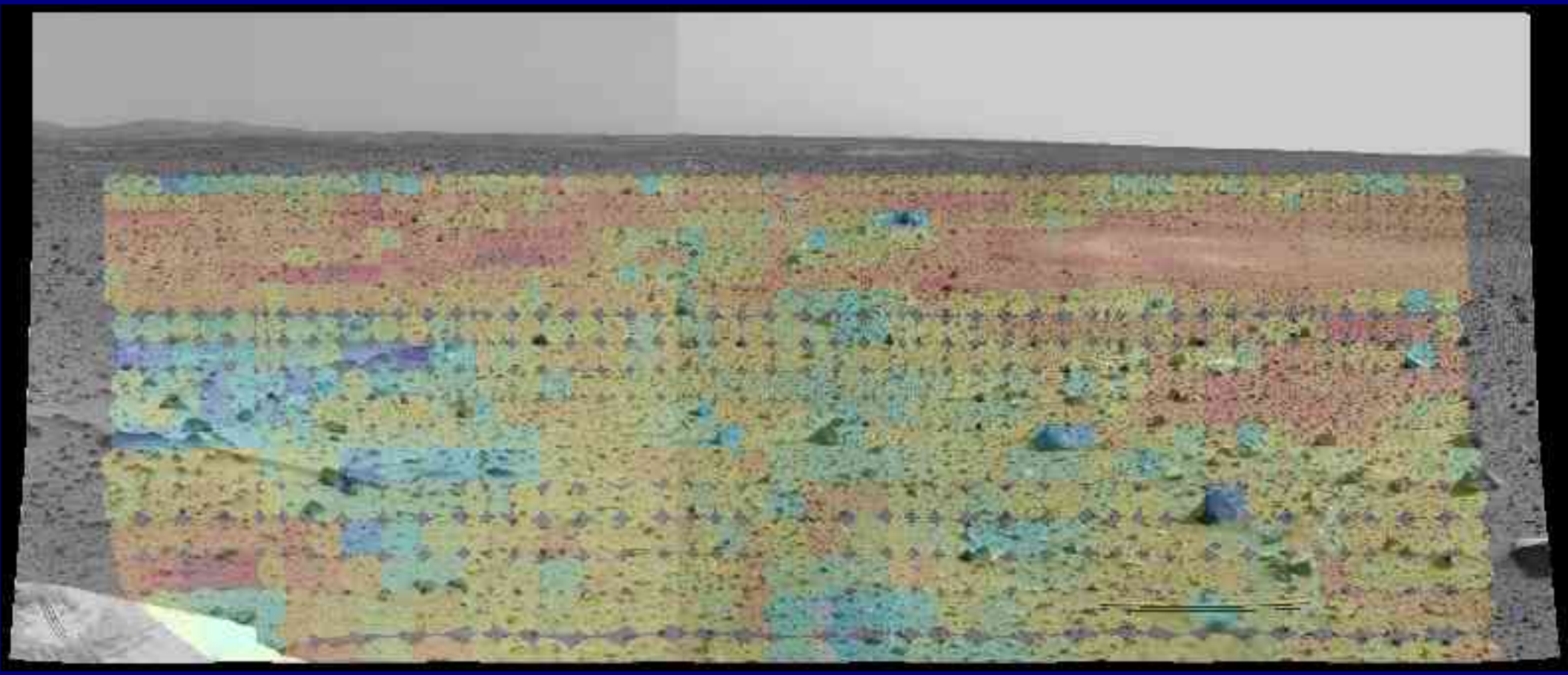
Heat shield

# Landing

- Strong winds: It's animation time
- Mission Success Panorama

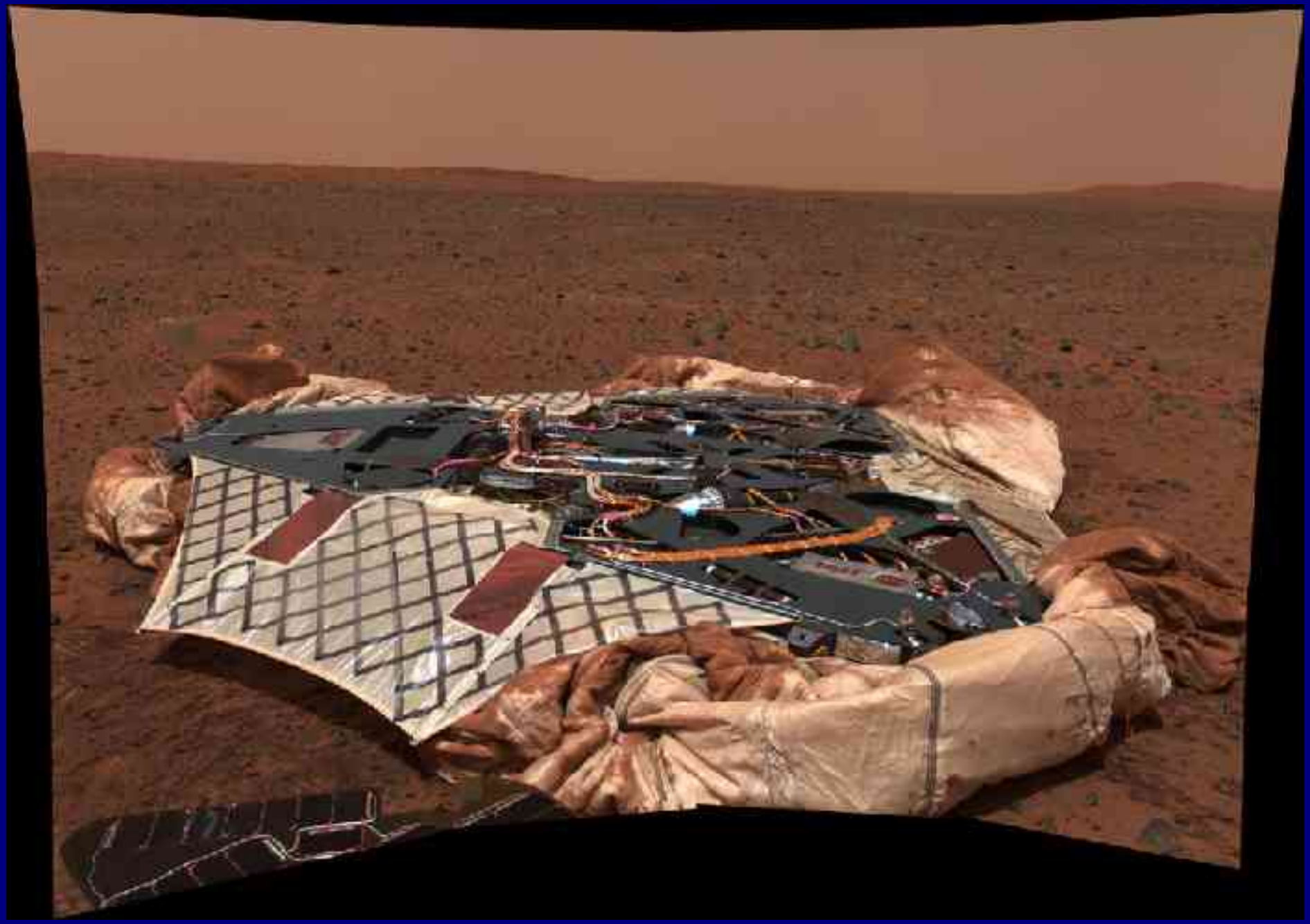
# Spirit activity so far

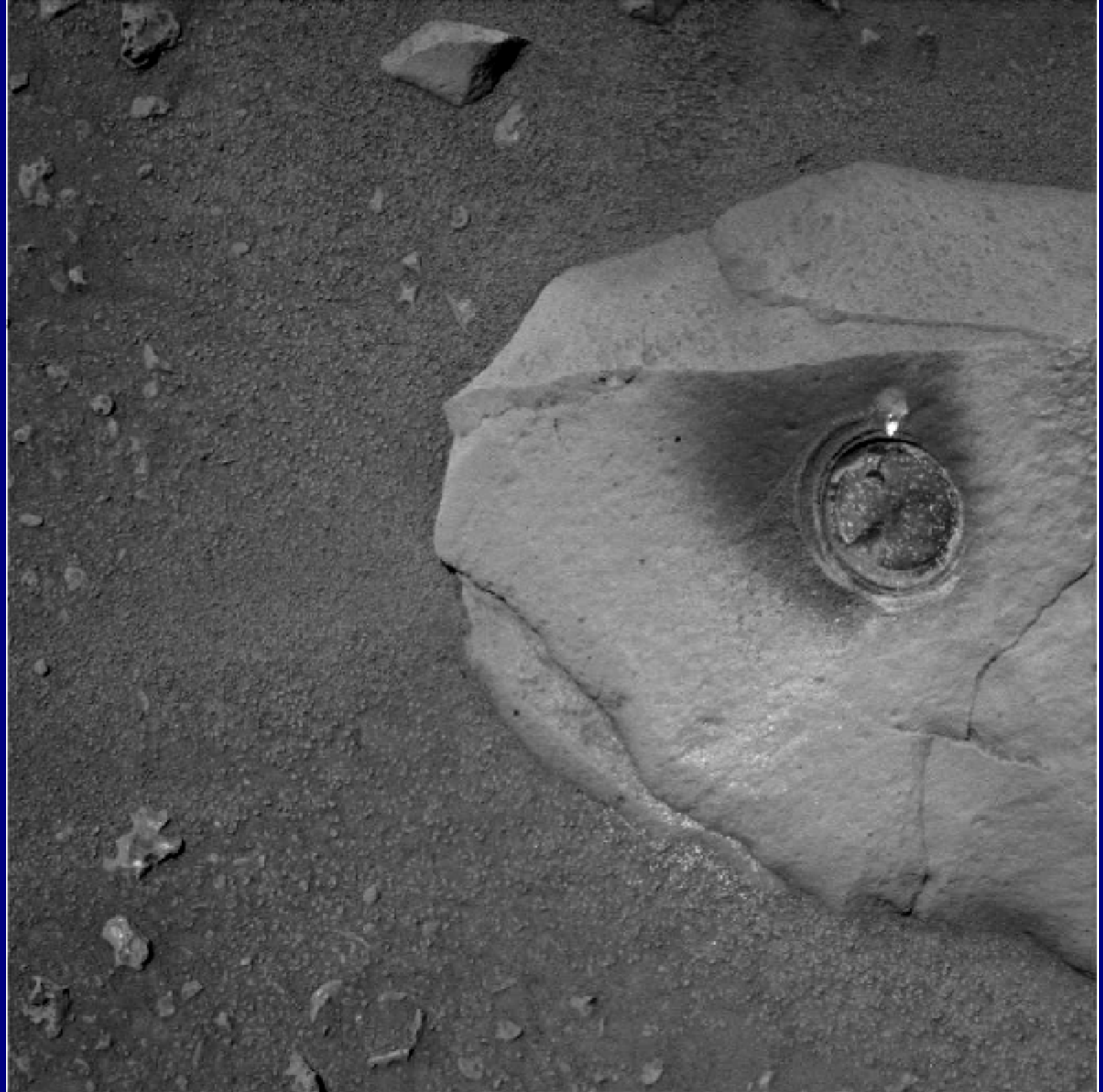
- Mapped surroundings
- Sampled several rocks (composition, morphology, etc.)
- Brushed and RATted a rock to test dust thickness and surface weathering
- Examined several regions of dust and soil, again for composition and morphology
  - Clumpiness has attracted notice... cementing by salts?

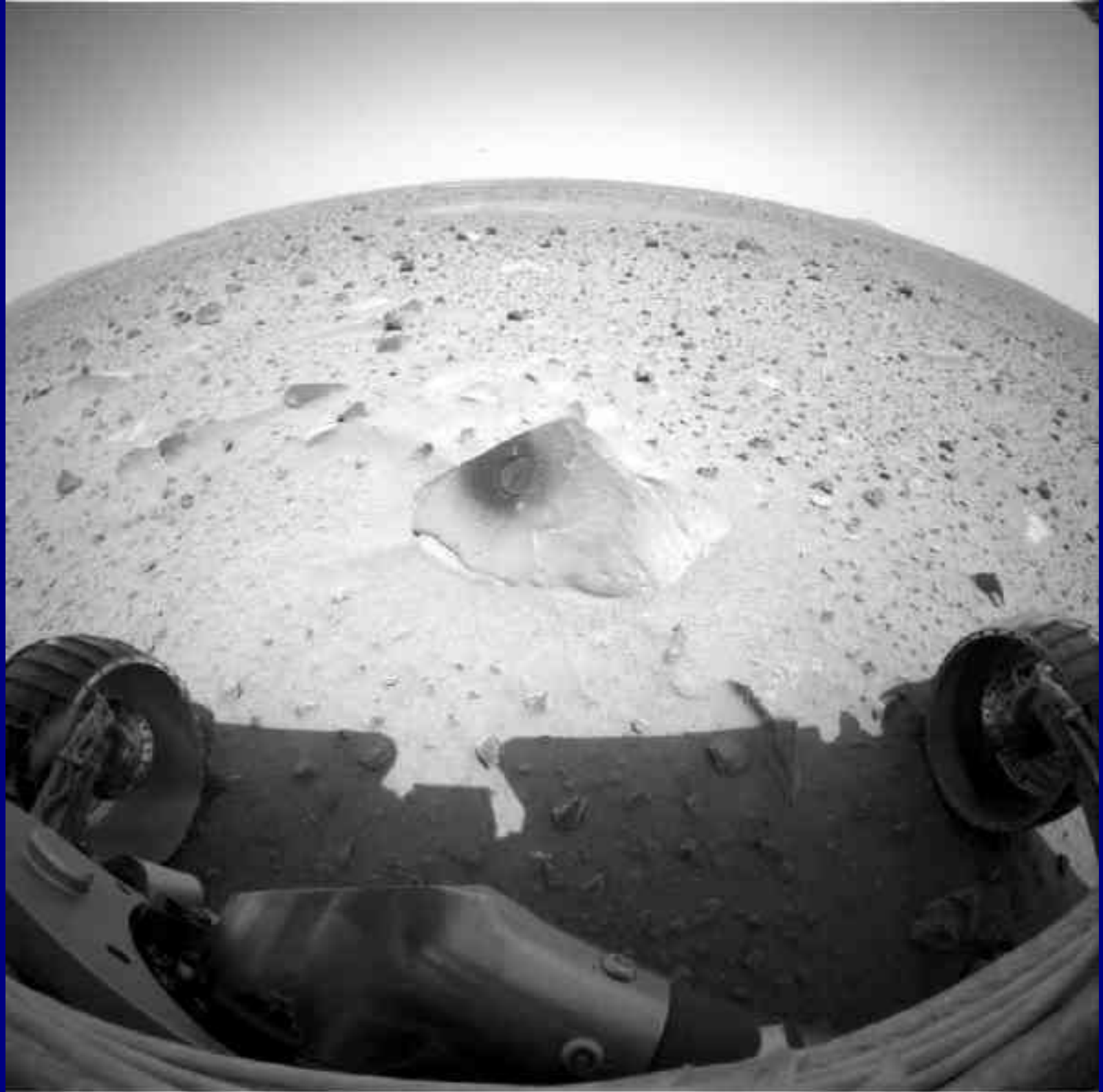


Mini-TES temperatures (red is warmer)

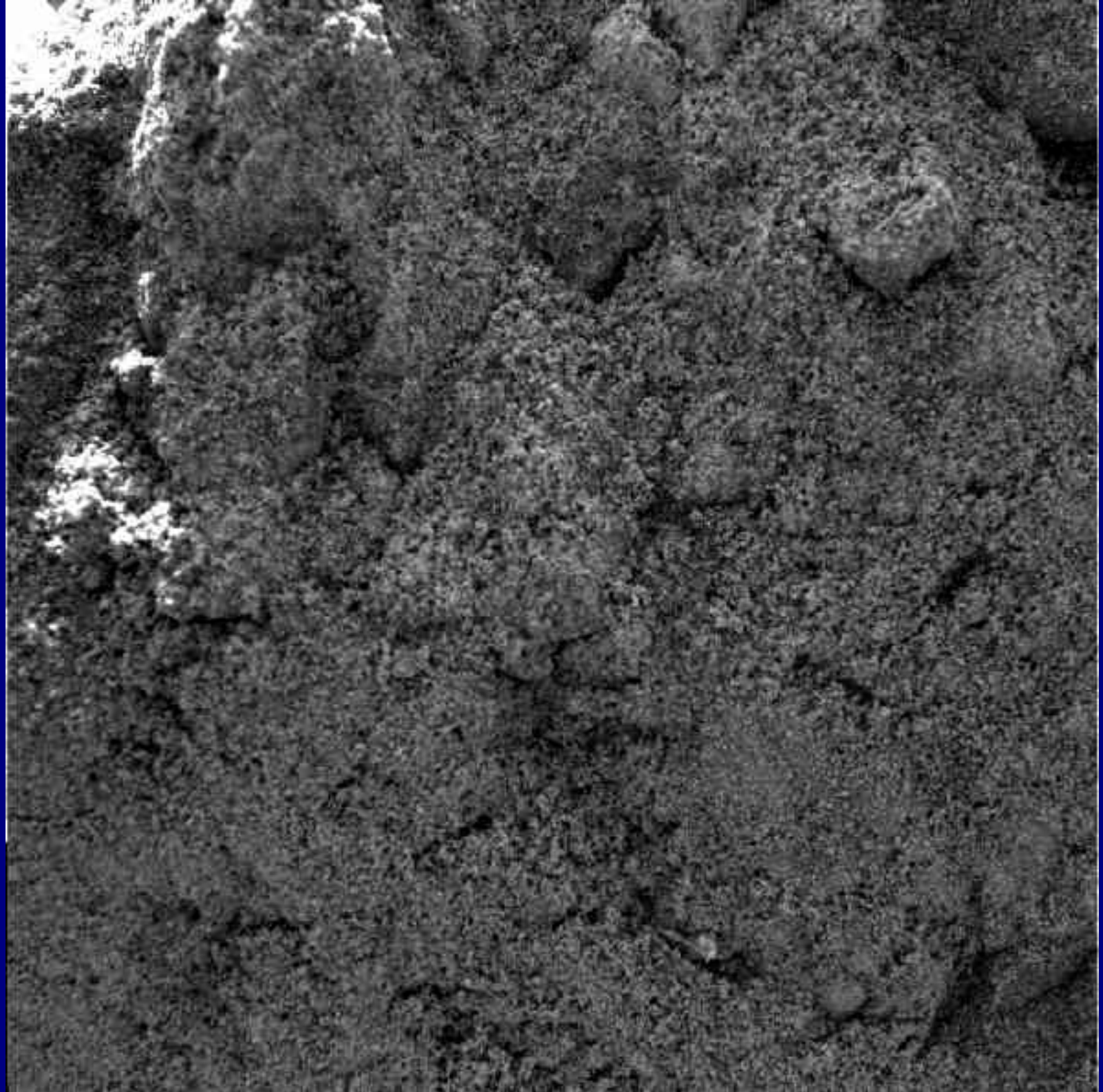

We are here.
JPL





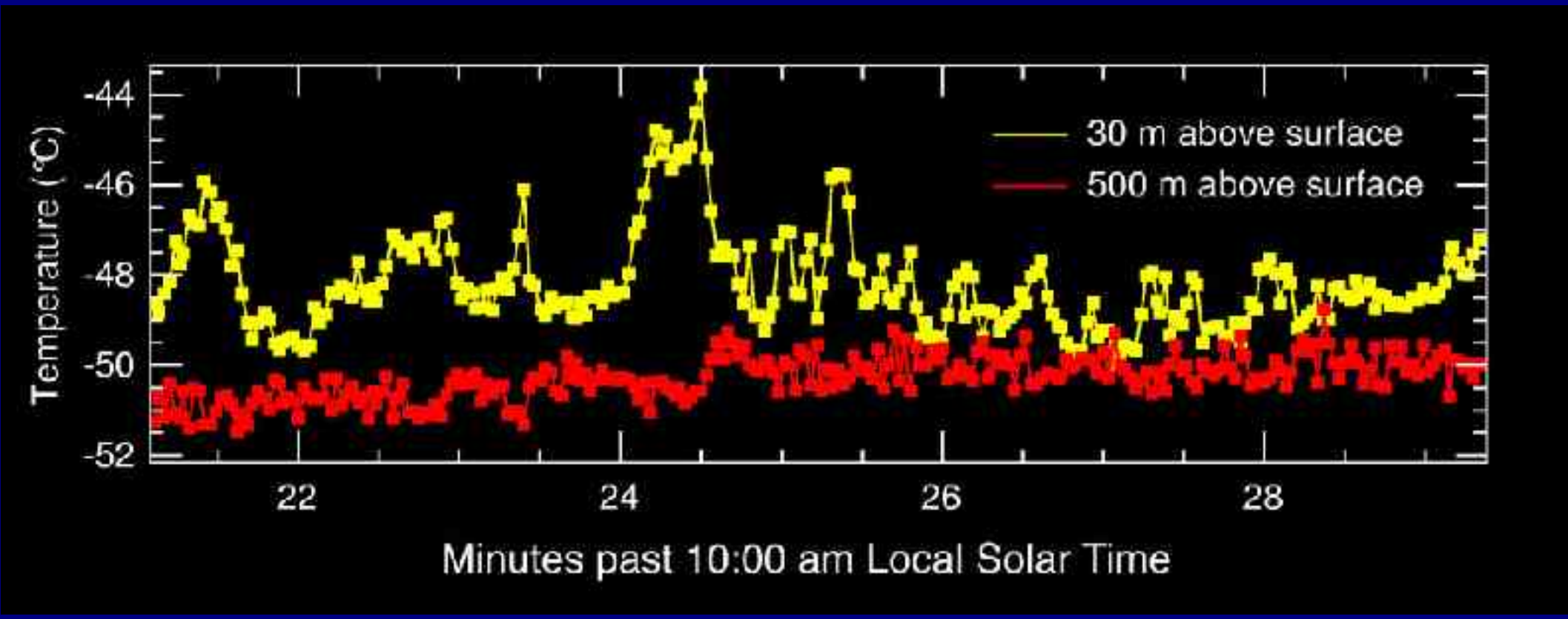


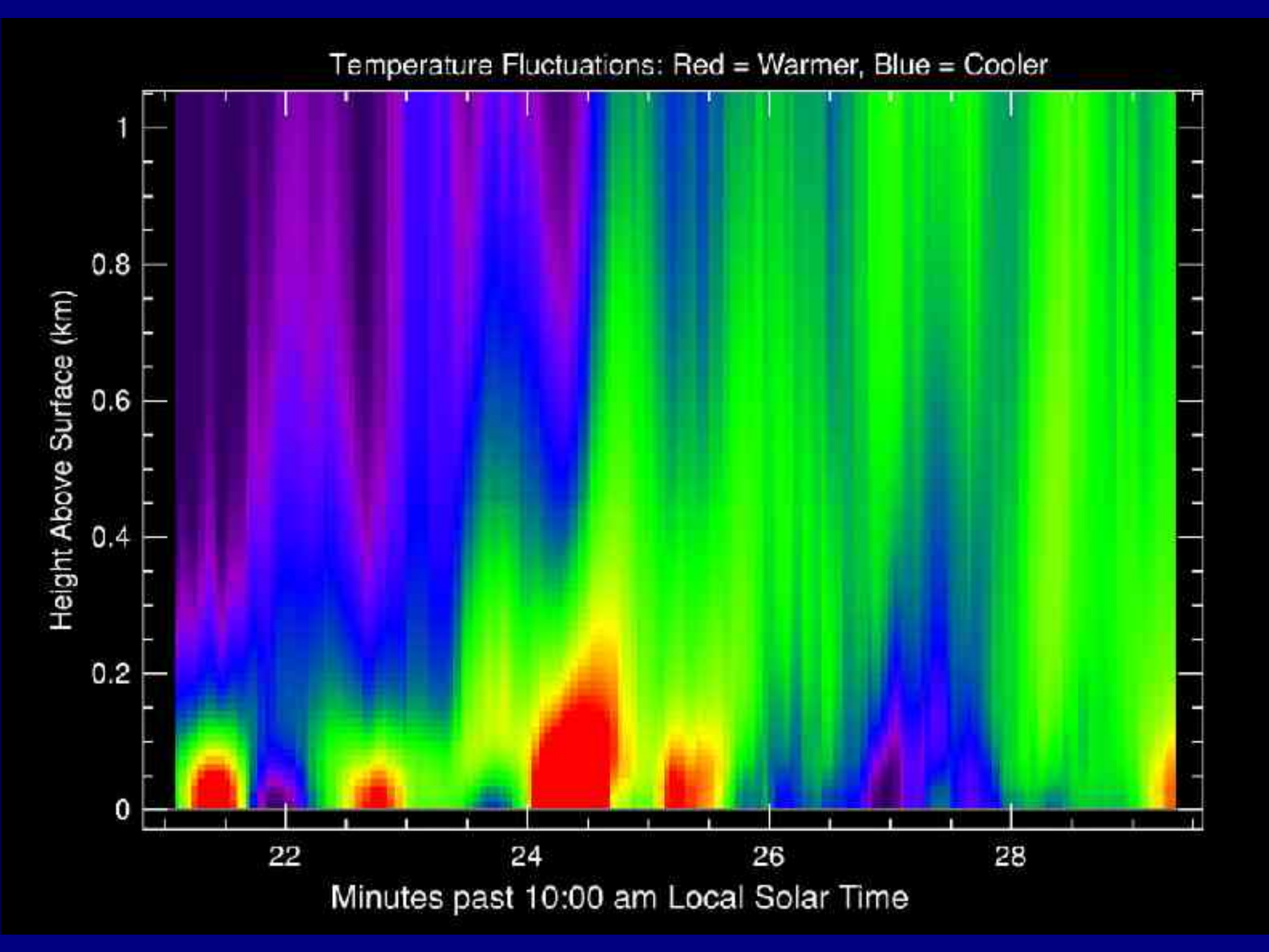

The lander



# Spirit activity so far (cont.)

- Atmospheric science!
- Most people are focused on geology, but Mini-TES is capable of significant atmospheric science

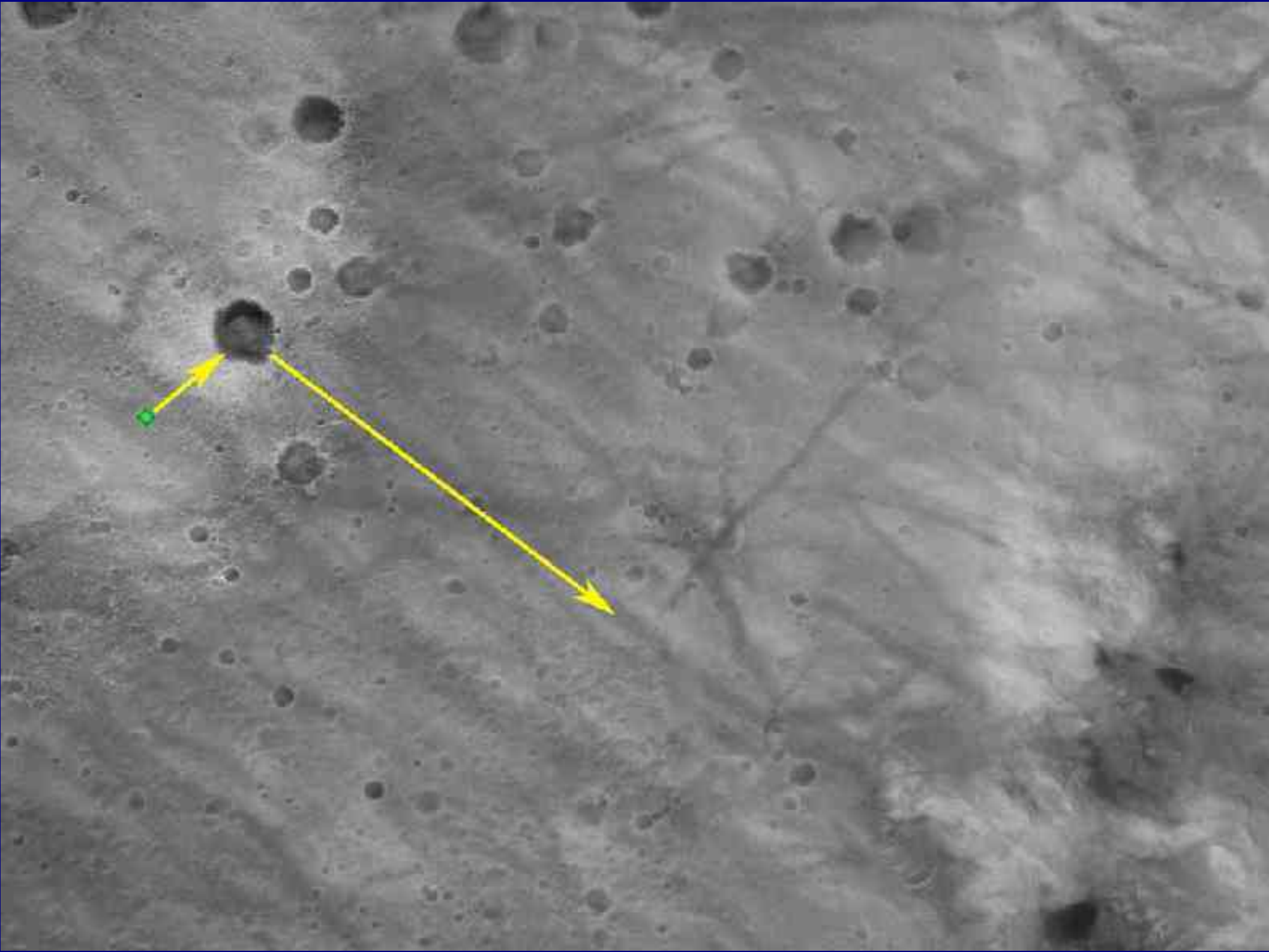

Temperature (°C)
-44
-46
-48
-50
-52
22
24
26
28
Minutes past 10:00 am Local Solar Time
30 m above surface
500 m above surface

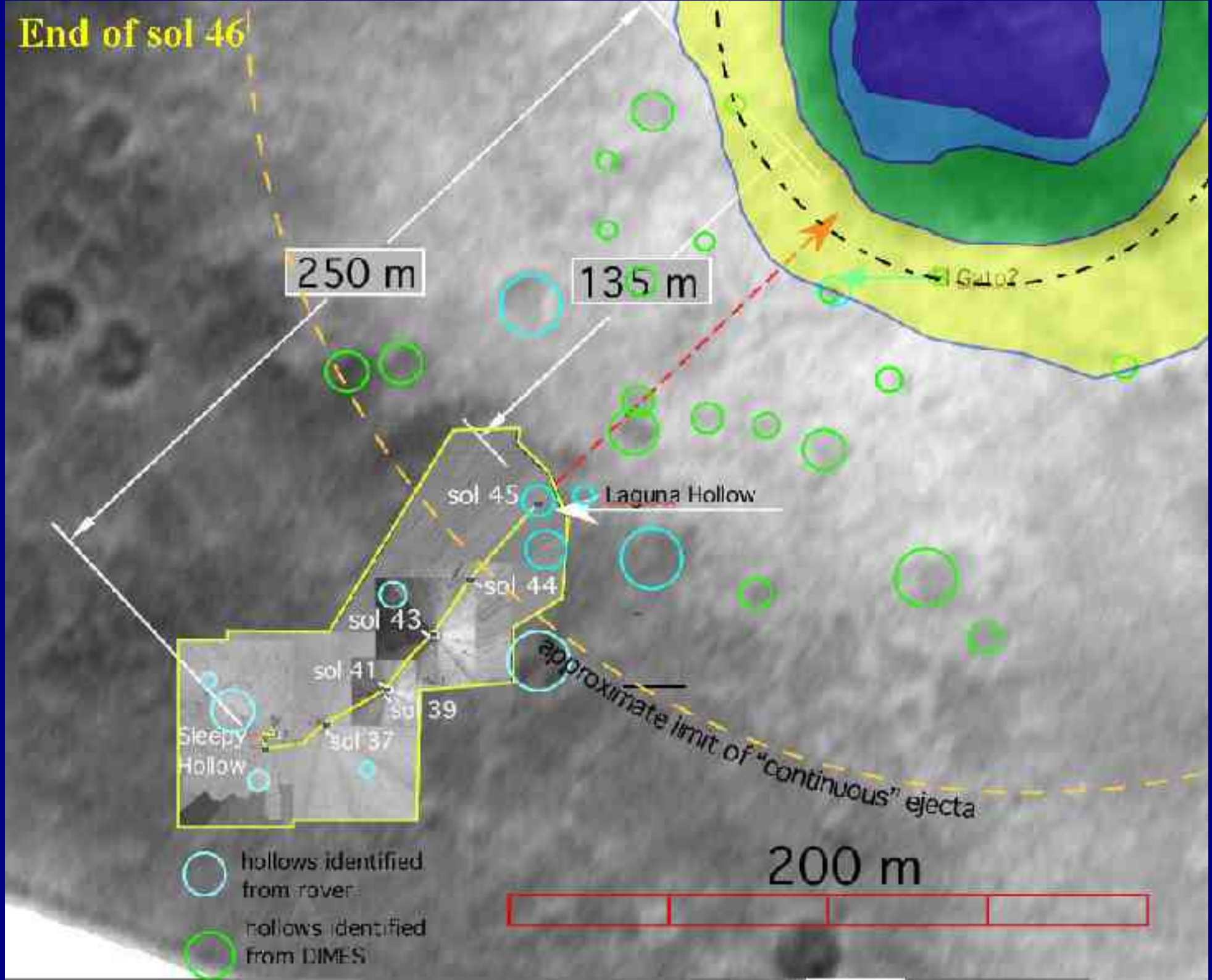

Temperature Fluctuations: Red = Warmer, Blue = Cooler
Height Above Surface (km)
1
0.8
0.6
0.4
0.2
0
22
24
26
28
Minutes past 10:00 am Local Solar Time

# Spirit plan

- Drive to the crater
  - Possibility of seeing to deeper layers from the rim
  - Ejecta can be examined along the way
  - Driving into the crater might not be possible, though
- Drive to the Columbia Hills Complex
  - Some think it is a protrusion of an underlying geological unit above the surface debris
  - May be to far to drive to, but Pancam and Mini-TES can make long-range observations

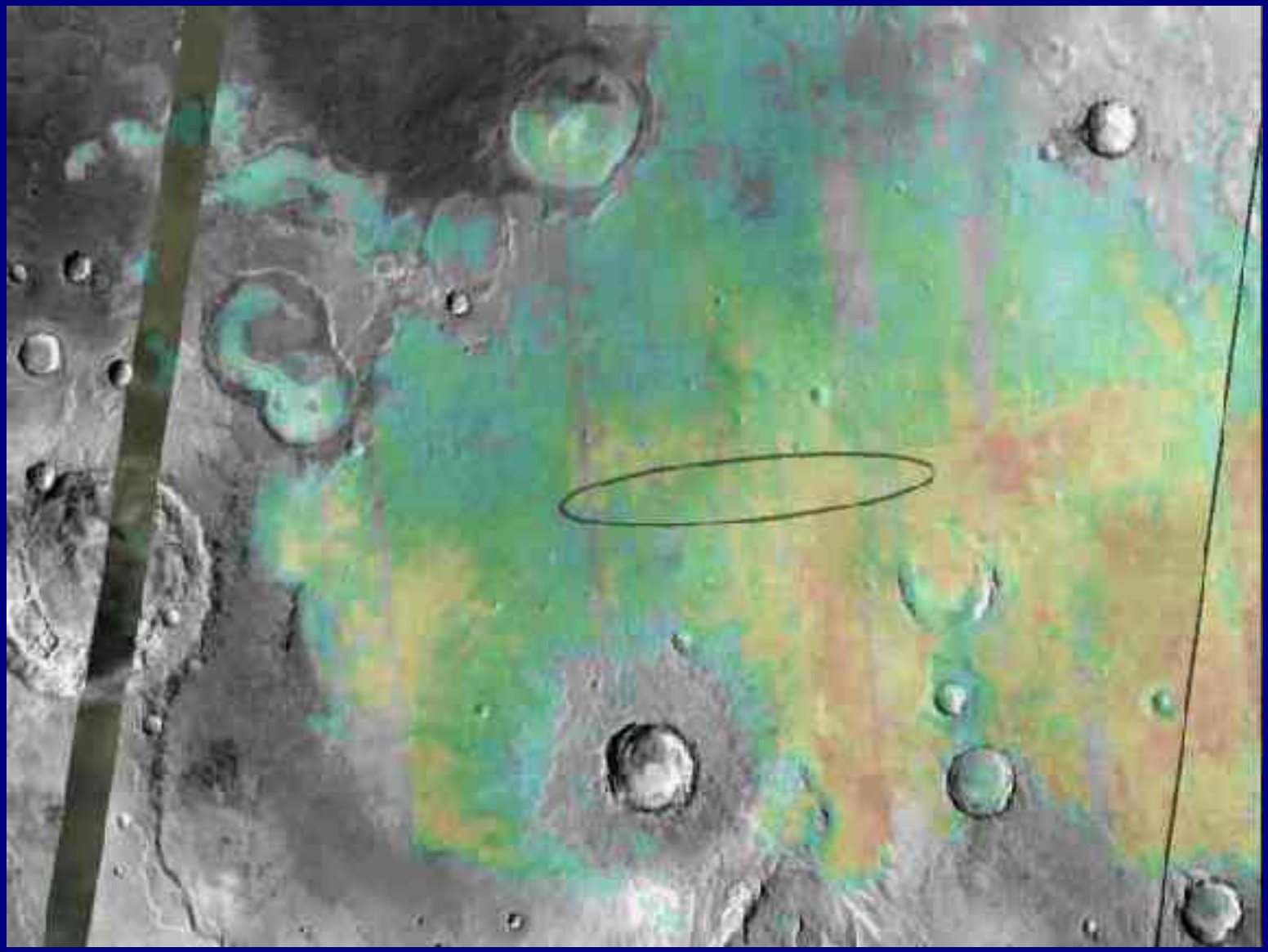
The crater rim

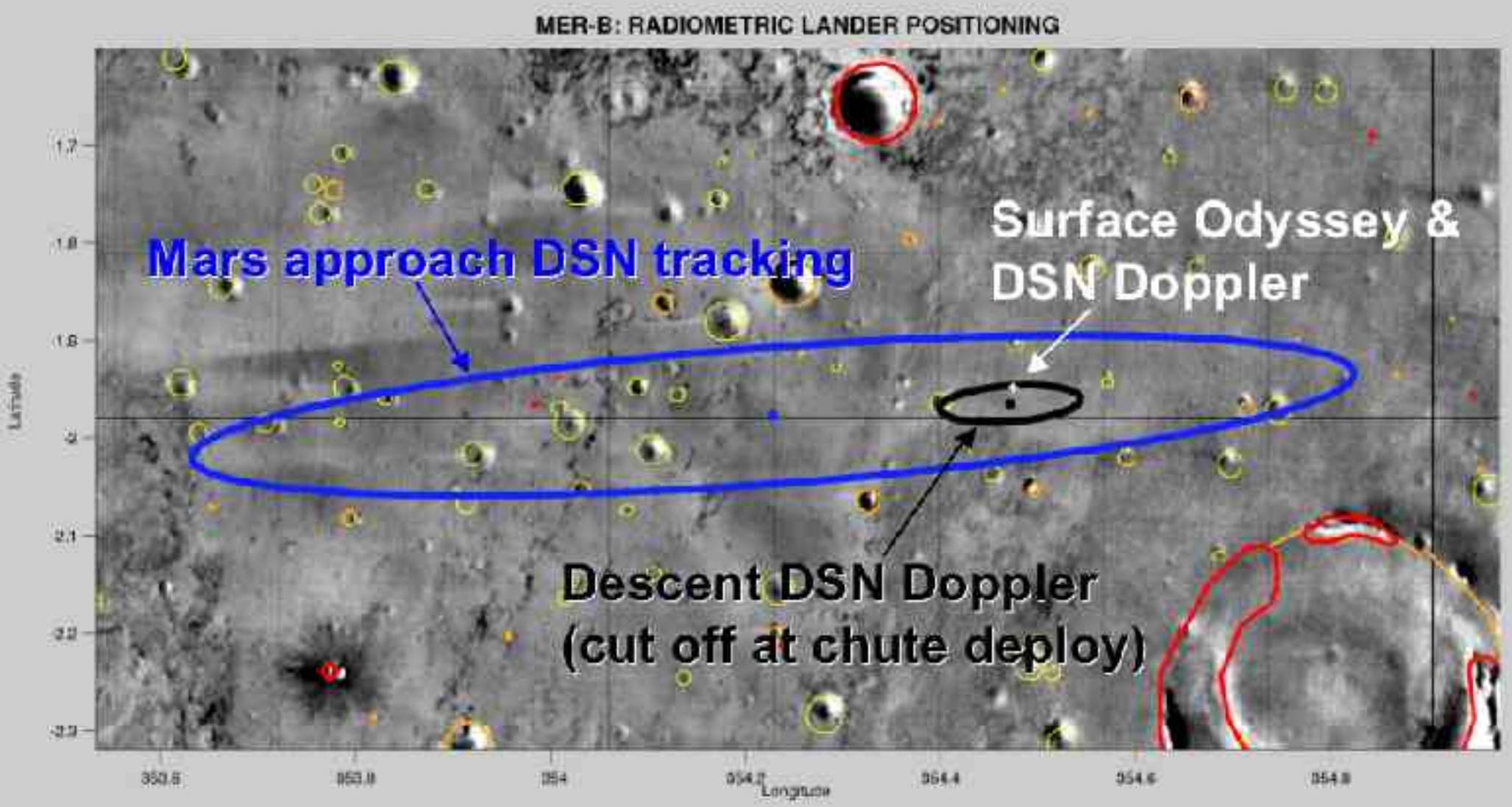


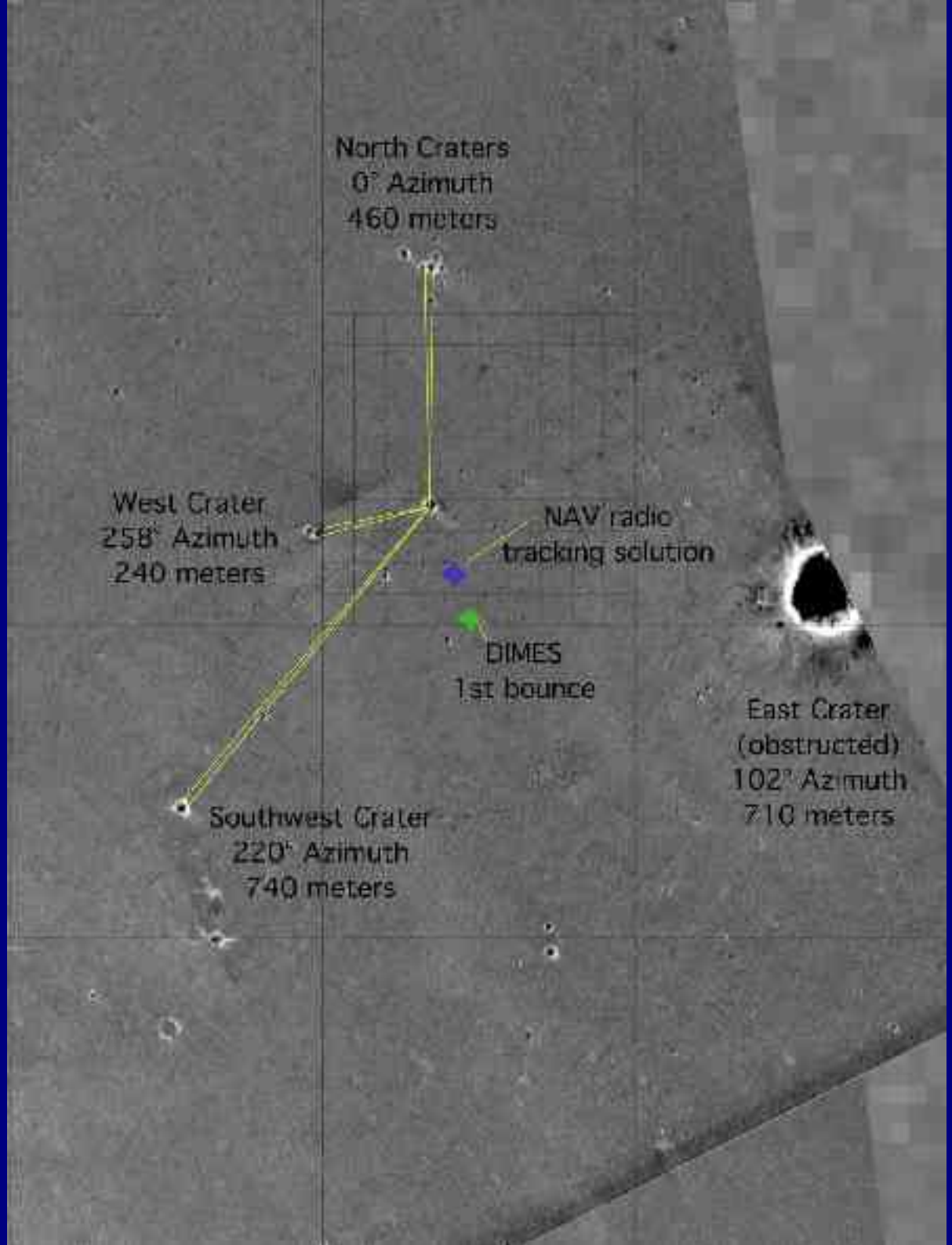

End of sol 46
250 m
135 m
sol 45
Laguna Hollow
sol 44
sol 43
sol 41
sol 39
sol 37
Sleepy Hollow
approximate limit of "continuous" ejecta
hollows identified from rover
hollows identified from DIMES
200 m

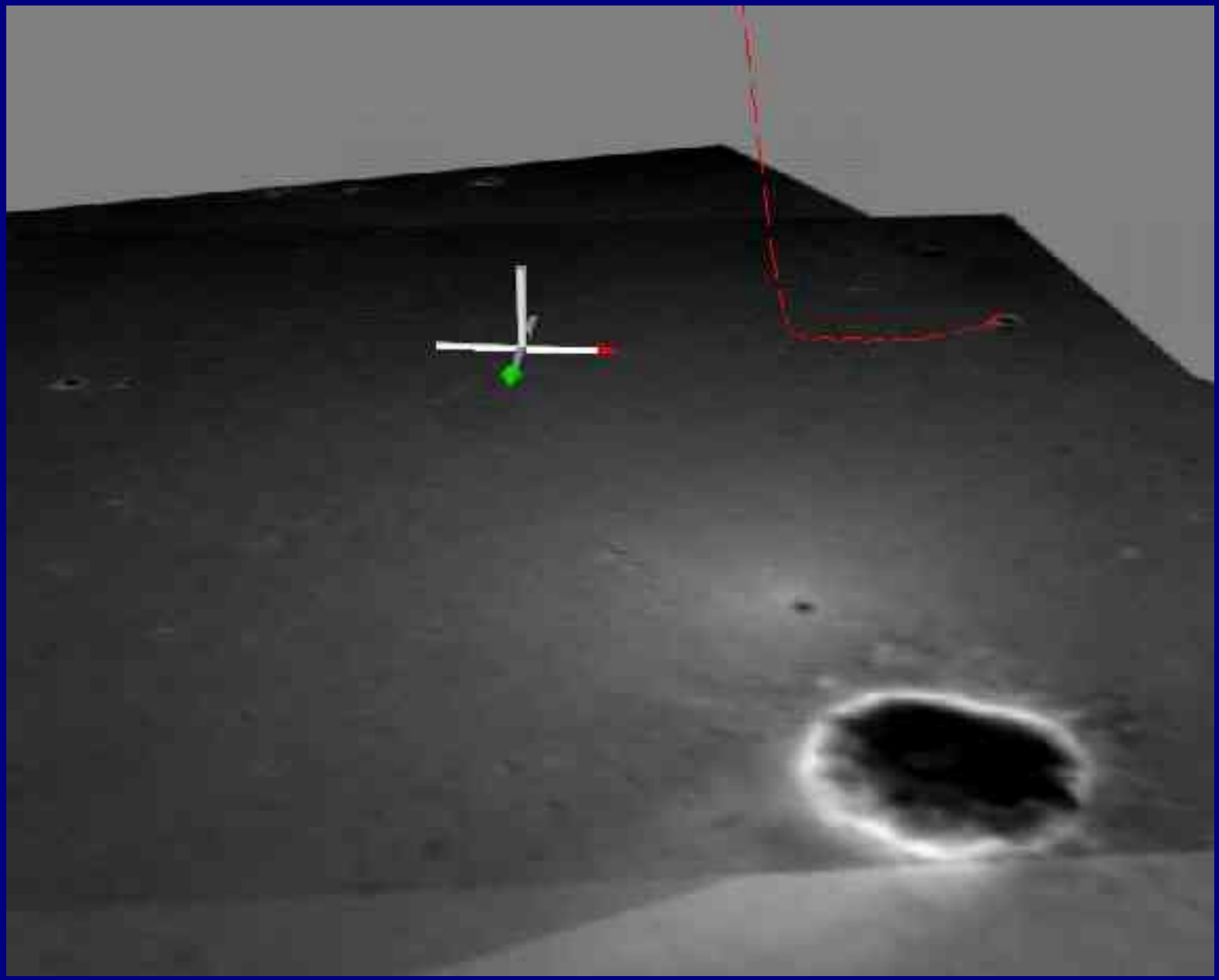
# MER-B: Opportunity

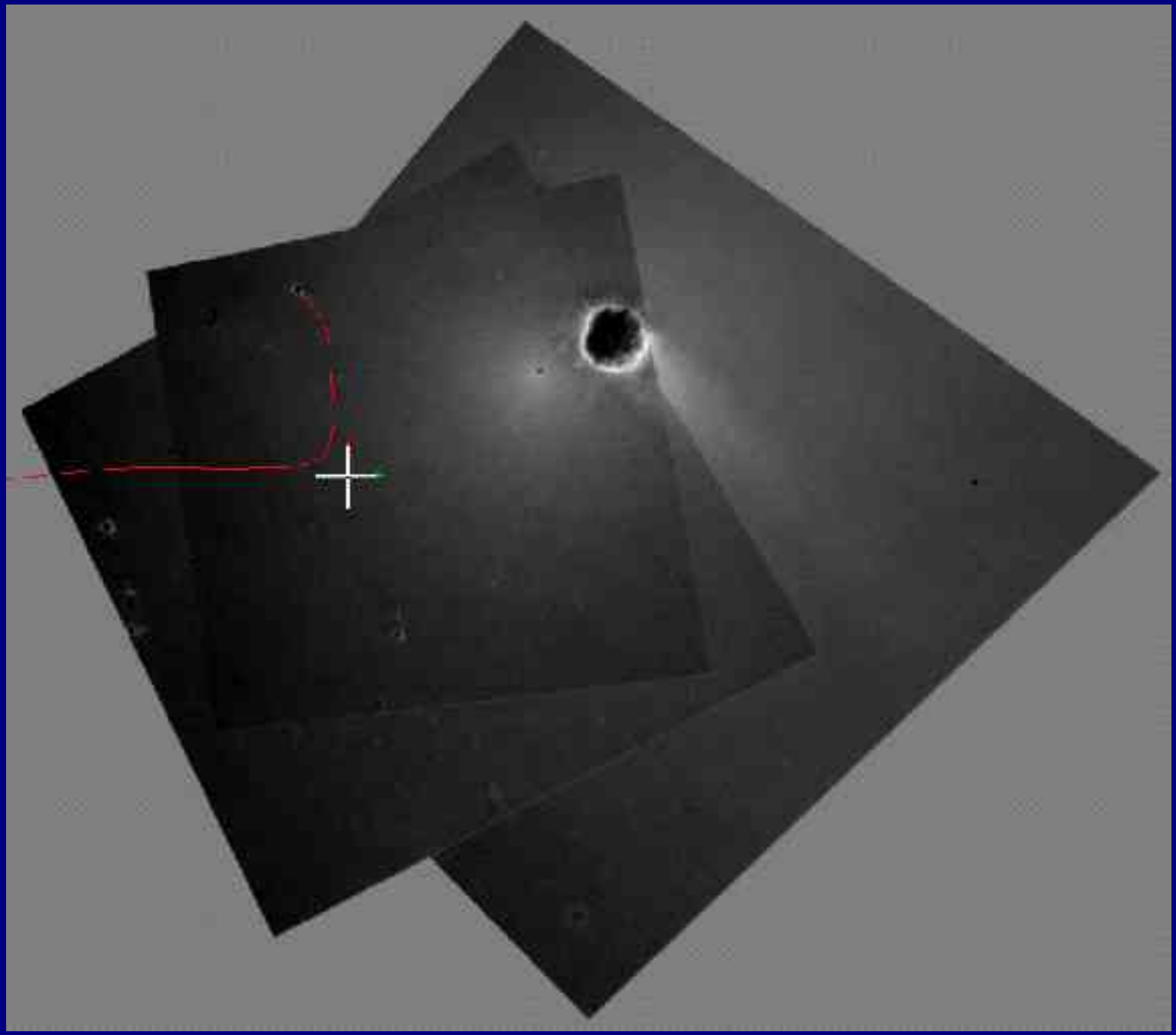
- Critical questions
  - What is the carrier of the hematite feature?
  - Which formation path did it take?
    - Was it formed by water?
    - Was there a lot of water or trace amounts?
    - Was the water standing or transient?
    - Geothermal or “cold” water?




MER-B: RADIOMETRIC LANDER POSITIONING
Mars approach DSN tracking
Surface Odyssey &
DSN Doppler
Descent DSN Doppler
(cut off at chute deploy)
Latitude
Longitude
1.7
1.8
1.9
2
2.1
2.2
2.3
353.6
353.8
354
354.2
354.4
354.6
354.8


North Craters
0° Azimuth
460 meters
West Crater
258° Azimuth
240 meters
NAV radio
tracking solution
DIMES
1st bounce
East Crater
(obstructed)
102° Azimuth
710 meters
Southwest Crater
220° Azimuth
740 meters



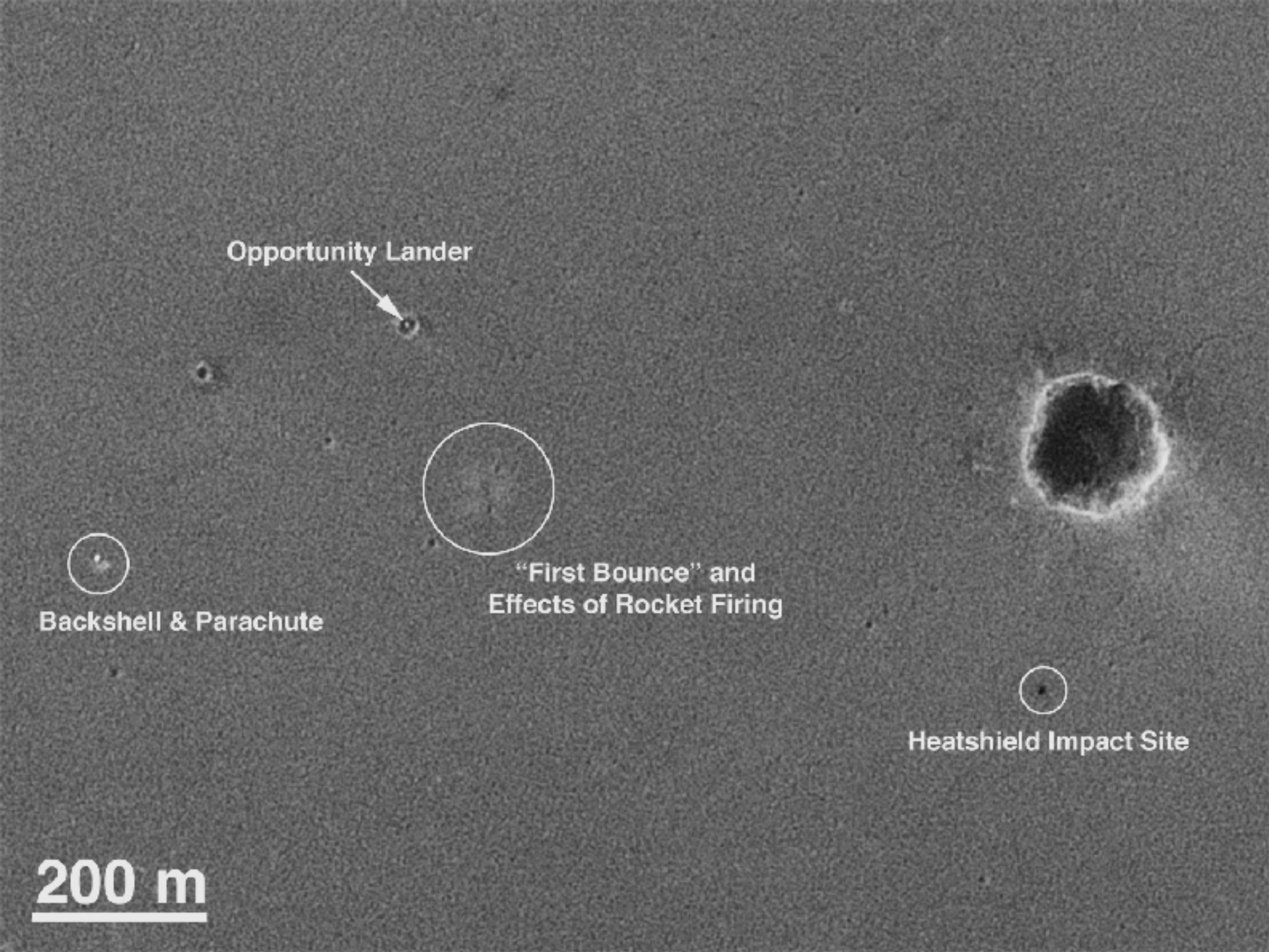


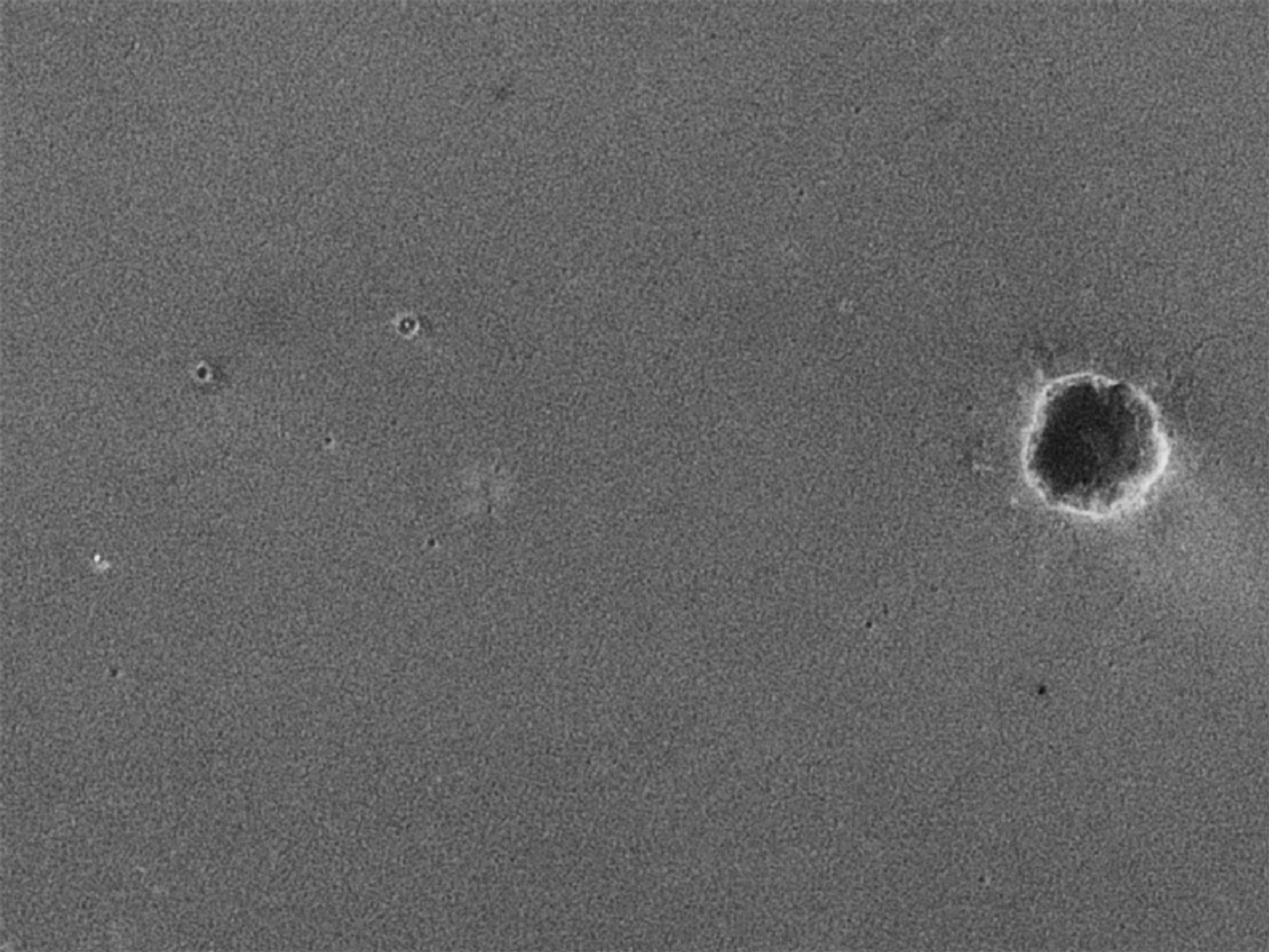
# Opportunity immediate vicinity

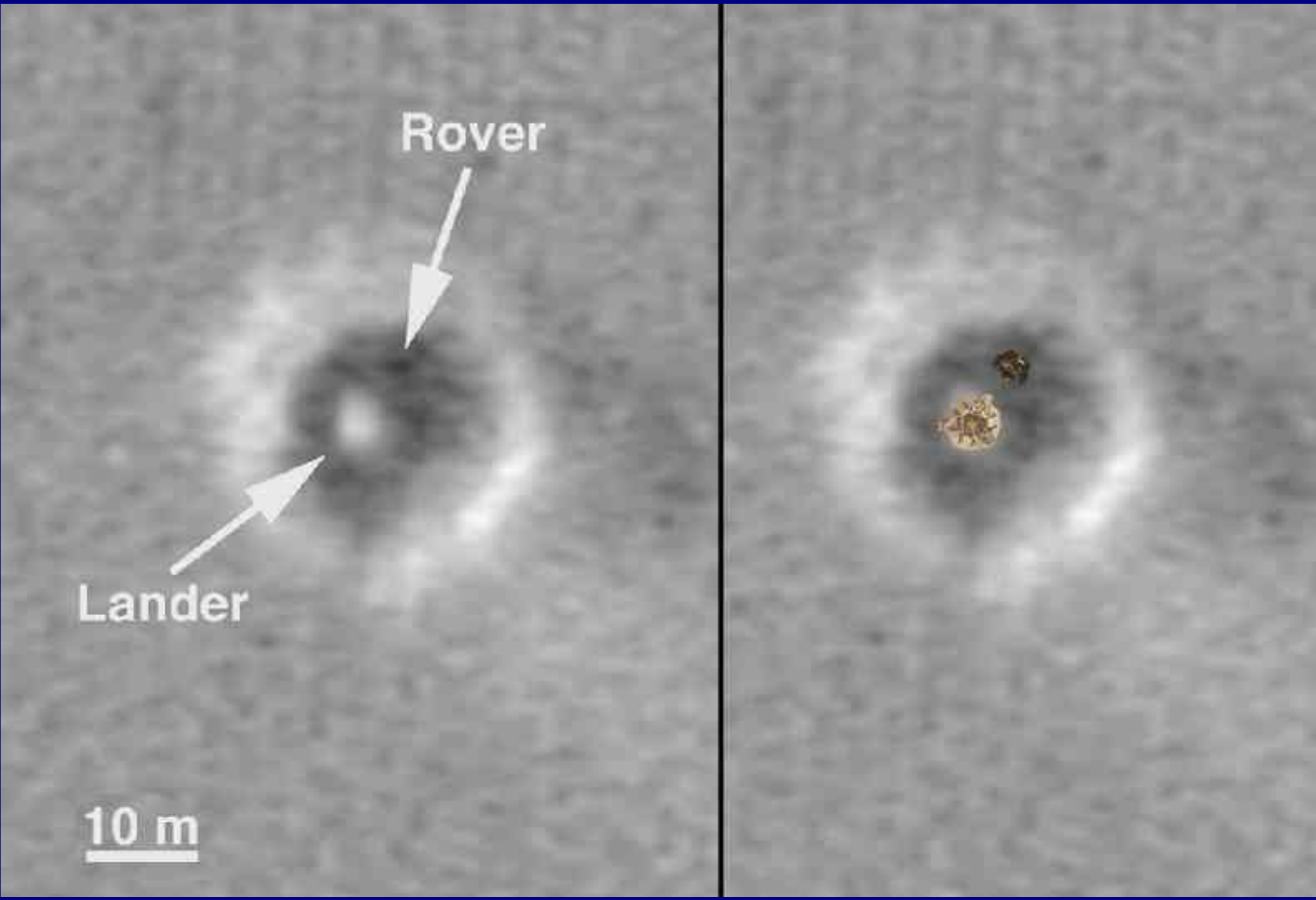
- In a 20 m diameter crater!
- Bedrock!  (Pay dirt.)
  - Never been observed before w/ a Mars lander
  - Should tell us the geological history of this location
  - An immobile lander (rather than a rover) could only stare longingly at it from a distance
- Area surrounding the crater is relatively flat and covered with dust
- A ~150 m diameter crater ~ 800 m away

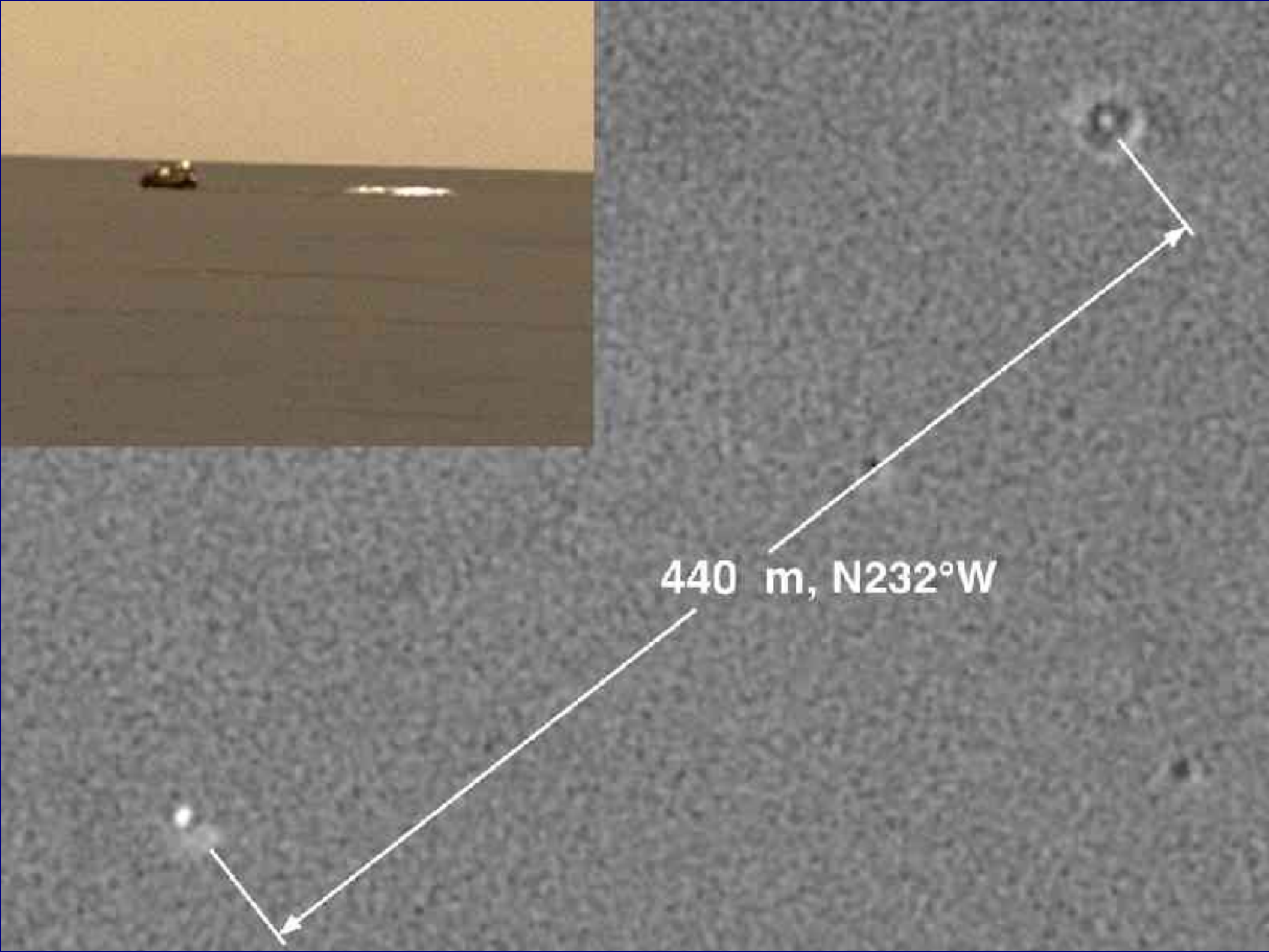
# Immediate Vicinity (cont.)

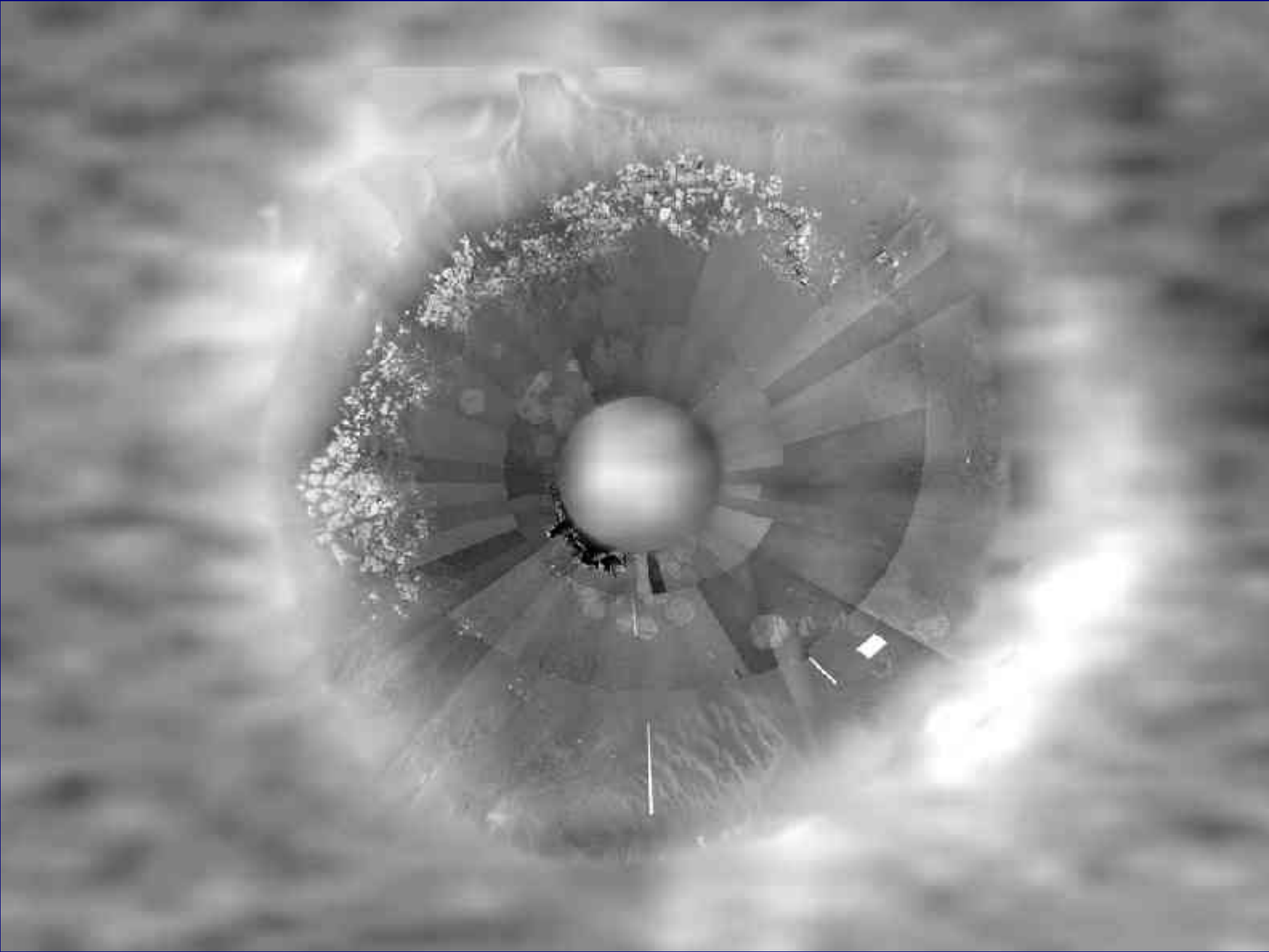
- Pancam Panorama
- Mini-TES hematite panorama


Opportunity Lander
"First Bounce" and
Effects of Rocket Firing
Backshell & Parachute
Heatshield Impact Site
200 m



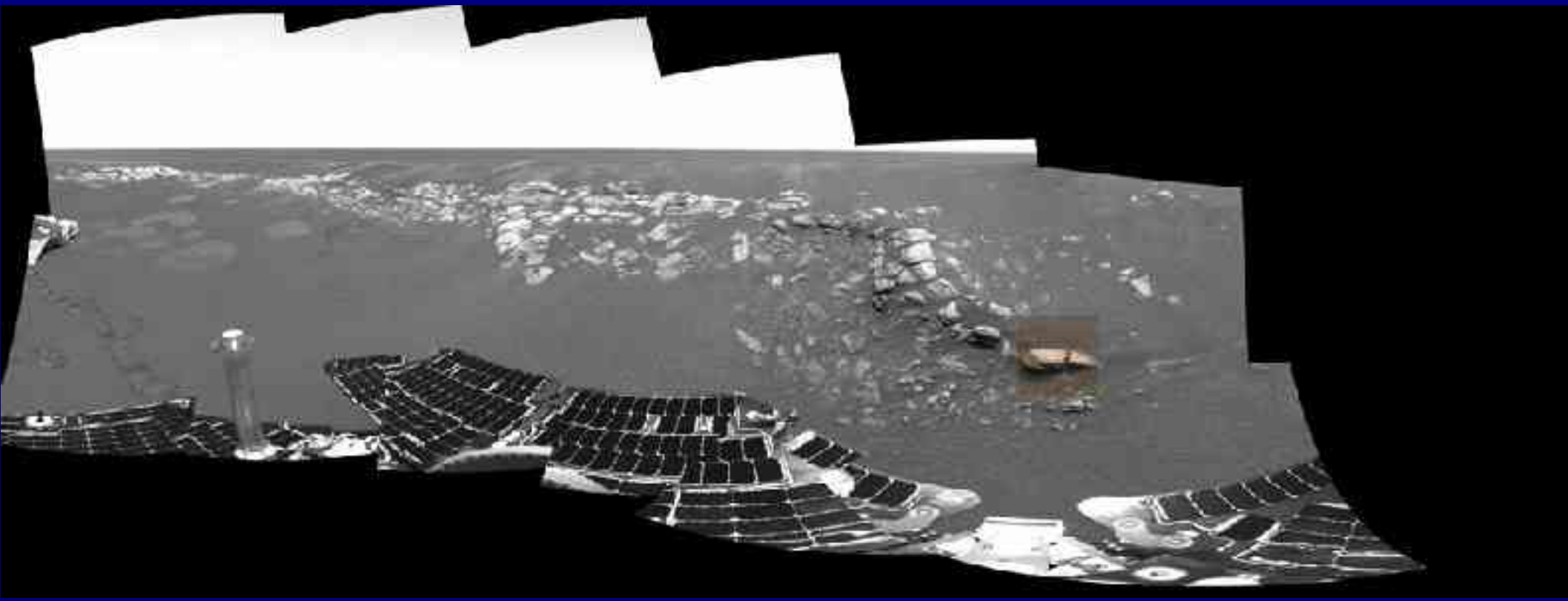

Rover
Lander
10 m

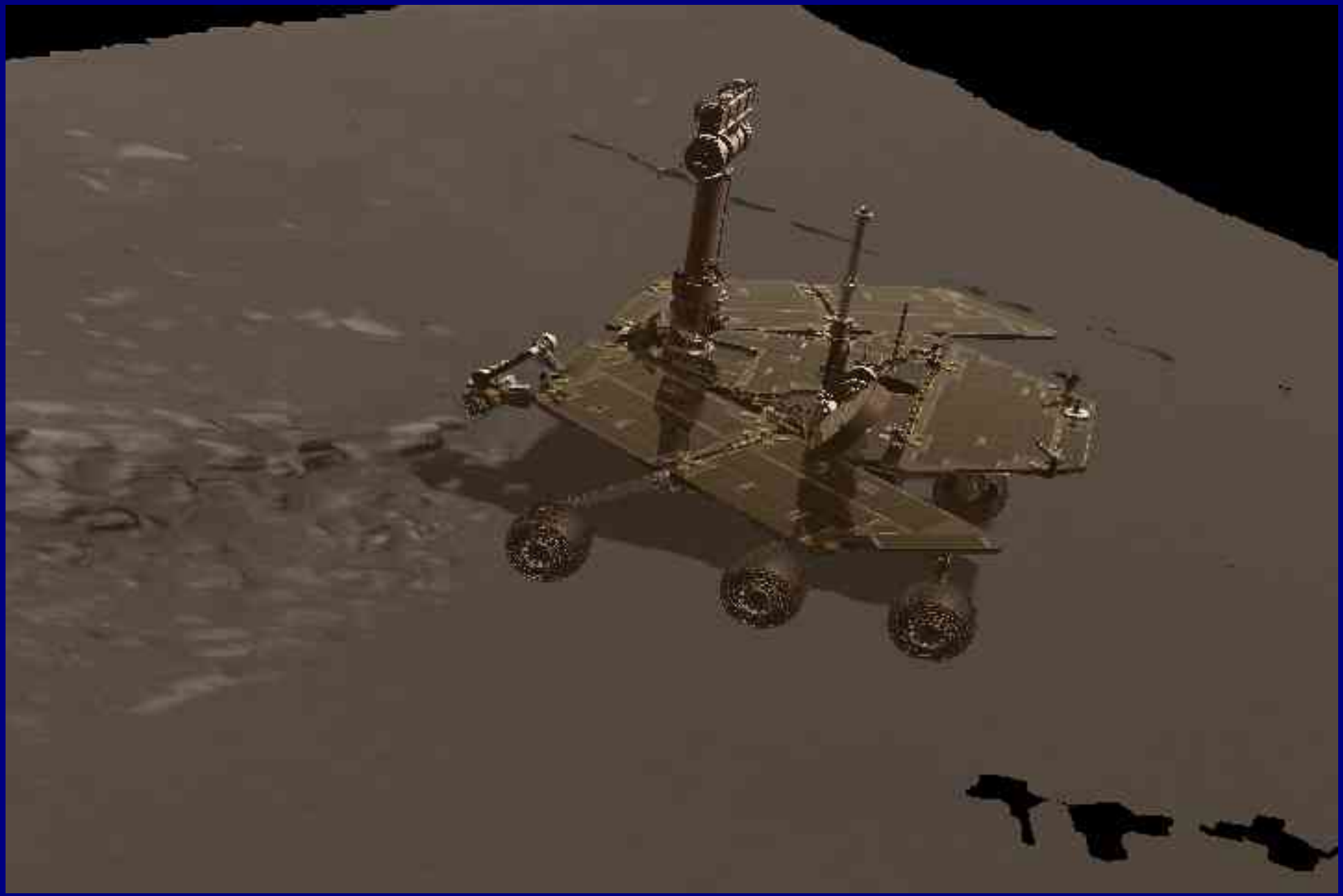

440 m, N232°W

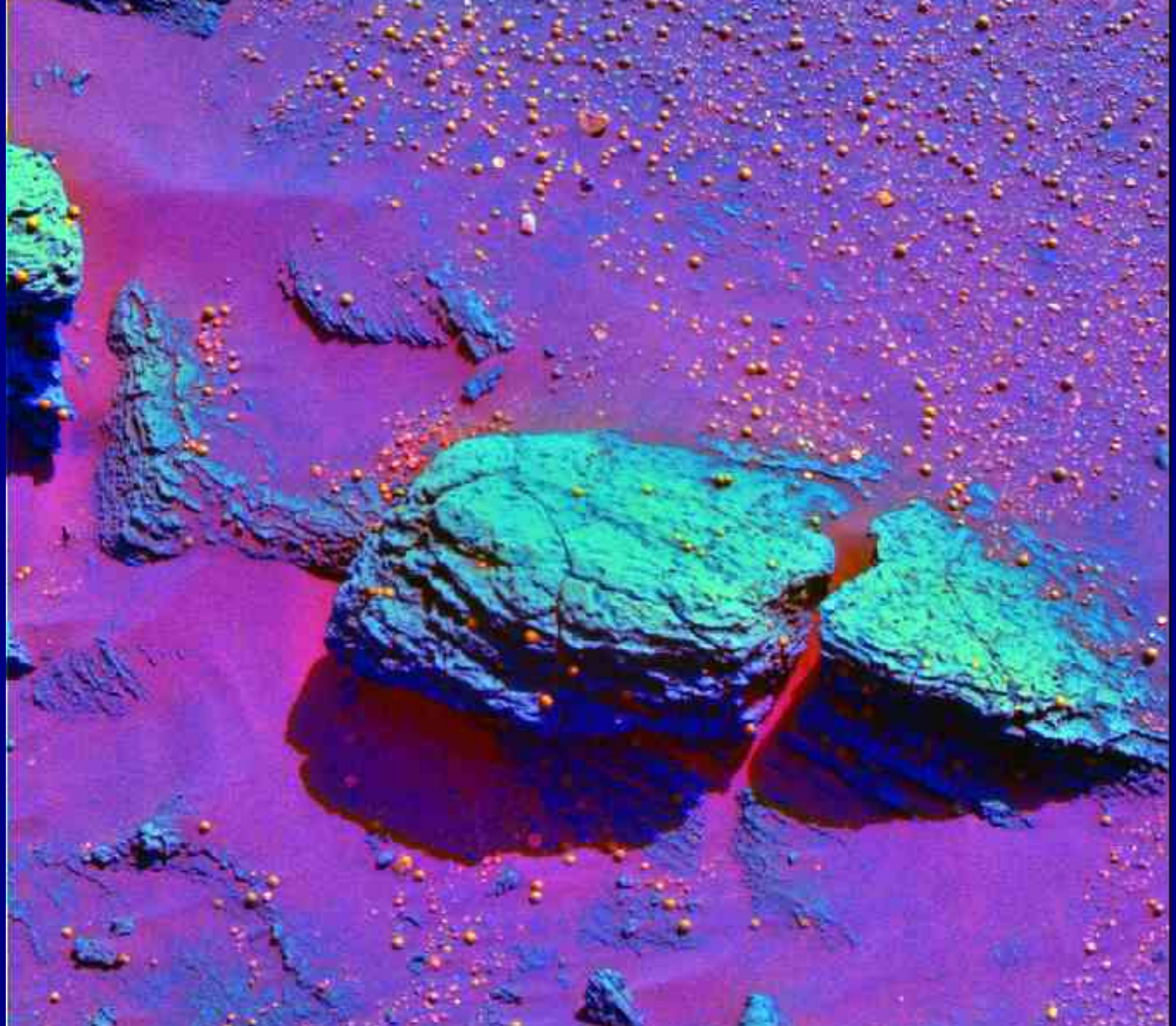


# New questions for Opportunity

- New critical questions, since we've seen the site:
  - Is the hematite only in the dust, or in the bedrock? Did it weather from the bedrock?
  - How did the bedrock form?
    - It is *layered*! This implies some sort of sedimentations
      - From the atmosphere or from water?
  - What are the "blueberries?"
    - Volcano or impact eject?
    - Aqueous rolling or precipitation?

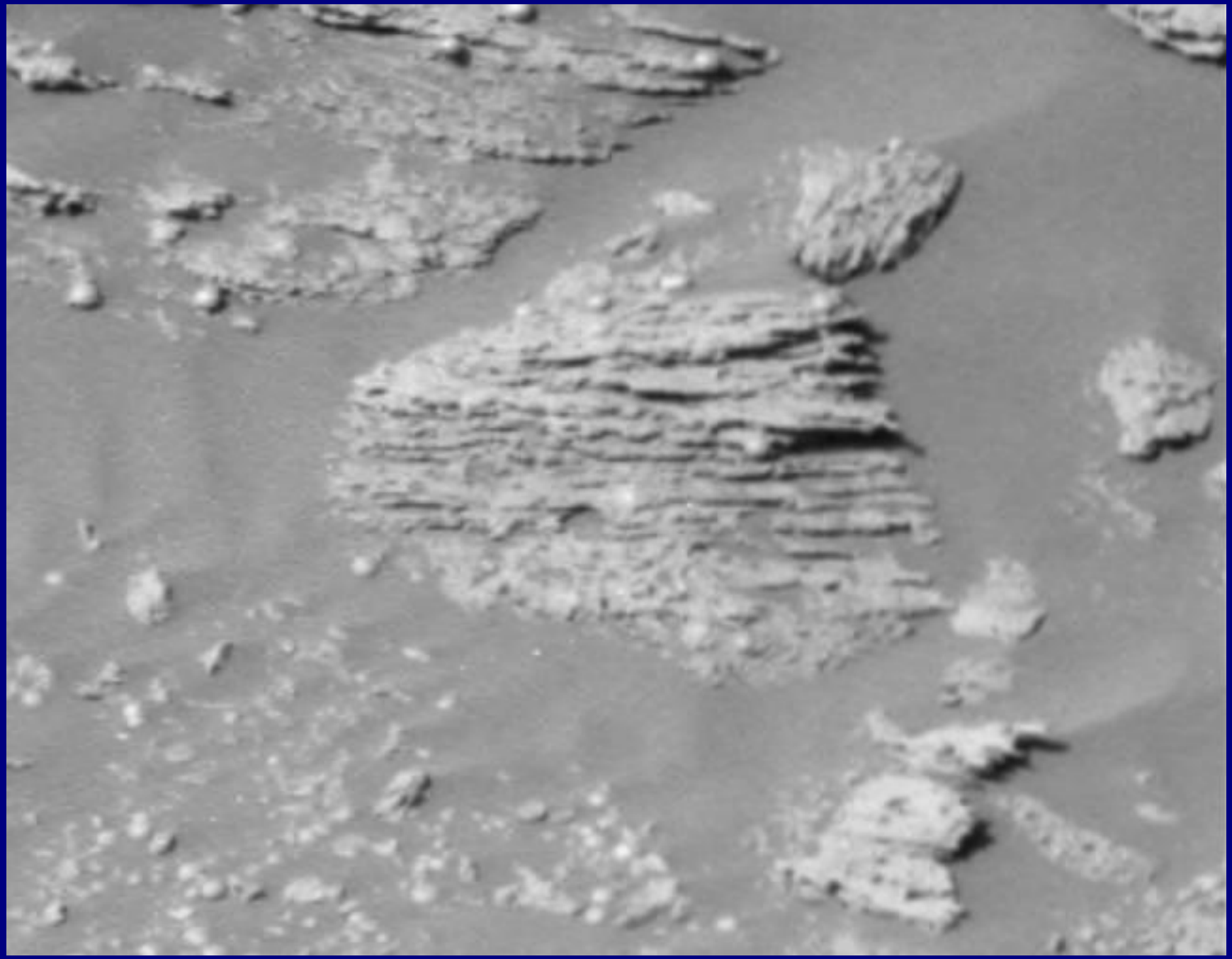




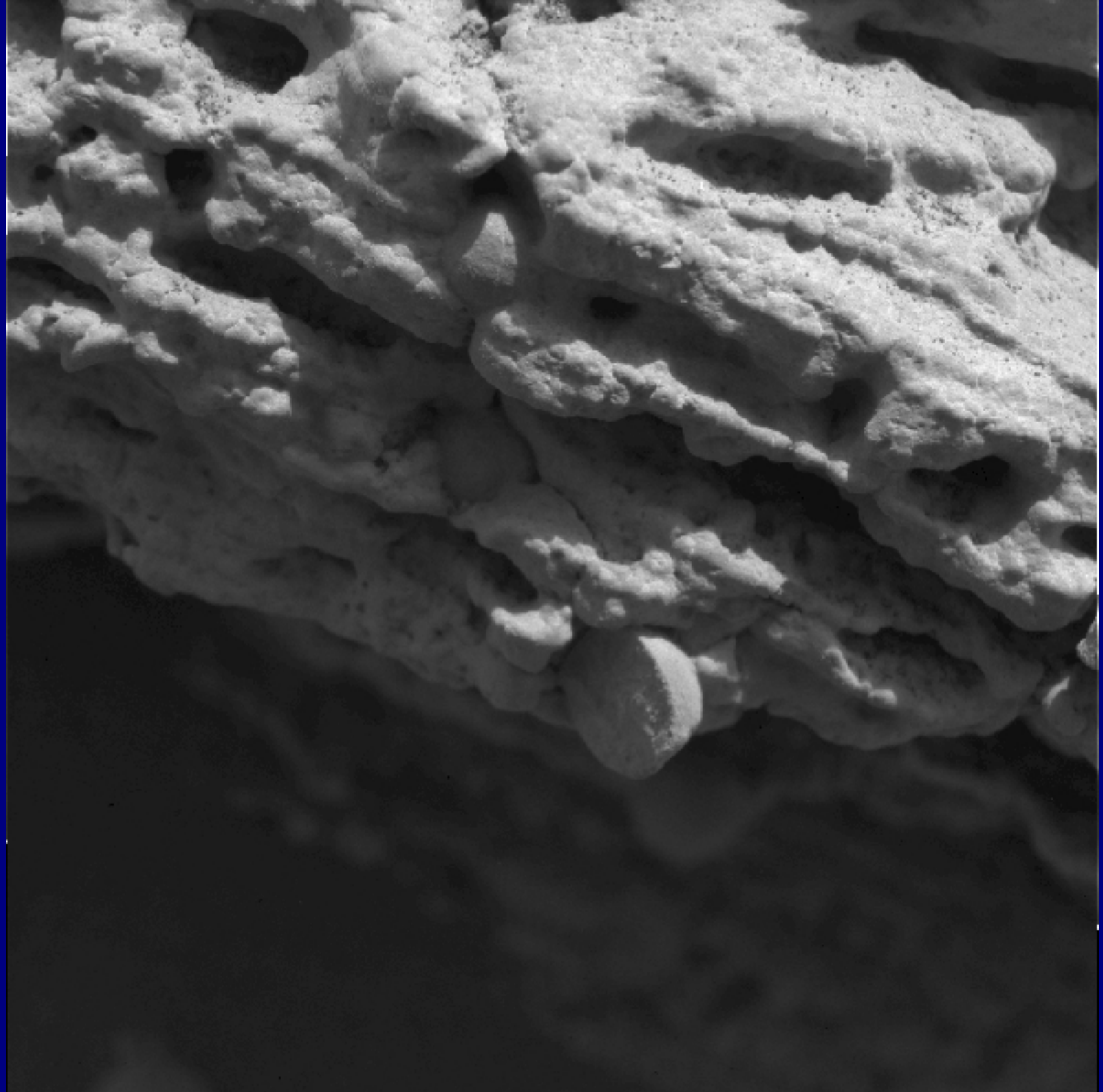


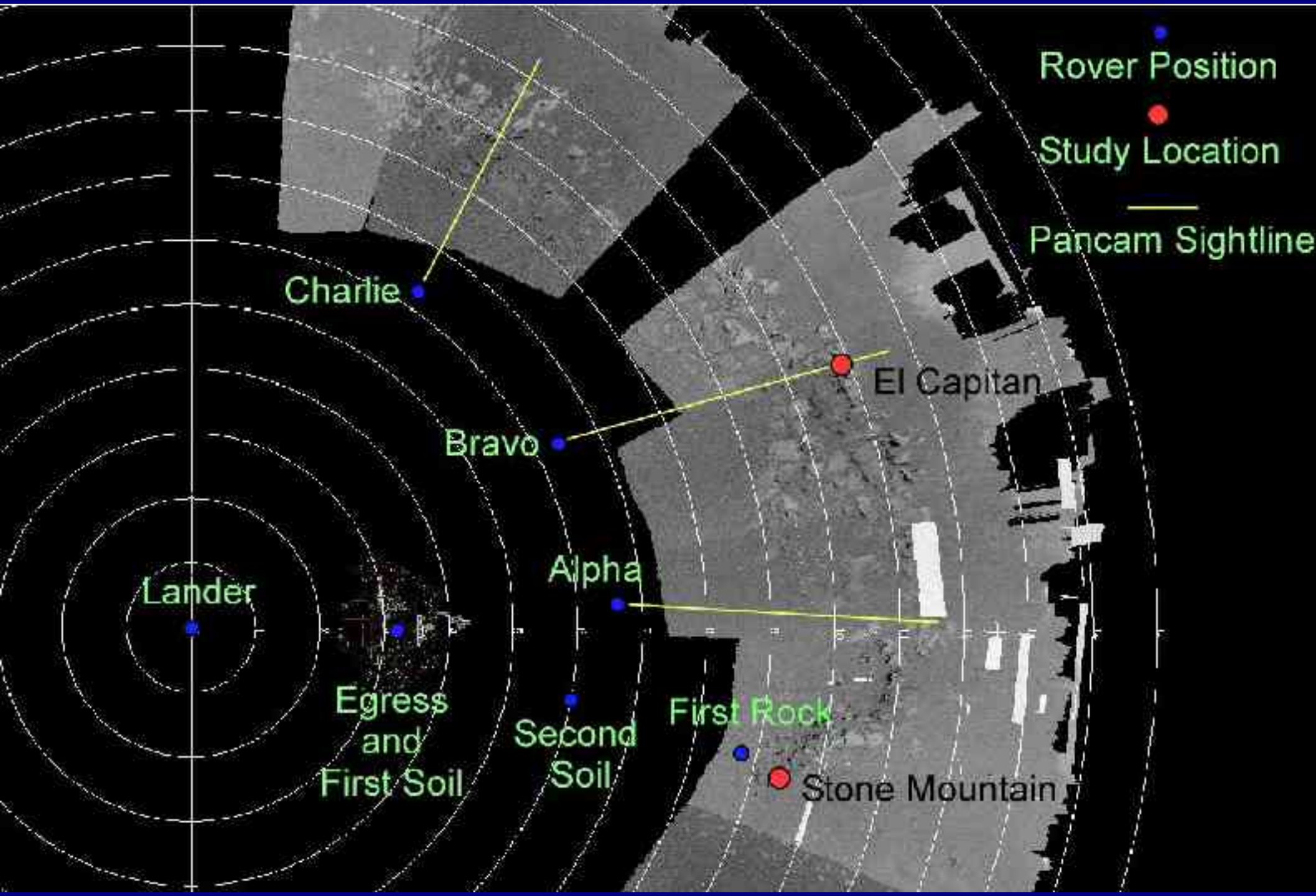
# Opportunity activity so far

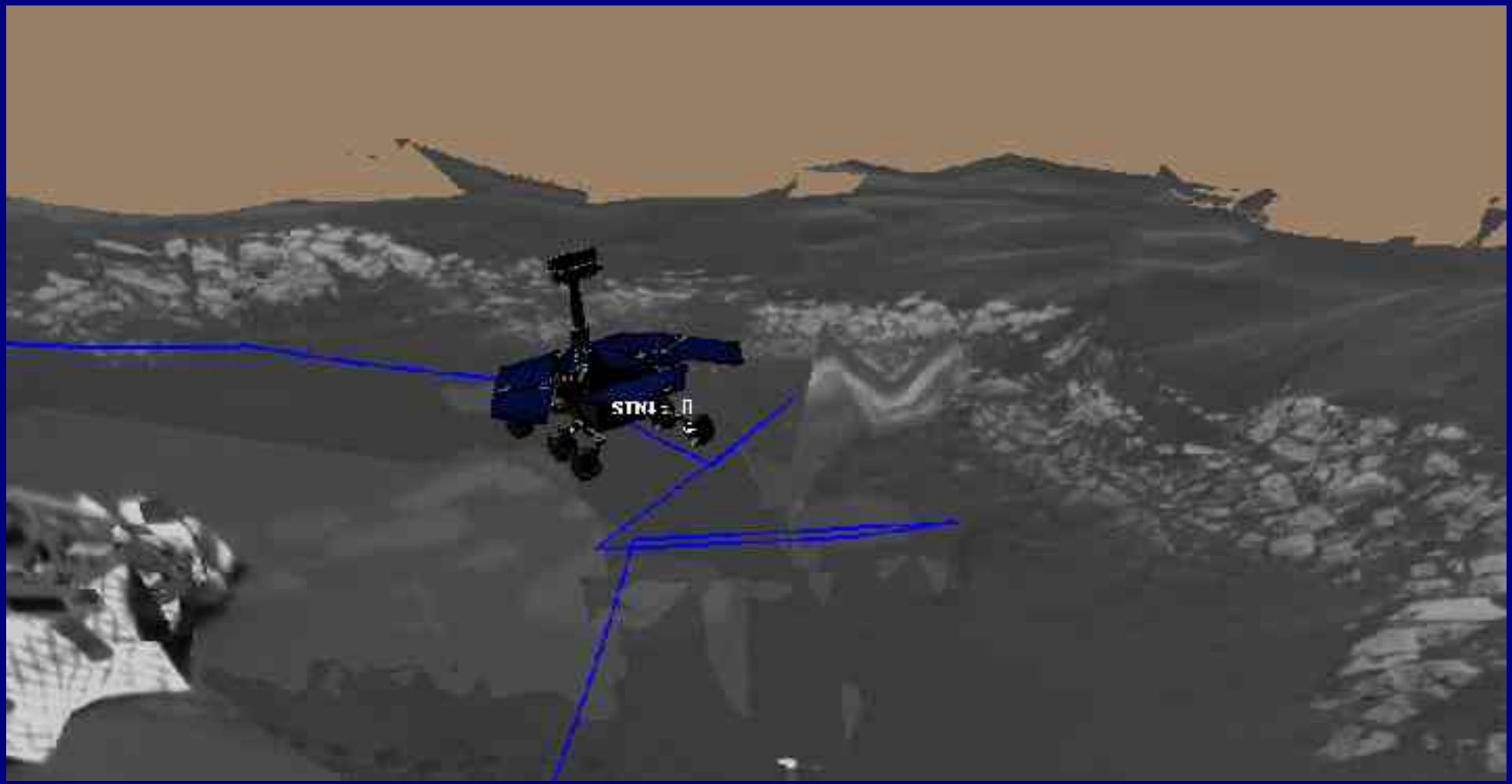
- Visual map of surroundings
- Mini-TES map of hematite in the crater
  - Seems to be in some dust but rare in the outcrop
- Scouting of the outcrop:
  - Initial MI & composition:
    - Finely layered
    - Blueberries embedded
    - High in sulfur
  - Detailed drive-by and visual inspection



An example of layered rock

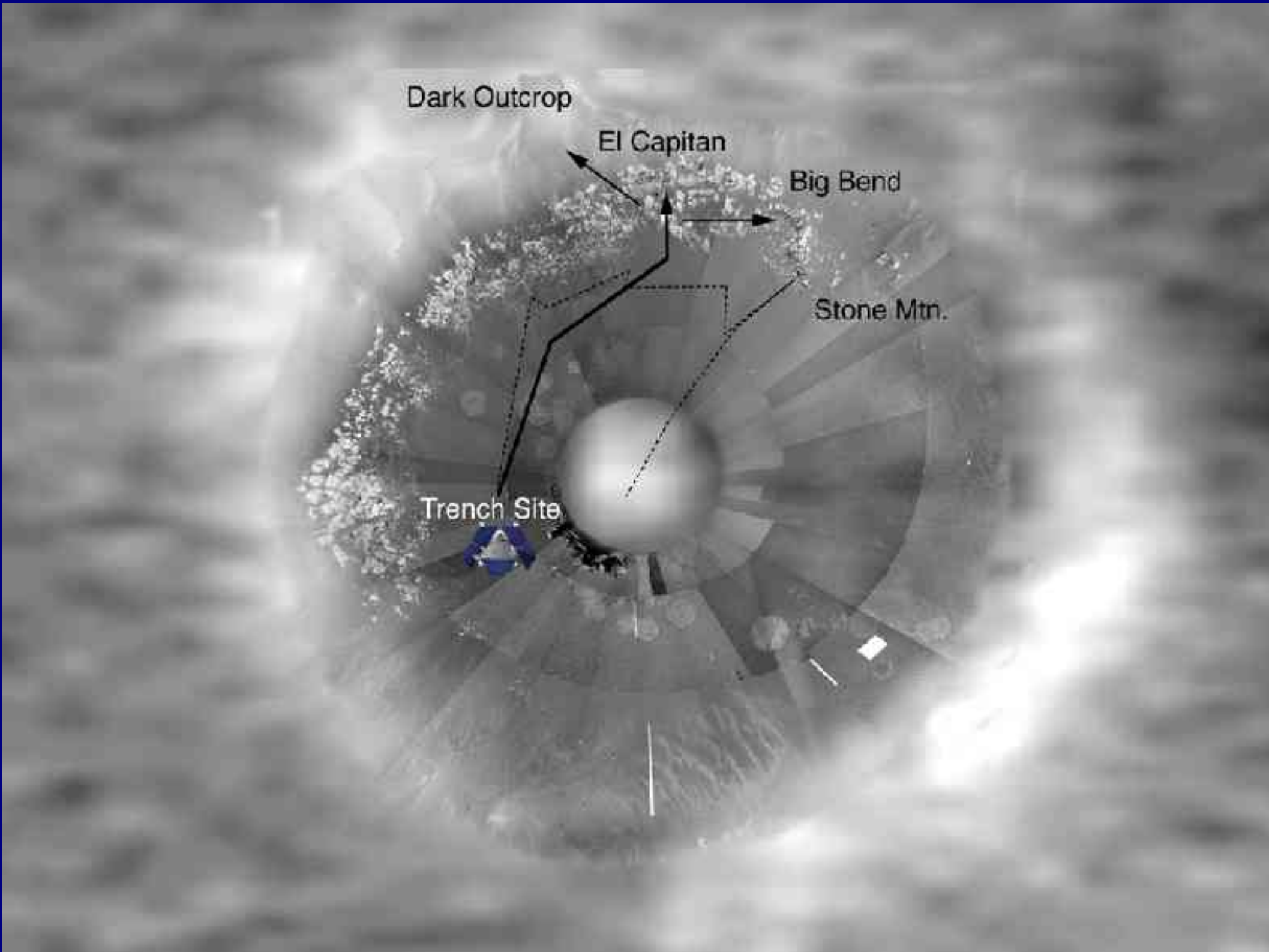


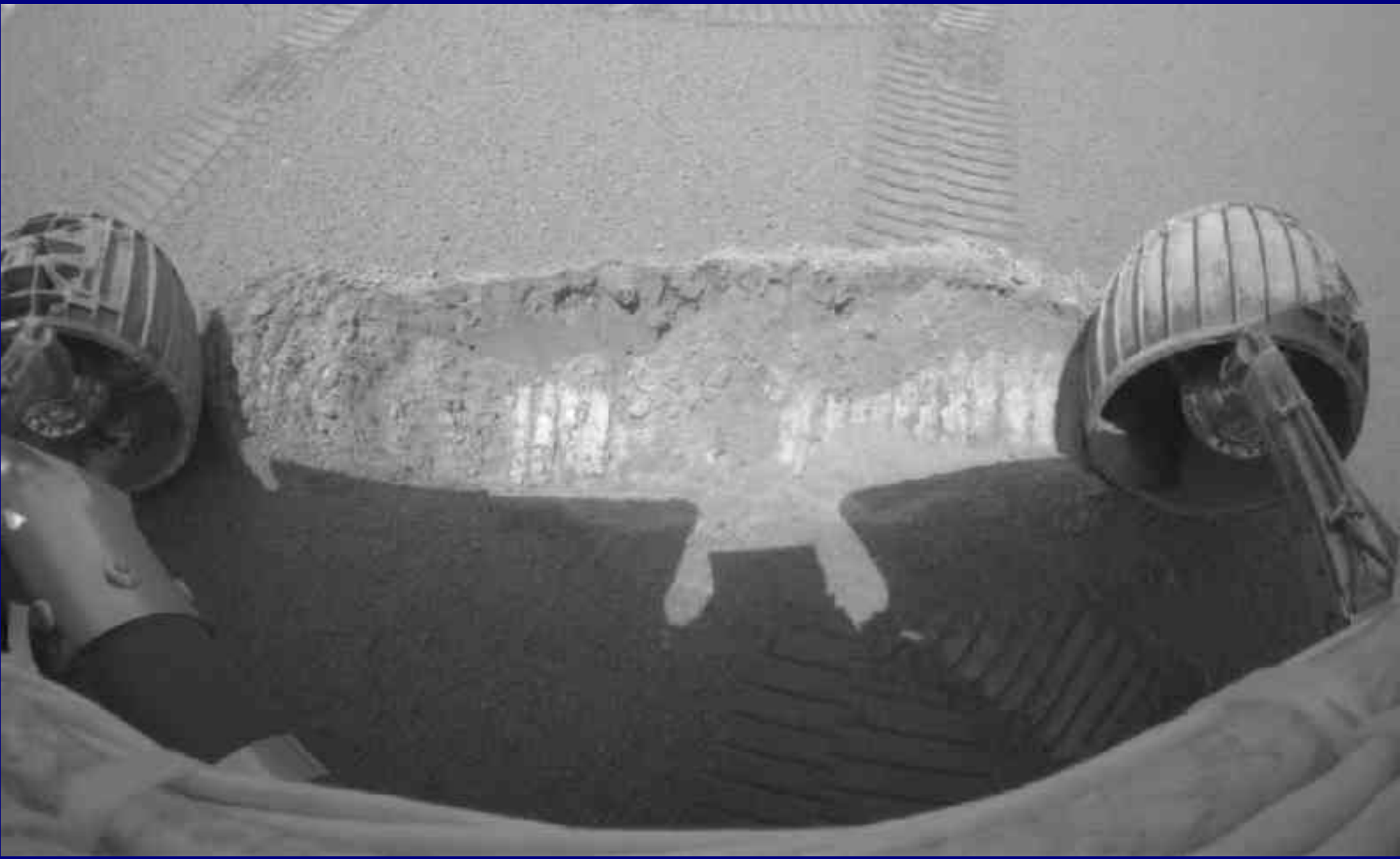

Rover Position
Study Location
Pancam Sightline
Charlie
El Capitan
Bravo
Alpha
Lander
Egress
and
First Soil
Second
Soil
First Rock
Stone Mountain

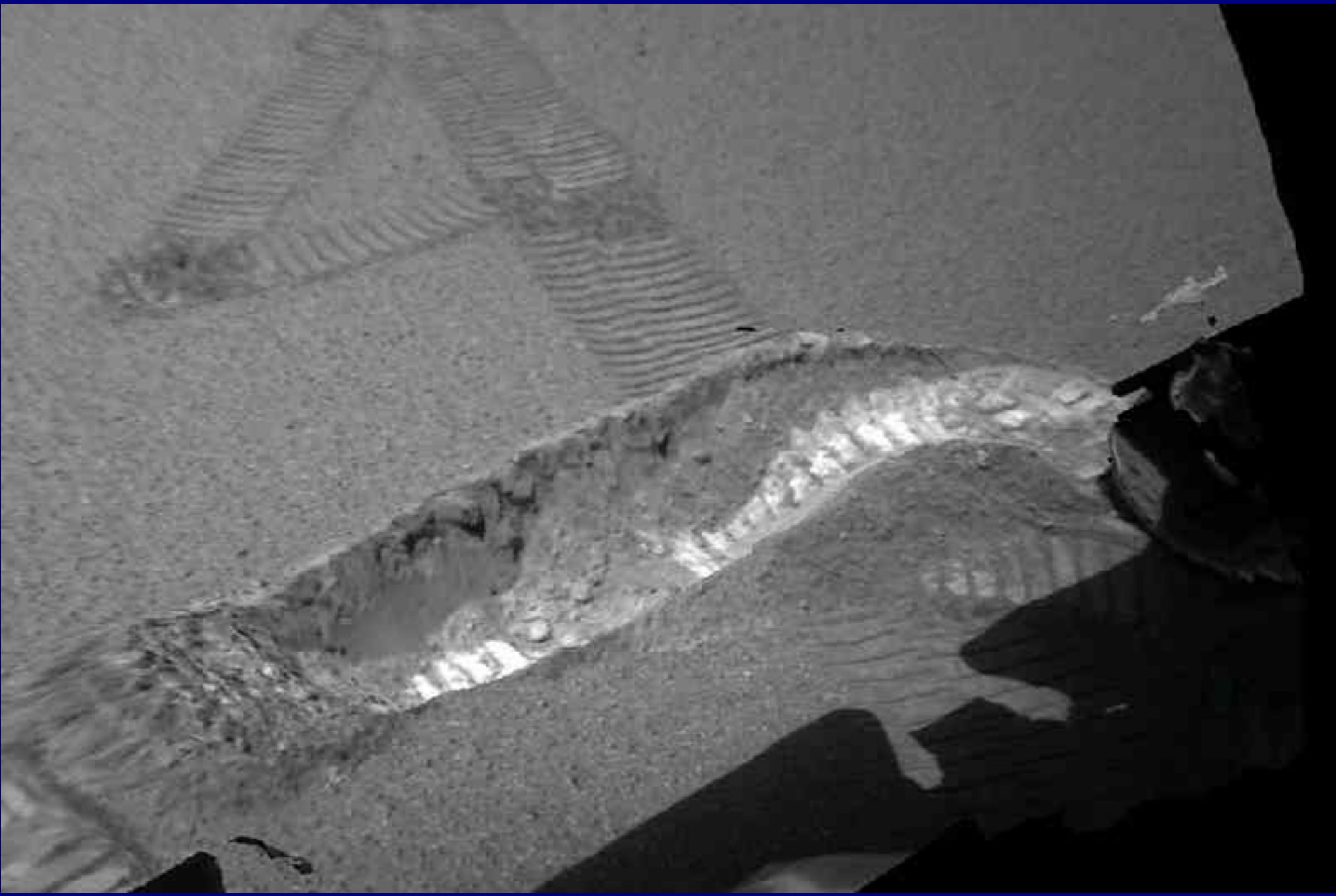


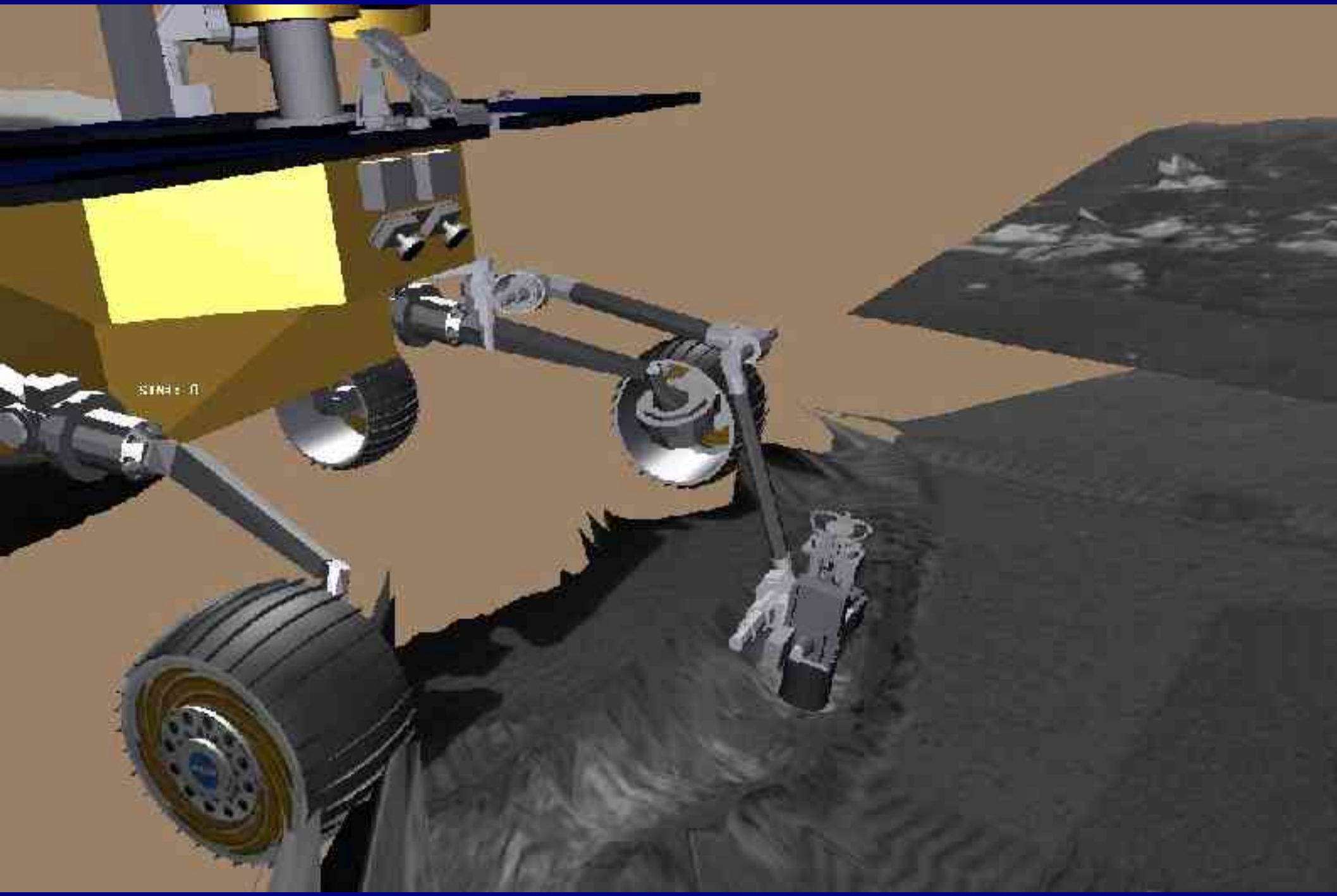
# Opportunity activities so far (cont.)

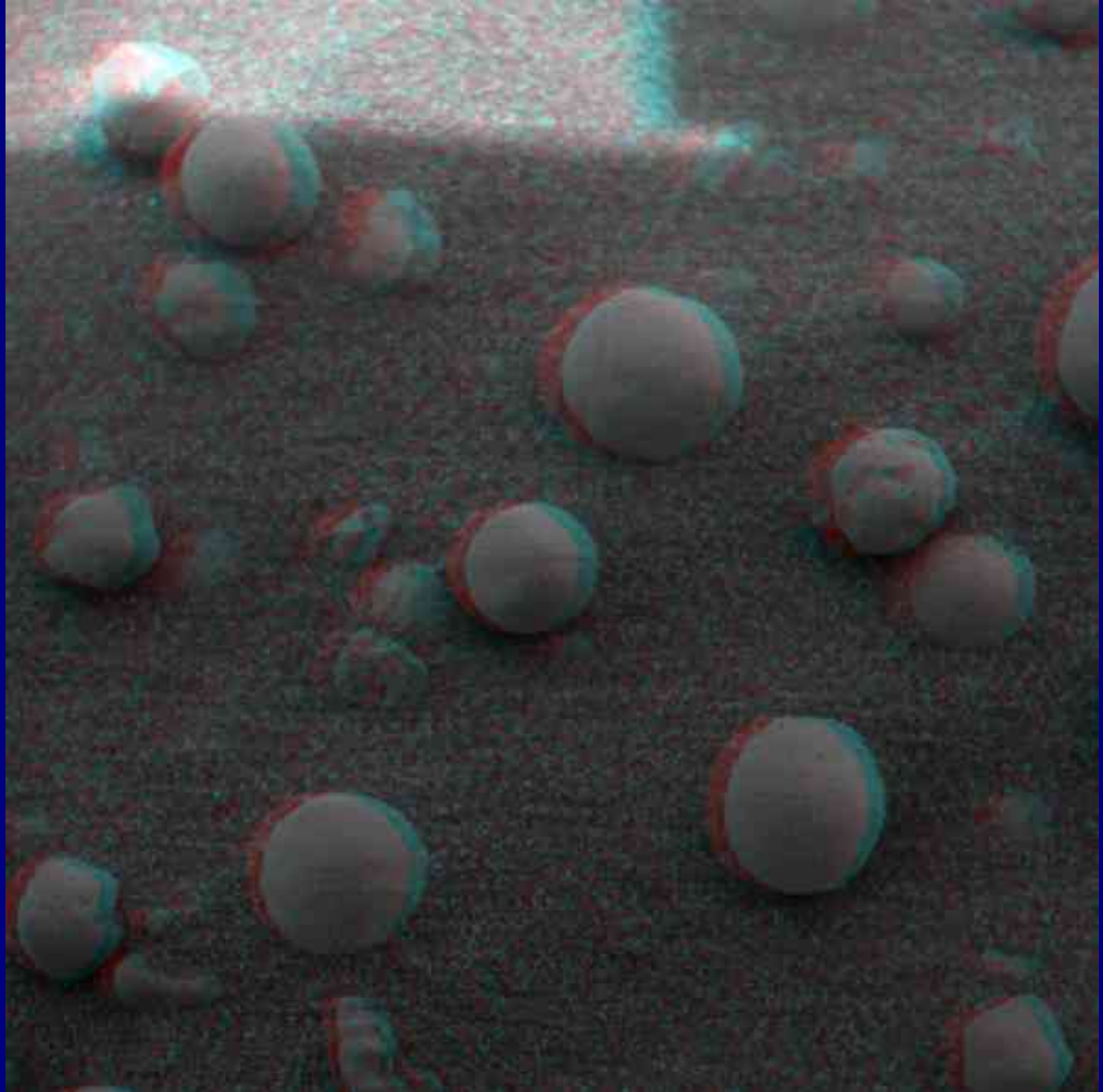
- Soil tests in a couple of locations
  - Surface measurements and trenching
    - Hematite spectra disappear on disturbed ground
    - Trenching revealed clumping and blueberries everywhere
- Detailed observations of the outcrop have begun
  - One region is being heavily explored (El Capitan)
    - Thought to expose the full range of strata in the outcrop
  - At least two locations are being RATted
    - One is normal to the layers, and the other is across the layers

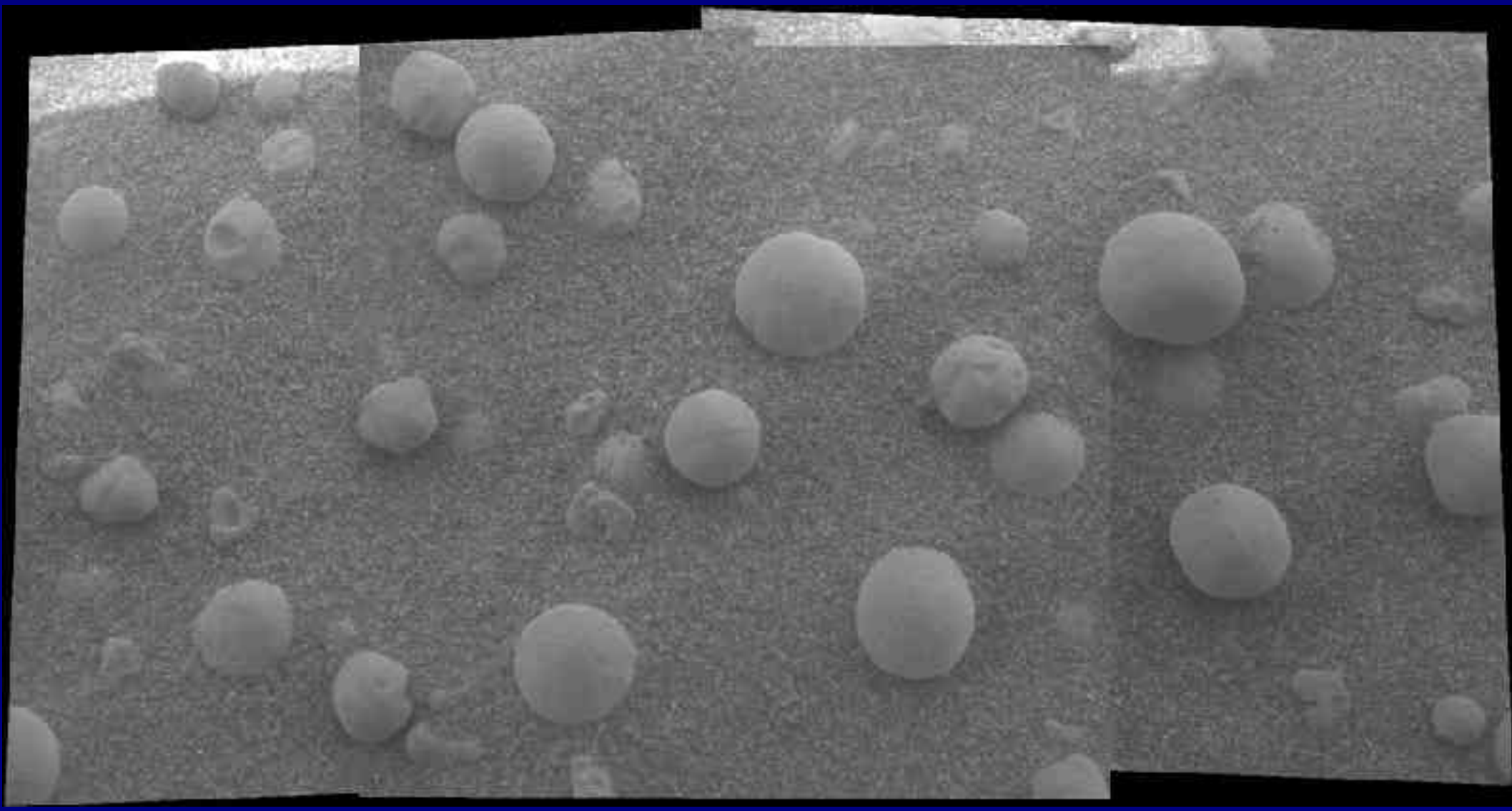

Dark Outcrop
El Capitan
Big Bend
Stone Mtn.
Trench Site



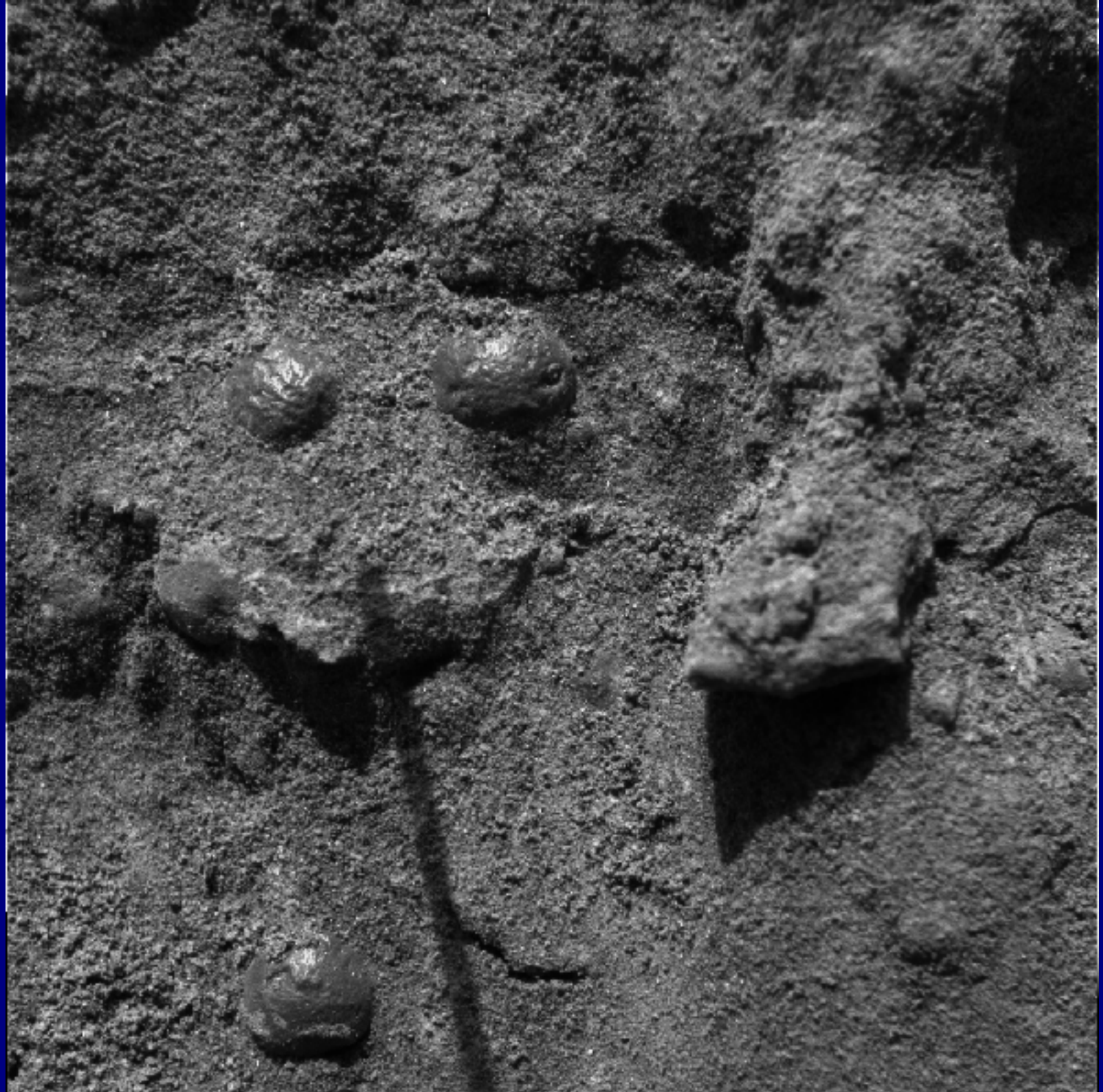


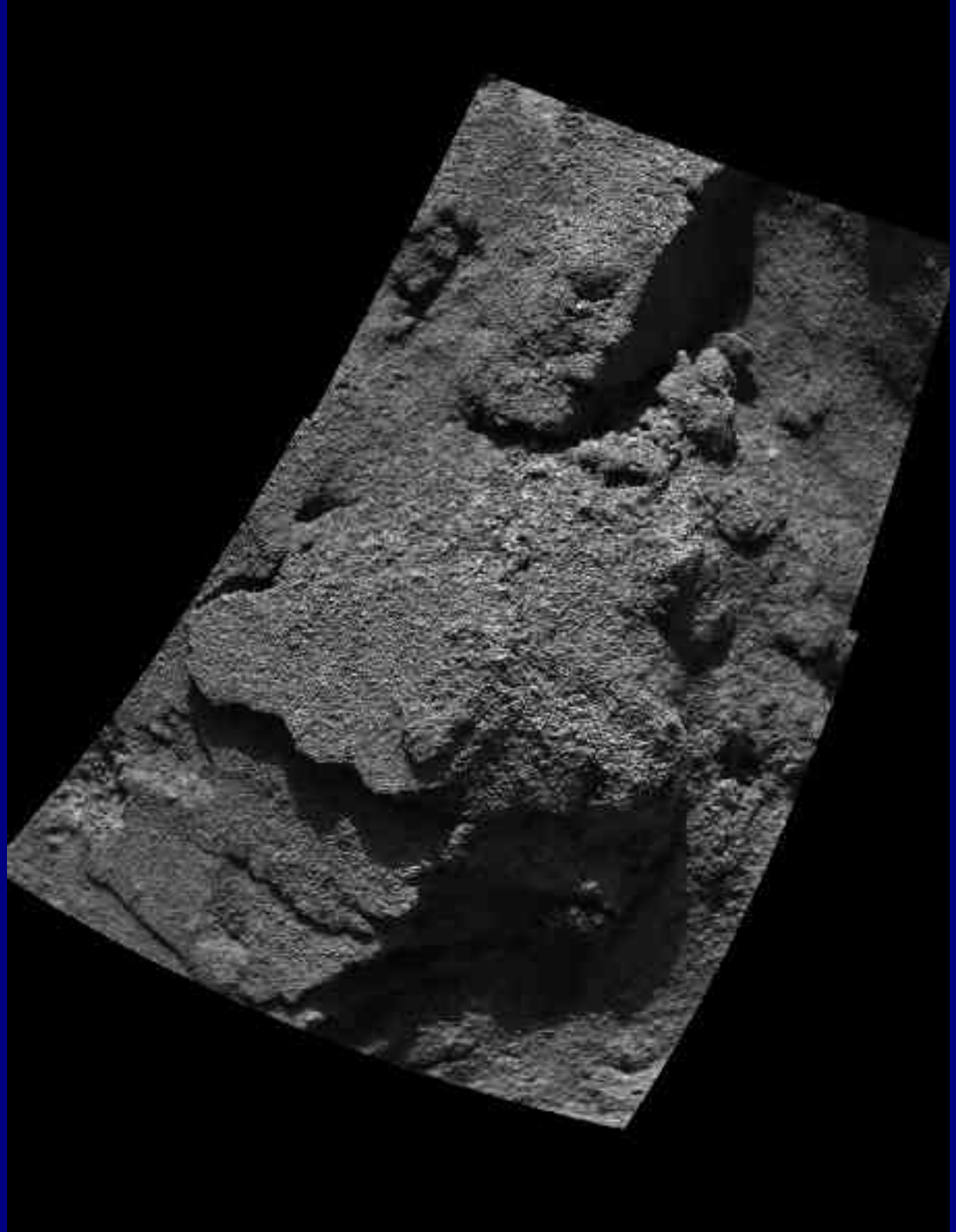


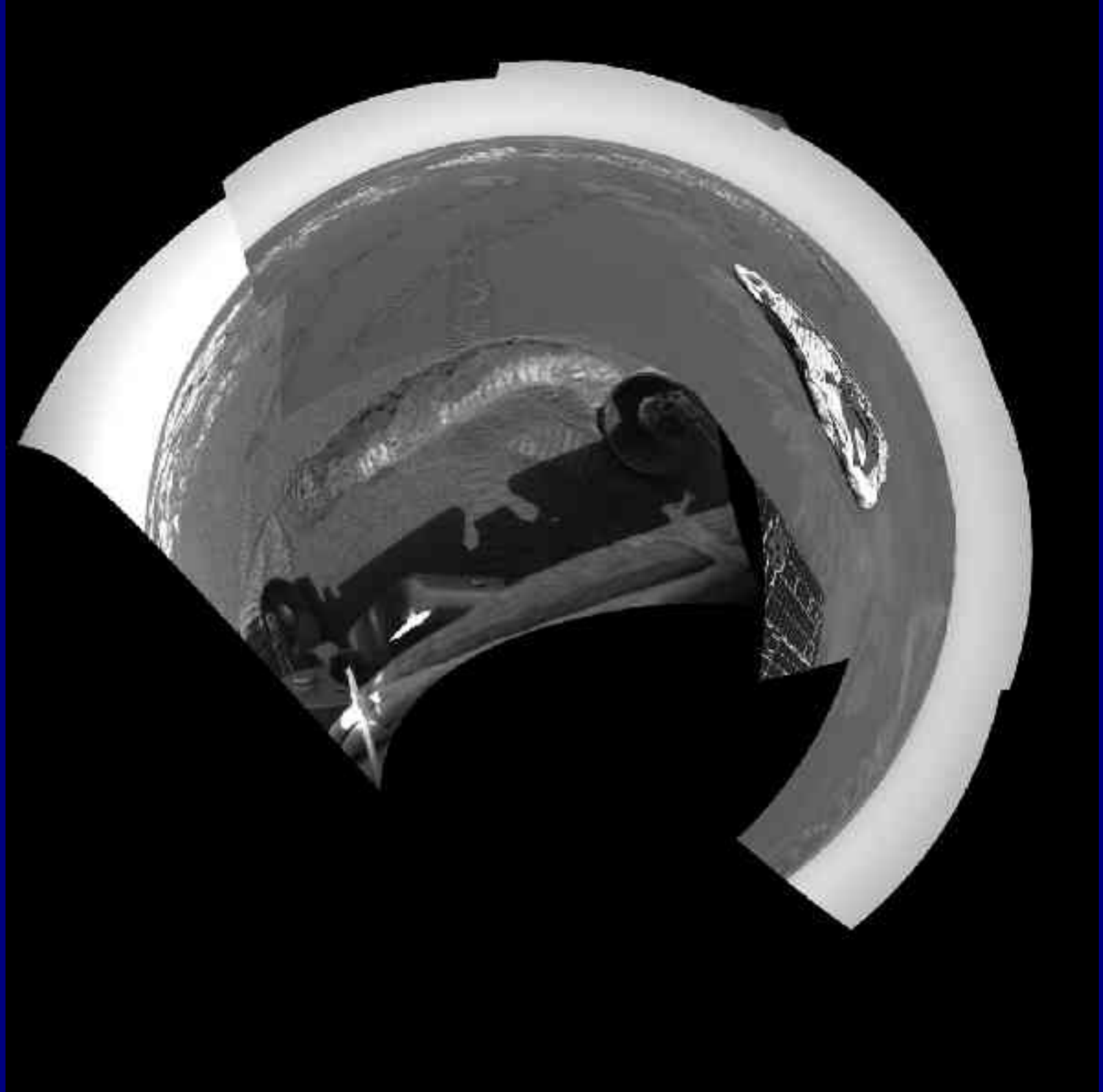




Before

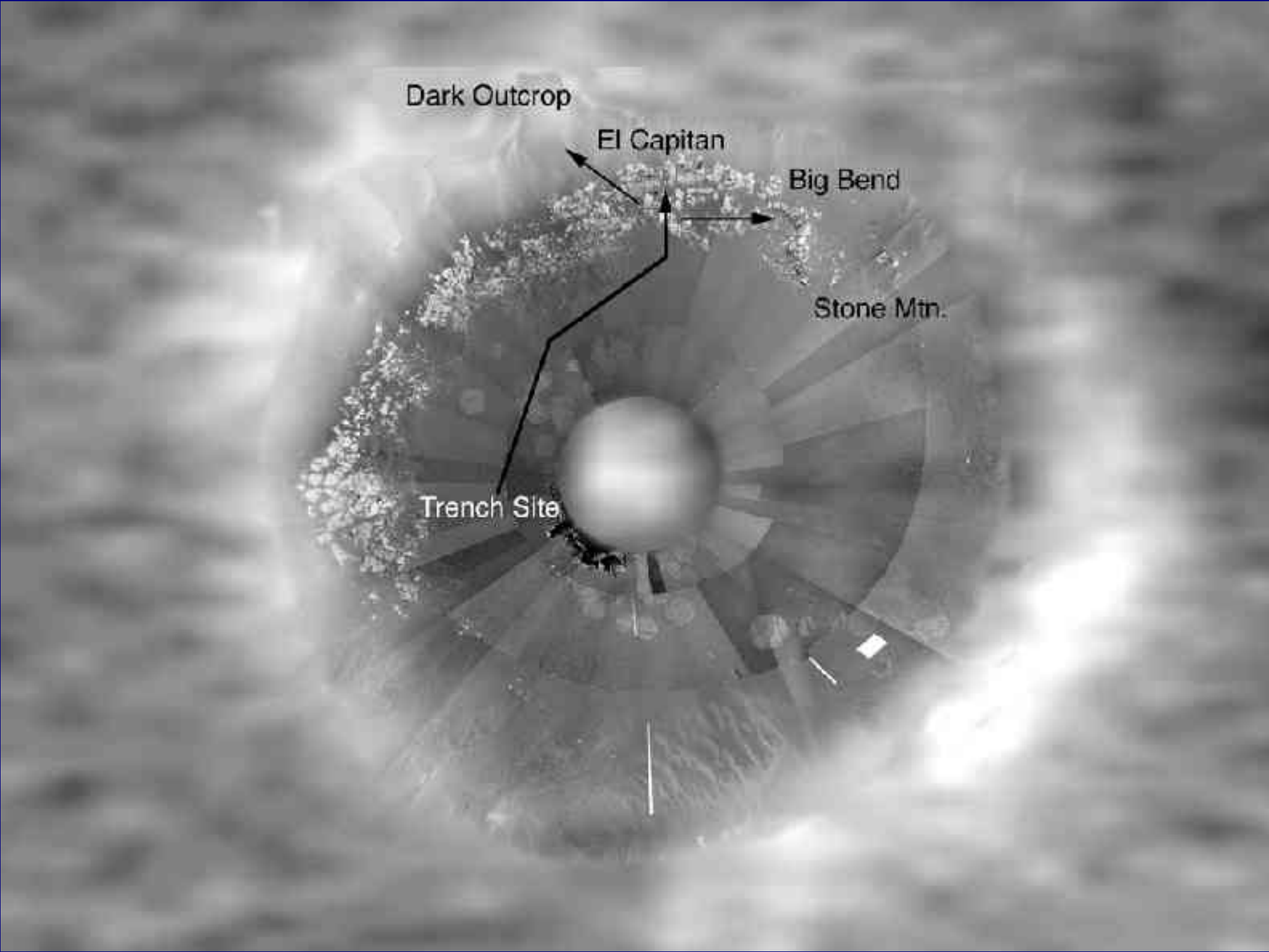


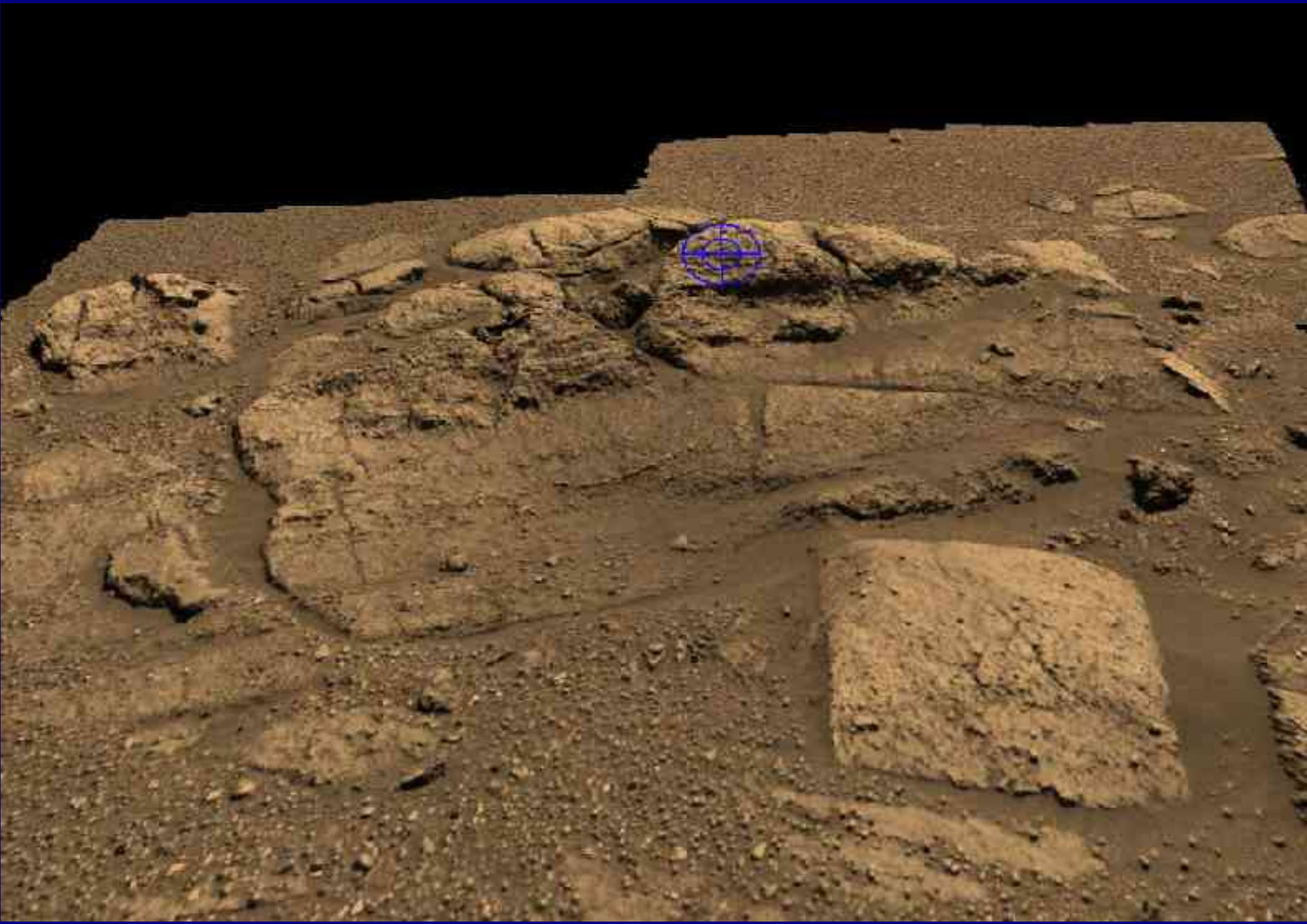


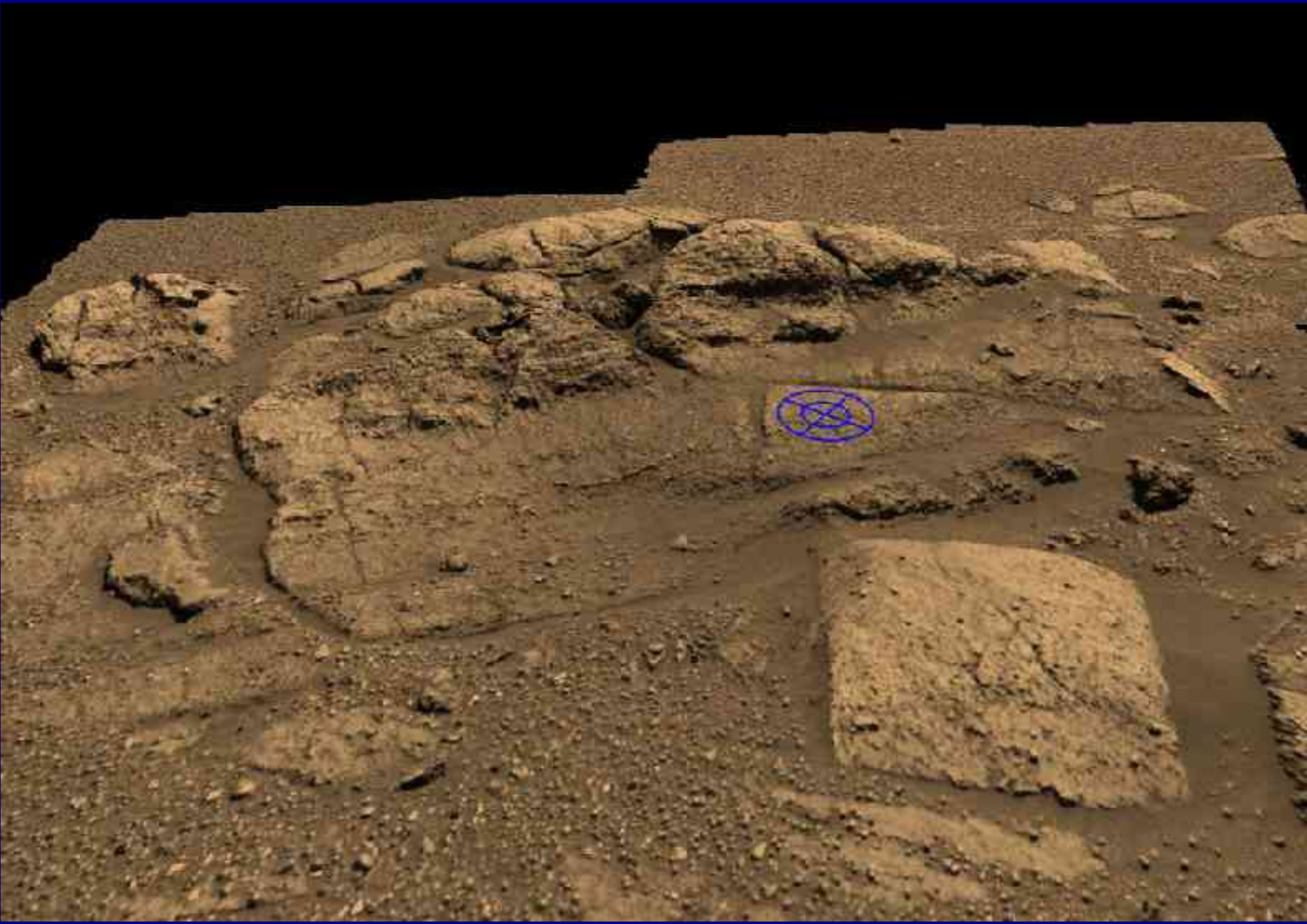


# Opportunity plan

- Finish exploration of the outcrop and crater
  - A significant amount of time may be spent here, depending on the results
  - Several possible long-range targets:
    - 150 m crater
    - Other small craters
    - Heat shield
    - Retro-rocket firing ground effects


Dark Outcrop
El Capitan
Big Bend
Stone Mtn.
Trench Site





# Conclusions

- John uses too many slides
- It's hard to cut pretty pictures from a talk
- The rovers have been busy so far
- It's too early (for us on the outside anyway) to draw any serious scientific conclusions
- There is still a significant amount of work to be done at each landing site... the rovers have a huge amount of work ahead of them