Mars Exploration Rovers Science Results from 6¼ Years on Mars

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and the Athena Science Team

“Follow the Water”

Mars Exploration Rovers Science Objective:

Determine the geologic and climatic history of two sites on Mars where evidence may have been preserved for past and persistent liquid water activity that may have supported biotic or pre-biotic processes.

Scientific Results of MER

- Positively established the importance of persistent water in the geological history of Mars.
- Started to explore the geological diversity of the planet through true field geology.
  - Rich range of mineralogy: Soils, rocks, meteorites
  - Detailed stratigraphic records
  - Abundant clues from geomorphology about erosional and depositional processes
- In-situ studies of dynamic processes
  - Meteorology: Clouds, winds, dust devils, thermal structure
  - Eolian processes
- Detailed geological studies of two locations
  - Massive sulfate sandstone deposits of Meridiani Planum
  - A volcanic complex within the inner basin of the Columbia Hills, Gusev Crater

Outline

- Description of Mars Exploration Rover mission
- Summary of results up to the Planet Mars II workshop, May 2005 (roughly sol 500 of the 90-sol mission)
- Science results since May 2005
- Current status, plans

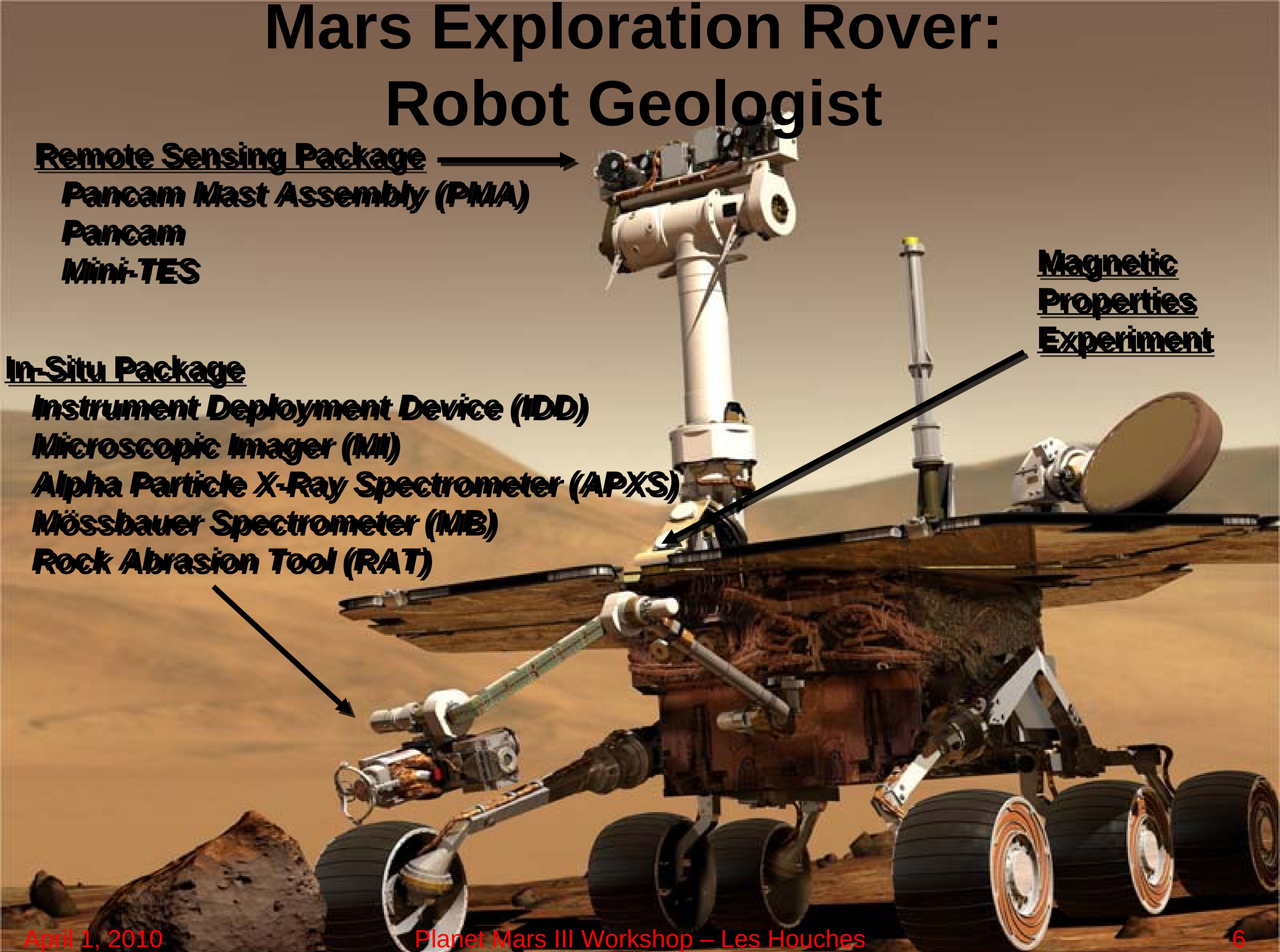
We know from orbital observations that the history of water on Mars happened, for the most part, several billion years ago.

So, the key to this history is contained in the rocks: their chemistry, crystal structure, texture, and morphology.

Therefore, we need a geologist to ferret out the subtle clues to the ancient past.

Robot Geologist
Real Geologist

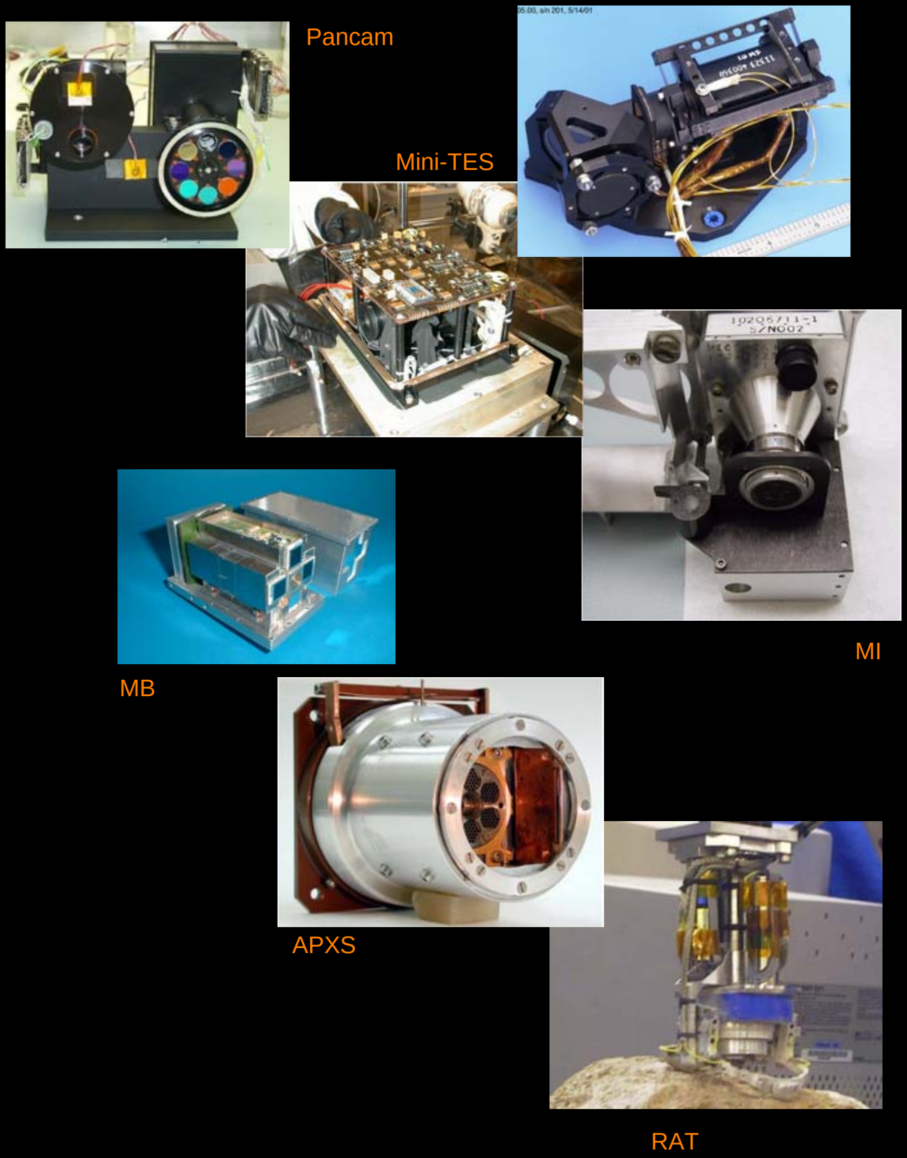
Mars Exploration Rover: Robot Geologist



Athena Science Payload

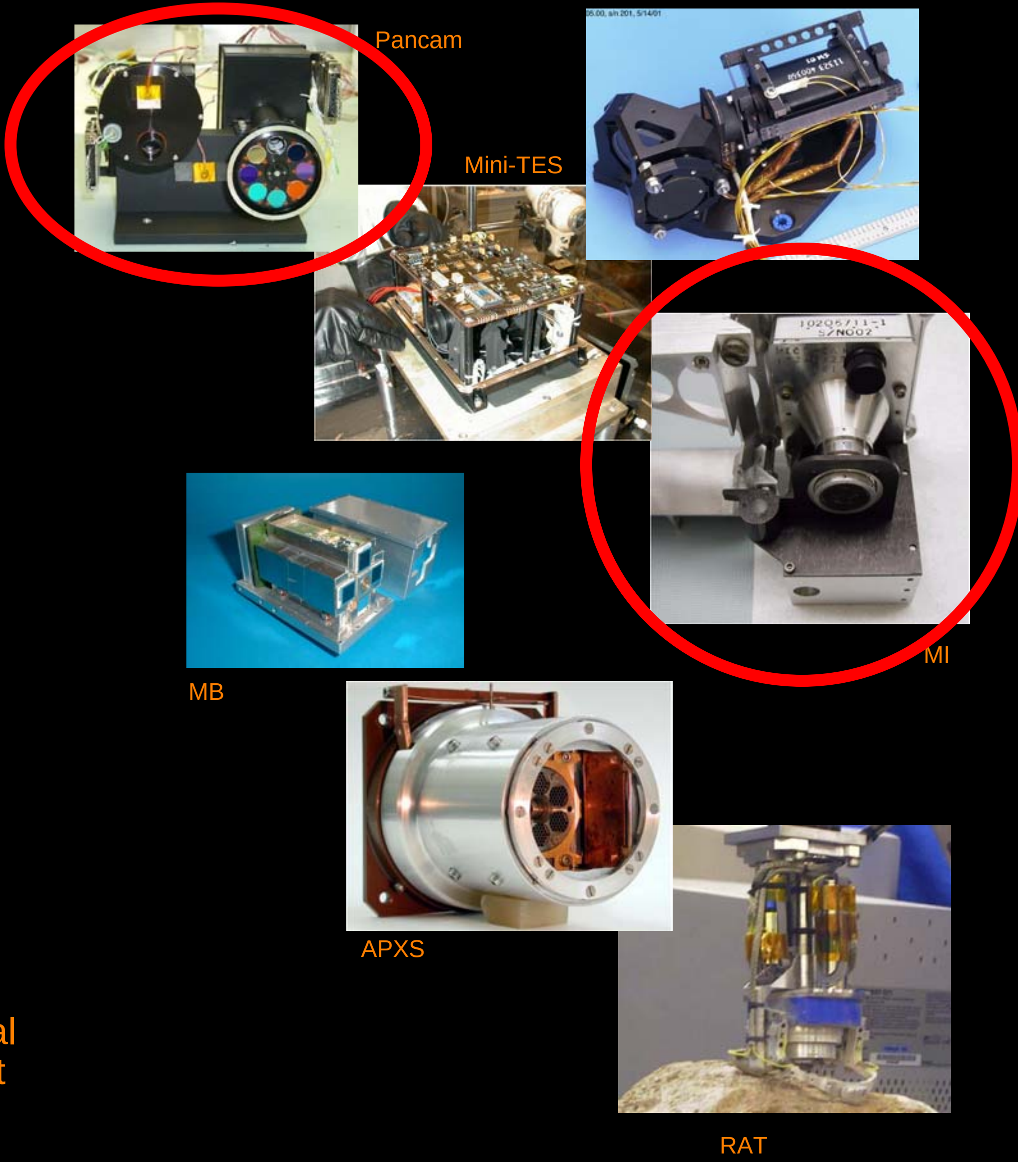
- **Pancam** – high-resolution (16°x16°) color panchromatic stereo cameras
- **Mini-TES** – mid-infrared point spectrometer
- **Microscopic Imager** – close-up imaging of rocks and soil
- **Mössbauer Spectrometer** – analysis of mineralogy of iron-bearing rocks
- **Alpha Particle X-Ray Spectrometer** – quantitative abundance of elements in rocks and soils
- **Rock Abrasion Tool** – used to remove outer surface of rocks for analysis of non-weathered rock material

- **Engineering cameras**
  - Navcams – 2 wide-angle stereo cameras (45°x 45°) used for traverse planning
  - Hazcams – 4 very-wide-angle (120°x120°) stereo cameras used for identifying potential hazards to rover driving and arm movement



Cameras:
“What does it look like?”

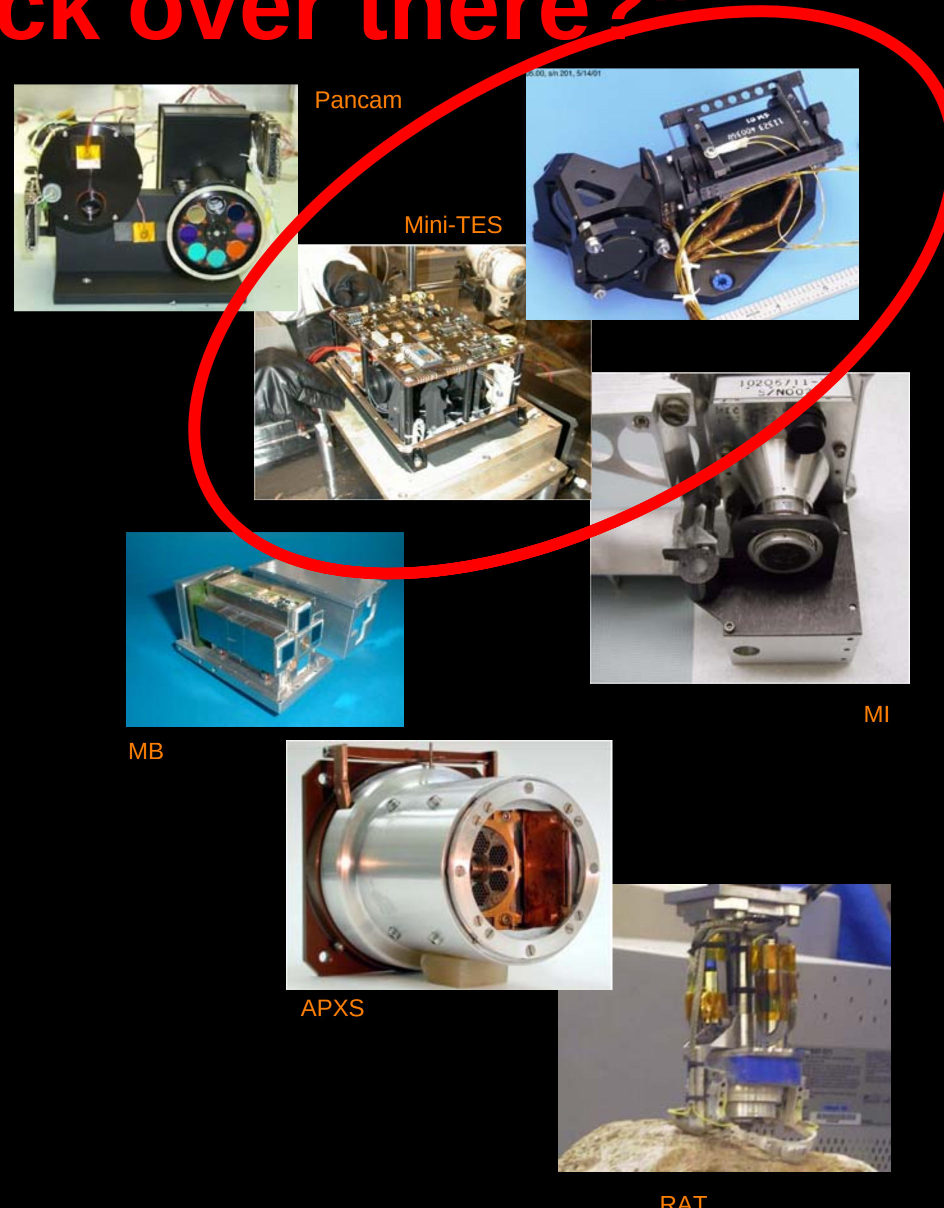
- **<u>Pancam</u>** – high-resolution (16°x16°) color panchromatic stereo cameras
- **<u>Microscopic Imager</u>** – close-up imaging of rock and “soil”



- **Engineering cameras**
  - <u>Navcams</u> – 2 wide-angle stereo cameras (45°x 45°) used for traverse planning
  - <u>Hazcams</u> – 4 very-wide-angle (120°x120°) stereo cameras used for identifying potential hazards to rover driving and arm movement

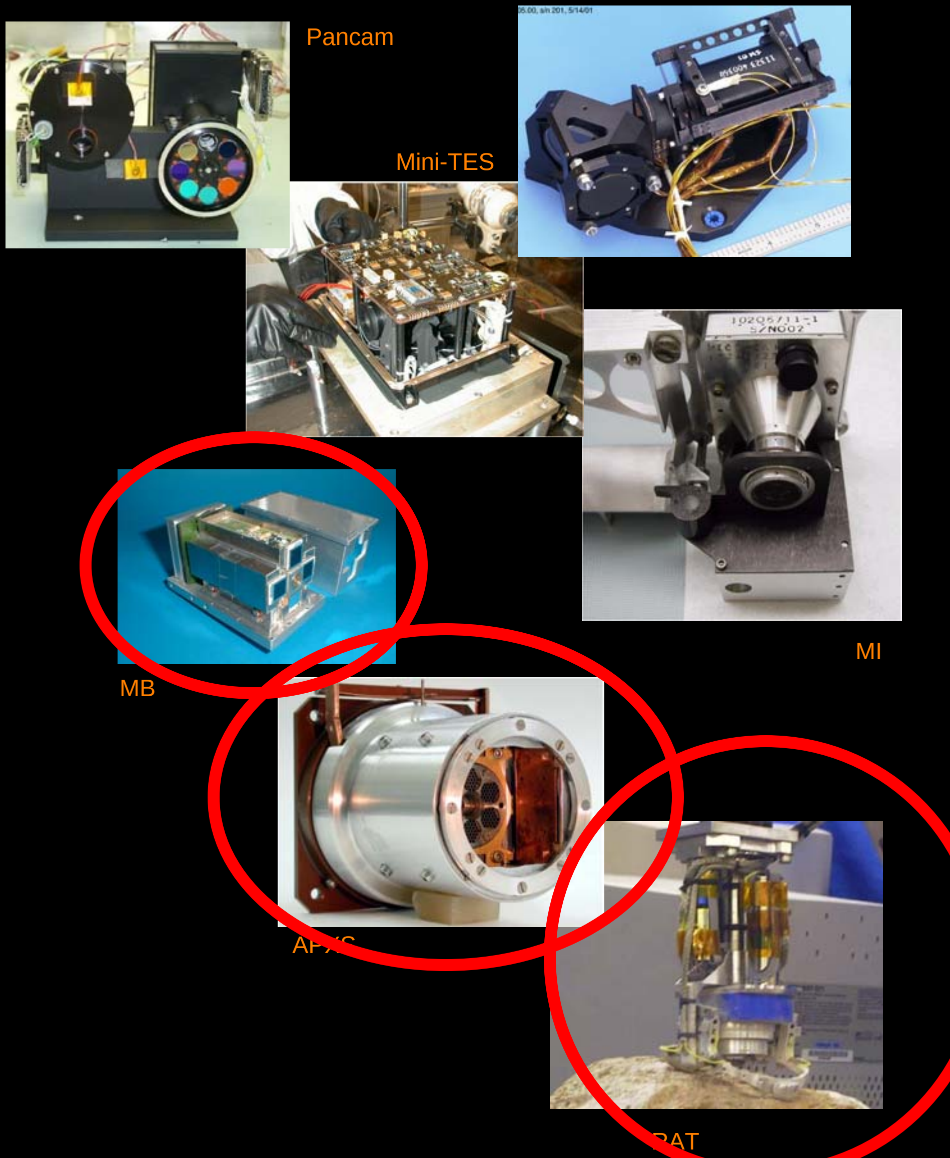
Infrared Spectrometer: "What is that rock over there?"

- **Mini-TES** – a mid-infrared point spectrometer



Contact Instruments:
"What is it made of?"

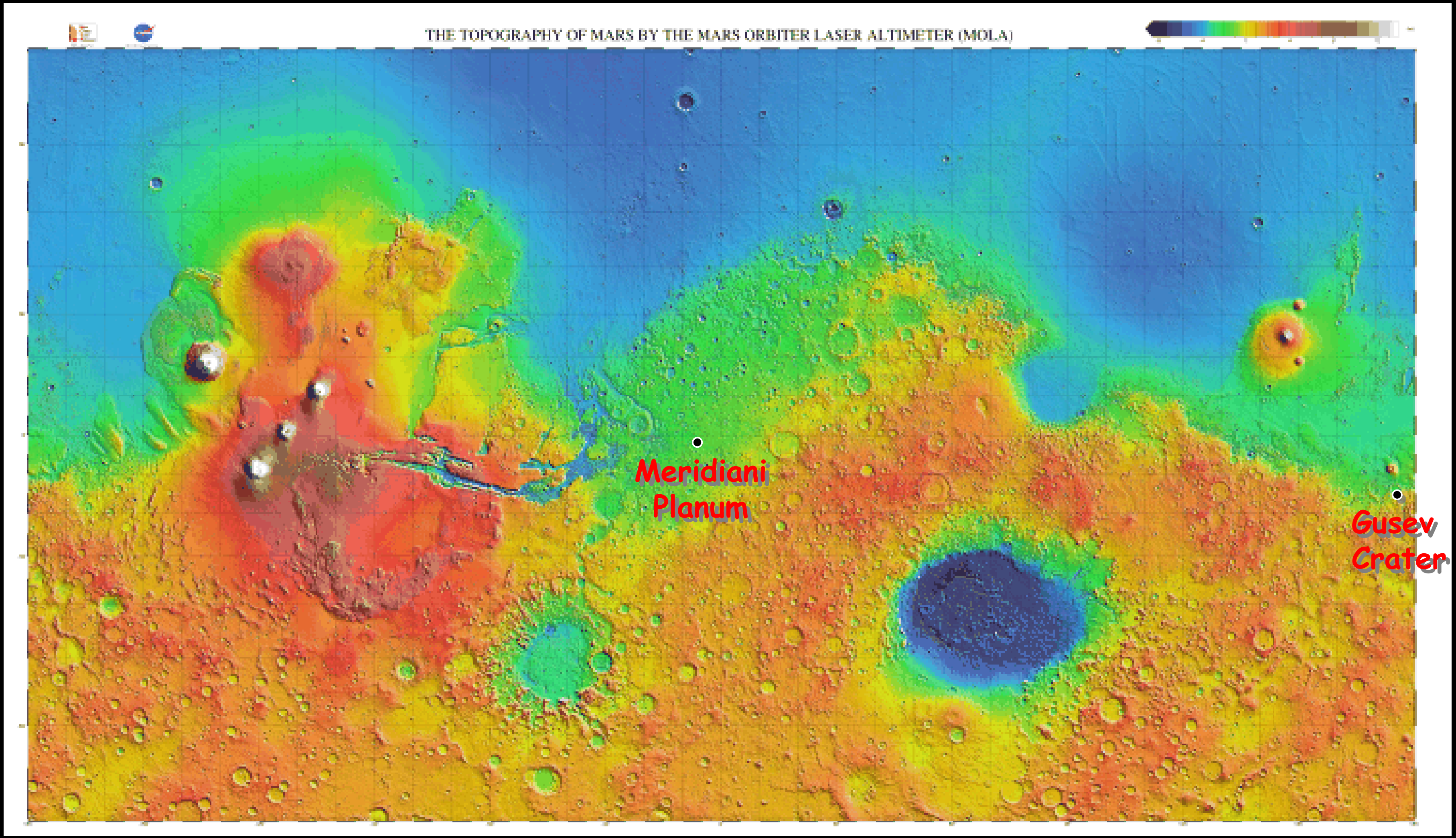
- **Mössbauer Spectrometer** – analysis of mineralogy of iron-bearing rocks
- **Alpha Particle X-Ray Spectrometer** – detects elements in rocks and "soils"
- **Rock Abrasion Tool** – used to remove outer surface of rocks for analysis of non-weathered rock material



Spirit – June 10, 2003

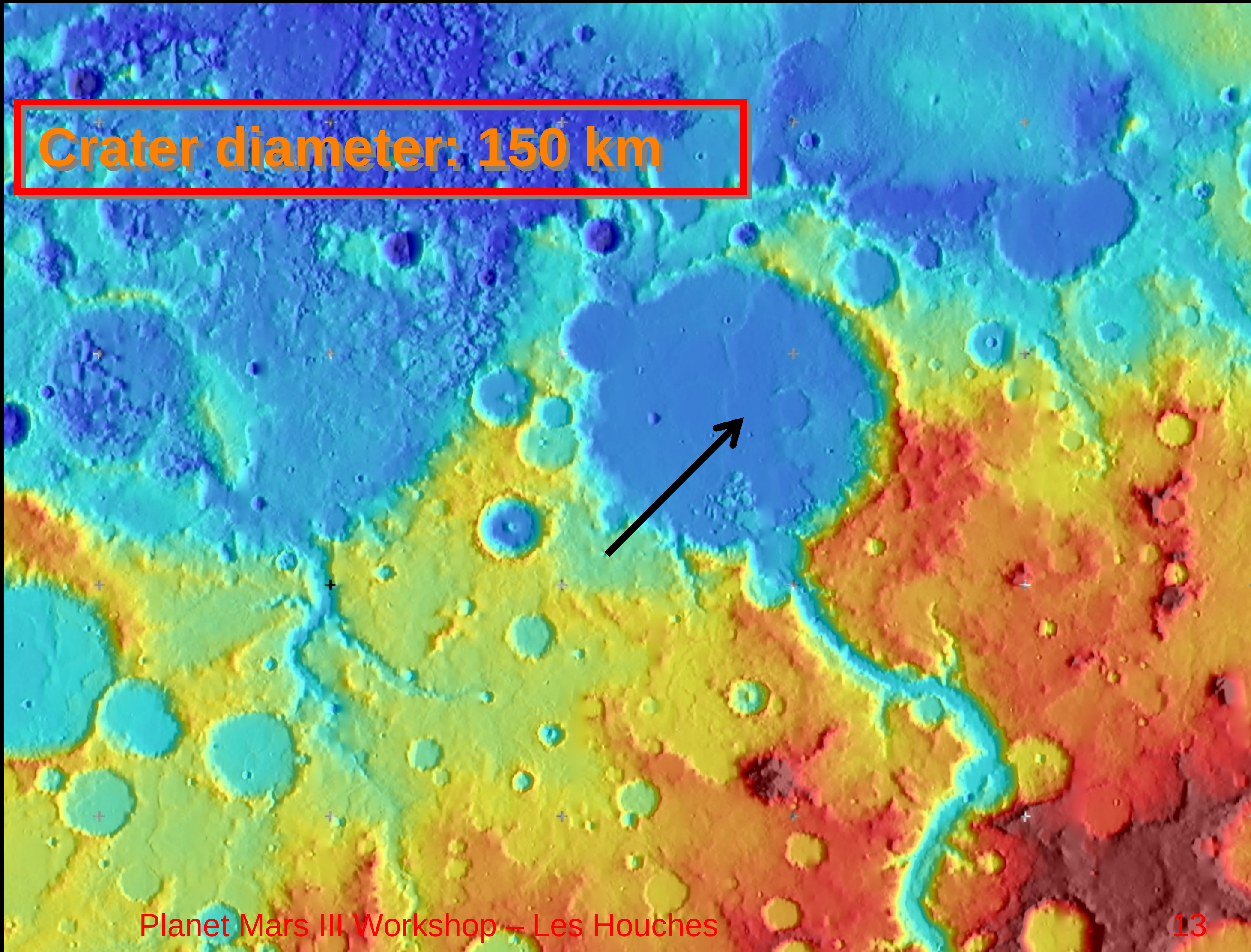
Opportunity– July 7, 2003

Landing Sites



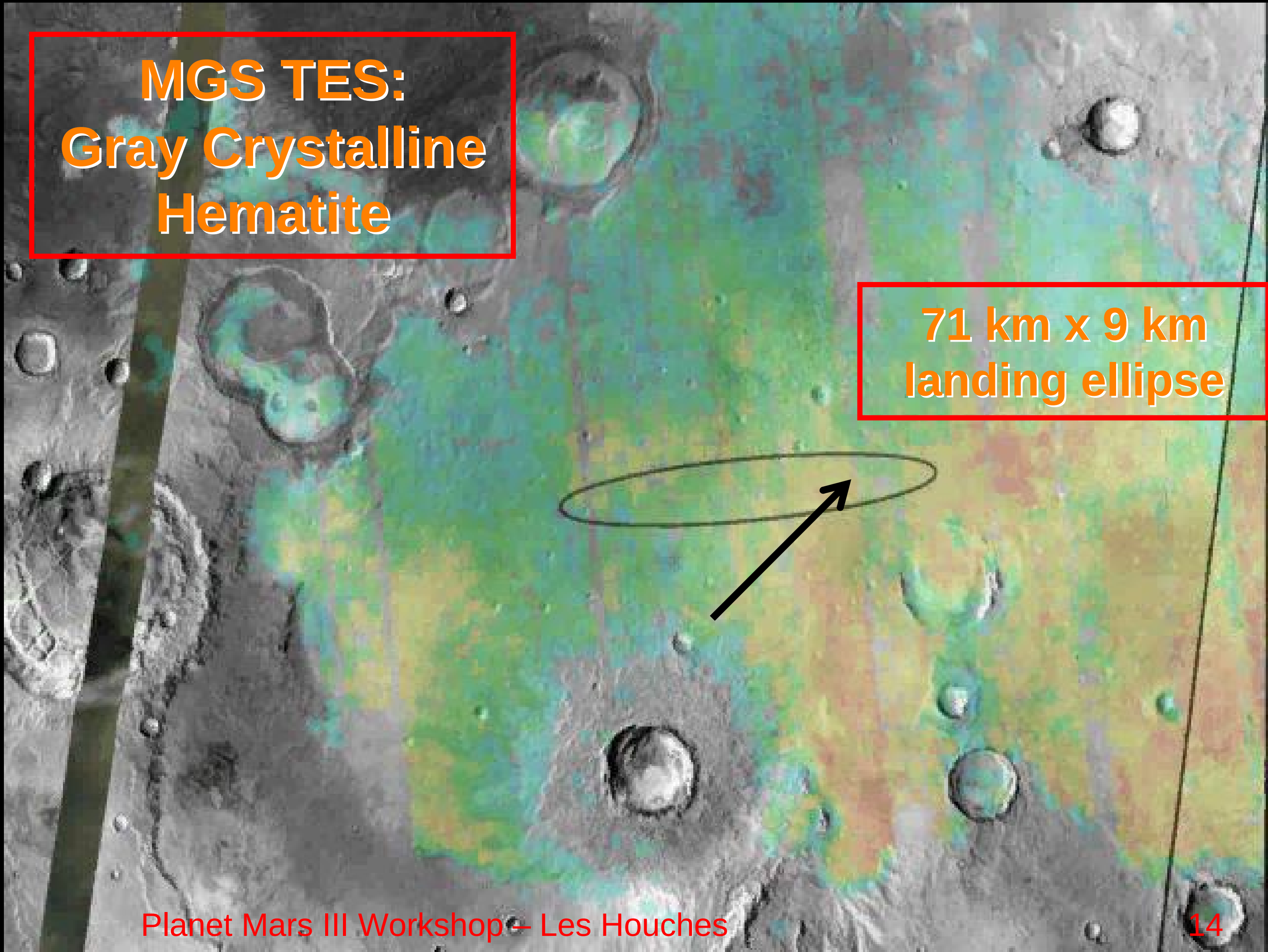
Spirit – Gusev Crater

Sol 2219, 11:51 LST-A
Distance traveled: 7,730.50 meters



Opportunity - Meridiani Planum

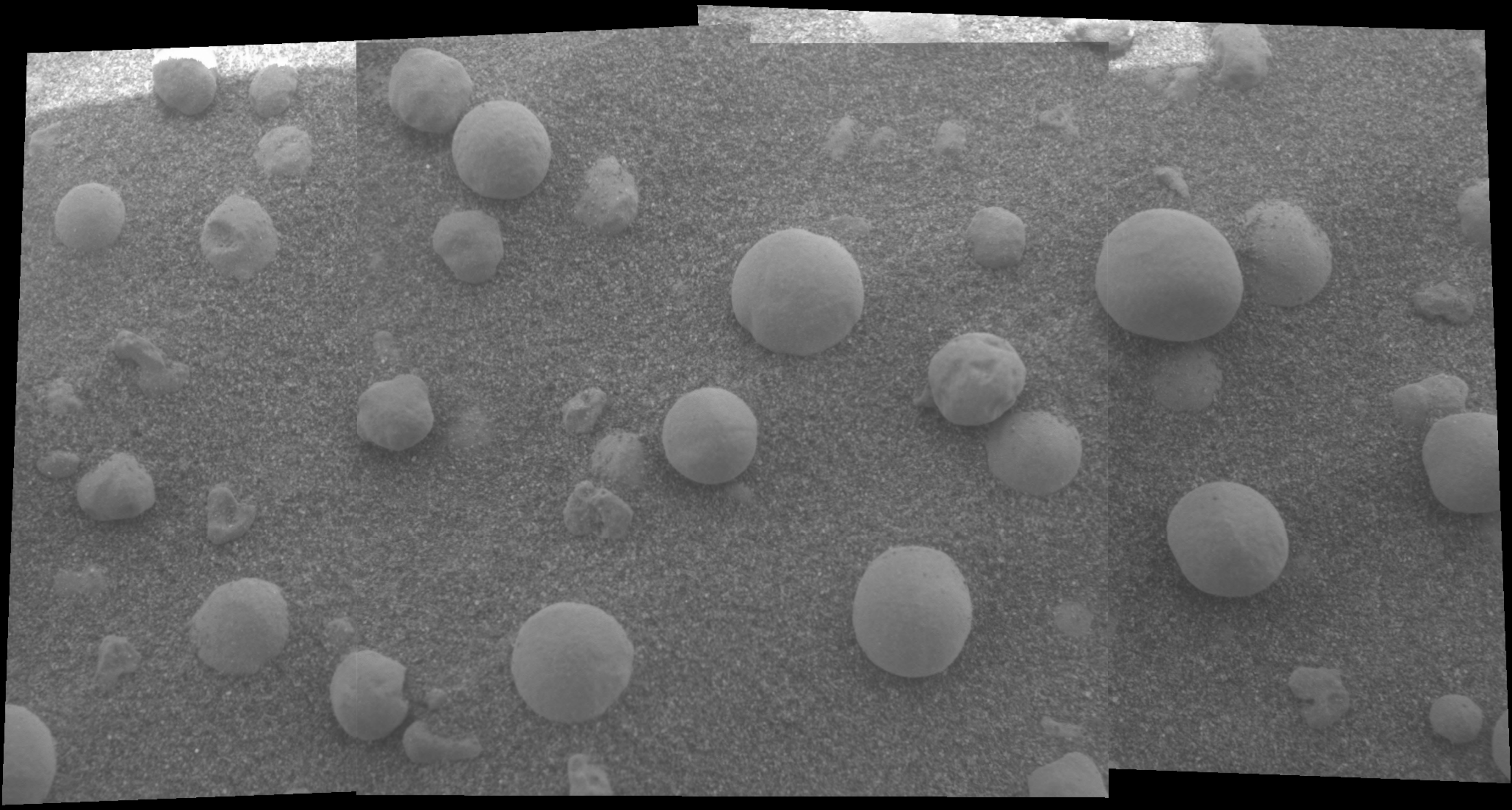
Sol 2198, 23:49 LST-B
Distance traveled: 20,196.22 meters

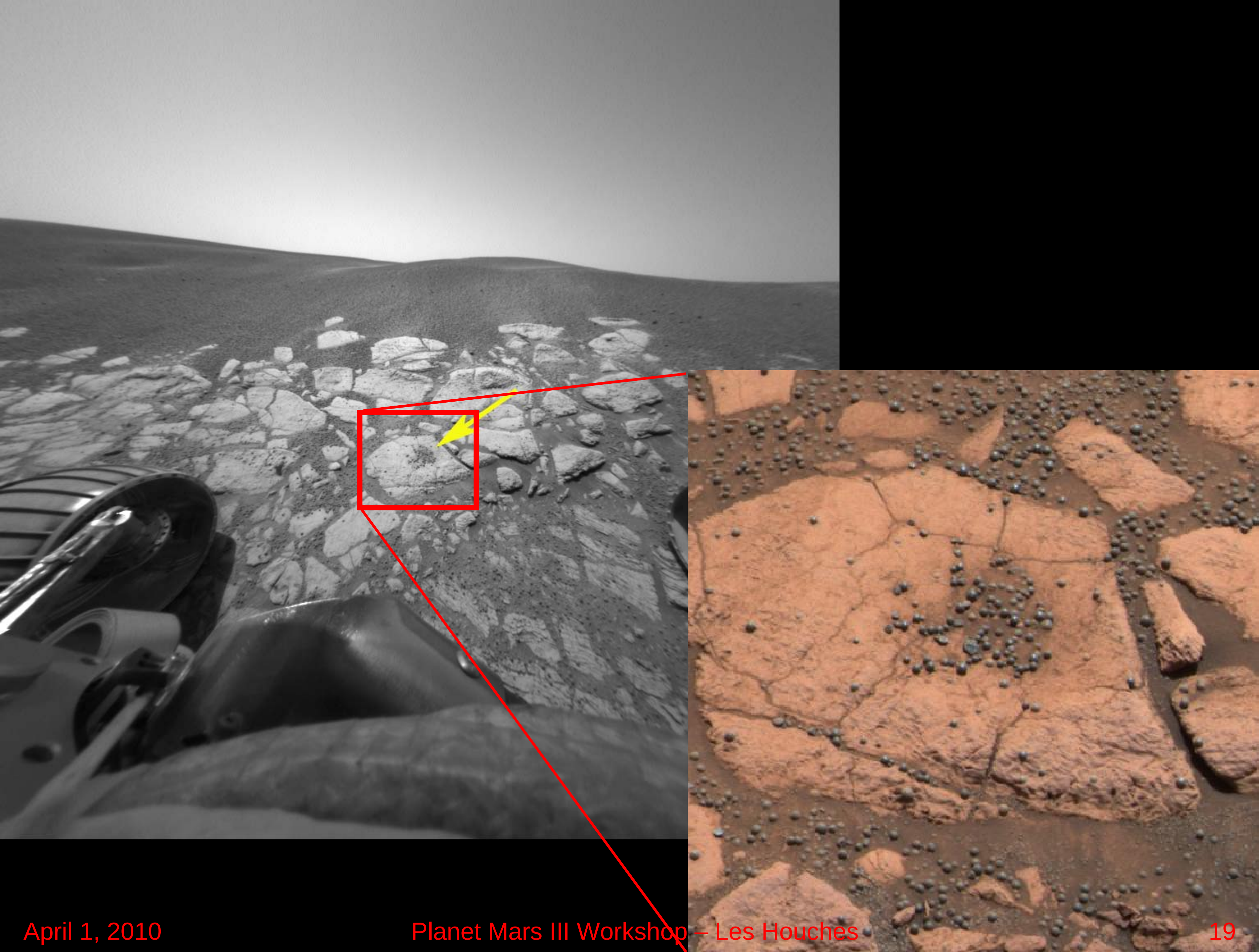


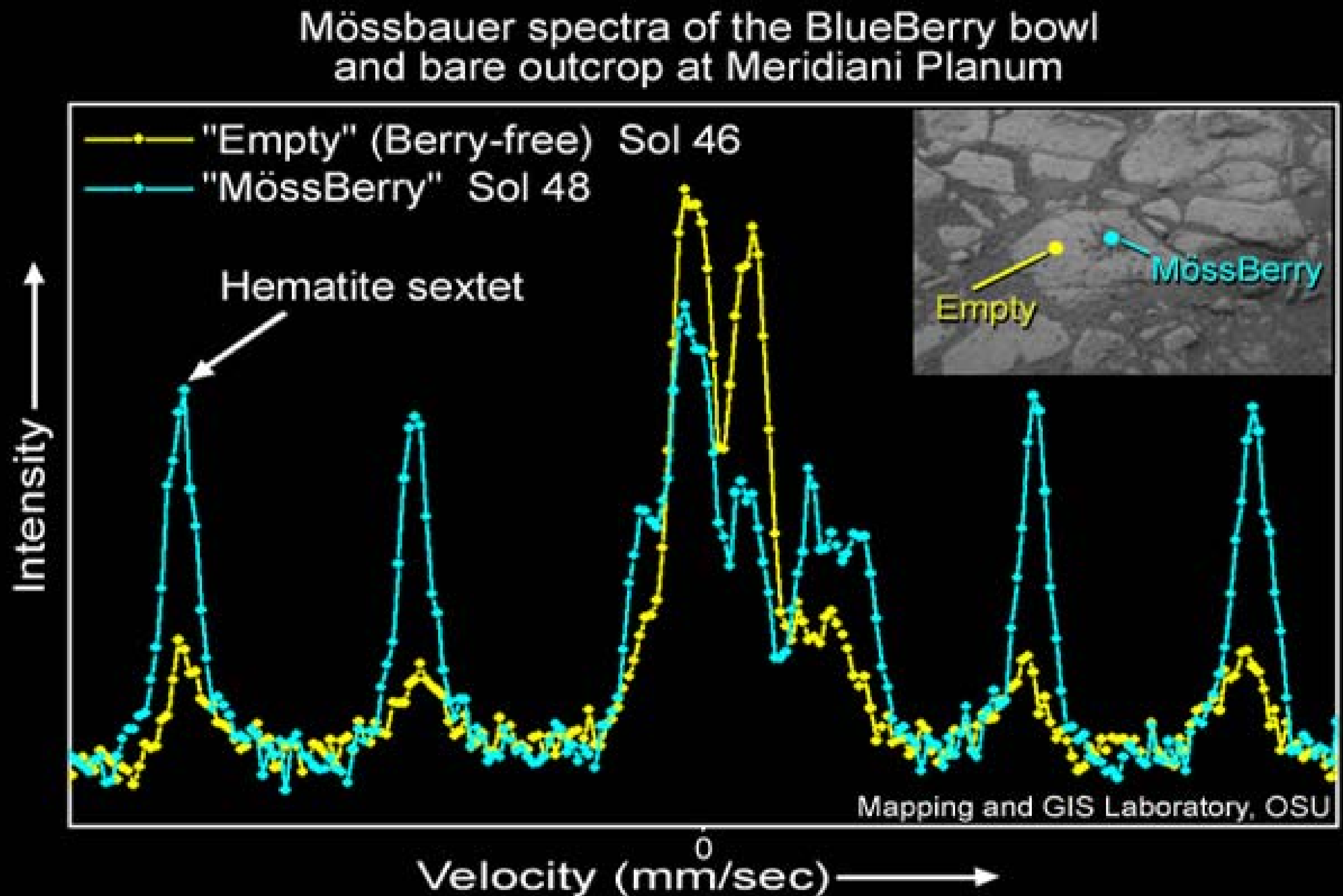
Opportunity:
The Hematite Story

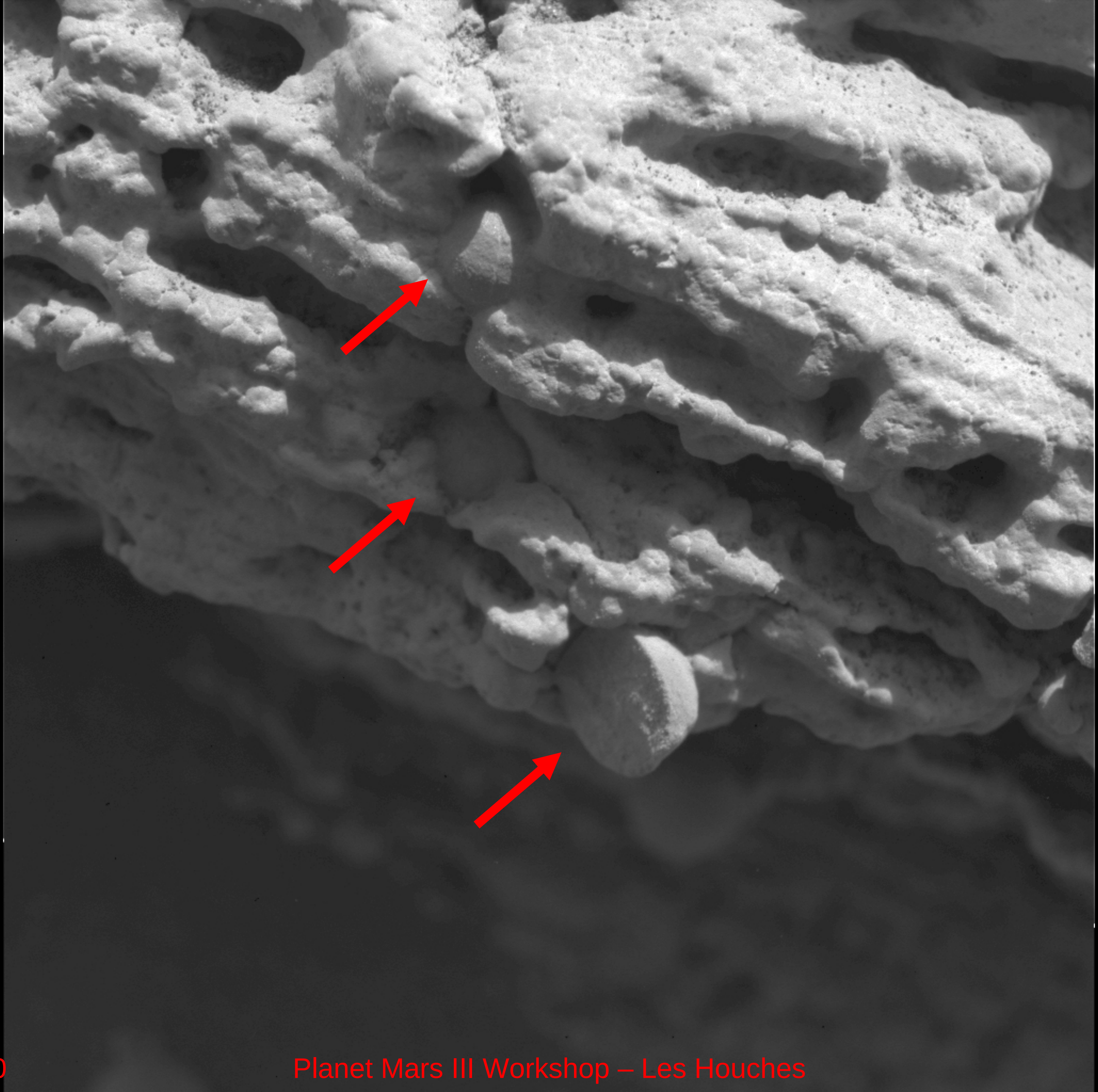
Hematite

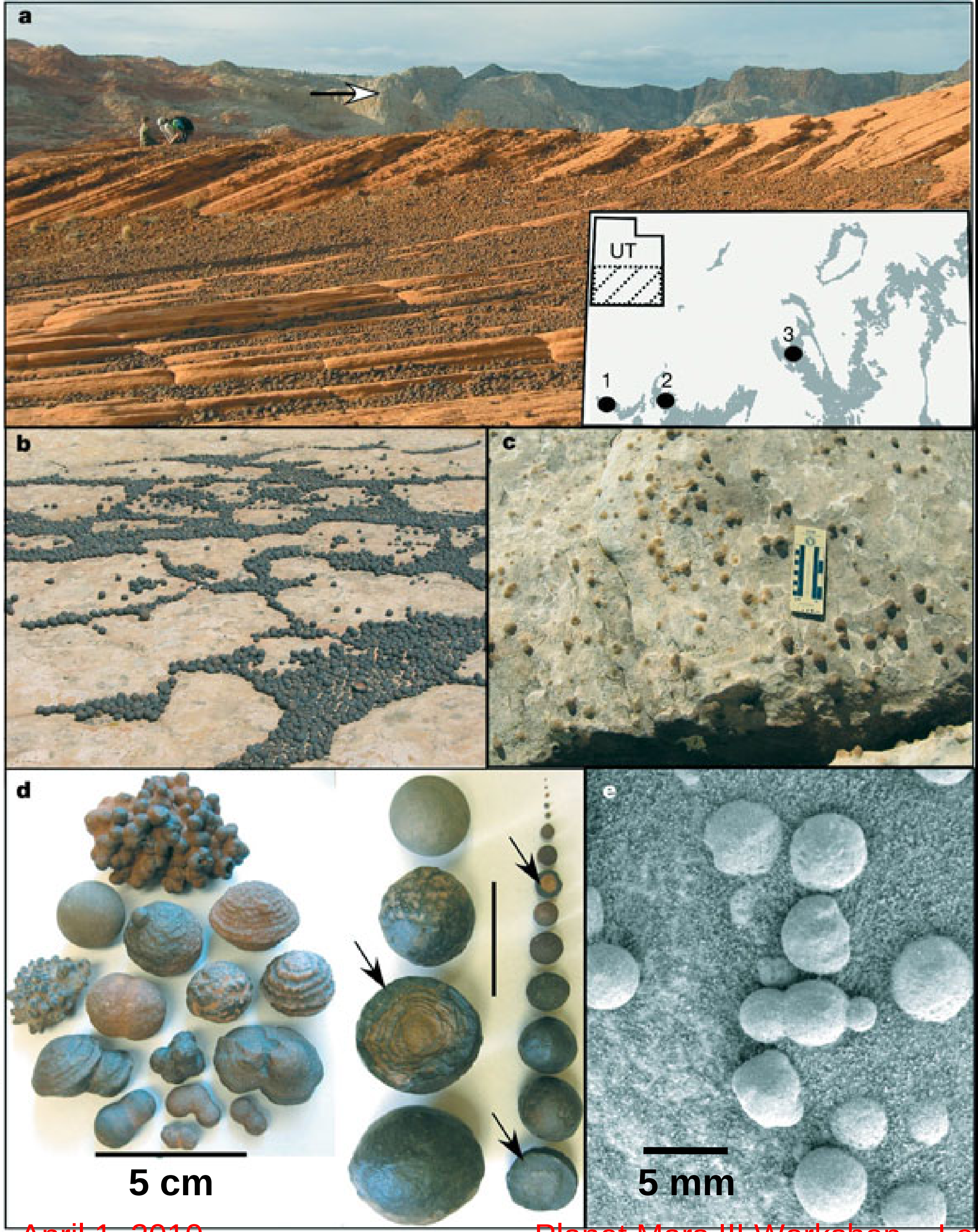
Chemical formula:	Iron(III) oxide, Fe_2O_3
Color:	Metallic grey to earthy red
Crystal system:	Hexagonal (rhombohedral)
Mohs hardness:	5.5 - 6.5
Specific gravity:	4.9 - 5.3






Mössbauer spectra of the BlueBerry bowl
and bare outcrop at Meridiani Planum
"Empty" (Berry-free) Sol 46
"MössBerry" Sol 48
Hematite sextet
Intensity
Empty
MössBerry
Mapping and GIS Laboratory, OSU
0
Velocity (mm/sec)





Hematite Concretions in Southern Utah

(Chan et al. 2004)

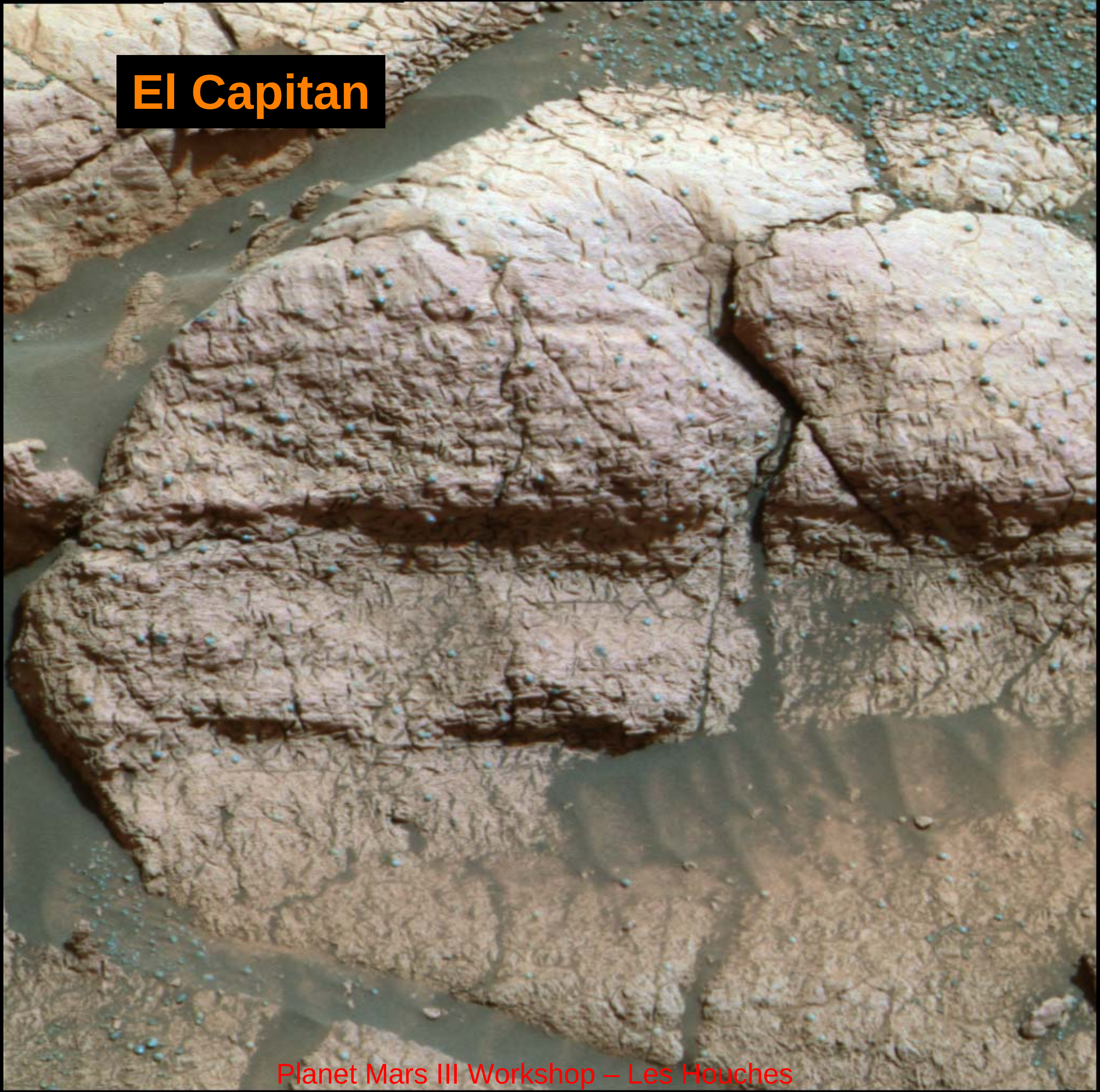
Hematite: Strong (but Indirect) Evidence for Water

- Hematite is present in widespread deposits in the form of 3-5 mm spherical pebbles.

- The hematite nodules appear to have formed in place, within the intact rock units.

- The most likely mechanism identified (concretion in solution) involves large amounts of groundwater flowing through the rock.

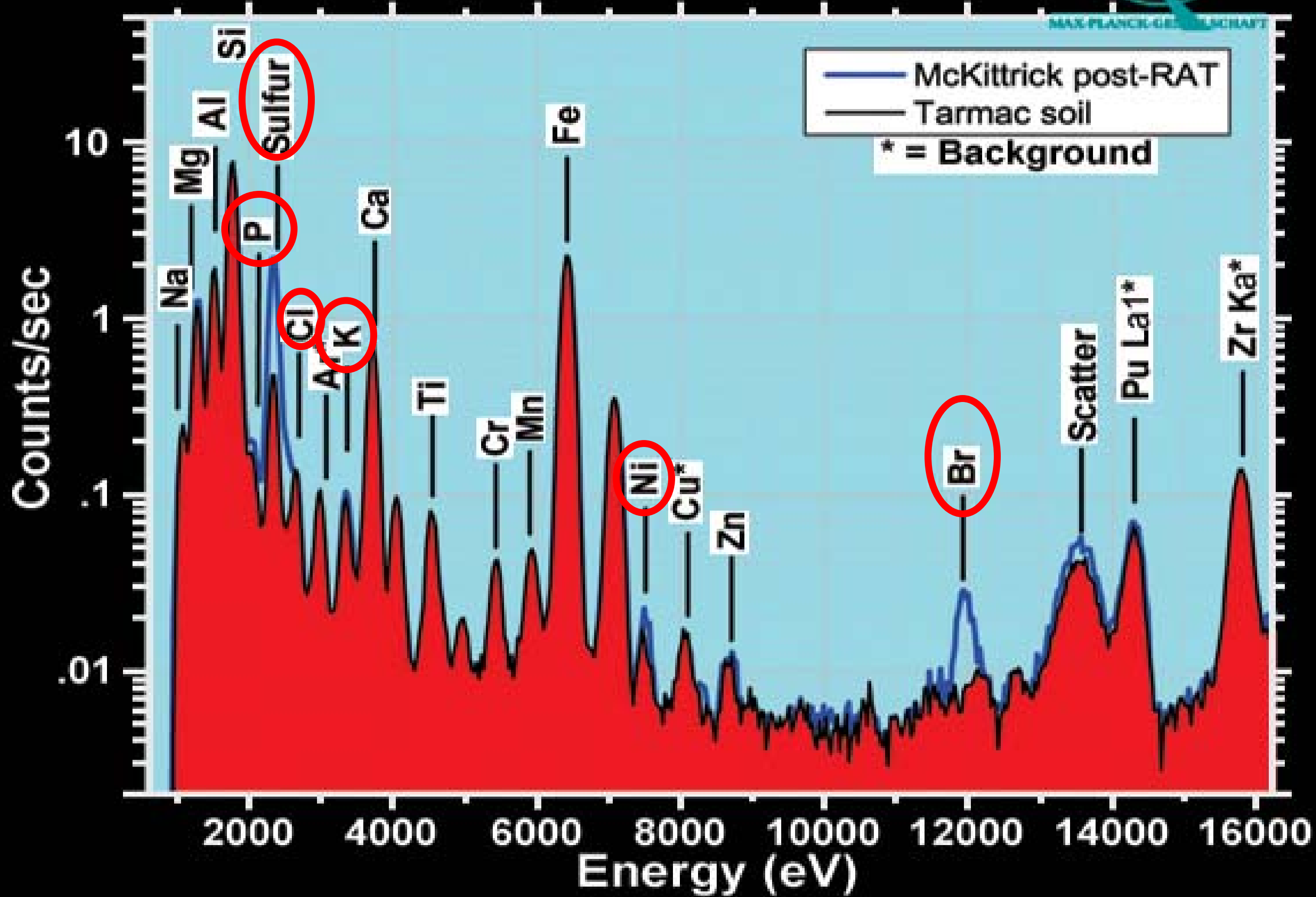
Opportunity:
The Jarosite Story


El Capitan

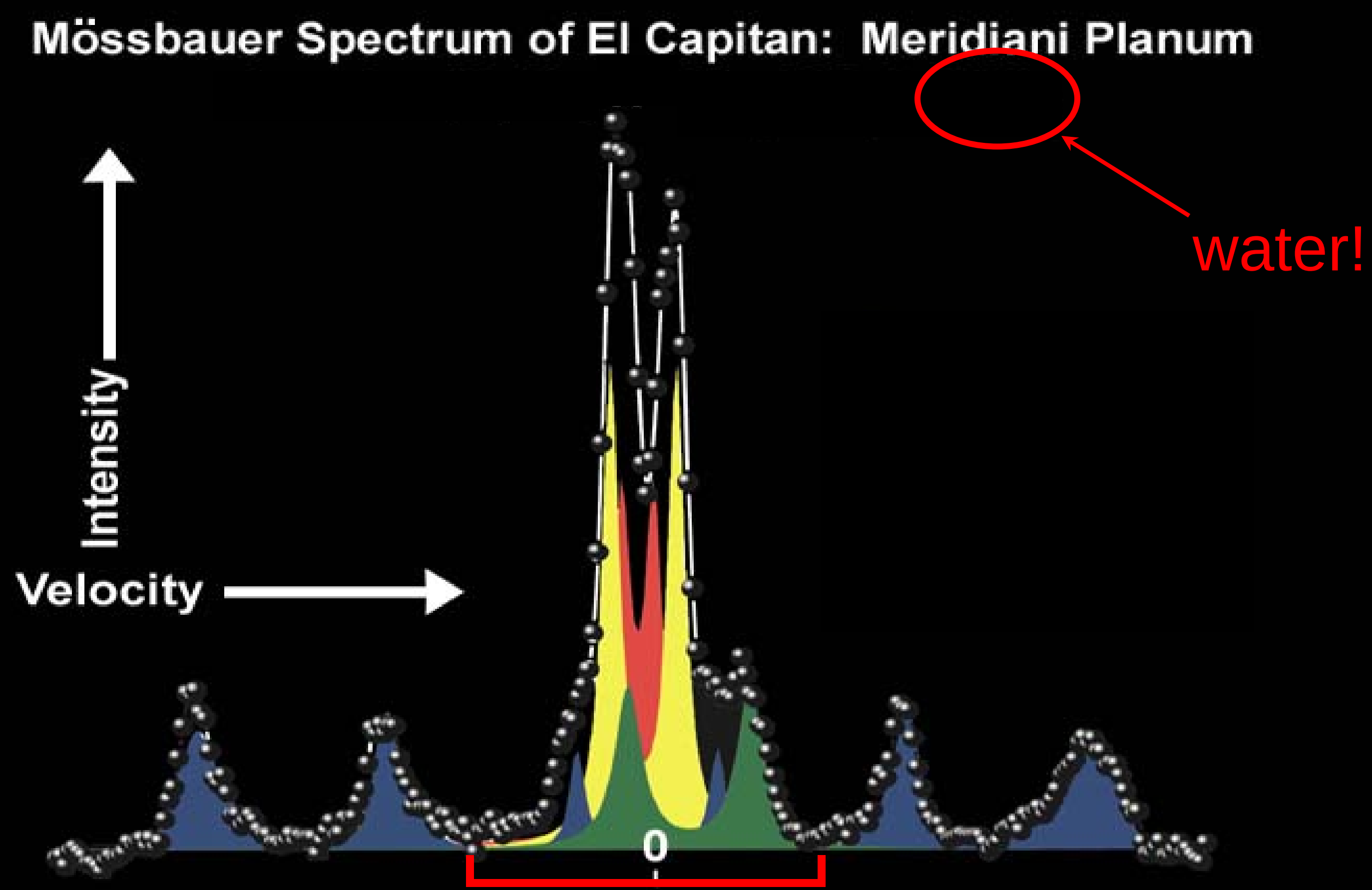
Pre-RAT

Post-RAT

APXS Rock and Soil X-ray Spectra at Meridiani



Mössbauer Analysis



Jarosite

Chemical formula:	Hydrated potassium-iron sulfate $KFe^{3+}_3 (SO_4)_2 (OH)_6$
Color:	Amber to yellowish-brown
Crystal system:	Hexagonal
Mohs hardness:	2.5 - 3.5
Specific gravity:	3.15 - 3.26

Jarosite: Direct Evidence for Water

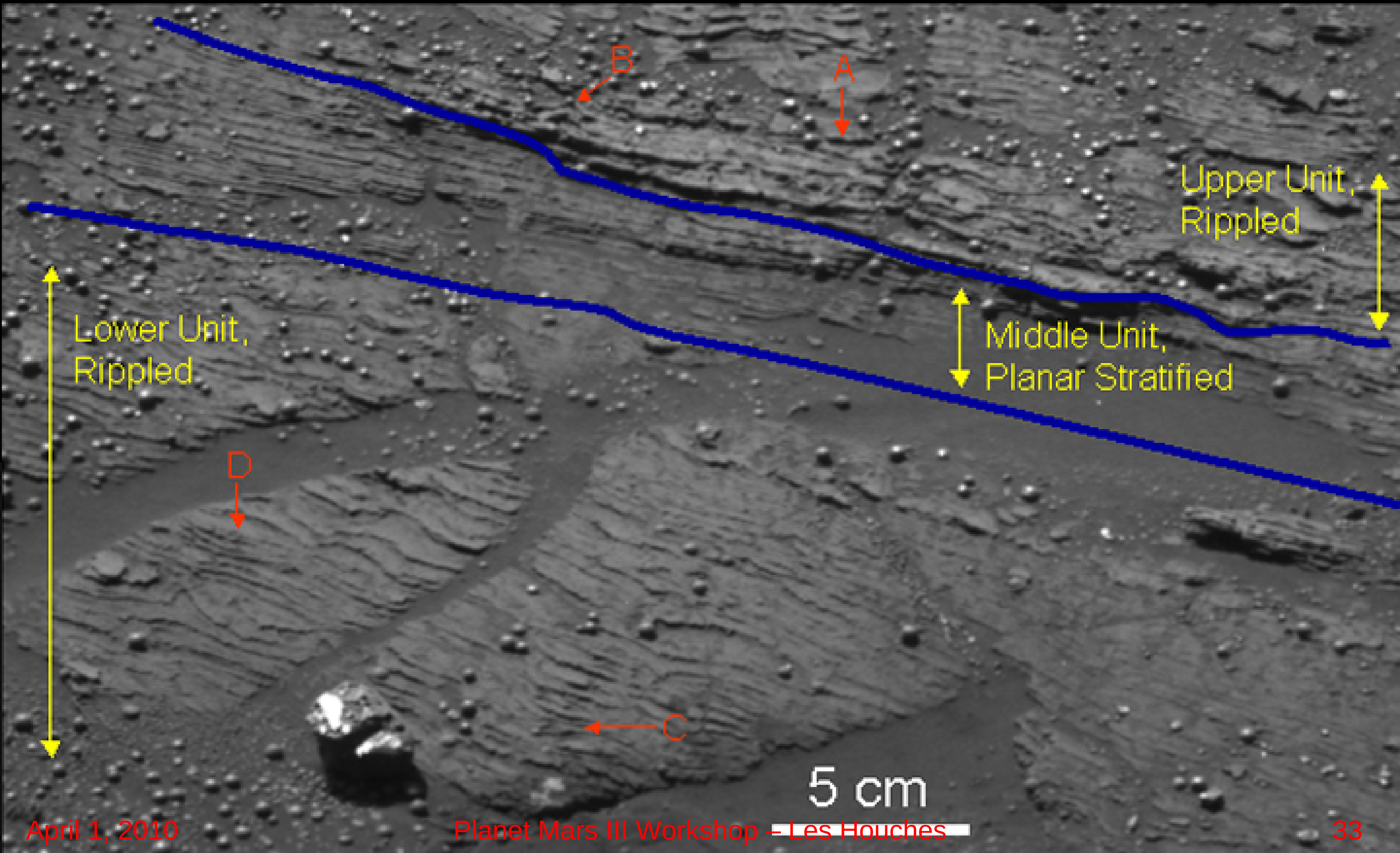
- The rocks found in Eagle Crater are sandstones made up of at least 60% iron sulfates, largely jarosite.
- The formation of jarosite <u>requires</u> water.
- The presence of jarosite tells us more about the environment in which it formed:
  - Moderate temperature
  - Acidic (ph = 2-4)
  - Oxidizing

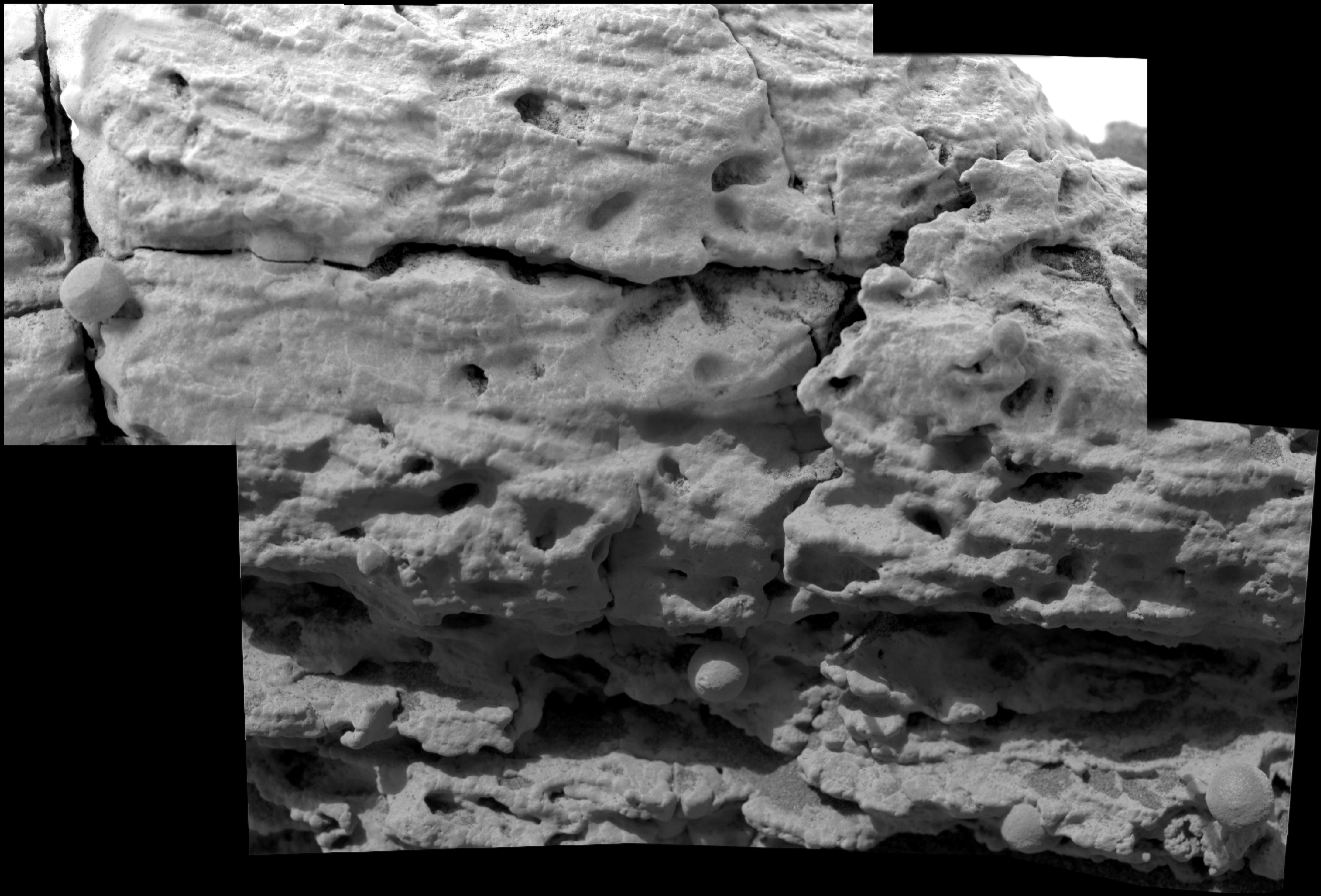
Rio Tinto, Spain

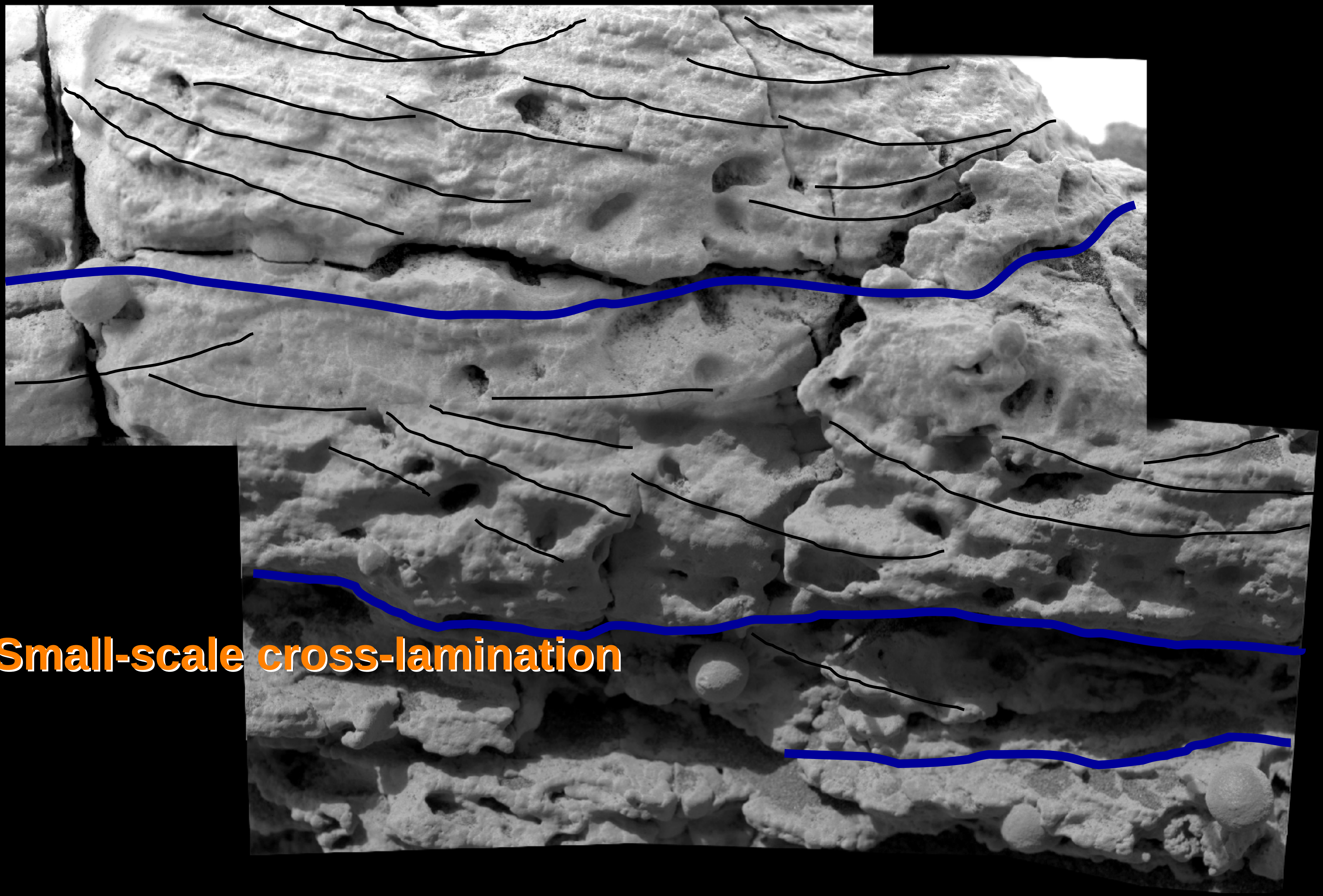
Opportunity: Changing Conditions and Surface Water

“Slickrock”

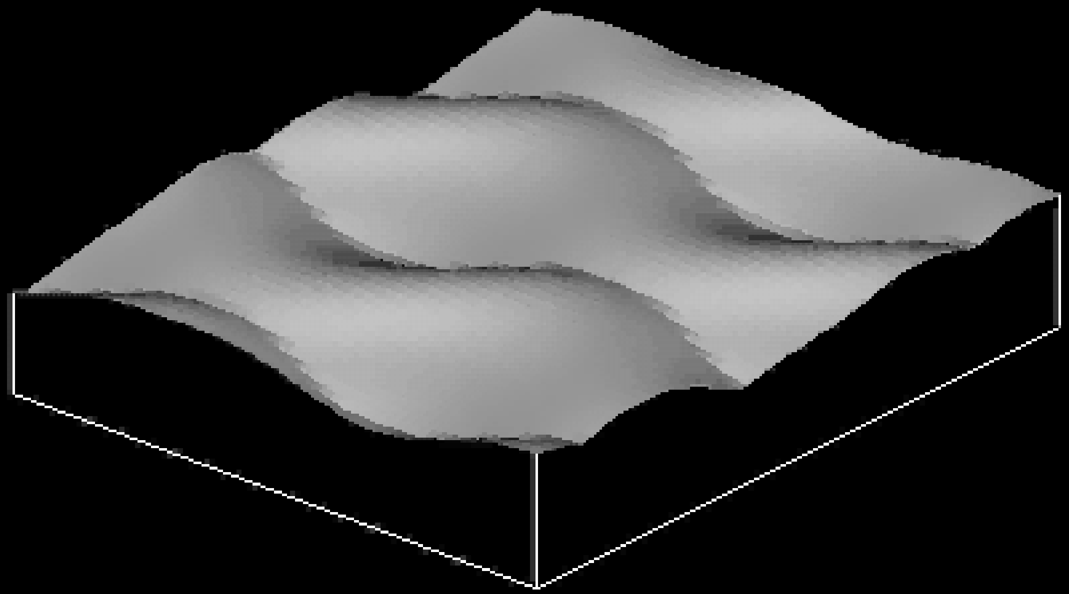
“Slickrock”


B
A
Upper Unit,
Rippled
Lower Unit,
Rippled
Middle Unit,
Planar Stratified
D
C
5 cm

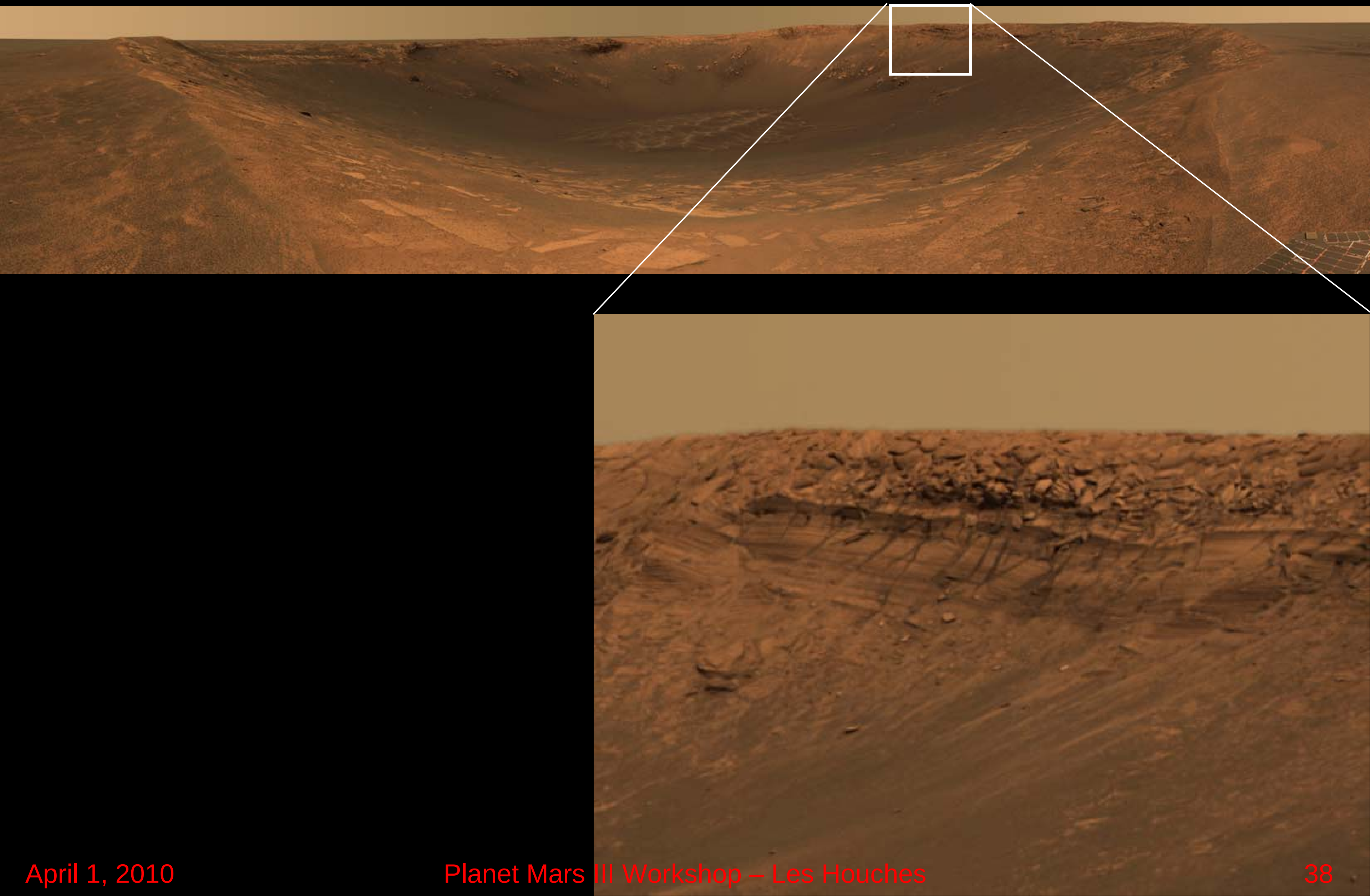




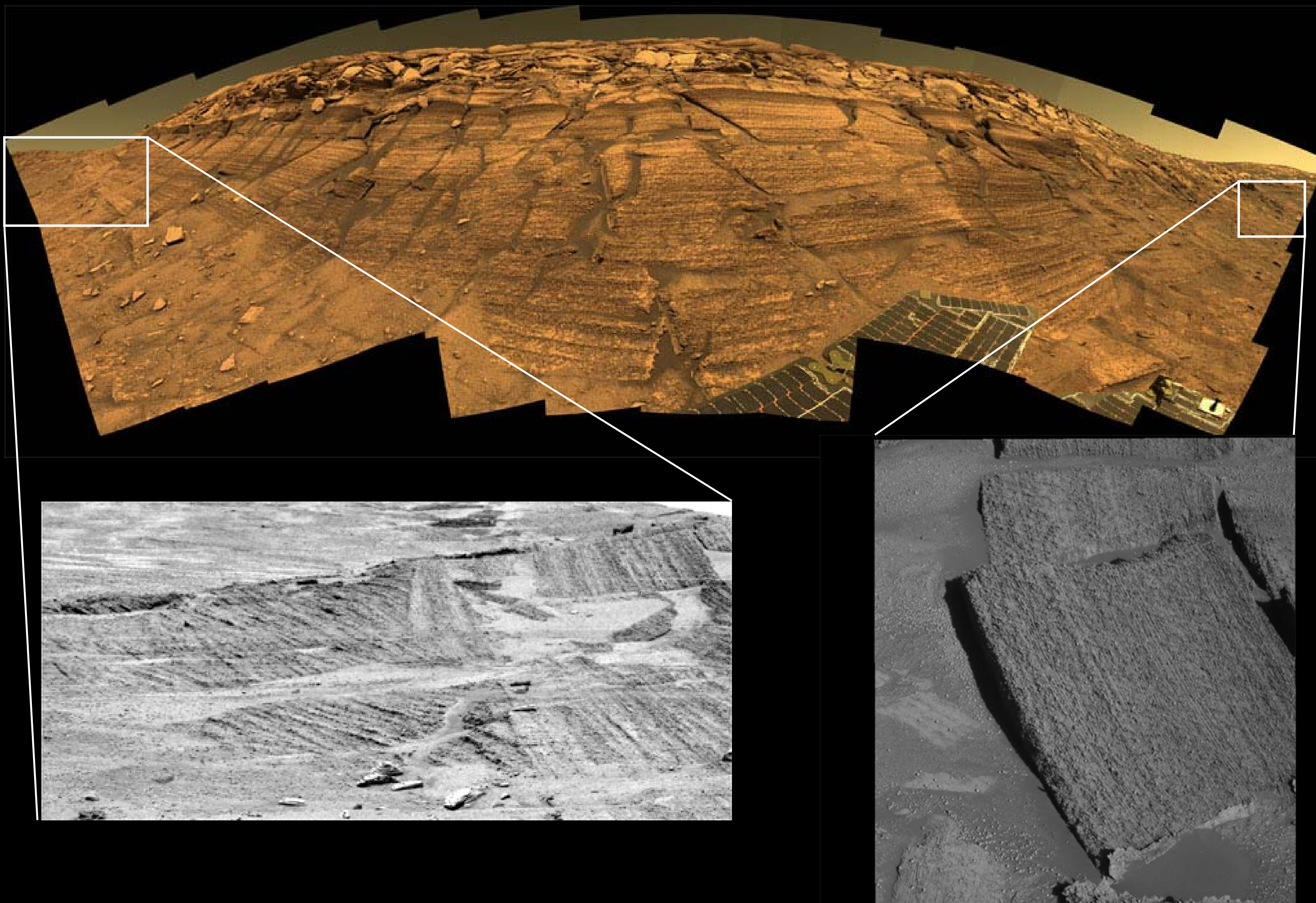
Small-scale cross-lamination

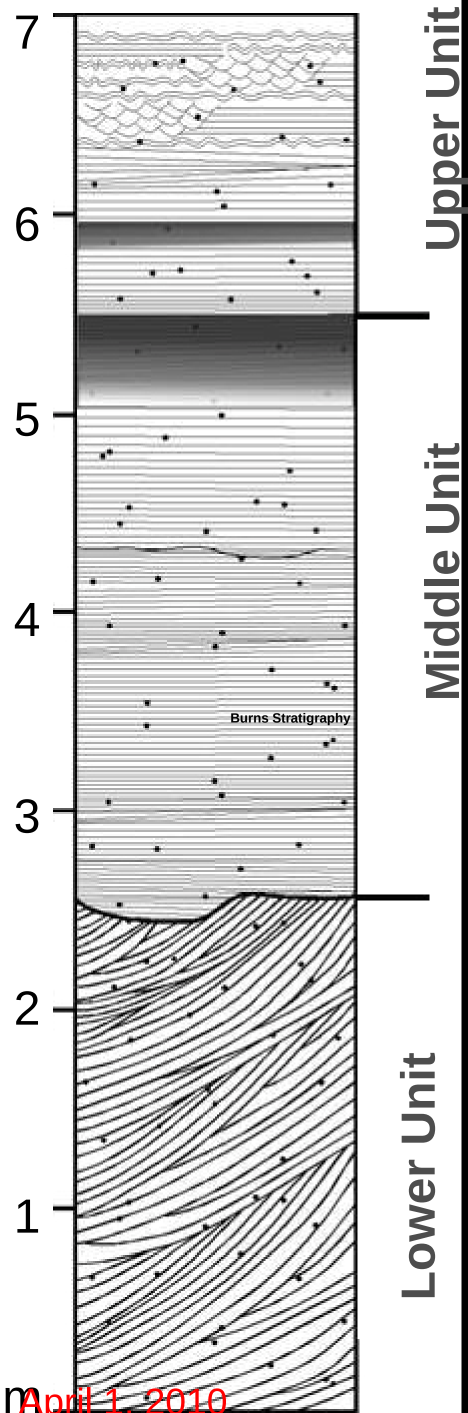


Endurance Crater



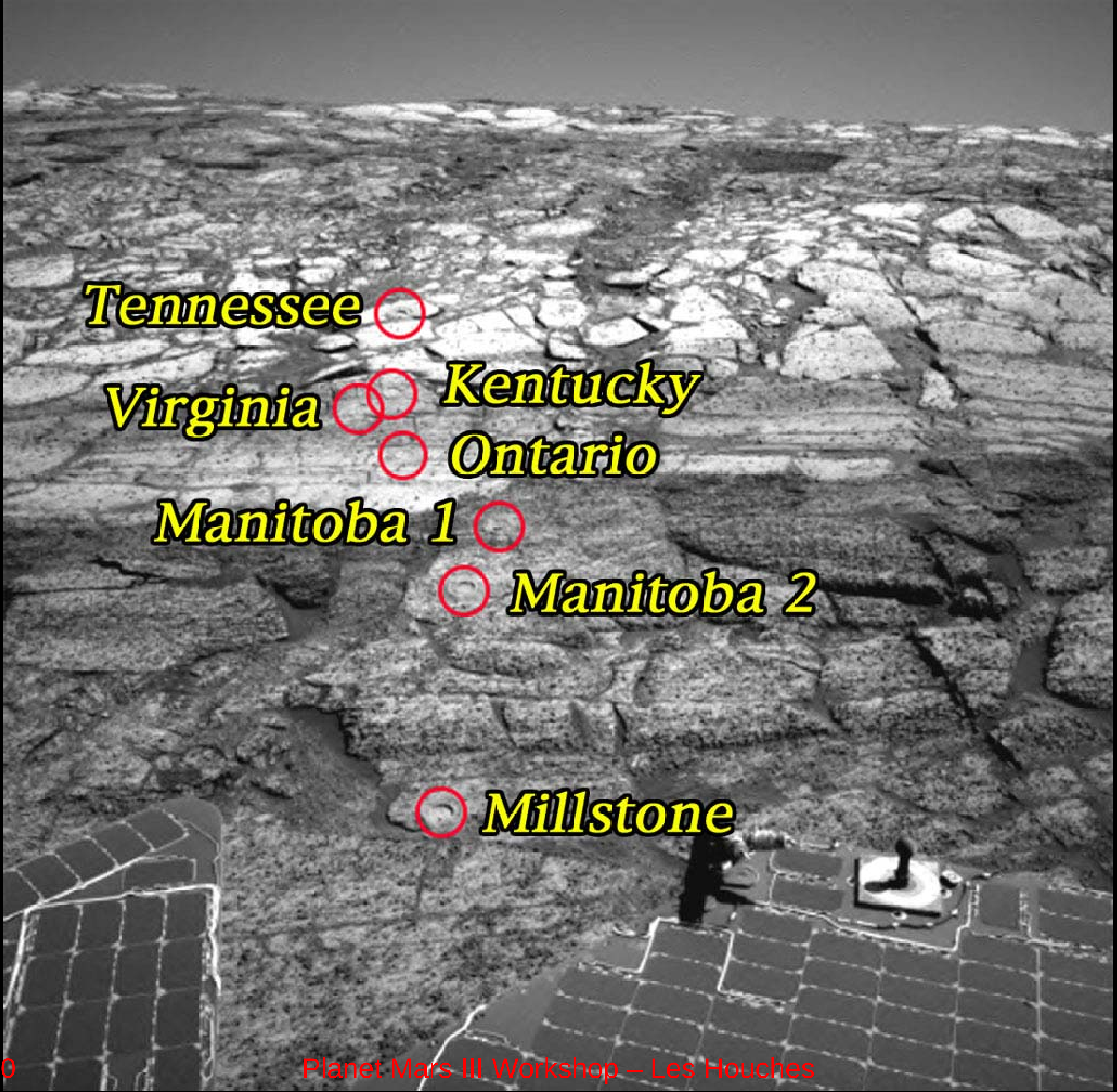
Burns Cliff

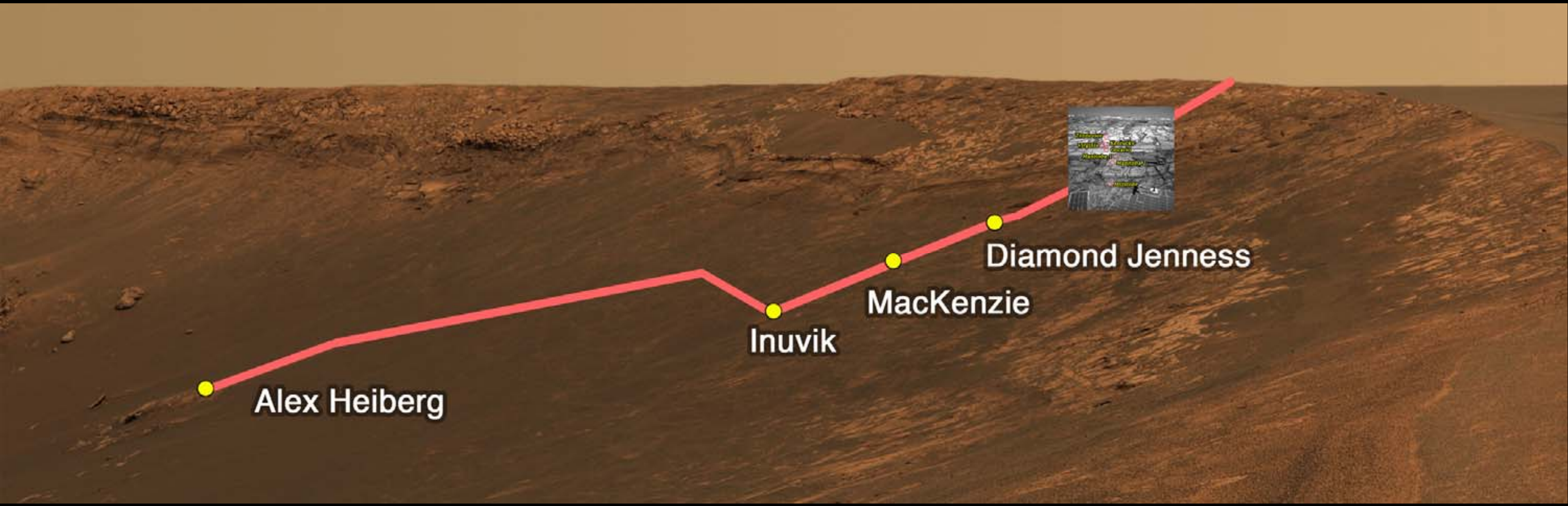




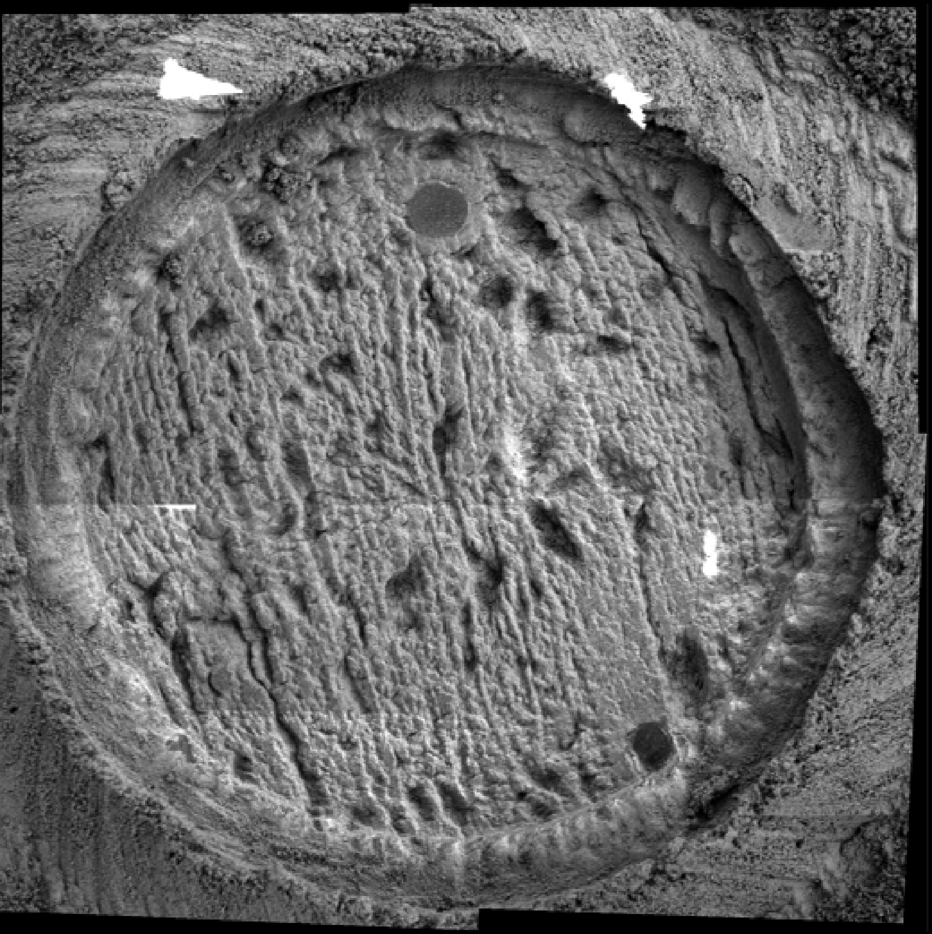
Burns Stratigraphy

- All units composed of “dirty evaporite” sand:
  - – Lower unit: Eolian dune deposits
  - – Lower/middle contact: Erosional
  - – Middle unit: Eolian sand sheet
  - – Middle/upper contact: Diagenetic
  - – Upper unit: Eolian sand sheet, transitioning upward to water-lain sand with abundant current ripples
- Environment: Interdune playas fed by acidic groundwater, which evaporated to yield sulfate-dominated sand that was reworked by the wind.
- Conditions were habitable, but could have posed challenges to the origin of life:
  - – Oxidizing
  - – Acidic
  - – Saline
  - – Arid and only intermittently wet


Tennessee
Virginia
Kentucky
Ontario
Manitoba 1
Manitoba 2
Millstone

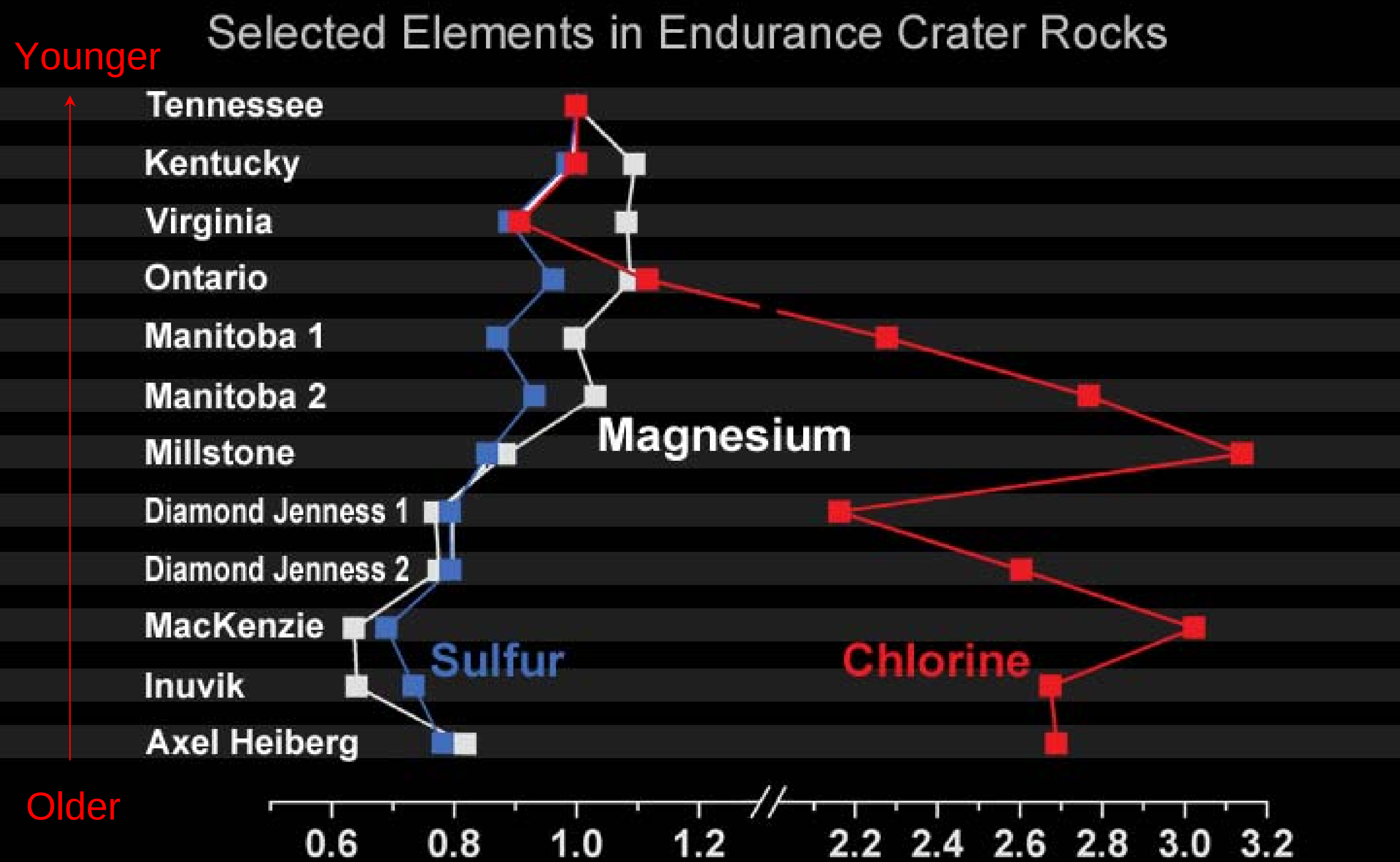

Diamond Jenness
MacKenzie
Inuvik
Alex Heiberg

Ontario

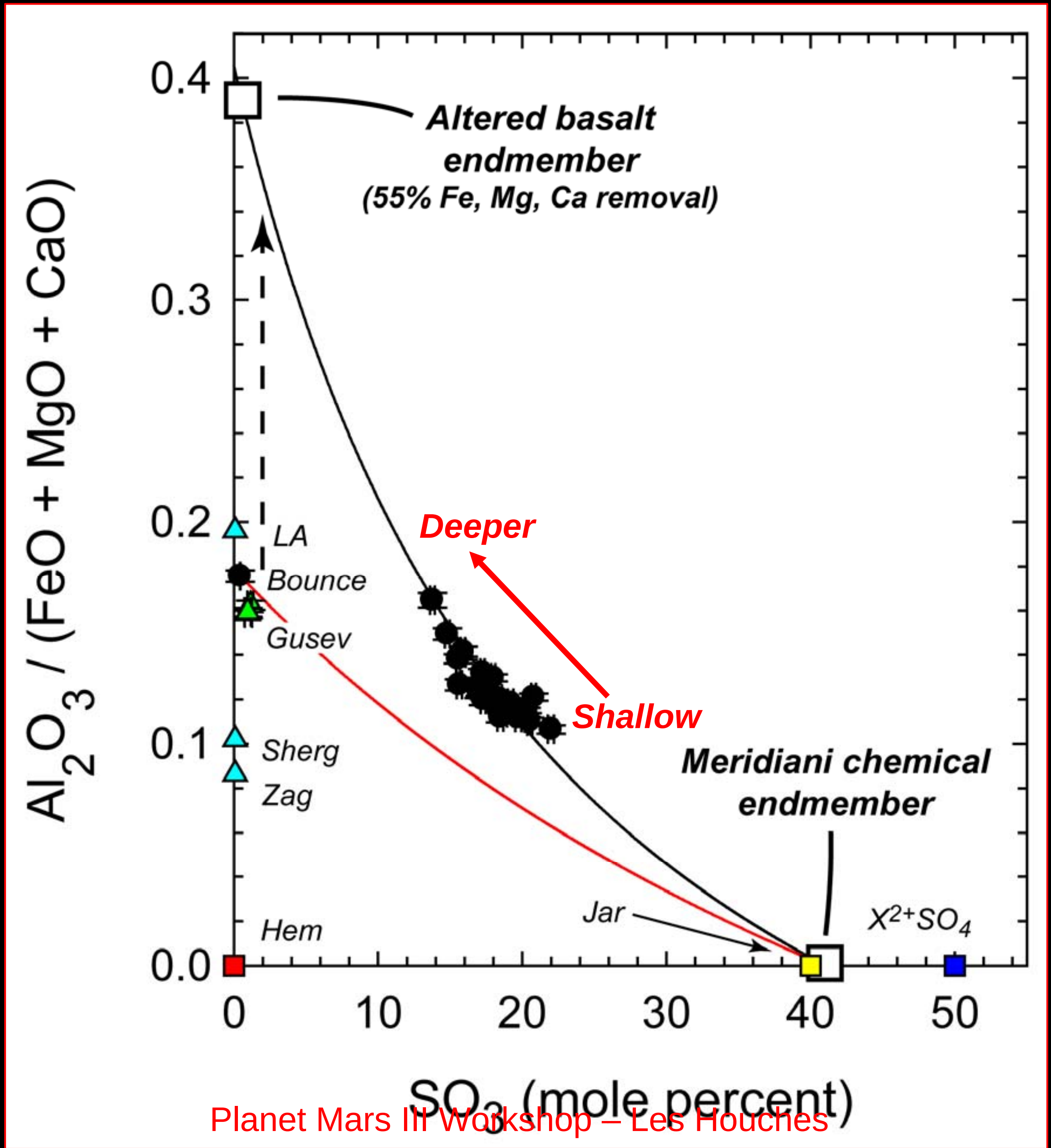


Diamond Jenness

Down Section

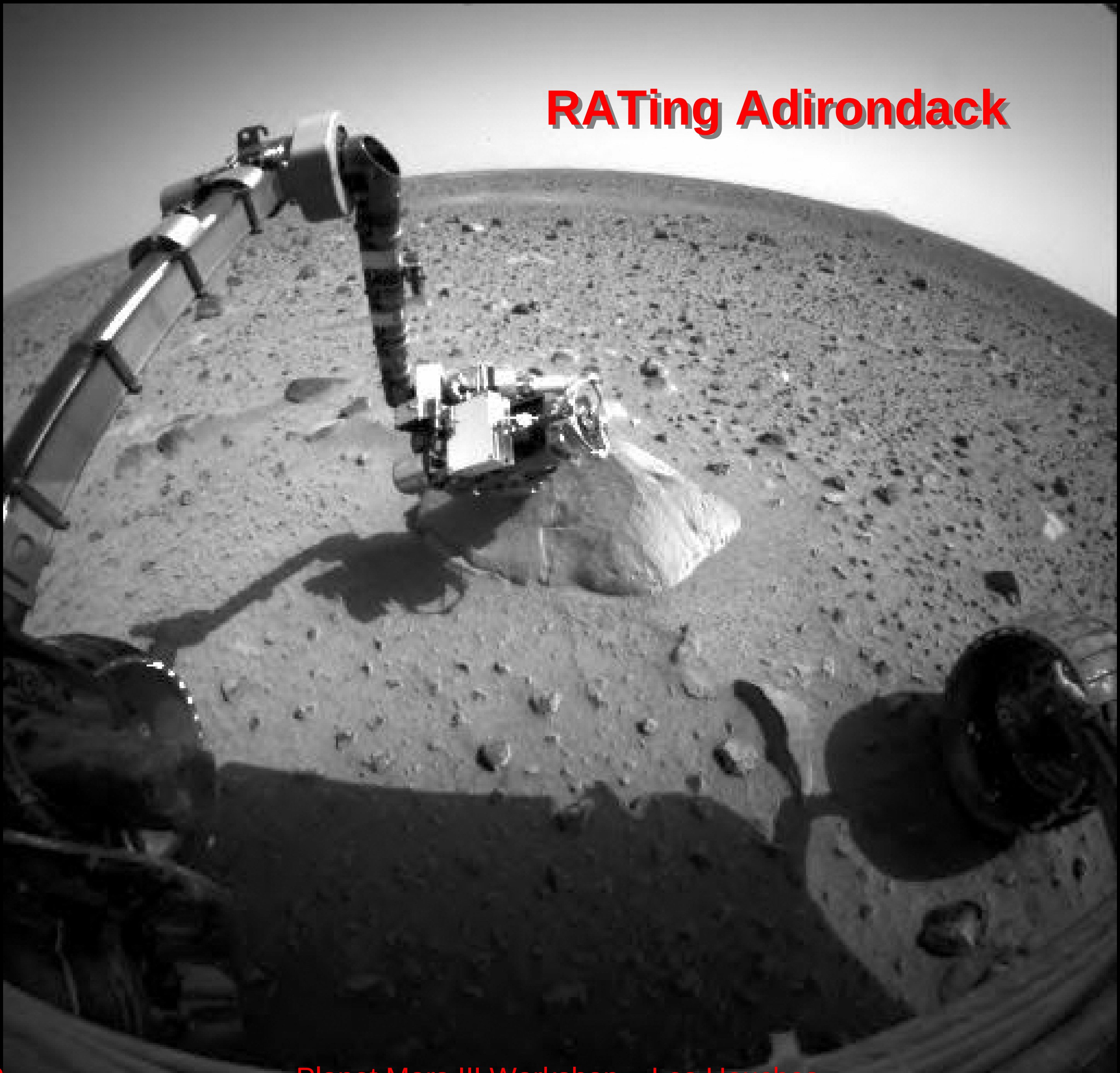

Selected Elements in Endurance Crater Rocks
Younger
Older
Tennessee
Kentucky
Virginia
Ontario
Manitoba 1
Manitoba 2
Millstone
Diamond Jenness 1
Diamond Jenness 2
MacKenzie
Inuvik
Axel Heiberg
Magnesium
Sulfur
Chlorine
0.6
0.8
1.0
1.2
2.2
2.4
2.6
2.8
3.0
3.2

Meridiani Bedrock Chemistry

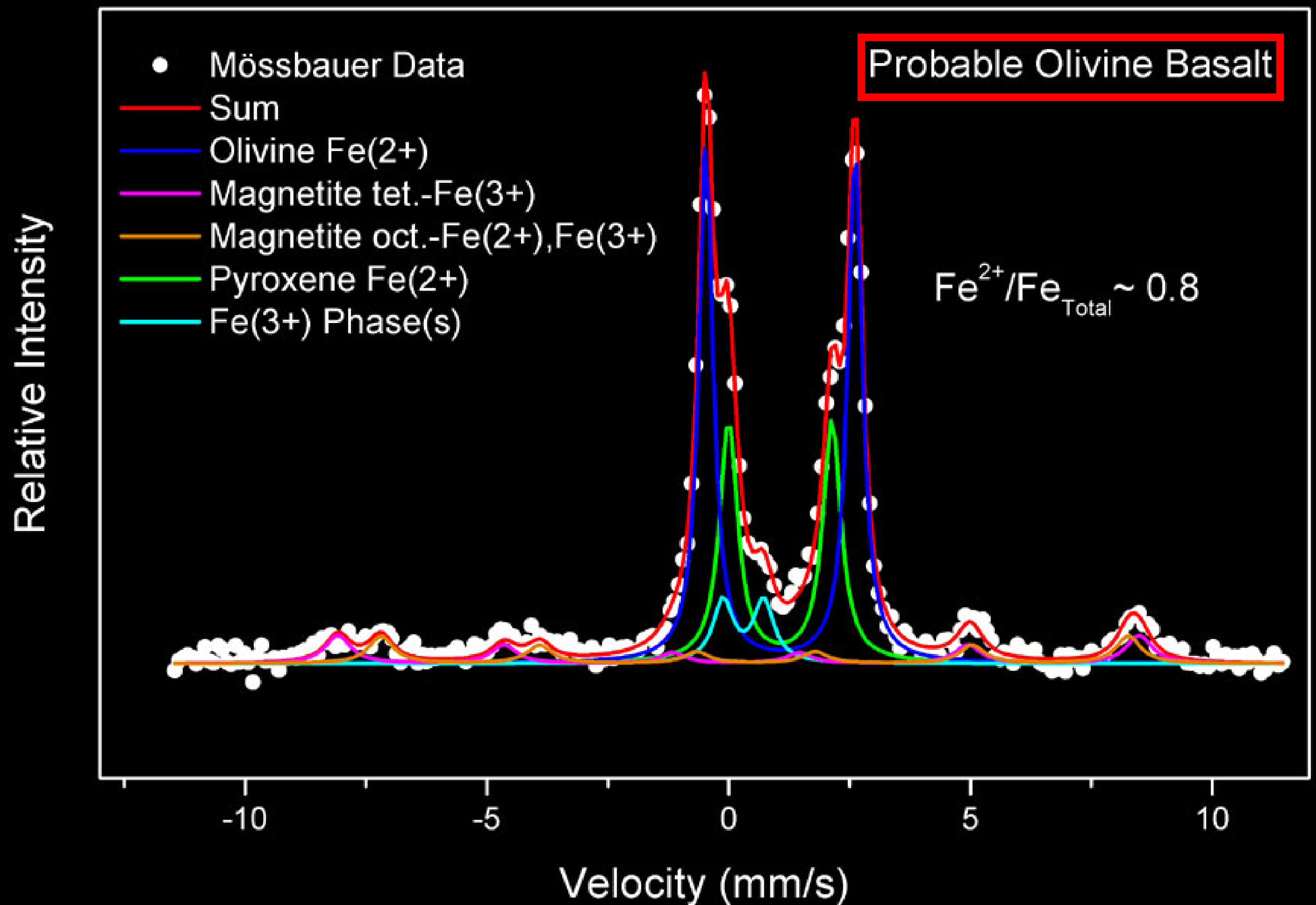


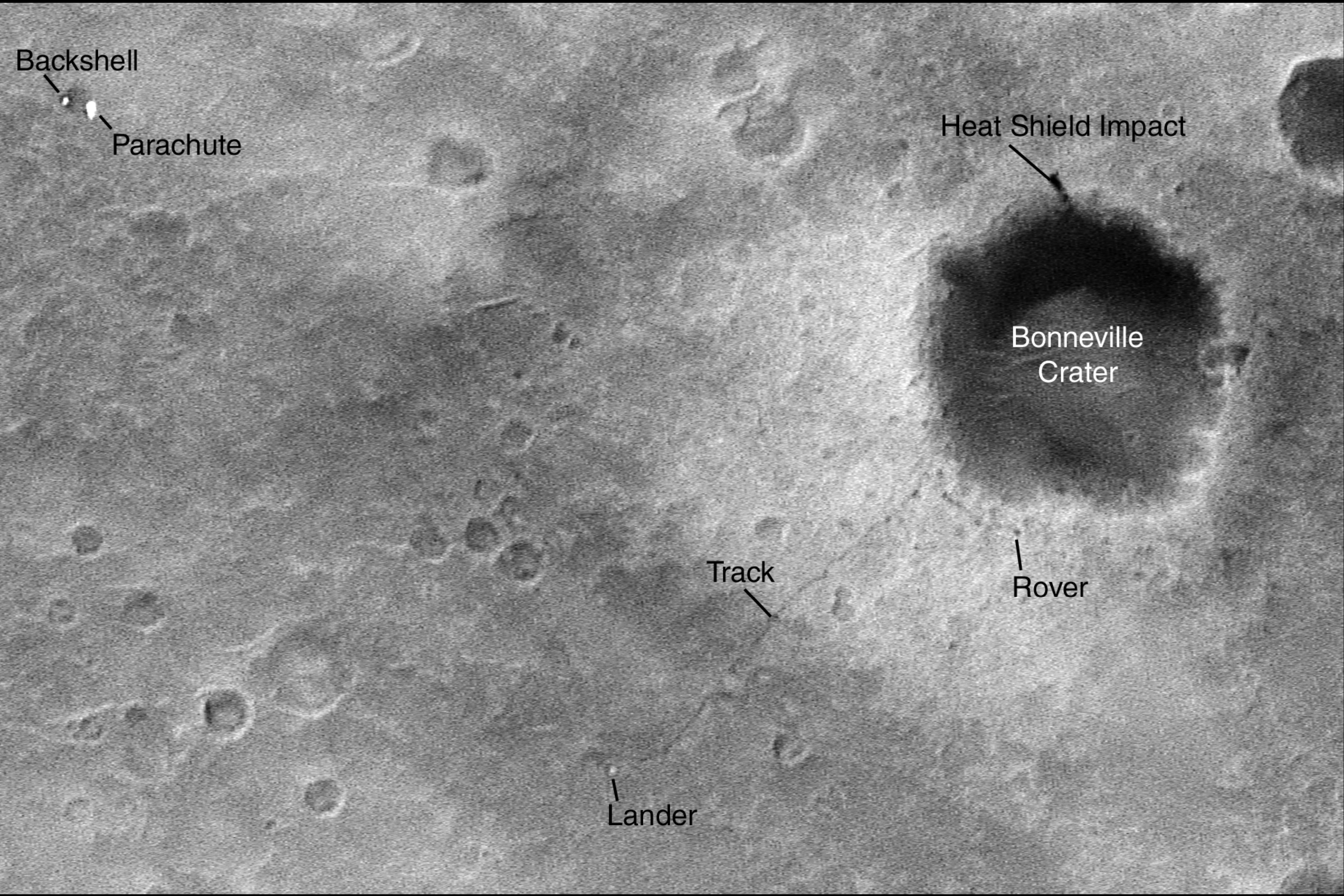
Spirit:
The Lakebed Story

Adirondack


RATing Adirondack

Mössbauer Spectrum of Adirondack Rock
(Sol 18, Gusev Crater, Mars)



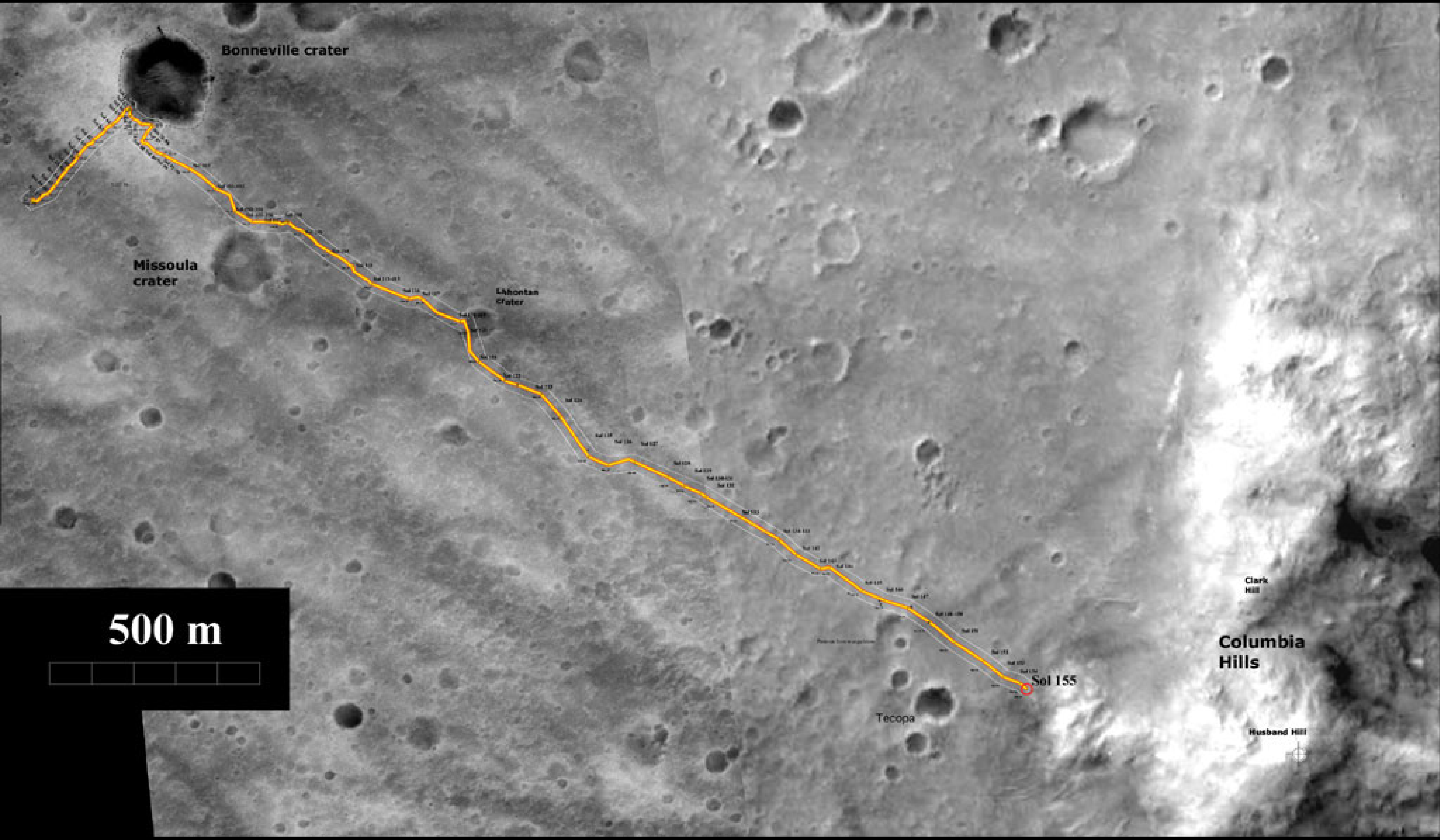

Backshell
Parachute
Heat Shield Impact
Bonneville
Crater
Track
Rover
Lander

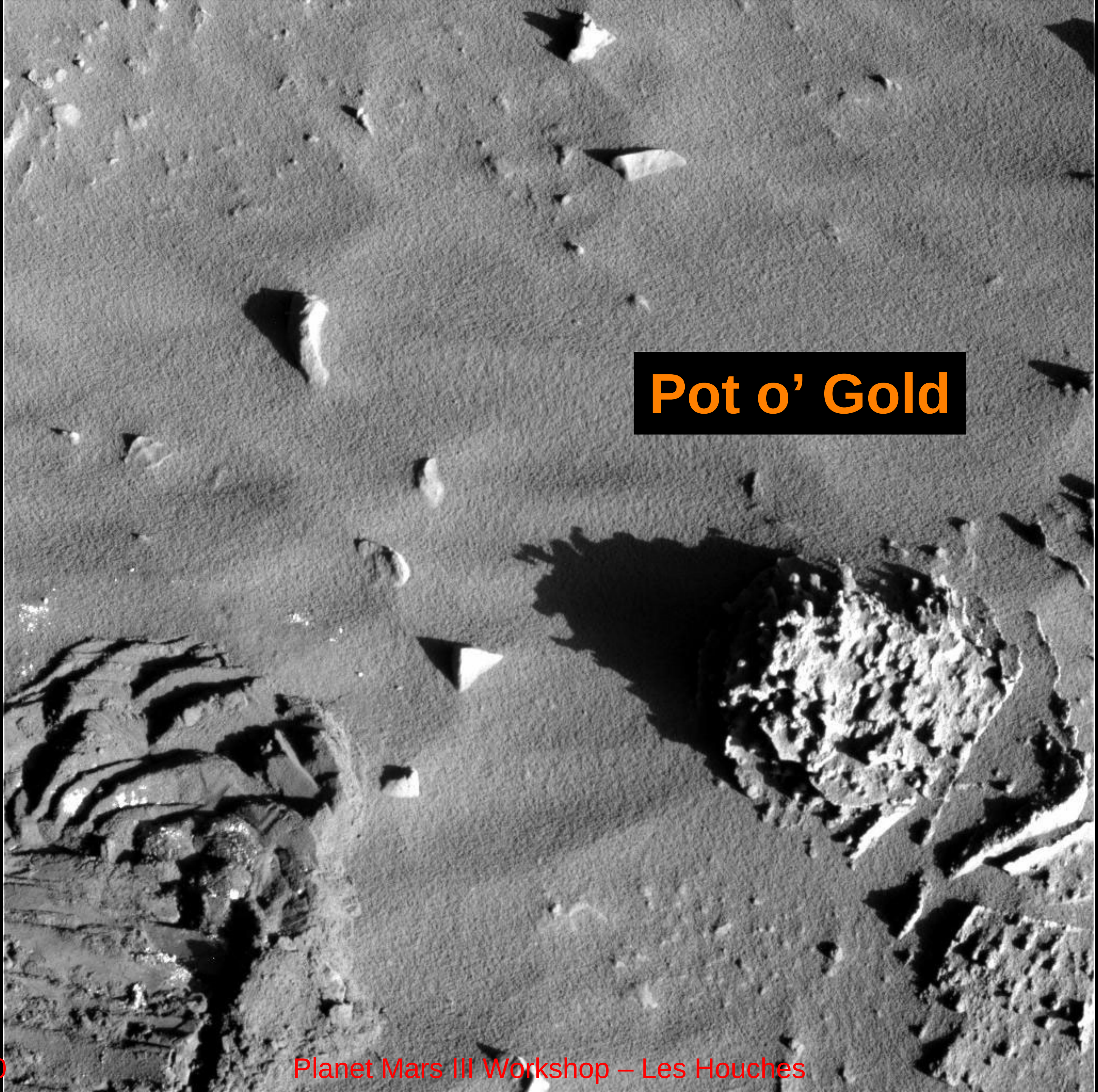
Bonneville Crater

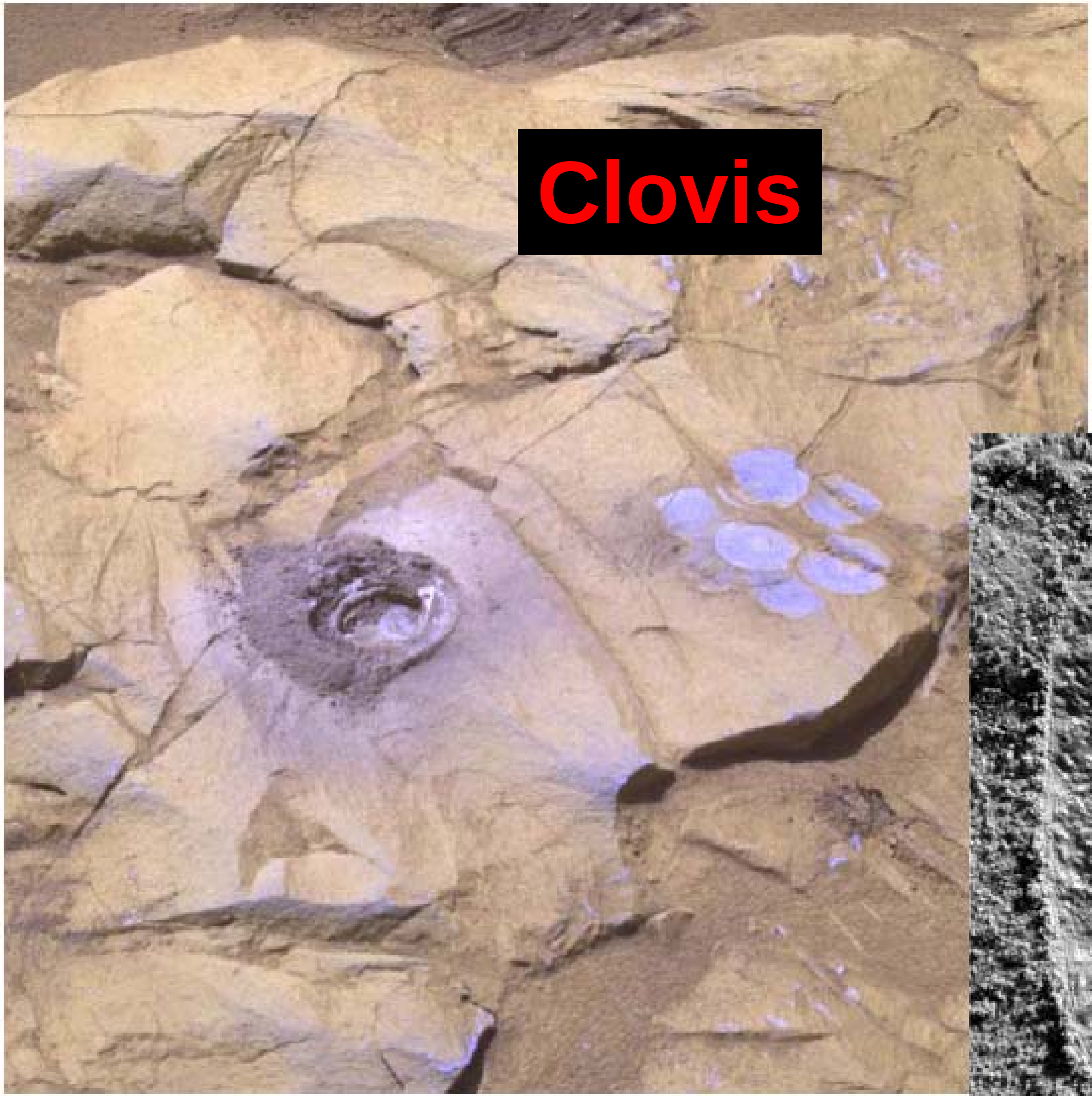
The Lakebed Story:

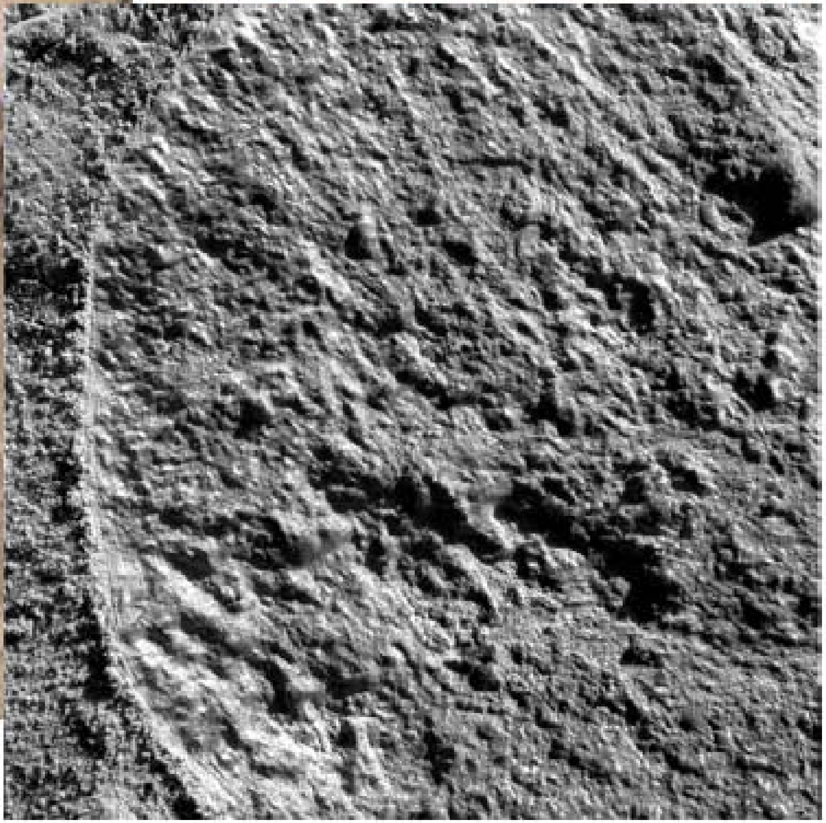
A tragedy of epic proportions – lava plains as far as the (digital) eye can see.

Spirit:
The Columbia Hills Story

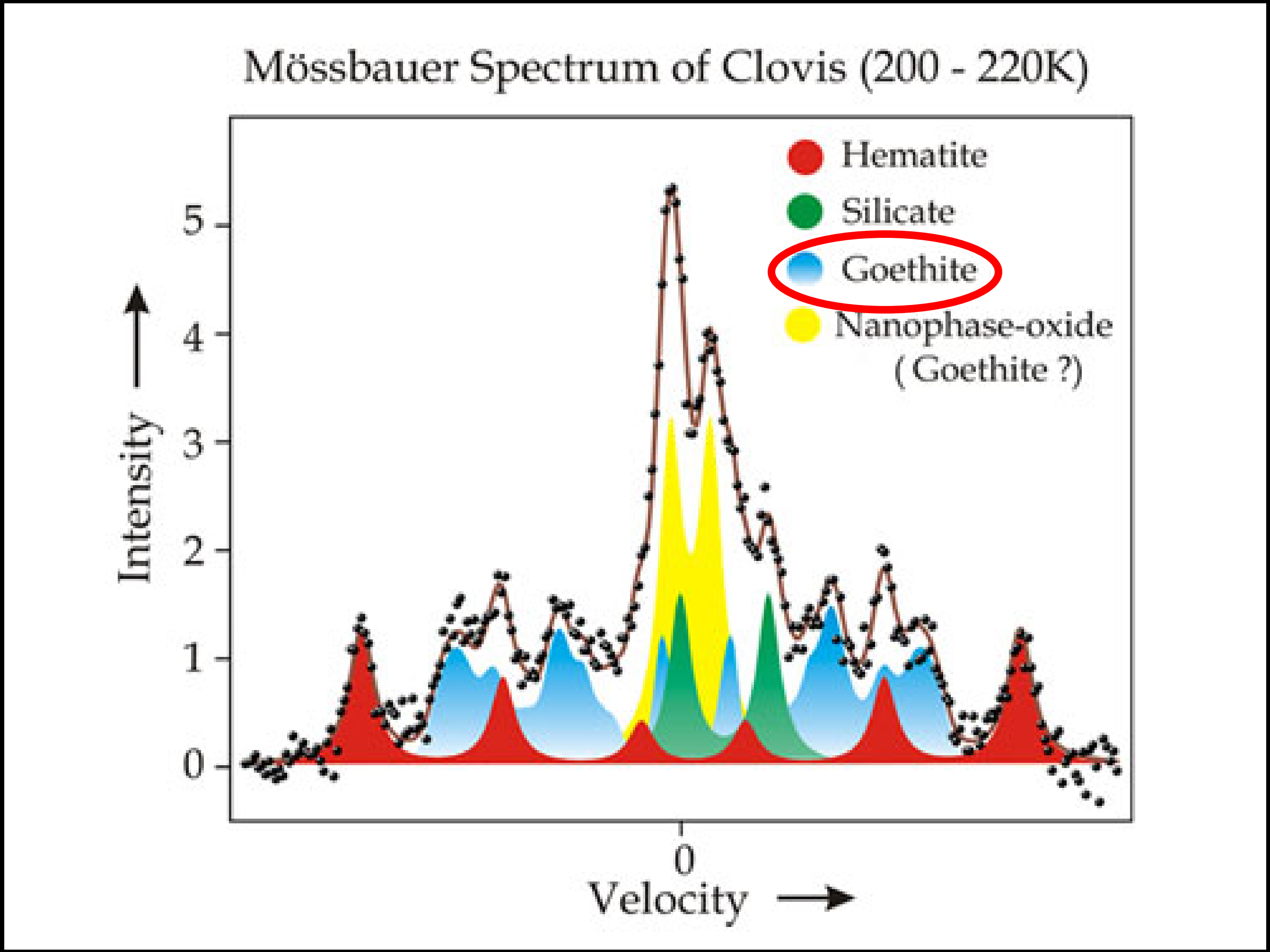

Bonneville crater
Missoula crater
Lahontan crater
Sol 155
Tecopa
Clark Hill
Columbia Hills
Husband Hill
500 m


Pot o' Gold


Clovis



First Unambiguous Evidence for Water at Gusev

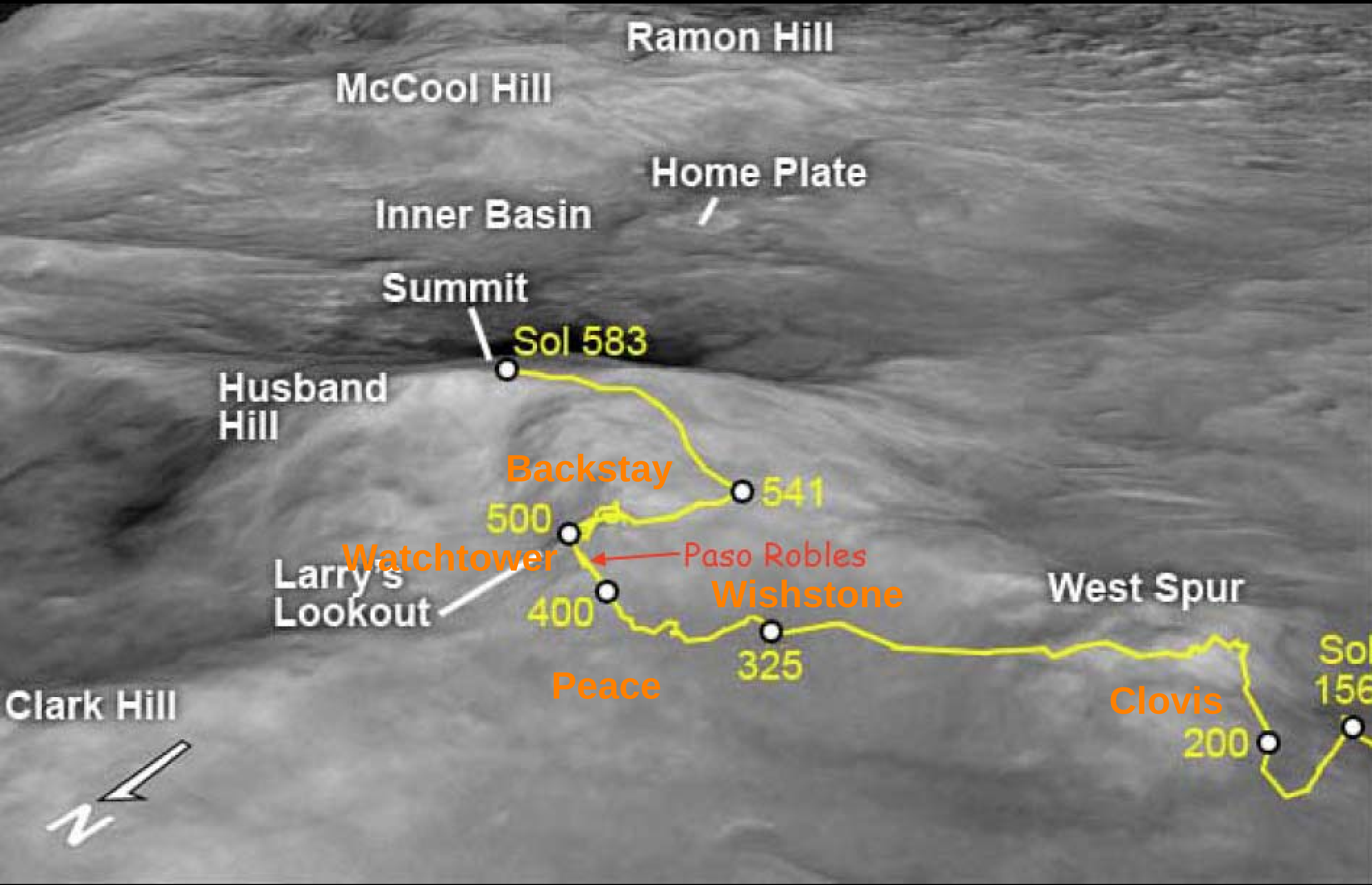


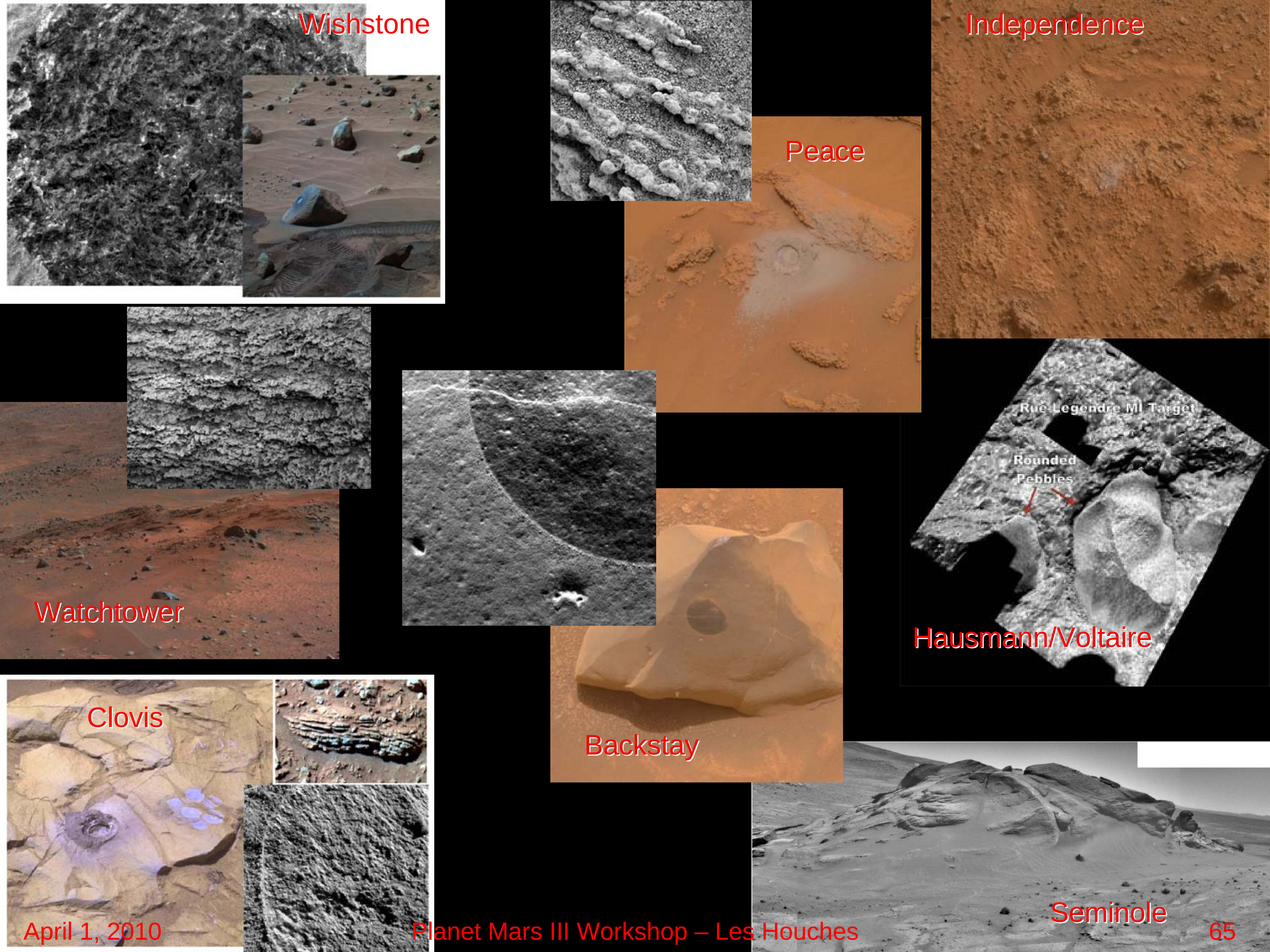
Goethite

Chemical formula:	Iron oxyhydroxide, FeO(OH)
Color:	Yellowish to reddish to dark brown
Crystal system:	Orthorhombic
Mohs hardness:	5 - 5.5
Specific gravity:	3.3 - 4.3

Results Since Planet Mars II

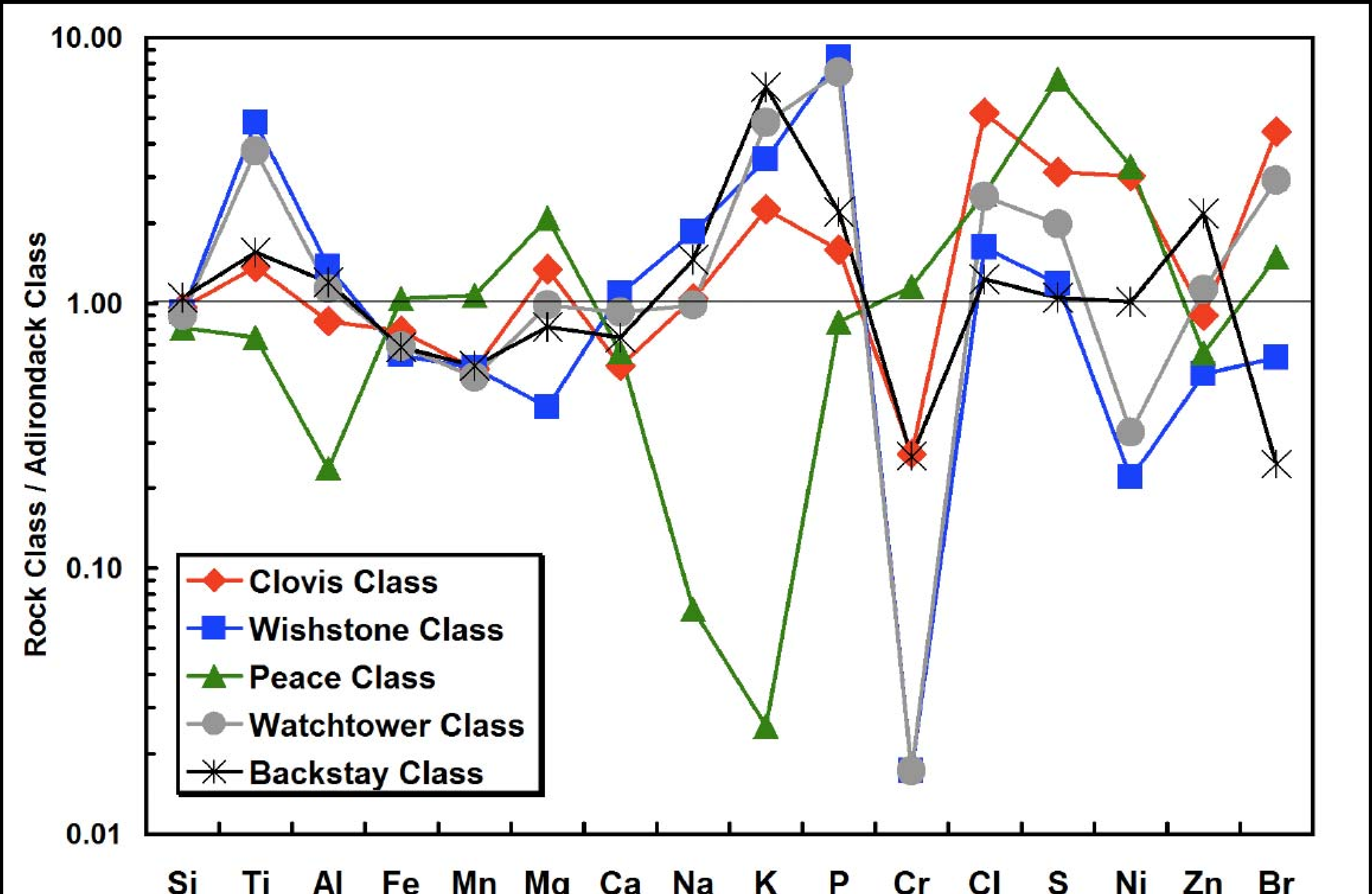
Spirit:
The Columbia Hills Story
(Continued)


Ramon Hill
McCool Hill
Home Plate
Inner Basin
Summit
Sol 583
Husband Hill
Backstay
541
500
Watchtower
Paso Robles
Larry's Lookout
400
Wishstone
West Spur
325
Peace
Clark Hill
Clovis
200
N


Wishstone
Independence
Peace
Watchtower
Rue Legendre MI Target
Rounded
Pebbles
Hausmann/Voltaire
Clovis
Backstay
Seminole

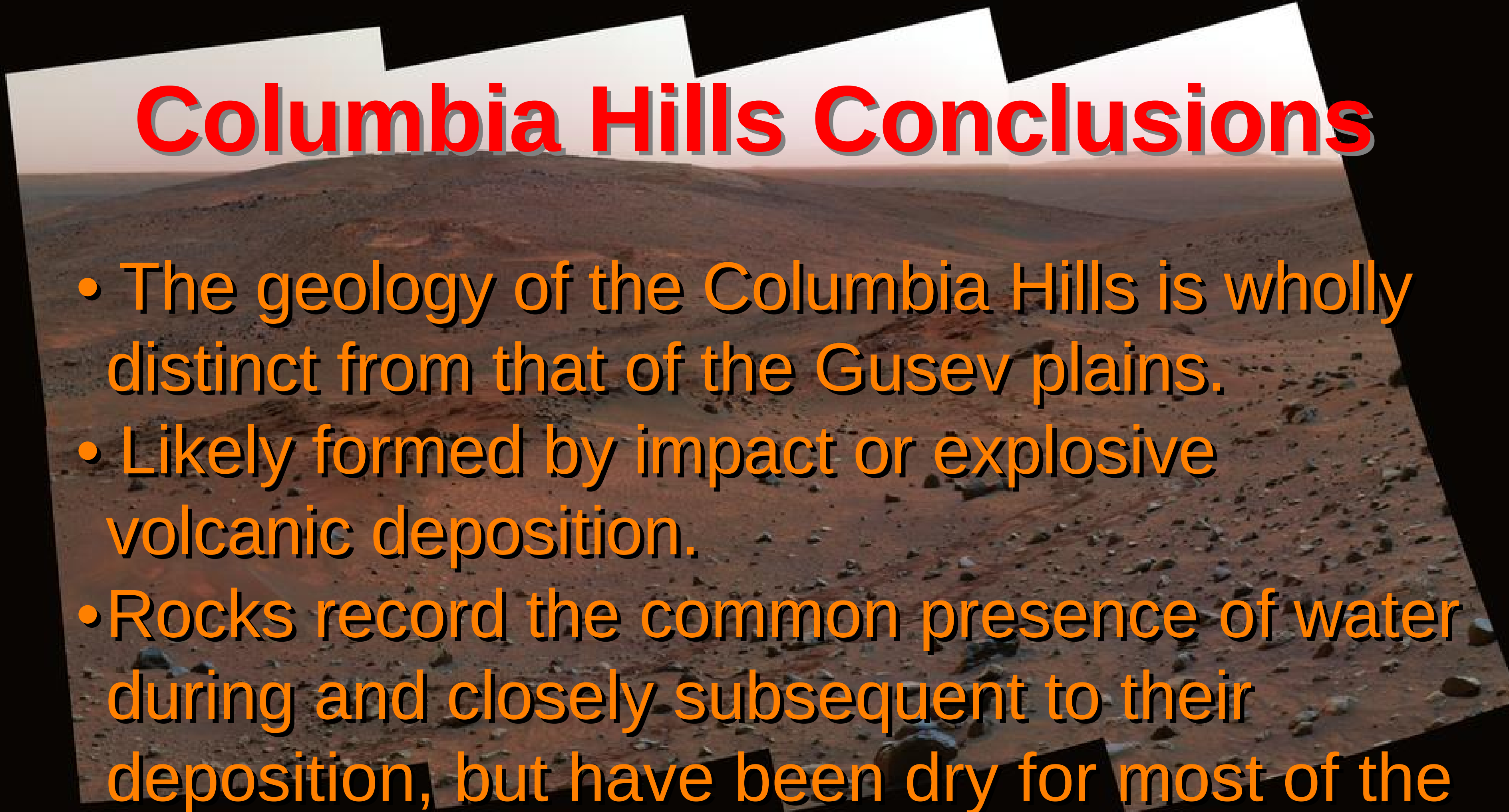
(At Least) Five New Classes of Rocks

Not the same old basalts!



Columbia Rocks Tell a Complex Story

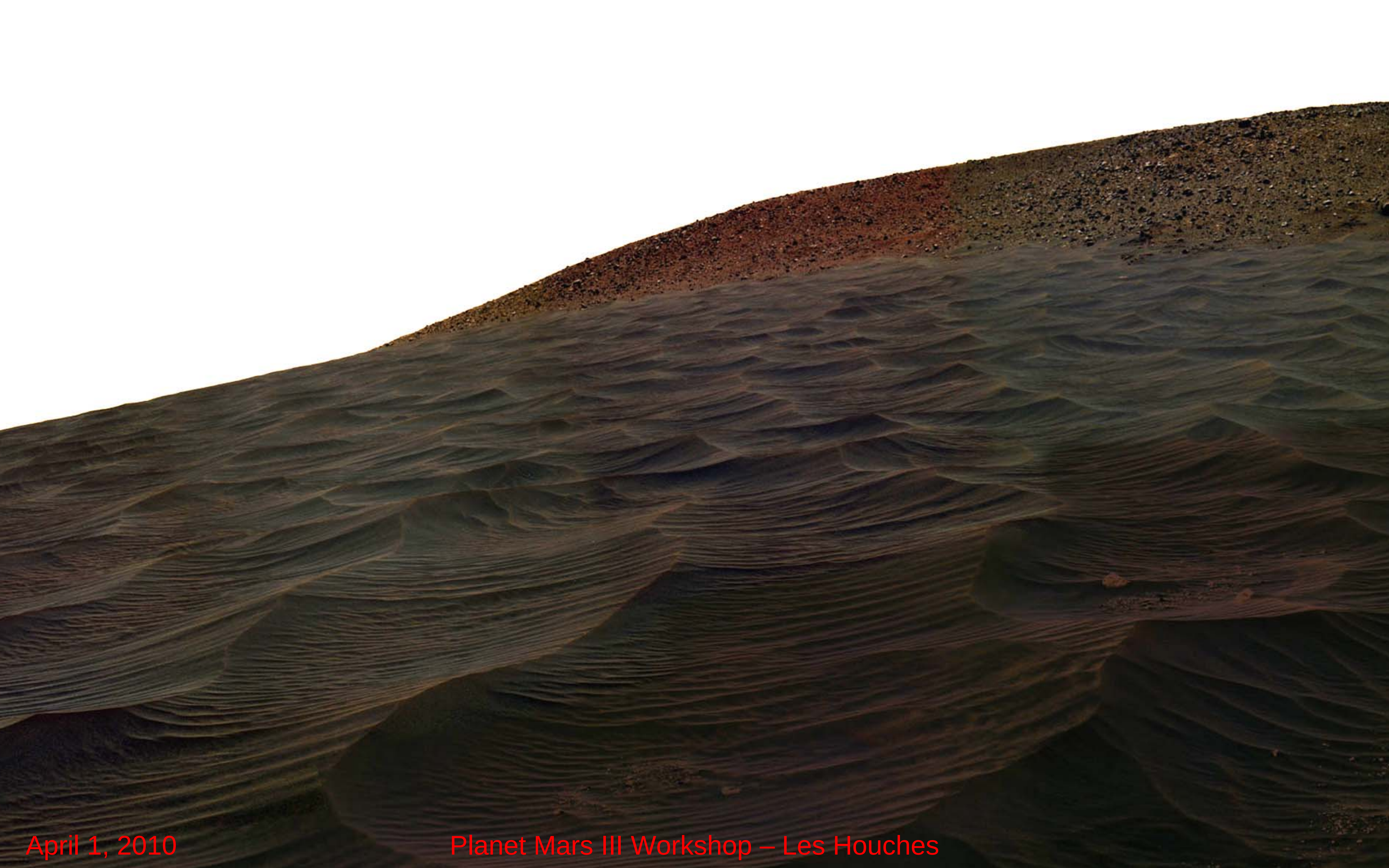
- Clovis: Some layering, poorly sorted clastic rock; basaltic chemistry, but elevated P, S, Cl, Br, and Ni; Fe oxides and oxyhydroxides; aqueously altered basaltic impact ejecta
- Wishstone: Tuff-like appearance; plagioclase with pyroxene, olivine, and minor phosphates; rich in Ti and P, low in Cr; possible pyroclastic deposit, moderately altered
- Peace: Finely layered, heavily cemented clastic rock; 6-μm water band, pyroxene, olivine, magnetite, ~20% $MgSO_4$ and $CaSO_4$; magnetite-rich basaltic sandstone cemented by Mg- and Ca-sulfate salts
- Watchtower: Massive to finely layered, highly variable texture; high Ti, high P and low Cr; highly variable mineralogy; probable impact ejecta, highly localized near-isochemical alteration implies low water/rock ratio
- Backstay: Similar to plains basalts, but higher in Ti, Al, K, and Na, and lower in Fe; essentially unaltered; formed by local intrusion after uplift and cessation of water activity



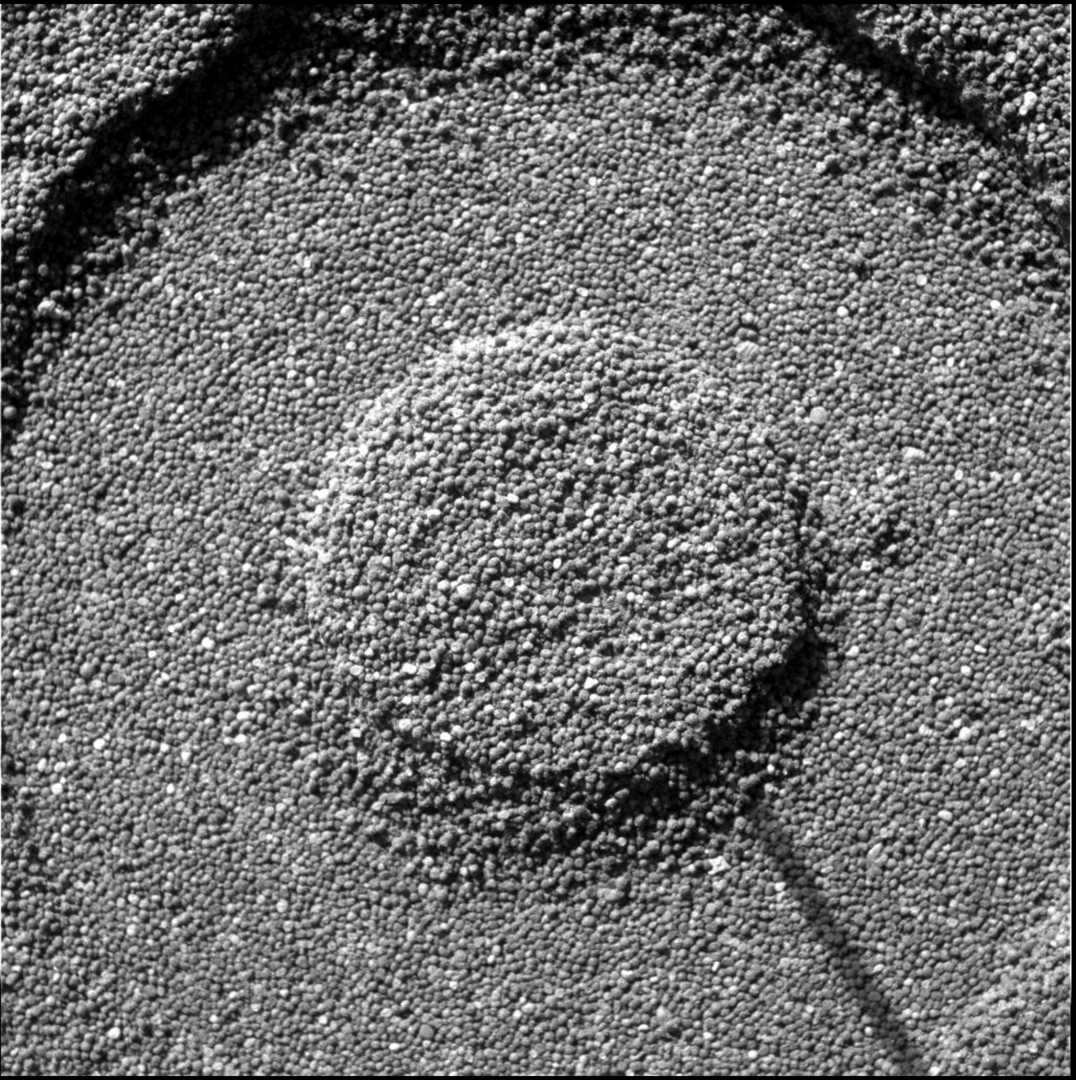
Columbia Hills Conclusions

- The geology of the Columbia Hills is wholly distinct from that of the Gusev plains.
- Likely formed by impact or explosive volcanic deposition.
- Rocks record the common presence of water during and closely subsequent to their deposition, but have been dry for most of the remaining time.
- May be typical of ancient martian crust.

El Dorado



El Dorado Up Close

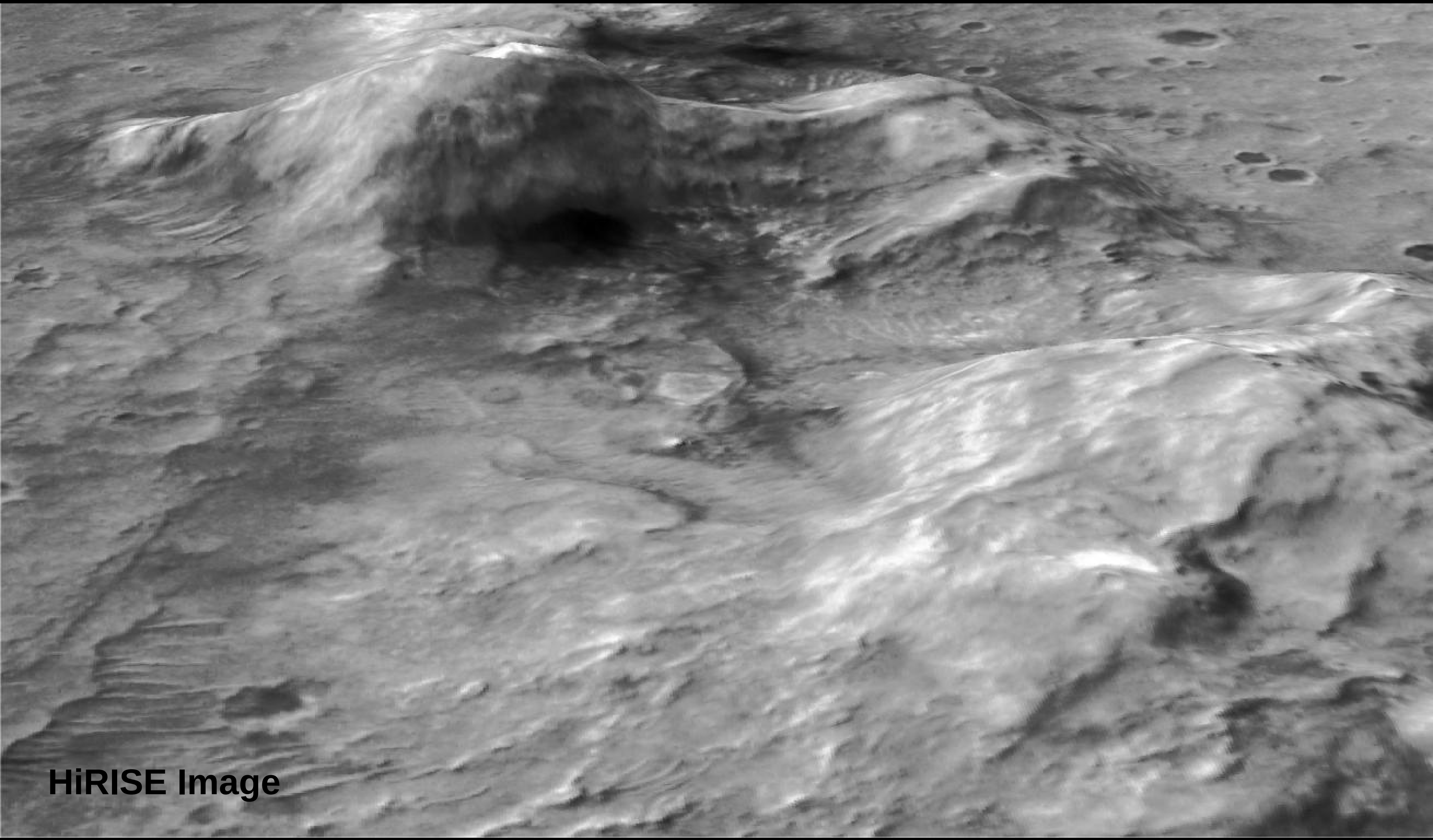


- **Very well sorted and rounded**
- **Similar chemistry to average Gusev soils, but higher in Mg and notably lower in S and Cl**
- **Mini-TES shows Olivine, (~Fo45), Pyroxene, and Plagioclase**
- **MB mineralogy is 49% Ol, 31% Px, 11% Mt, 9%npOx**
- **Fe^{3+}/Fe_{total} is only 0.17**

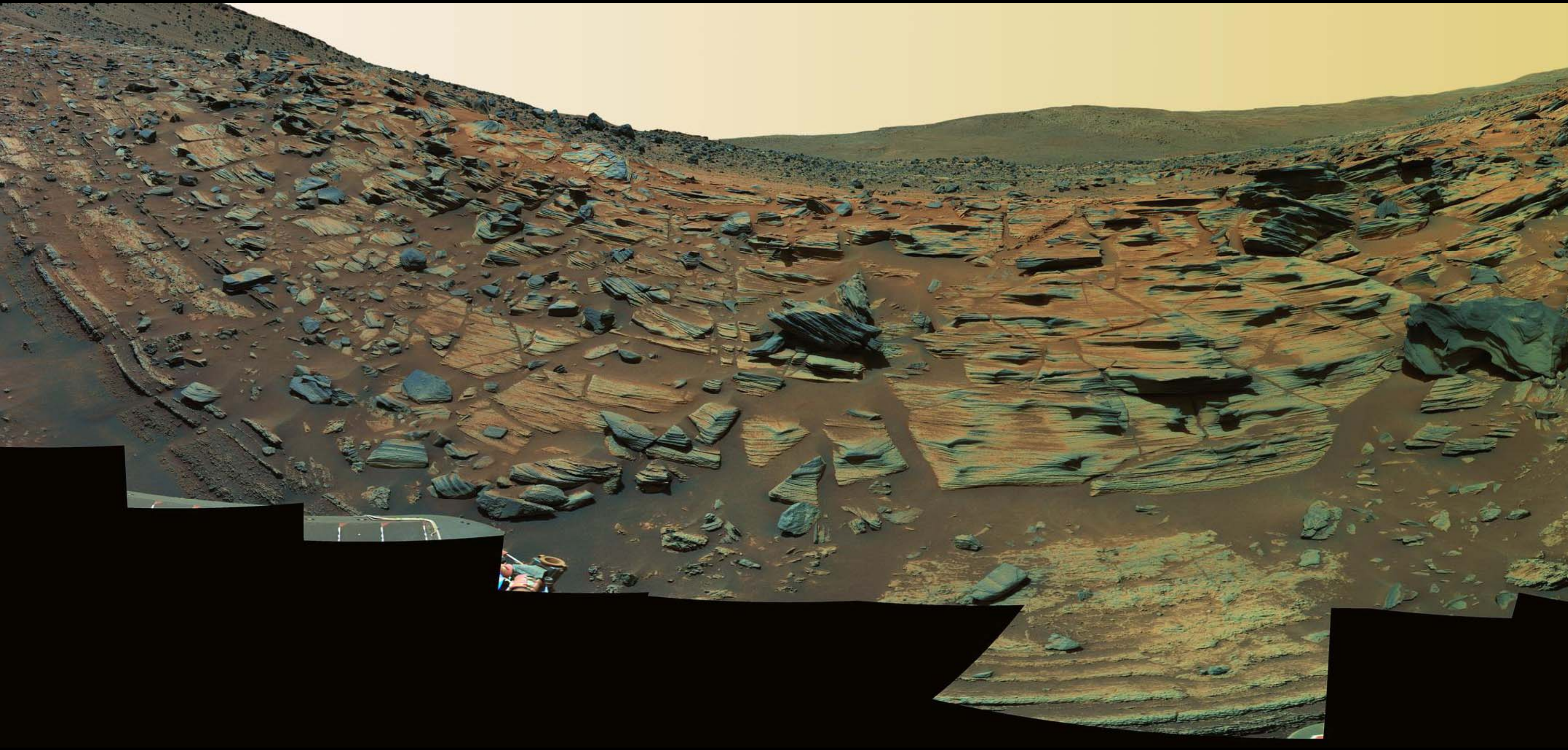
- **No evidence for any aqueous weathering**

Spirit: The Inner Basin Story (Ongoing)

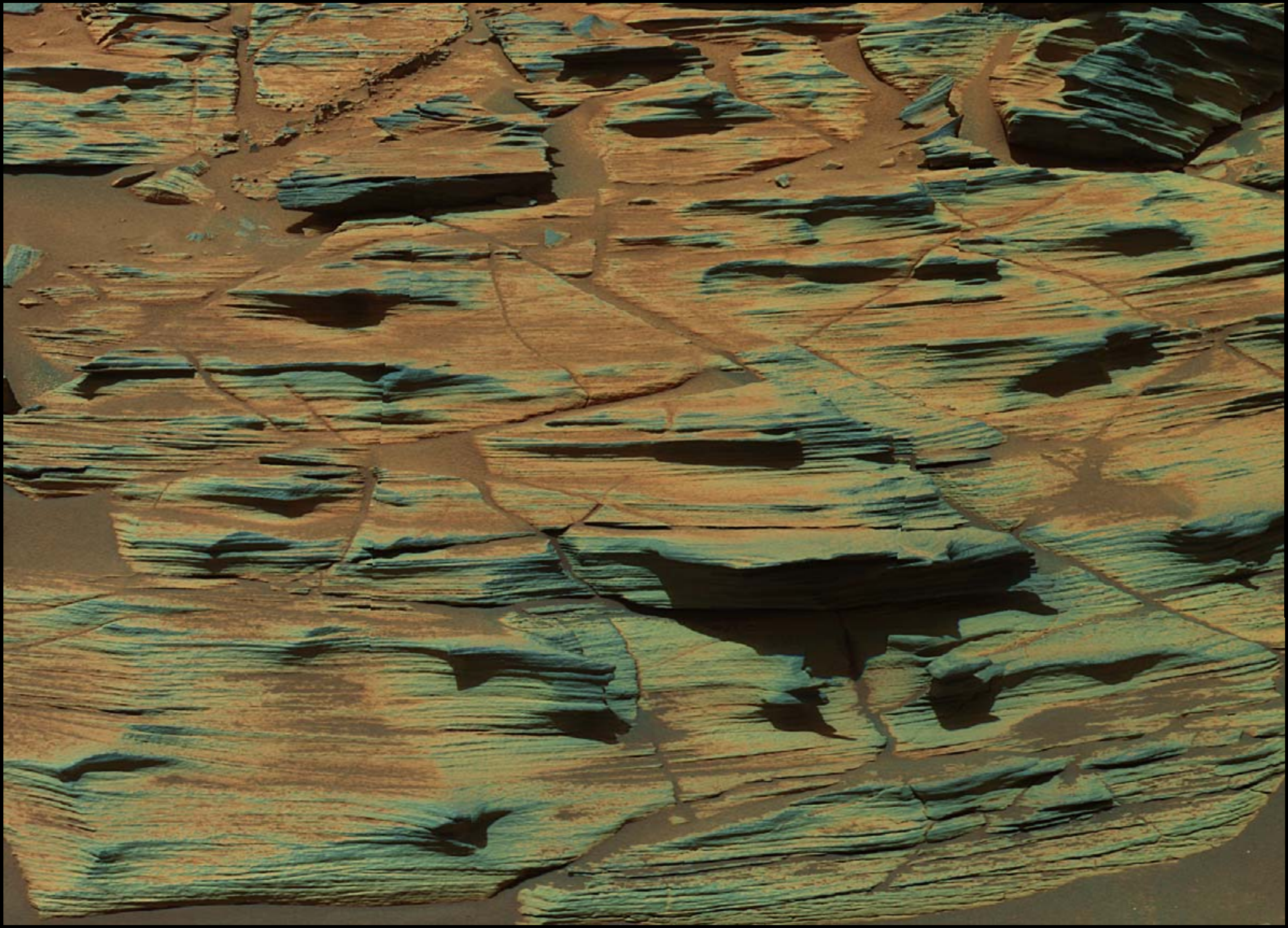
Columbia Hills Inner Basin, as Seen from MRO



Home Plate

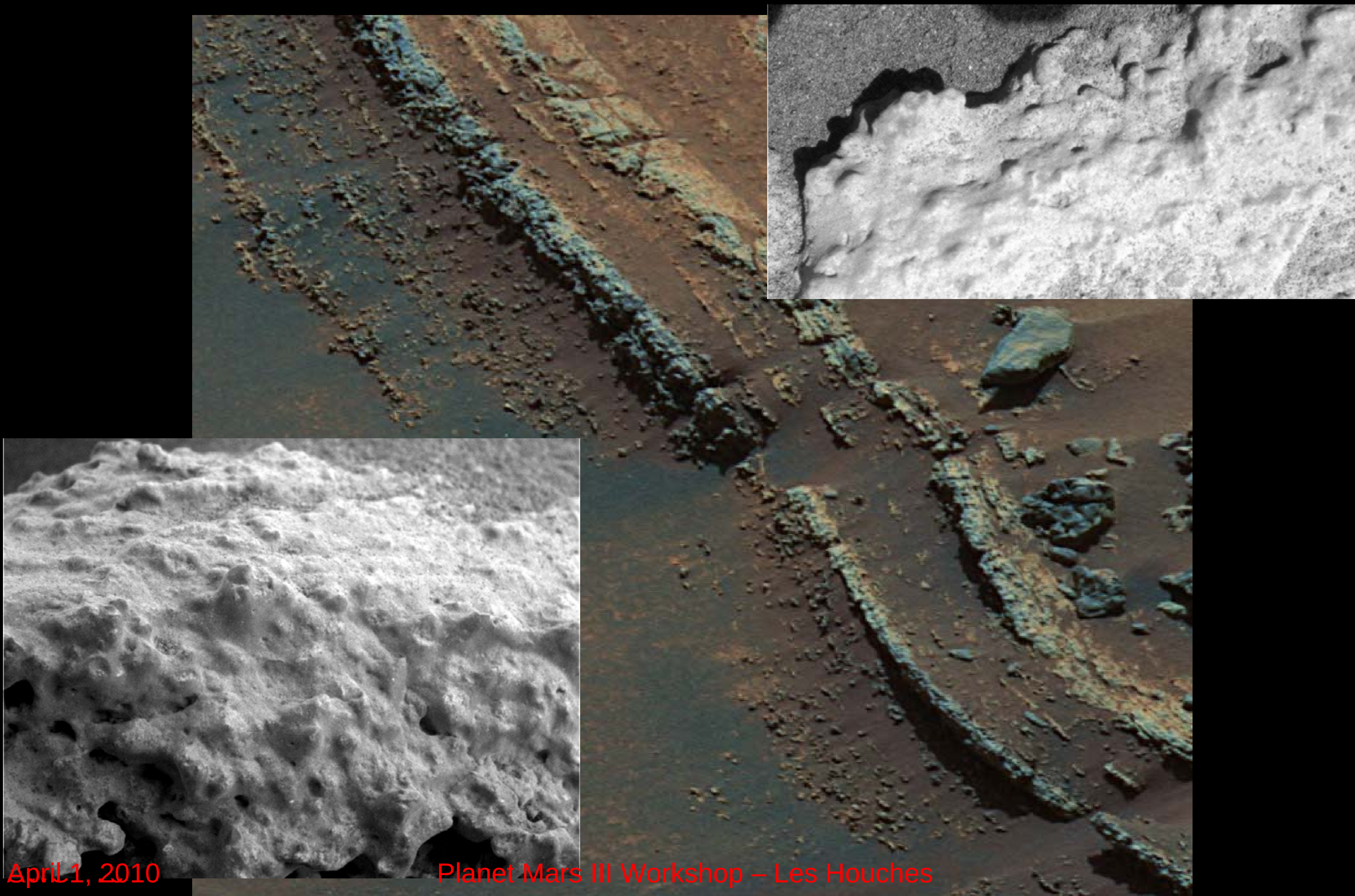


Fine-Grained Upper Unit

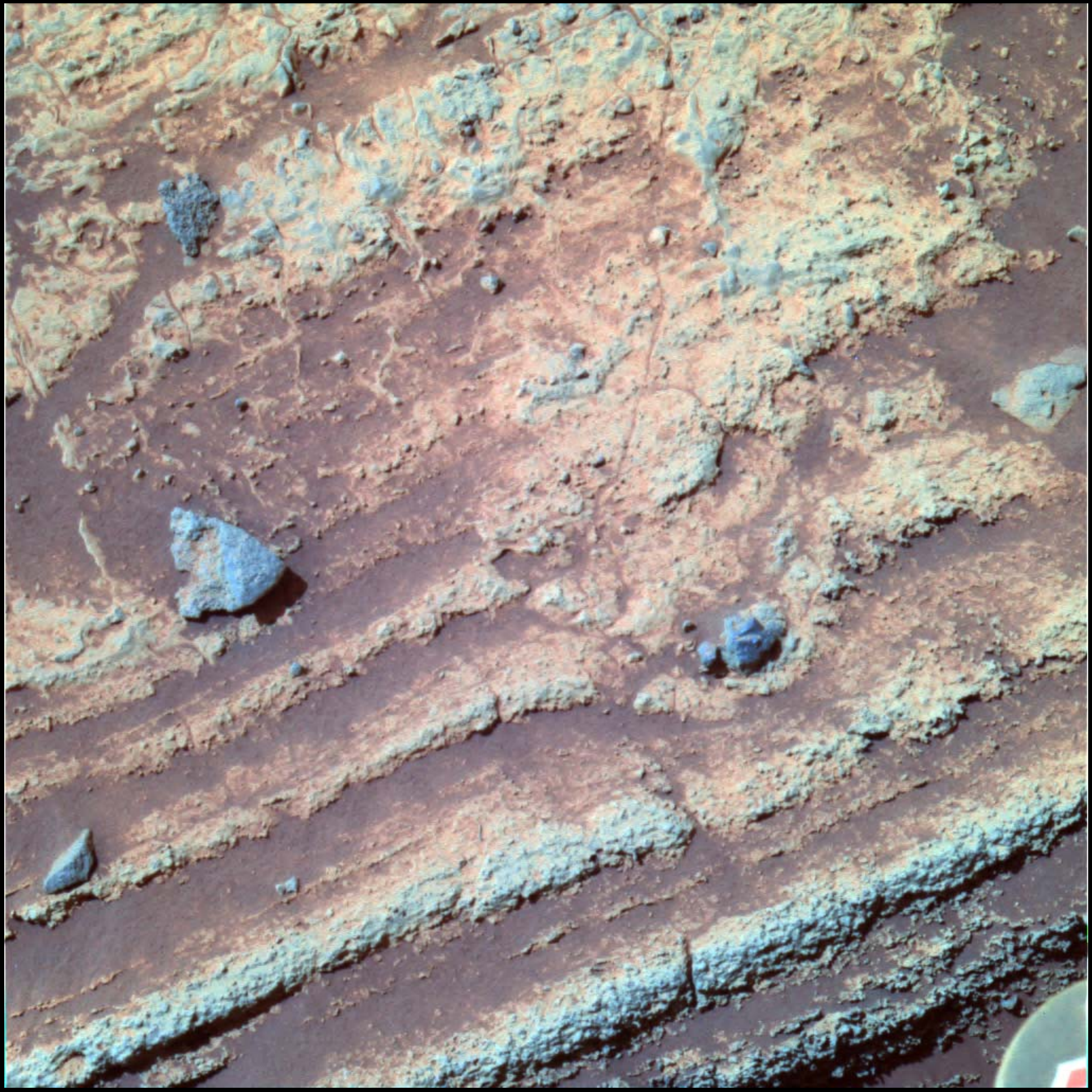


Cross-Stratification In Upper Unit

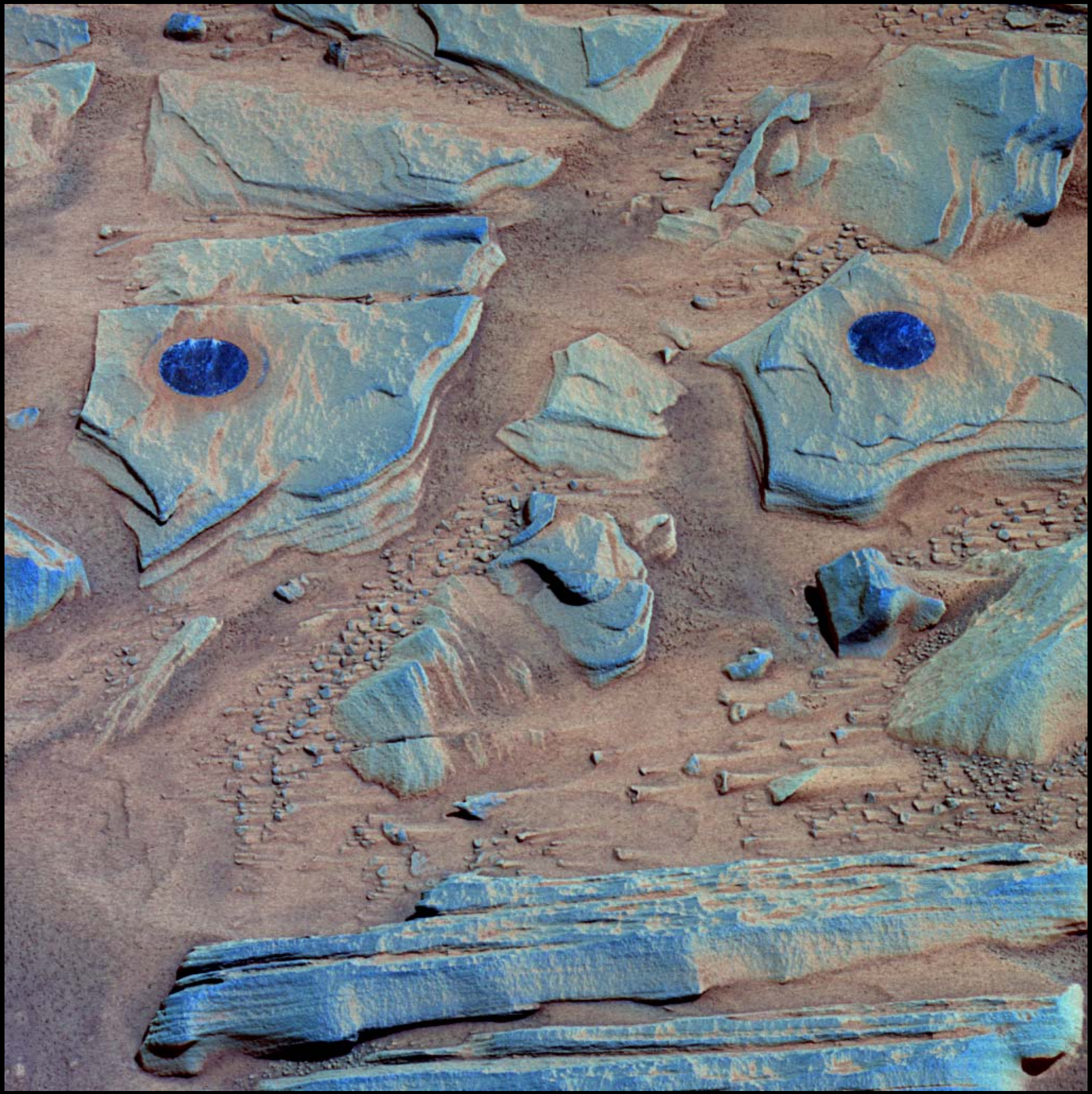
Coarse-Grained Lower Unit



Probable Bomb Sag in Lower Unit



Mössbauer Mineralogy



~18% Olivine

~23% Pyroxene

~28% npOx

~30% Magnetite

Minor Hematite

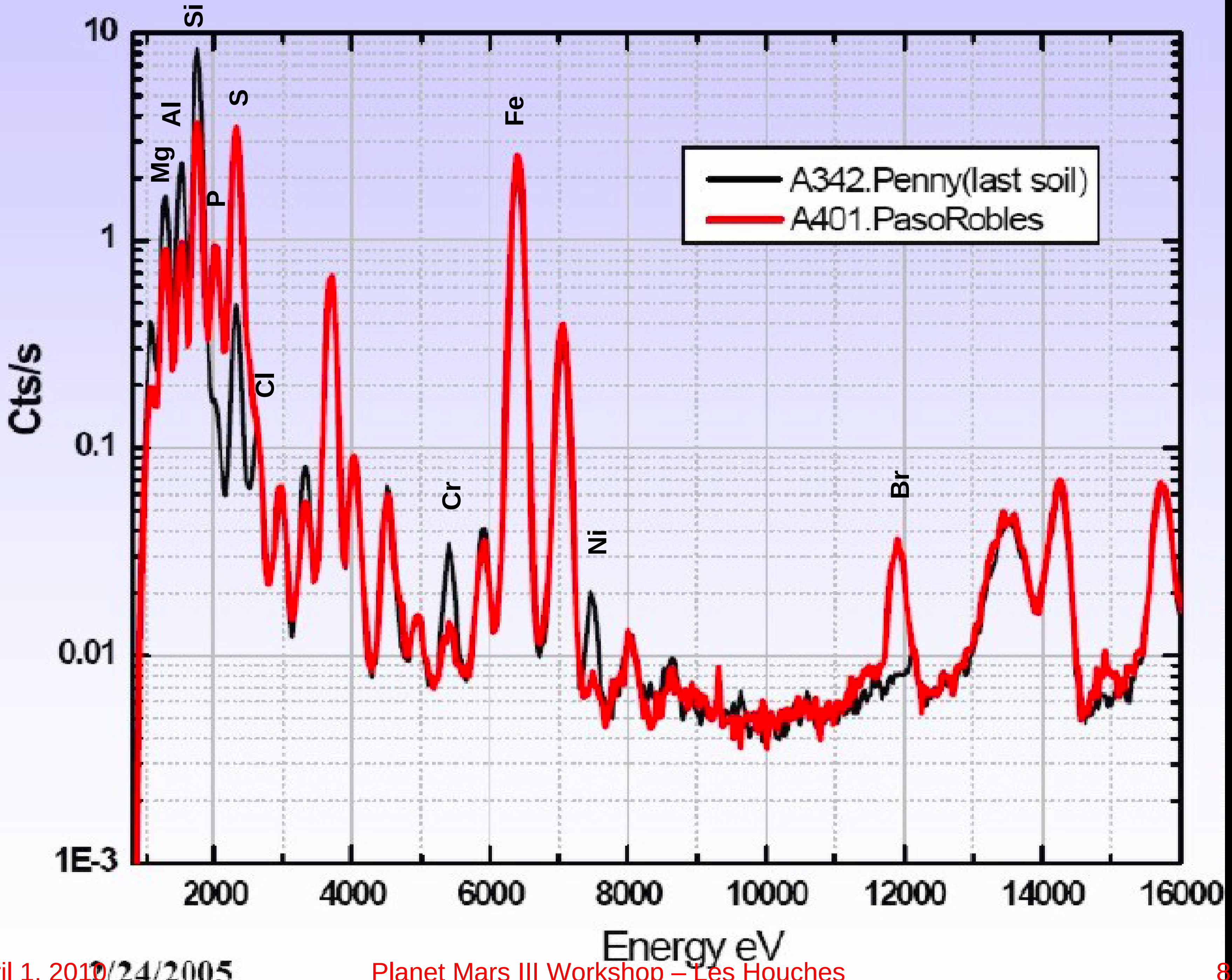
Fe^{3+}/Fe_{total} ~50%

An altered basalt

Spirit:
The “White” Soil Story

Paso Robles – Light-Colored Soil

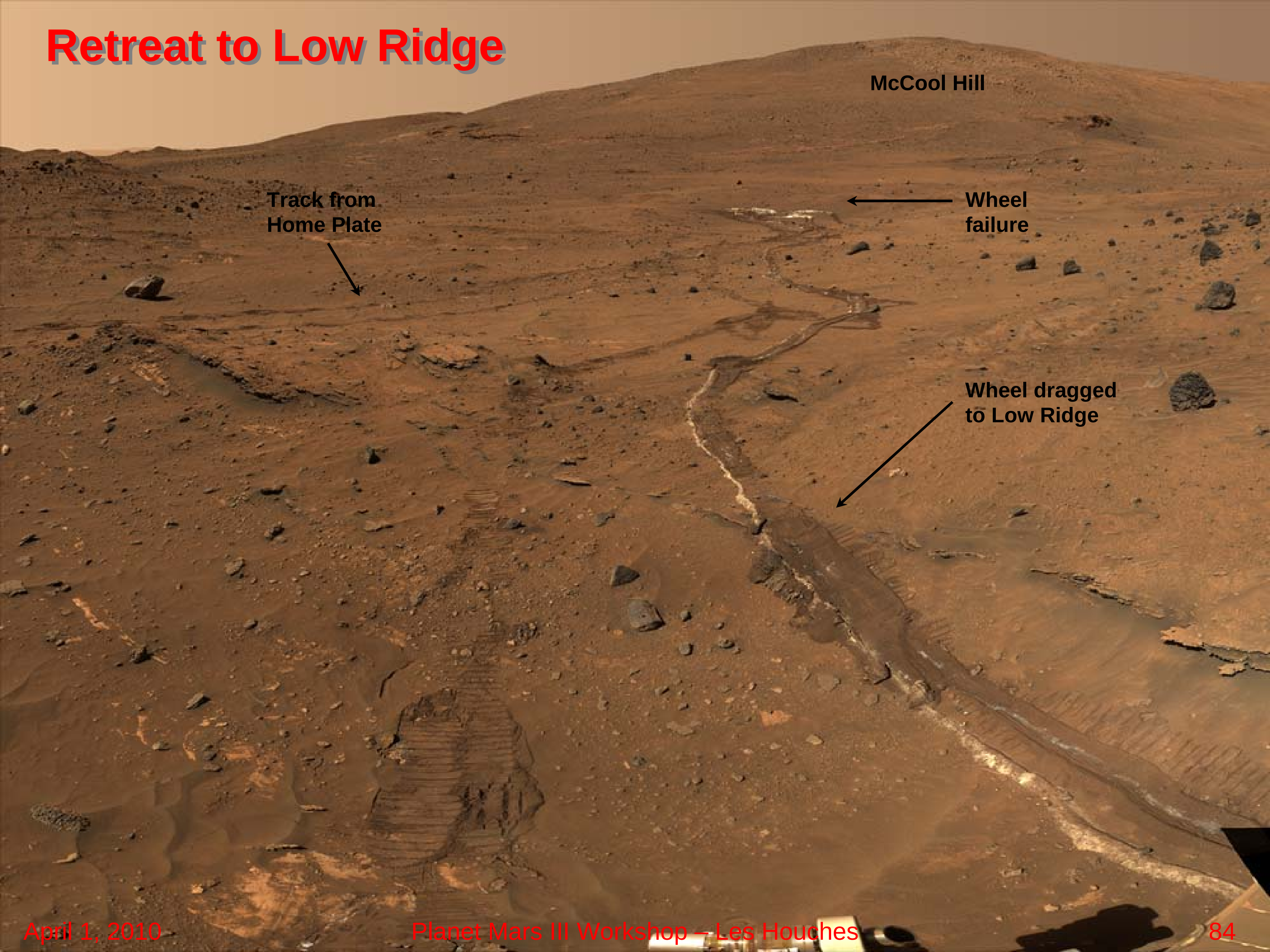
Paso Robles Soil



Si
Al
Mg
S
P
Fe
Cl
Cr
Ni
Br
A342.Penny(last soil)
A401.PasoRobles
Cts/s
10
1
0.1
0.01
1E-3
2000
4000
6000
8000
10000
12000
14000
16000
Energy eV
2/24/2005

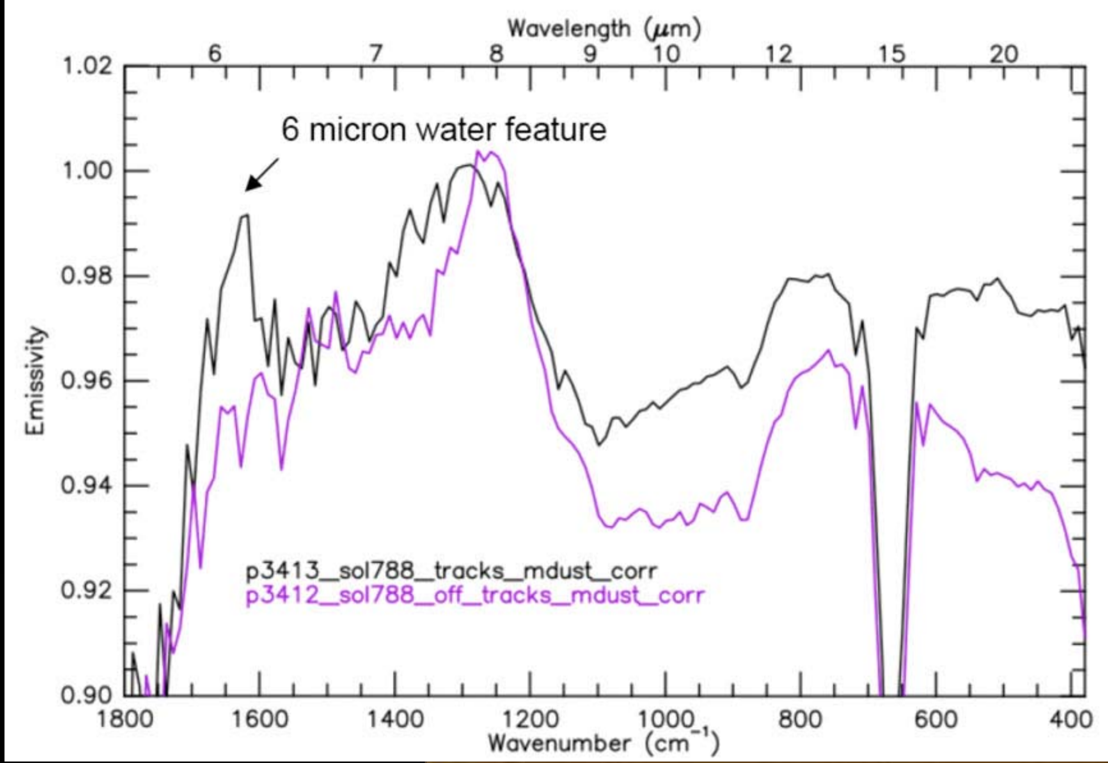
Sol 779: Right Front Wheel Failure

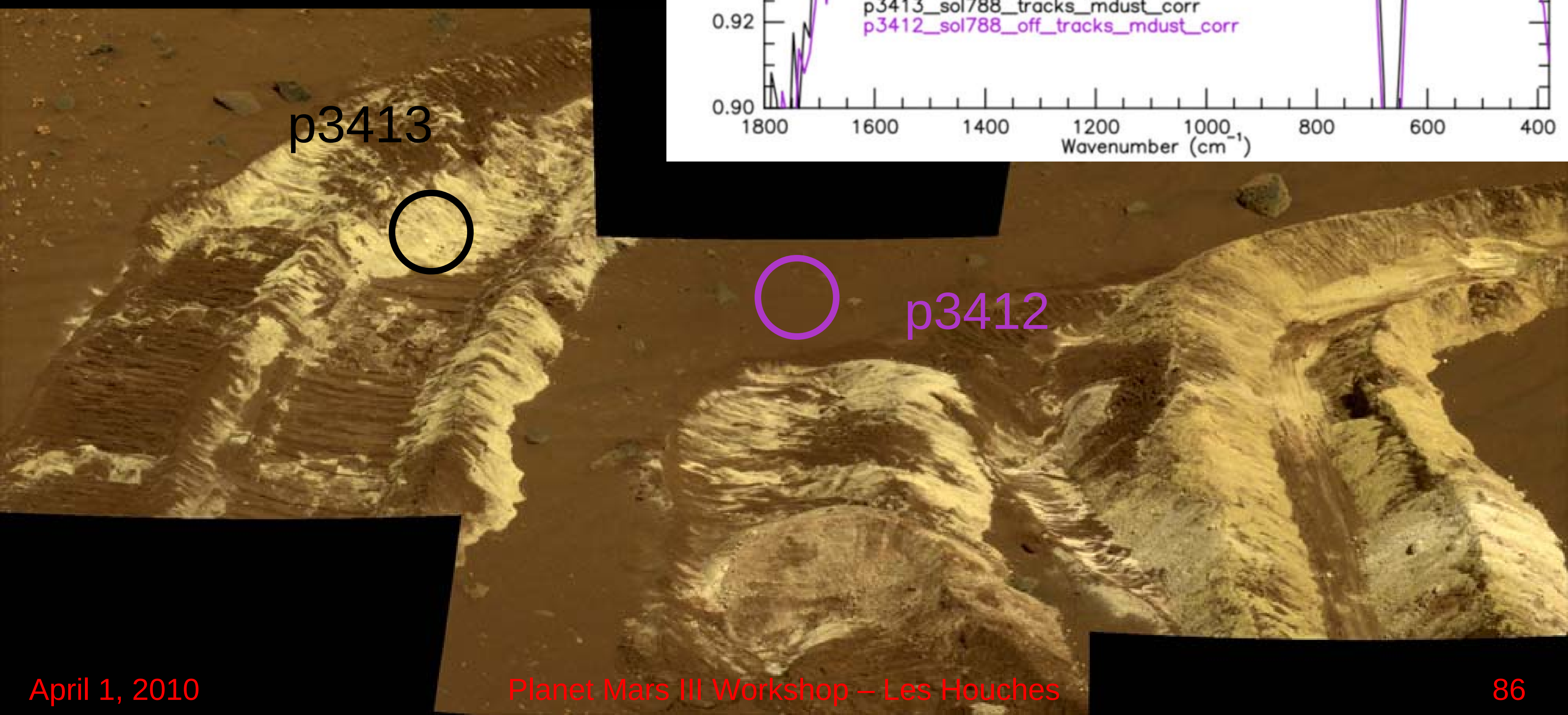
Retreat to Low Ridge



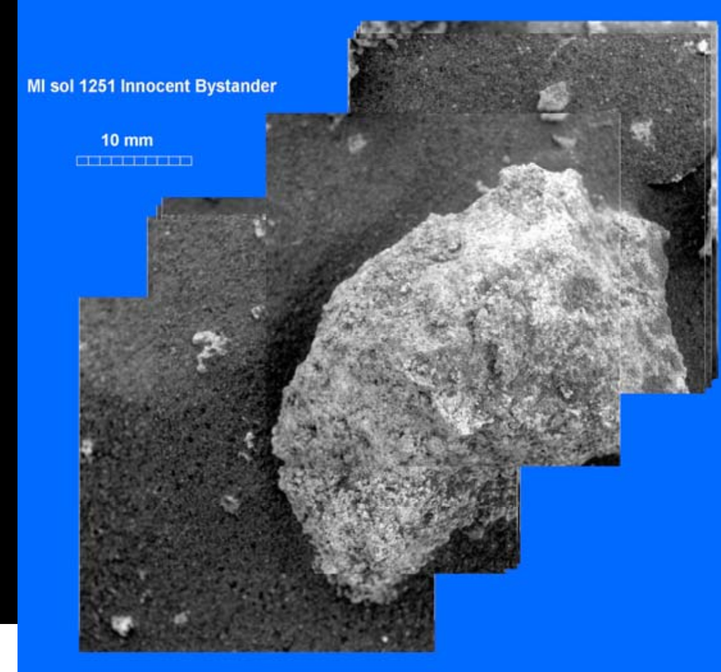
White Soil at Tyrone

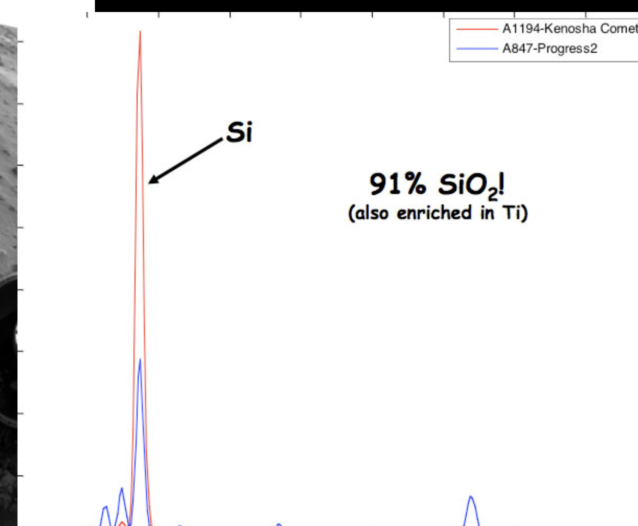
Hydrated Sulfate Salts



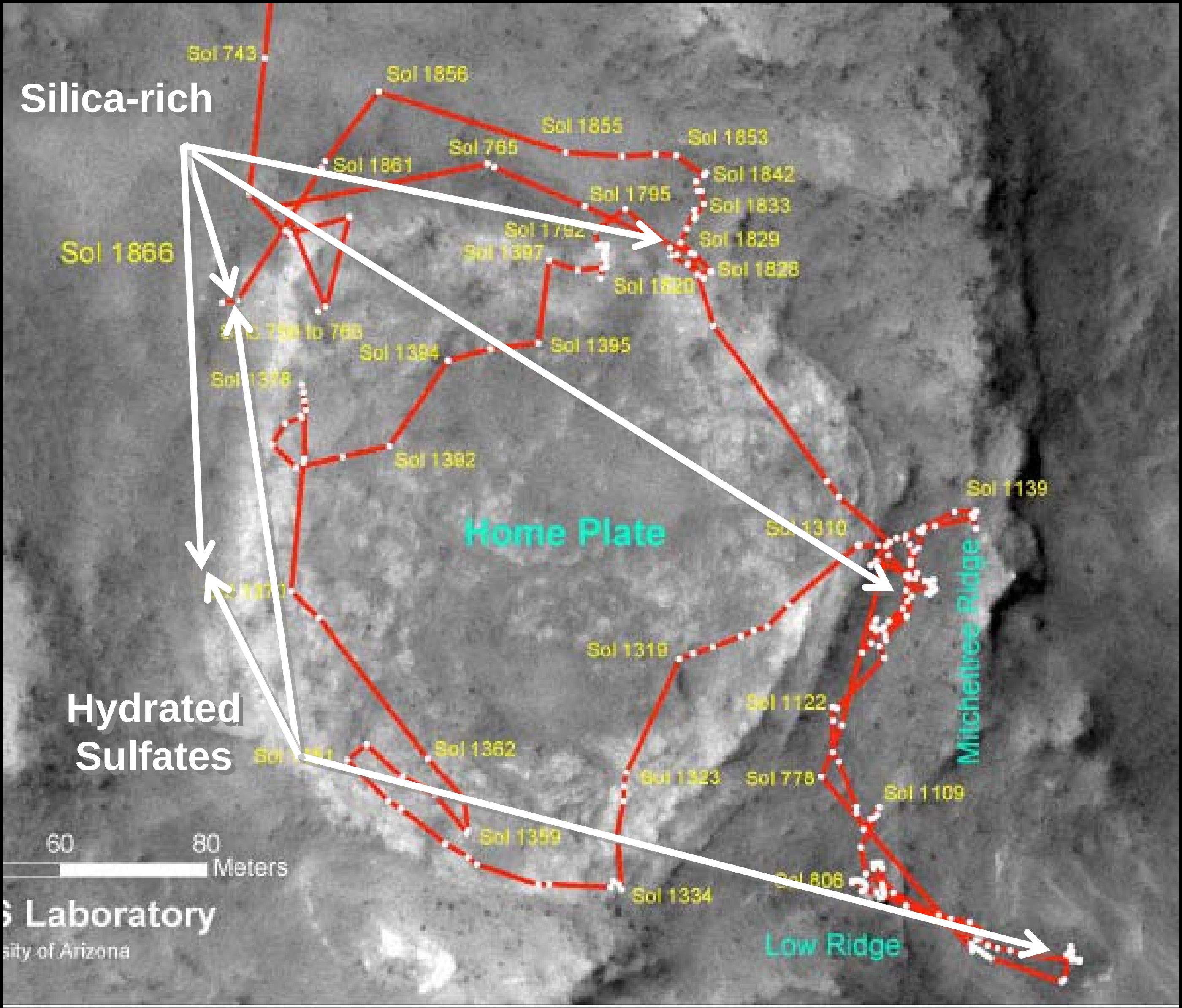


Gertrude Weise
>90% SiO_2

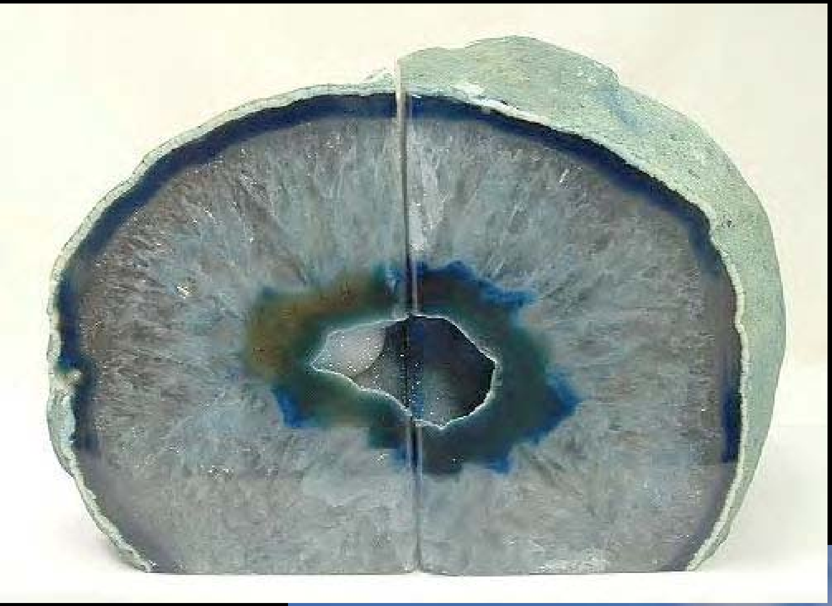




Widely Distributed Around Home Plate

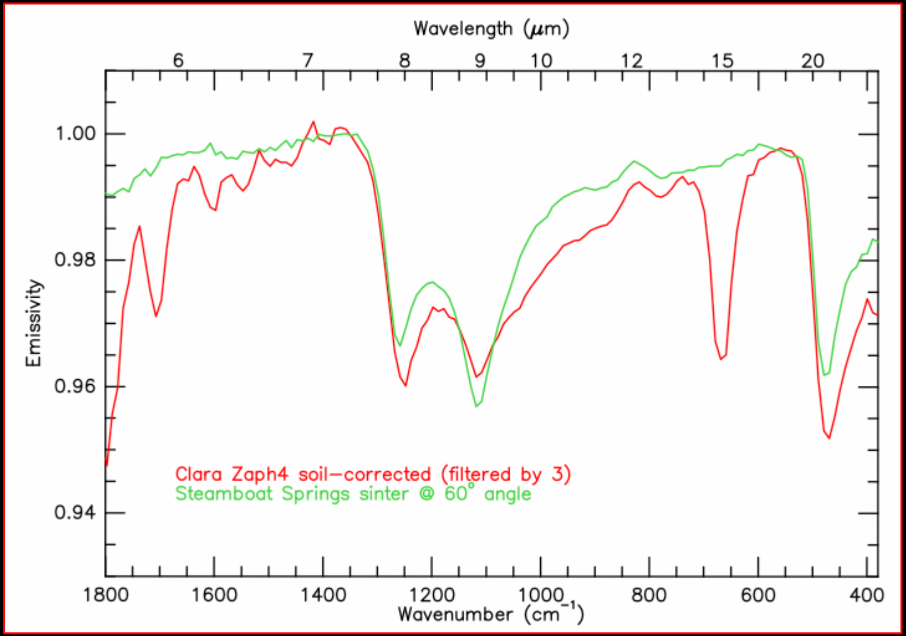


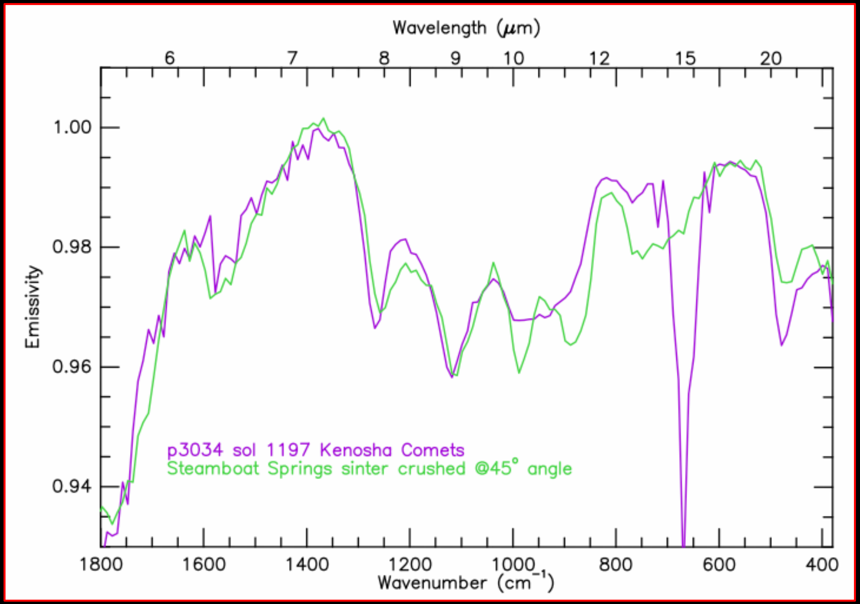
Amorphous Silica (Opal)



Chemical formula:	SiO_2
Color:	White, yellow, red, brown, blue
Crystal system:	Amorphous
Mohs hardness:	5.5 - 6
Specific gravity:	1.9 - 2.3

Hot Spring Siliceous Sinter?





These Light-Toned Soils Provide a Unique Angle on the Water Story

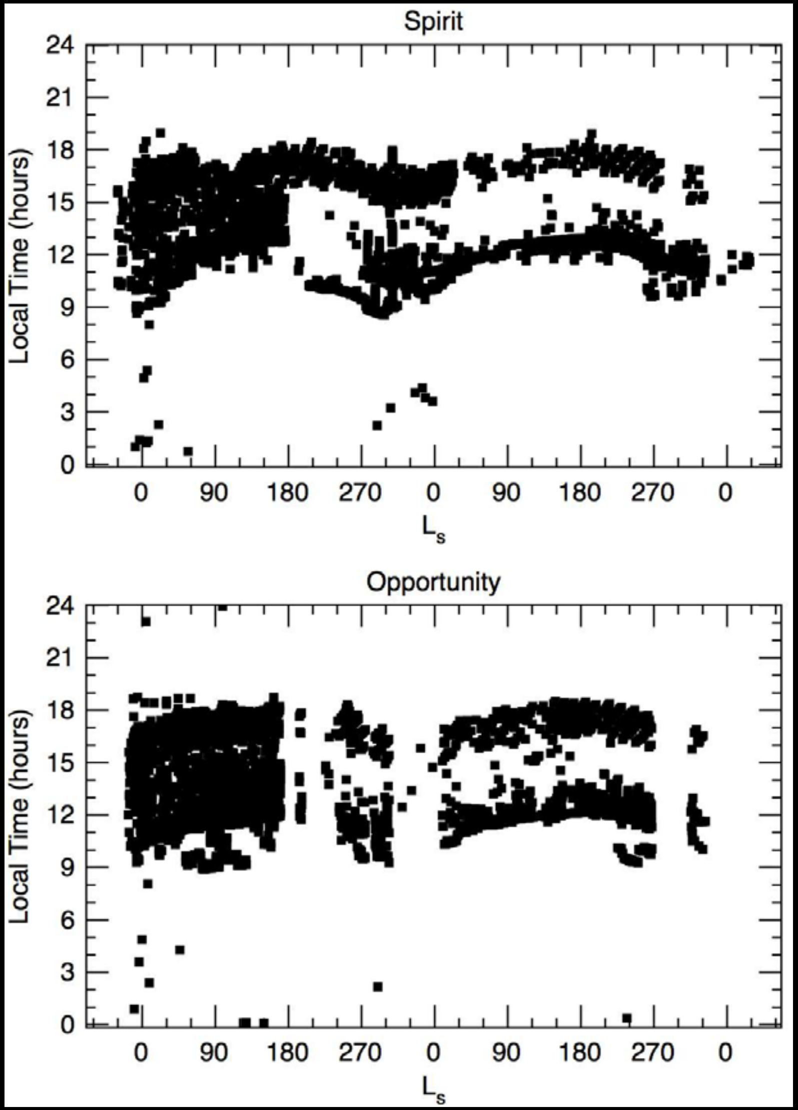
- Hydrated sulfate salts have been found in several locations. Each has subtle chemical fingerprints of the surrounding rocks, indicating the local mobilization of chemicals by the action of water.

- High concentrations of silica form by leaching (of non-silica component) or precipitation in hydrothermal systems or volcanic fumaroles.

- All these soils have been found just below the surface of the loose soil – this implies that these processes could be relatively recent!

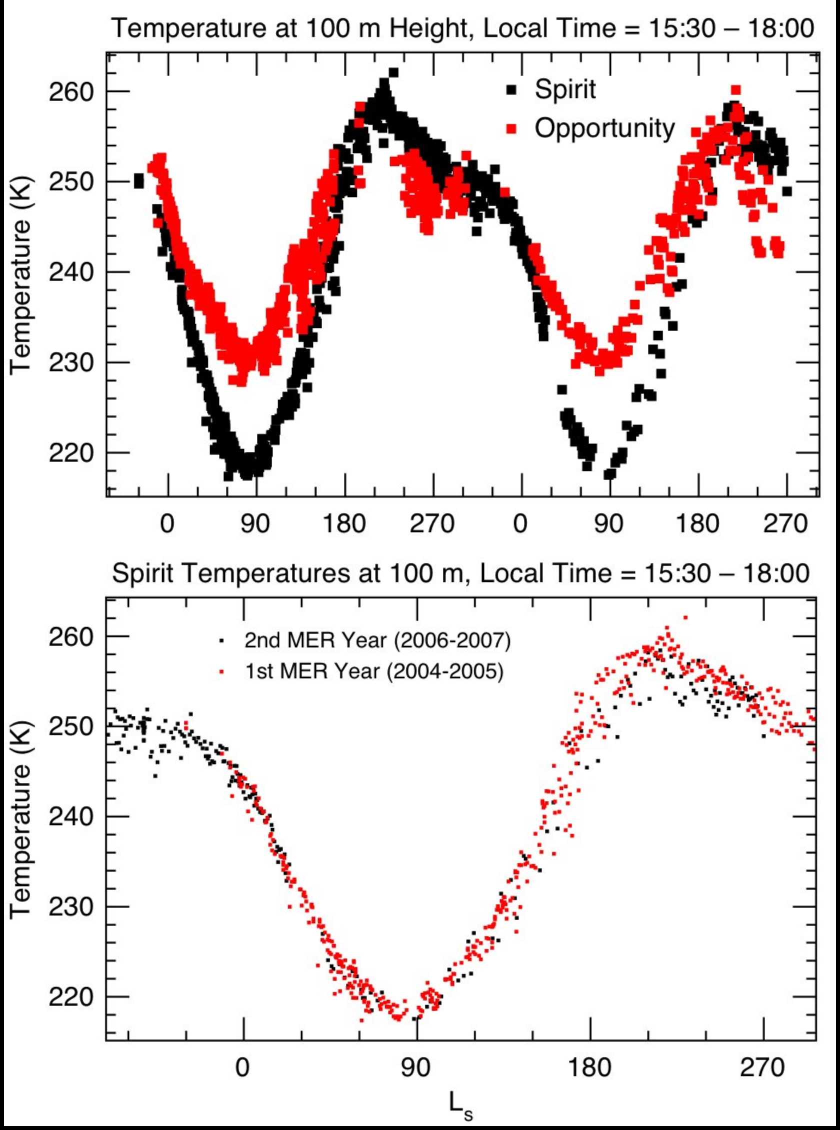
Atmospheric Science

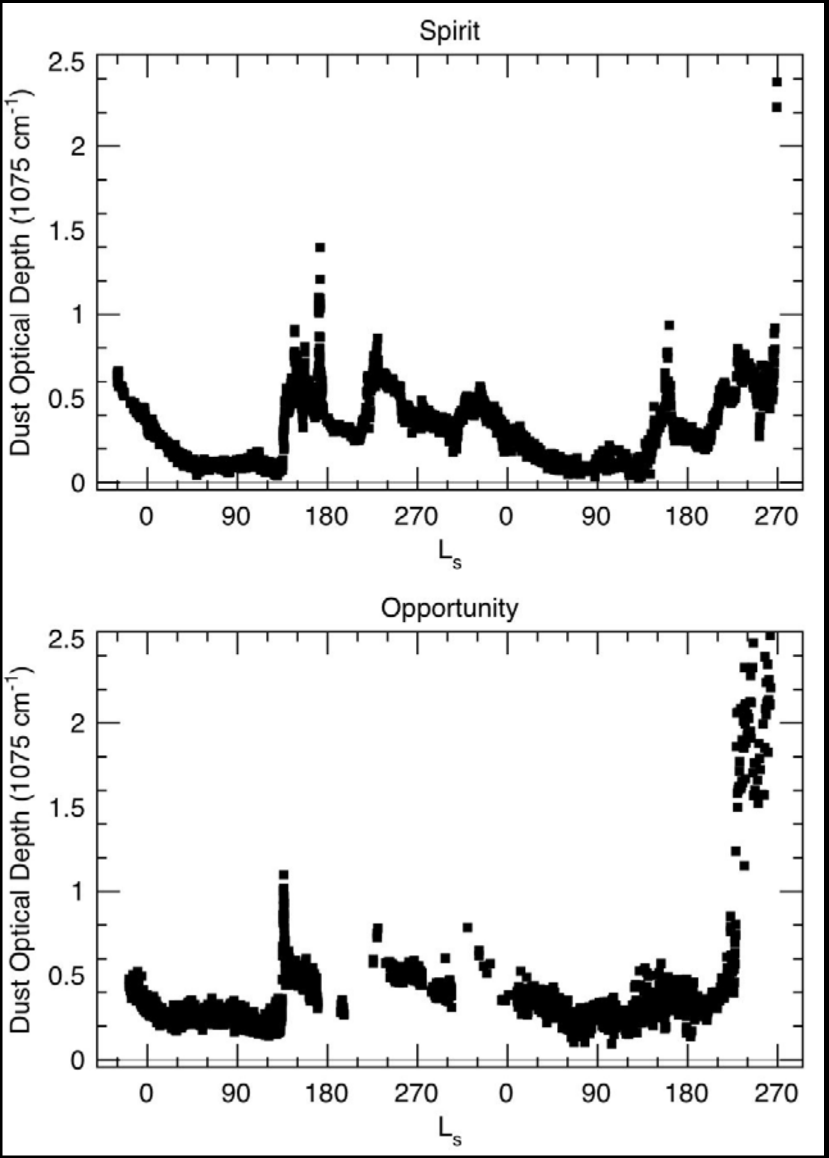
Mini-TES Atmospheric Observations



- About two martian years of observations
- ~750,000 spectra from Spirit
- ~900,000 spectra from Opportunity

Seasonal Variations in T and Tau

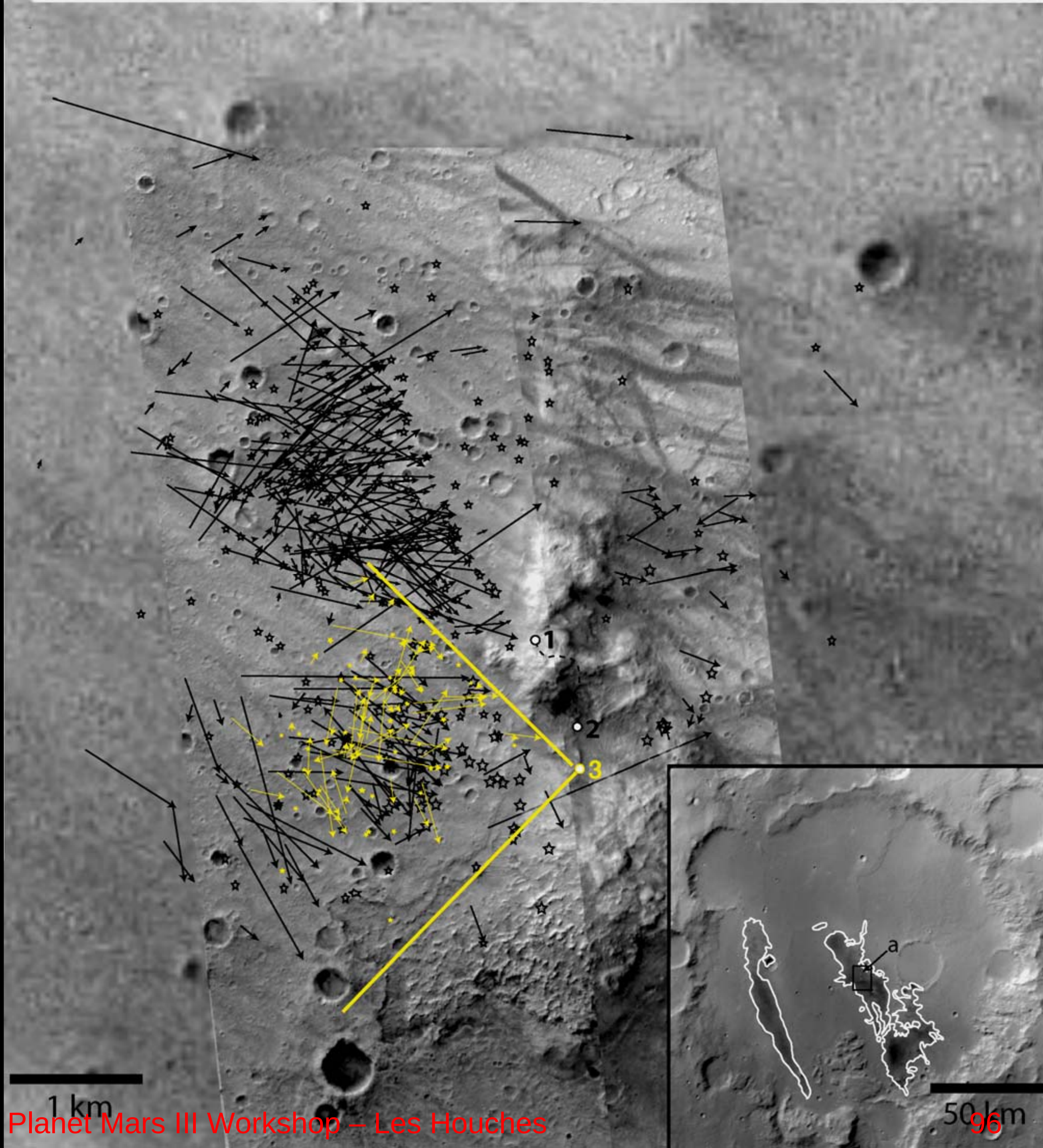




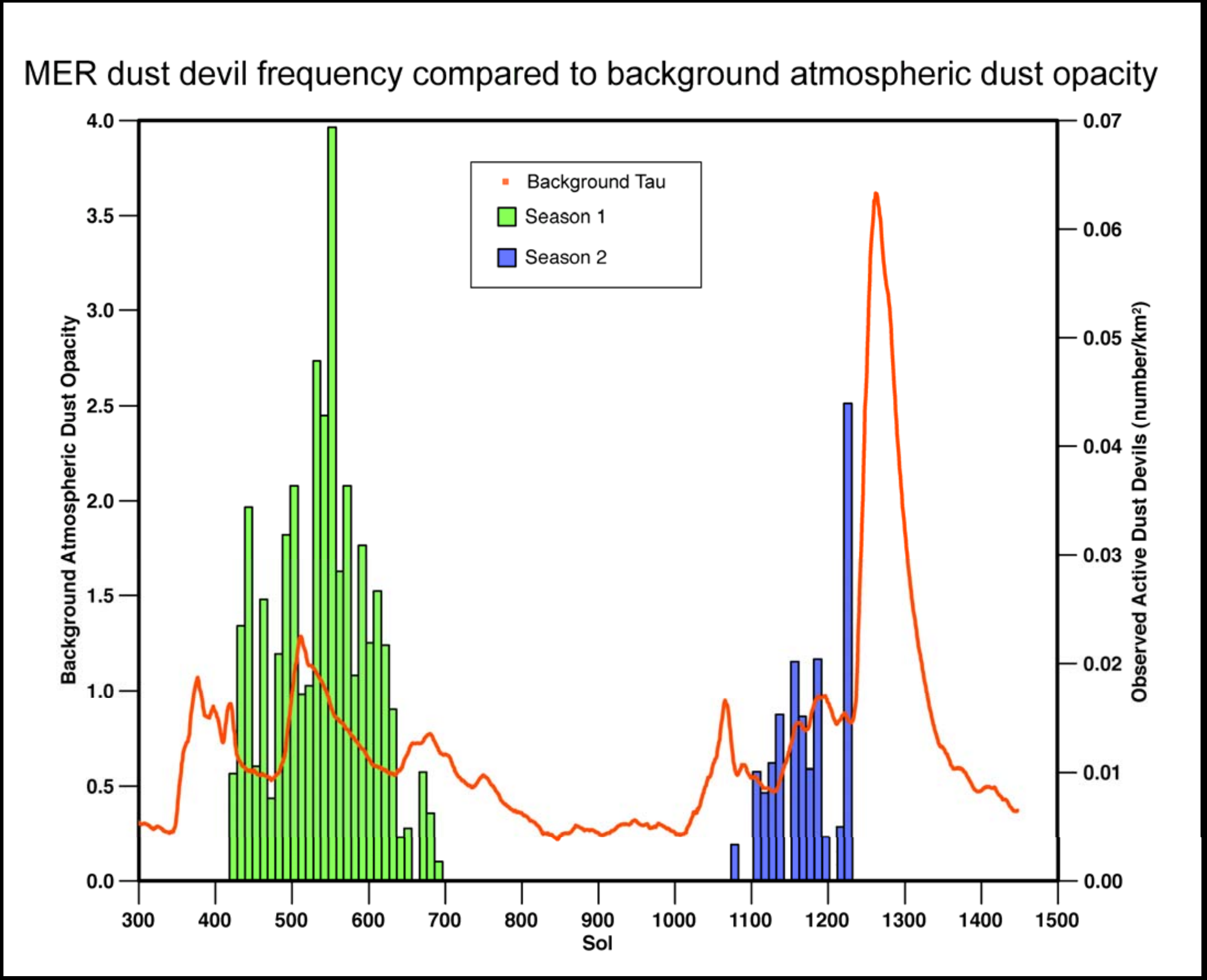

0000

Dust Devils

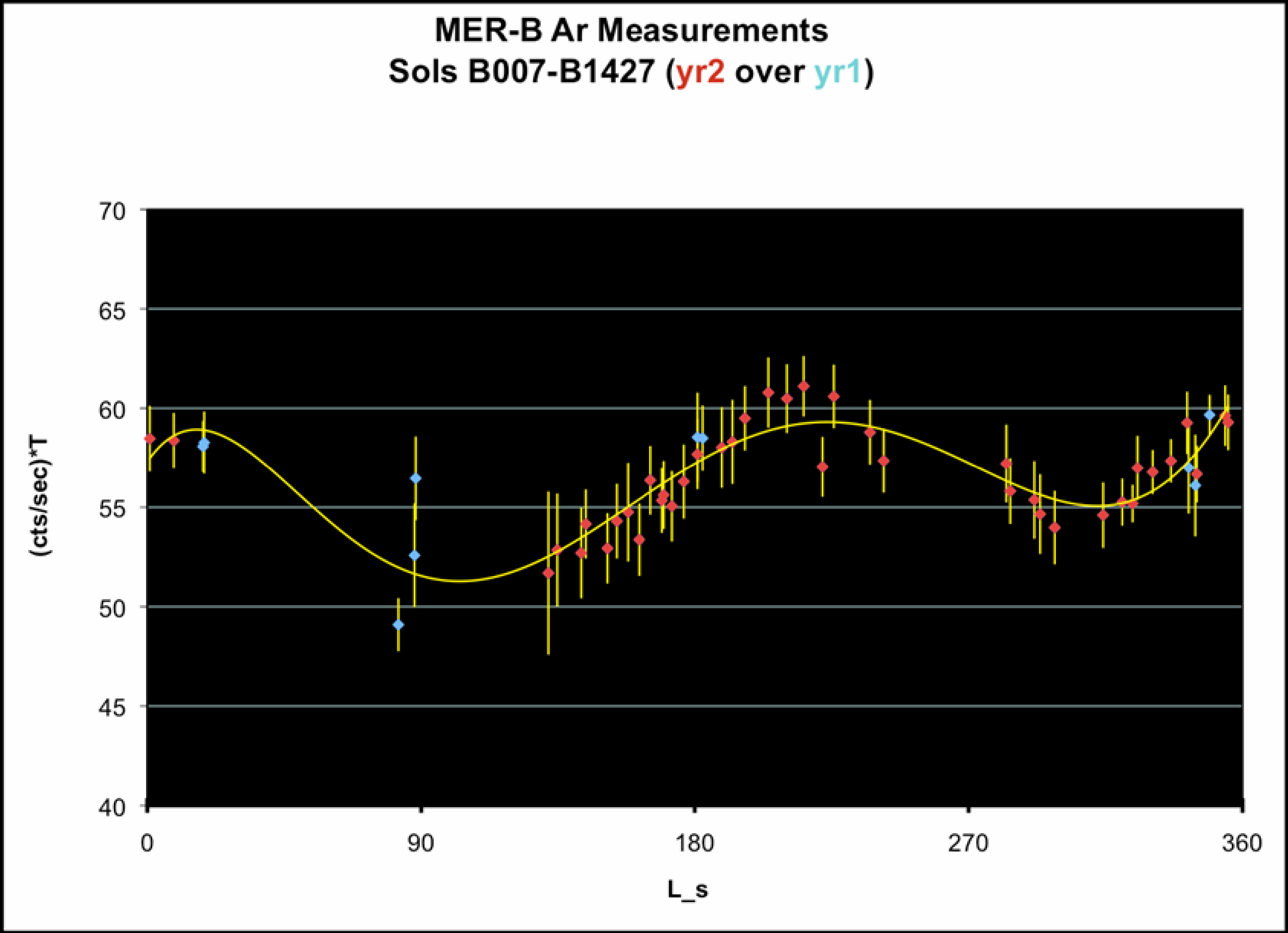
Black = Season 1
Yellow = Season 2



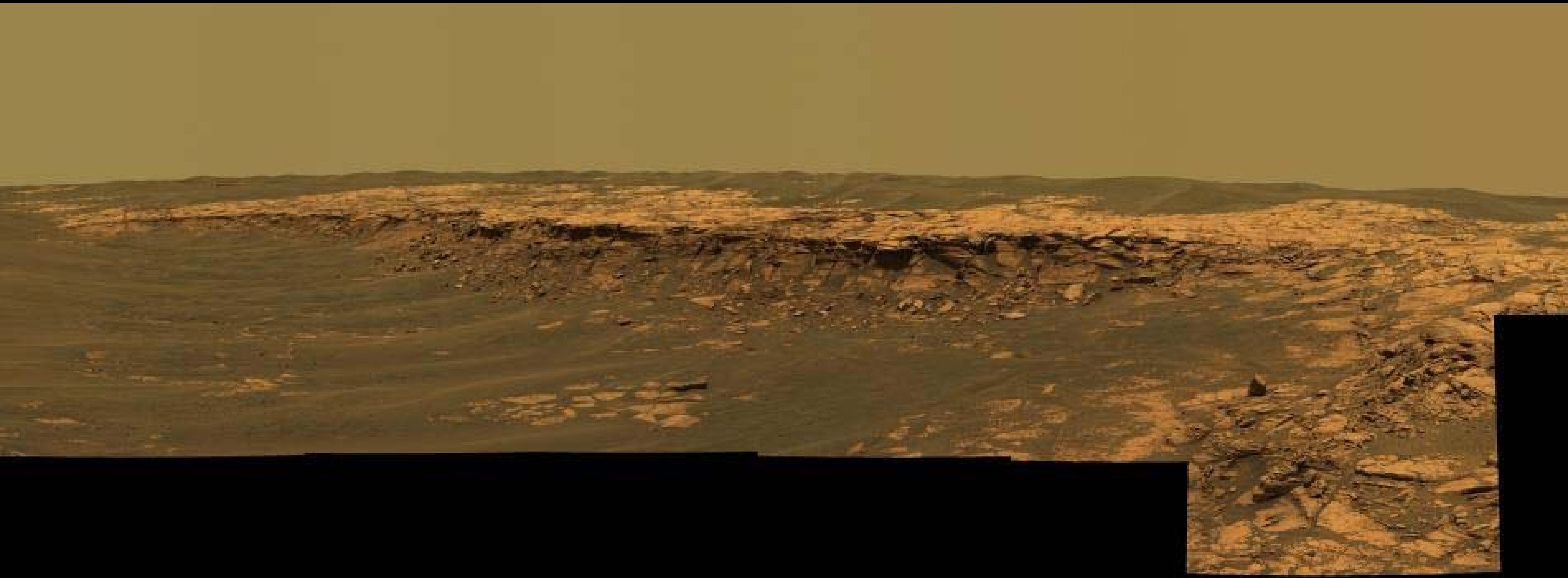
Dust Devils vs. L_s and Tau



APXS Argon Measurements

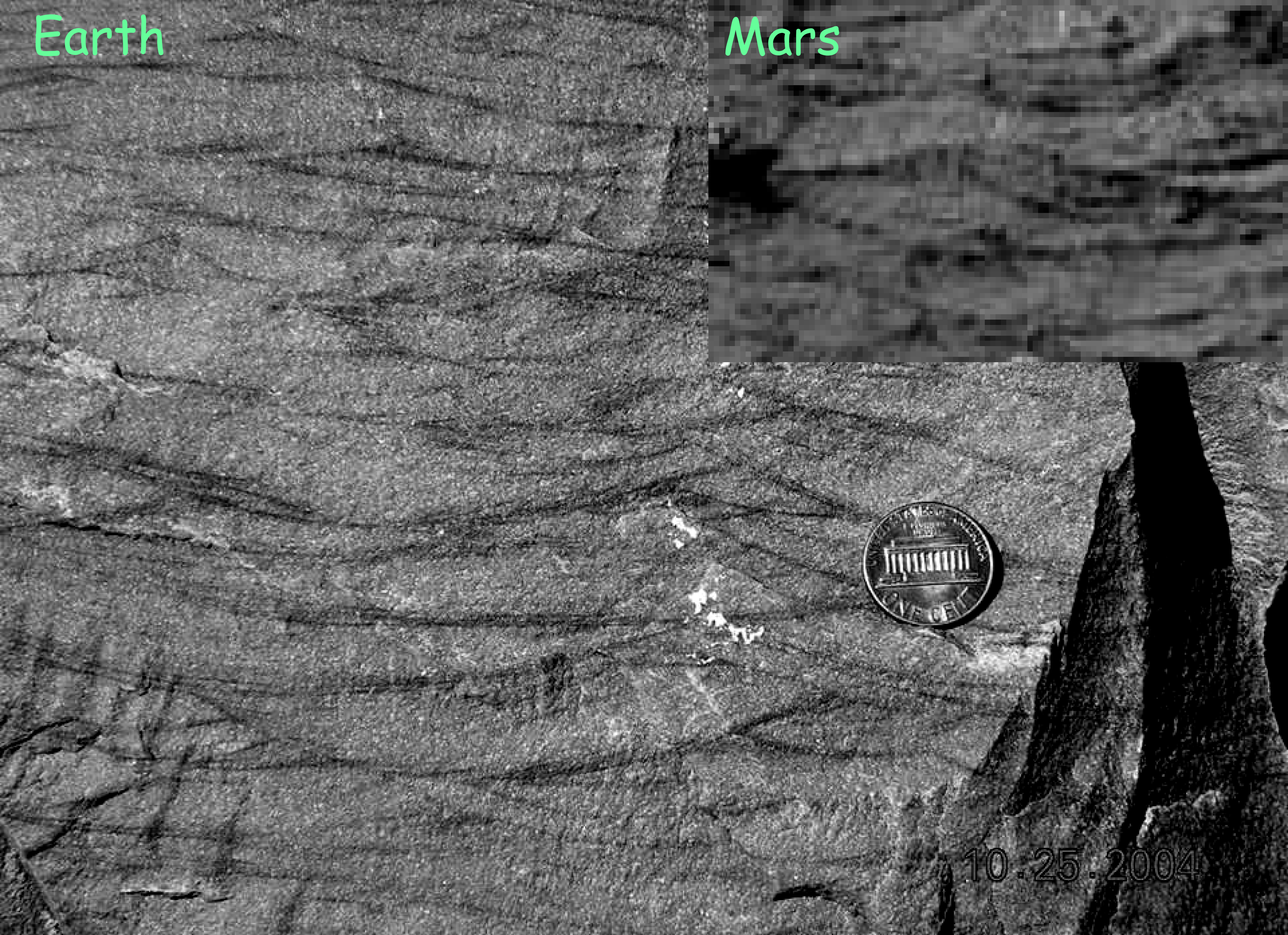


Opportunity:
The Trek South
(Ongoing)

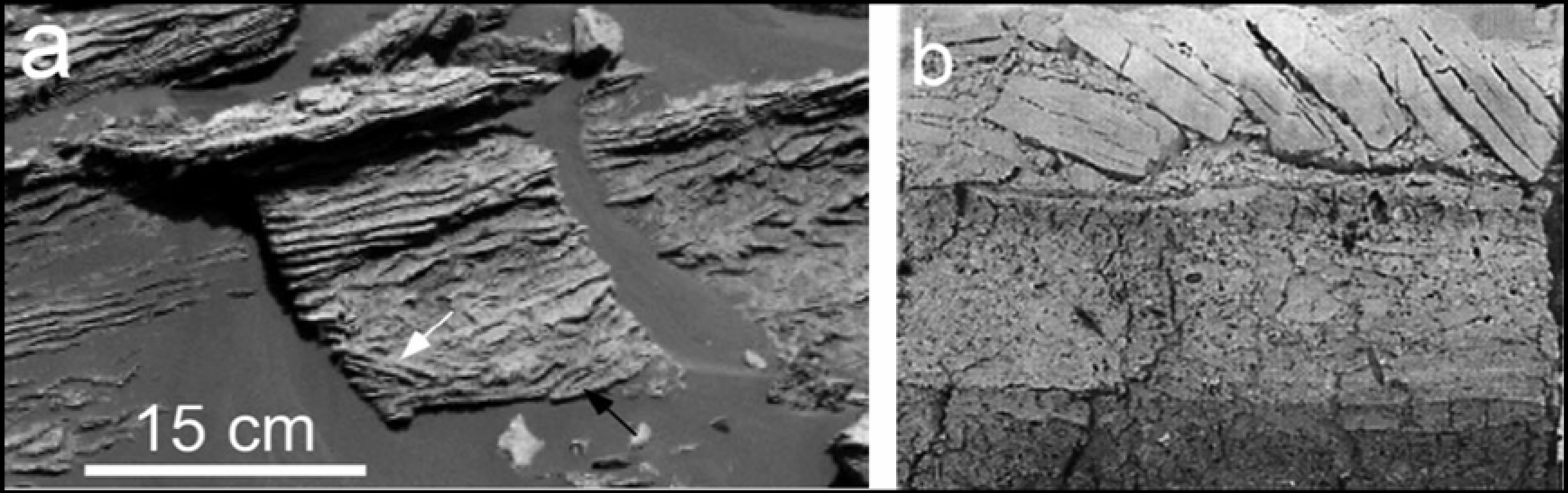


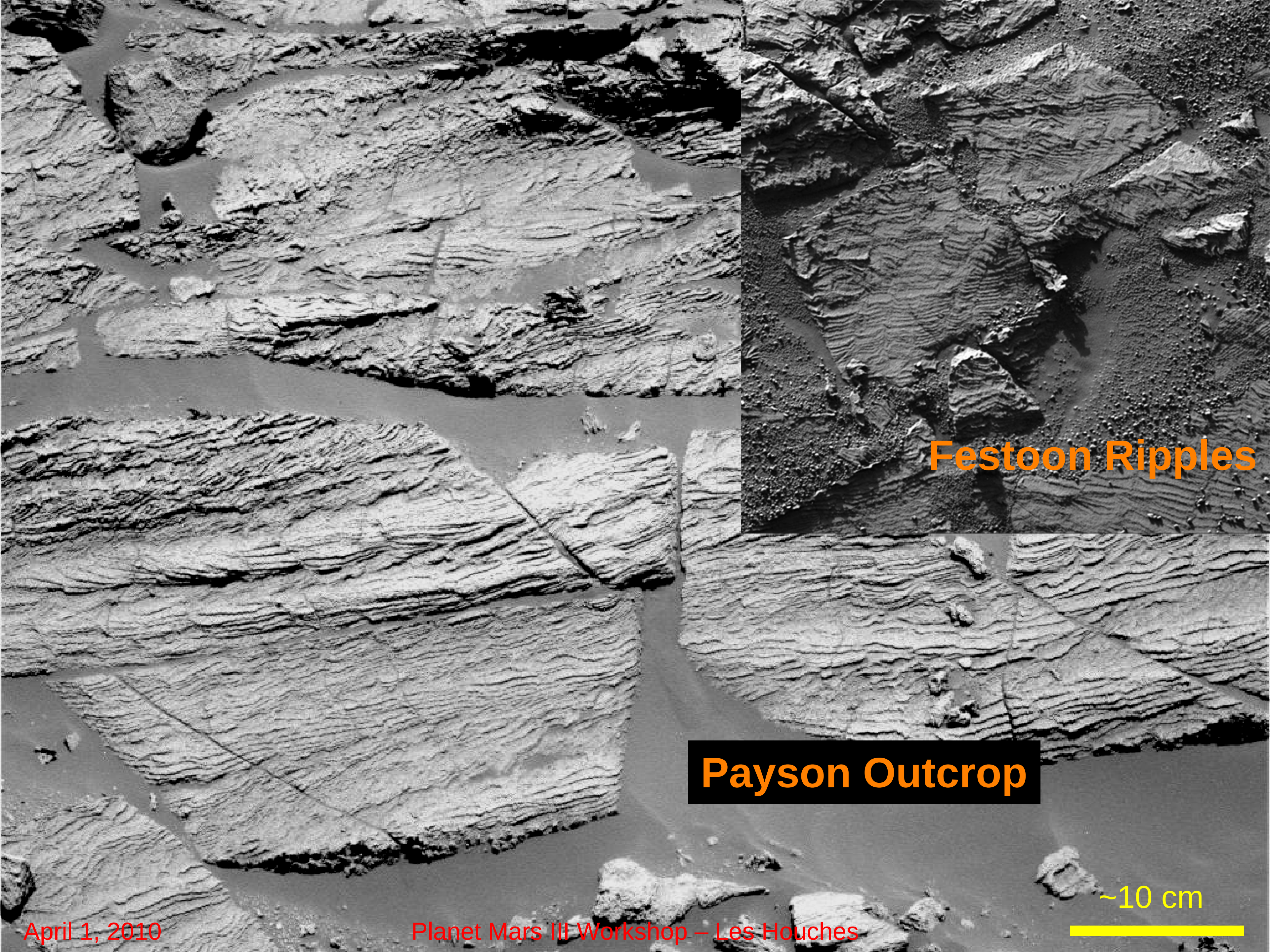
Evidence for Surface Water at Erebus Crater

Upper Overgaard

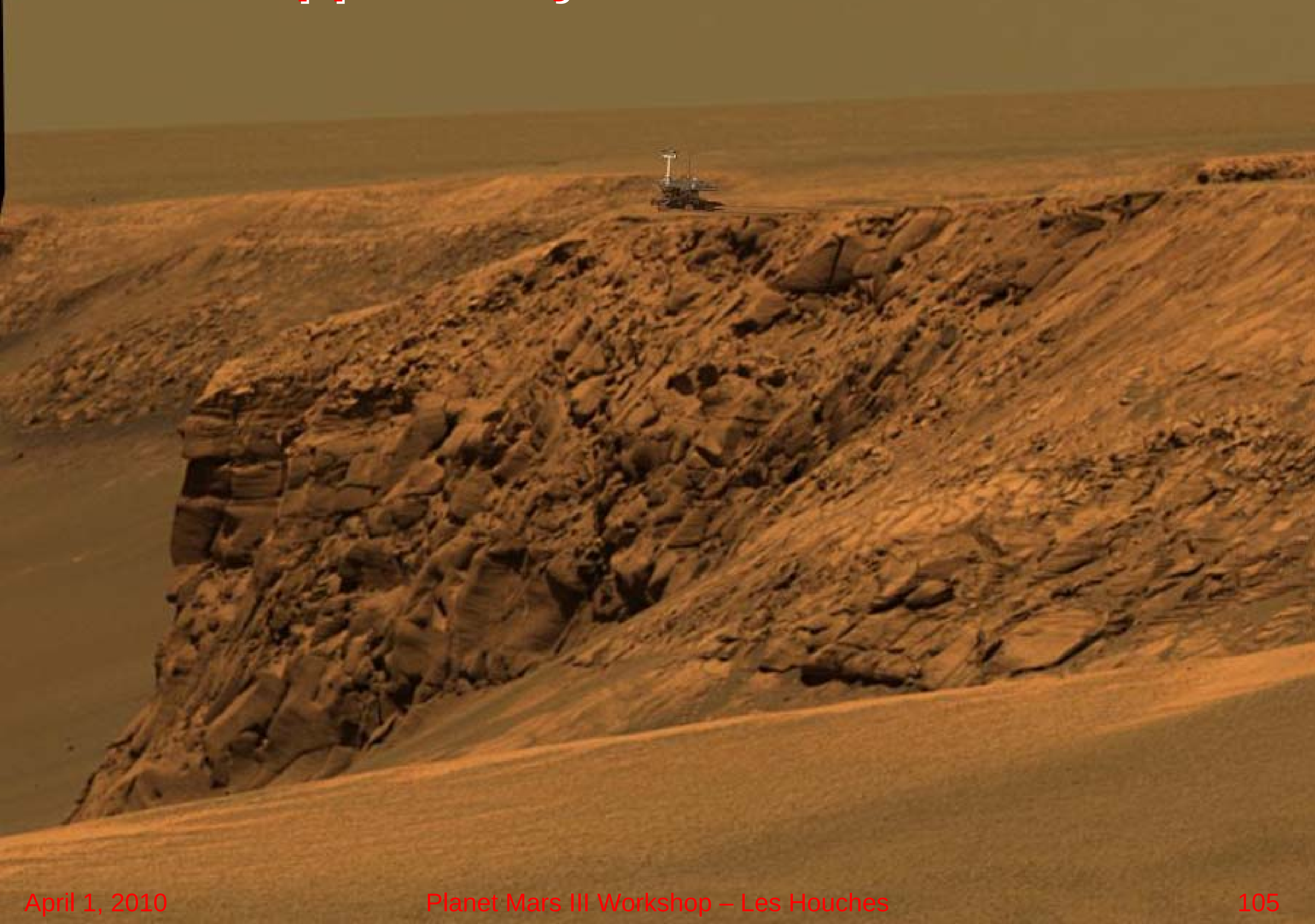

Earth
Mars
10.25.2004

Rip-Up Clasts

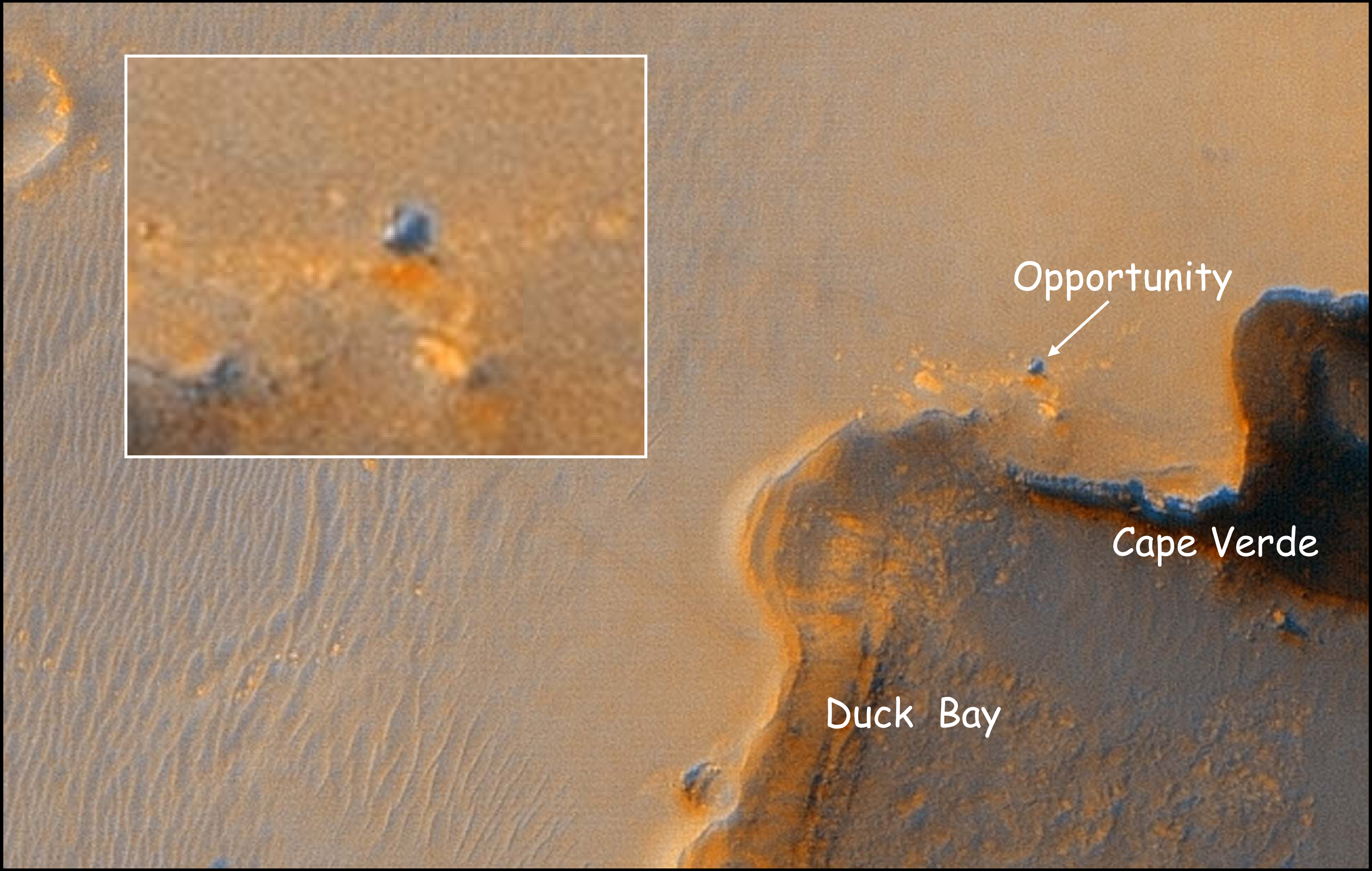



Festoon Ripples
Payson Outcrop
~10 cm

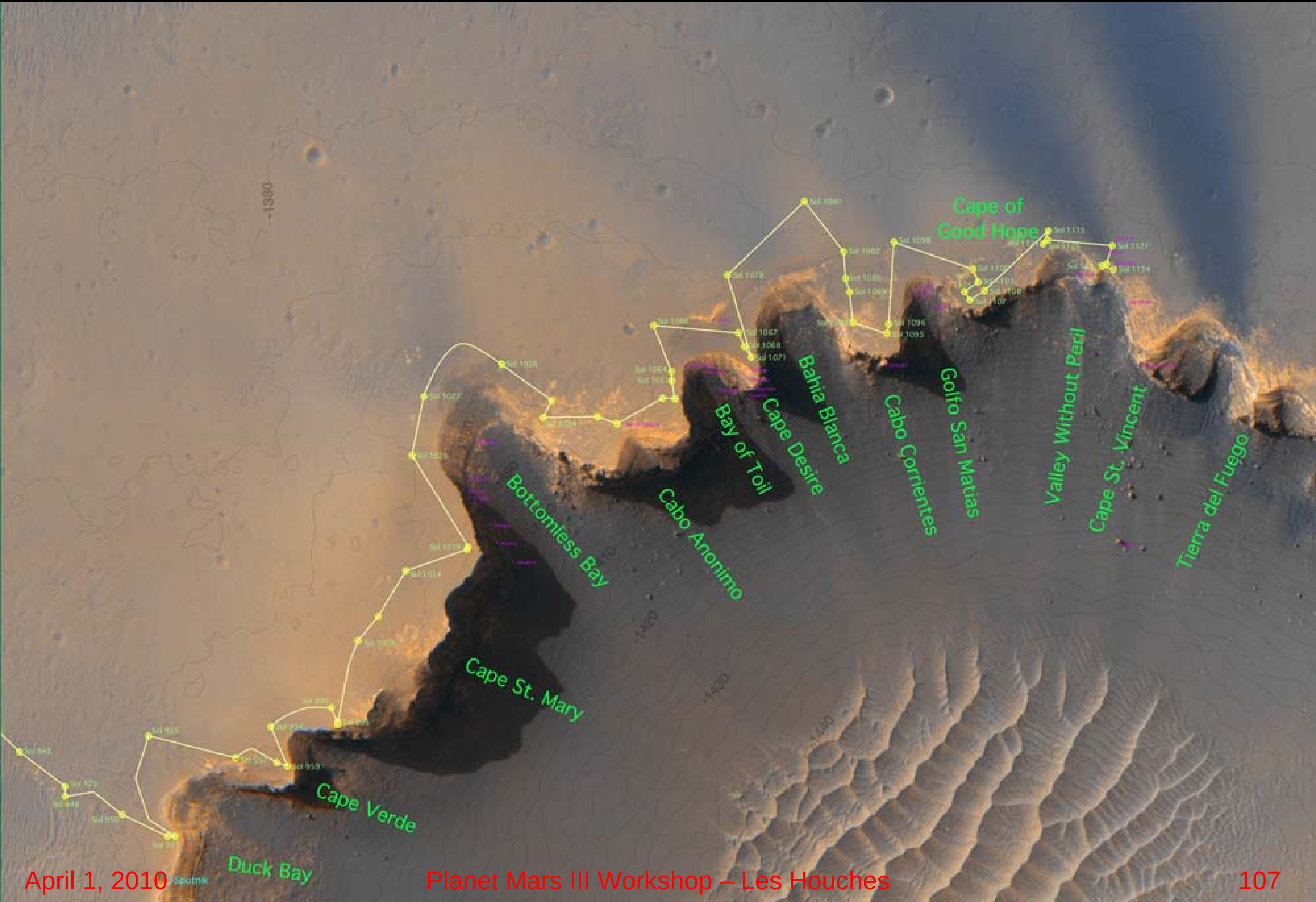
Opportunity at Victoria Crater



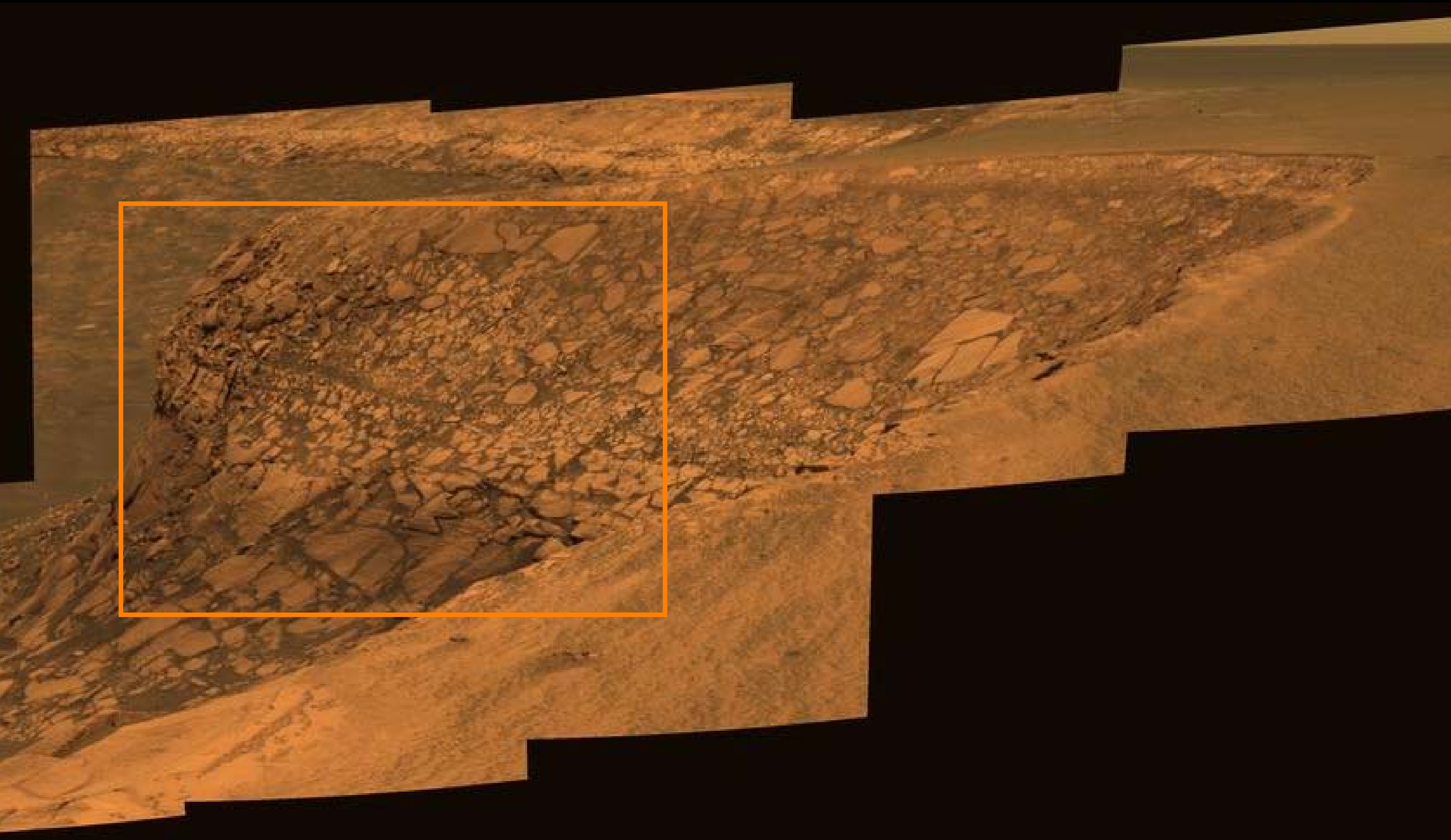
Opportunity at Victoria Crater



Working Around Victoria



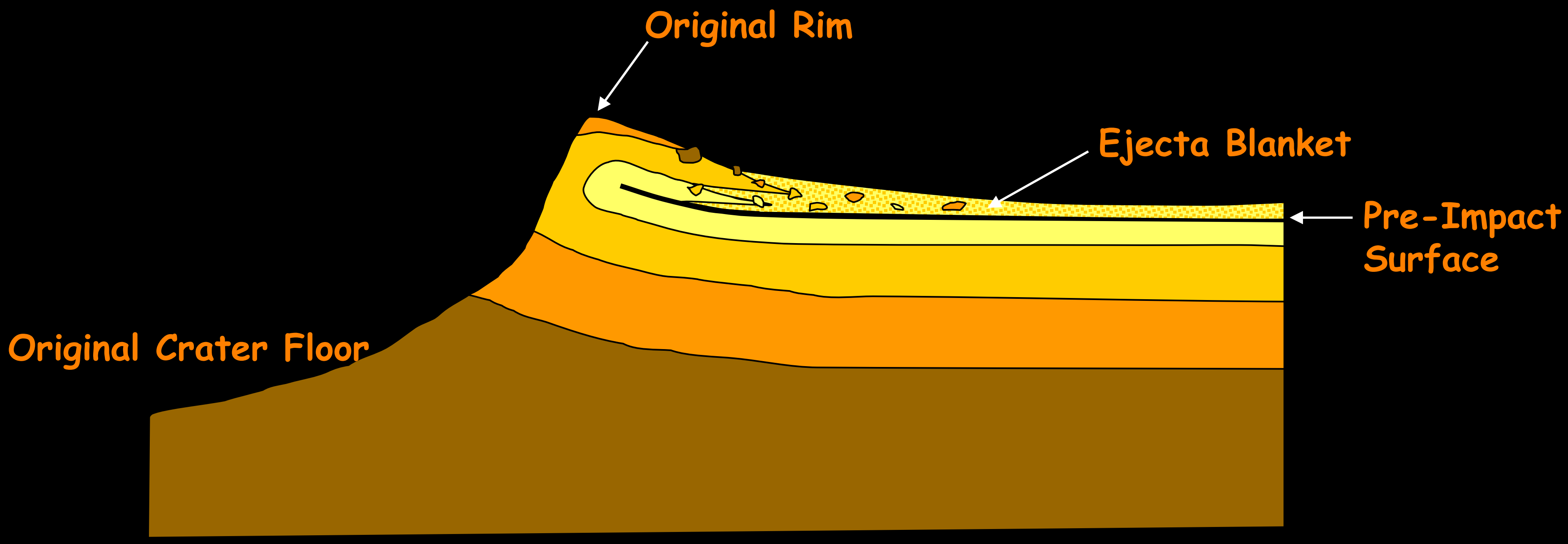
Cape Verde from Cape St. Mary



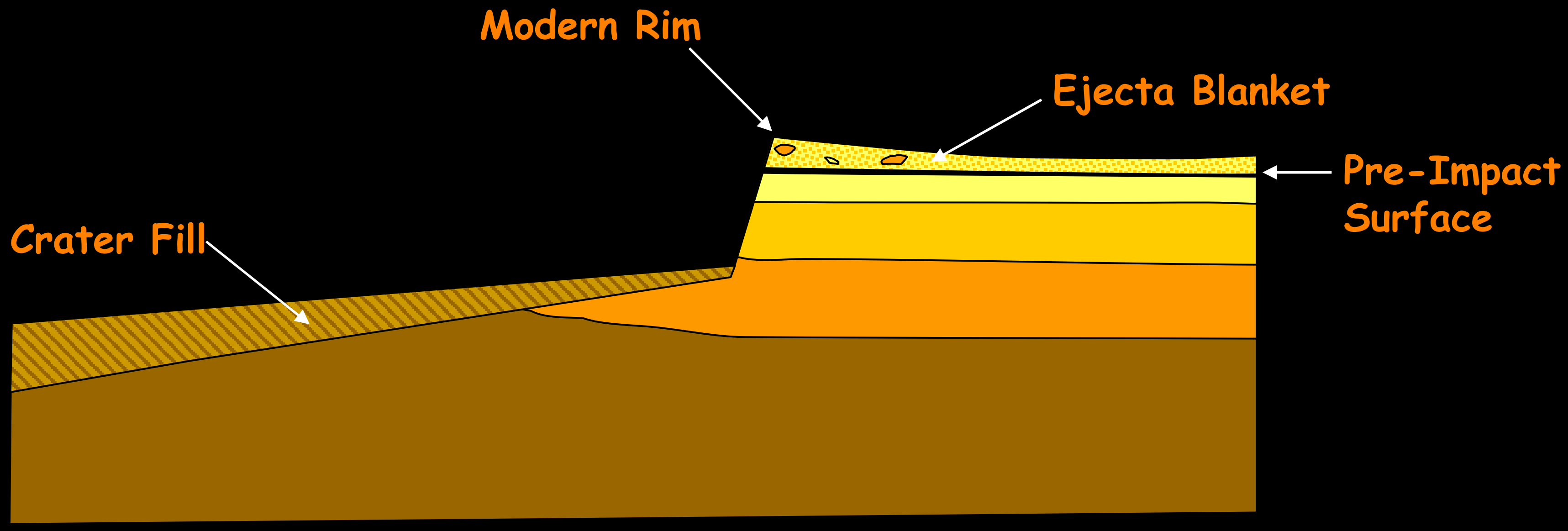
Upper Victoria Stratigraphy

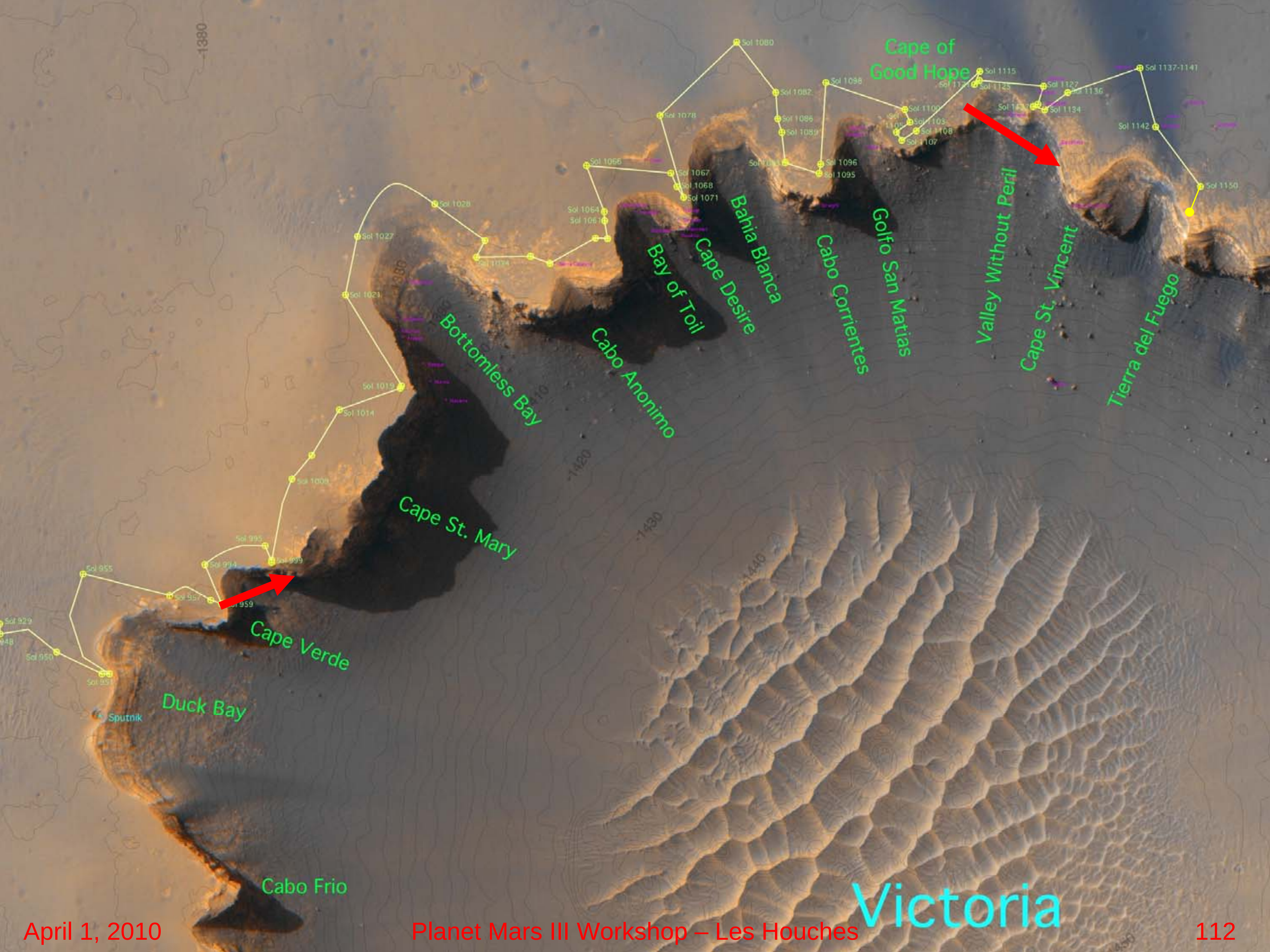
Steve Squyres

Victoria After Formation



Victoria Today

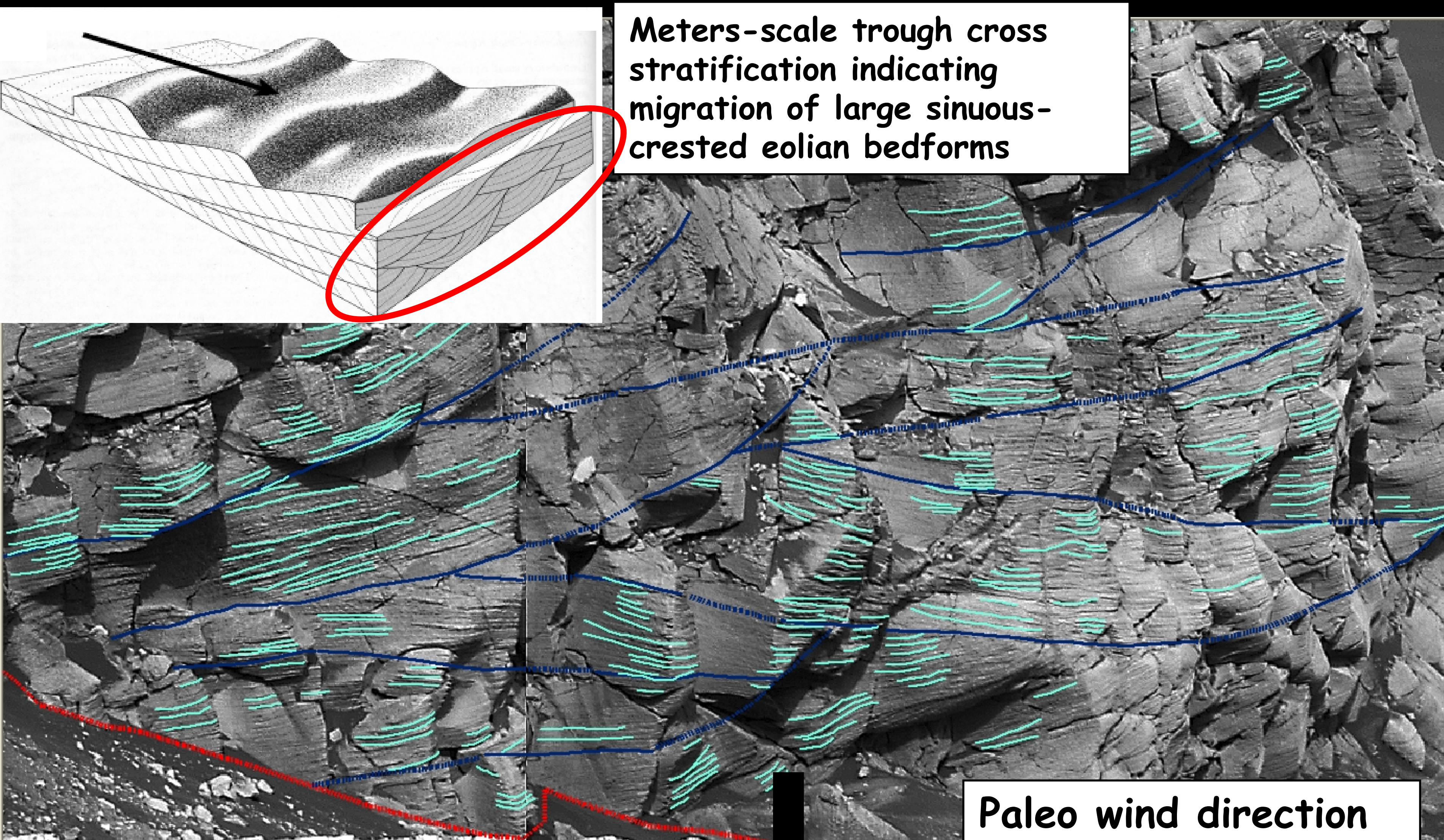



Cape of Good Hope
Valley Without Peril
Cape St. Vincent
Tierra del Fuego
Golfo San Matias
Cabo Corrientes
Bahia Blanca
Cape Desire
Bay of Toil
Cabo Anonimo
Bottomless Bay
Cape St. Mary
Cape Verde
Duck Bay
Sputnik
Cabo Frio
Victoria

Cape St. Mary from Cape Verde

Cape St. Mary

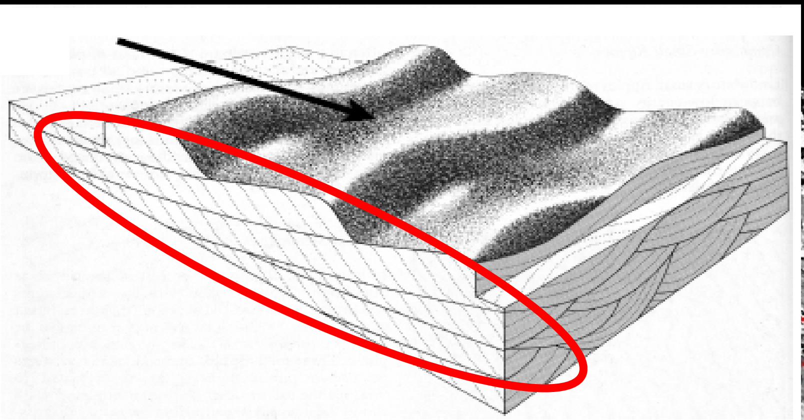
Cape St. Mary



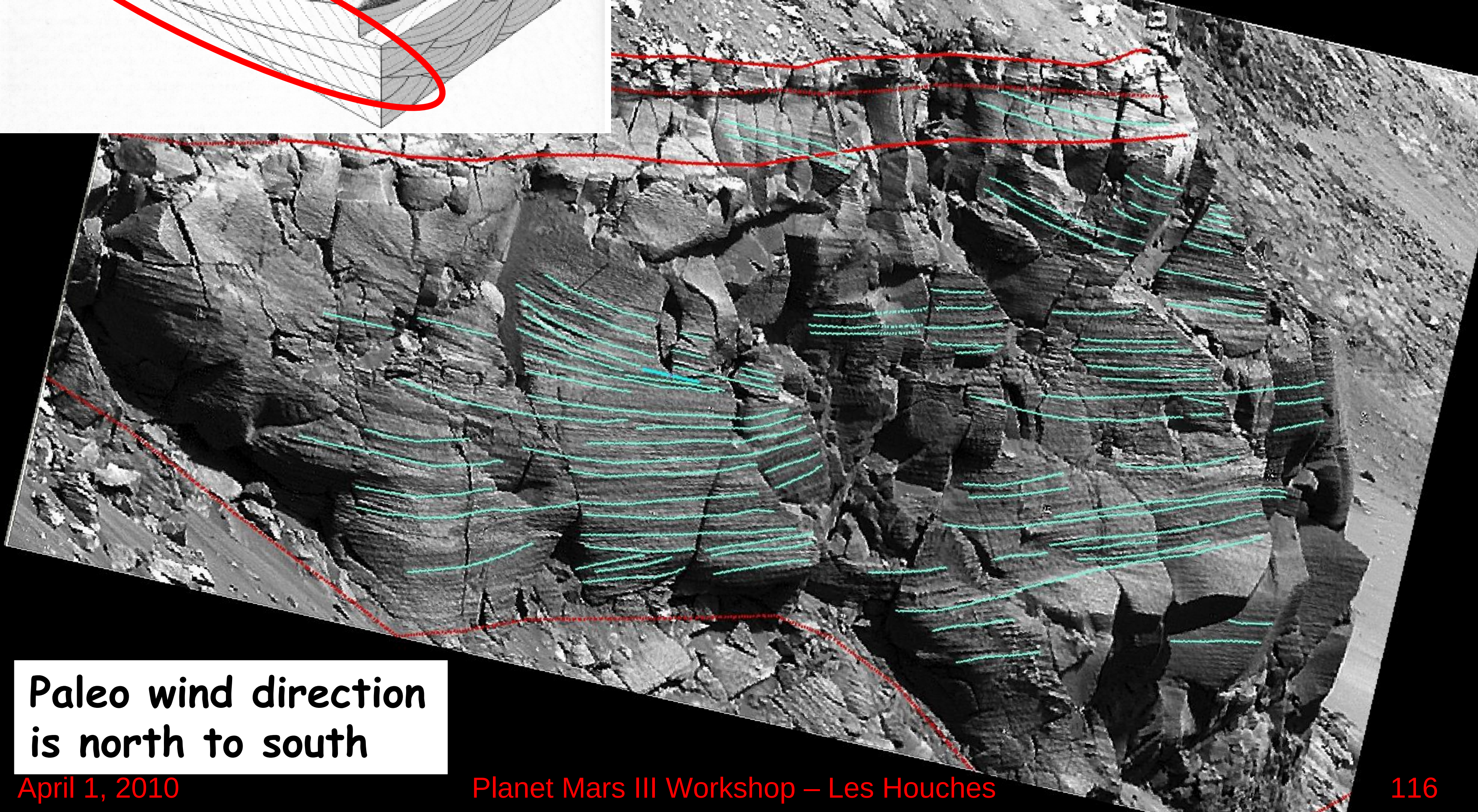
Meters-scale trough cross stratification indicating migration of large sinuous-crested eolian bedforms

Paleo wind direction is north to south <u>or</u> south to north

Cape St. Vincent



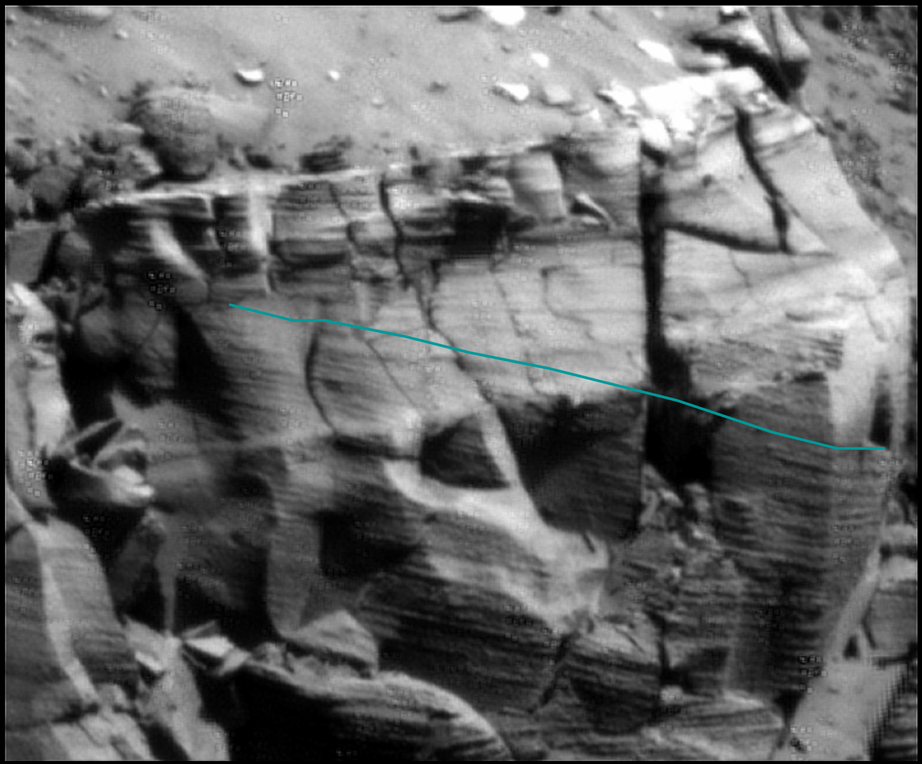
~7-meter thick climbing eolian bedform

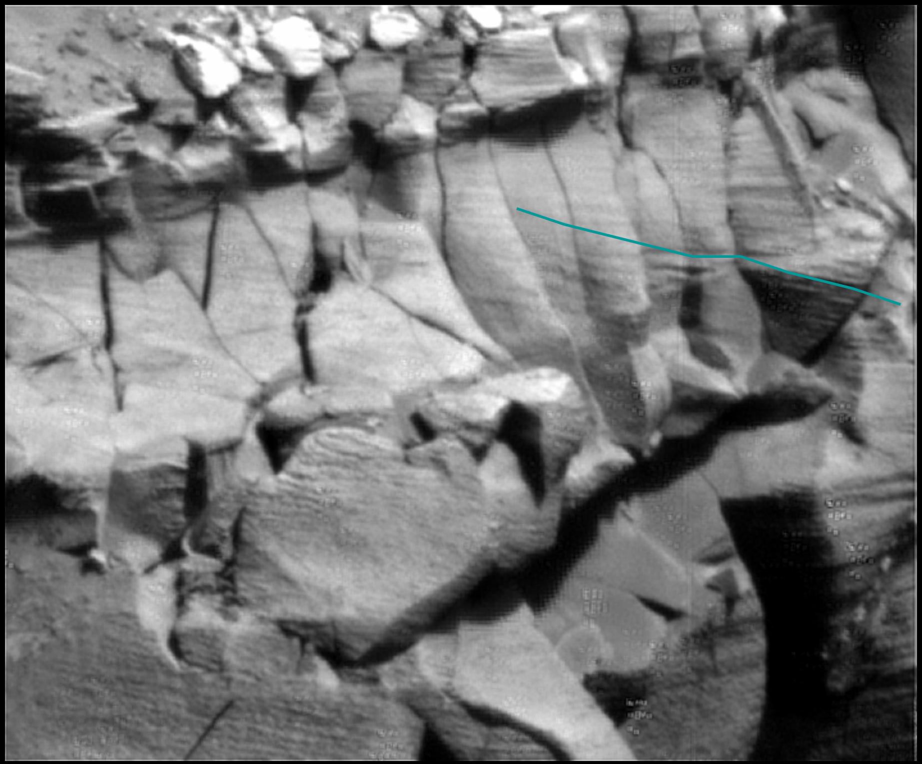


Paleo wind direction is north to south

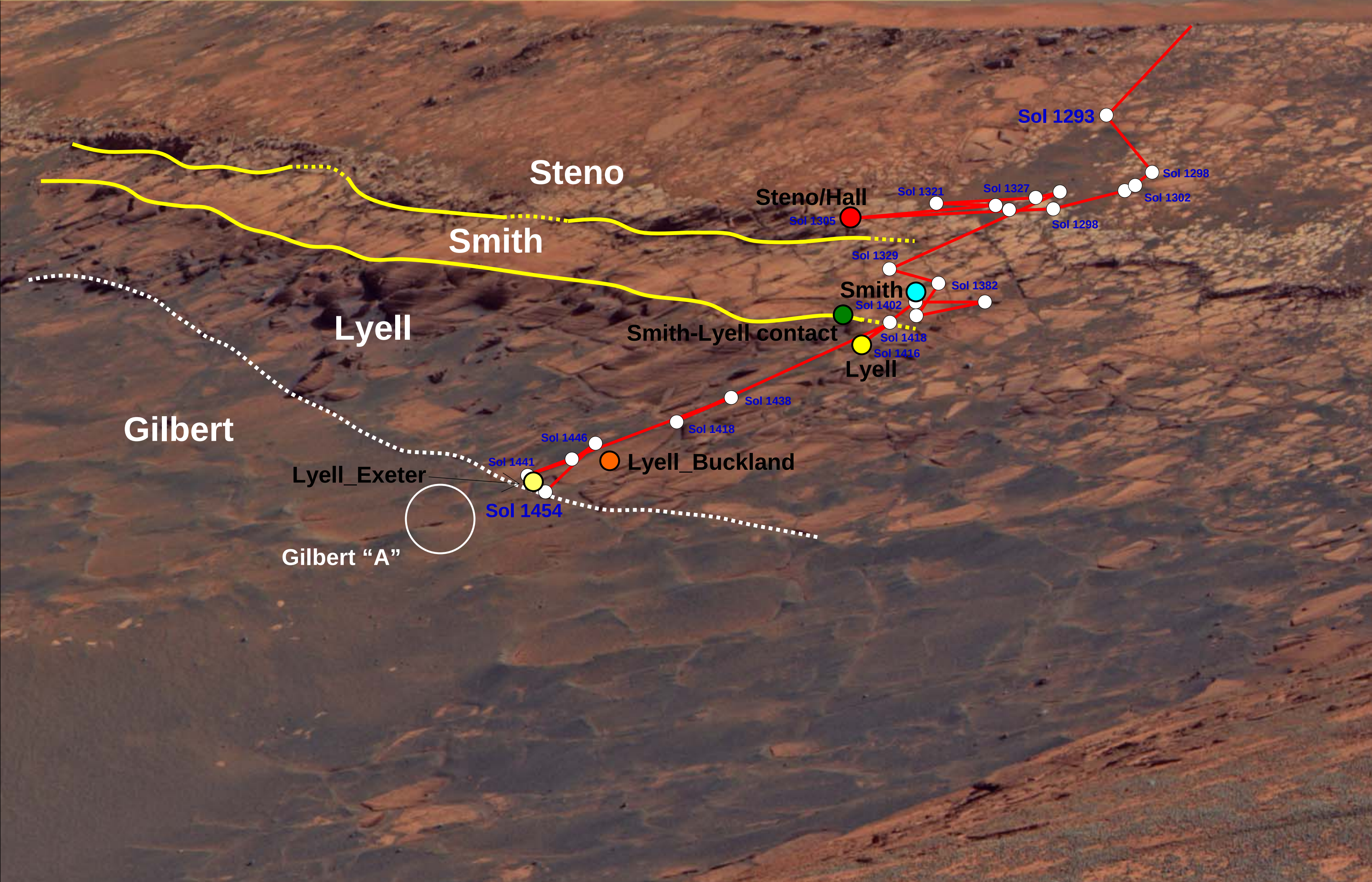
Bright Band in the Stratigraphy

Super-Resolution Images of the Bright Band





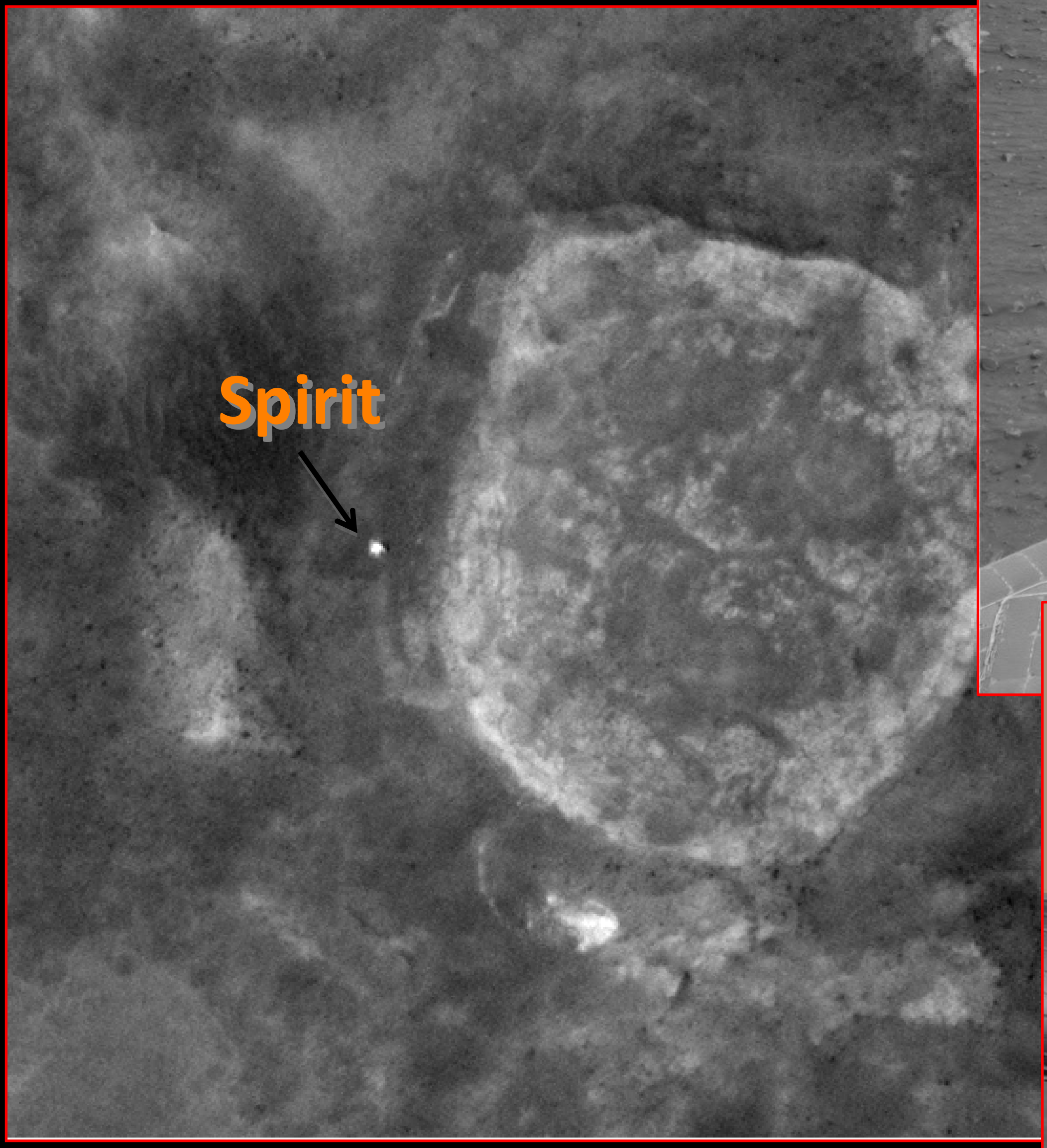
Victoria Crater Traverse (Sols 1293 to 1454)

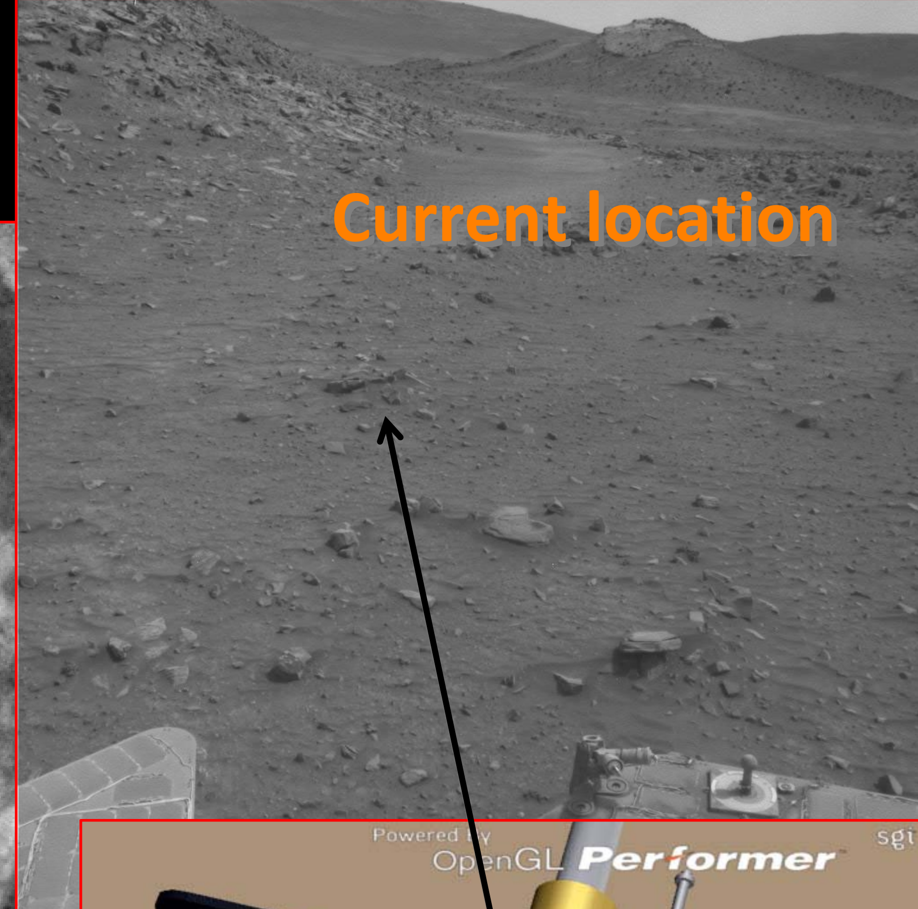


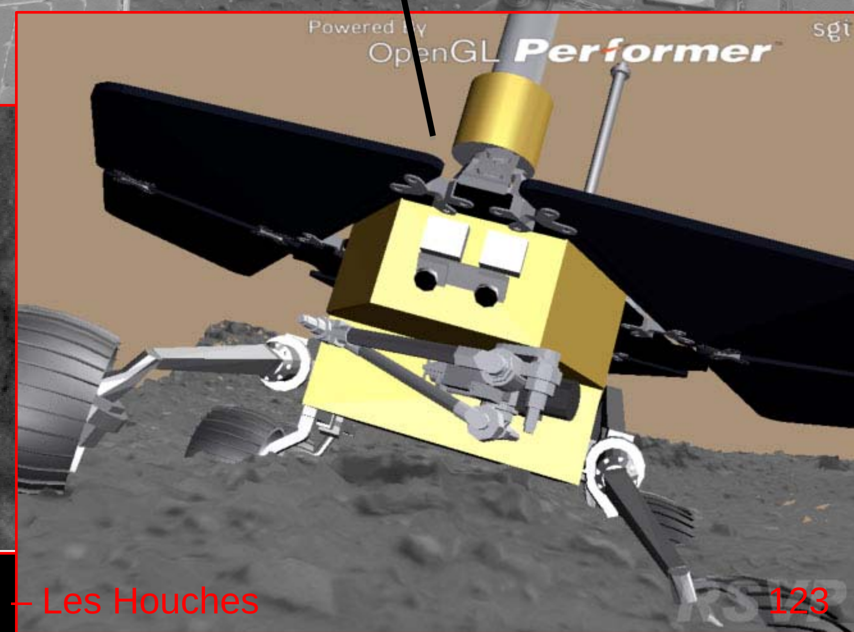
RAT Hole Chemistry

	SO_3	Cl
Steno	22.7	0.56
Smith	18.7	0.67
Lyell	20.2 19.7	1.19 1.37

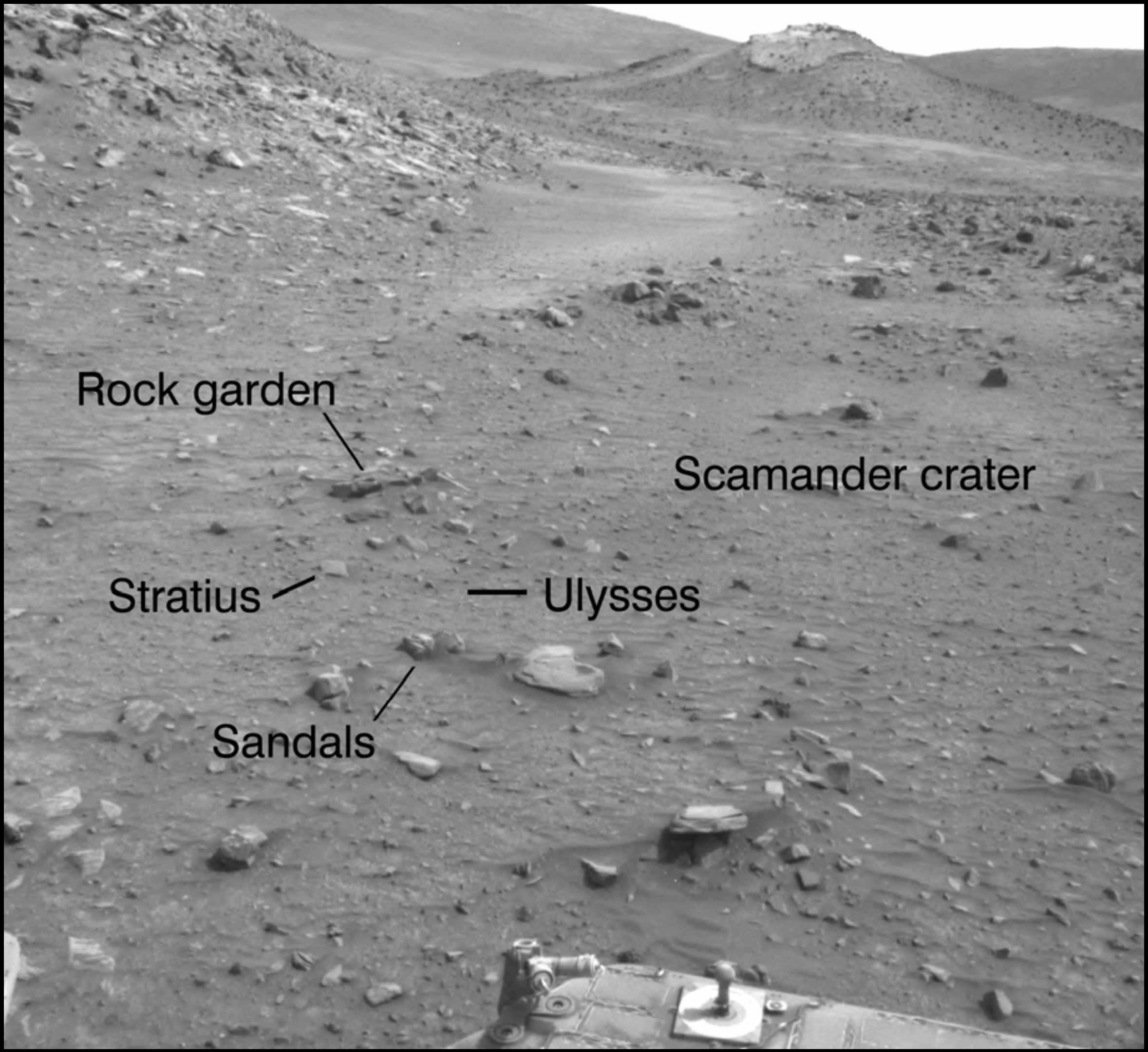
Spirit at Troy


Spirit

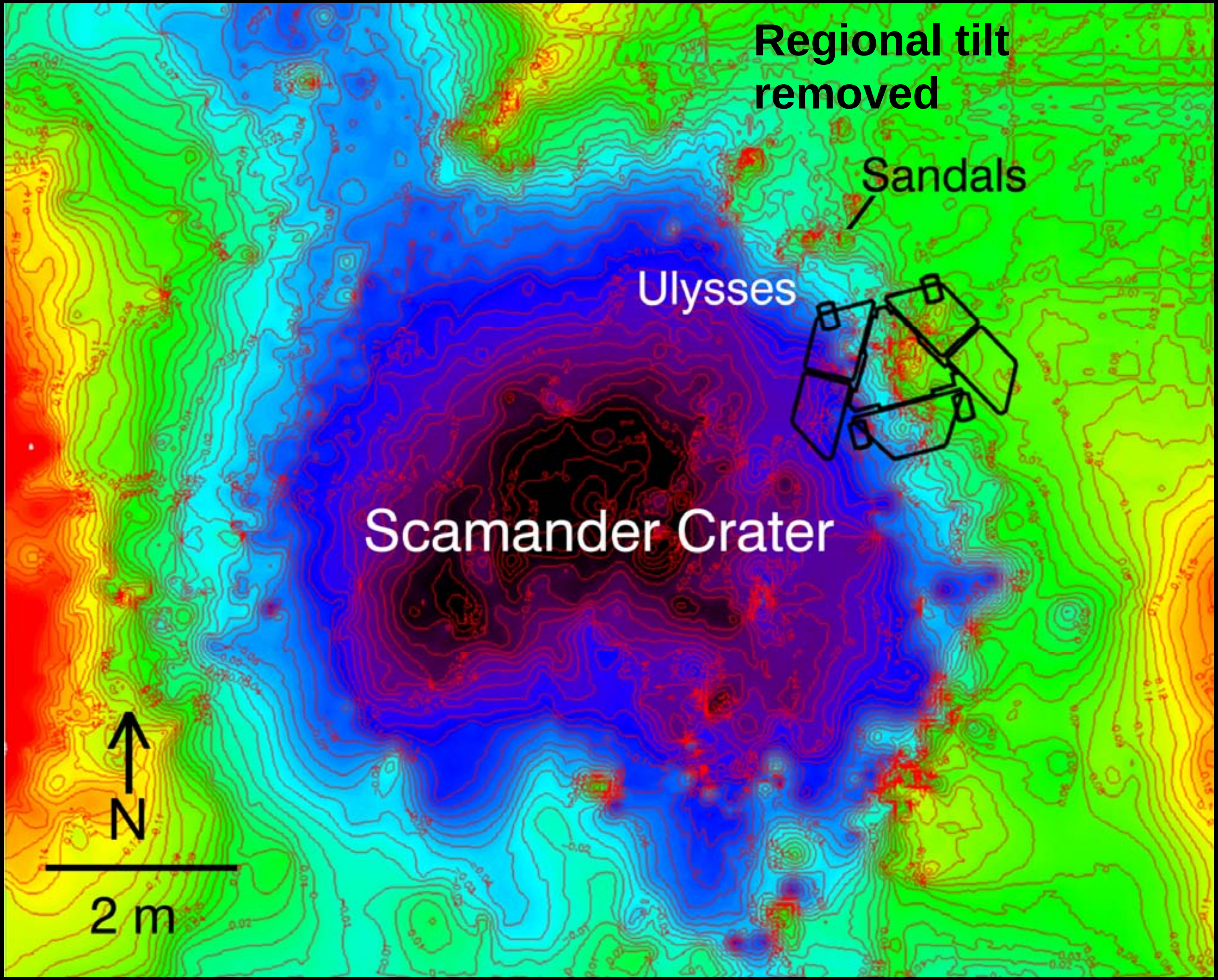

Current location


OpenGL Performer
sgi

Troy Before Spirit's Arrival

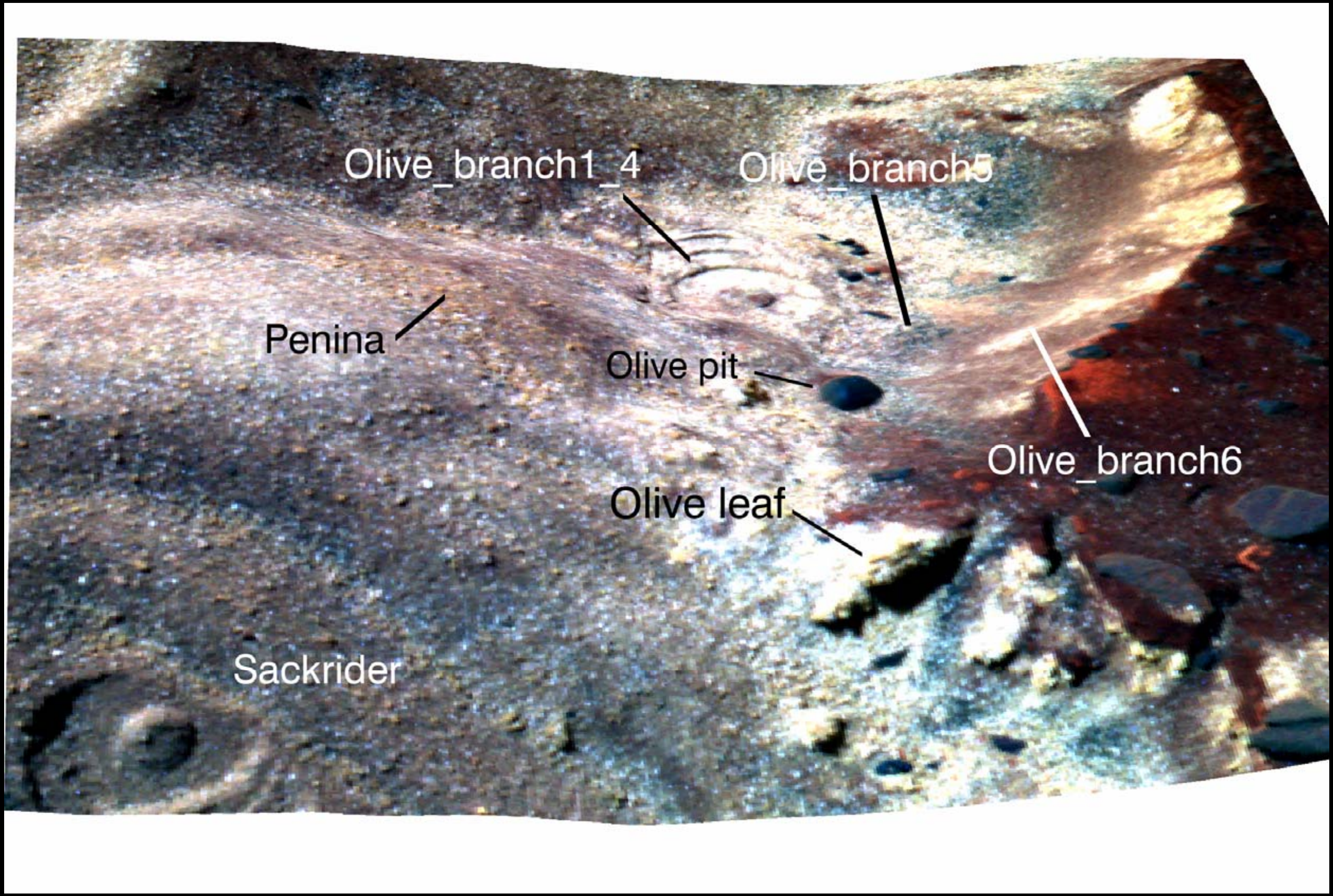


The Topography Of Troy

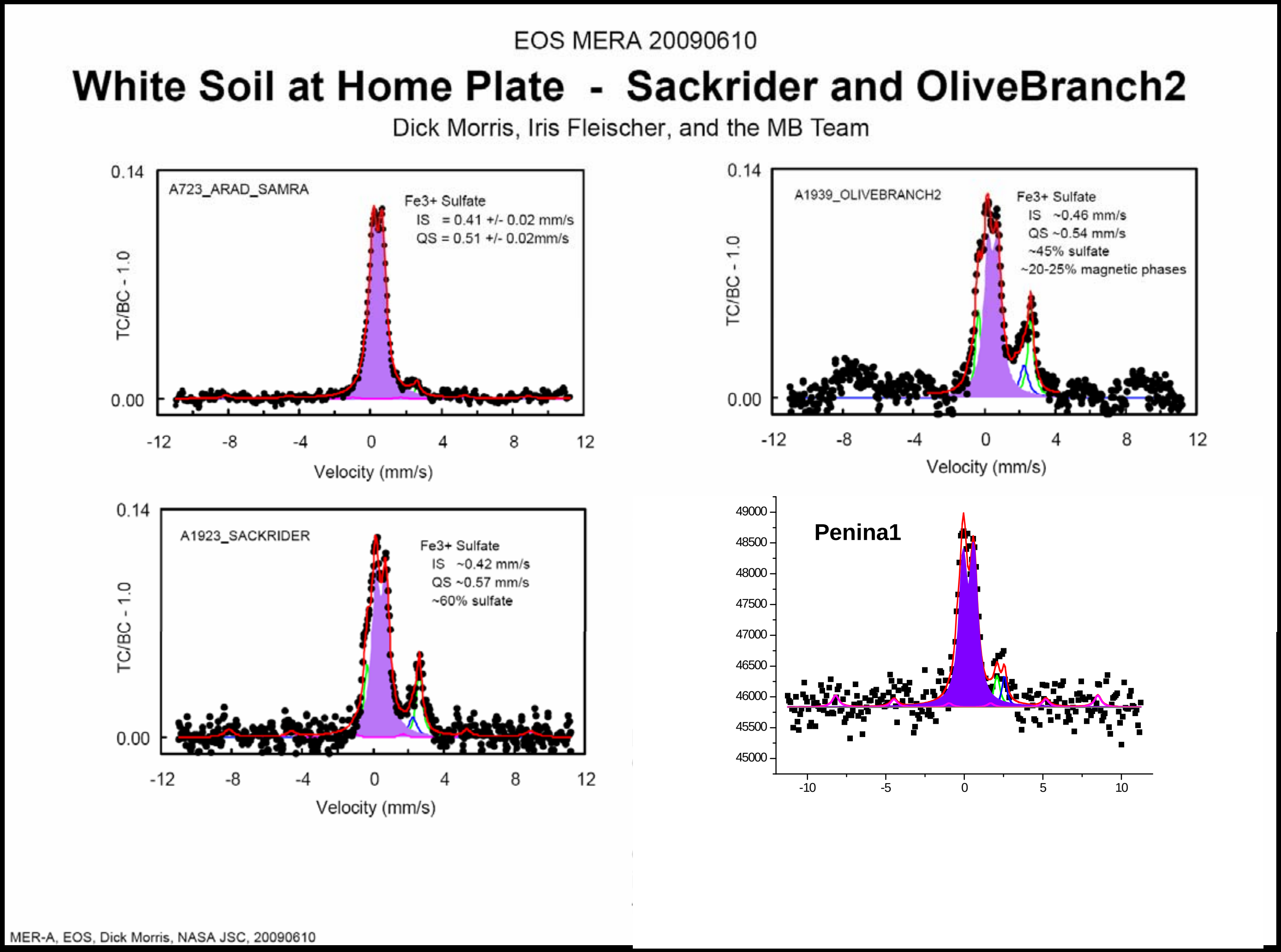


Targets Investigated at Troy

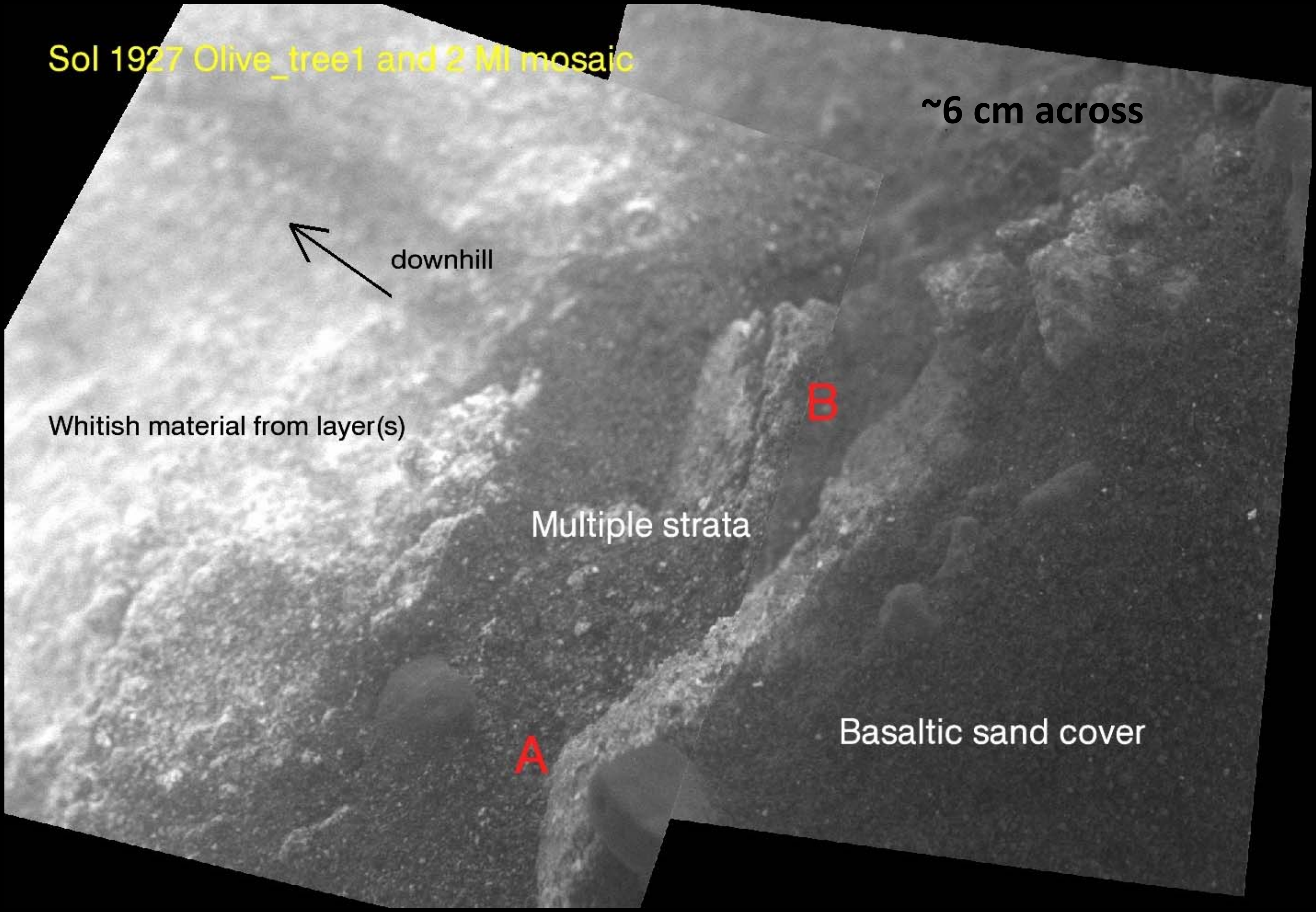
Color Evidence For Compositional Heterogeneity



Compositions Dominated by Fe^{3+} Sulfates



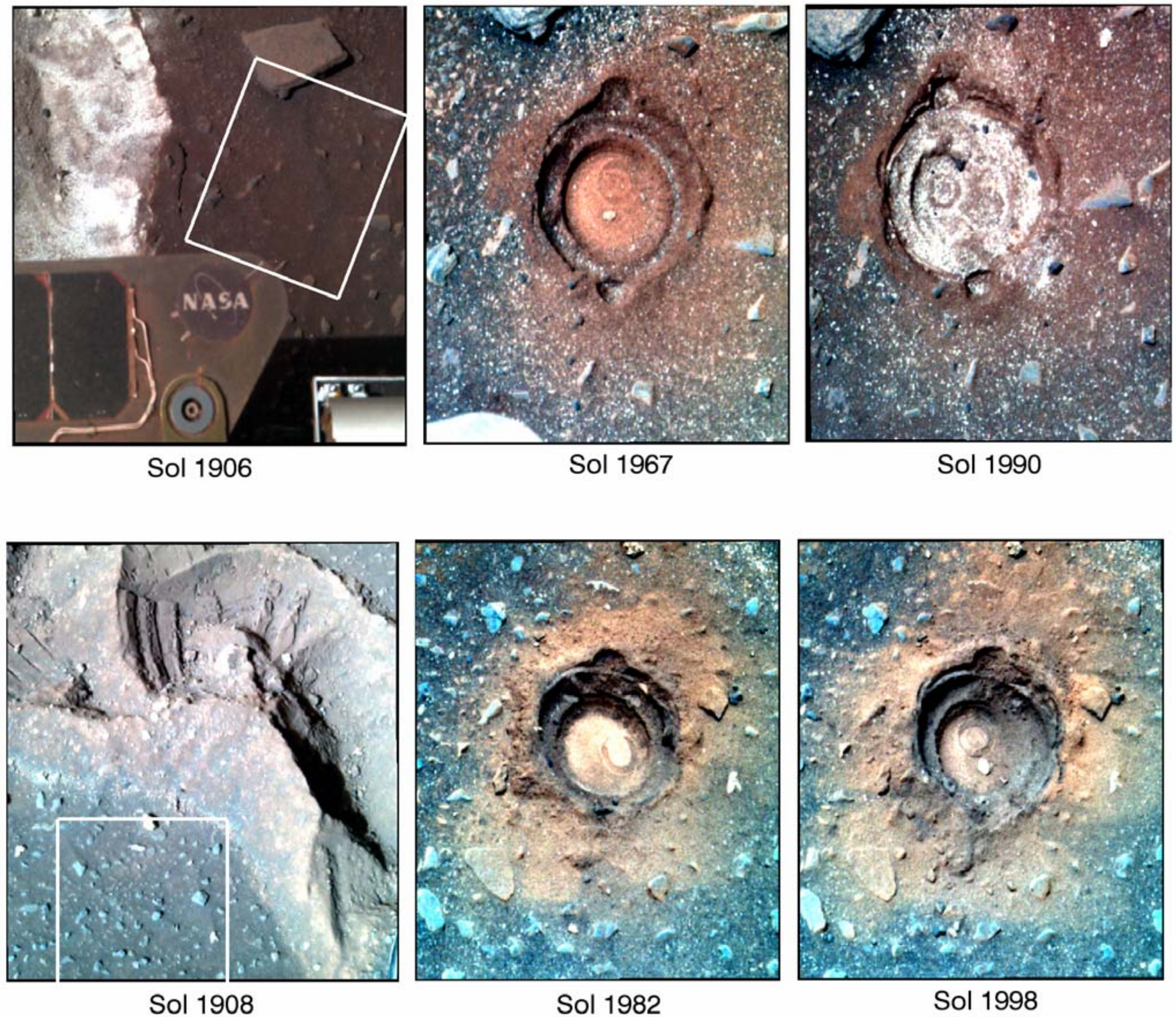
Morphologic Evidence For Stratification



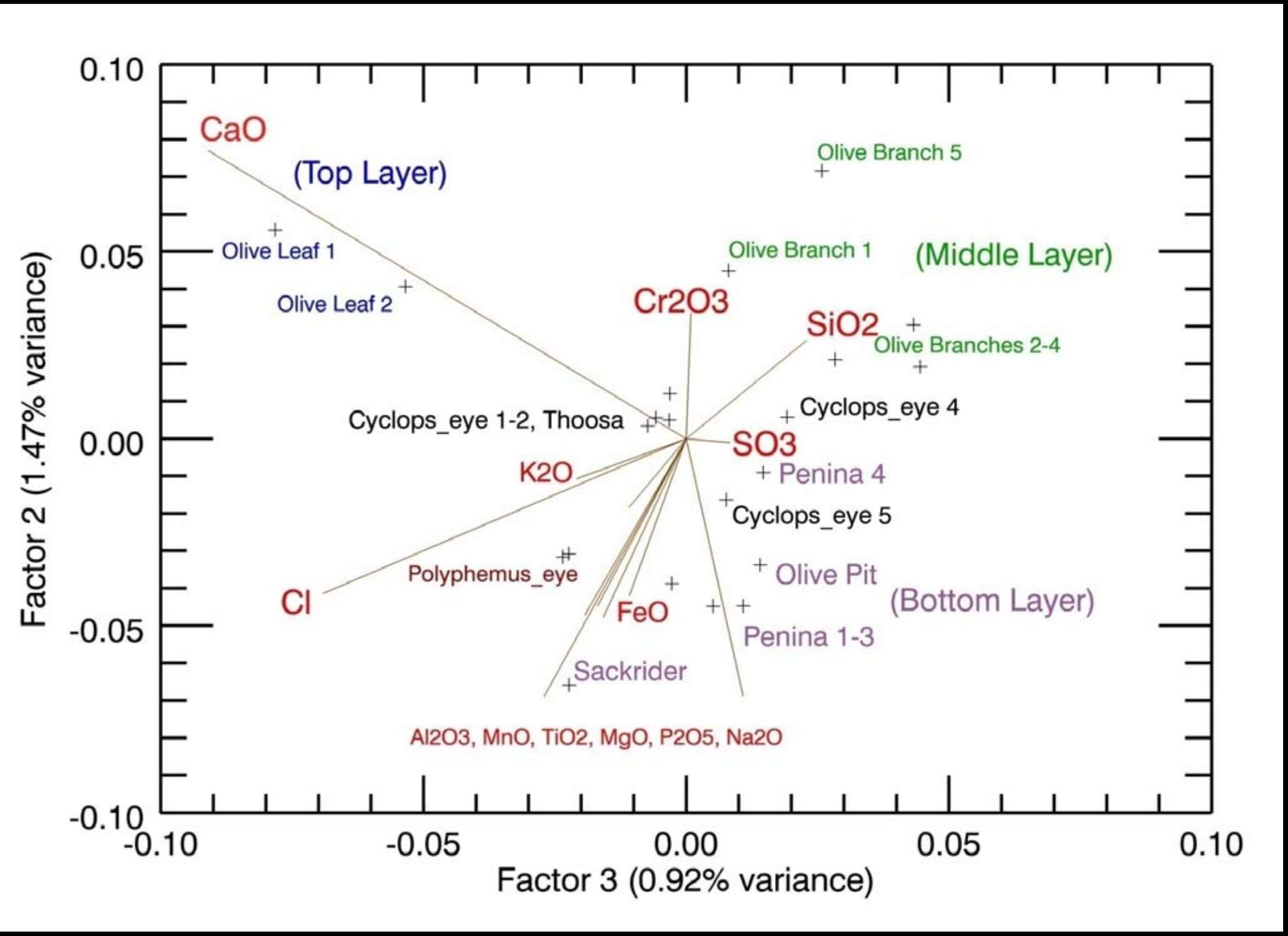
Sequential Excavation Of Strata With The RAT

Cyclops Eye:

Polyphemus Eye:

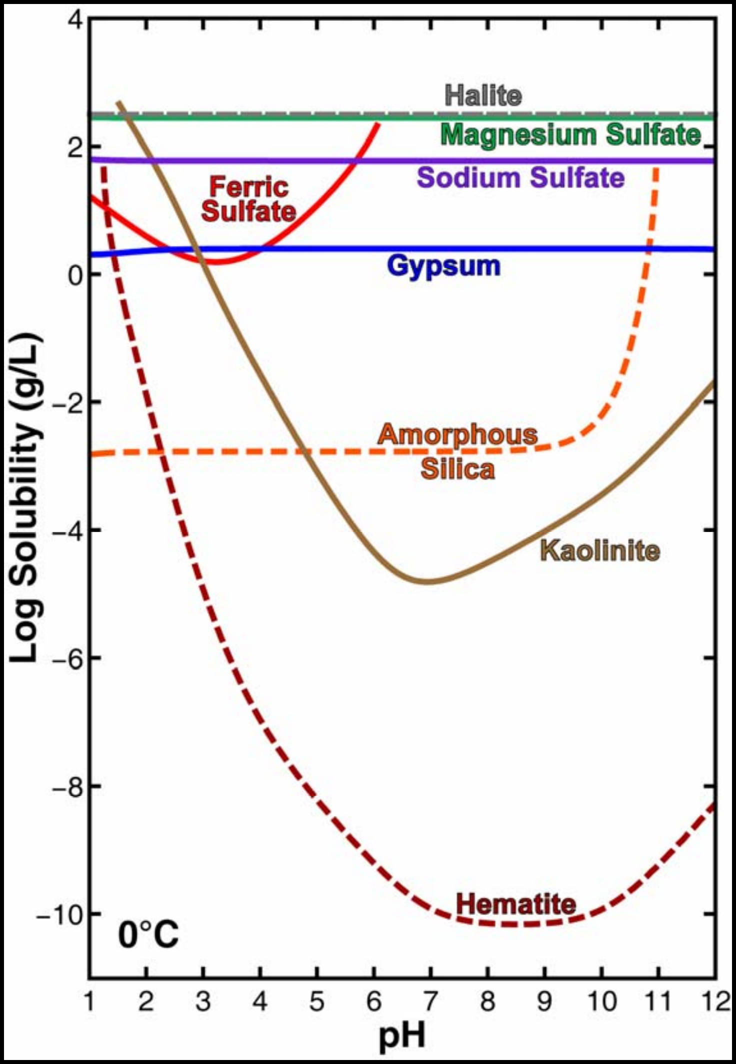


Possible Compositional Layering



- **Factor 1 shows mixing between basalt and sulfate end members.**
- **Factors 2 and 3 suggest compositional layering:**
  - **Surface soils enriched in Ca sulfate**
  - **Middle layer also has a Si enrichment**
  - **Underlying deposits are dominated by Fe sulfates (Mg sulfates also present)**

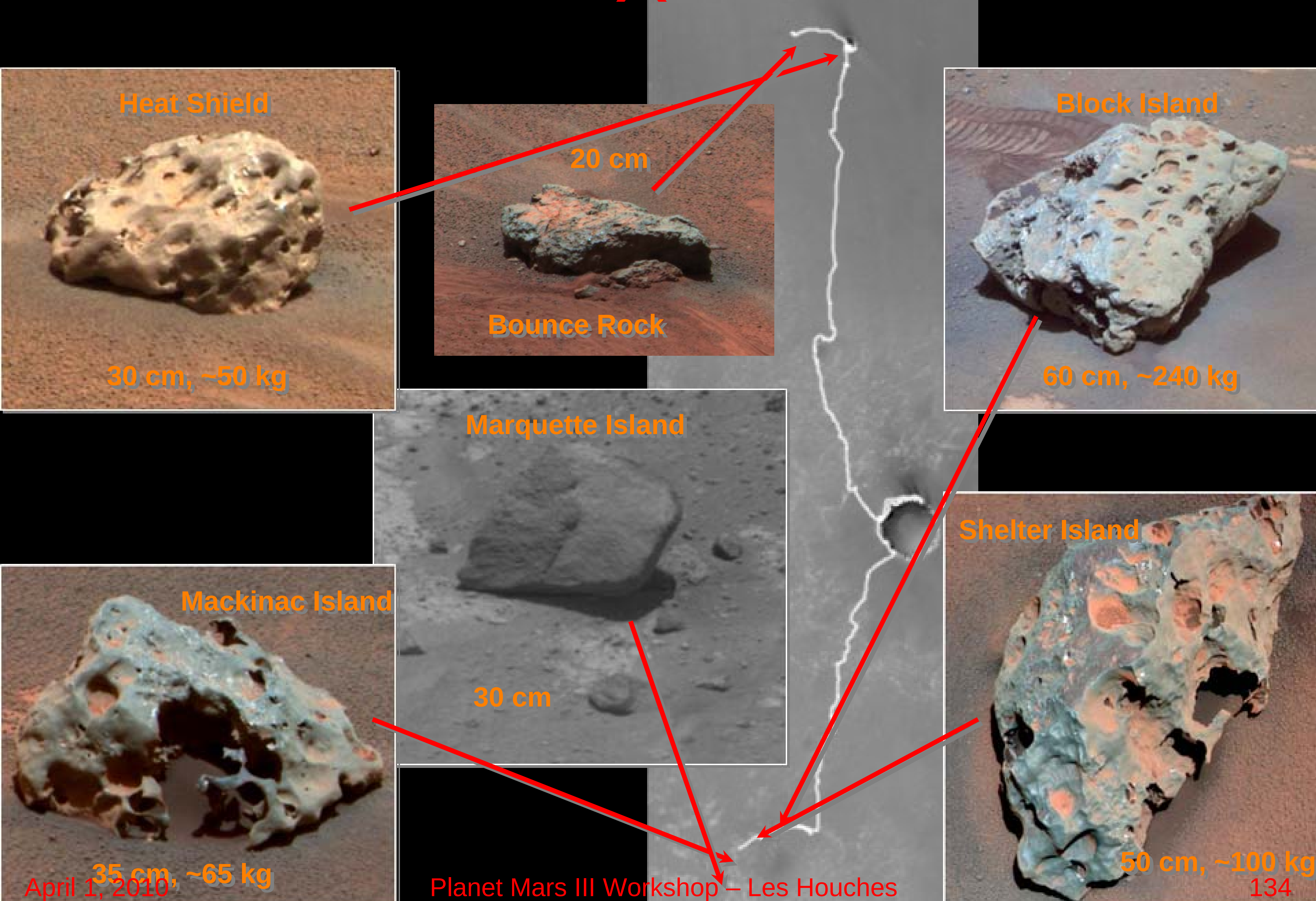
Hypothesis For Origin Of Compositional Layering



- **Low solubility phases (hematite, silica, gypsum) are concentrated near the top of the section.**
- **Higher solubility phases (ferric and magnesium sulfates) are present deeper in the section.**
- ***Could* imply downward transport of soluble phases by downward percolation of water.**

The Meteorite Story

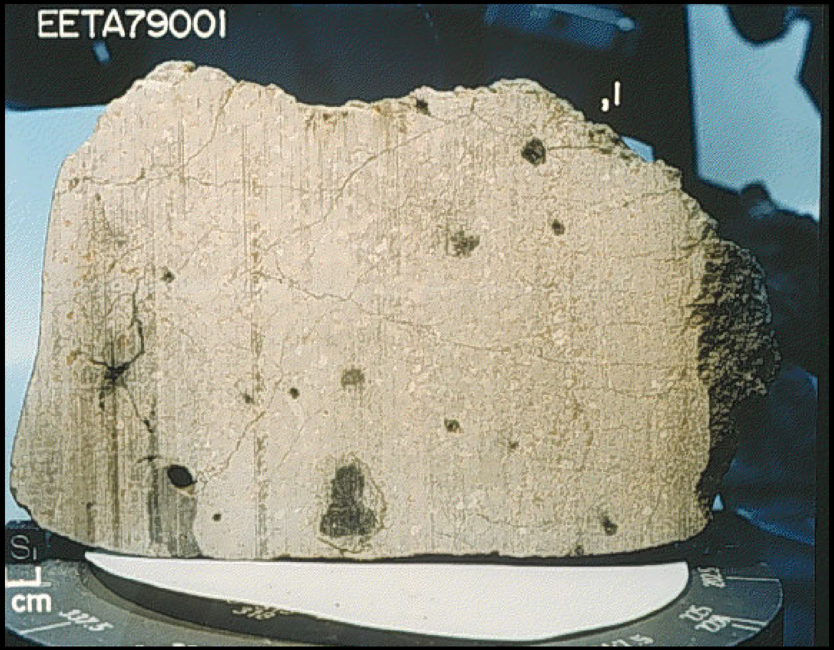
A Tale of ~~6~~ 5 Meteorites



Bounce Rock

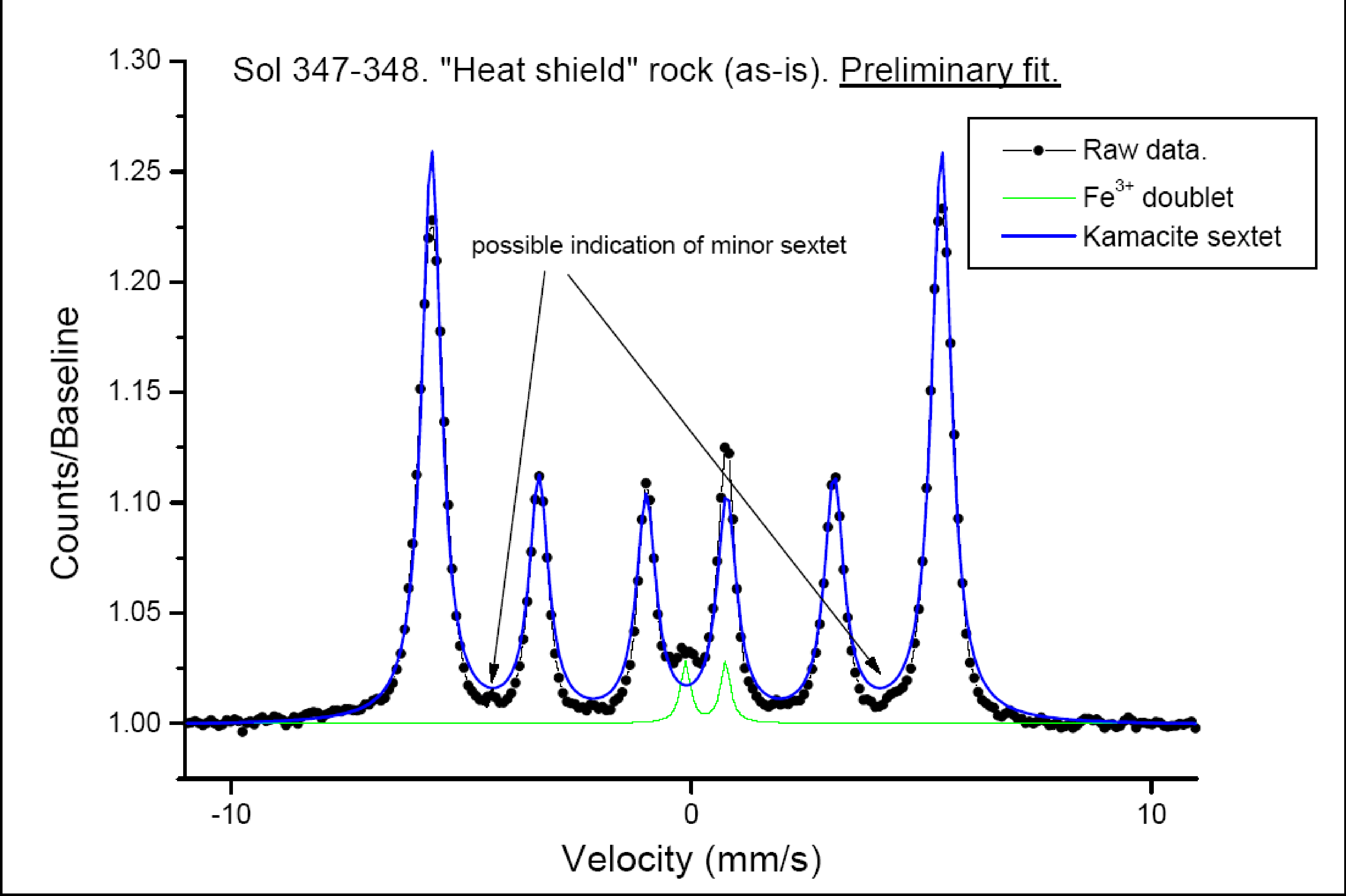
Bounce Rock: Shergottite Chemistry

Oxides [% wt.]	EETA 79001-B Lodders 98, average	Bounce (MER-B sol 68) Ralf/Oxides (2)
MgO	6.57	6.47
Al2O3	11.2	10.16
SiO2	49.4	51.23
CaO	10.8	12.63
TiO2	1.18	0.79
FeO	17.4	15.61
Na2O	1.74	1.33
P2O5	1.28	0.92
S	0	
K		
K2O	0.075	0.11
Cr	0.115	
Cr2O3	0.168	0.13
Mn		
MnO	0.43	0.57
Cl	0	
[ppm wt.]		
Ni	28	287
Zn	91	107
Br	0.025	31
Sum:	100.25	100.00
Ratios:		
Mg/Si	0.17	0.16
Al/Si	0.26	0.22
Mg/(Mg + Fe	0.23	0.24

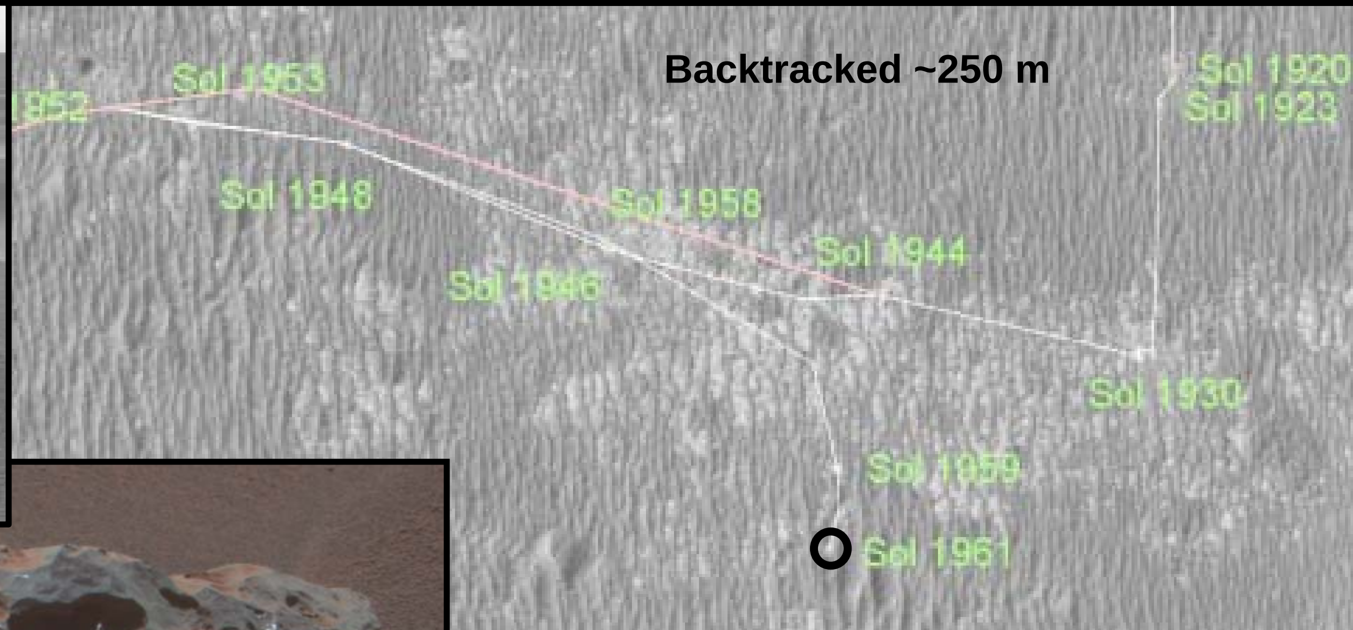


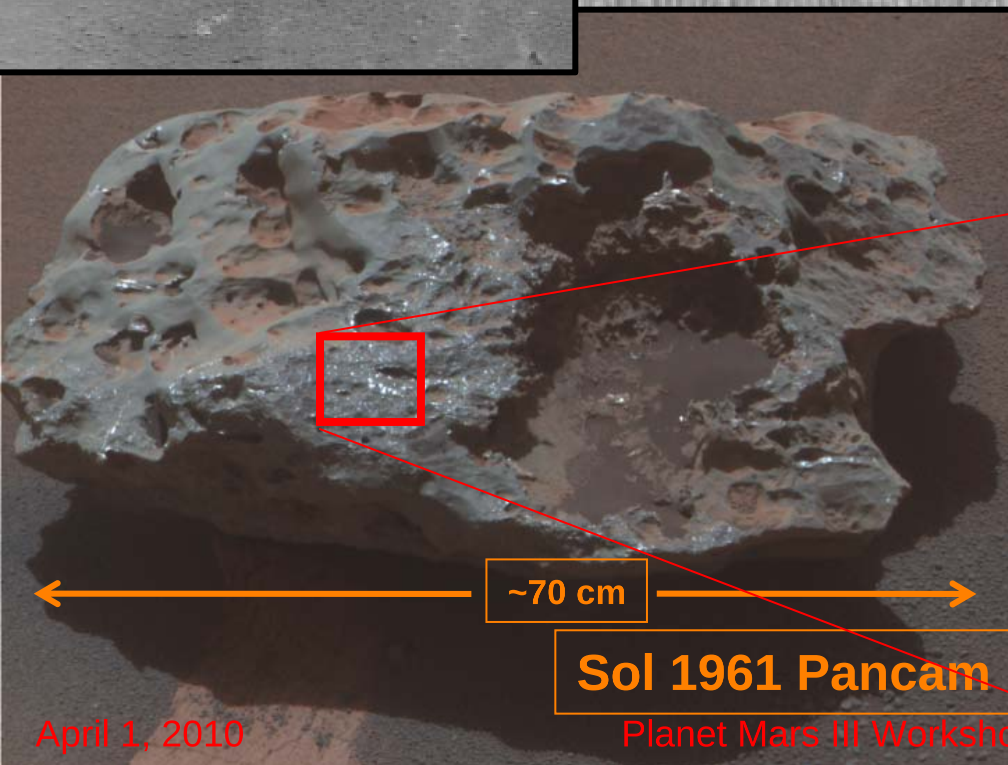
Heat Shield Rock

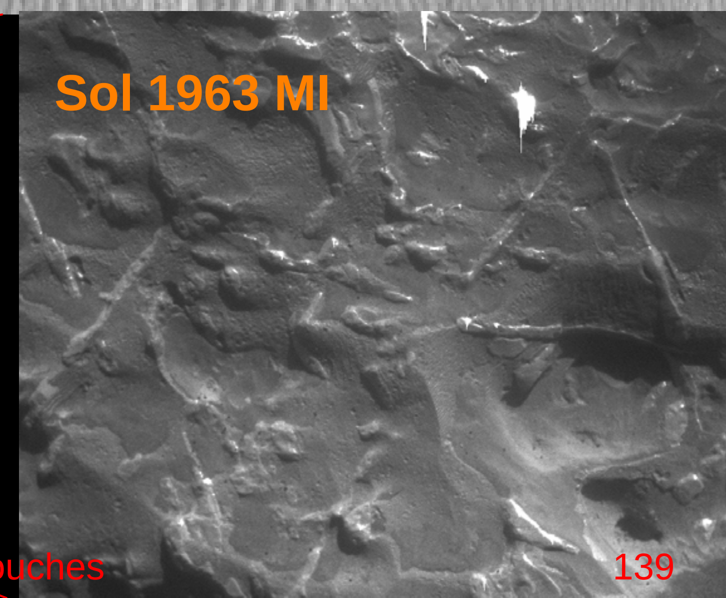
Heat Shield Rock Mineralogy: An Iron Meteorite



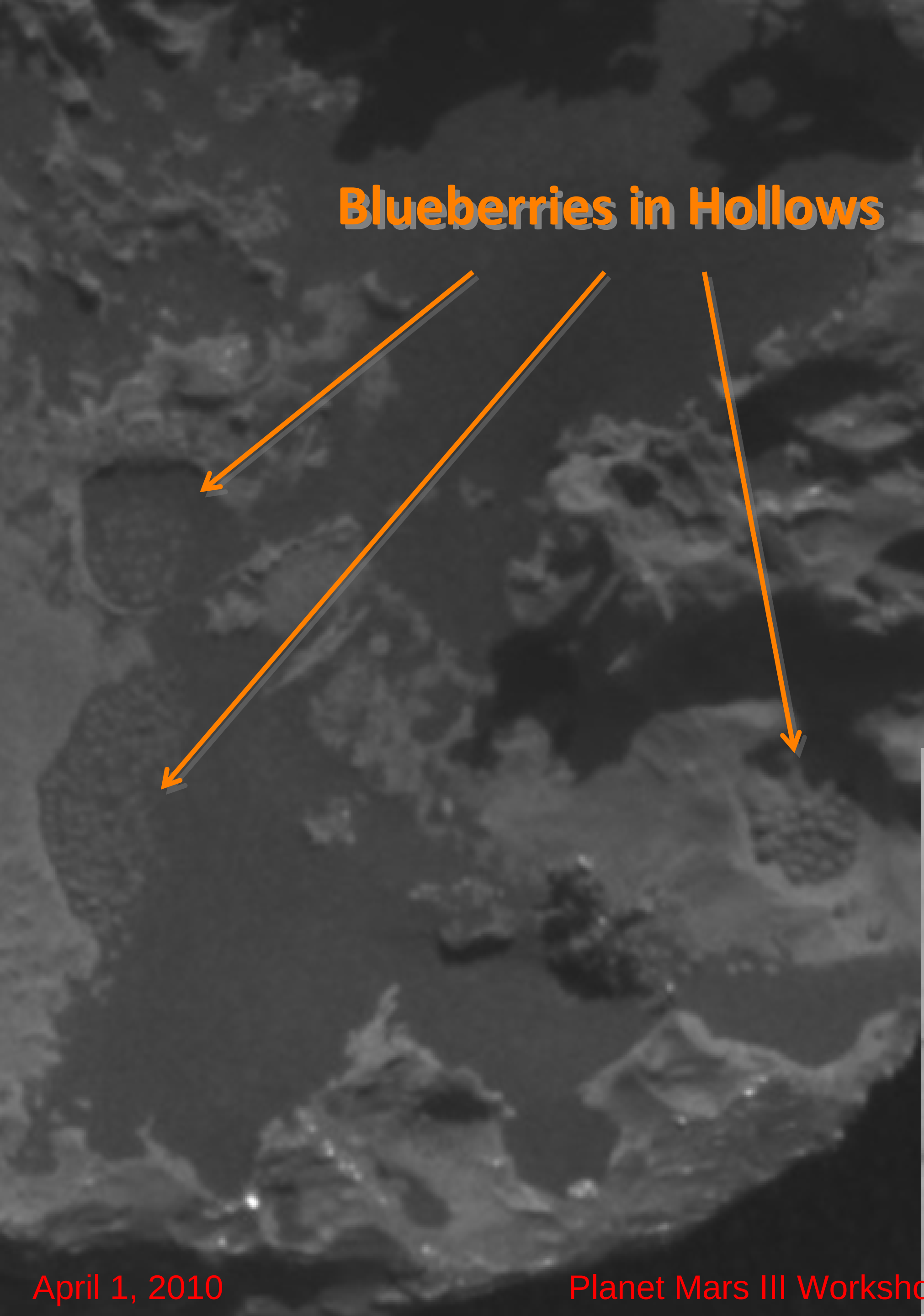
Block Island







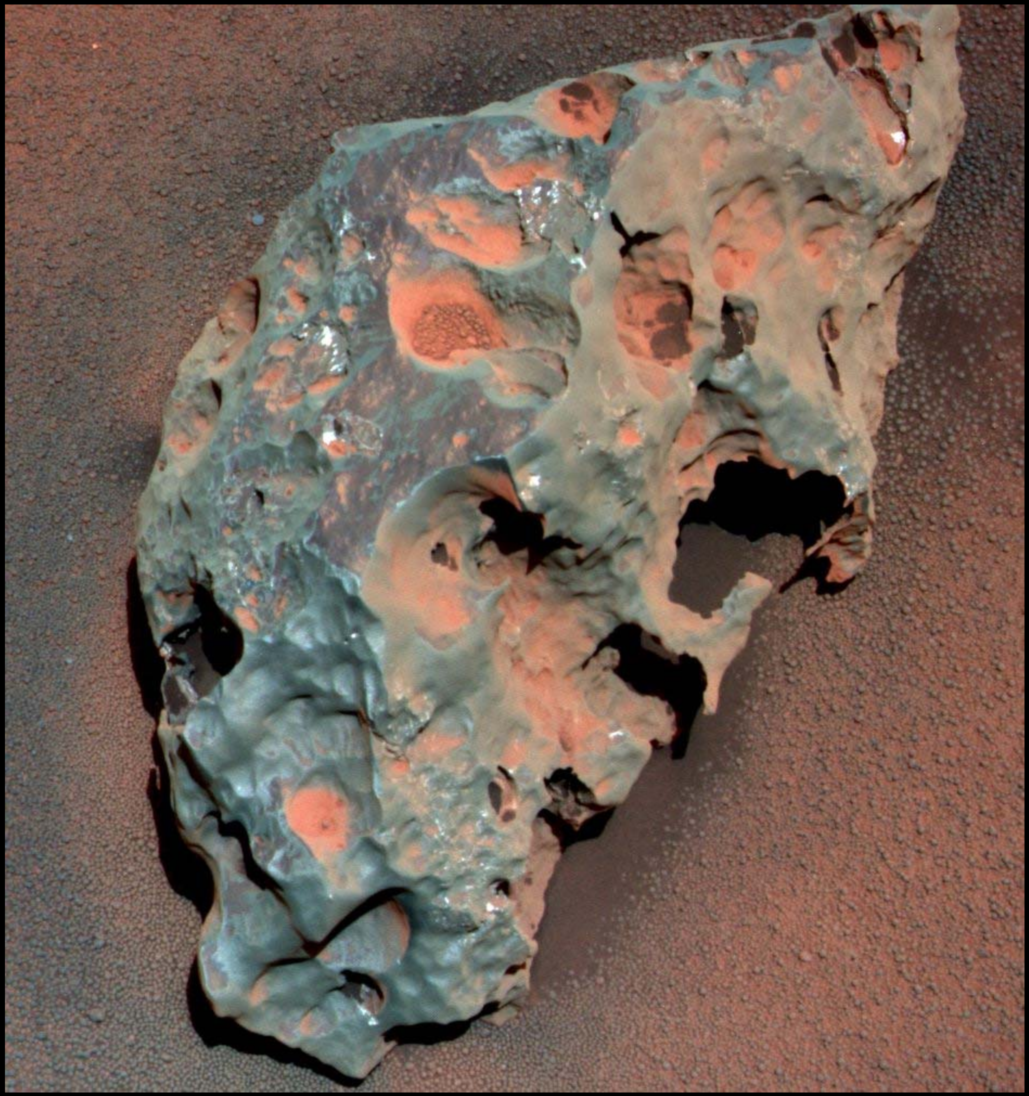
What Has Happened to Block Island Since it Landed?



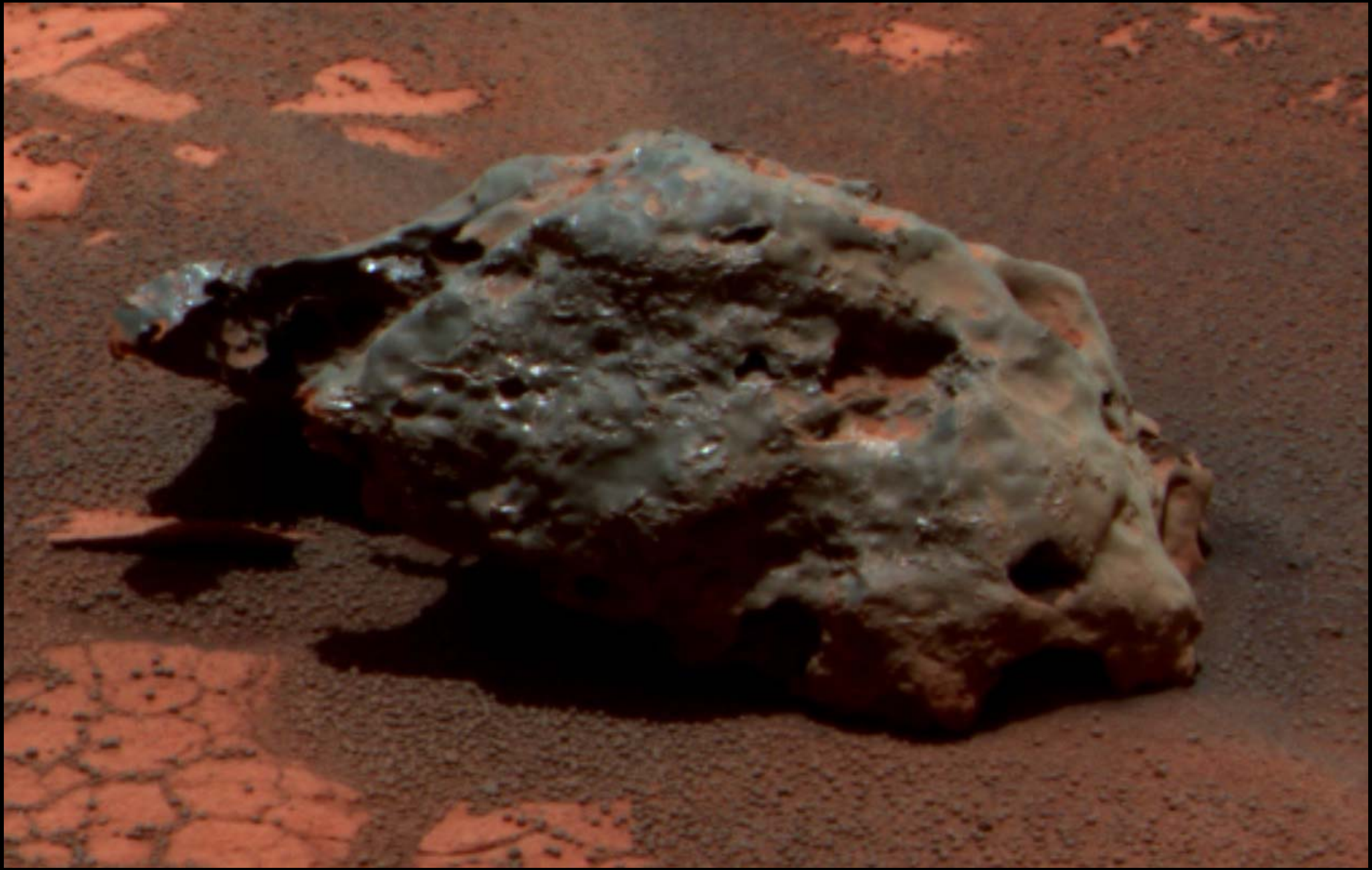
Block Island: Key Findings

- Block island must have fallen through a much thicker atmosphere than is present today.
  - The maximum meteorite projectile mass is less than 100 kg under current atmospheric density. Block Island is ~240 kg.
- Block island has likely been on the surface for quite some time.
  - Blueberries in hollows requires ripple migration $\geq$15 cm high.
  - Block island is on a pedestal about 4 cm high of outcrop – records erosional history.
- How long?
  - Last phase of ripple migration was at least 100,000 years ago!
    - Hundreds of thousands of years at a minimum.
  - Thicker atmosphere favors distant past – Late Noachian (~ 3.8 Ga)
- Meteorite as recorder of climate:
  - If Block Island fell more than 3 billion years ago, its pristine surface argues for cold dry conditions since.

Shelter Island



Mackinac Island



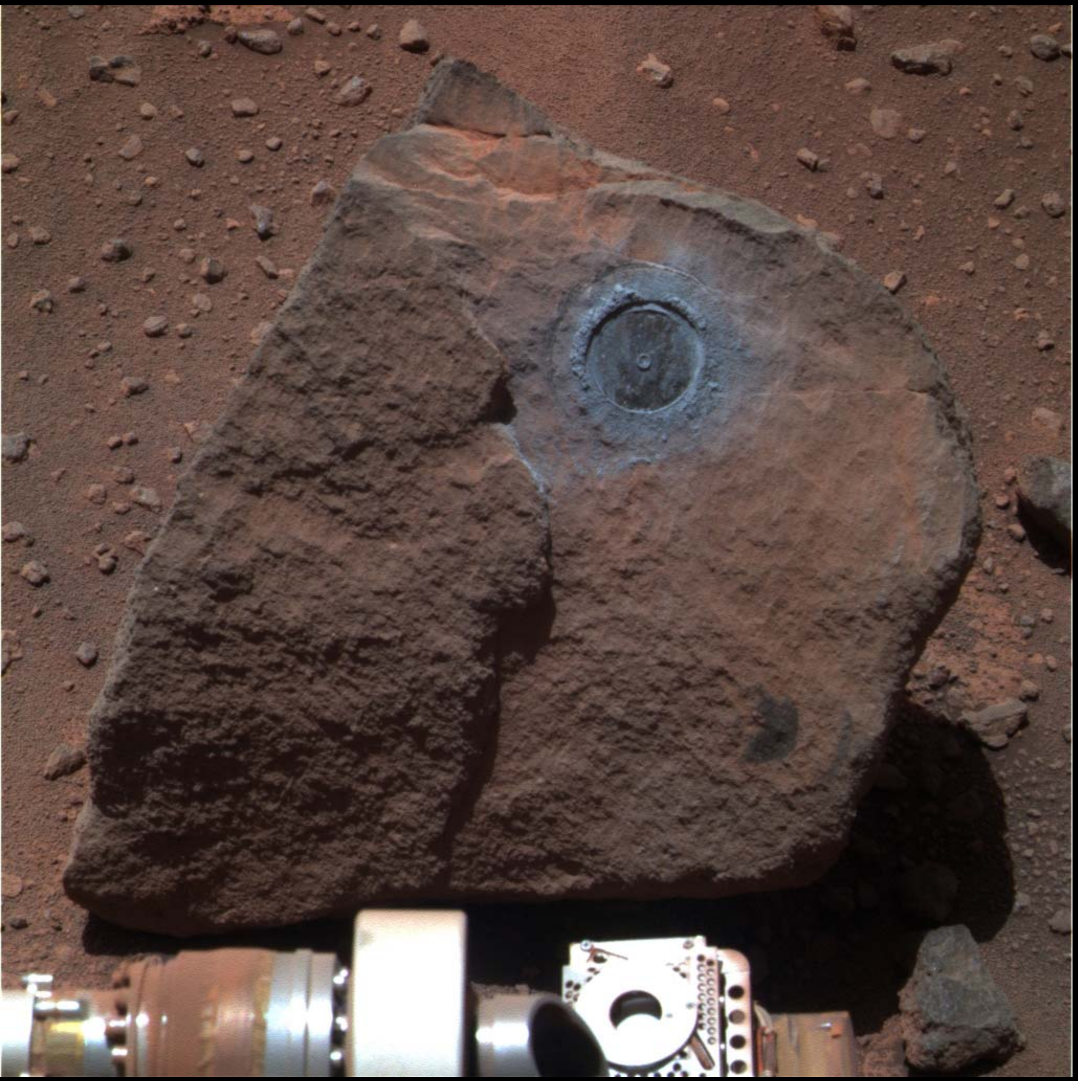
A Weathered Iron Meteorite On Earth

Willamette Meteorite

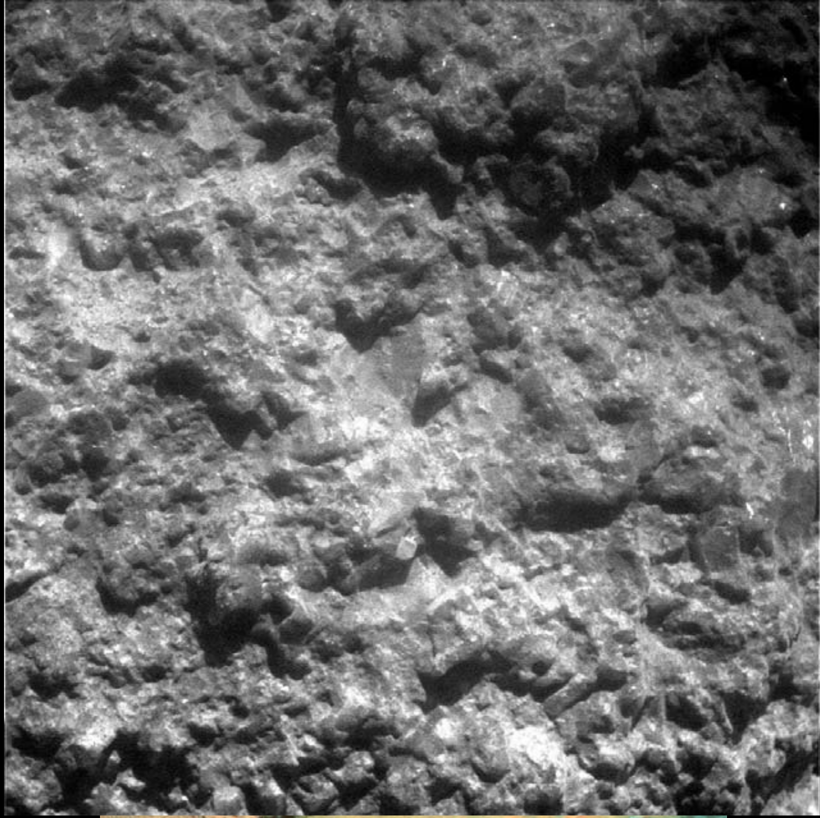
Iron Meteorites

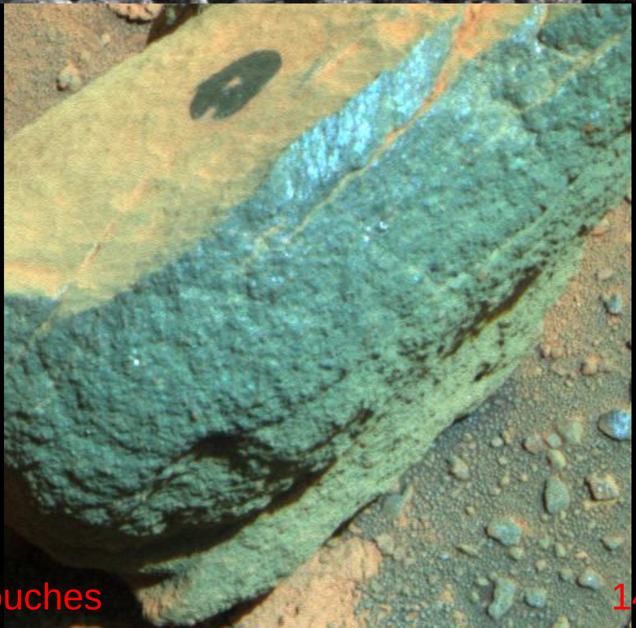
- Heat Shield Rock, Block Island, and Shelter Island are all type IAB iron meteorites. (Mackinac Island was not investigated with APXS). IAB irons comprise ~1% of meteorite falls on Earth.
- No evidence for compositional heterogeneity (e.g., Fe sulfide inclusions).
- The three recent finds are all plausibly part of a strewn field created by a single impactor. The relationship to Heat Shield Rock is less clear.
- Blueberries on surfaces indicate a history of burial and exhumation.
- The weathering states of the four meteorites vary substantially:
  - Heat Shield Rock appears fairly pristine
  - Mackinac Island is deeply cavernously weathered, but with little or no surface weathering.
  - Shelter Island and Block Island are intermediate.

Marquette Island



30 cm

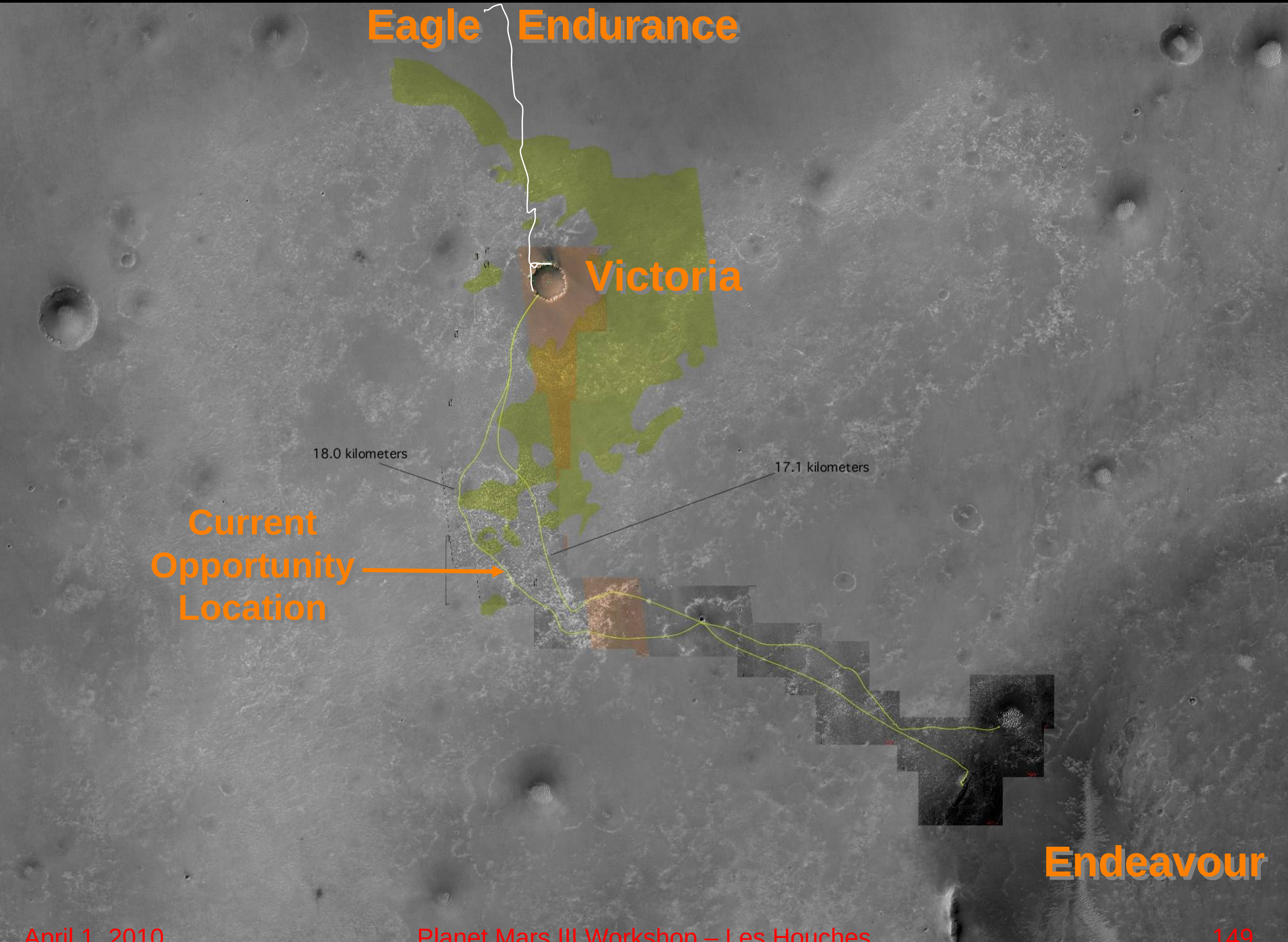


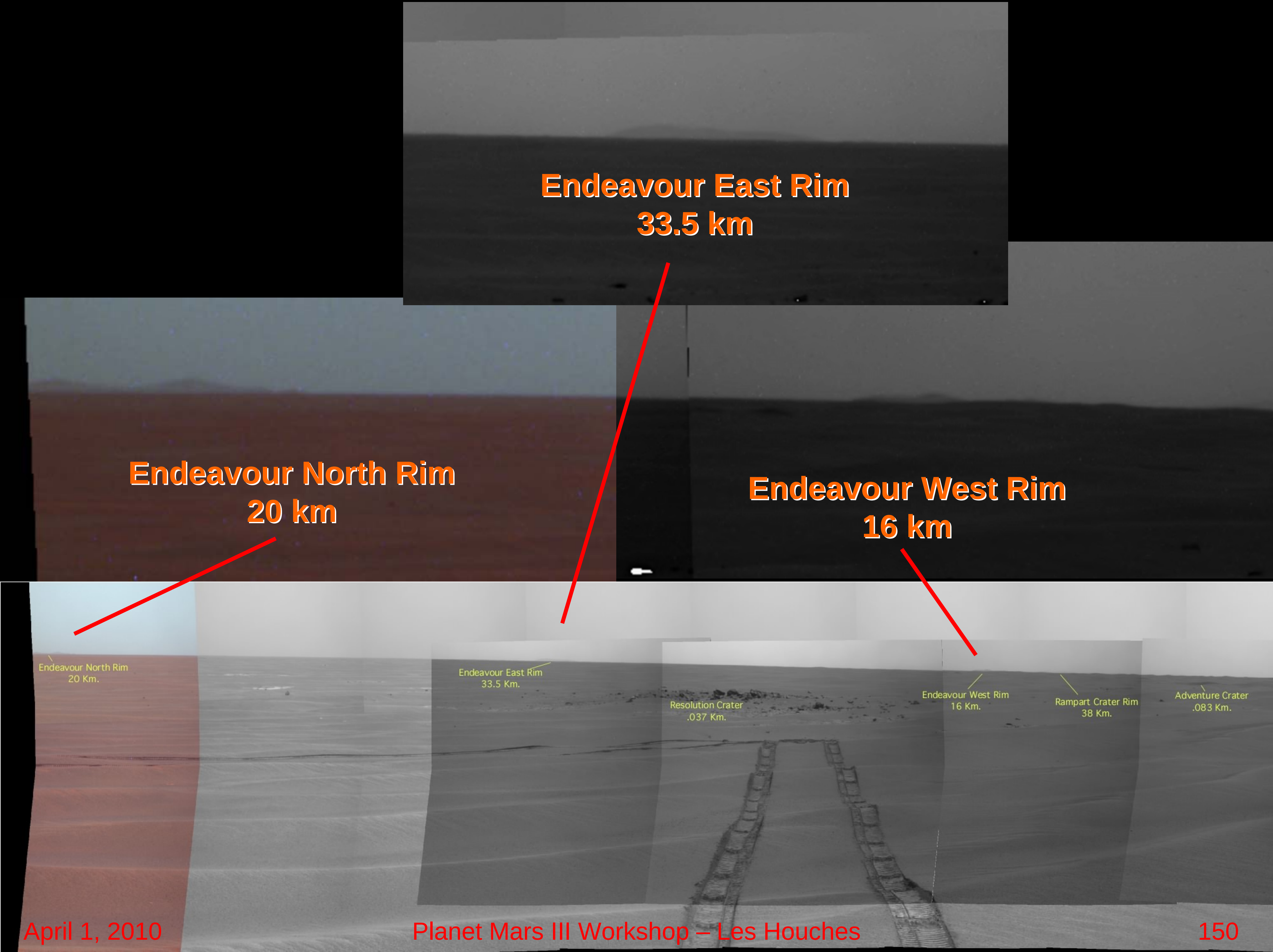


Marquette Island: Not a Meteorite

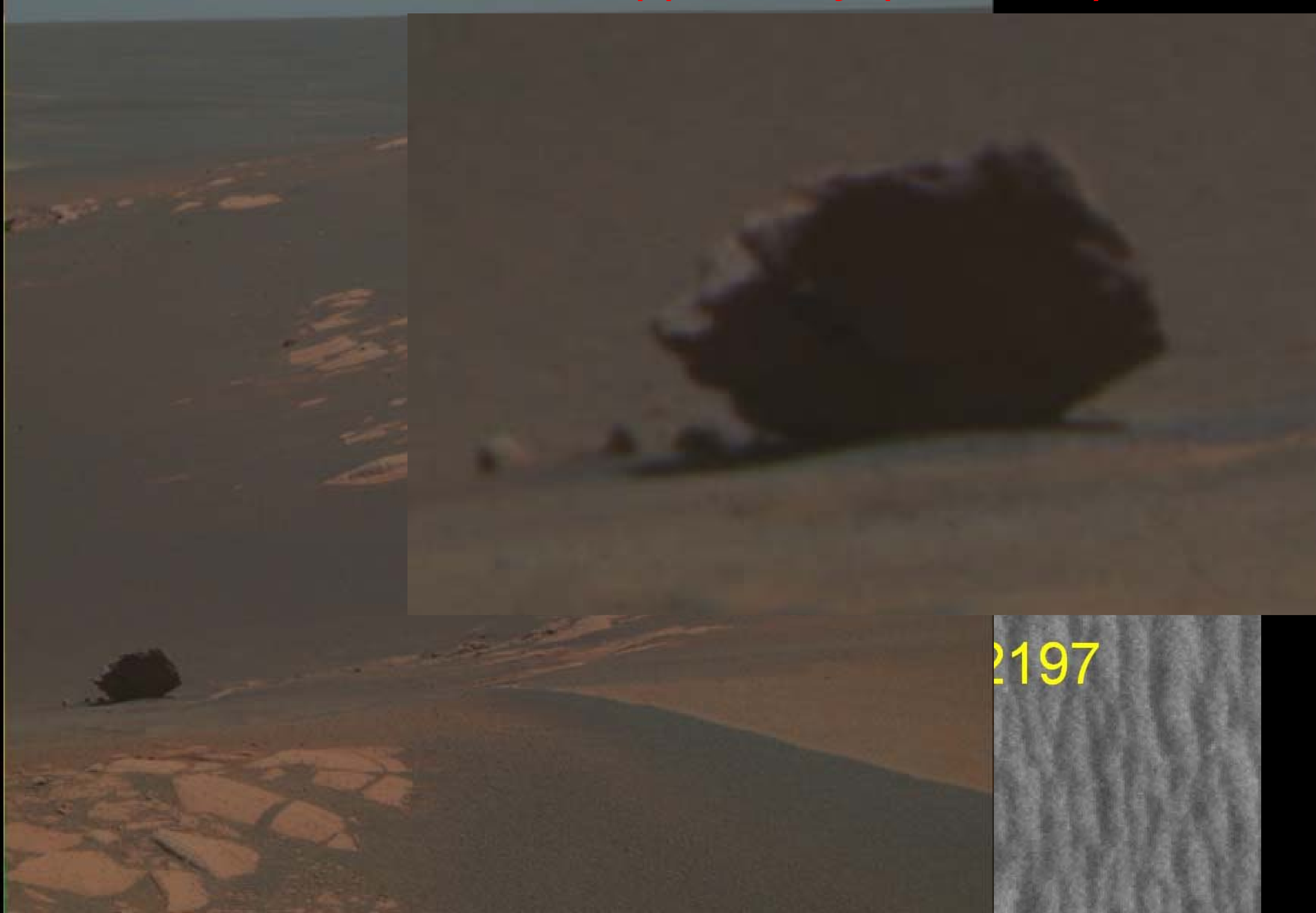
- APXS data show that the rock is mafic, but the composition does not match any known martian meteorite or any rock observed to date by either Spirit or Opportunity.
- Mössbauer data reveal substantial olivine and some pyroxene.
- Normative calculations imply that substantial plagioclase is also present.
- Pancam and MI images show mm-size crystals, and no layering or sedimentary textures.
- Mackinac Island is interpreted to be ejecta from a distant crater, providing a sample of previously unexamined martian crustal material.

What's Next for Opportunity?


Eagle
Endurance
Victoria
18.0 kilometers
17.1 kilometers
Current
Opportunity
Location
Endeavour


Endeavour East Rim
33.5 km
Endeavour North Rim
20 km
Endeavour West Rim
16 km
Endeavour North Rim
20 Km.
Endeavour East Rim
33.5 Km.
Resolution Crater
.037 Km.
Endeavour West Rim
16 Km.
Rampart Crater Rim
38 Km.
Adventure Crater
.083 Km.

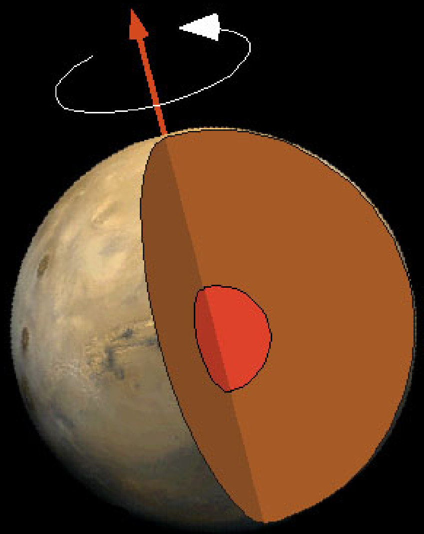
Just Down From Opportunity (Sol 2197)

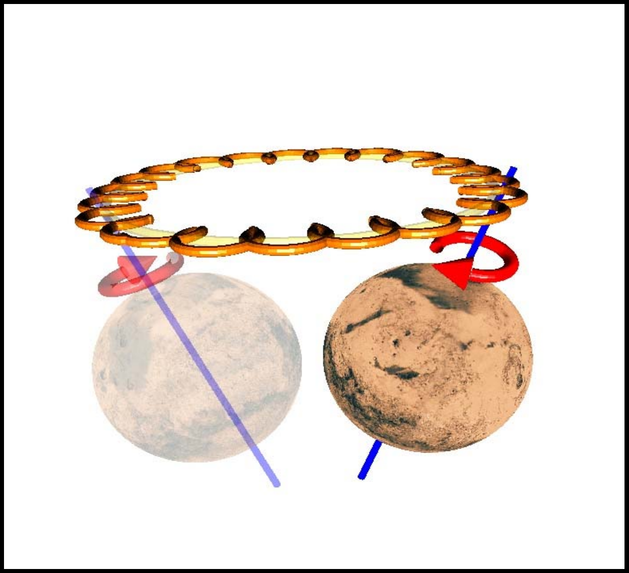


What’s Next for Spirit?

Radio Science

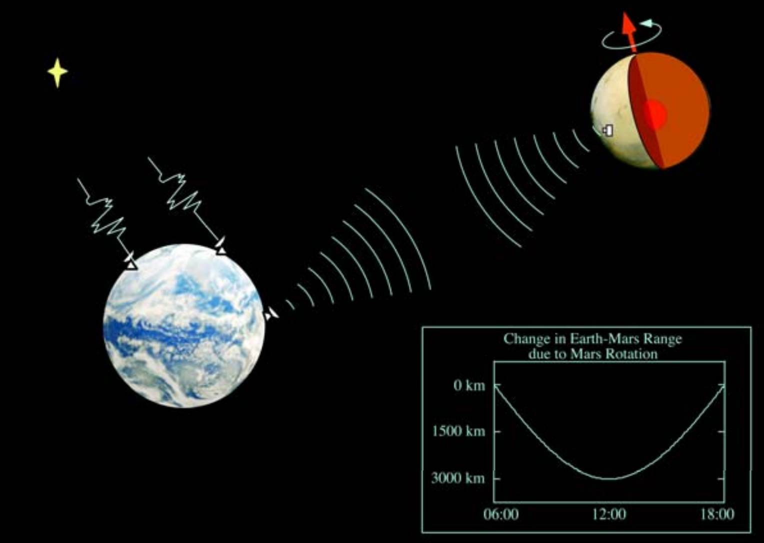
- Science objectives: Constrain size, state, and density of Mars core.
  - –Provide insight into evolution of terrestrial planets.
  - –Provide information on the evolution of Mars' magnetic field over time.
- Core parameters are derived from determining time-dependent spin-axis direction.
  - –Two-way Doppler tracking of fixed vehicle gives spin axis direction at time of track.





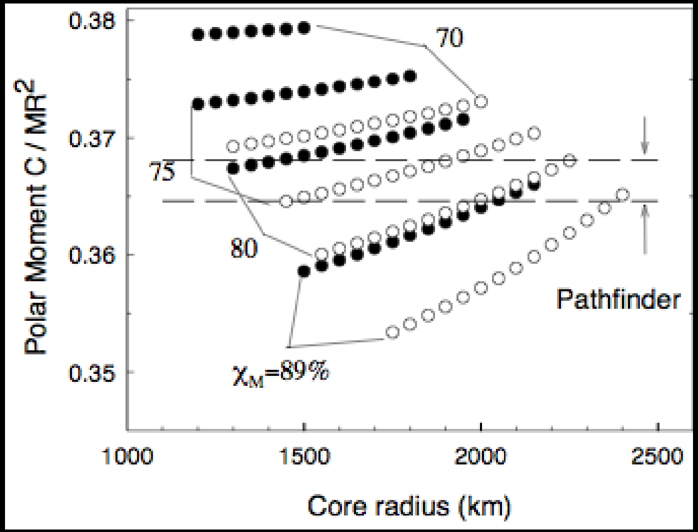
Martian Core Constraints

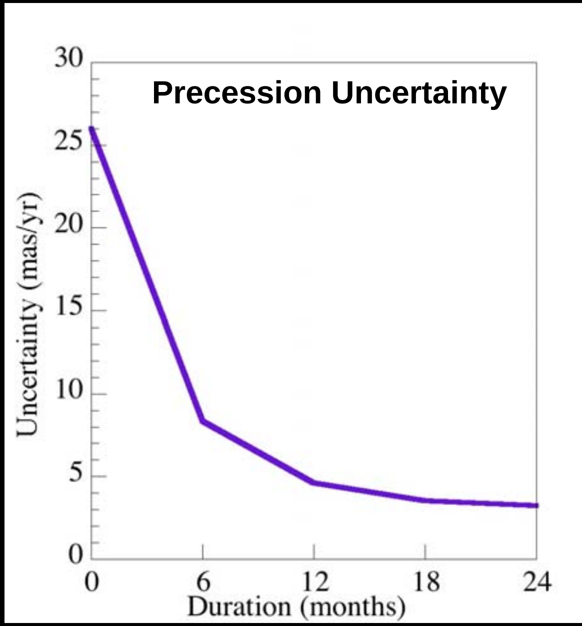
- First measured constraint on Mars core size came from combining radio measurements from Viking and Pathfinder.
  - 3 months of Pathfinder tracking determined direction of spin axis about as well as 2 years of Viking tracking.
  - Difference of spin axis direction over 20 year baseline gave precession rate and hence moment of inertia.
- Since Pathfinder, MGS and Odyssey tracking have given Love number k_2 estimates.
  - Helps constrain core size.



Precession

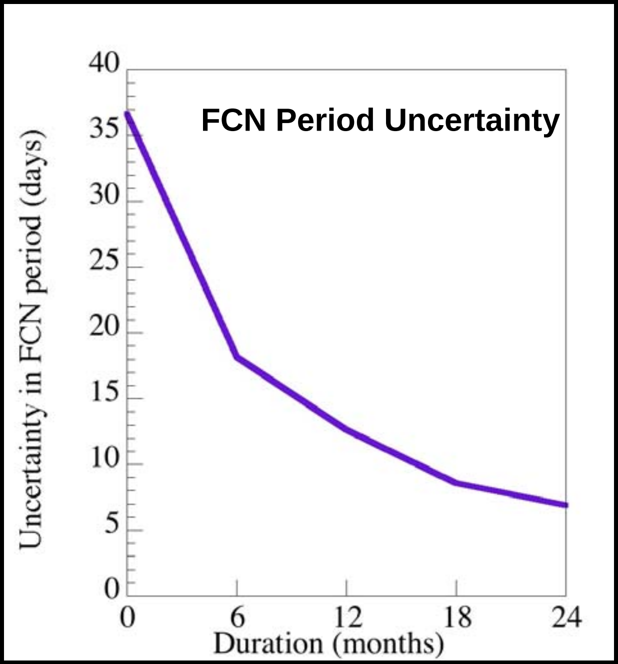
- Measuring precession determines polar moment of inertia, constraining mass distribution and core radius, assuming plausible compositions of core and mantle.
- Three months of Spirit tracking will reduce precession uncertainty by ~30%.
- Six months of Spirit tracking will reduce precession uncertainty by ~65%.





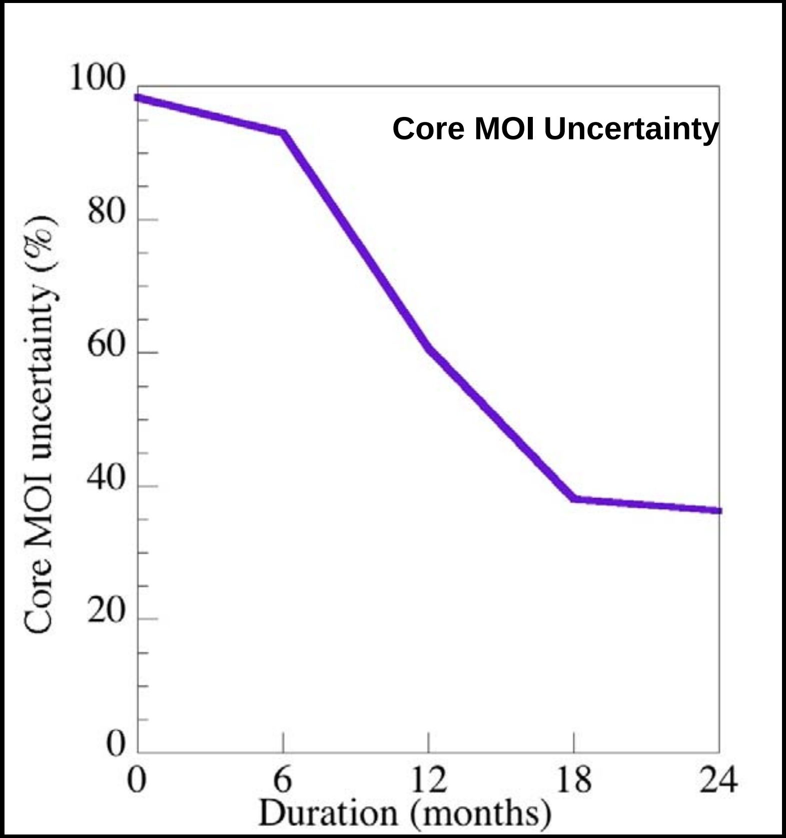
Free Core Nutation

- Mars' free core nutation depends on whether the core is liquid or solid.
- Free core nutation is related to the angle between the rotation axis of the core and the rotation axis of the mantle if the core is liquid and flattened.
- Six months of tracking will reduce the uncertainty in the free core nutation period by ~50%.



Core Moment of Inertia

- Mars' semi-annual nutation depends on the moment of inertia of the core.
- Core MOI will give strong constraint on core composition.
- Detection of signature requires about 1/2 martian year (~360 sols) of observation.



Measurement Plan

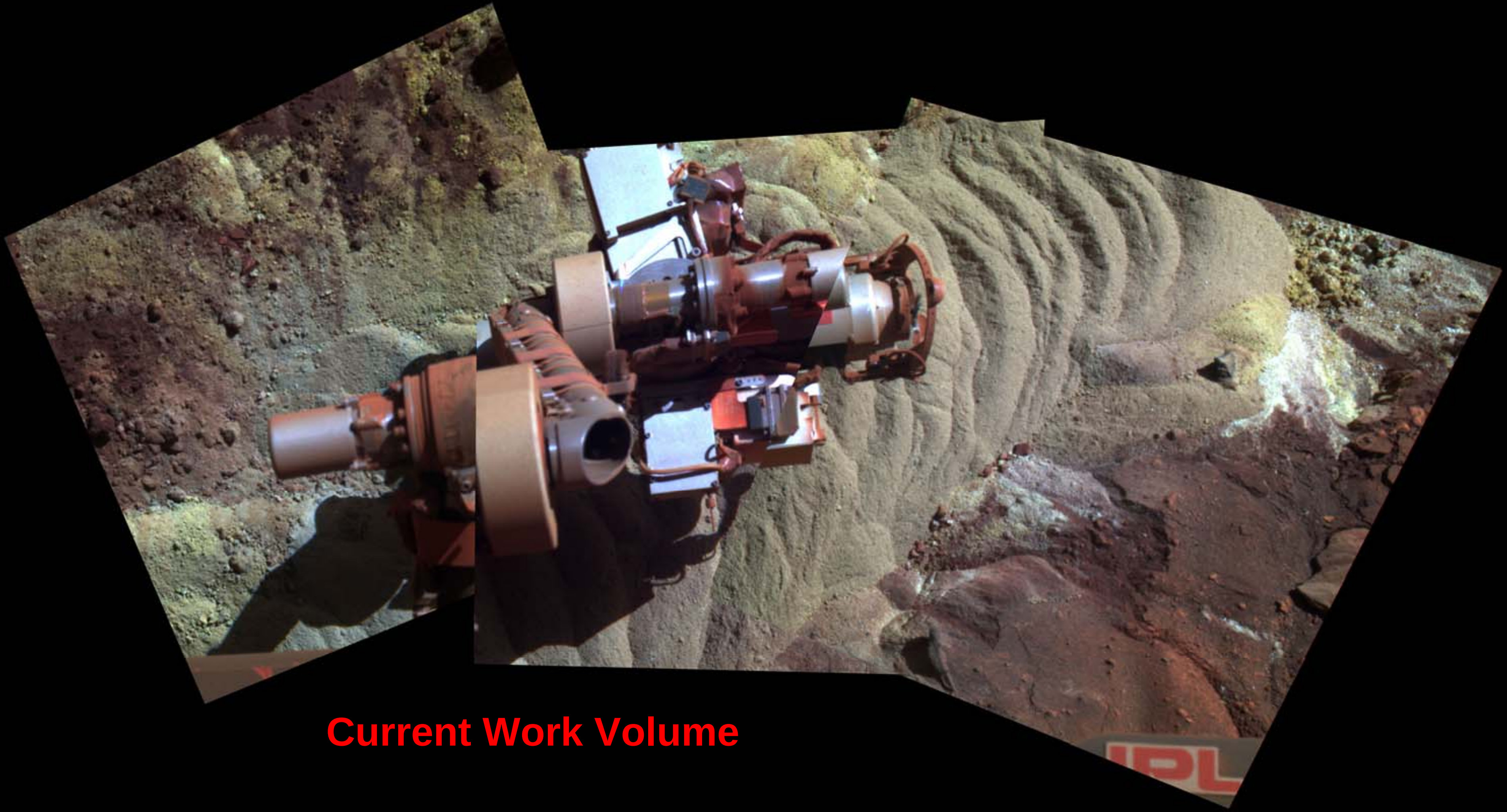
- Adequate tracking to perform this experiment requires a 6-12 month period of:
  - Limited rover motion.
  - Sufficient power for tracking passes.

- The seventh extended mission will be the first time a MER rover has had substantial power but restricted mobility.

- The simulations described here assume hour-long tracking passes once per week.
  - 2-way X-band Doppler tracking by DSN 34m.
  - Earth at relatively low elevation as seen from MER (at least 1.5-2 hours from zenith).
  - Long passes can be replaced by multiple shorter passes during the week if different elevations of Earth are viewed (i.e., at different times of day).
  - Passes scheduled when MRO is occulted by Mars to eliminate interference.

- Occasional, small well-characterized movements of the rover are acceptable.
  - Tracking measurement goal is ~3 cm accuracy

Incredible Diversity of Soils in New Post-Winter Work Volume



Current Work Volume

This Just Down From Spirit (sol 2218)

Sweet Dreams…