Sniffing out the Story on the Habitability Potential of Mars: Follow the Volatiles!

NASA/JPL-Caltech/MSSS

Pan Conrad
Deputy PI, SAM Investigation
Mars Science Laboratory

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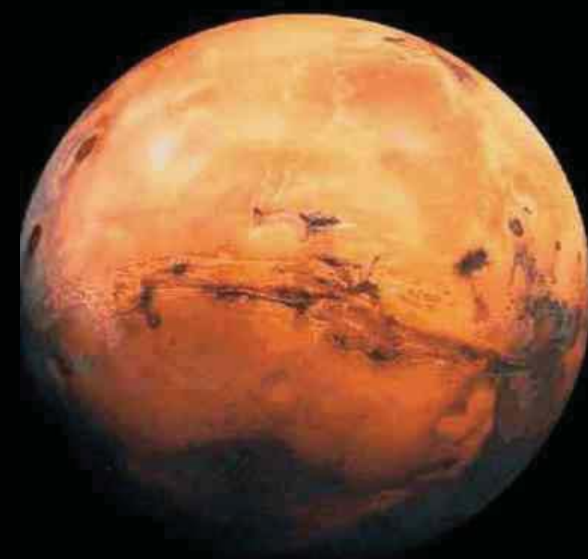
Is or was Mars alive ?

Earth

- Warm
- Wet
- Heavy atmosphere
- Magnetic dynamo

Current Mars

- Cold
- Mostly dry/water ice
- Thin atmosphere
- Only remnant magnetic fields



Curiosity's primary scientific goal is to explore and quantitatively assess a local region on Mars' surface as a potential habitat for life, past or present

- **Biological potential**
- **Geology and geochemistry**
- **Role of water**
- **Surface radiation**

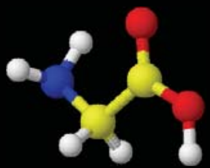
Curiosity's Science Objectives

What makes a habitable environment?

Chemical Requirements:

Major Biogenic Elements (Building Blocks) + Energy + Water = ?

Carbon C
Hydrogen H
Oxygen O
Nitrogen N
Phosphorus P
Sulfur S



e.g. Sunlight
(photosynthesis)

Chemical (Food)

Thermal

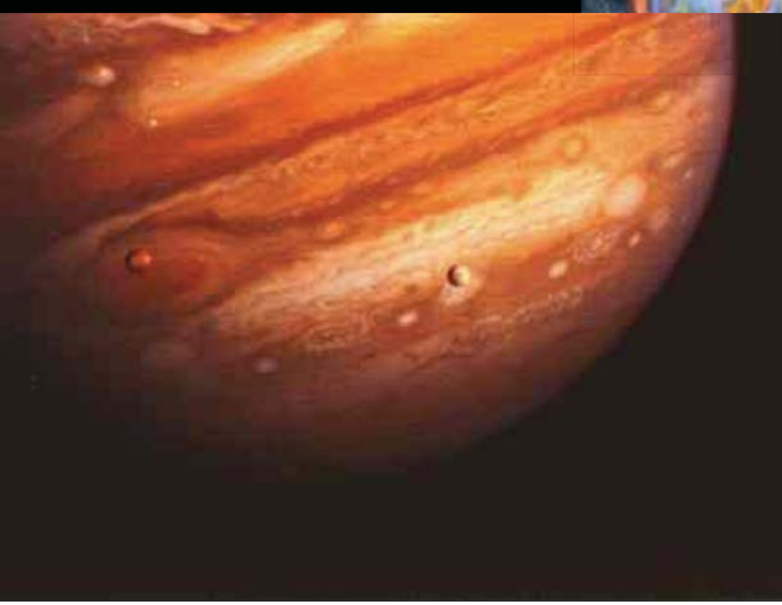
Liquid
(chemistry)

But wait! There's more!

Physical Requirements:

Location + Size + Dynamics + Time

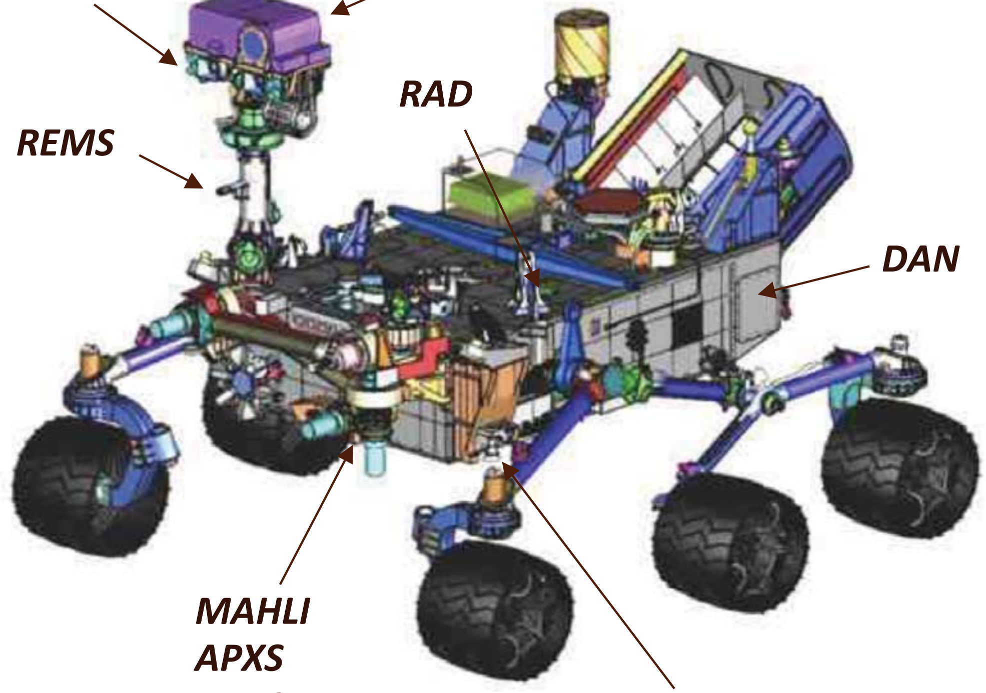
+ Thermal environment + ????



Introduction

Some things that we have debated and should resolve

- **What does life require, and does Mars have it?**
- **What should we measure and what have we already done?**
- **What can we measure to assess past habitability in the rock record?**
- **Do some environmental attributes cluster in a meaningful way?**
- **Can any of these measurements be weighted for indexing the habitability potential of different environments relative to one another?**



Wheel Base:	**2.8 m**
Height of Deck:	**1.1 m**
Ground Clearance:	**0.66 m**
Height of Mast:	**2.2 m**
Mass:	**900 kg**

REMOTE SENSING

Mastcam (M. Malin, MSSS) - Color and telephoto imaging, video, atmospheric opacity

ChemCam (R. Wiens, LANL/CNES) – Chemical composition; remote micro-imaging

CONTACT INSTRUMENTS (ARM)

MAHLI (K. Edgett, MSSS) – Hand-lens color imaging

APXS (R. Gellert, U. Guelph, Canada) - Chemical composition

ANALYTICAL LABORATORY (ROVER BODY)

SAM (P. Mahaffy, GSFC/CNES/JPL-Caltech) - Chemical and isotopic composition, including organics

CheMin (D. Blake, ARC) - Mineralogy

ENVIRONMENTAL CHARACTERIZATION

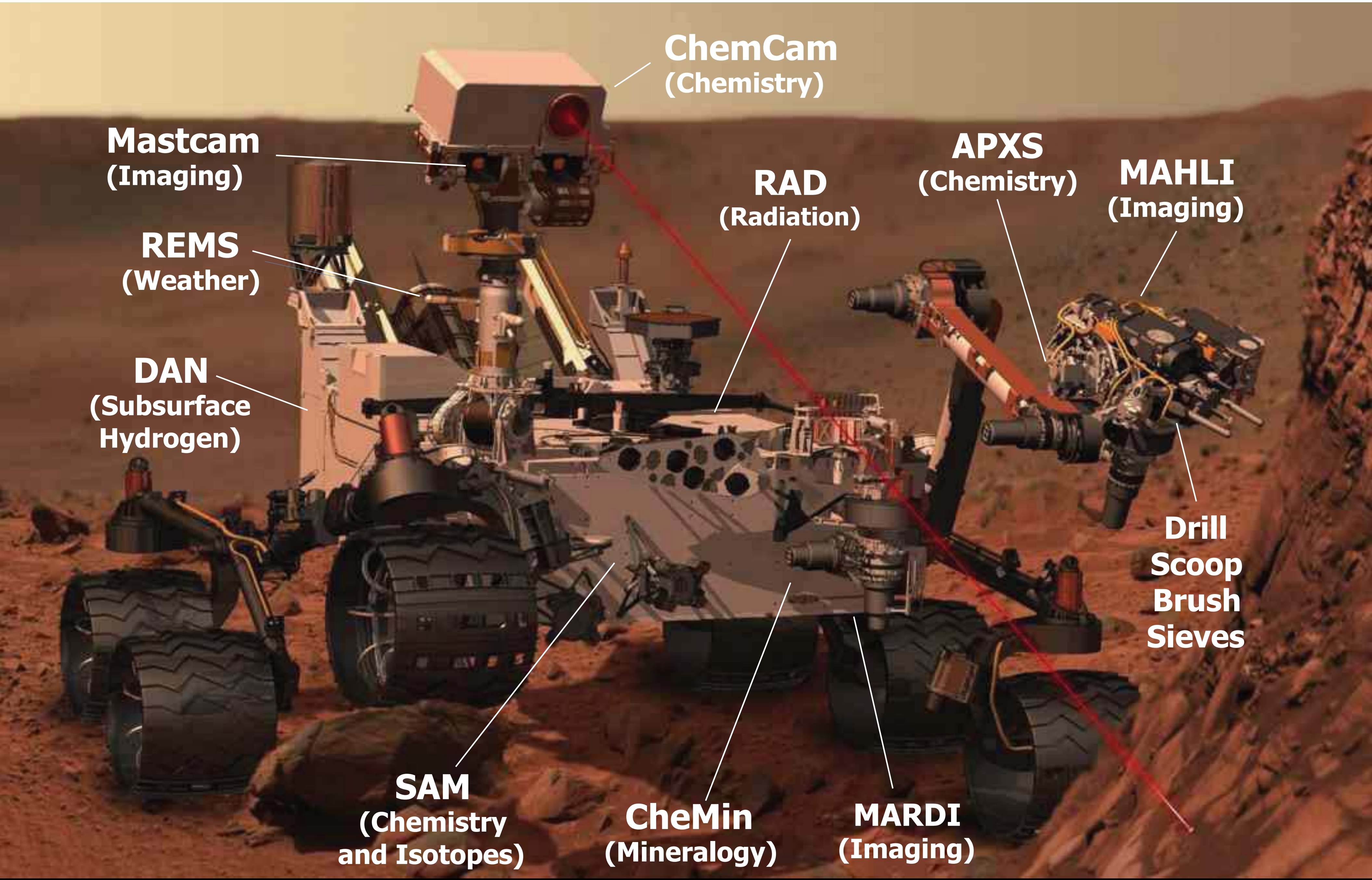
MARDI (M. Malin, MSSS) - Descent imaging

REMS (J. Gómez-Elvira, CAB, Spain) - Meteorology / UV

RAD (D. Hassler, SwRI) - High-energy radiation

DAN (I. Mitrofanov, IKI, Russia) - Subsurface hydrogen

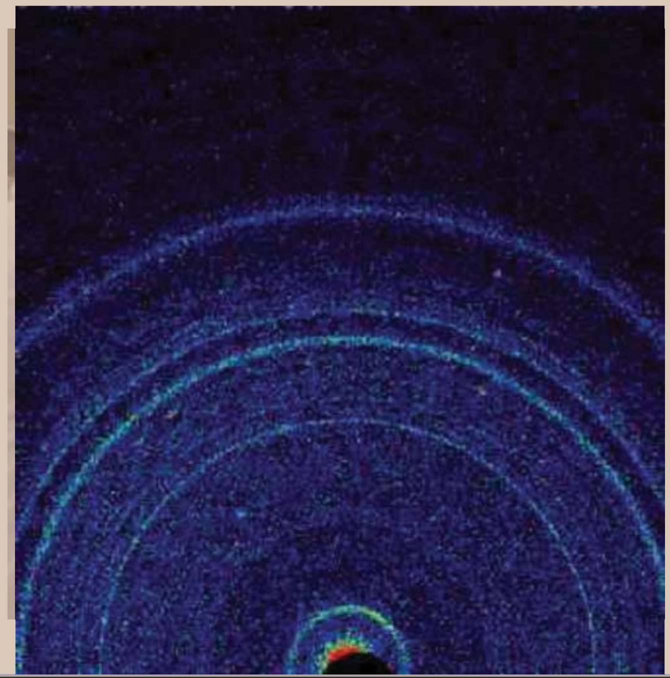
Curiosity's Science Payload



Curiosity's Science Payload

In depth Analysis: Instruments that ingest samples

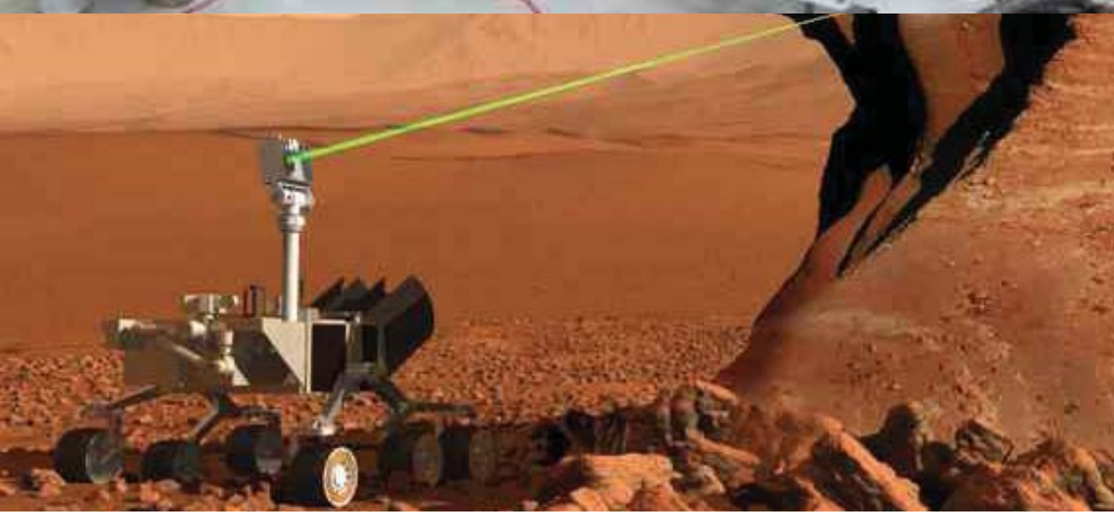
CHEMIN:
Identifies Minerals, including those formed in water



SAM:
Identifies Organics, the Chemical Building Blocks of Life

In Body

In the belly of the beast is SAM

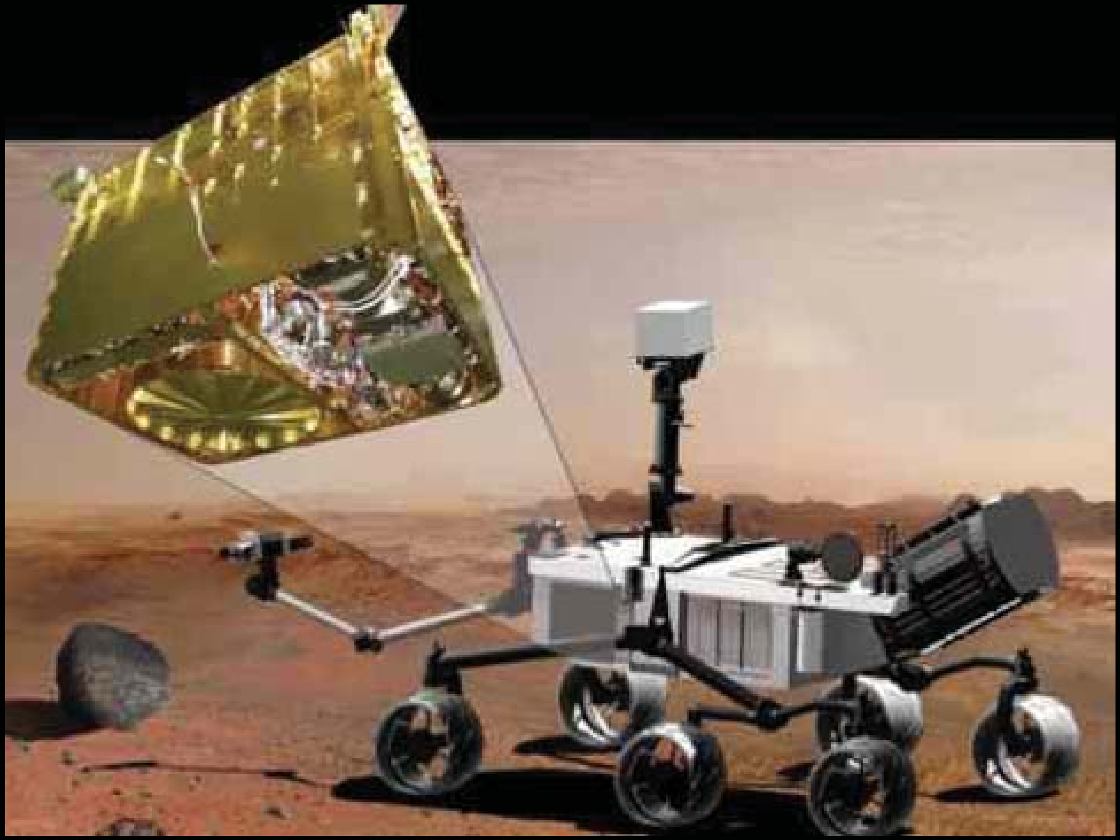


SAM itself is made up of three instruments

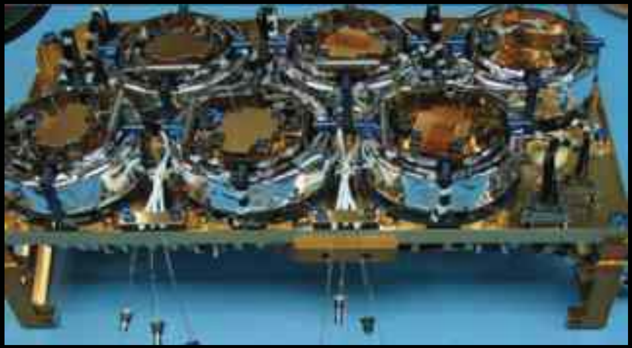
Principal Investigator: Paul Mahaffy

NASA Goddard Space Flight Center

Quadrupole Mass Spectrometer

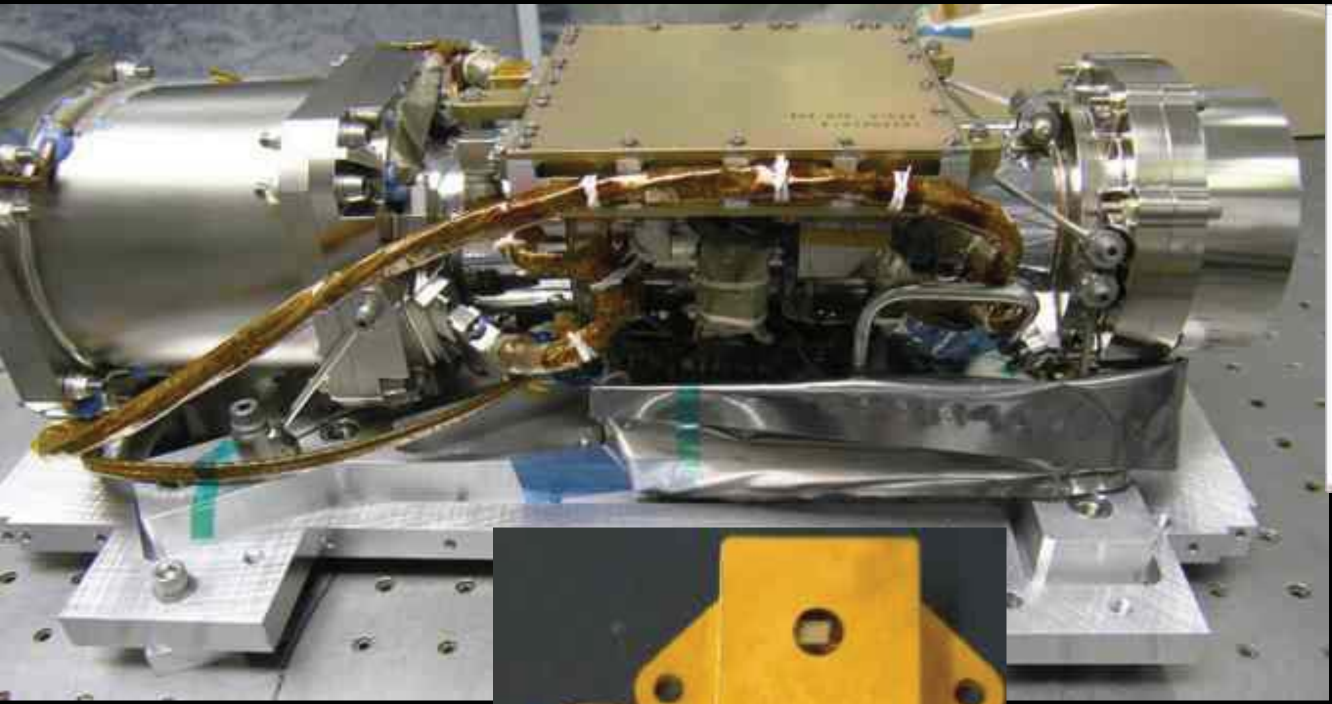


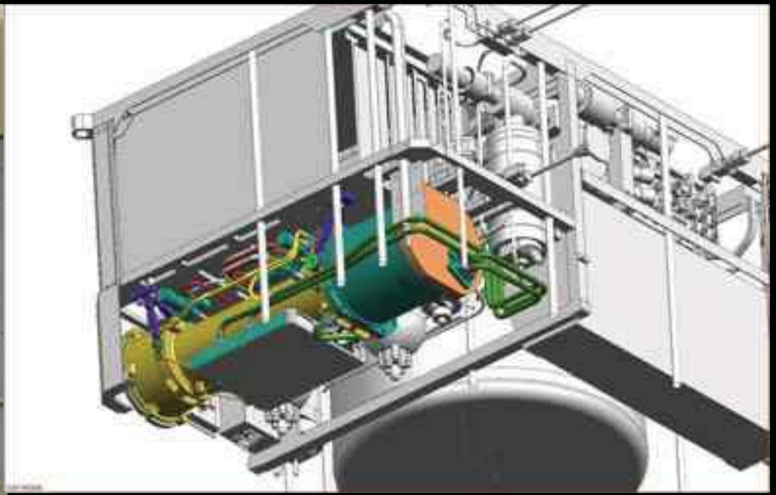
Gas Chromatograph

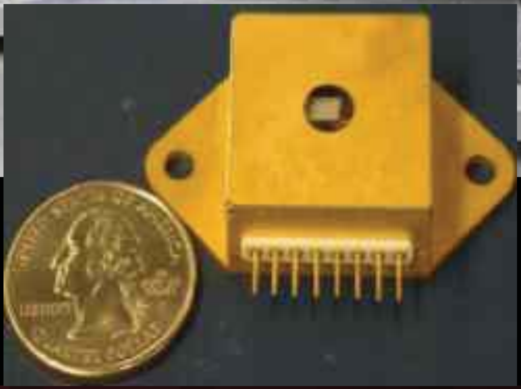


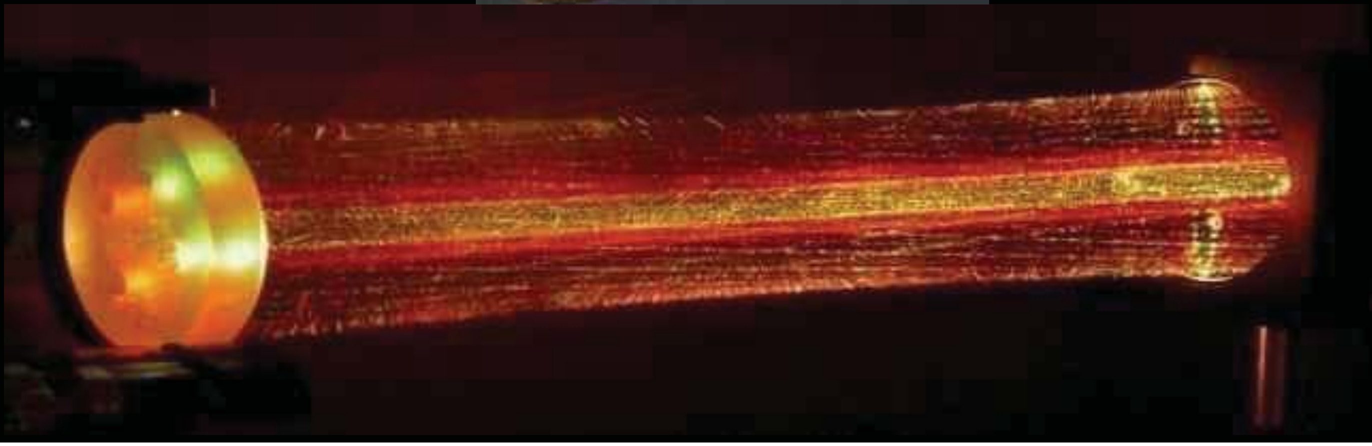
Tunable Laser Spectrometer

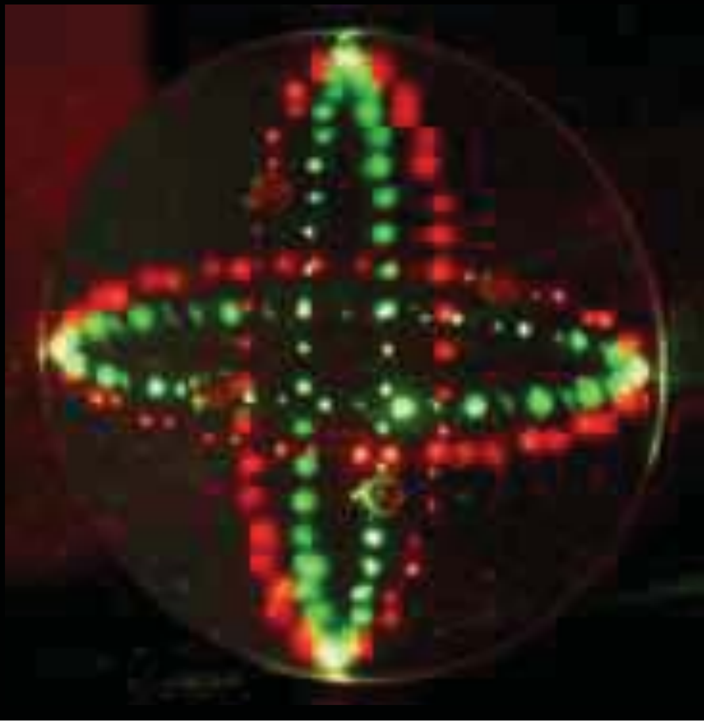
The SAM Tunable Laser Spectrometer developed by Webster/JPL

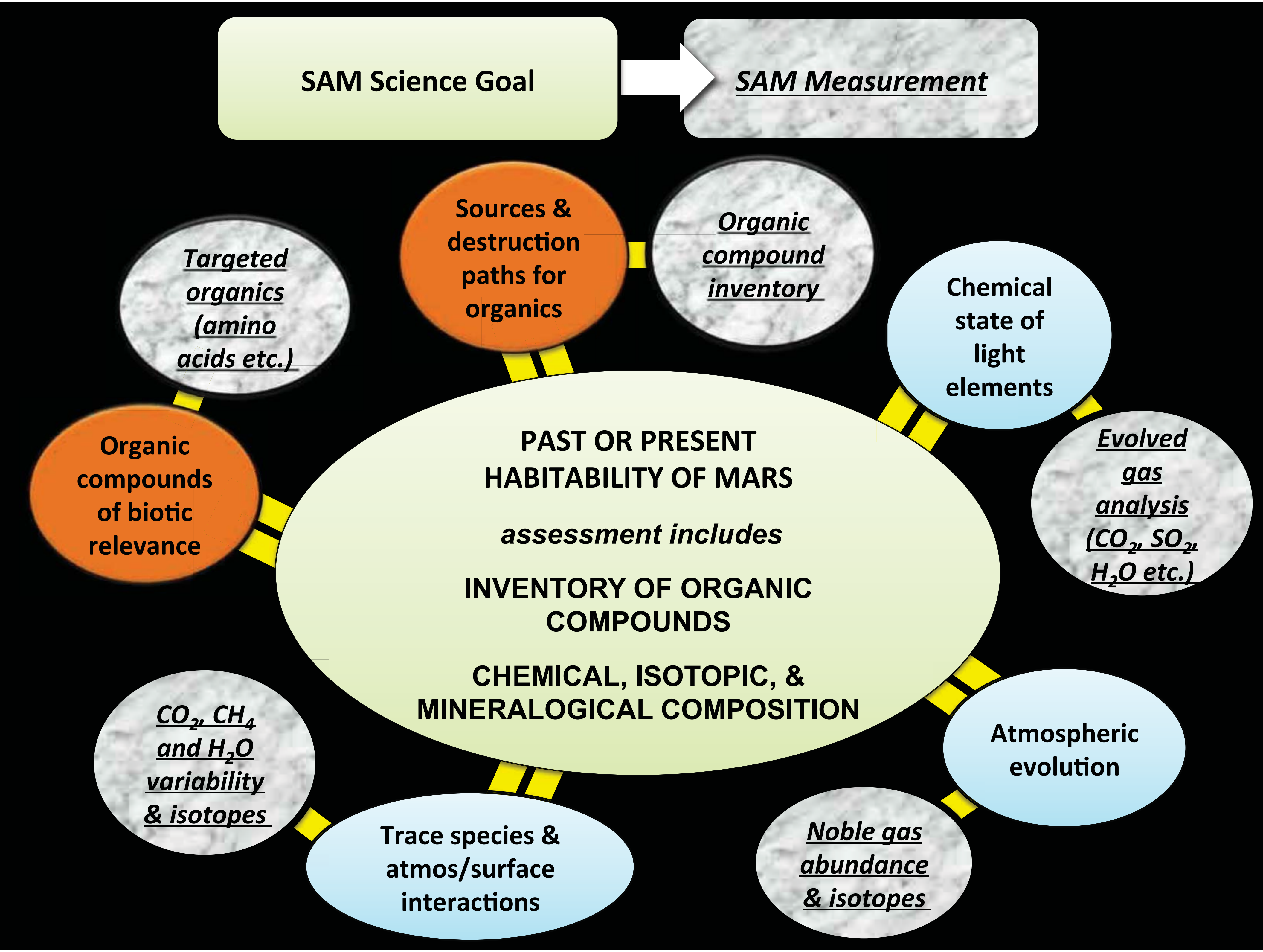




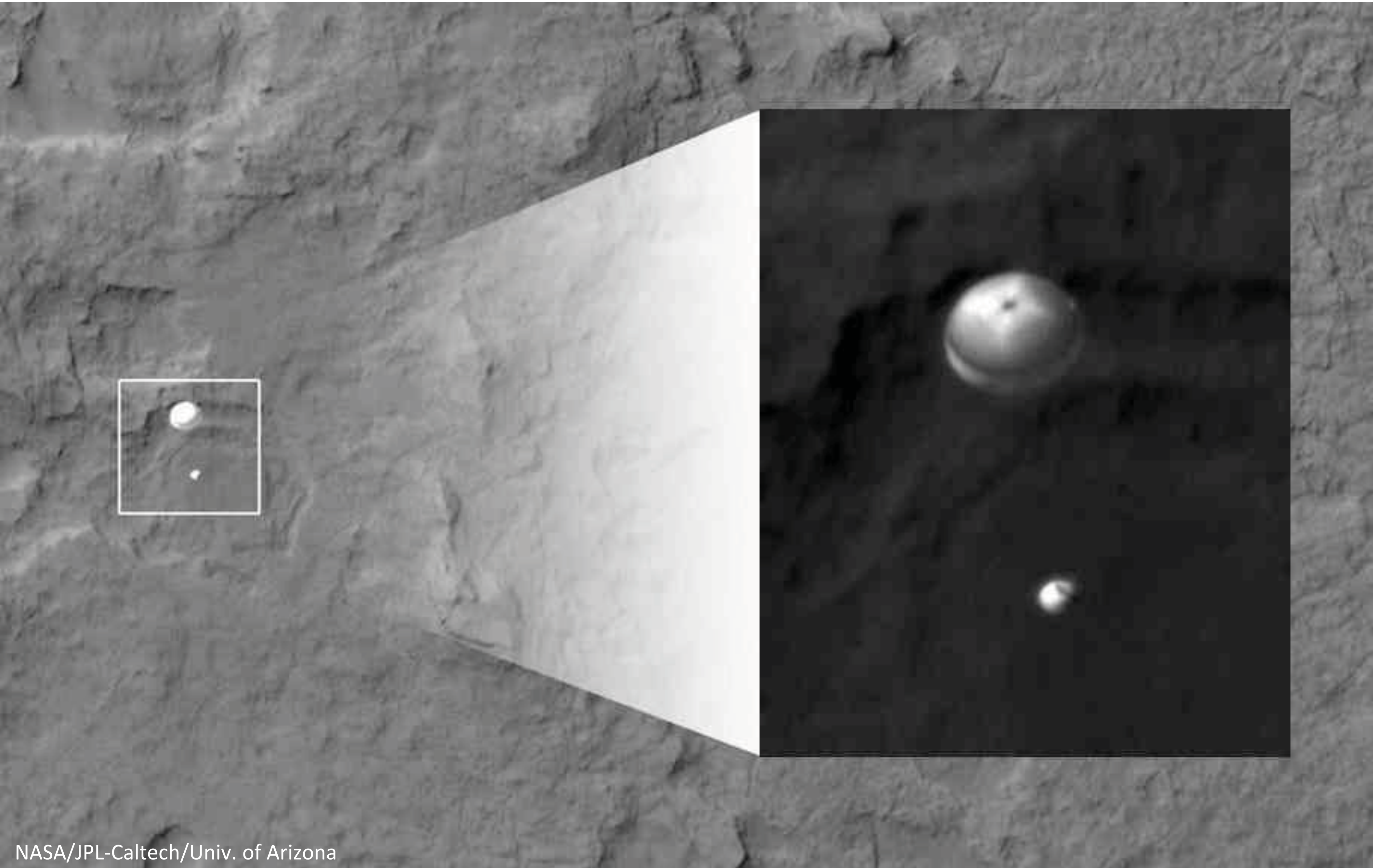







SAM Science Goal
SAM Measurement
Sources & destruction paths for organics
Organic compound inventory
Targeted organics (amino acids etc.)
Chemical state of light elements
Organic compounds of biotic relevance
Evolved gas analysis (CO_2, SO_2, H_2O etc.)
PAST OR PRESENT HABITABILITY OF MARS
assessment includes
INVENTORY OF ORGANIC COMPOUNDS
CHEMICAL, ISOTOPIC, & MINERALOGICAL COMPOSITION
CO_2, CH_4 and H_2O variability & isotopes
Atmospheric evolution
Trace species & atmos/surface interactions
Noble gas abundance & isotopes

Heat shield separation captured by Curiosity's Mars Descent Imager



Curiosity on parachute, imaged by HiRISE on the Mars Reconnaissance Orbiter

Casting our own shadow

Sol types: Curiosity's daily business

1. REMOTE SENSING

- Landscape imaging
- Sampling of rock and soil chemistry

2. TRAVERSE/APPROACH

- Driving up to 100 m per sol
- Imaging and profiling chemistry along the drive
- Locating sampling targets

3. CONTACT SCIENCE

- Removal of surface dust
- Chemical and hand-lens observations of a specific target

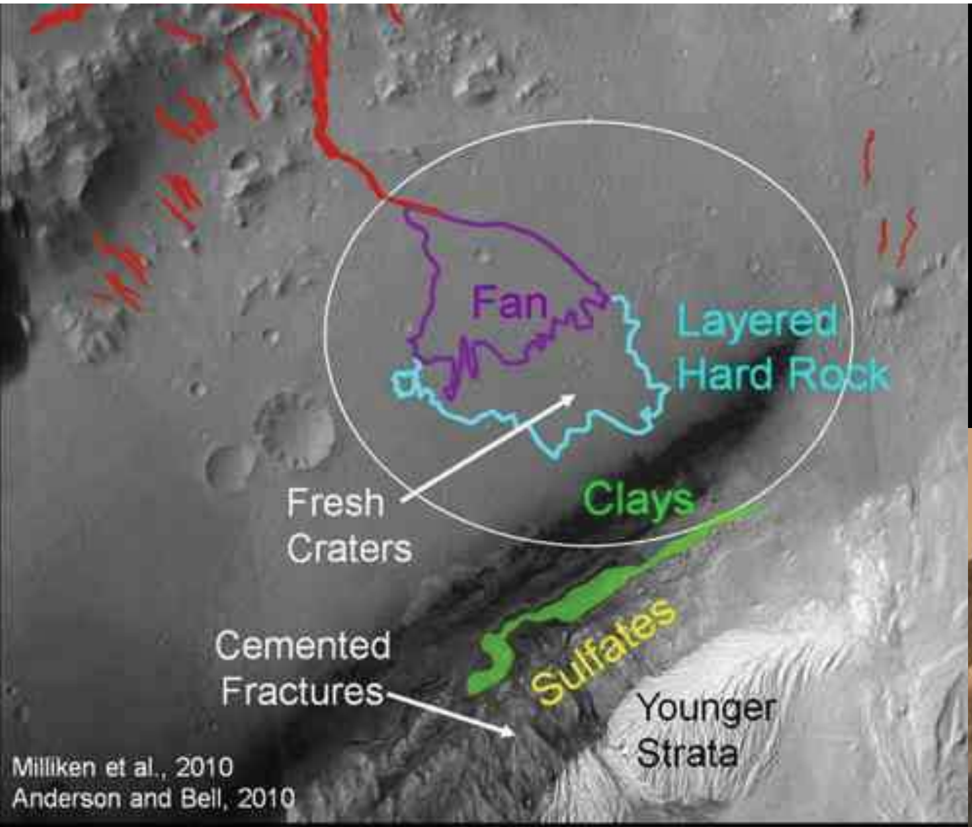
4. SAMPLE ACQUISITION/ANALYSIS

- Drilling, processing, and delivering sample material the rover's lab instruments
- Analyzing for mineralogy, organics, elemental and isotopic chemistry

Each activity may require multiple "sols".
Results are reviewed on Earth before moving on to the next activity.
Weather and radiation monitoring occur on all sols.

Candidate Measurements

CHEMICAL
Elemental abundance, ratios and phase state
Inorganic molecular inventory
Organic inventory
Hydration state and phase of water
PHYSICAL
Temperature (absolute, frequency & magnitude of diurnal and seasonal variation, including air, surface and interface gradients)
Thermal inertia of the surface
Wind speed, direction & variability
Pressure (atmospheric, lithostatic, etc.)
Light (solar bandwidth, wavelength-specific intensity)
Other ionizing radiation, e.g., cosmic, SEP, radiogenic elements in the environment
Slope
Electrostatic charge
GEOLOGICAL
Mineral abundances
Rock type and texture
Frequency & type of volcanic and seismic events
GEOGRAPHIC
Latitude, elevation or depth below surface
Areal extent of environment



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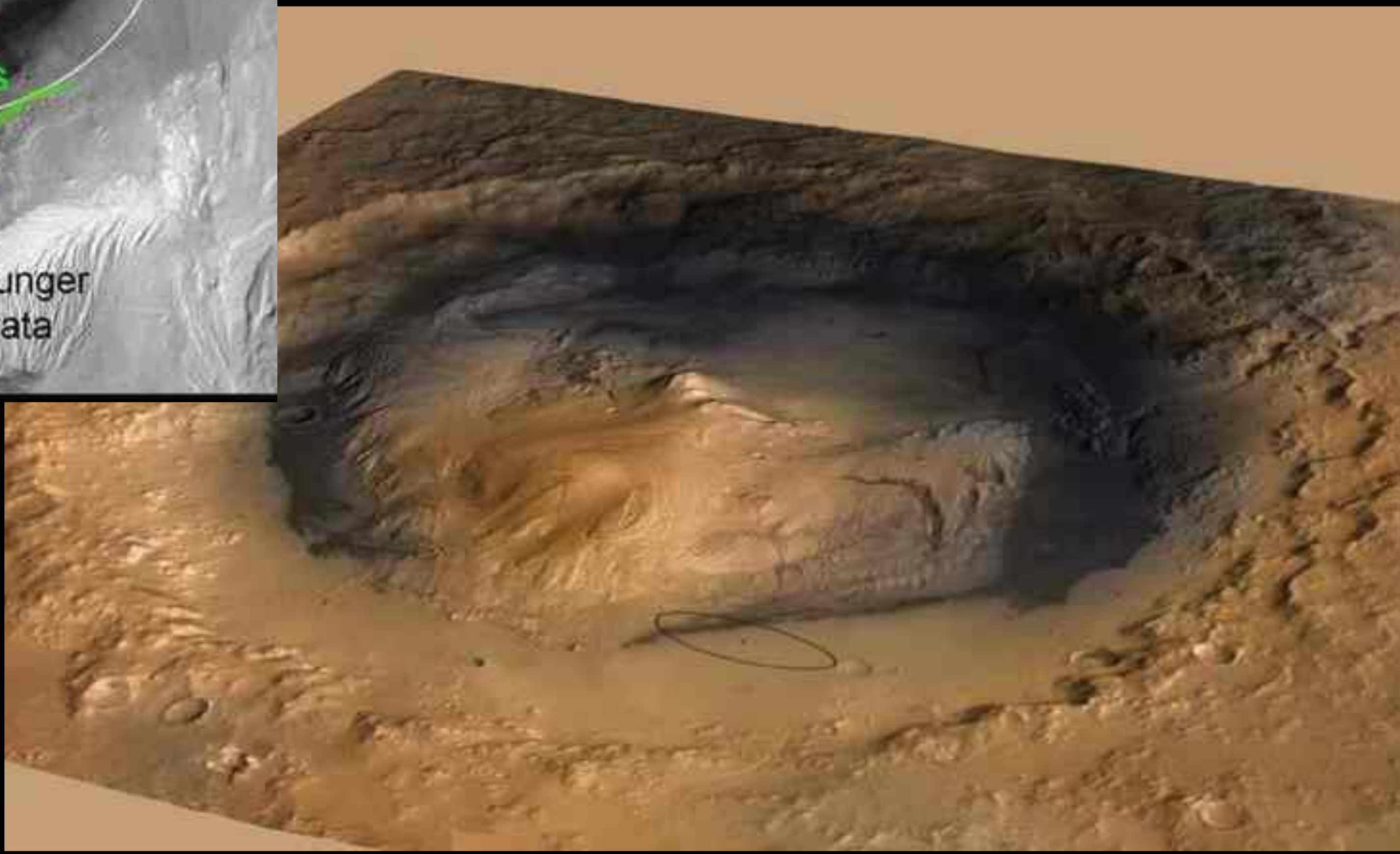
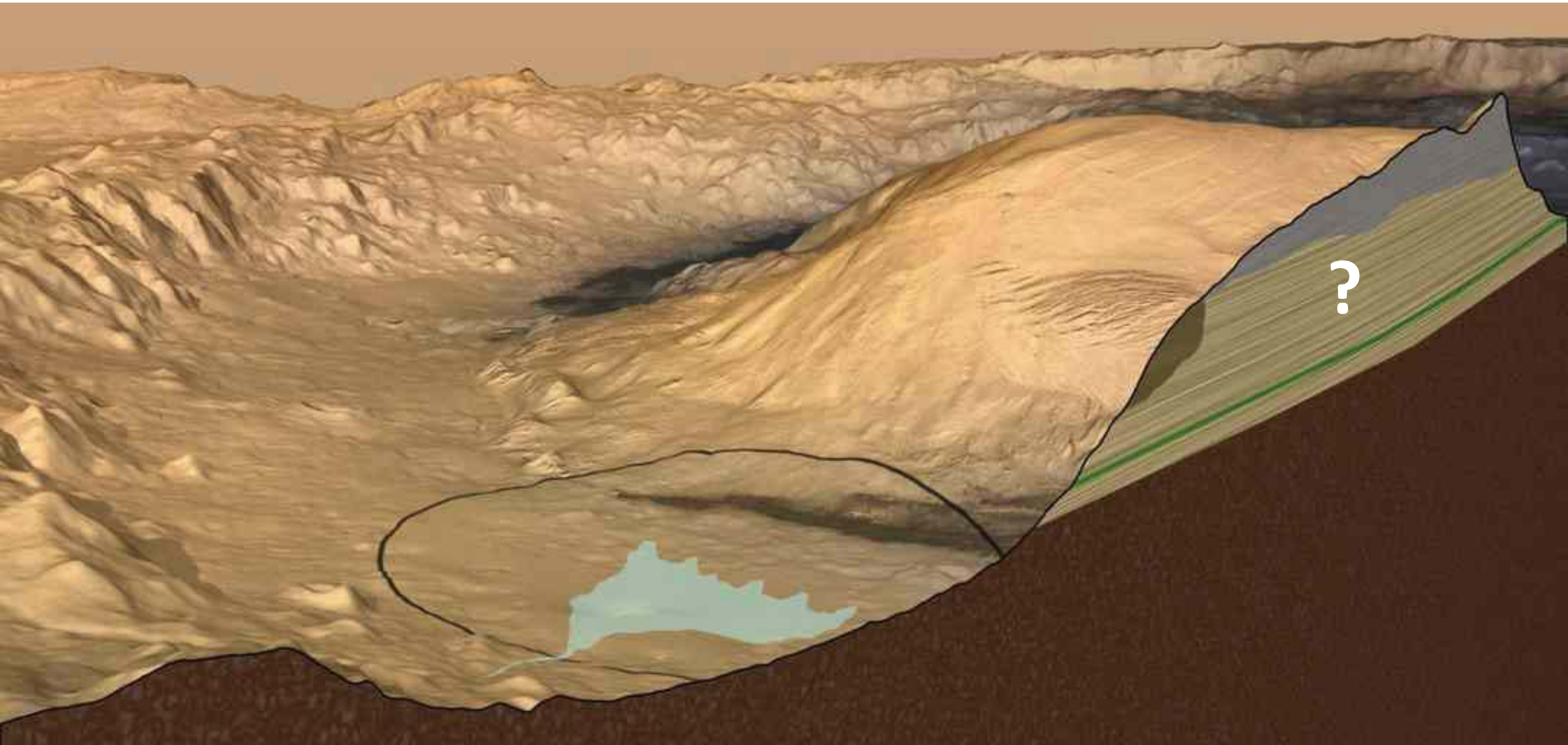


NASA/JPL-Caltech/ESA/DLR/FU Berlin/MSSS

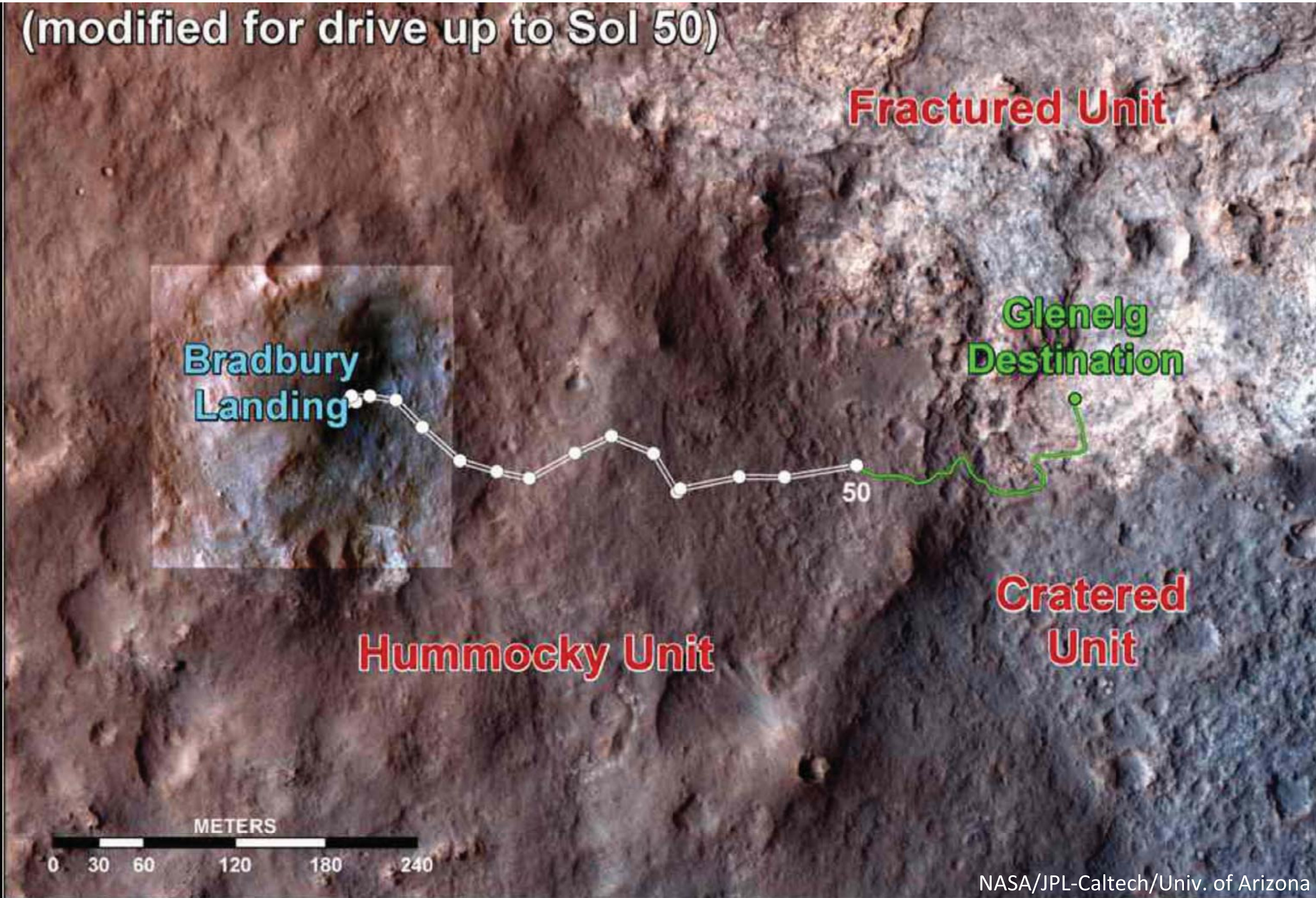
Location context: Gale Crater and Mount Sharp



150-km Gale Crater contains a 5-km high mound of stratified rock. Strata in the lower section of the mound vary in mineralogy and texture, suggesting that they may have recorded environmental changes over time. Curiosity will investigate this record for clues about habitability, and the ability of Mars to preserve evidence about habitability or life.

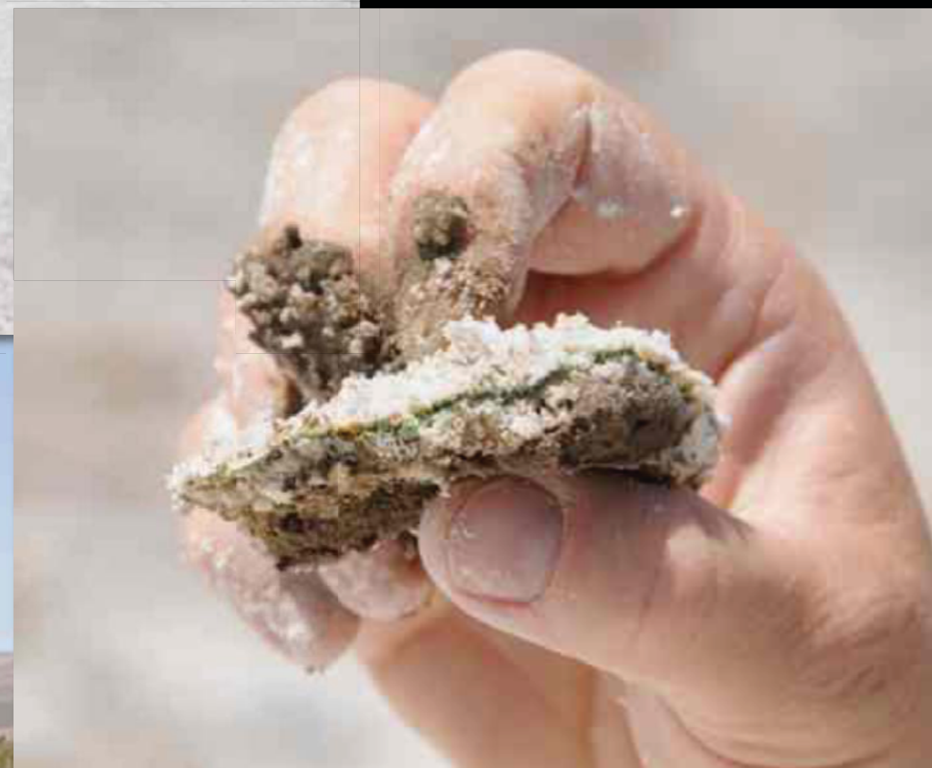
NASA/JPL-Caltech

Target: Gale Crater and Mount Sharp

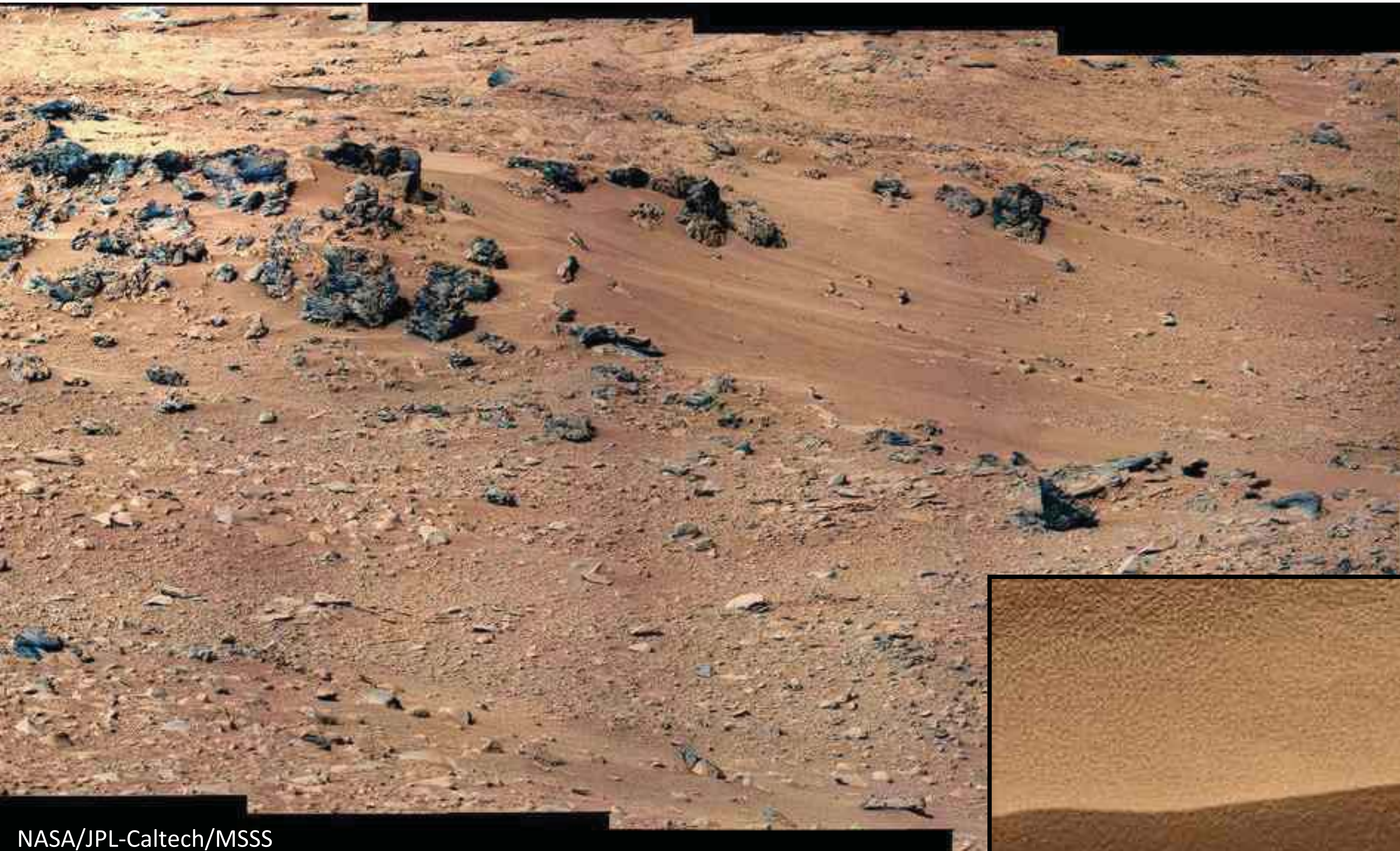


Curiosity progressed toward Glenelg, where three distinct terrain types meet

This context is the blueprint for construction of a habitat



Rocknest Scooping Campaign



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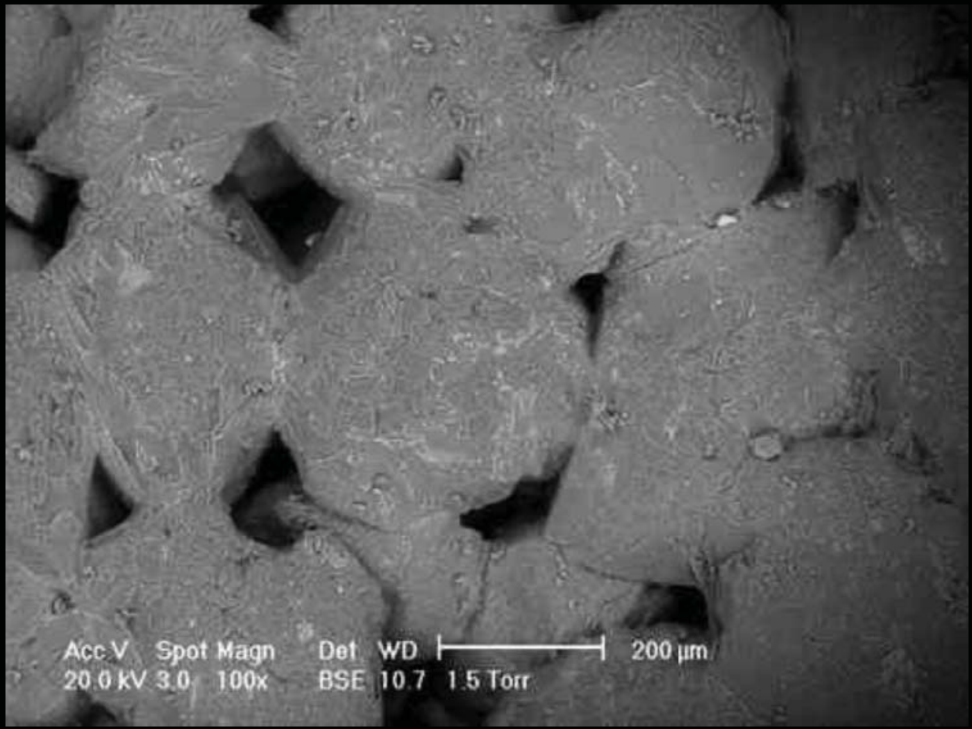
Windblown “sand shadow” at the Rocknest site

Wheel scuff to confirm depth of sand, for safe scooping

MAHLI view of coarse (0.5 to 1.5 mm) sand from the ripple’s surface, and fine (< 0.25 mm) sand on wall and floor of trench

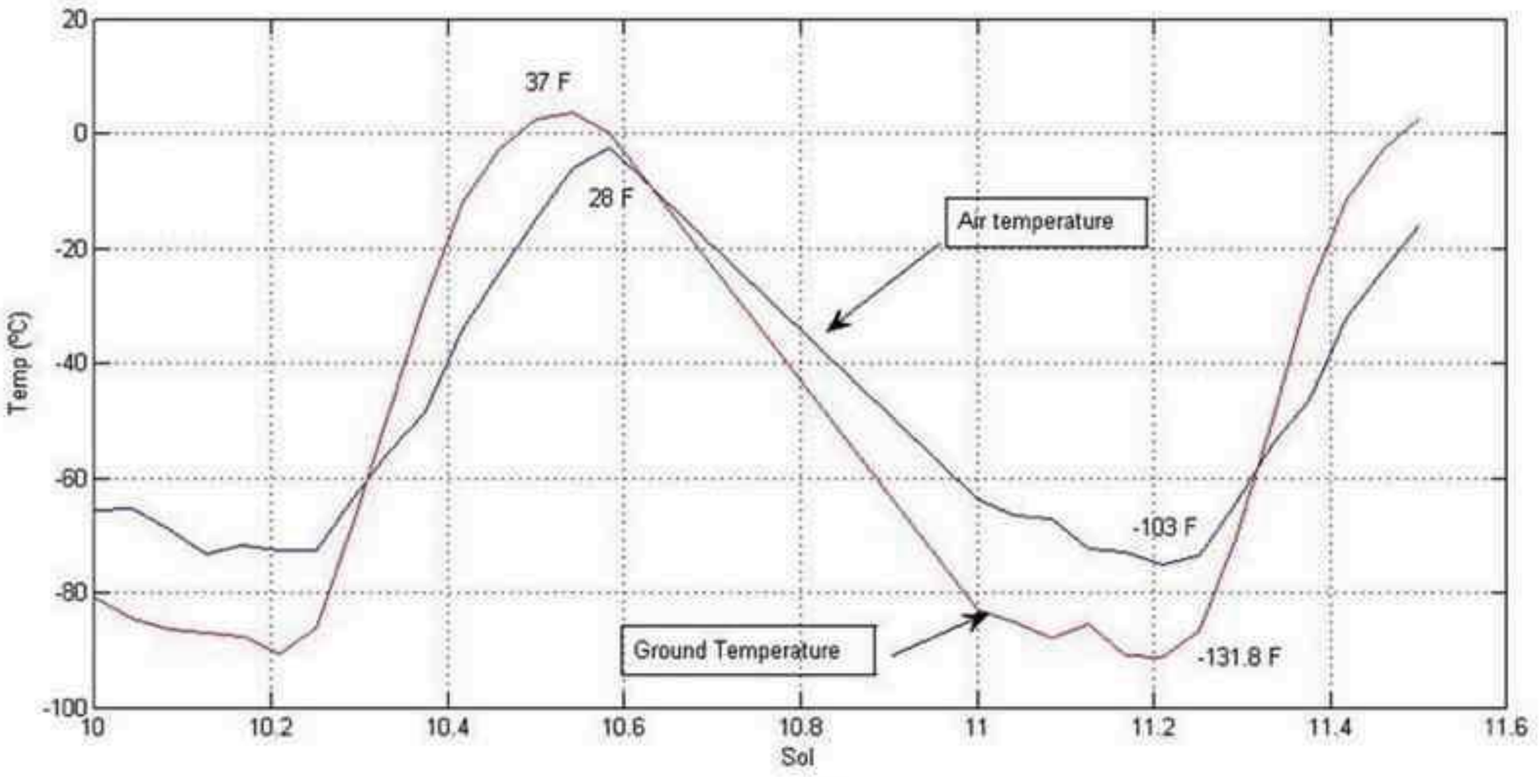
Physical properties of the rock affect its chemistry, its habitability potential and its ability to preserve chemical fossils



Environmental Physics

CHEMICAL
Elemental abundance, ratios and phase state
Inorganic molecular inventory
Organic inventory
Hydration state and phase of water
PHYSICAL
Temperature (absolute, frequency & magnitude of diurnal and seasonal variation, including air, surface and interface gradients)
Thermal inertia of the surface
Wind speed, direction & variability
Pressure (atmospheric, lithostatic, etc.)
Light (solar bandwidth, wavelength-specific intensity)
Other ionizing radiation, e.g., cosmic, SEP, radiogenic elements in the environment
Slope
Electrostatic charge
GEOLOGICAL
Mineral abundances
Rock type and texture
Frequency & type of volcanic and seismic events
GEOGRAPHIC
Latitude, elevation or depth below surface
Areal extent of environment

GROUND AND AIR TEMPERATURE SENSOR



Sol

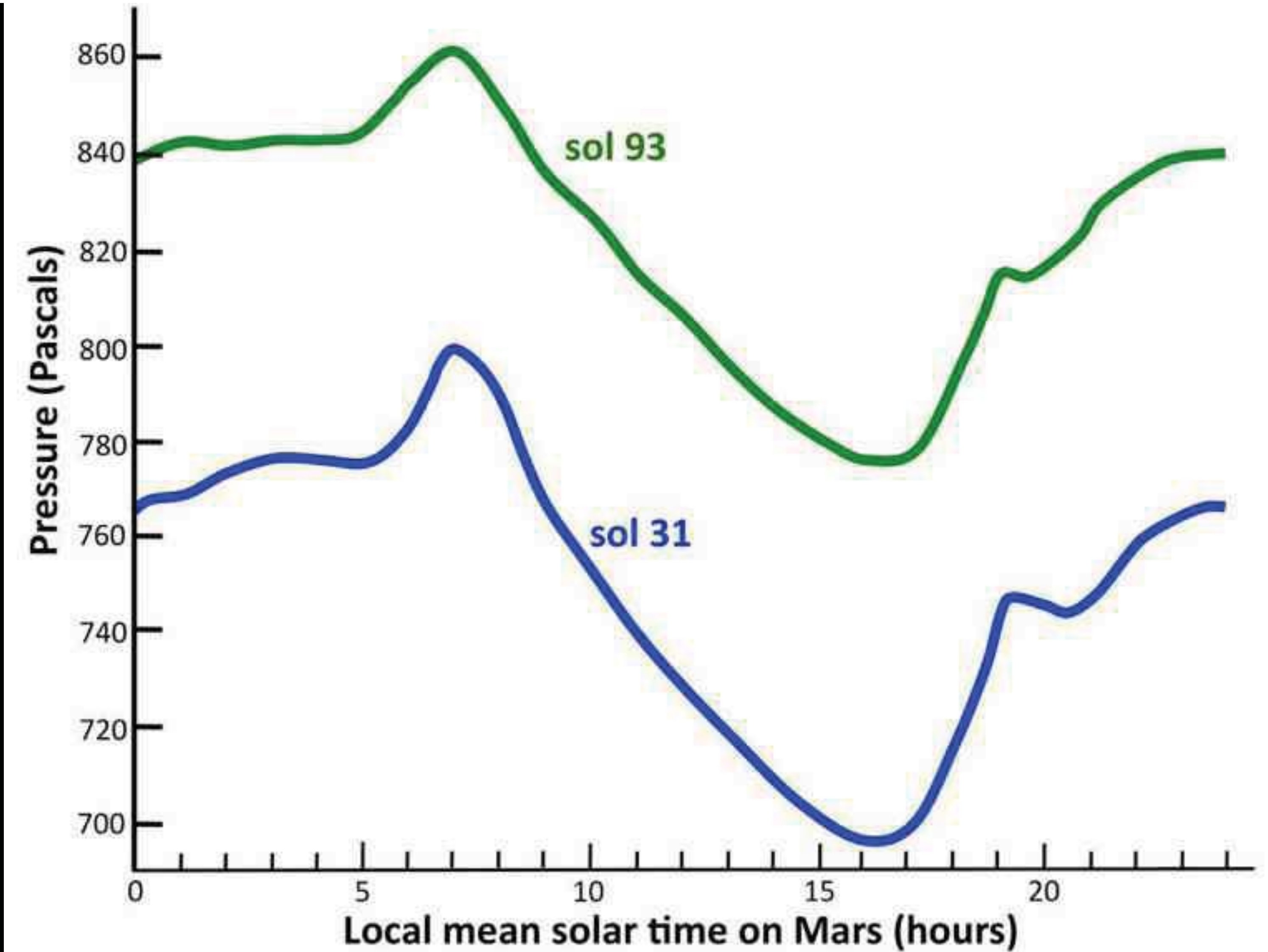
NASA/JPL-Caltech/CAB(CSIC-INTA)

REMS' ground and air temperature sensors are located on small booms on the rover's mast

The ground temperature changes by 90°C (170 degrees Fahrenheit) between day and night

The air is warmer than the ground at night, and cooler during the morning, before it is heated by the ground

Curiosity's Rover Environmental Monitoring Station is taking weather readings 24 × 7



NASA/JPL-Caltech/CAB(CSIC-INTA)/FMI/Ashima Research

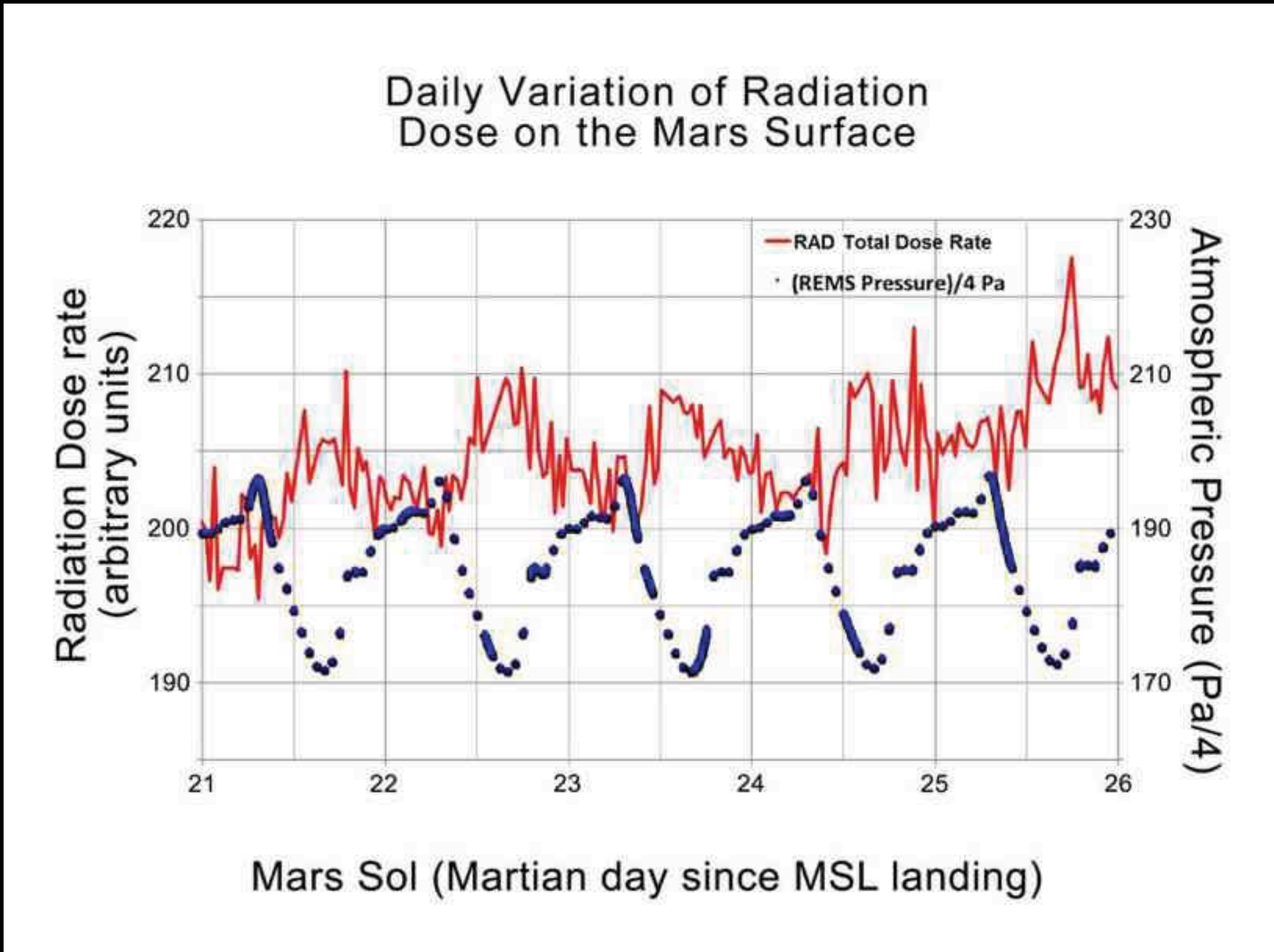
Each day the pressure varies by over 10%, similar to the change in pressure between Los Angeles and Denver

Solar heating of the ground drives a pressure "tidal wave" that sweeps across the planet each day

Overall, the pressure is increasing as carbon dioxide sublimates from the southern seasonal polar cap

Earth's atmosphere = 101,325 Pascals, or about 140 times the pressure at Gale Crater

REMS pressure measurements detect local, regional, and global weather phenomena

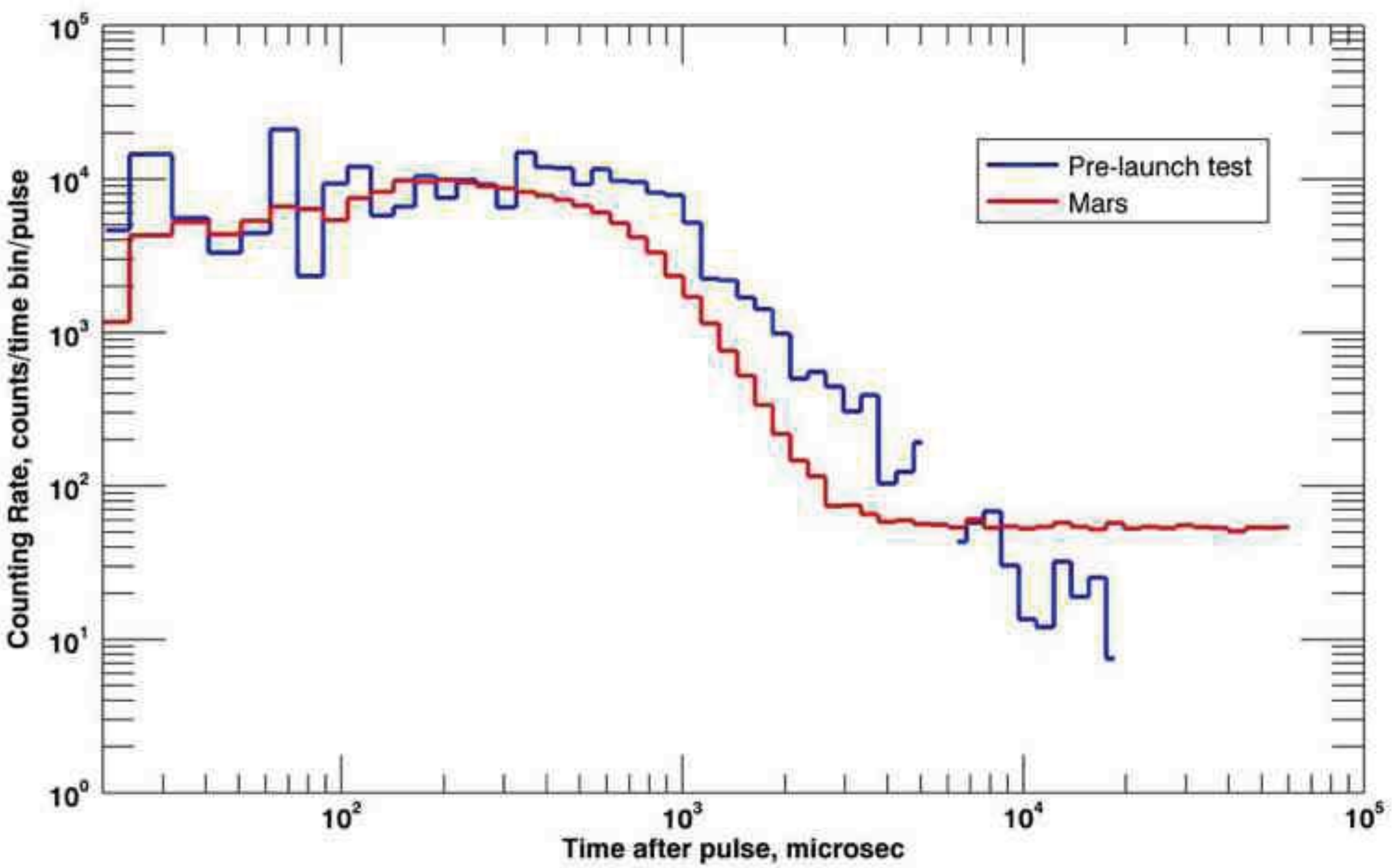


NASA/JPL-Caltech/SwRI

RAD observed galactic cosmic rays and five solar energetic particle events traveling from Earth to Mars

Mars' atmosphere partially shields the surface from radiation. When the atmosphere is thicker (higher REMS pressure), RAD measures less radiation.

Curiosity's Radiation Assessment Detector measures high-energy radiation



NASA/JPL-Caltech/Russian Space Research Institute

DAN sends ten million neutrons into the ground, ten times a second

The "echo" back is recorded. If hydrogen is present in the ground, perhaps in aqueous minerals, some neutrons will collide and lose energy

DAN is used to survey the upper one meter of the ground below the rover as it drives along

Curiosity's Dynamic Albedo of Neutrons experiment sounds the ground for hydrogen

Chemistry

CHEMICAL
Elemental abundance, ratios and phase state
Inorganic molecular inventory
Organic inventory
Hydration state and phase of water
PHYSICAL
Temperature (absolute, frequency & magnitude of diurnal and seasonal variation, including air, surface and interface gradients)
Thermal inertia of the surface
Wind speed, direction & variability
Pressure (atmospheric, lithostatic, etc.)
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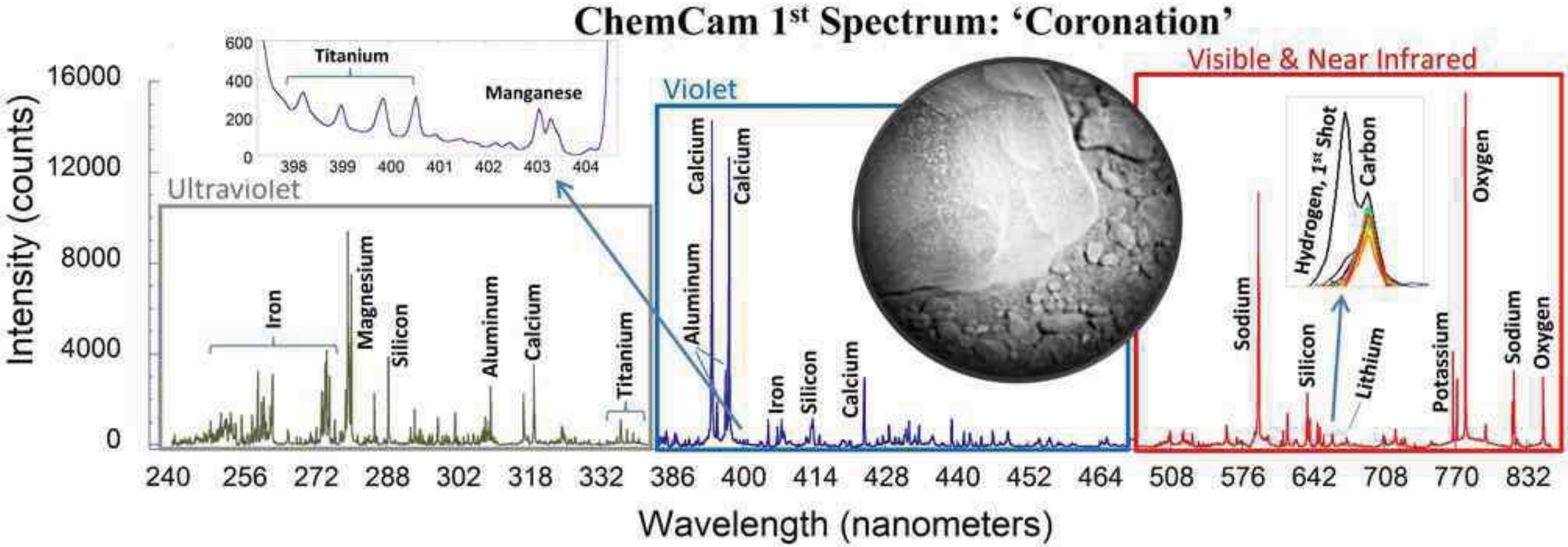
Slope
Electrostatic charge
GEOLOGICAL
Mineral abundances
Rock type and texture
Frequency & type of volcanic and seismic events
GEOGRAPHIC
Latitude, elevation or depth below surface
Areal extent of environment

The conglomerate “Link” with associated loose, rounded pebbles



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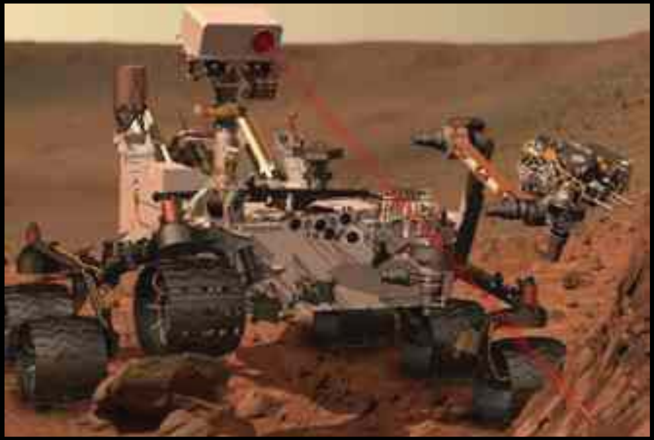
ChemCam spectra of Coronation

Target: Coronation (N165)
Sol 13
Shots: 30



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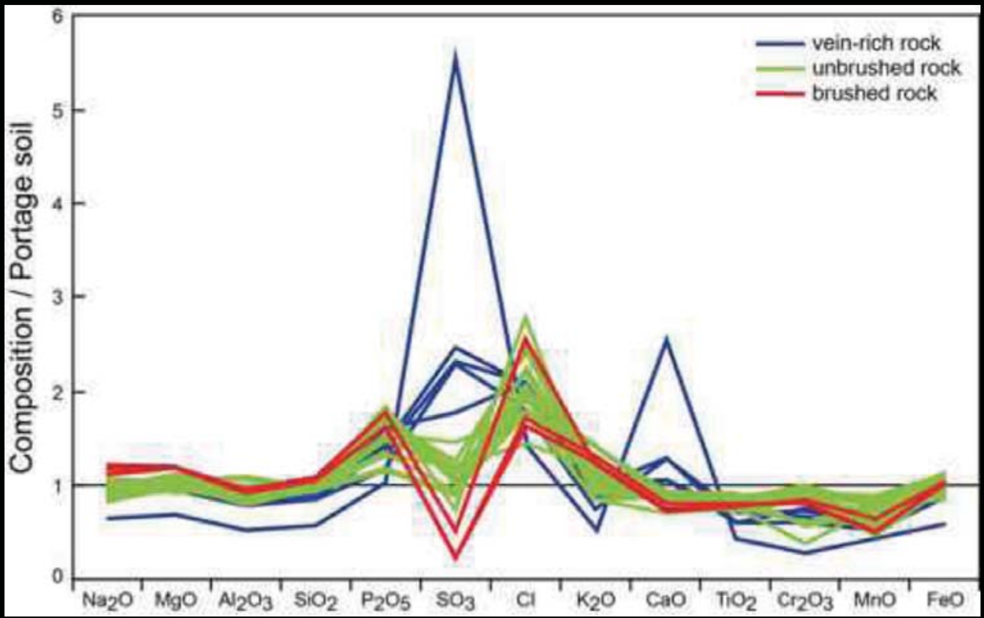
This works for everything, including organisms



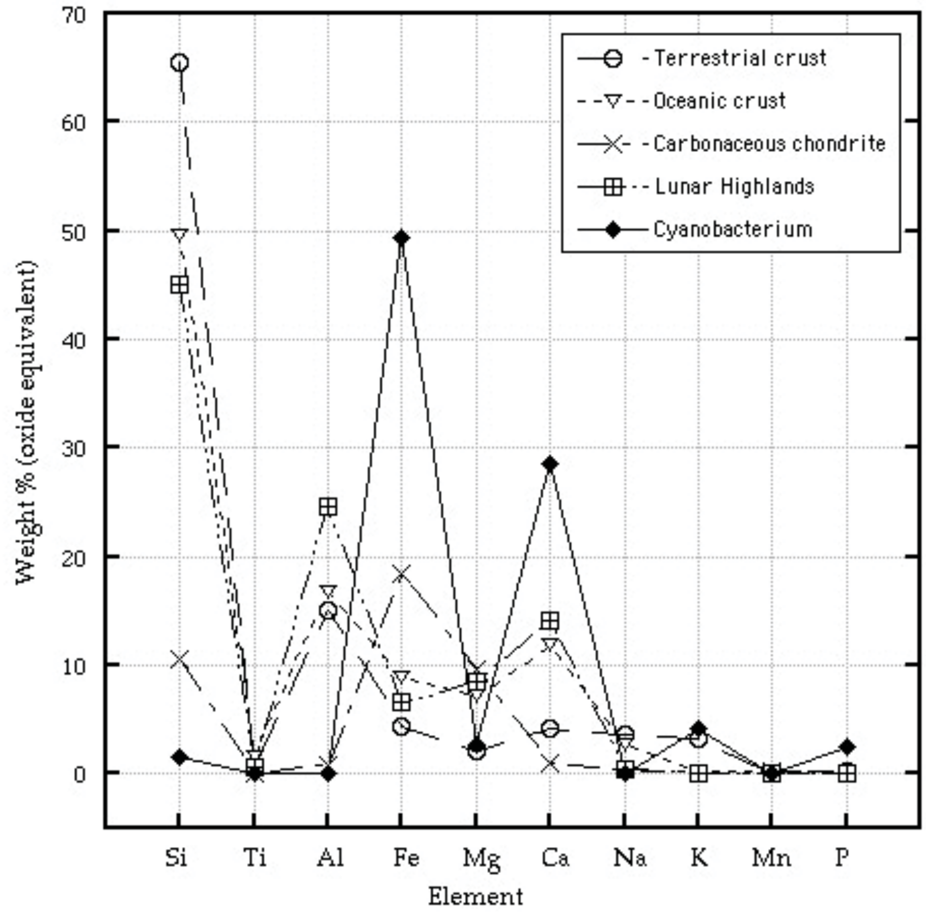
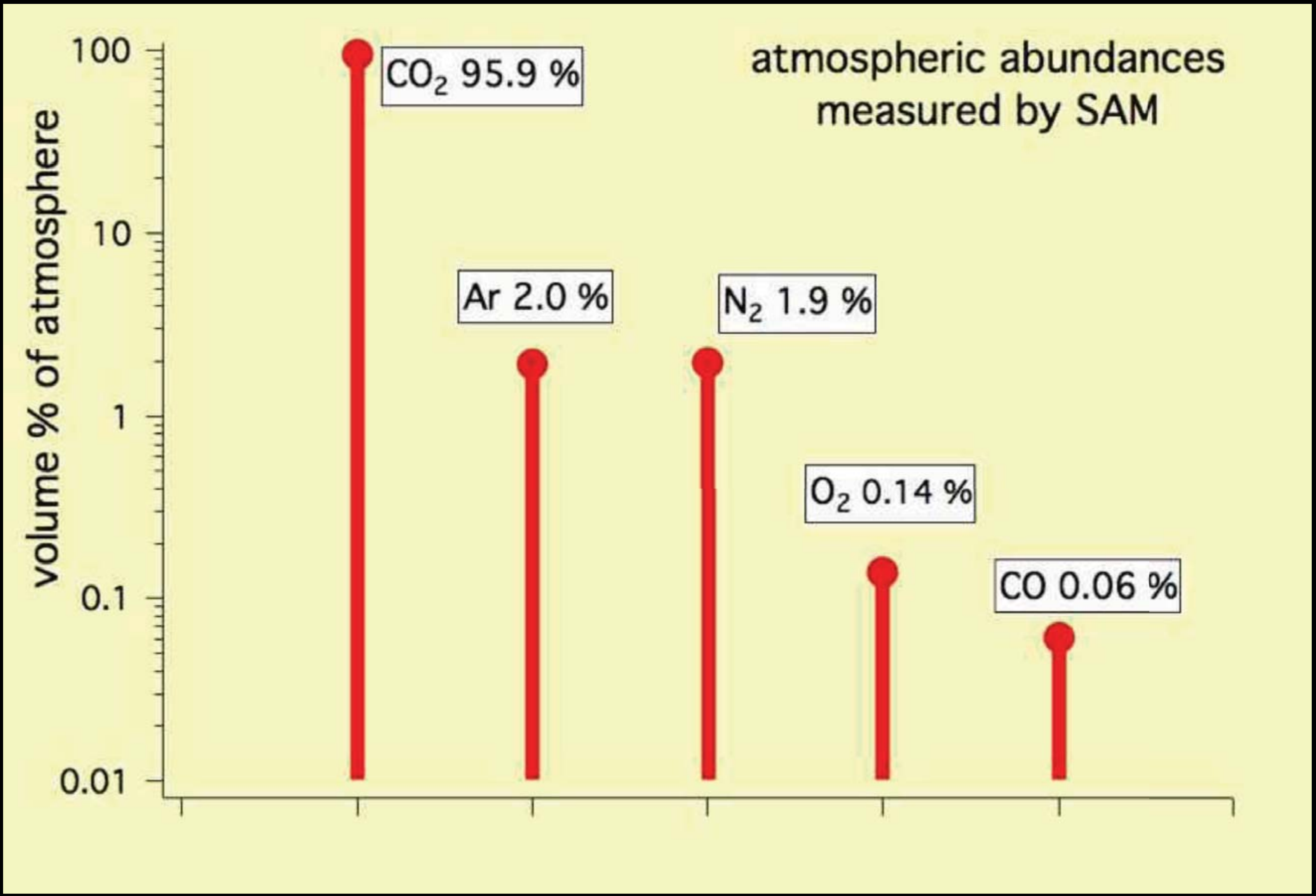
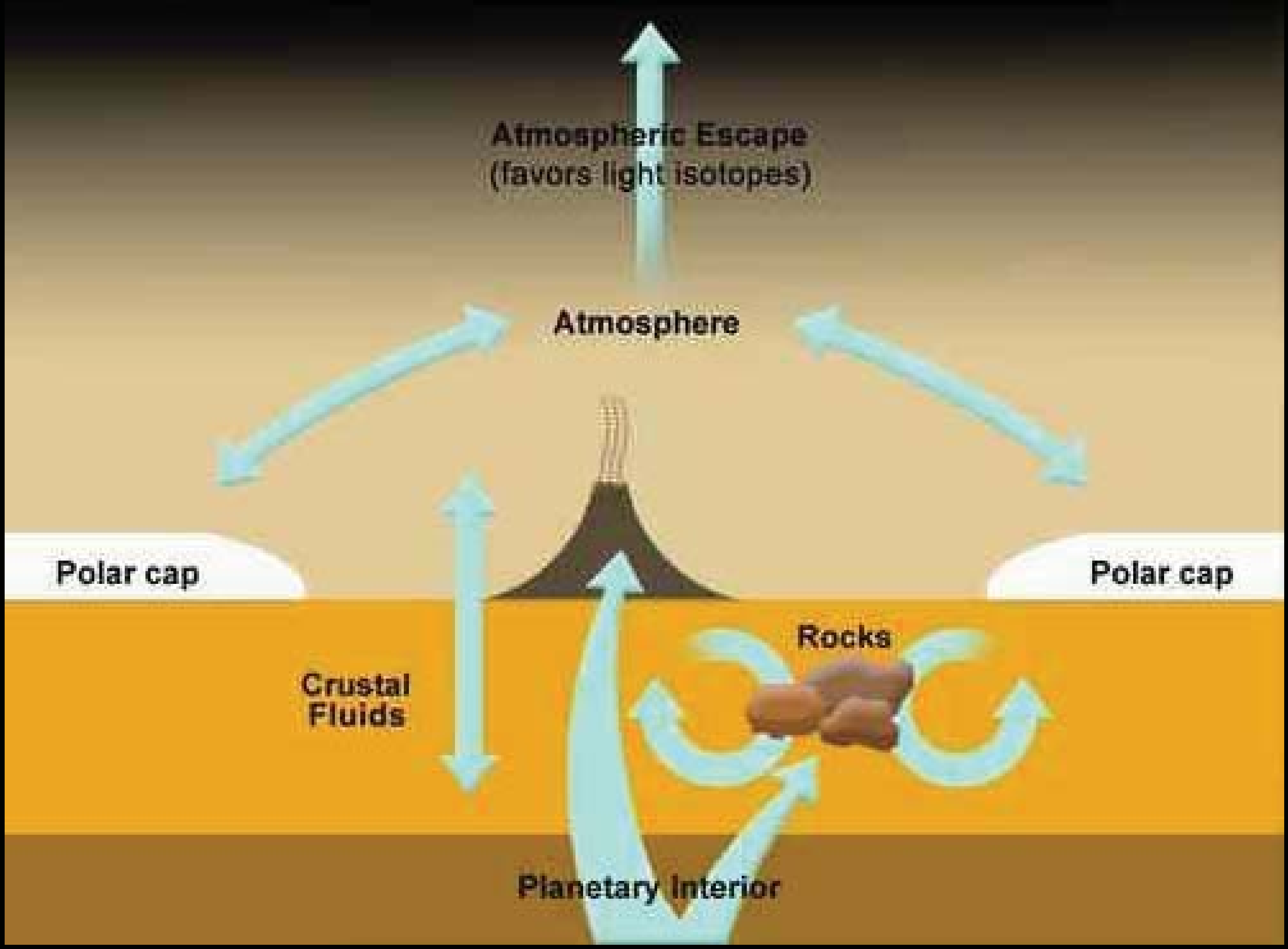


Figure 2

SAM Analyzes the Martian Atmosphere



Volatiles on Mars: Simplified Reservoirs and Interactions



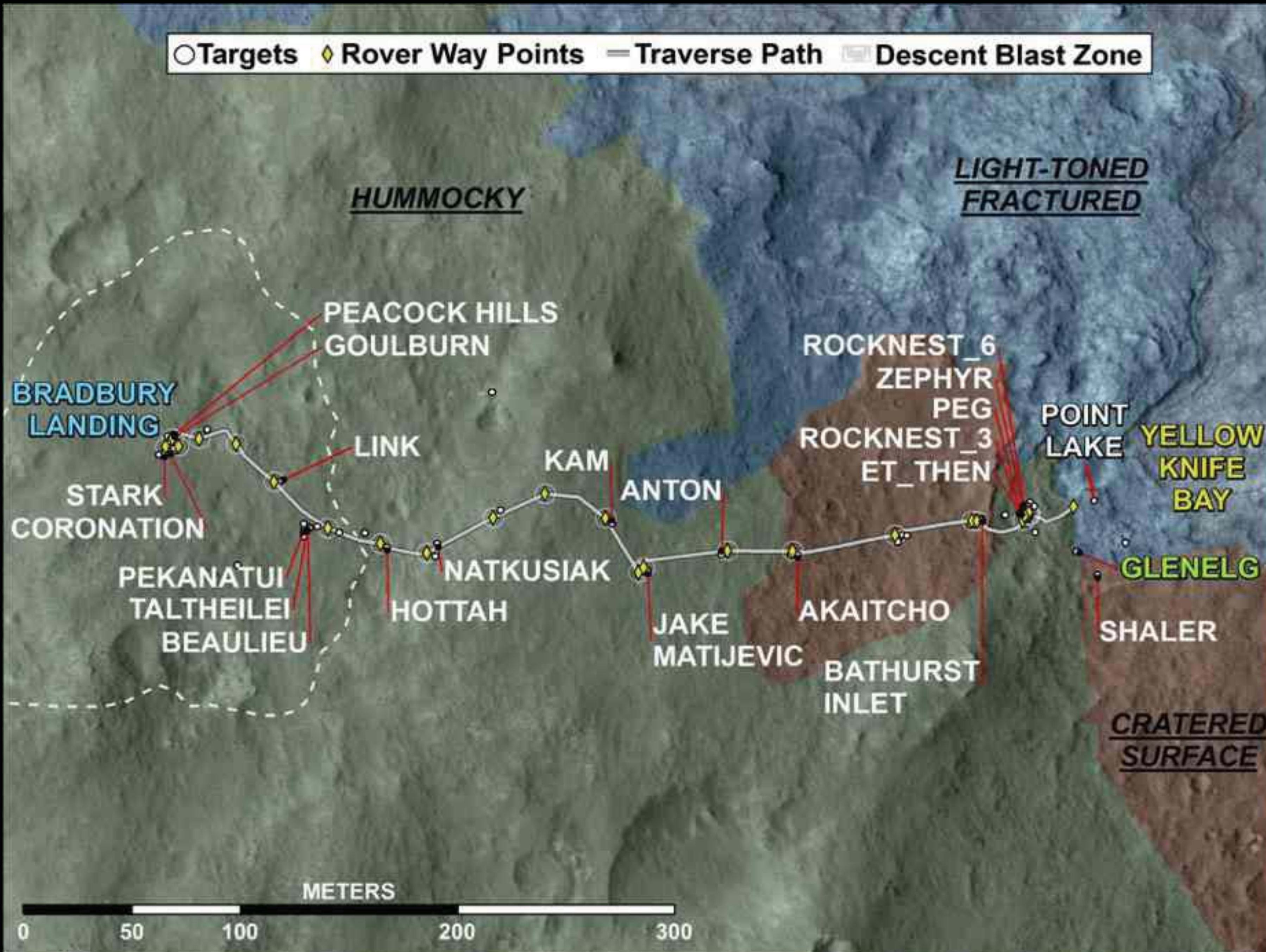
Habitability potential: Present Mars

- The soil is oxidized and has water associated with a component that is either amorphous or so fine-grained it cannot be characterized by CheMin.
- There is a carbon source– we see evolved CO_2
- The surface environment is dynamic
- The atmospheric measurements support the idea of substantial escape
- The flux of cosmic and UV radiation at the martian surface is more substantial than for Earth.
  - On the other hand, if life has evolved here, would it adapt its metabolic and repair mechanisms to take advantage of this?

Habitability potential: Past Mars

- Elemental chemistry is rather benign
- If there is sedimentary rock that has water associated with it AND we have evidence of aqueous deposition and weathering (e.g., presence of conglomerates, sedimentary structures and minerals that are chemical precipitates, etc.), we have interfaces that can be exploited.
- There is a carbon source– we see evolved CO_2. We have only looked at one rock with SAM and CheMin but we have promising evidence of more than one redox state.
- The atmospheric measurements support the idea of substantial escape.
- The flux of radiation at the martian surface became more substantial when (a) Mars lost its magnetic field and (b) the atmosphere thinned

Where are we now?

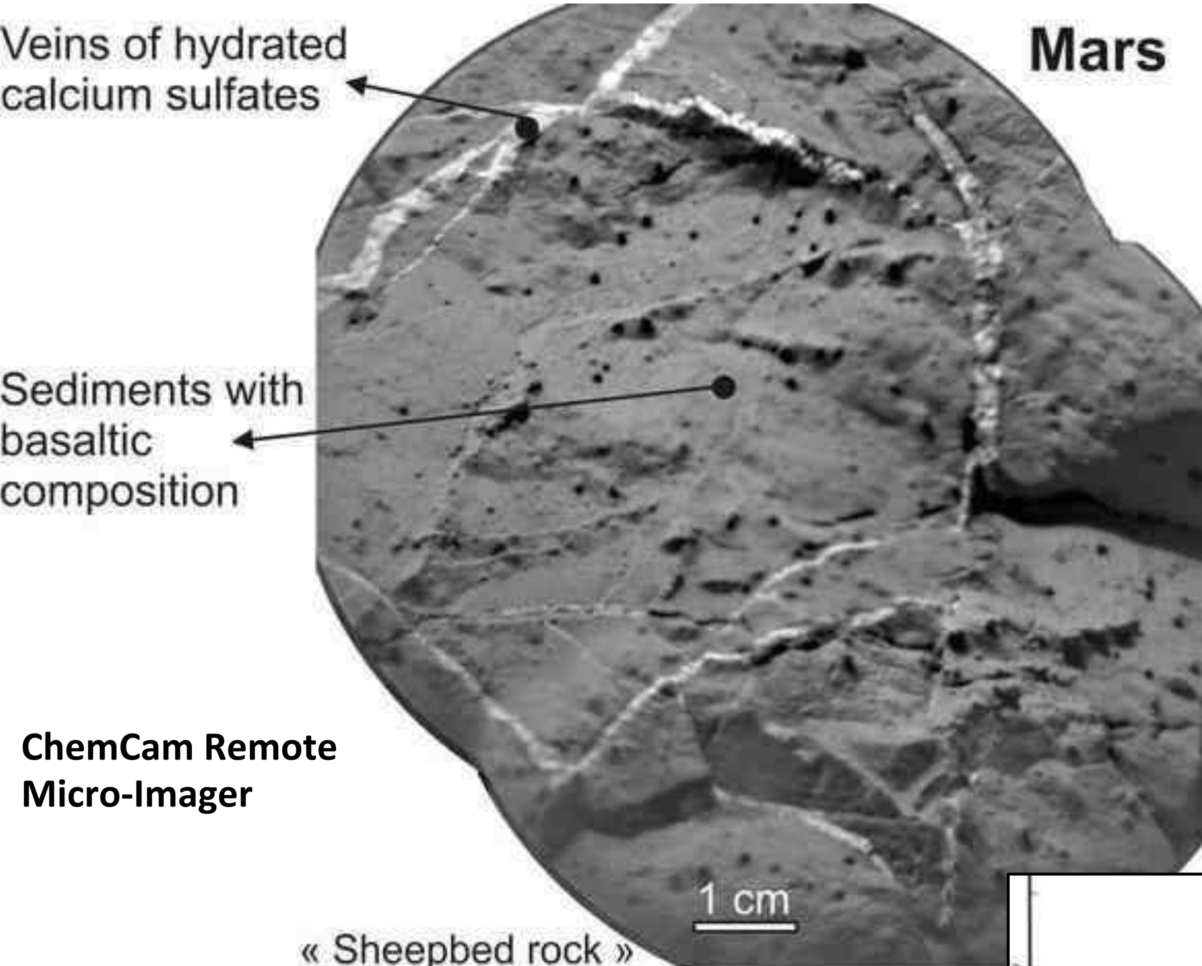


Drill Campaign at John Klein, Yellowknife Bay

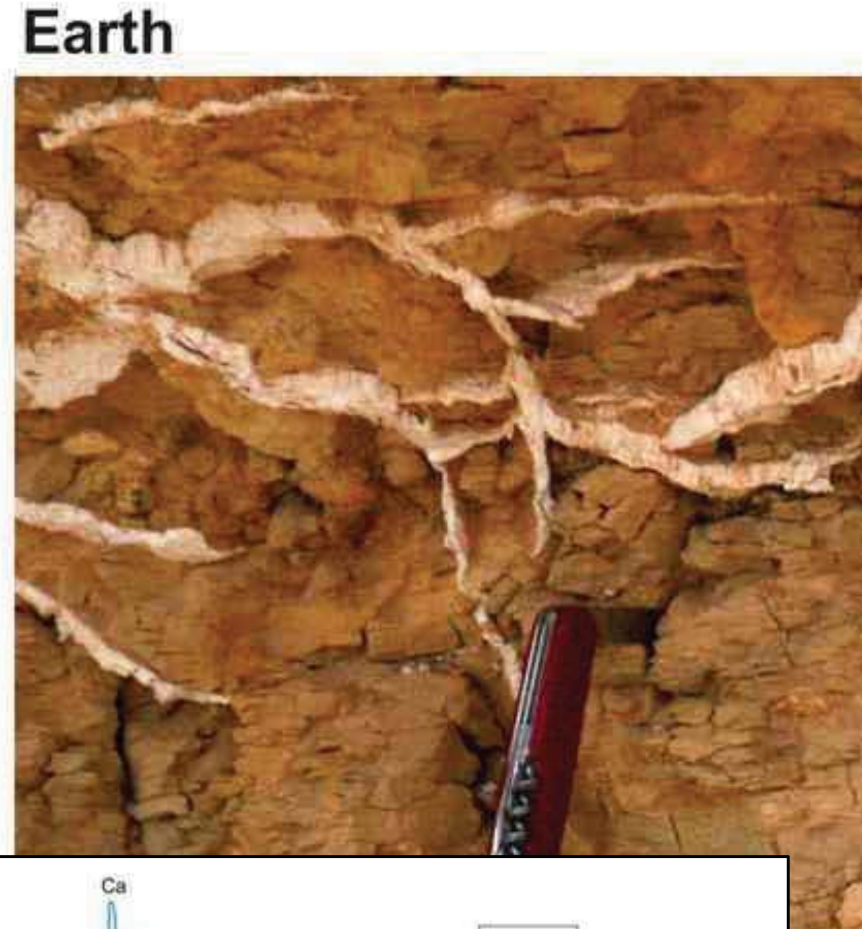
NASA/JPL-Caltech/MSSS

Heading into Yellowknife Bay

Postcards from Yellowknife Bay showing a diversity of rock types, fractures, and veins



ChemCam Remote Micro-Imager



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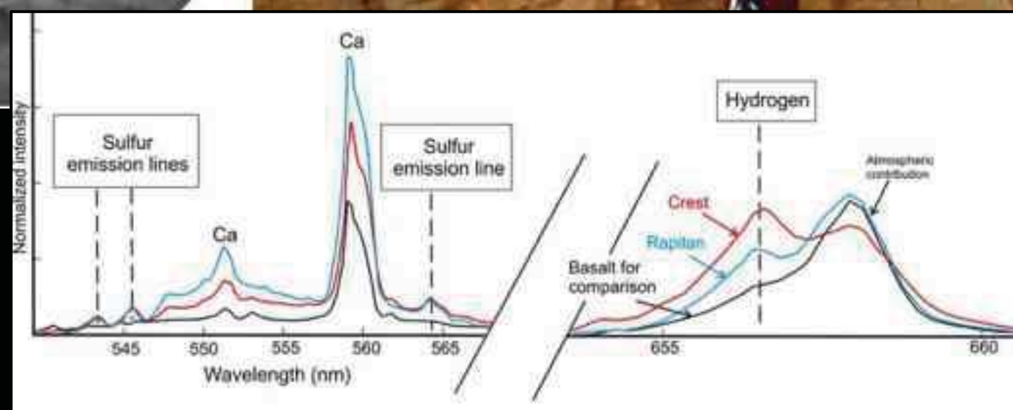
LPGN/CNRS/LGLyon/Planet-Terre

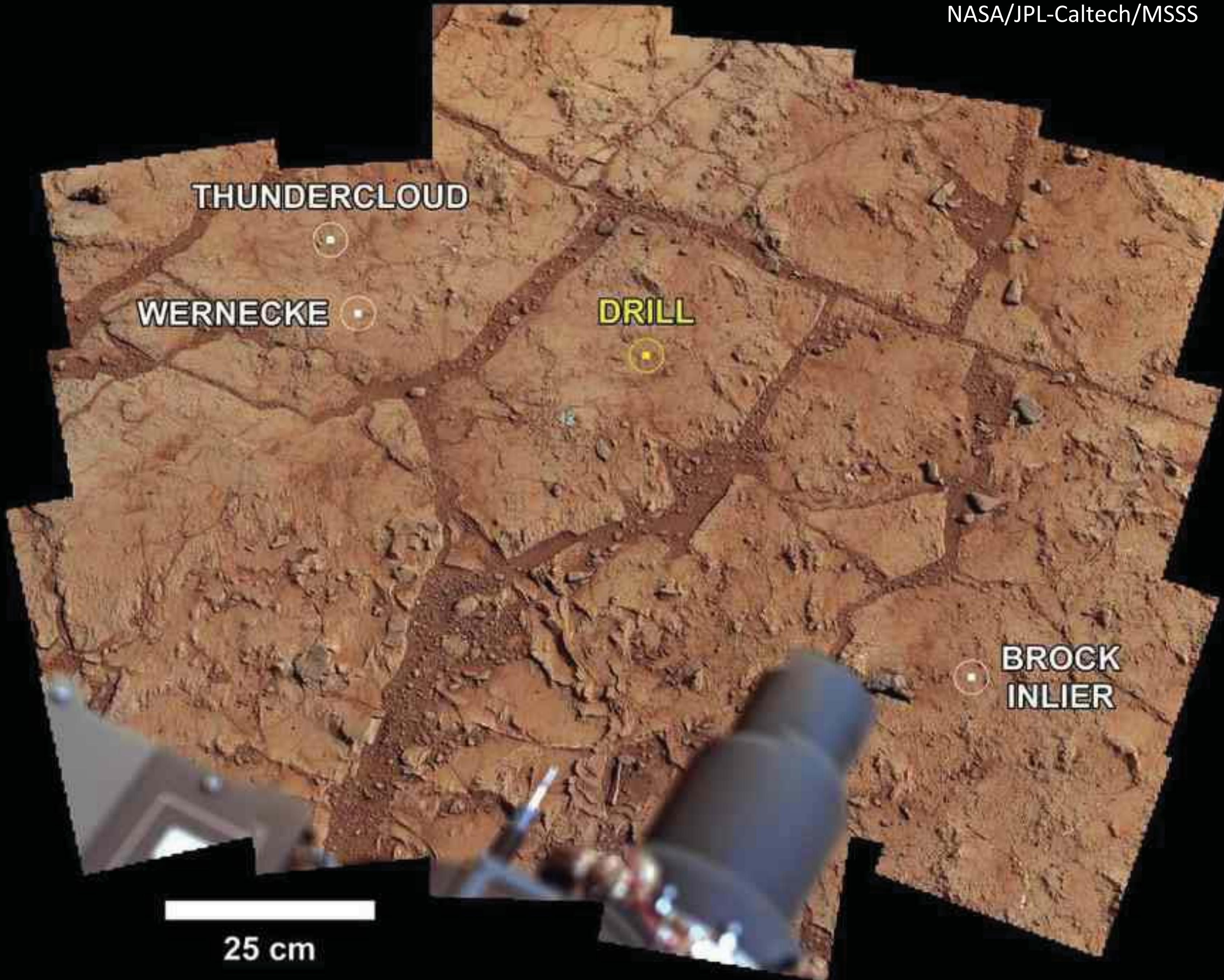
ChemCam spectra from sol 125 "Crest" and 135 "Rapitan"



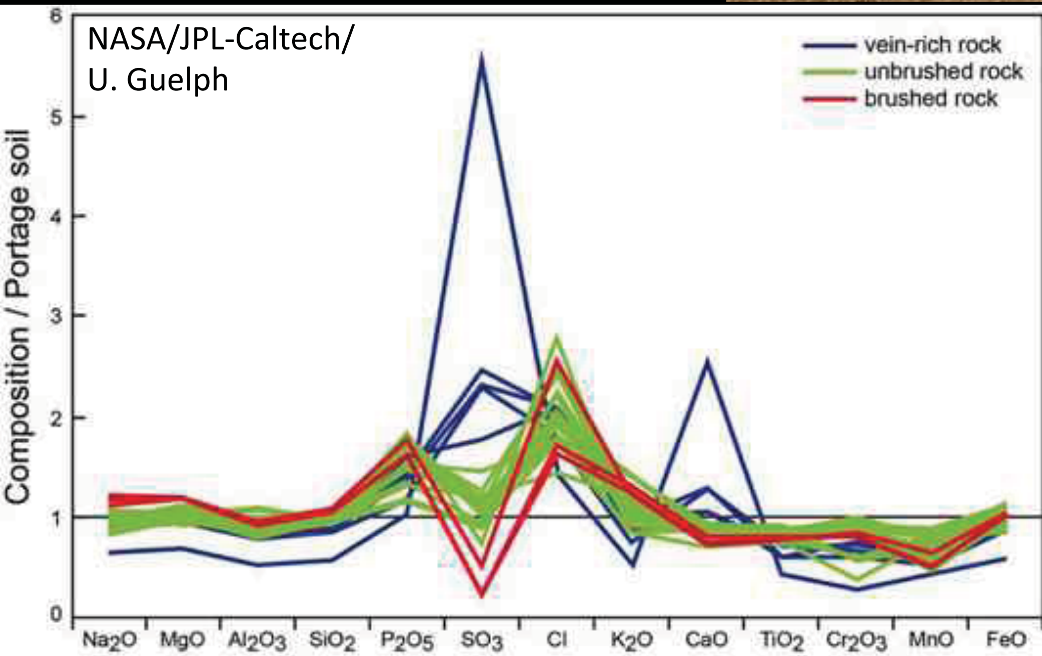
"Sheepbed" rocks contain 1 to 5-mm fractures filled with calcium sulfate minerals that precipitated from fluids at low to moderate temperatures

NASA/JPL-Caltech/MSSS

John Klein drill site showing fractured bedrock and ridge-forming veins

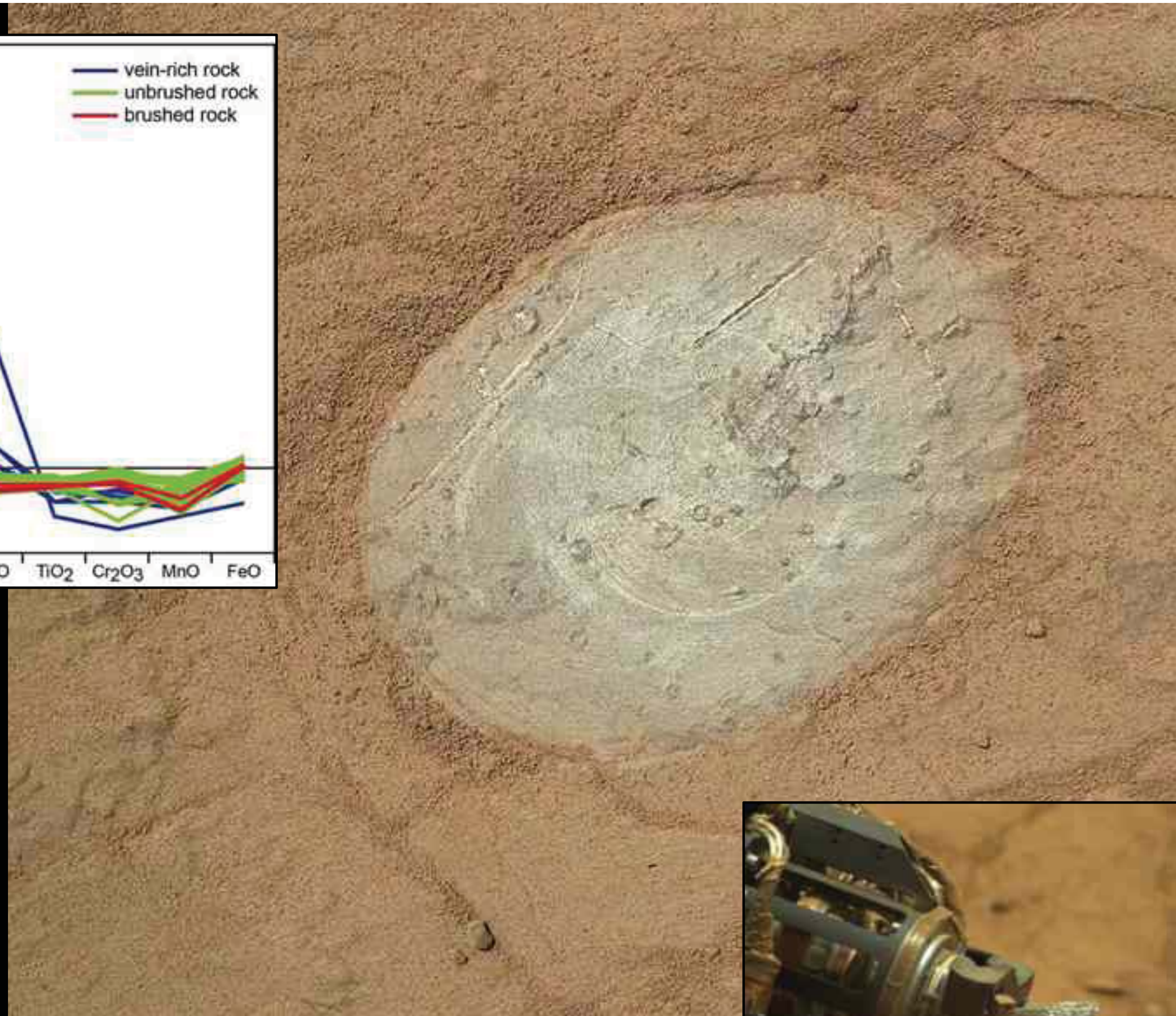


Targets studied to prepare for drilling



APXS sees higher sulfur and calcium in vein-rich rock

Removing the dust results in slightly lower sulfur



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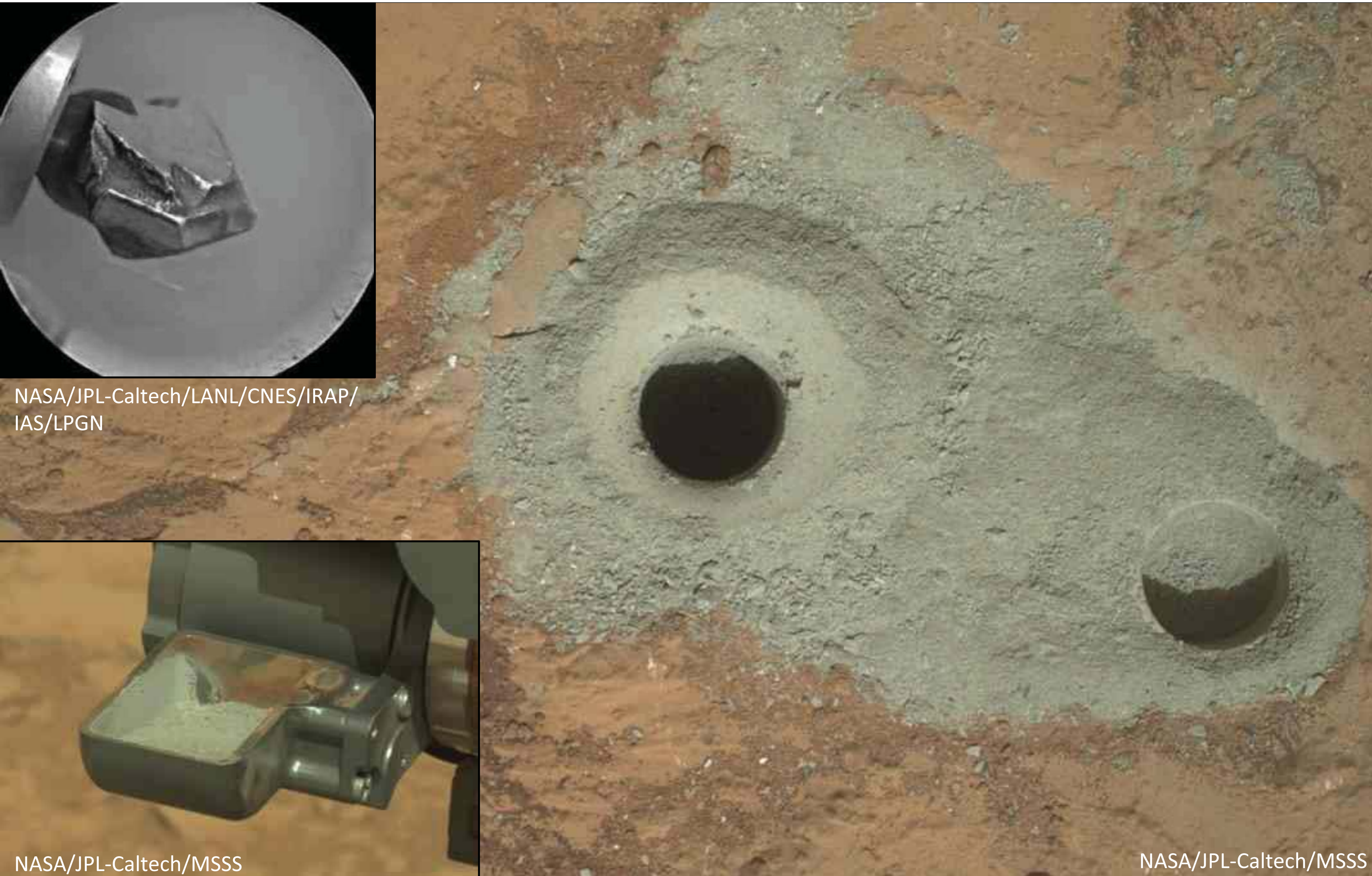
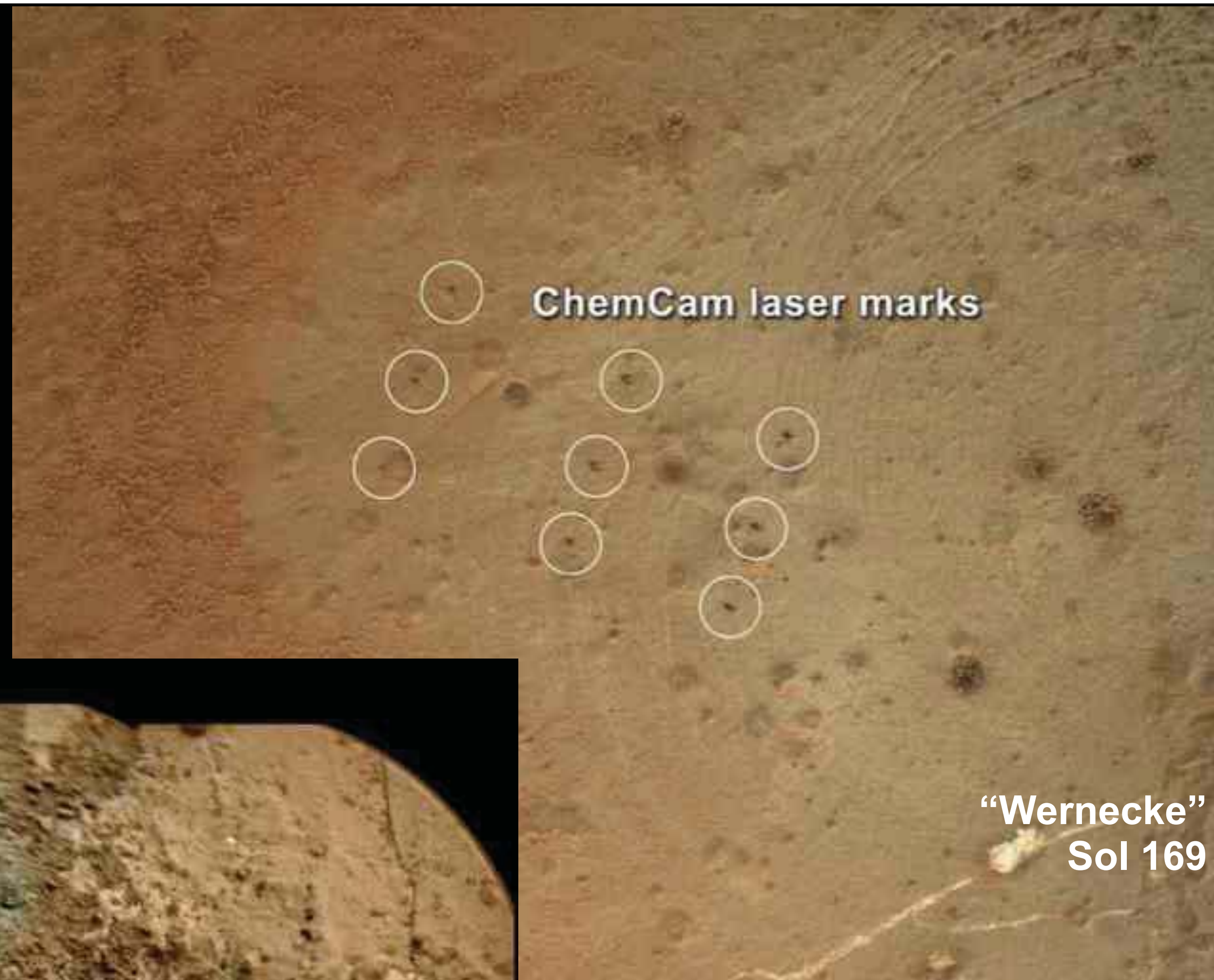
APXS and the dust-removing brush

NASA/JPL-Caltech/D. Bouic

Arm deployed at John Klein

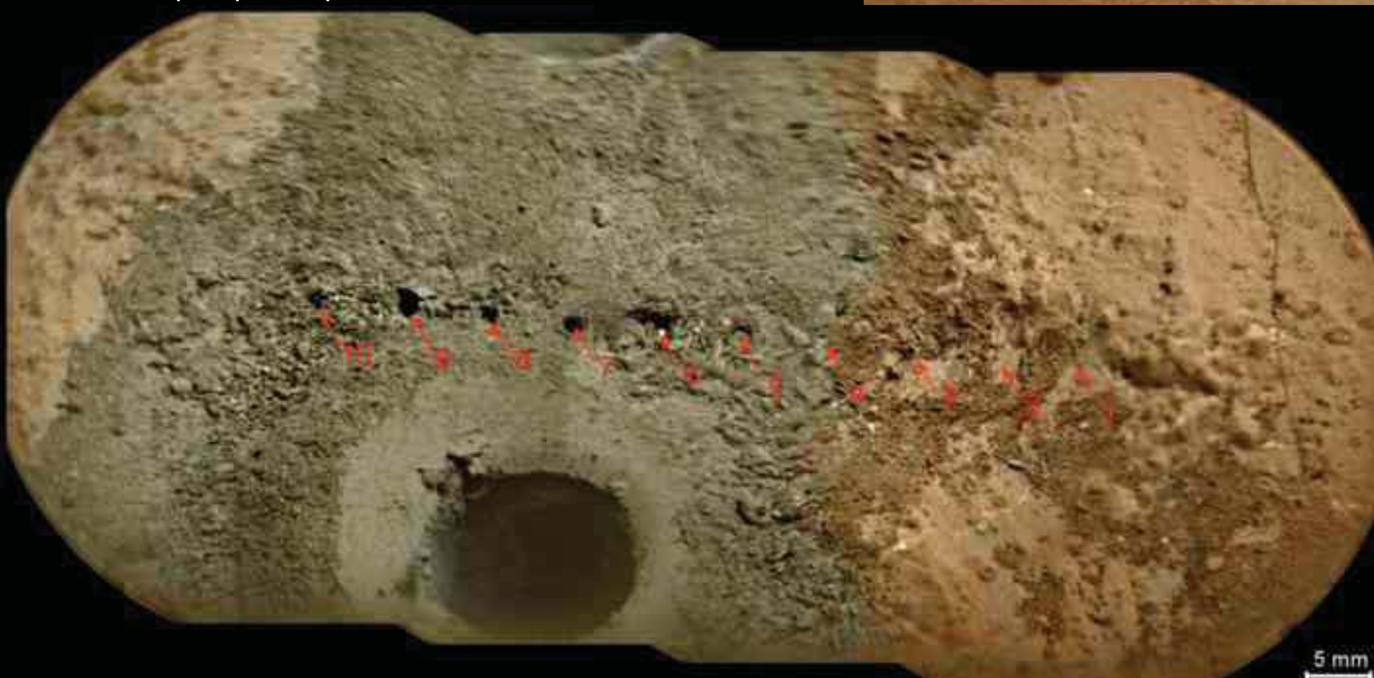


Curiosity's 1.6-cm drill bit, drill and test holes, and scoop full of acquired sample

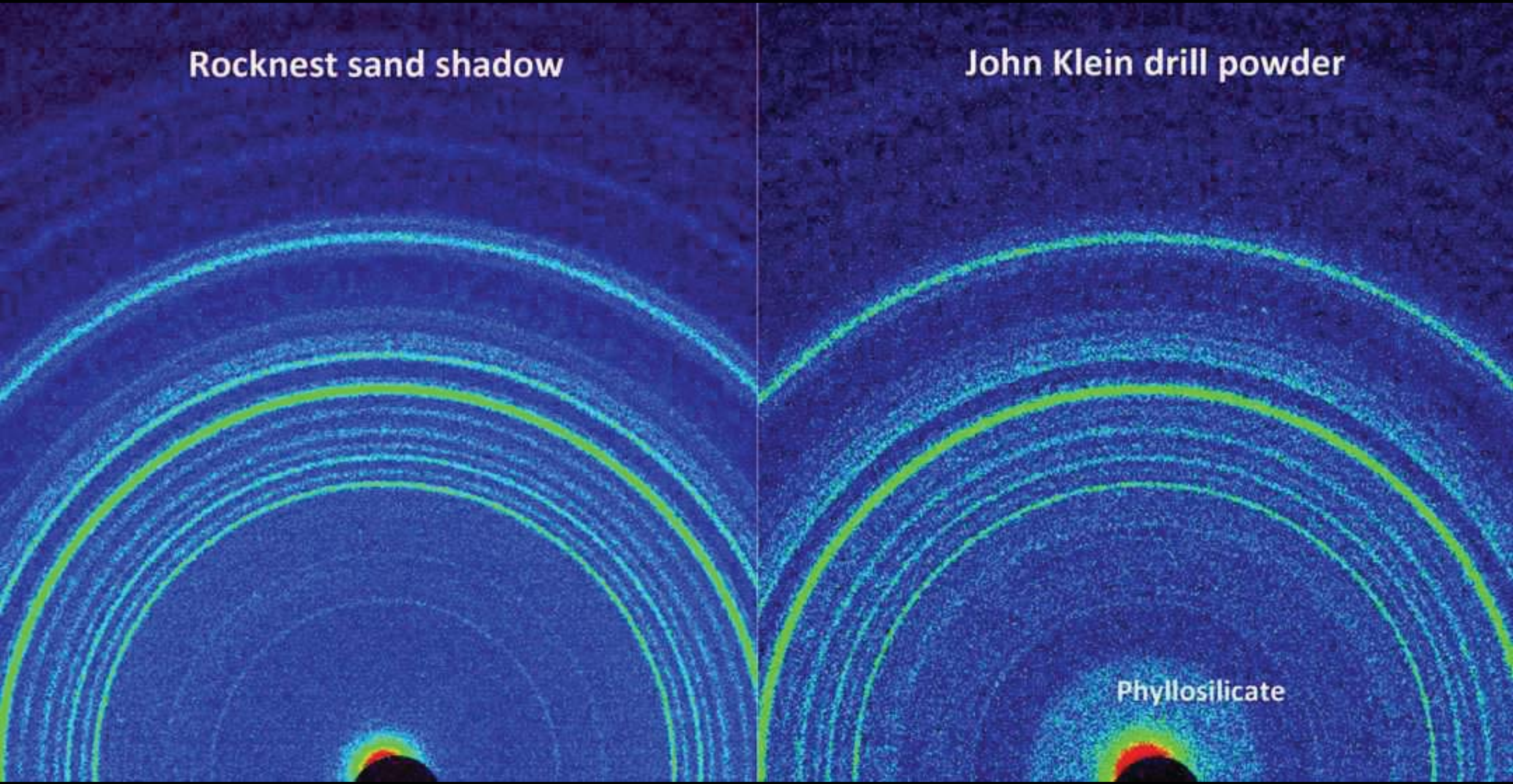


NASA/JPL-Caltech/MSSS/Honeybee
Robotics/LANL/CNES

NASA/JPL-Caltech/LANL/IRAP/CNES/
LPGNantes/IAS/CNRS/MSSS



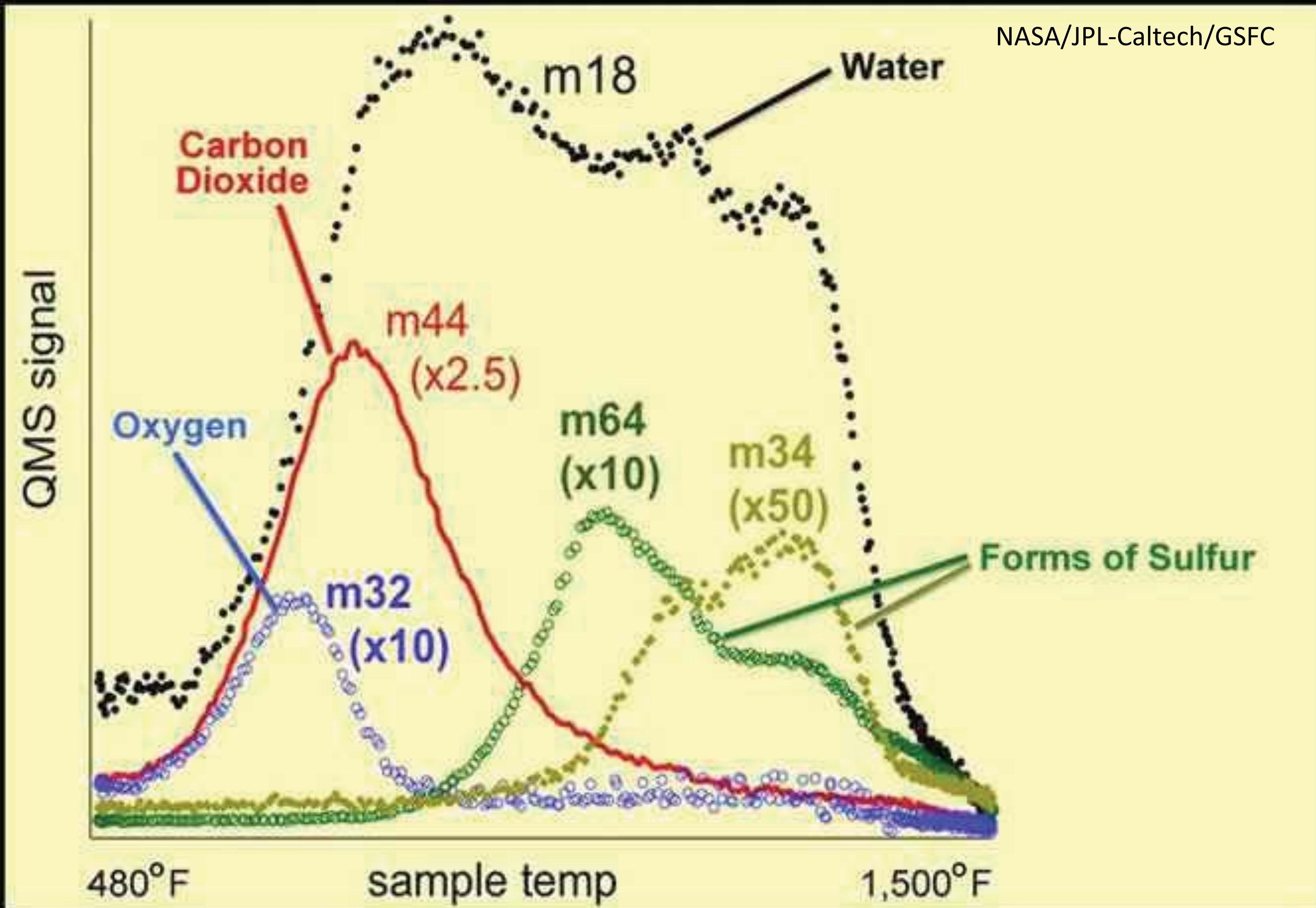
ChemCam laser shots of brushed rock and drill tailings pile



NASA/JPL-Caltech/Ames

The drill powder contains abundant phyllosilicates (clay minerals), indicating sustained interaction with water

X-ray diffraction patterns from Rocknest (left) and John Klein (right)

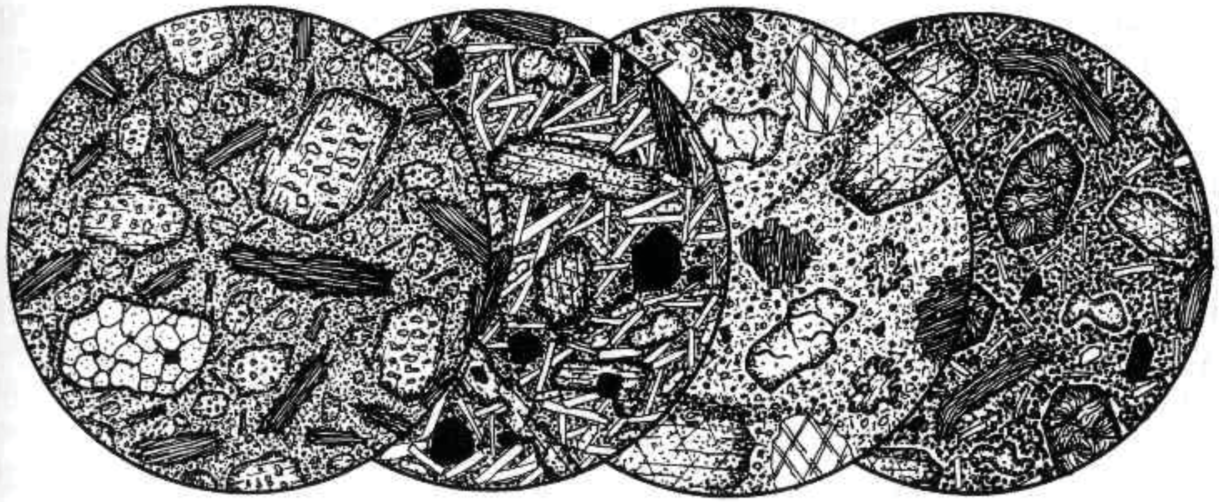


SAM analysis of the drilled rock sample reveals water, carbon dioxide, oxygen, sulfur dioxide, and hydrogen sulfide released on heating. The release of water at high temperature is consistent with smectite clay minerals.

Major gases released from John Klein sample and analyzed by SAM

Curiosity's ultimate goal is to explore the lower reaches of the 5-km high Mount Sharp

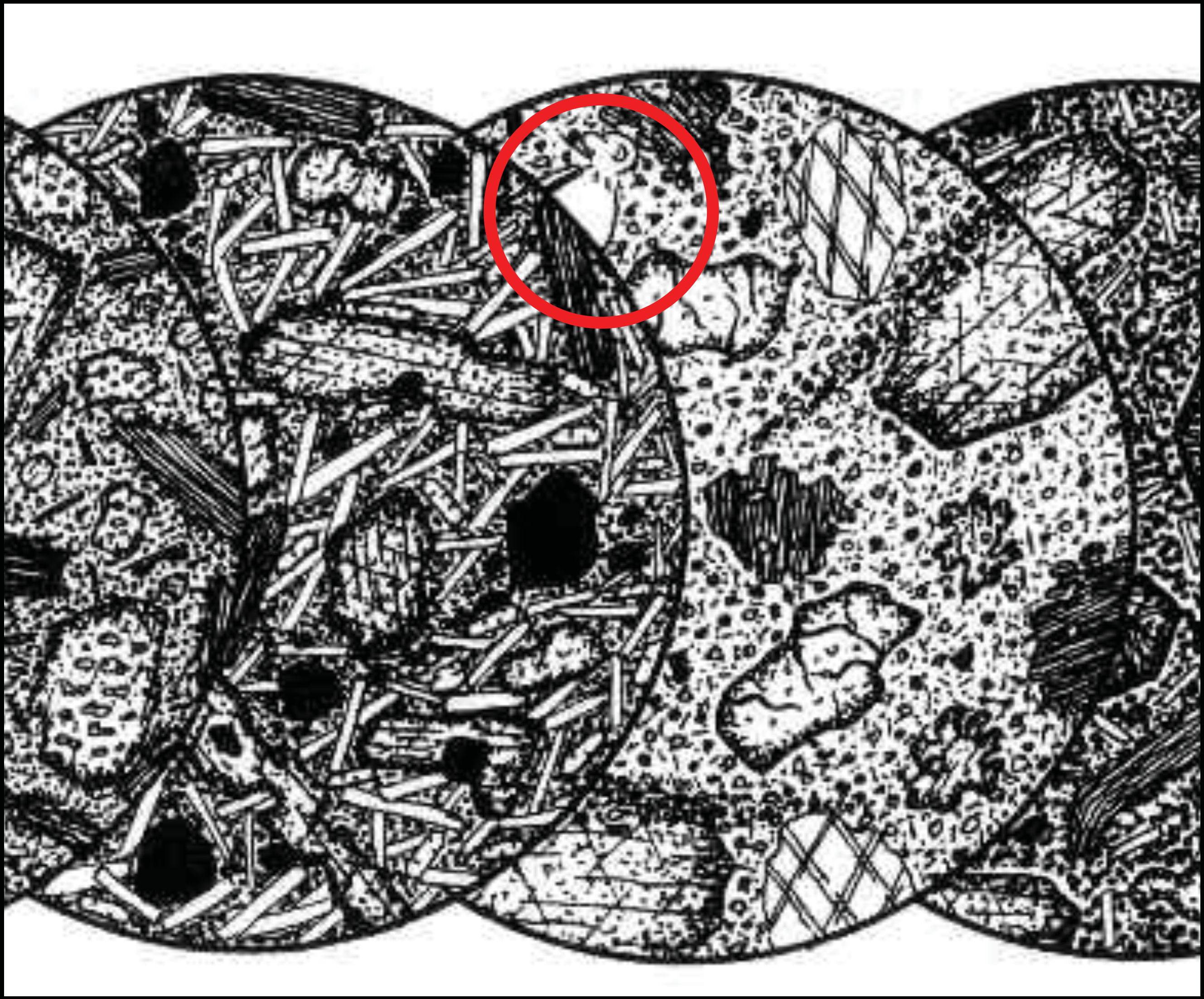
One last thing before questions…



(a) (b) (c) (d)

Figure 11–19 Petrographic features of lamprophyres and kimberlite. (a) A calc-alkaline biotite lamprophyre (minette) from a volcanic neck in the Navajo region of Arizona contains reddish-brown biotite with oxidized rims, zoned augite, orthoclase, magnetite, and abundant accessory apatite. A small altered xenolith of granitic basement rock is shown at the left edge. (b) An alkaline lamprophyre (camptonite) from the Oregon Coast Range contains phenocrysts of dark-brown barkevikite, Ti-augite, and olivine in a groundmass rich in andesine and apatite. (c) An alnoite from the Oka Complex of Quebec has phenocrysts of biotite, augite, and olivine in a matrix of melilite, carbonates, perovskite, magnetite, and apatite. (d) A kimberlite from the Premier Diamond Pipe of South Africa consists of serpentinized olivine, phlogopite, ilmenite, garnet, and altered rock fragments in a turbid groundmass of calcite, serpentine, and clay.

From McBirney 1993



From McBirney 1993

For more information

http://marsprogram.jpl.nasa.gov/msl/

http://ssed.gsfc.nasa.gov/sam/