

What news about organic molecules ?

Michel Cabane

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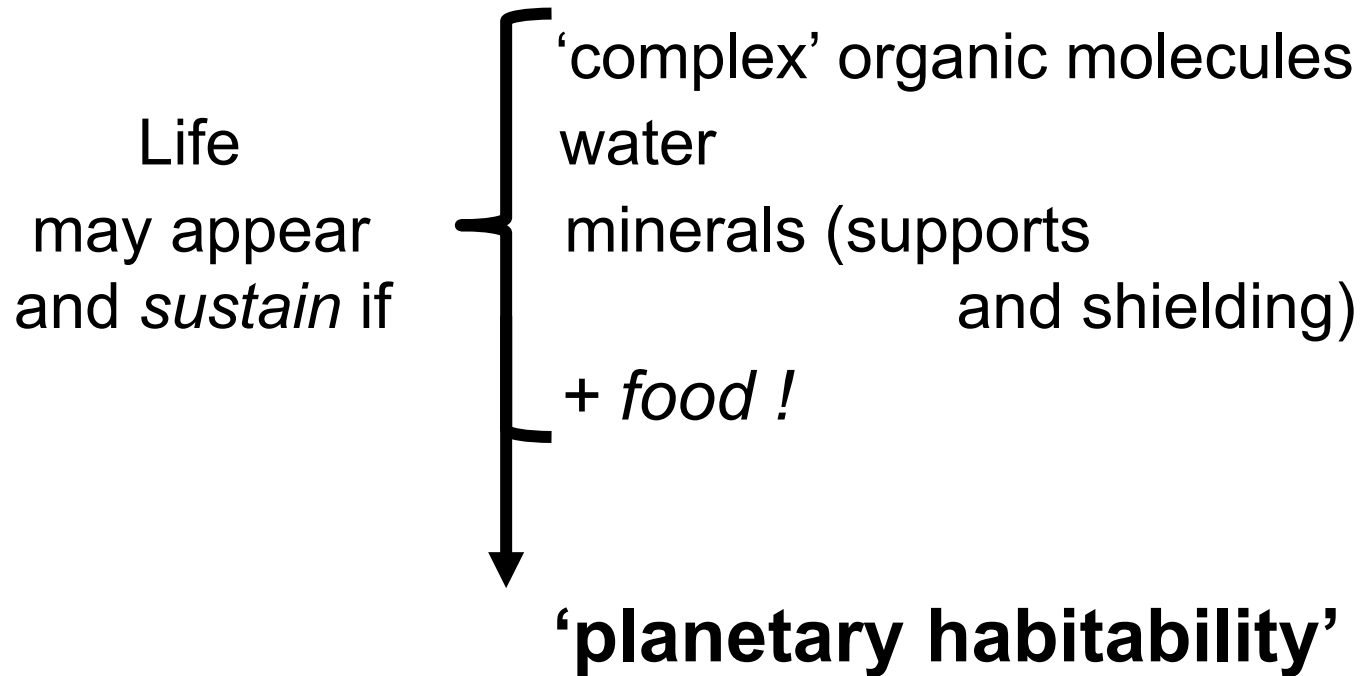
Paris

European Mars Convention 2018

La Chaux de Fonds

October 26-28

What news about habitability ?

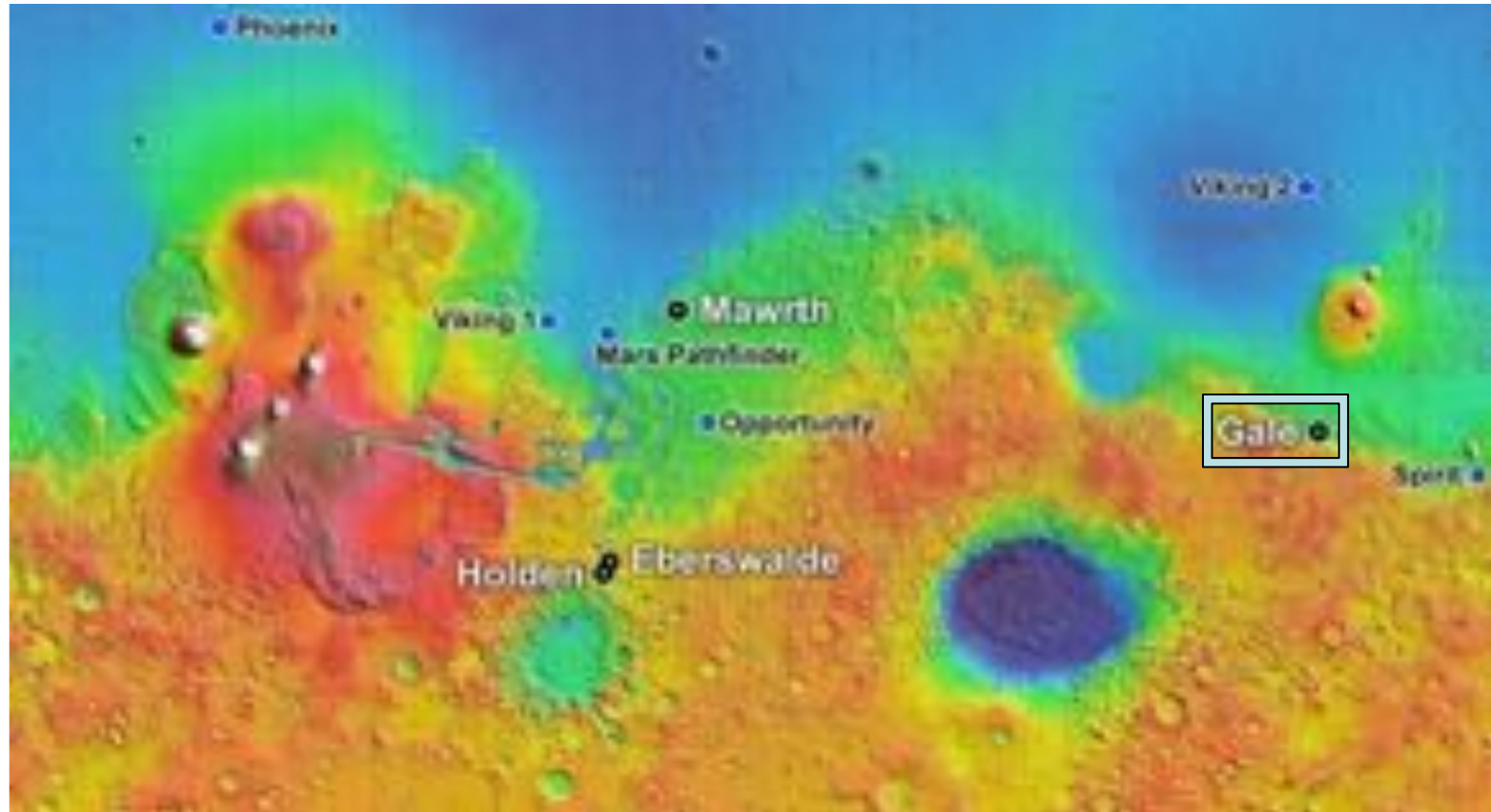


The 'Mars Science Laboratory' project

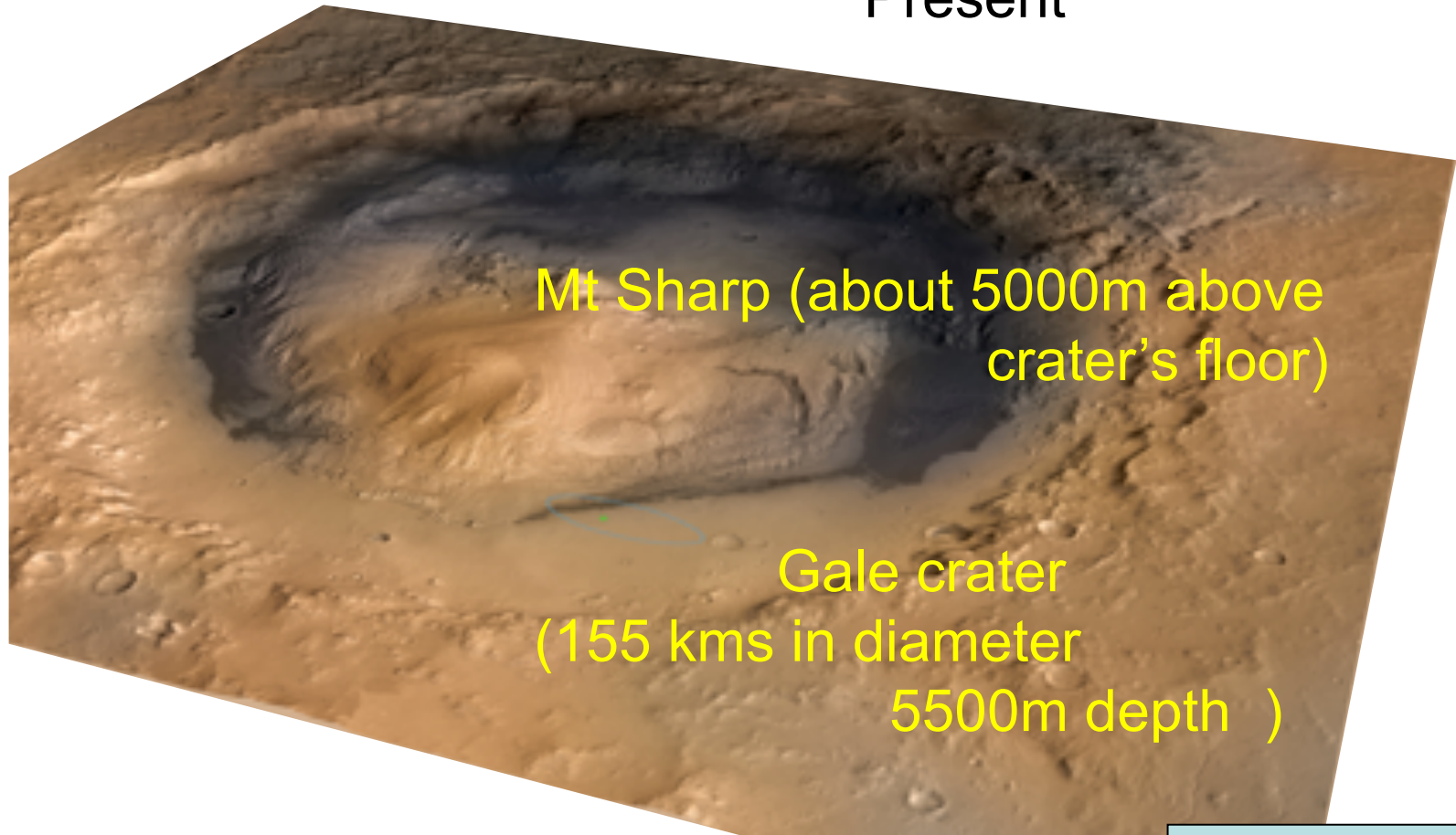




GALE Crater was chosen by MSL project



Present

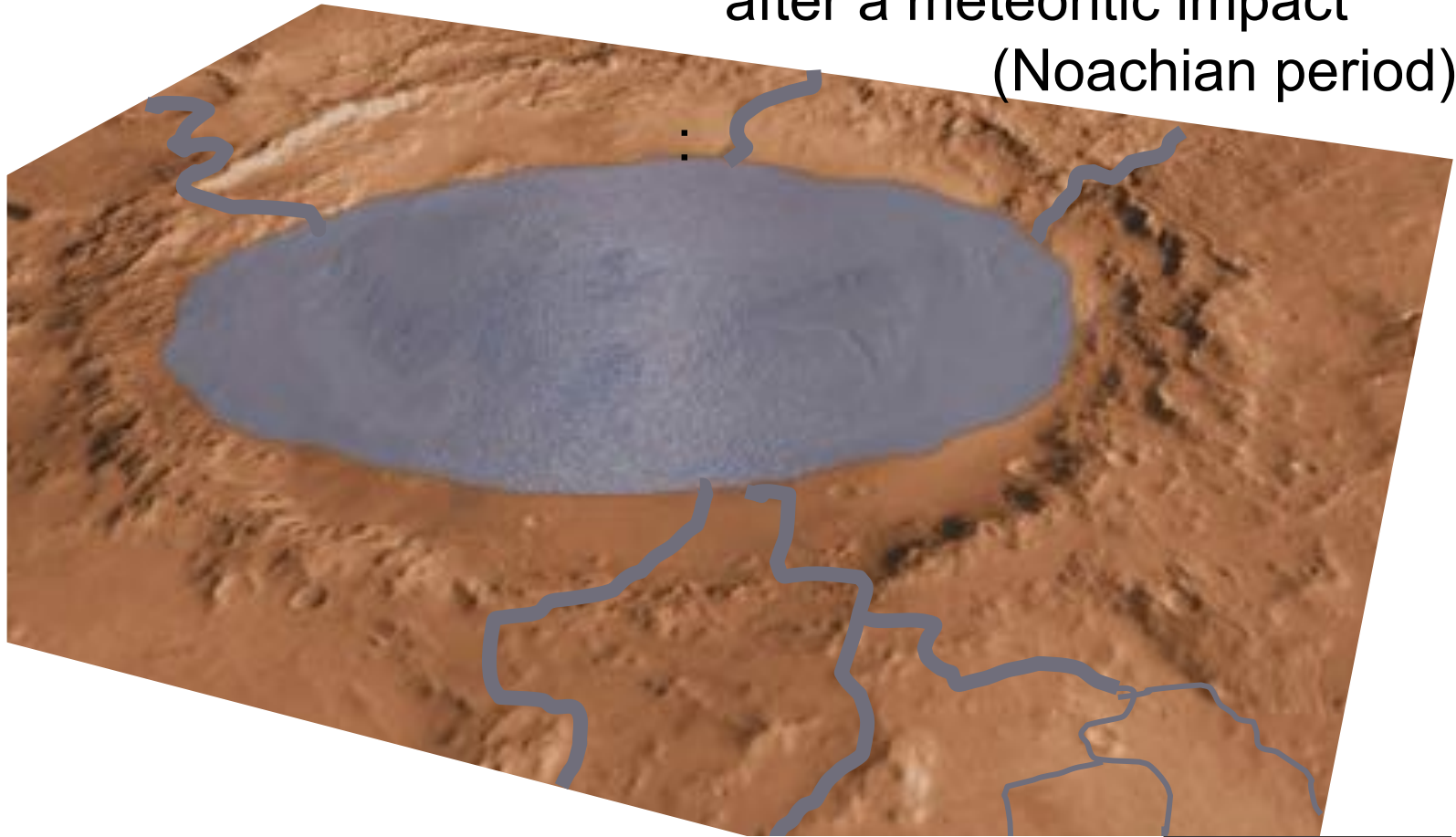


Mt Sharp (about 5000m above
crater's floor)

Gale crater
(155 kms in diameter
5500m depth)

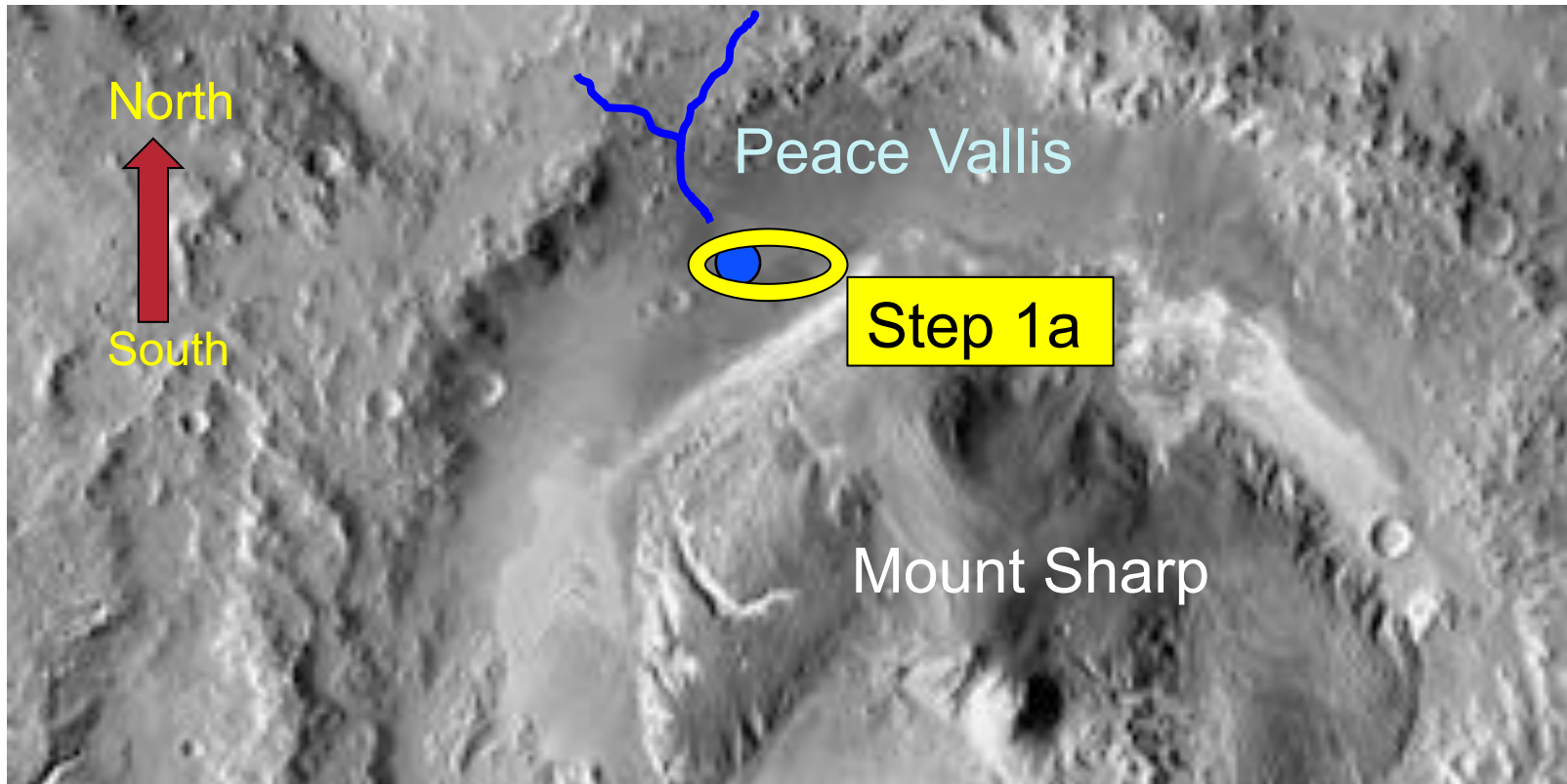
Reconstructed 3D
from MRO images

Building Mt Sharp
after a meteoritic impact
(Noachian period)



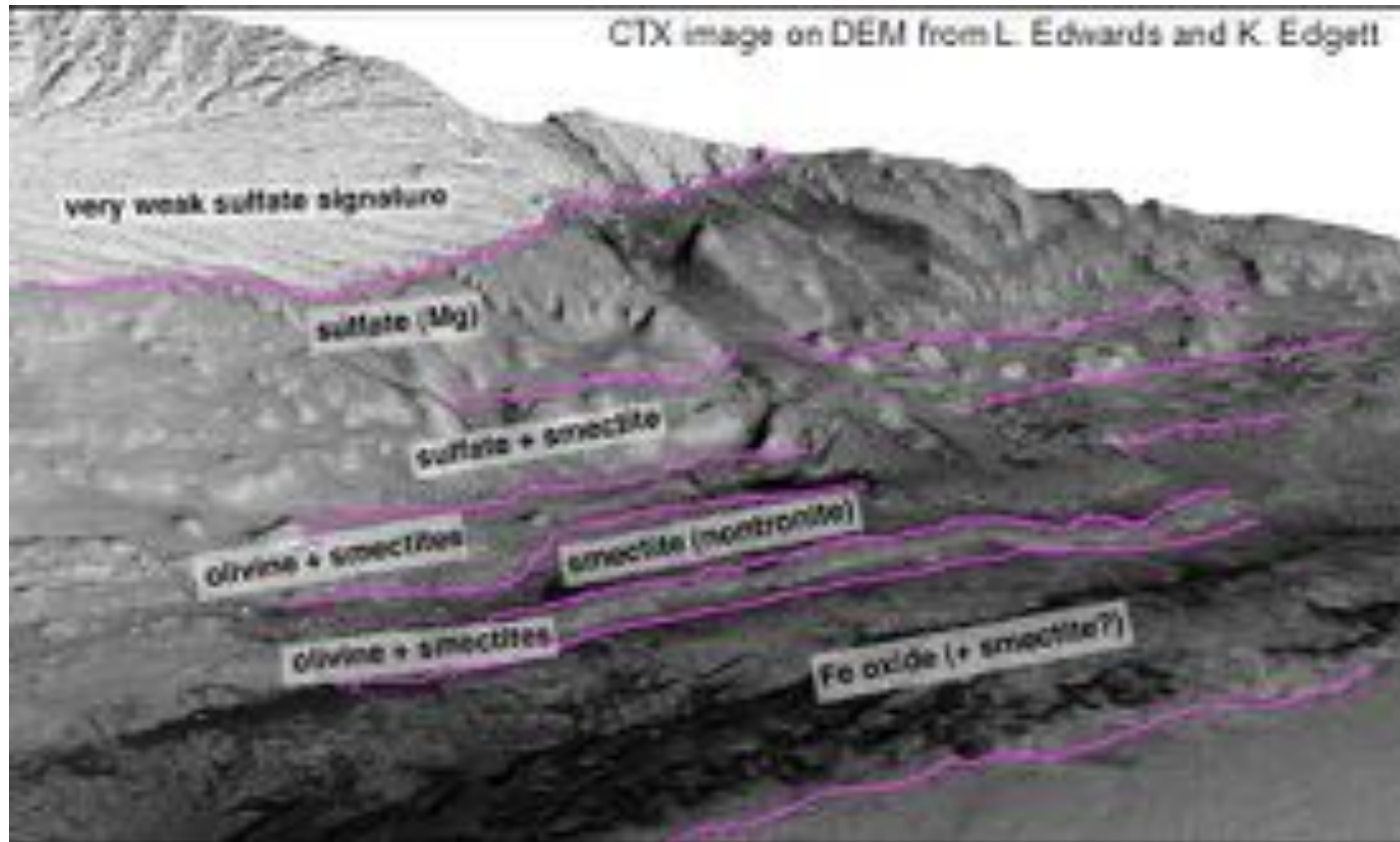
Reconstructed 3D
from MRO image
+ artist view

GALE Crater



Landing site : 'Ray Bradbury' (●)

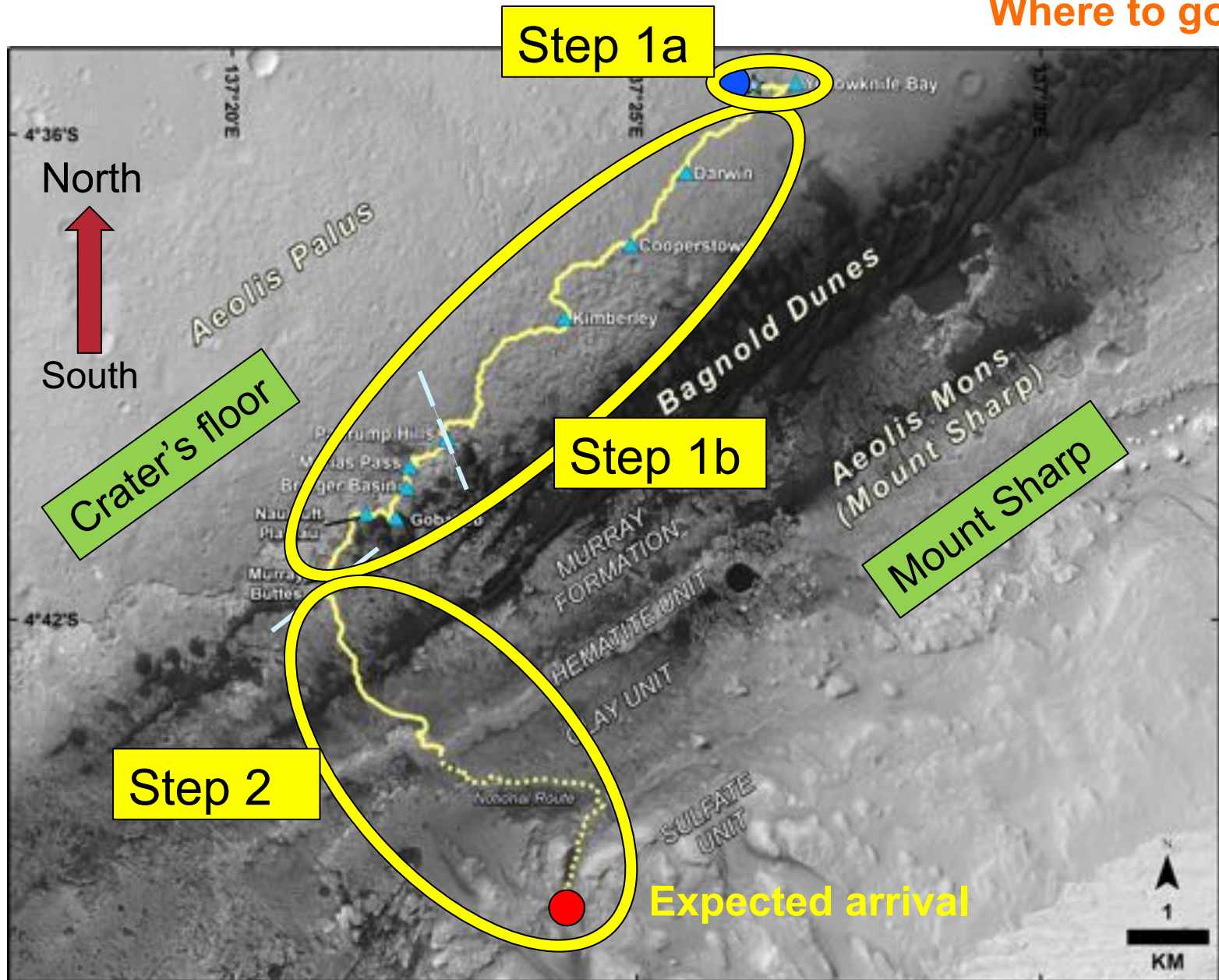
But Mt Sharp is a go-to place !



Layers !

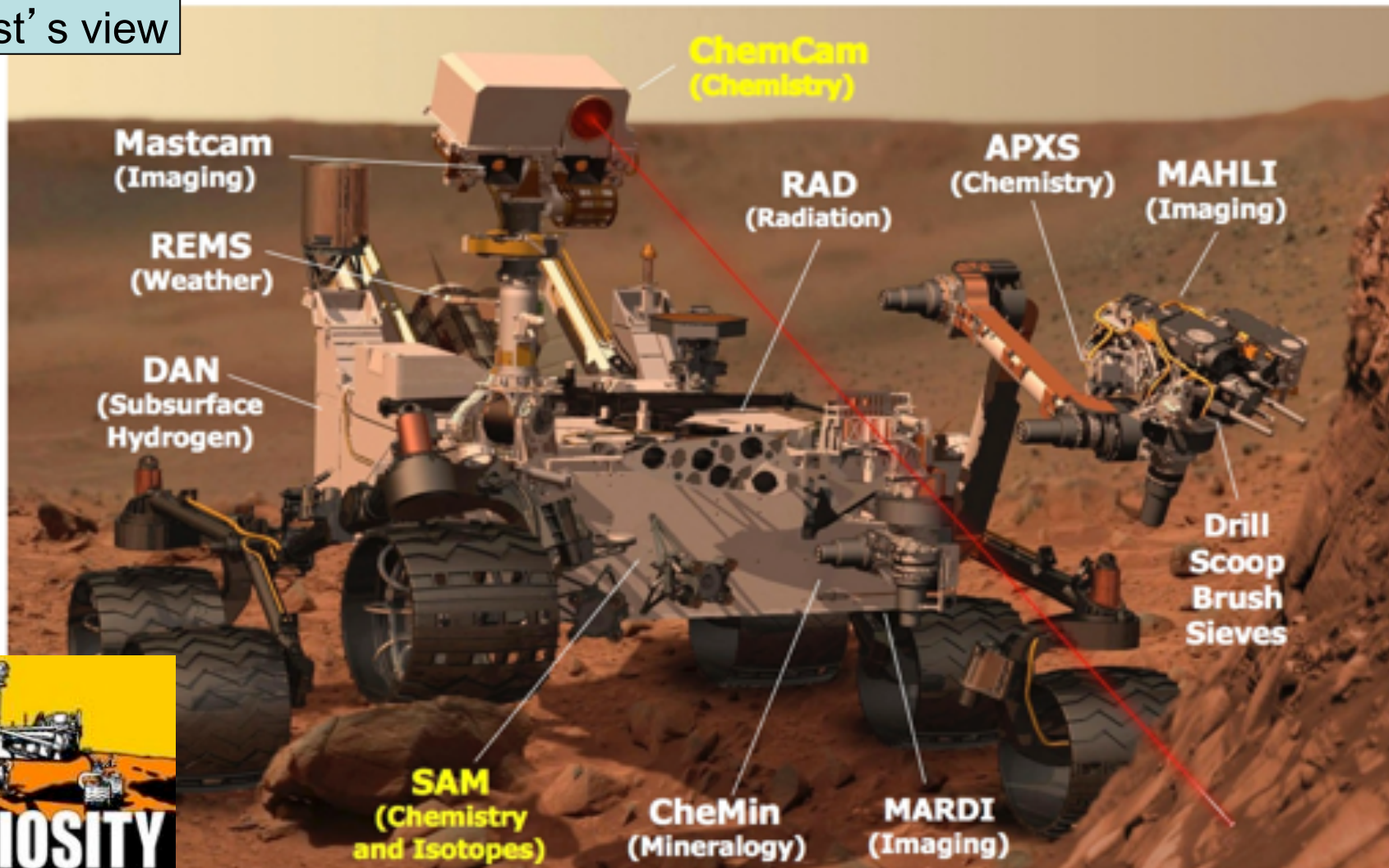
Then ... stratigraphy

Where to go ?



Curiosity and instruments

Artist's view



2mx2mx3m ; 900kg ; Science payload : 80 kg

USA

Germany

Spain

Russia

Canada

France

EMC18
La Chaux de Fonds

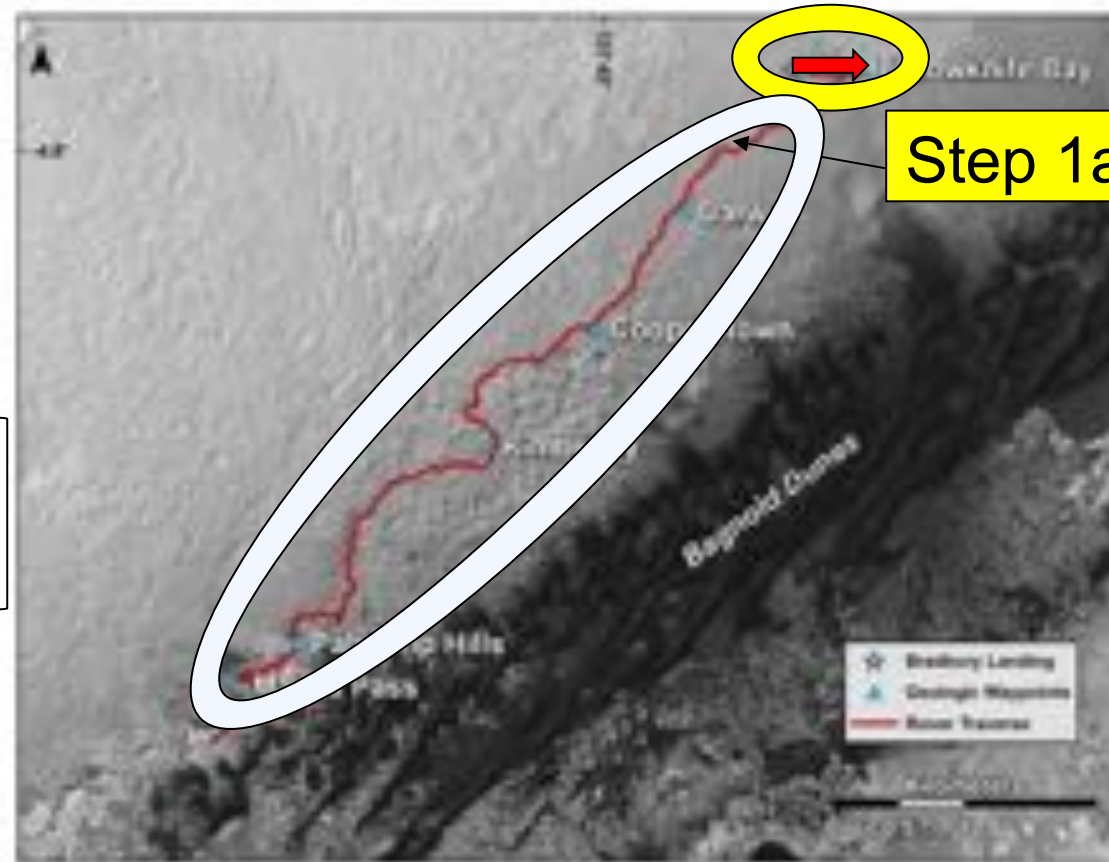
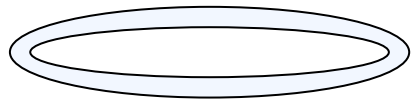
M. Cabane LATMOS
Sorbonne Université

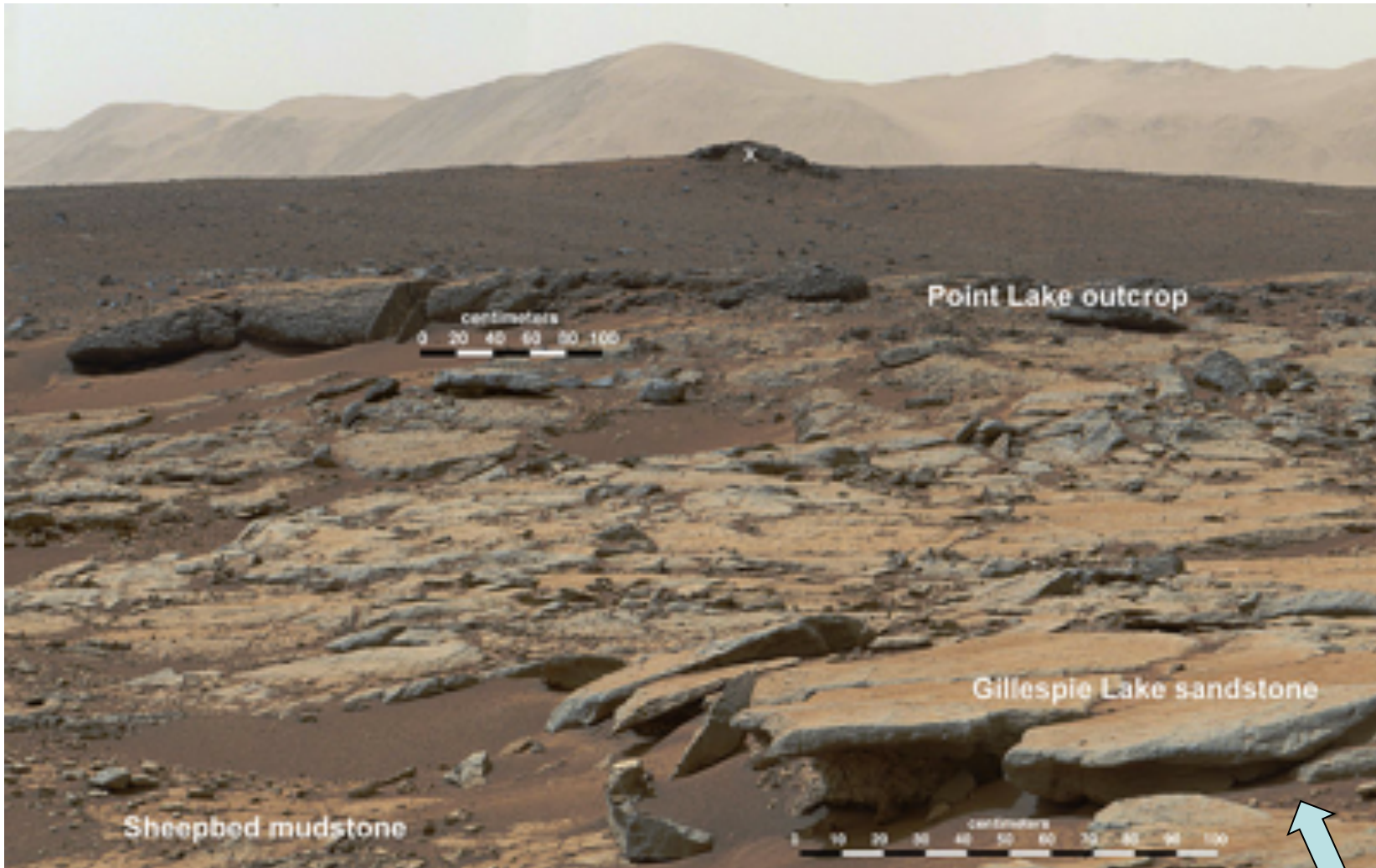
Step 1a : no huge movings ... the alluvial cone

Step 1b : on the way to Mt Sharp

400m traversed
between Sol 1 and
Sol 297

then
step 1b



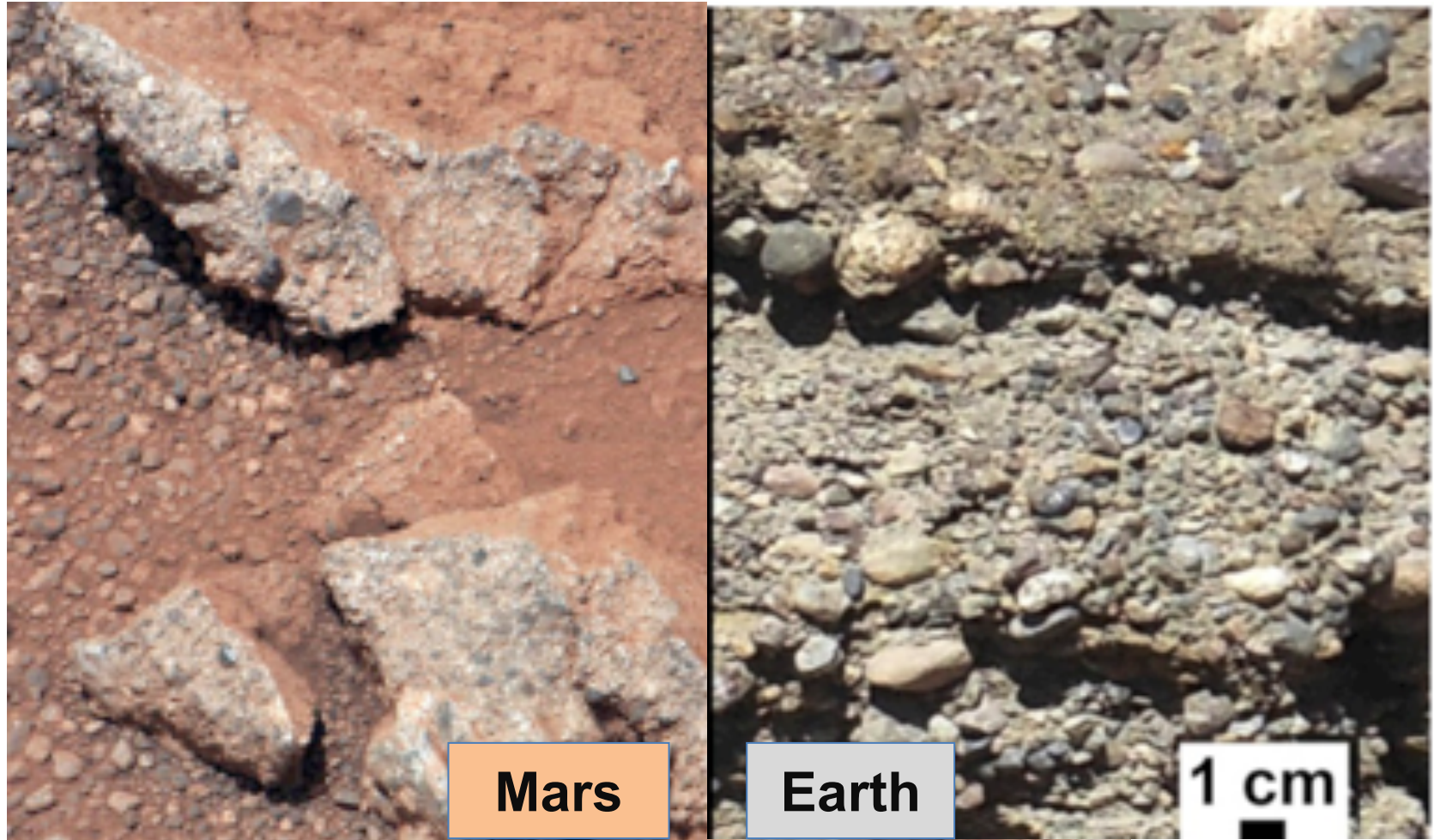


www.nasa.gov/jpl/msl/mars-rover-curiosity-pia17603.html#.W9GNXBMzZqw

Erosion due to winds

Sol 27

1a : alluvial cone
liquid water



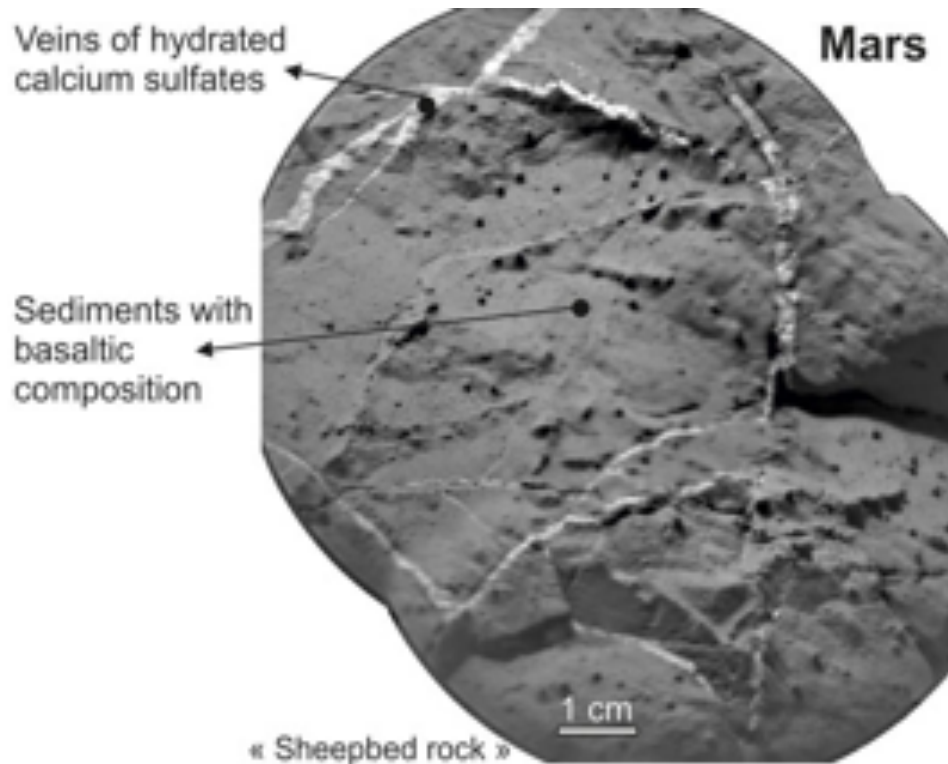
Conglomerates made from pebbles : water was running (torrent)

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Sol 126

1a : alluvial cone
liquid water



Mars

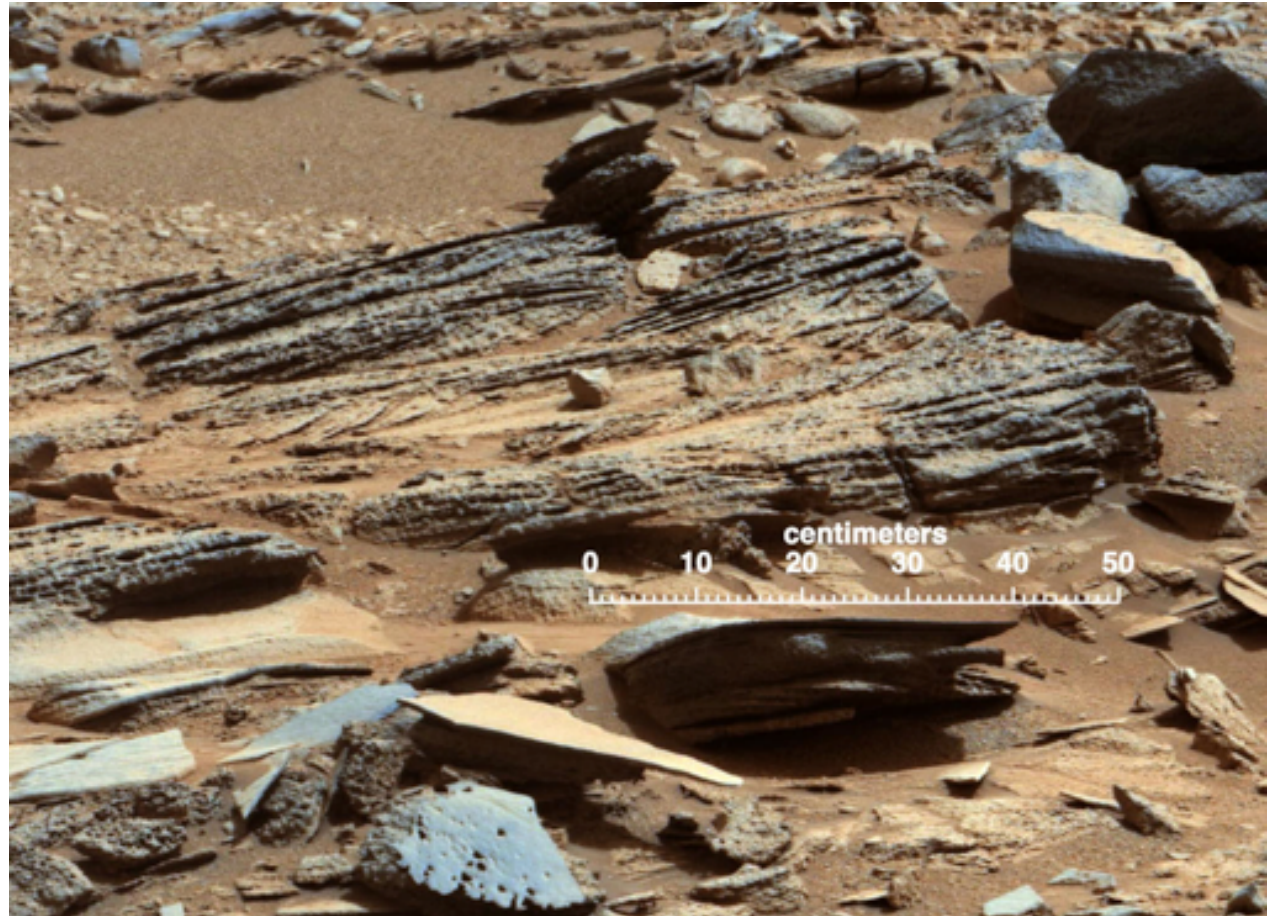
Earth



ChemCam : Veins of hydrated CaSO_4 (gypsum, bassanite, etc.) :
Water lost its salinity and produced evaporites

1a : alluvial cone
liquid water

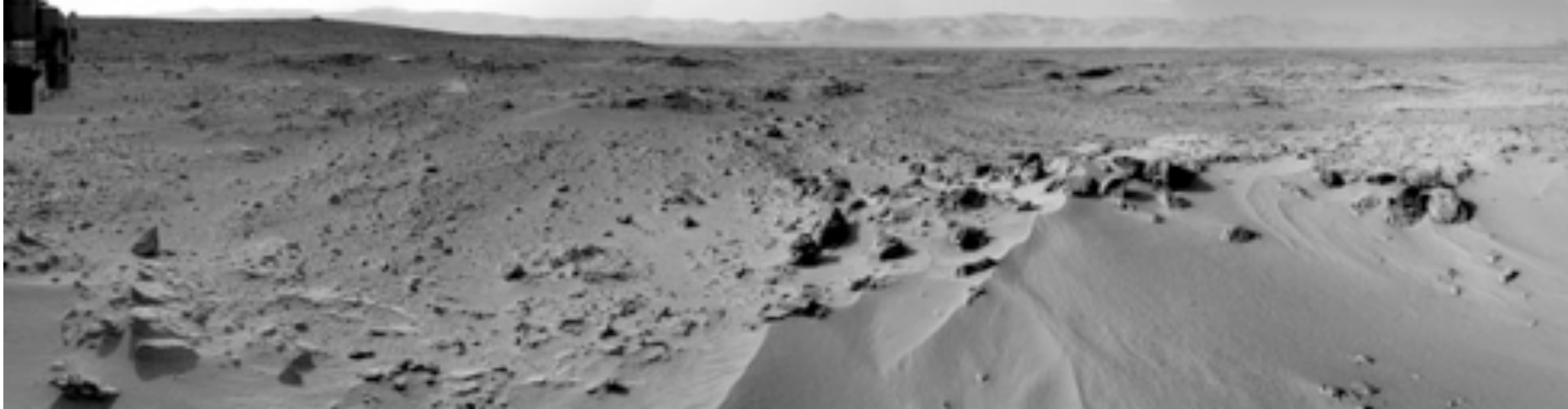
Sol 120



sediments were **transported**

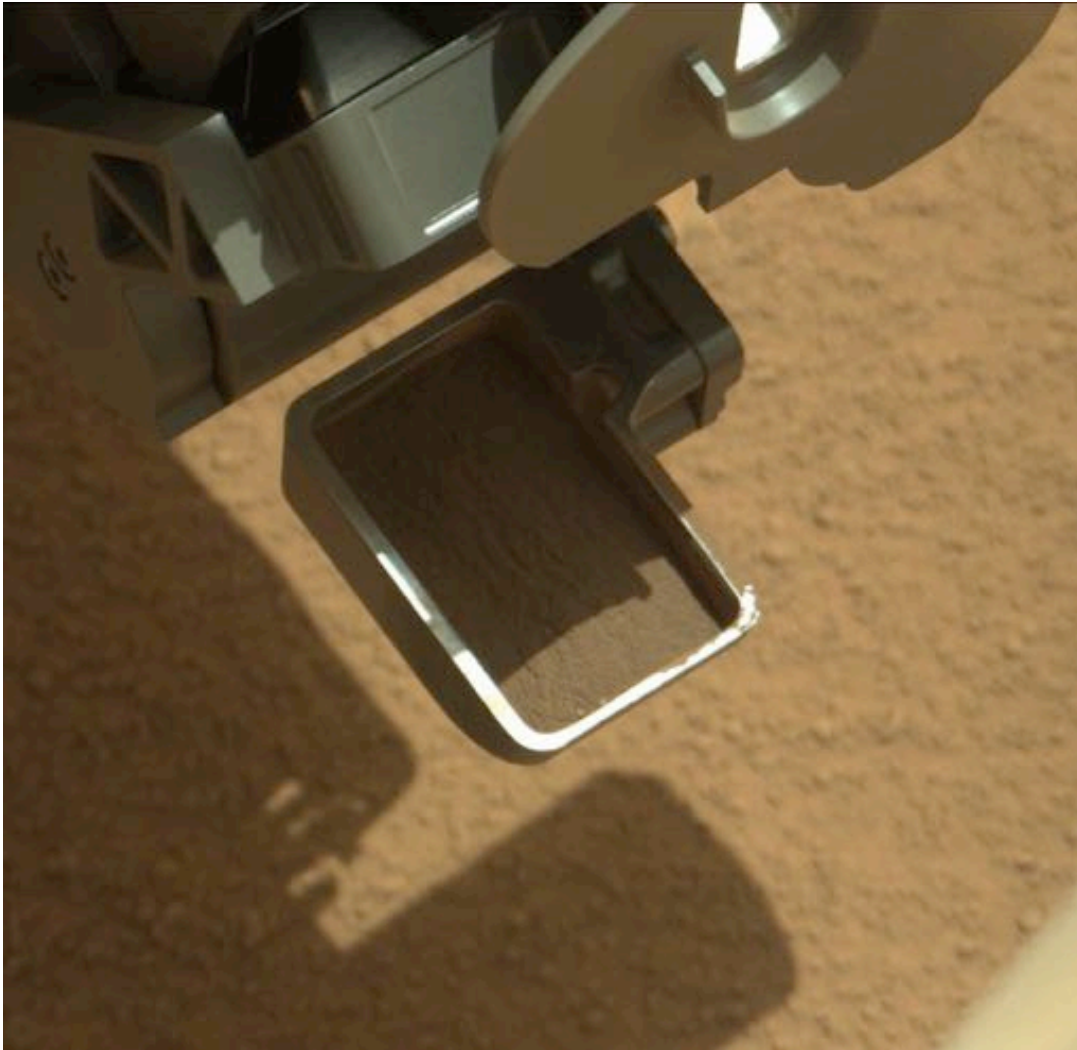
Sol 56

1a : alluvial cone
water in minerals



‘Rocknest’ sand dune

**1a : alluvial cone
water in minerals**

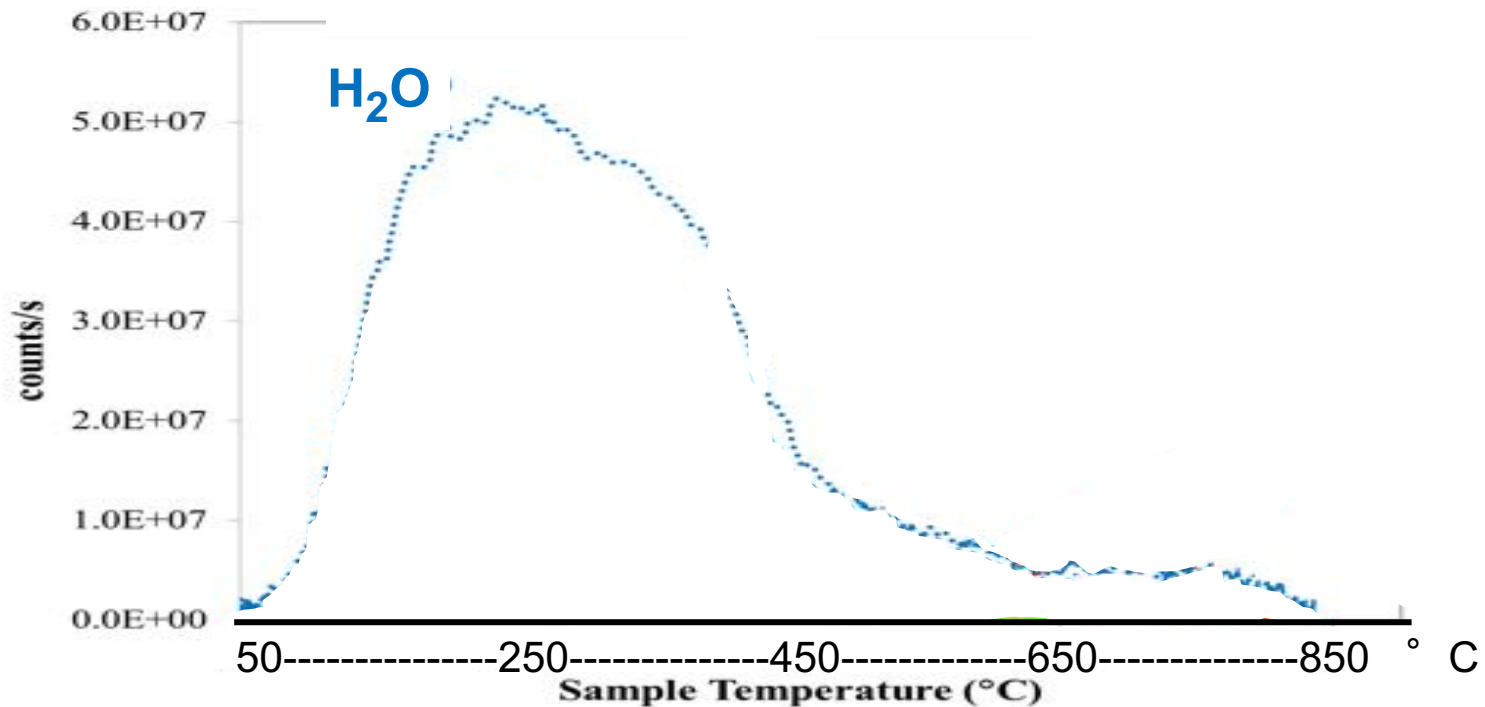


< 150 μm

Scooping and
analyses at Rocknest
by SAM
sols 89 to 101

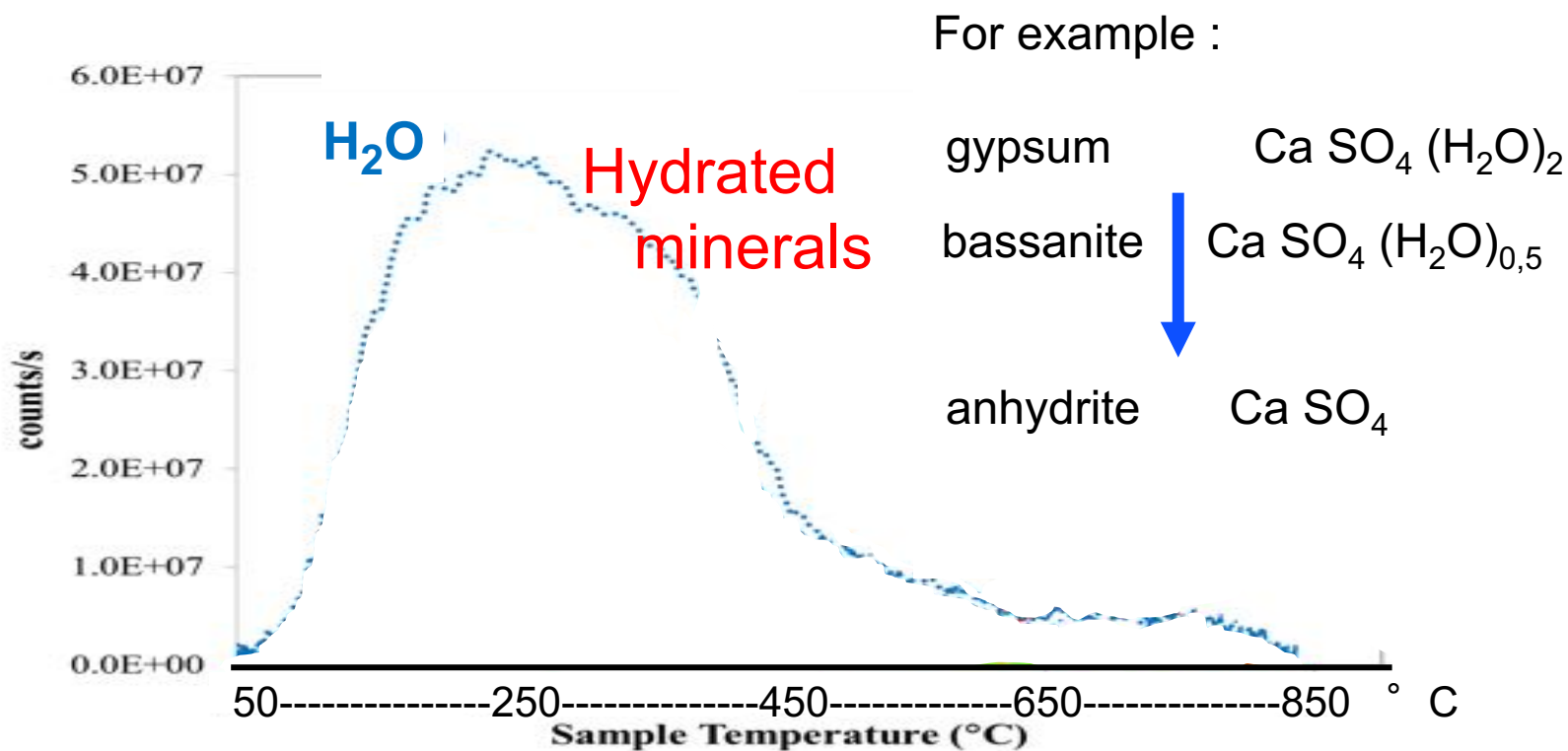
SAM's Mass Spectrometer 'follows' the water when samples are heated
(EGA : evolved gas analysis)

1a : alluvial cone
water in minerals



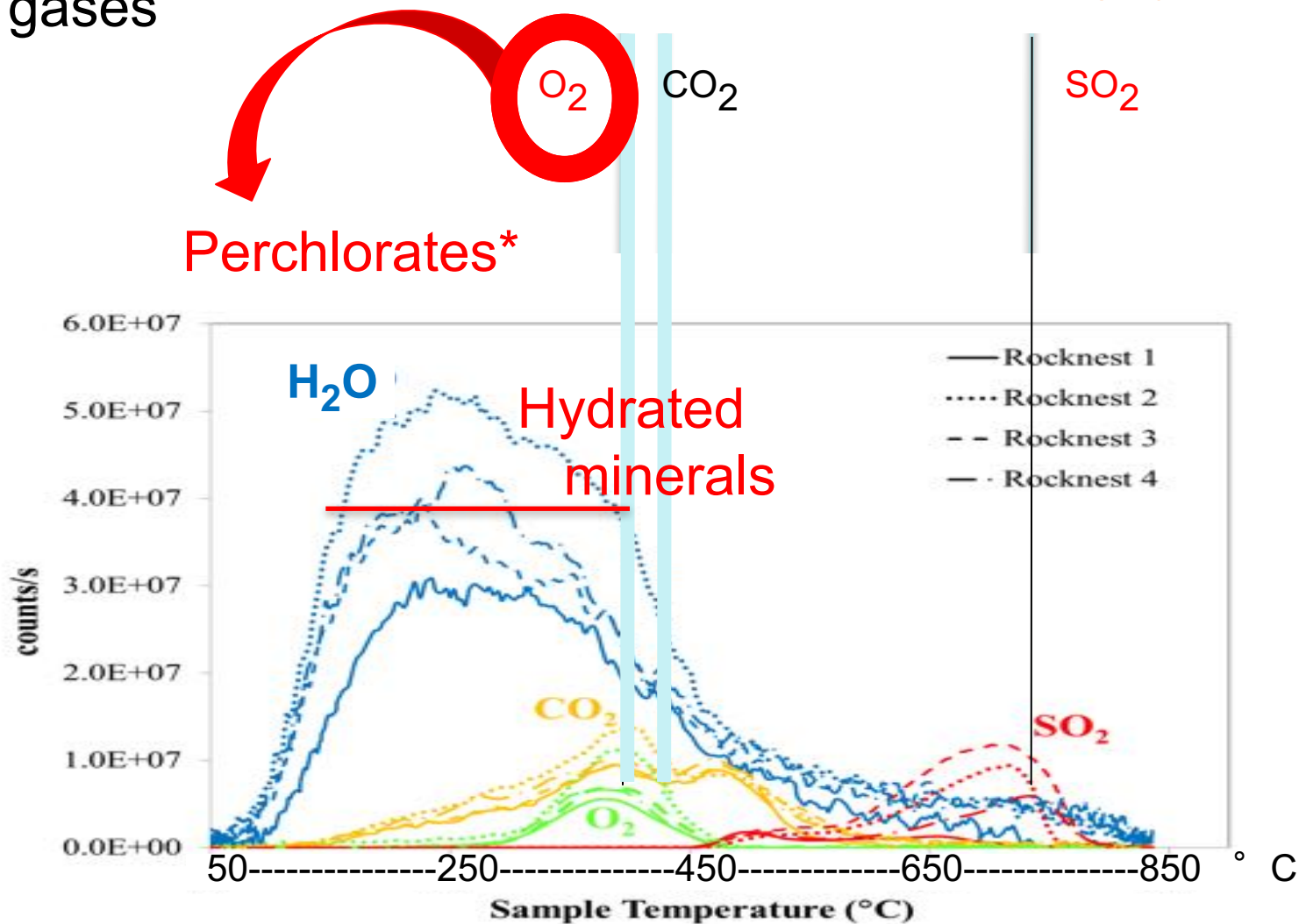
SAM's Mass Spectrometer 'follows' the water when samples are heated
(EGA : evolved gas analysis)

1a : alluvial cone
water in minerals



SAM's Mass Spectrometer may 'follow' other gases

1a : alluvial cone and .. in minerals



* See later

1a : alluvial cone
and .. in minerals



Yellowknife Bay

1a : alluvial cone
and .. in minerals

In Sheepbed formation
(Yellowknife Bay = YKB) :

Drilling
rock
John Klein
at YKB

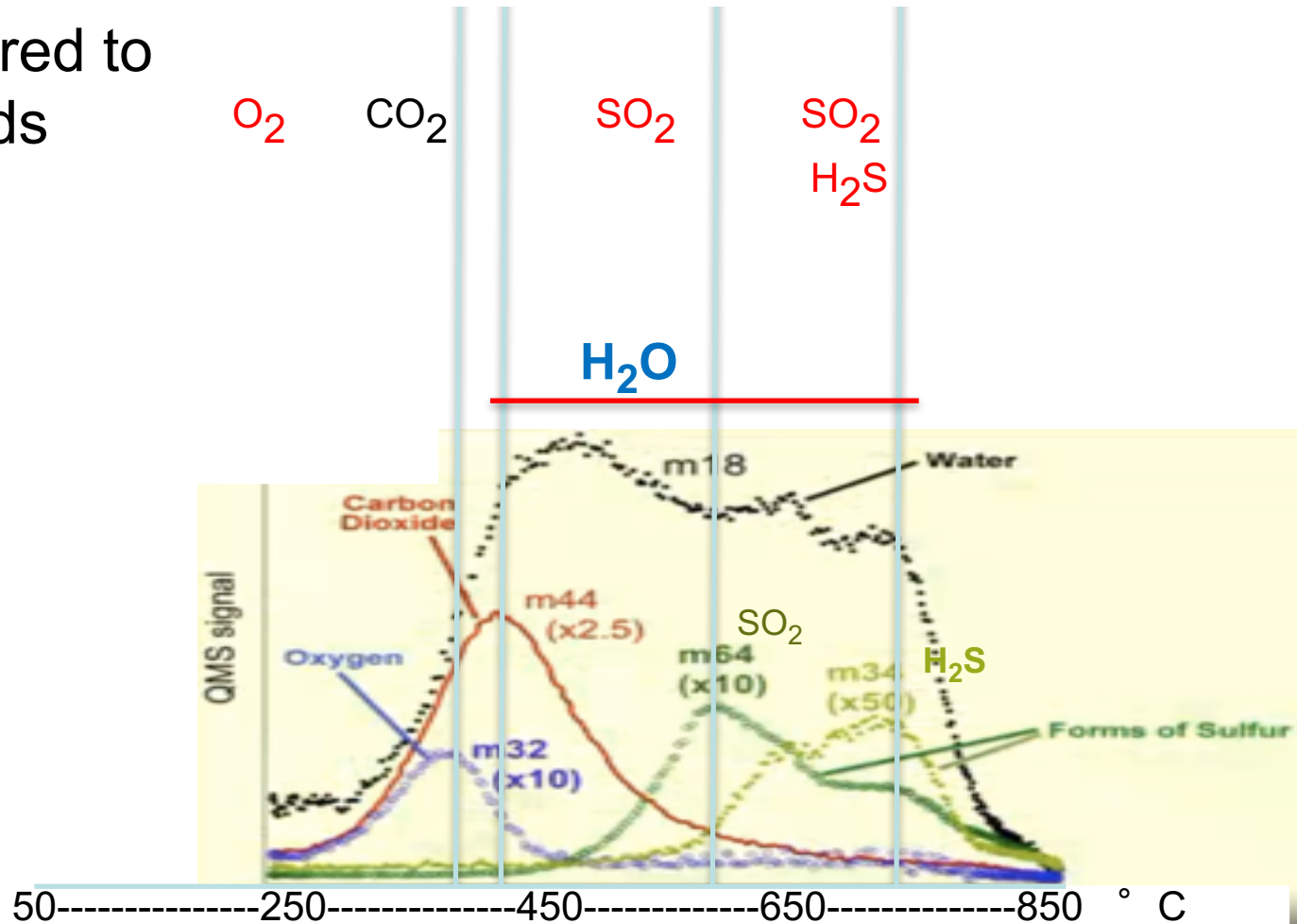


Traces of ChemCam laser shots

Following some gases (EGA) using SAM's MS

(to be compared to EGA on sands at Rocknest)

1a : alluvial cone and .. in minerals



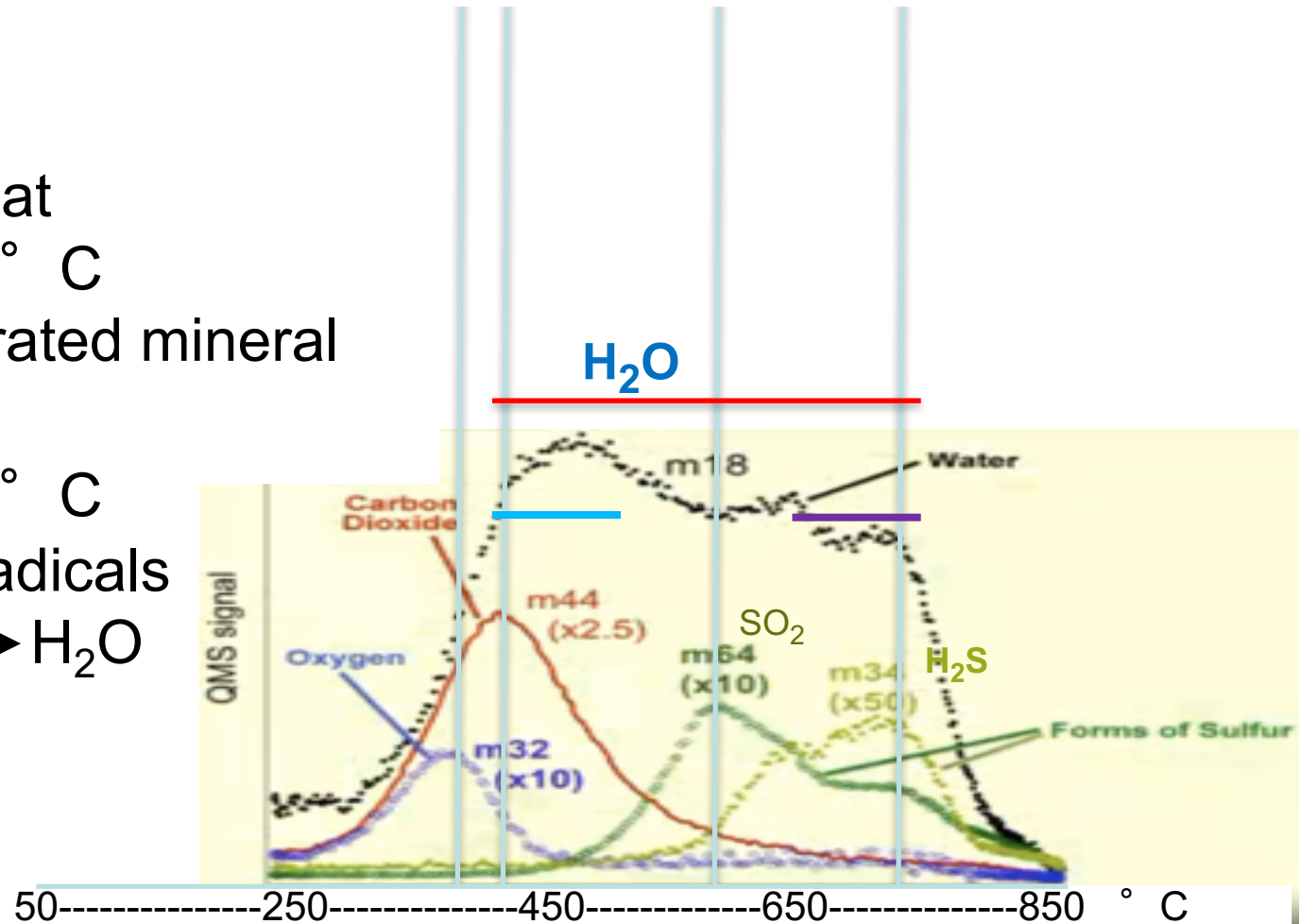
1a : alluvial cone
and .. in minerals

Water peaks at
450 ° C

(—) hydrated mineral

and 750 ° C

(—) OH radicals
recombine → H₂O



1a : alluvial cone
and .. in minerals

Water peaks at
450 ° C
(—) hydrated mineral

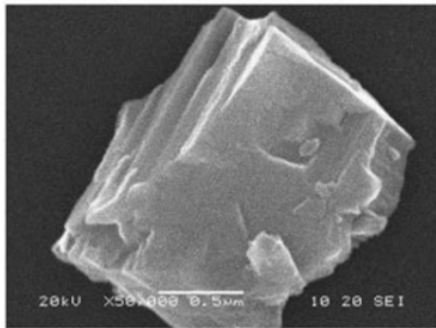
and 750 ° C
(—) OH radicals
recombine → H₂O

Signature of a clay

e.g.

a montmorillonite

confirmed by **CheMin** (X ray diff.)



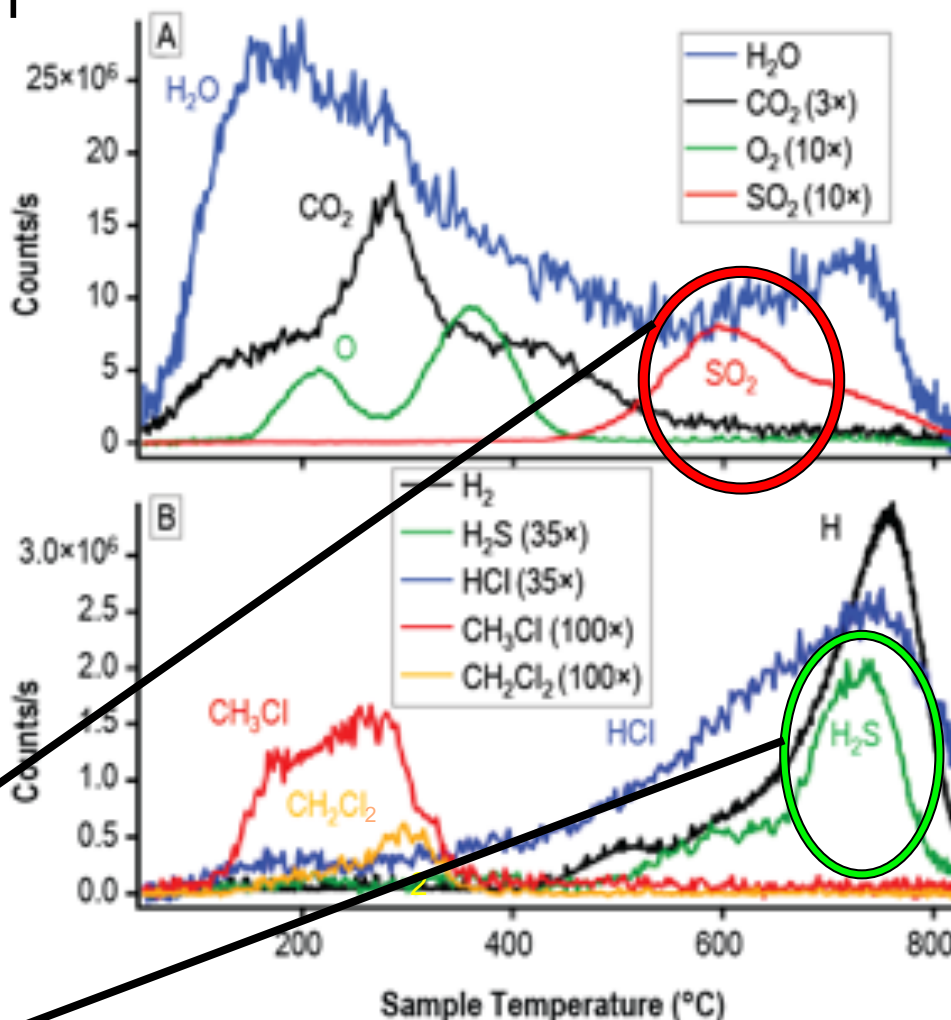
← **Excellent support shield for organic molecules**

An other EGA at John Klein

1a : alluvial cone
food ?

REDOX !

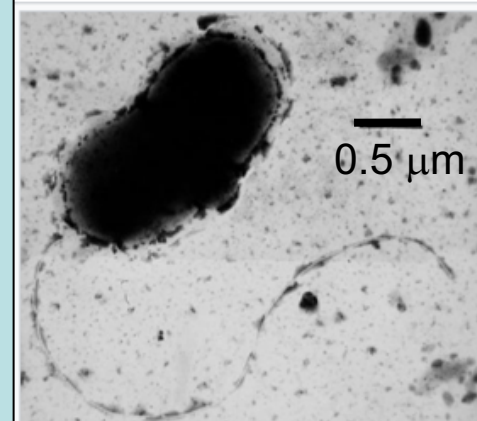
FOOD !



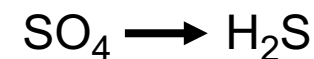
Oxidized
sulfur

Reduced
sulfur

On Earth :



Desulfovibrio vulgaris :



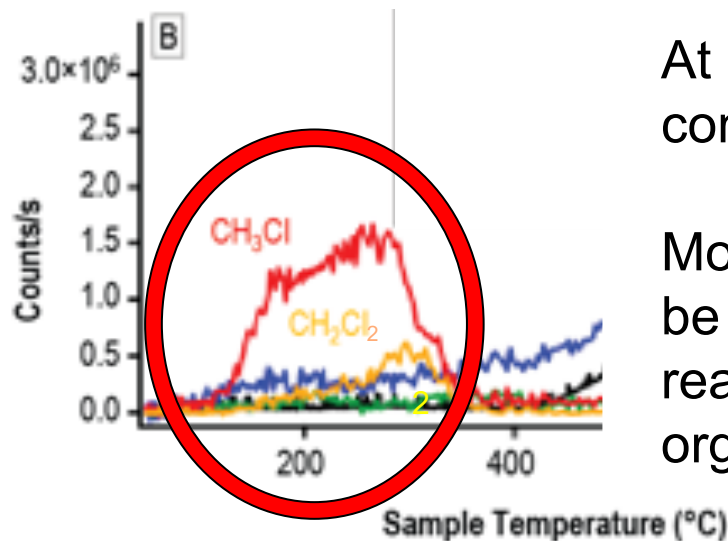
An other EGA

1a : alluvial cone
chlorine ?

(**Vikings 1976** observes chlorinated organic compounds :
« artefacts from earthly cleaning ».

Phoenix 2009 observes perchlorates at high latitudes)

Curiosity 2012 : chlorine (perchlorates) observed at the equator !

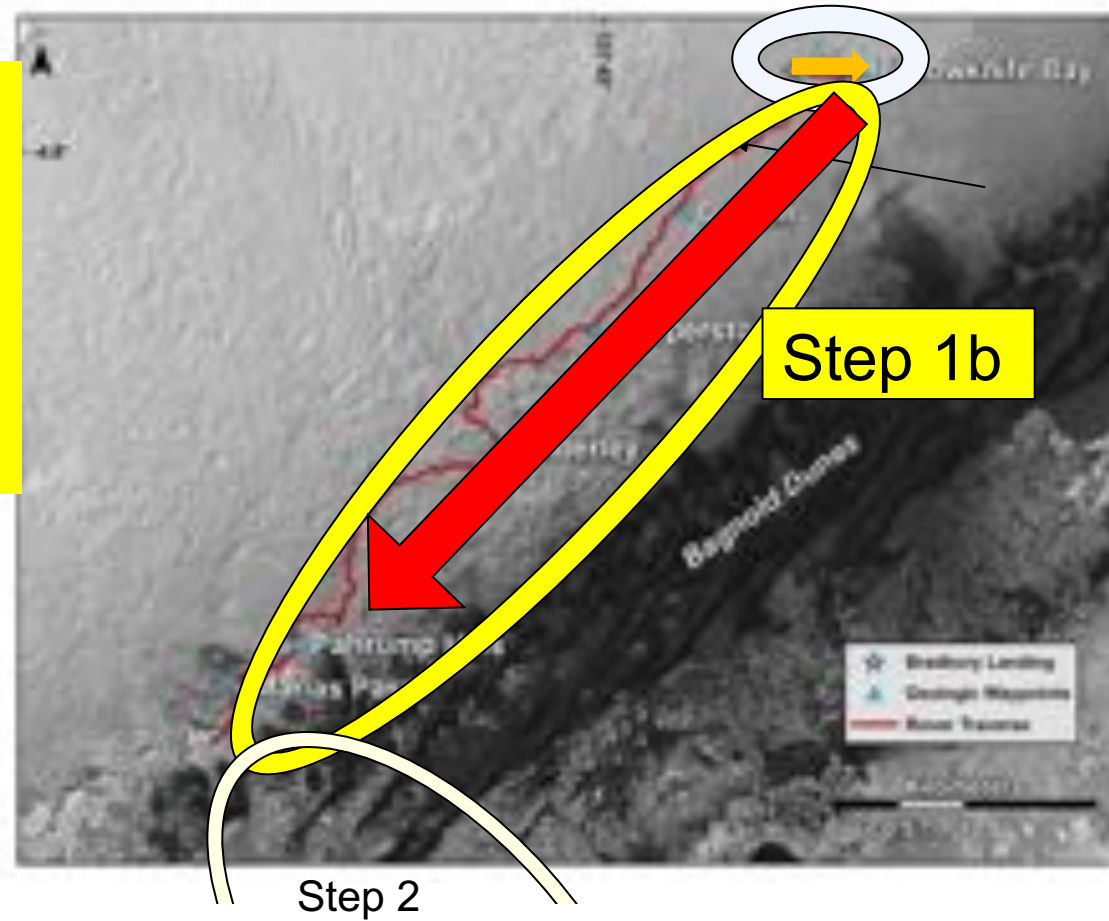


At high T, ClO_4 destroys
complex organic moles.

Modified analytic technics are to
be used on Mars to avoid 'hot
reactions' btw ClO_4 and complex
organics

1b : from alluvial cone to Mt Sharp

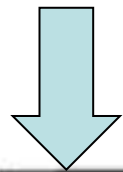
≈ Sol 297 :
change of
course and
step 1b
(about 15 kms).



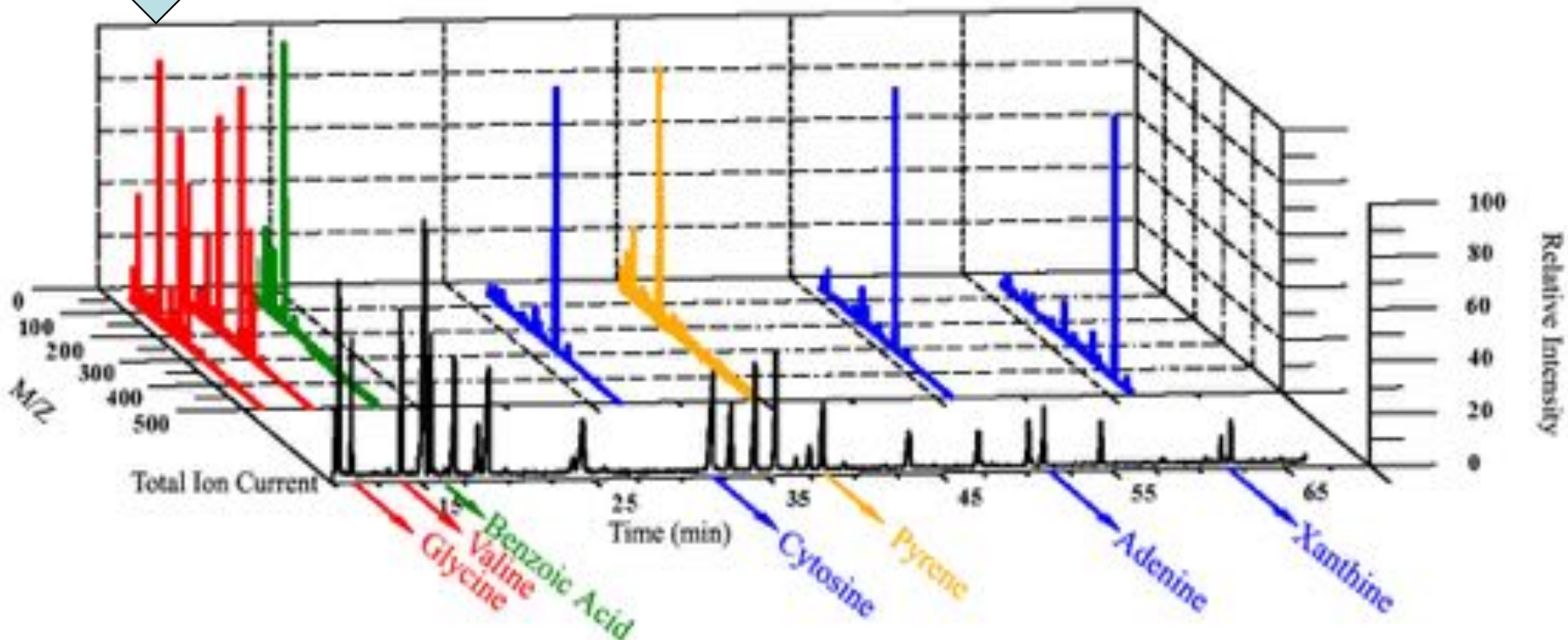
North
↑
South

Use of GC and MS when drilling rocks : search for 'organics'

1b : from alluvial
cone to Mt Sharp



Schematics of a GC-MS analysis



The molecular families present in a gas mixture come out of the GC separated in time and are, then, identified by the MS

**1b : from alluvial
cone to Mt Sharp**

Drilling Cumberland rock at Yellowknife Bay



A : benzène instrumental

B : toluène instrumental

1 : chloromethane

2 : dichlorométhane

3 : trichlorométhane

4 : tétrachlorure de carbone

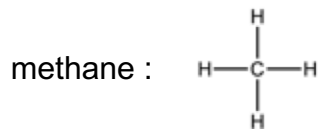
5 : 1,2-dichloroéthane

6 : 1,2-dichloropropane

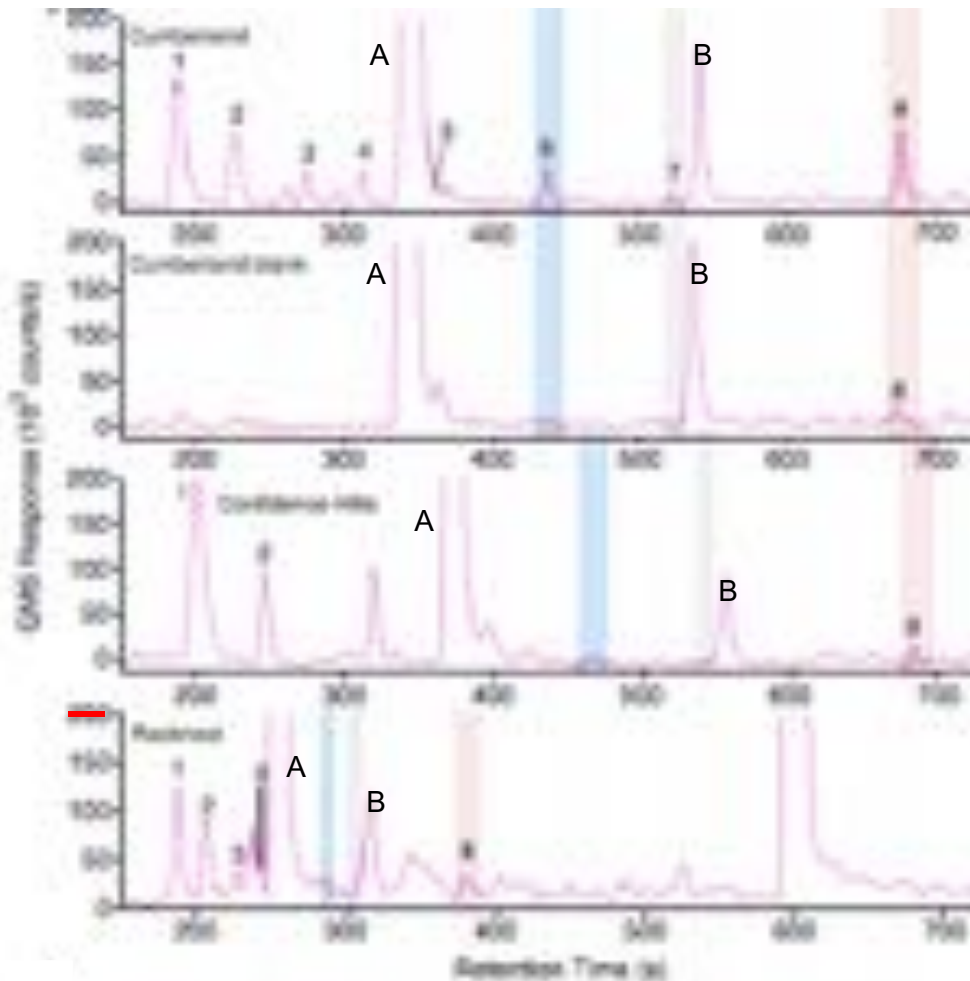
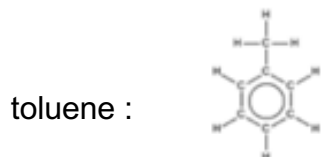
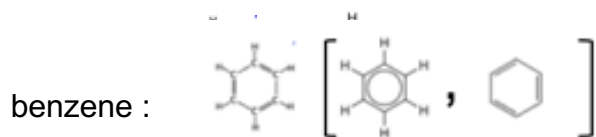
7 : 1,2-dichlorobutane

8 : chlorobenzene

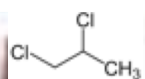
Alcanes



etc.



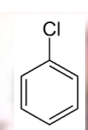
1,2-dichloropropane



Outlet of the MS :

NIST database :

chlorobenzene



A : benzène instrumental

B: toluène instrumental

1 : chloromethane

2 : dichlorométhane

3 : trichlorométhane

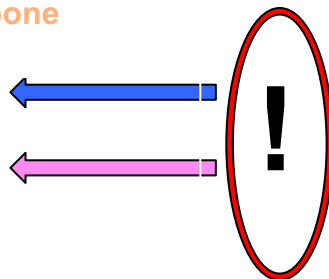
4 : tétrachlorure de carbone

5 : 1,2-dichloroéthane

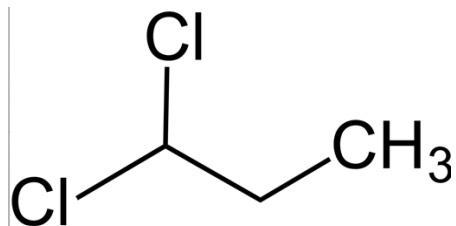
6 : 1,2-dichloropropane

7 : 1,2-dichlorobutane

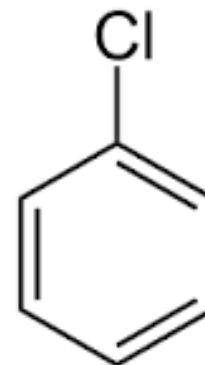
8 : chlorobenzene



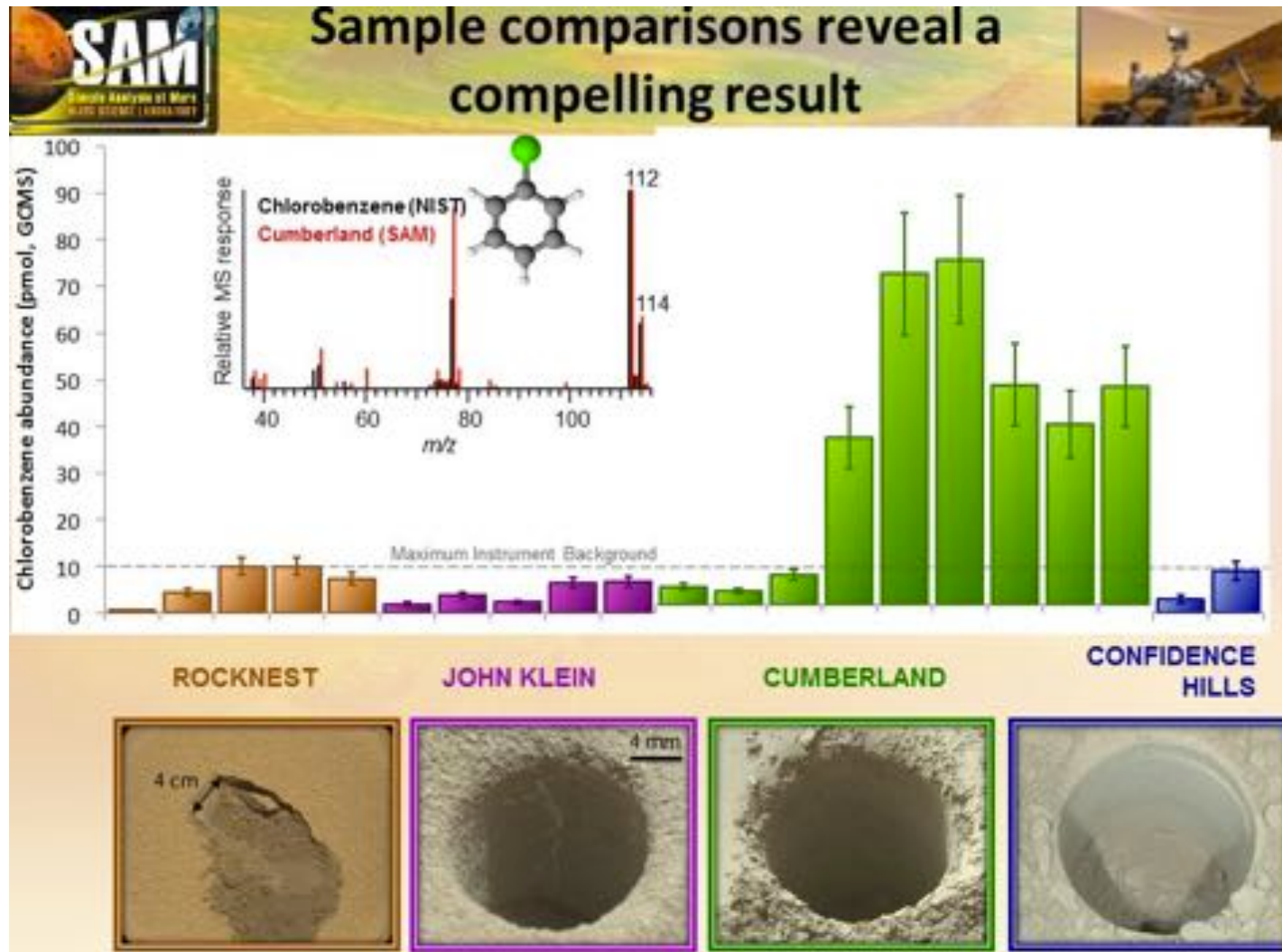
1,2-dichloropropane



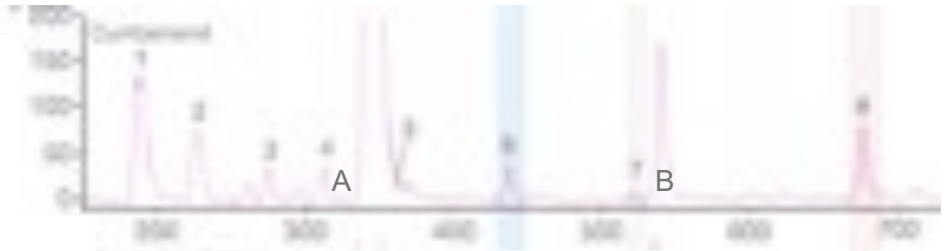
chlorobenzene



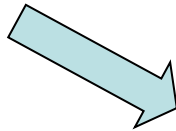
1b : from alluvial cone to Mt Sharp



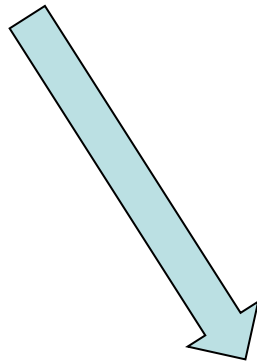
Drilling in Cumberland mudstone



6 : 1,2-dichloropropane



8 Chlorobenzene



heavy hydrocarbons

fragmentation (pyrolysis / SAM)

C₃ hydrocarbons

pyrolysis / SAM (+ ClO₄⁻)



150 à 300 ppb of **1,2-dichloropropane**

(μ)meteorites, comets, IDP, etc.

polycyclic aromatics HC, kerogens

oxydations (Benner)

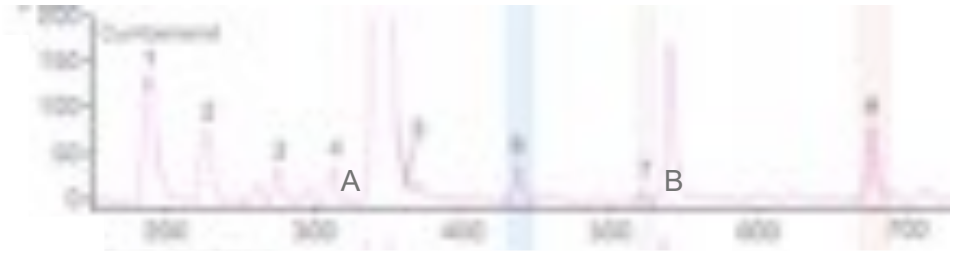
Benzene carboxylates (phtallic, mellitic acids)

pyrolyse SAM (+ ClO₄⁻)

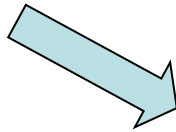


25 à 70 ppb of **chlorobenzene**

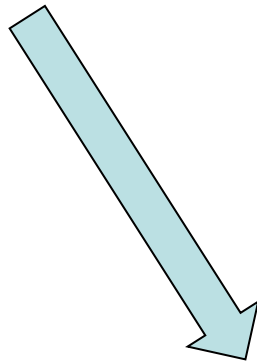
Drilling in Cumberland mudstone



6 : 1,2-dichloropropane



8 Chlorobenzene



heavy hydrocarbons

**CHECKED
in lab !**

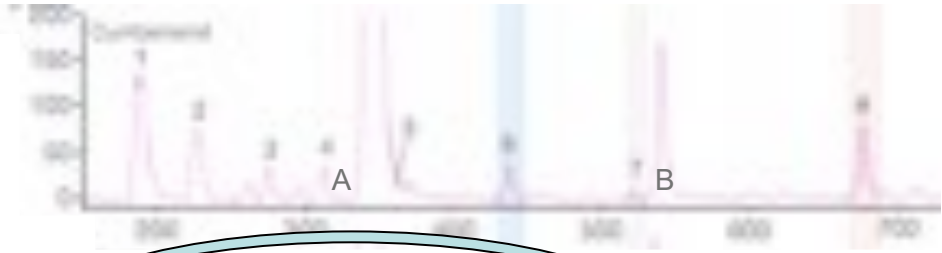
150 à 300 ppb of **1,2-dichloropropane**

(μ)meteorites, comets, IDP, etc.

**CHECKED
in lab !**

25 à 70 ppb of **chlorobenzene**

Drilling in Cumberland mudstone



6 : 1,2-dichloropropane

8 Chlorobenzene

heavy hydrocarbons

CHECKED
in lab !

150 à 300 ppb of **1,2-dichloropropane**

(μ)meteorites, comets, IDP, etc.

CHECKED
in lab !

25 à 70 ppb of **chlorobenzene**

**Ancient
organic
matter**



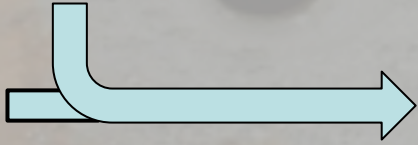
1b : from alluvial
cone to Mt Sharp

What can be said :

Complex **organic** molecules

Carbonates, **clays**, gypsum, **liquid water** ($T > 0^{\circ} \text{C}$)
neither too acidic
nor too basic

Oxidized and reduced sulfur (SO_2 , H_2S)

and perchlorates ?  'biological
energy'

Life has all it needs to develop

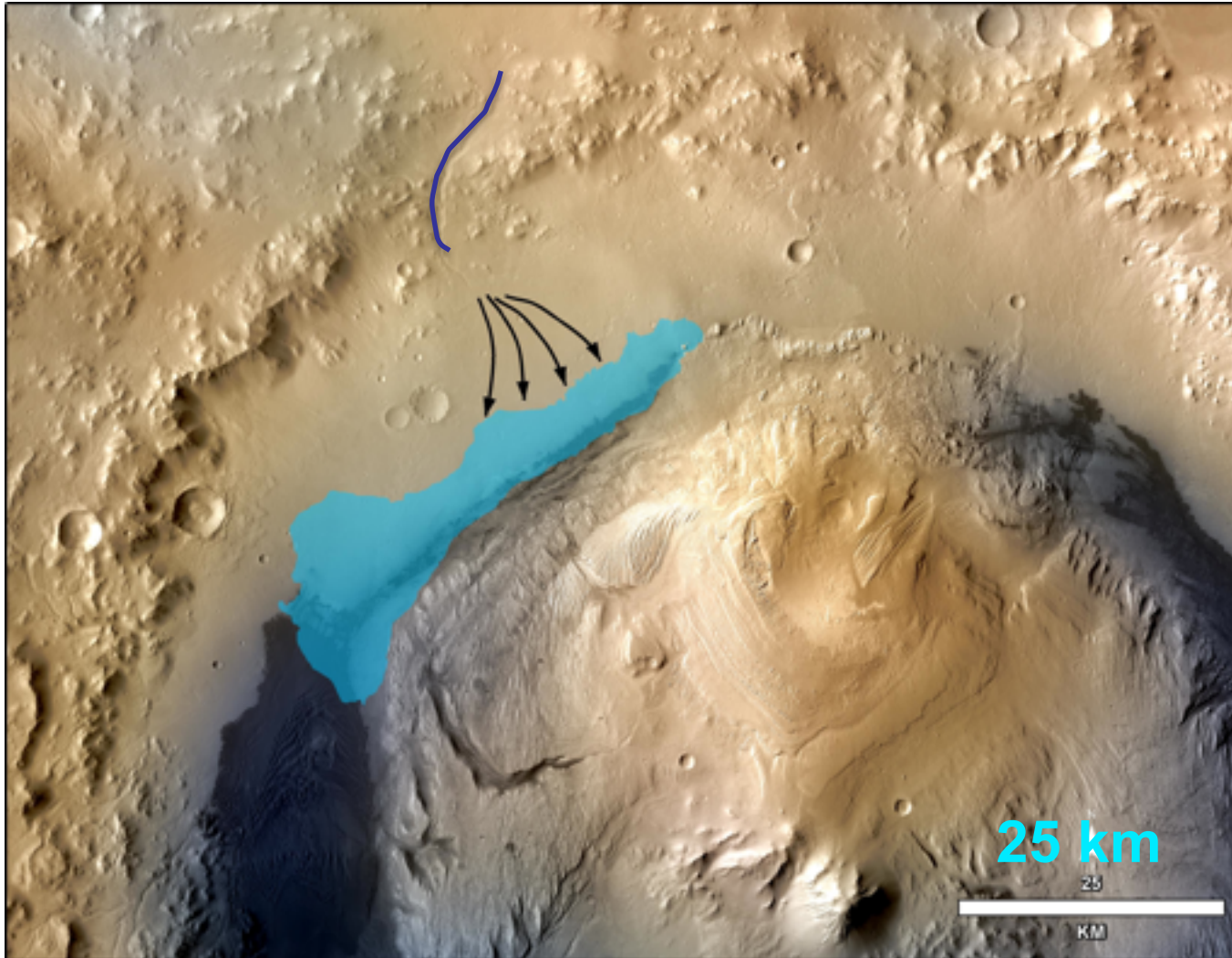
MARS WAS HABITABLE

YellowKn.

Drilling

Rock

1b : from alluvial
cone to Mt Sharp



Paleolake

habitability

**for how
long ! ?**

Drilling rocks at Pahrump Hills

Mohave mudstone (Murray formation)

**1b : from alluvial
cone to Mt Sharp**



Mohave mudstone

Evolved gas analysis

Part 1

Molécules
containing 1 carbon

2 carbons

3

4

5

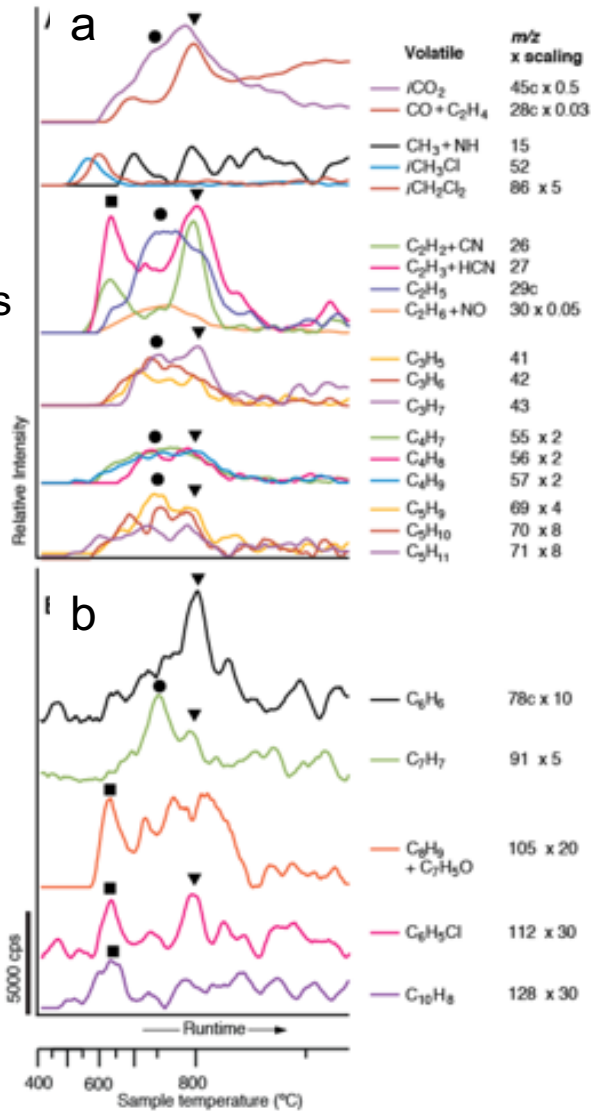
6

7

8

9

10



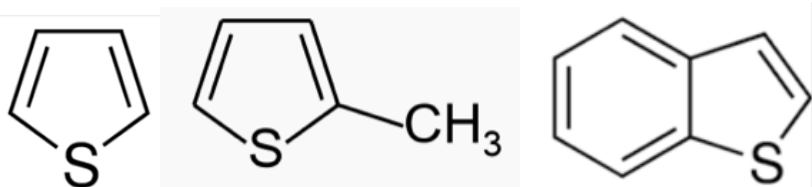
a : aliphatics mol. (open chain)
b : aromatics mol. (cyclic)

Mohave mudstone

Evolved gas analysis

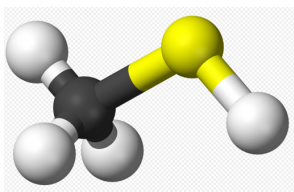
Part 2

A : C_4H_4S ; C_5H_6S ; C_8H_6S

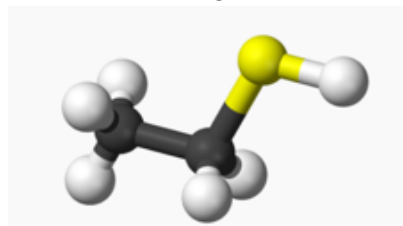


Thiophens (thioph., méthyl-th., benzo-th.)

B : CH_3-SH ; C_2H_5SH

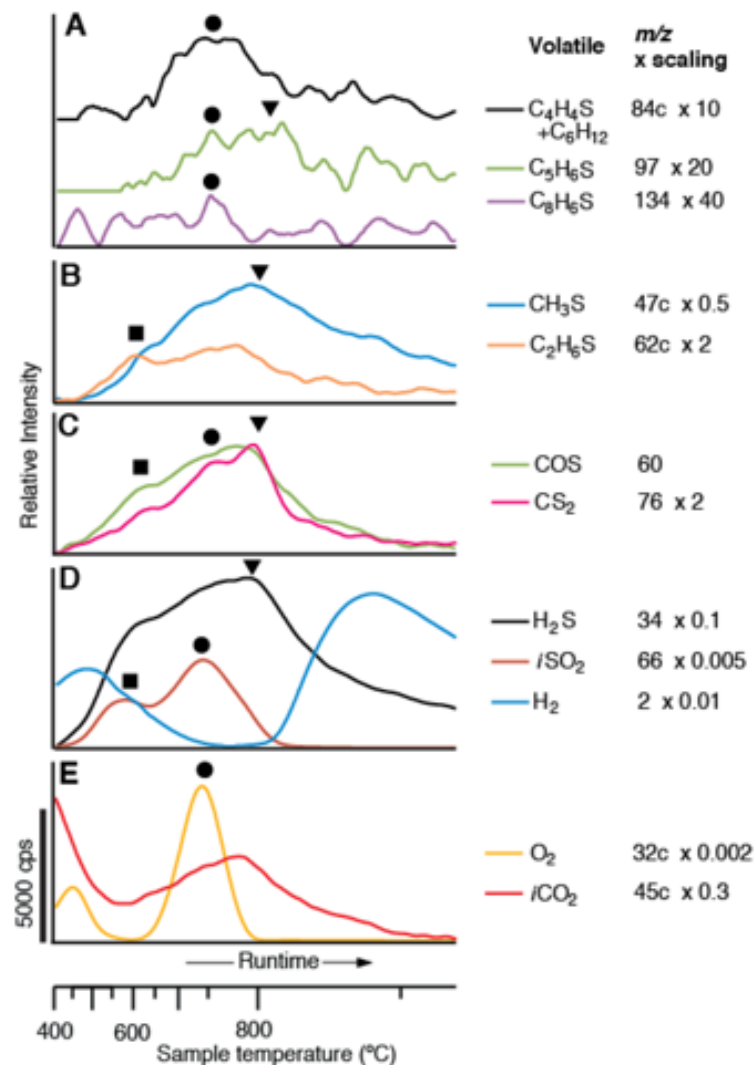


Thiols : (methane-thiol),



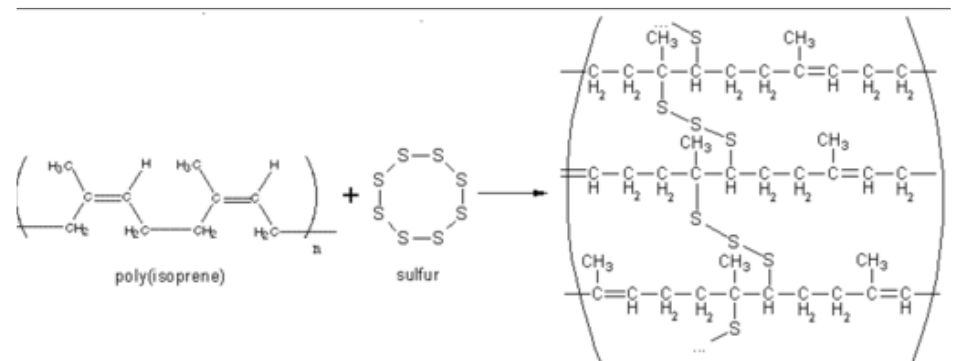
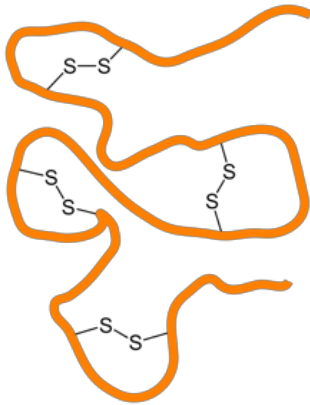
ethane-thiol)

C,D,E : sulfides, etc.



Sulfur in sediments, and sulfur in molecular structures.

On Earth , sulfurization **stabilizes, preserves** :
(disulfure bridges proteins, rubber vulcanization).



On Mars:

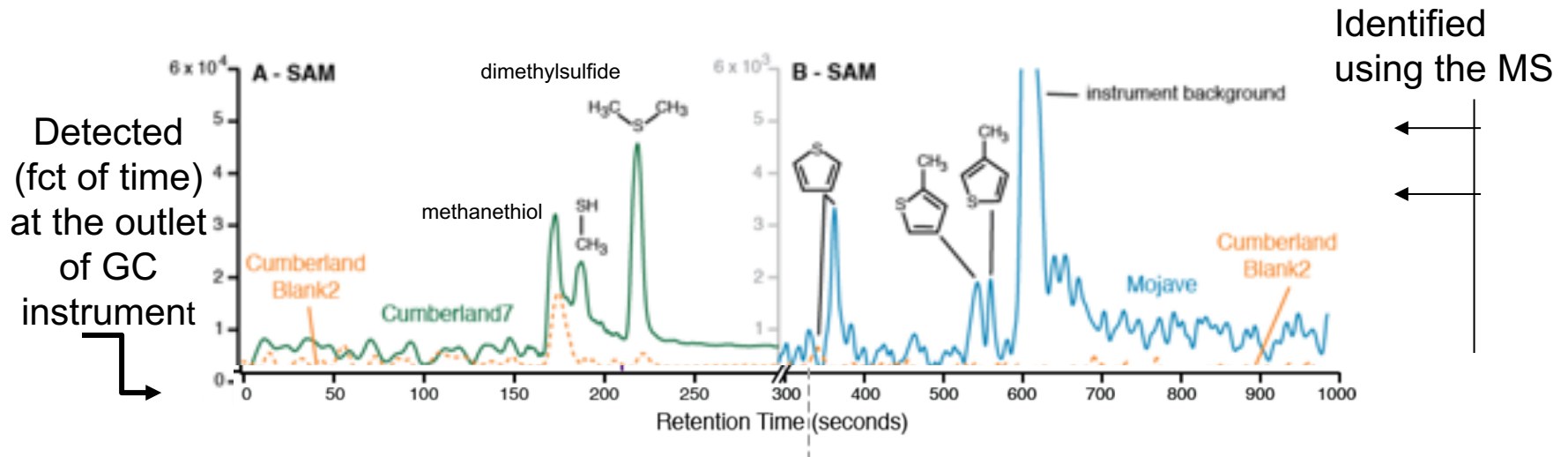
sulfurization | before or after deposit
 | during diagenesis

—————> preserving organic matter

then go to sulfate layer ! (step 2)

1b : from alluvial cone to Mt Sharp

GC-MS at **Cumberland** (Yellowknife Bay) and **Mojave** (Pahrump Hills)

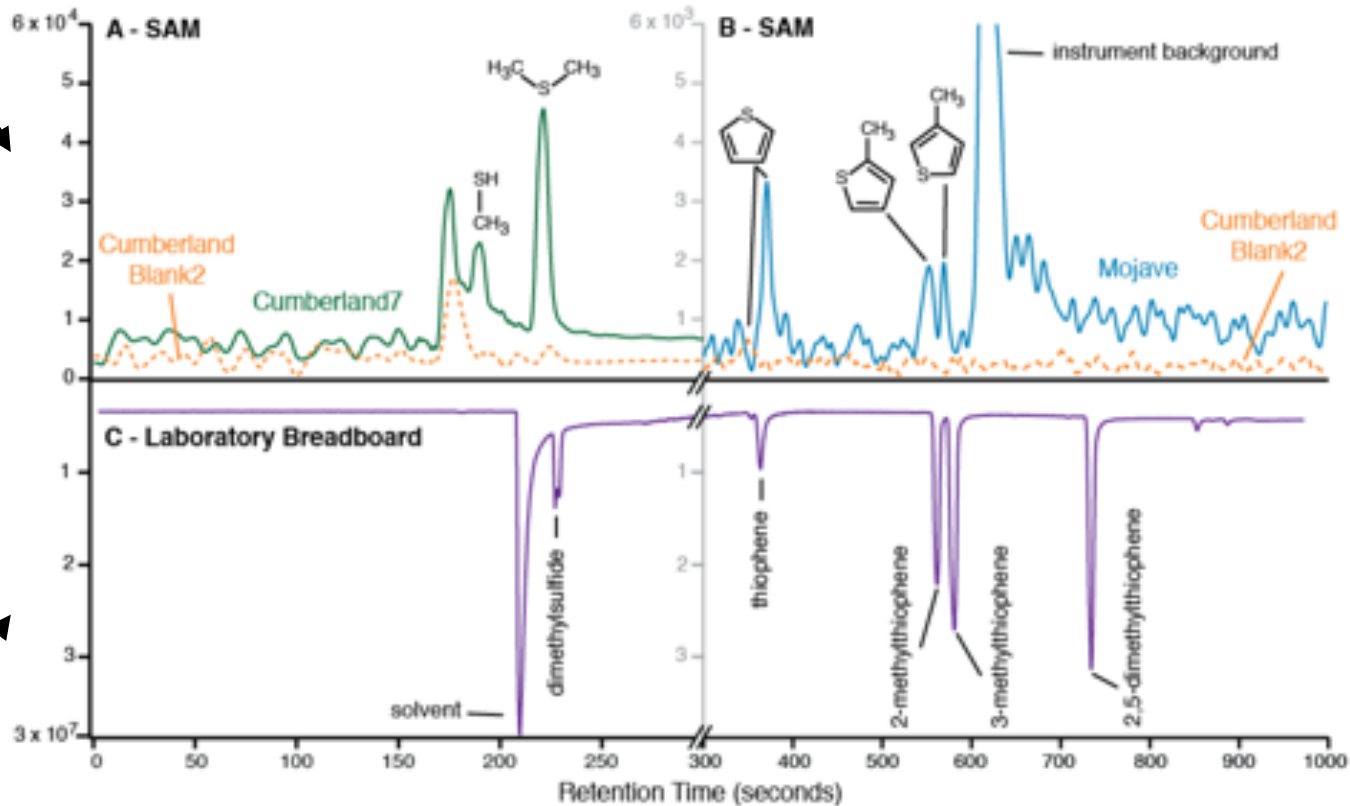


Checkings !

1b : from alluvial cone to Mt Sharp

GC-MS at **Cumberland** (Yellowknife Bay) and **Mojave** (Pahrump Hills)

Mars
and
Earth



GC-MS on a gas mixture **in the laboratory** (spare models on Earth)

Murray formation mudstones (Carbon in nmols)

Molecule → (nmols) Mudstone ↓	Thiophenic	Aromatic	Aliphatic	C & C2 sulfur	Total organic Carbon
Confidence Hills	2.02 +/- .84	8.03 +/- 2.11	20.8 +/- 2.79	29.3 +/- 7.61	60.2 +/- 8.42
Confidence Hills blank	0.49 +/- .18	3.04 +/- 0.86	5.35 +/- 0.83	1.49 +/- 0.42	10.4 +/- 1.28
Mojave	2.2 +/- .93	6.99 +/- 1.99	38.4 +/- 5.63	43.8 +/- 11.6	91.4 +/- 13.1
Telegraph Peak	0.70 +/- .26	2.92 +/- 0.86	9.51 +/- 1.28	20.0 +/- 5.43	33.1 +/- 5.65

Adapted from J. Eigenbrode,
Science 08 Jun 2018:
 Vol. 360, Issue 6393, pp. 1096-1101
 DOI: 10.1126/science.aas9185

Murray formation mudstones (Carbon in nmols)

Molecule → (nmols) Mudstone ↓	Thiophenic	Aromatic	Aliphatic	C & C2 sulfur	Total organic Carbon
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Confidence Hills blank	0.49 +/- .18	3.04 +/- 0.86	5.35 +/- 0.83	1.49 +/- 0.42	10.4 +/- 1.28
Mojave	2.2 +/- .93	6.99 +/- 1.99	38.4 +/- 5.63	43.8 +/- 11.6	91.4 +/- 13.1
Telegraph Peak	0.70 +/- .26	2.92 +/- 0.86	9.51 +/- 1.28	20.0 +/- 5.43	33.1 +/- 5.65

And at Yellowknife Bay ?

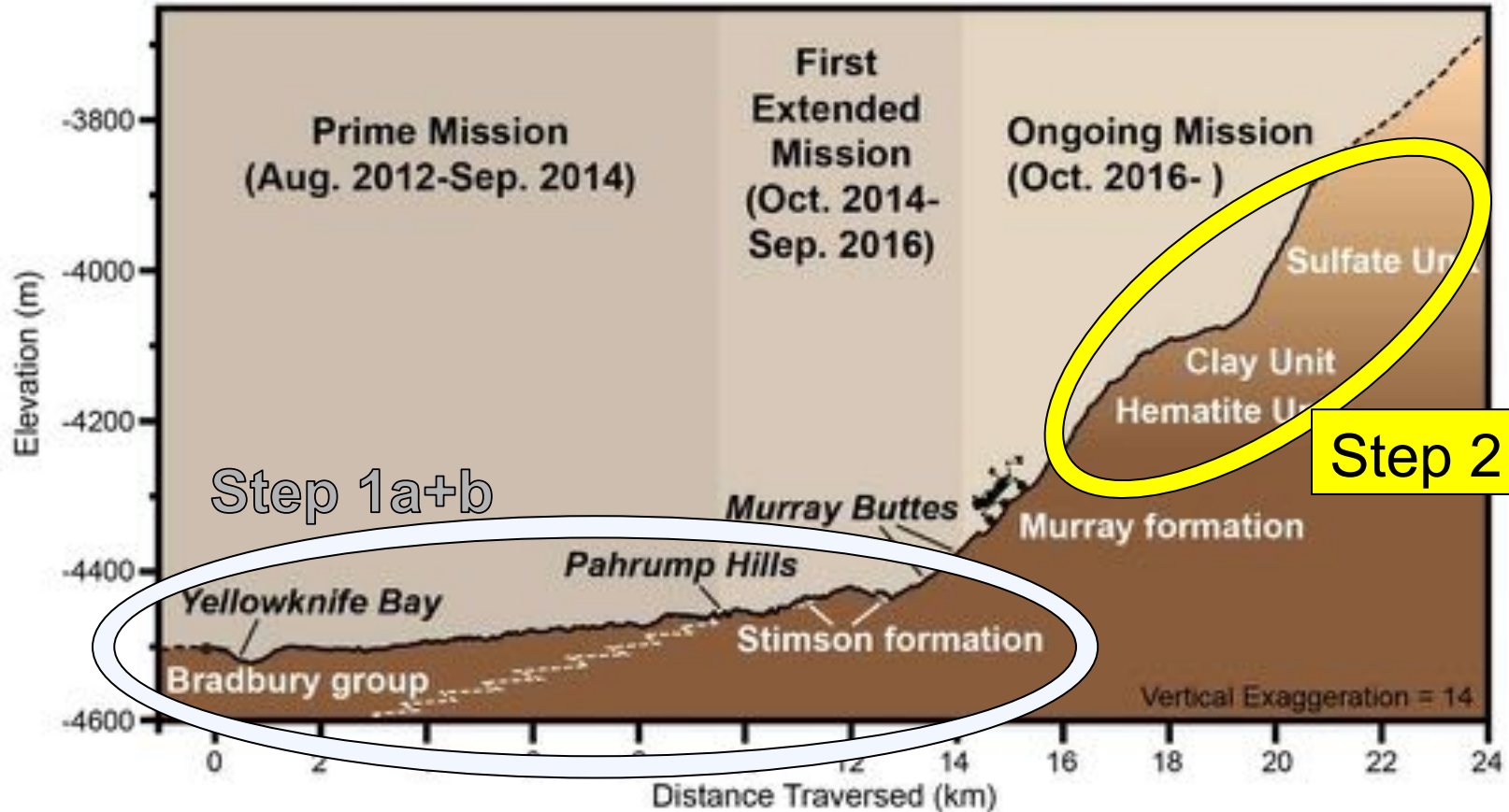
Sheepbed formation mudstones (Carbon in nmols)

Cumberland	0.28 +/- .10	1.15 +/- 0.10	19.7 +/- 2.42	3.17 +/- 0.44	22.9 +/- 2.51
Cumberland blank	0.43 +/- .17	2.02 +/- 0.12	3.82 +/- 0.32	0.81 +/- 0.22	6.65 +/- 0.67

≈ Sol 1400

2 : Mt Sharp

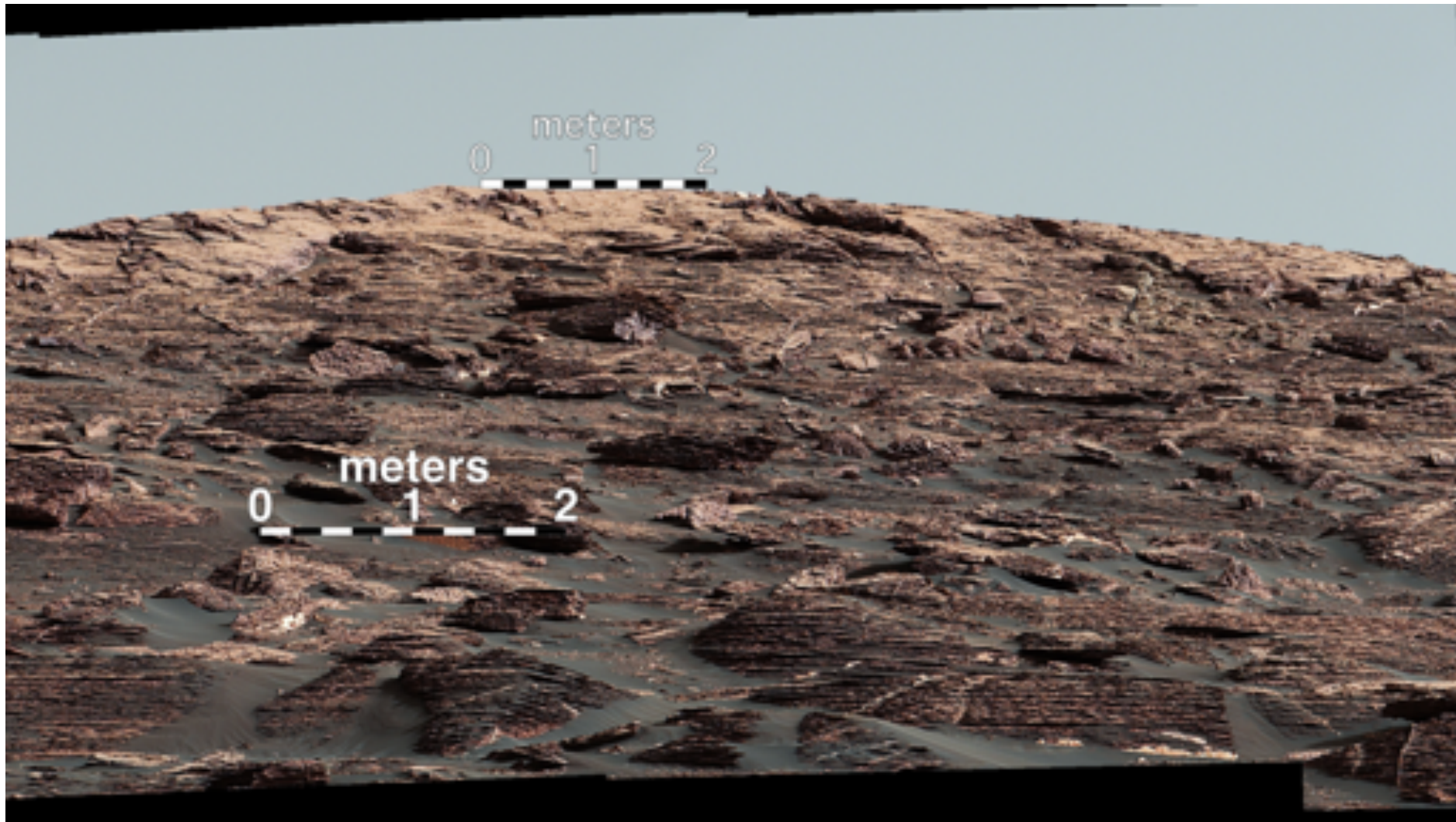
Then ..go to **Step 2**



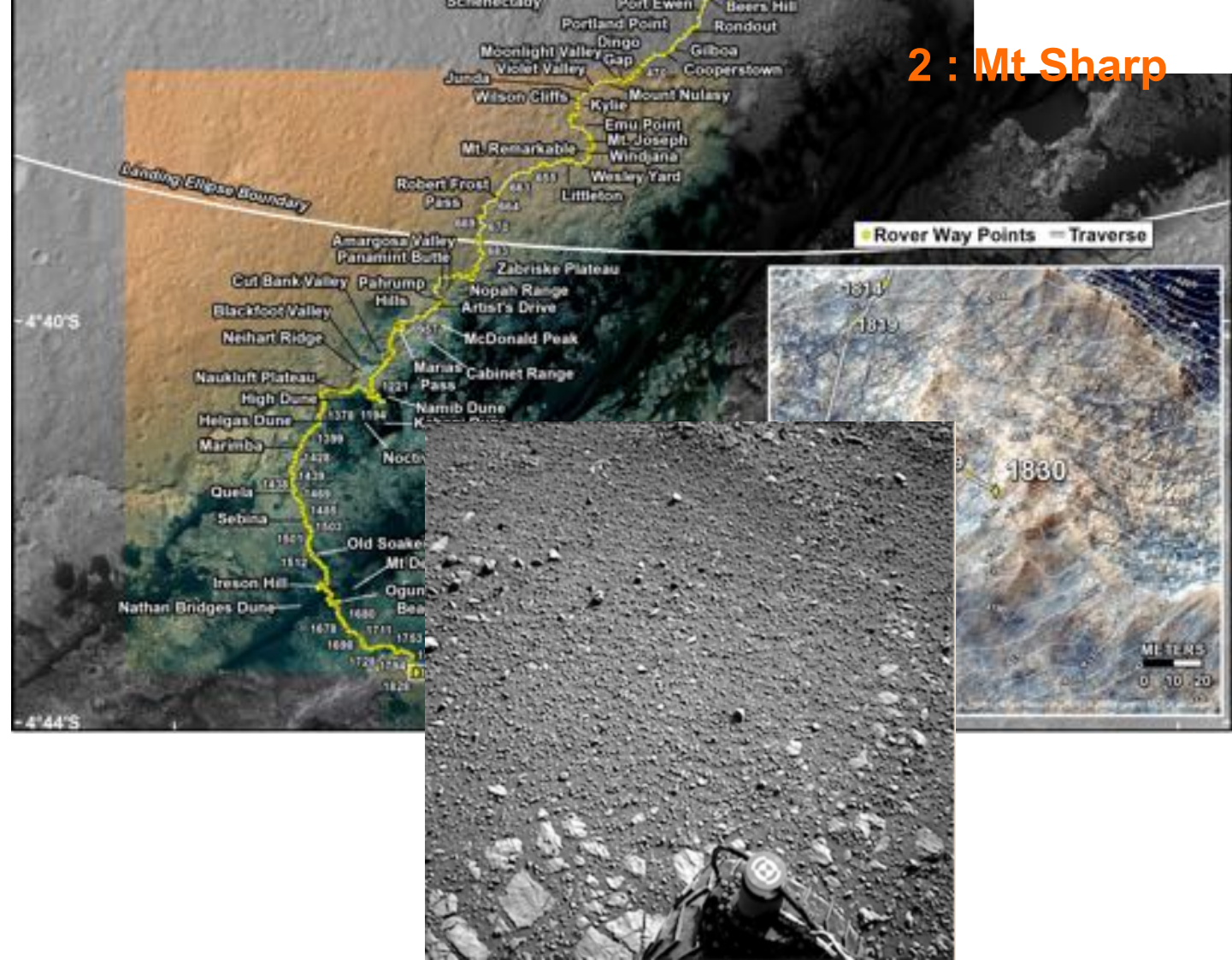
Vera Rubin Ridge

2 : Mt Sharp

(hematite layer)



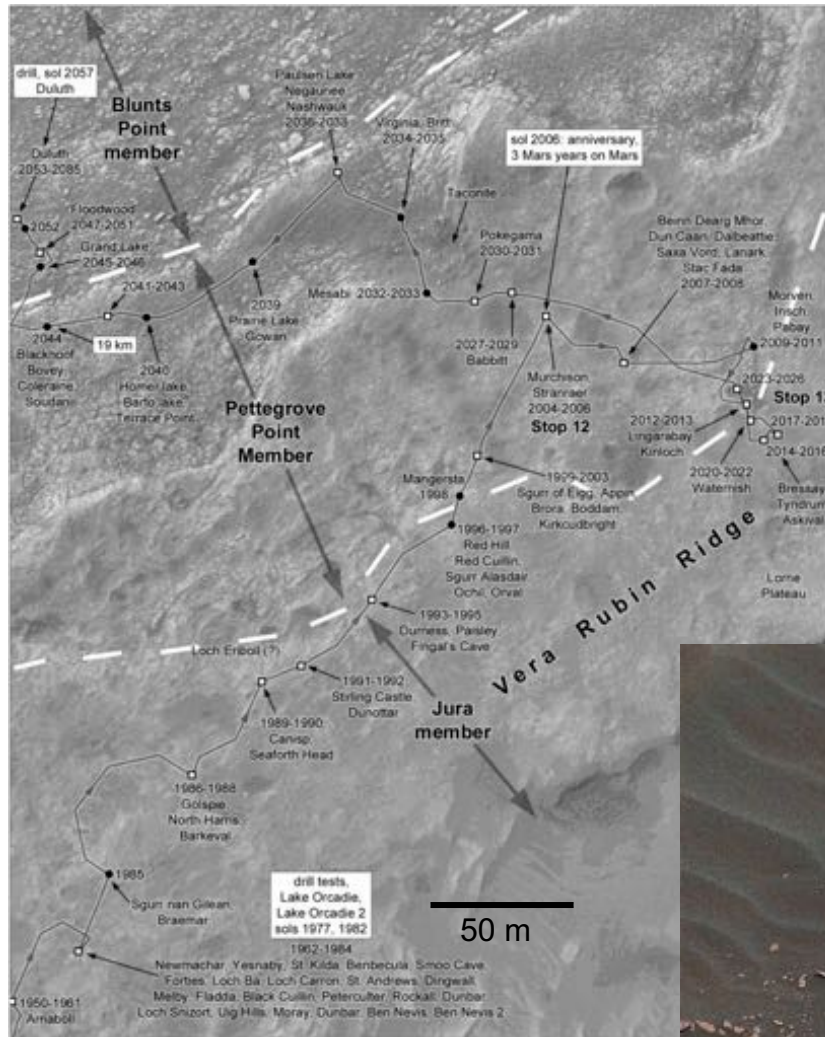
2 : Mt Sharp



7 :

2 : Mt Sharp

Sol 2087
DULUTH



Sol 1950
ARNABOLD

EMC18
La Chaux de Fonds

20 May 20th 2018
Sol 2057
Drilling at Duluth

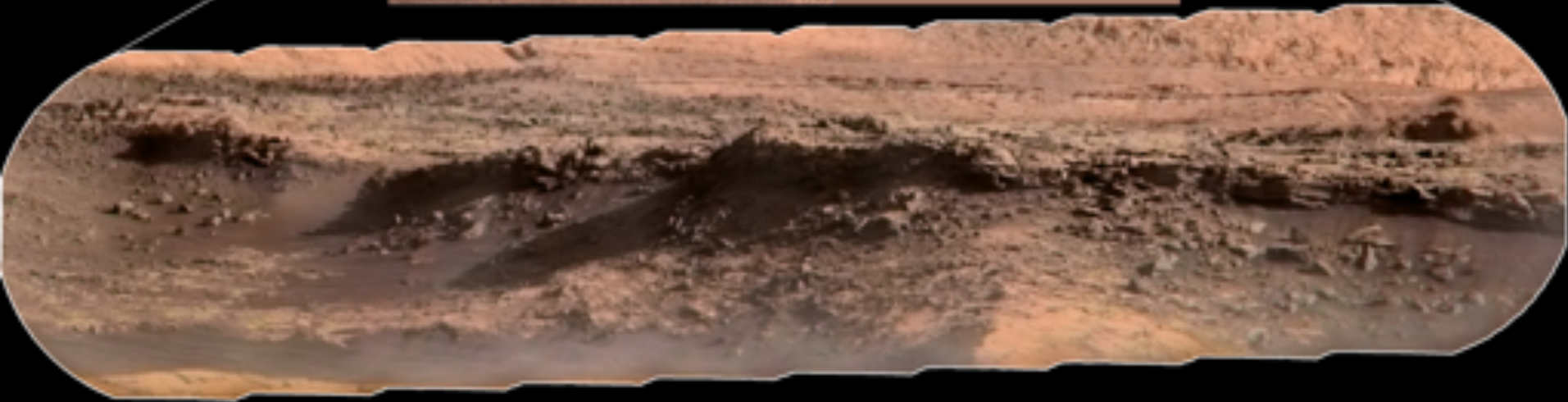
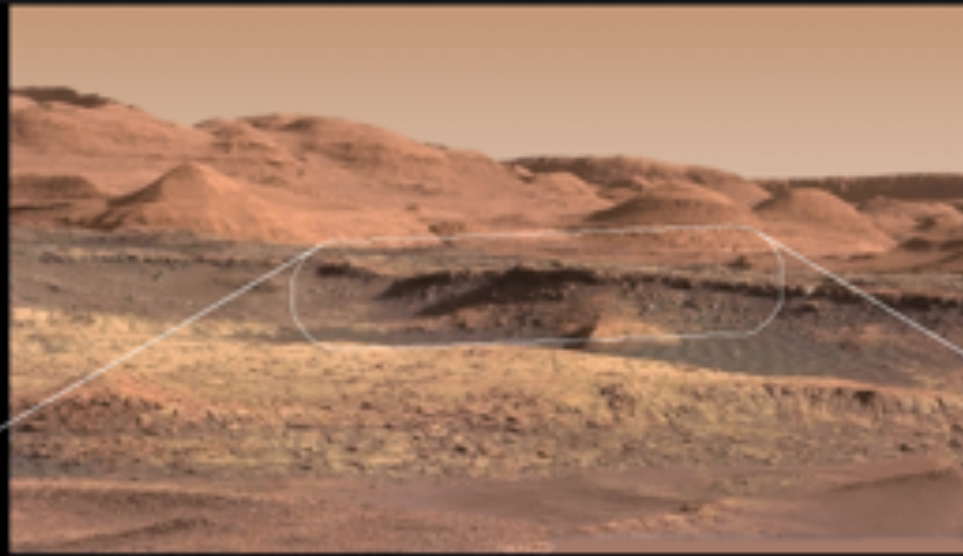


M. Cabane LATMOS
Sorbonne Université

2 : Mt Sharp

Sol 1981

January 2018



Zooming on a distant outcrop of Phyllosilicate Valley with Remote Micro Imager - sol 1981 - NASA/JPL-Caltech/MSSS/LANL/IRAP/Processed by Thomas Appéré

« Clays in sight ! »

Methane CH₄ on Earth

ABIOTIC

3%

geology

serpentinization

etc

BIOTIC

97%

past life (geology)

thermogenic CH₄

graphites

kerogens

etc

present life (biology)

various fermentations

Lifetime in martian atmosphere :
≈ 300 years (≈10 years on Earth)

CH₄ / Earth : 1700 ppb
= 1650_'life' + 50_geology

Methane CH₄ on Mars

Remote sensing

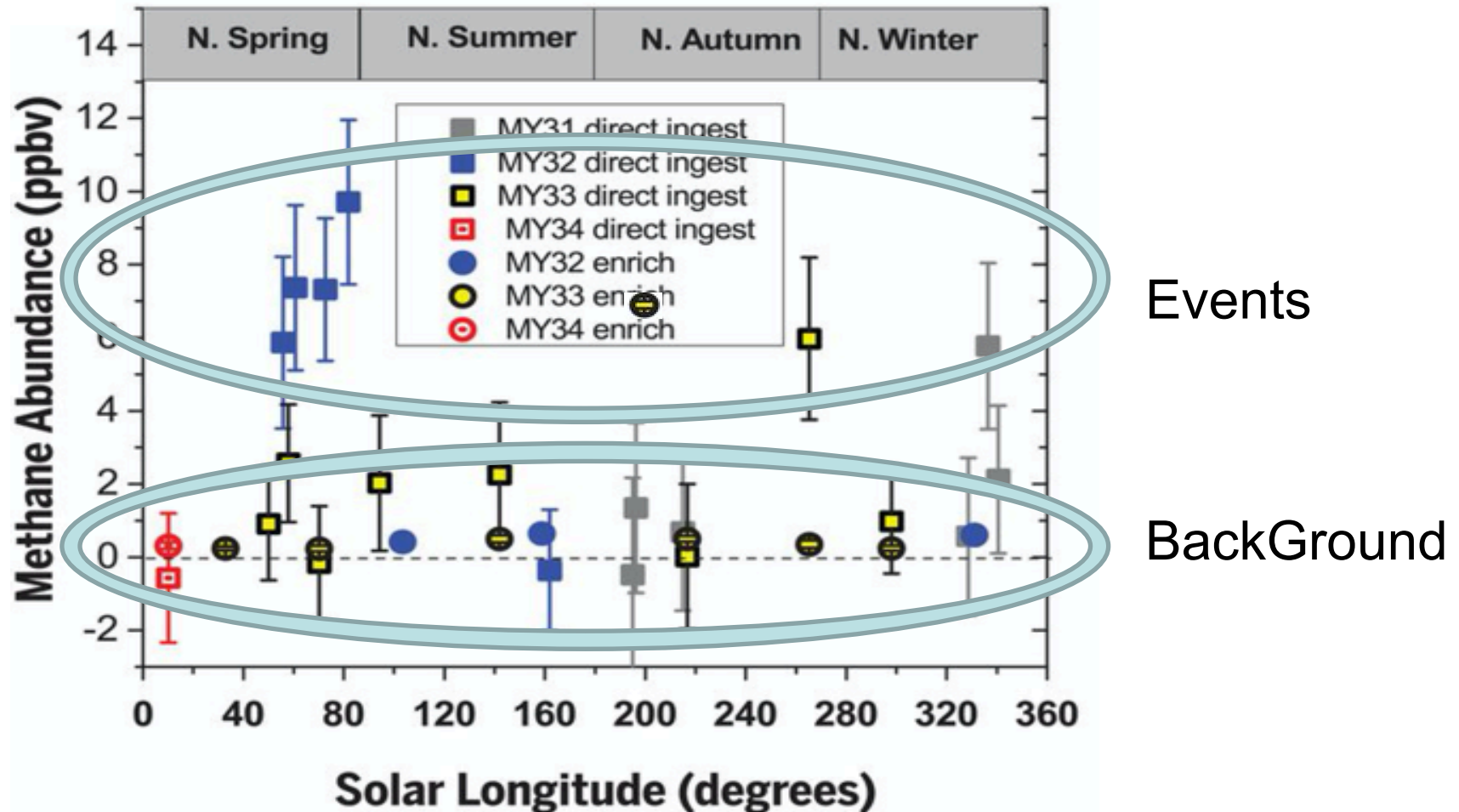
Mars observed from Earth : 10 à 40 ppb (variable)

10 +/- 3 ppb

from a martian orbit : 10 +/- 5 ppb

not so clear

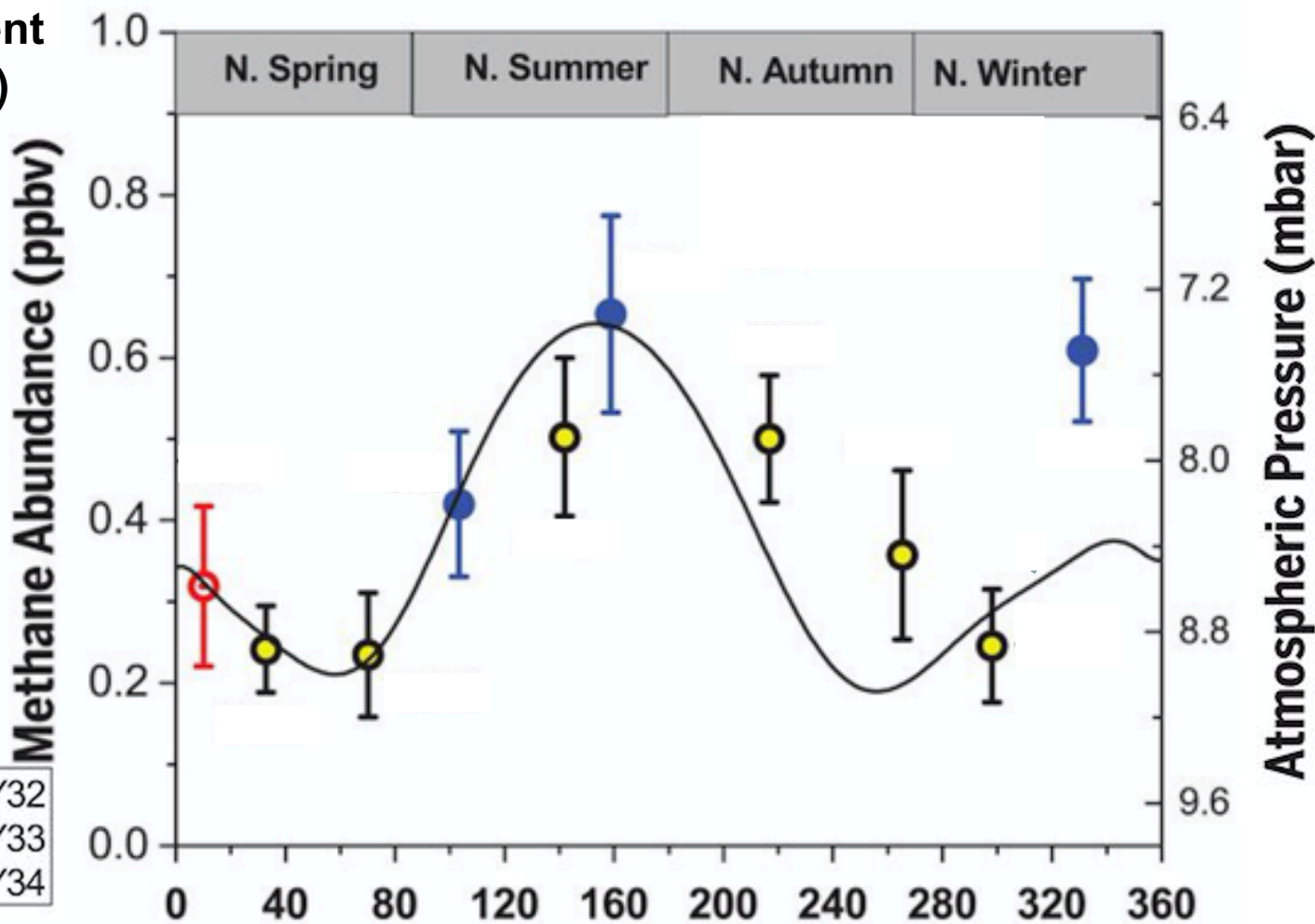
Measurements 'in situ' using SAM' TLS (ground level)



Background measurements at ground level

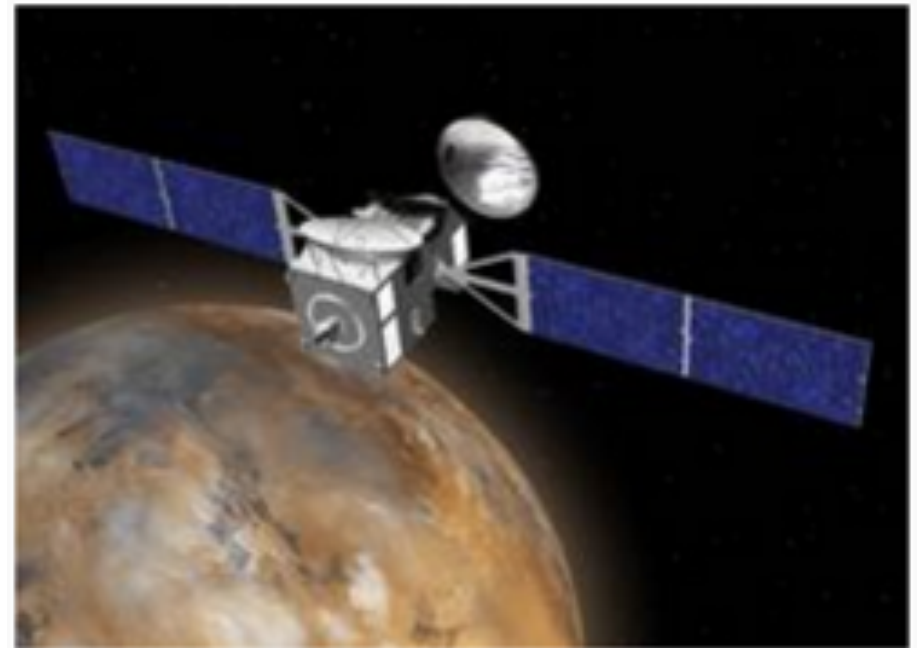
The case of CH₄

(enrichment
technique)



uptake - - - release - - - uptake ?

..... waiting for Exomars TGO !



Vue d'artiste d'ExoMars Trace Gas Orbiter

Thanks for attention

Mars was habitable...

