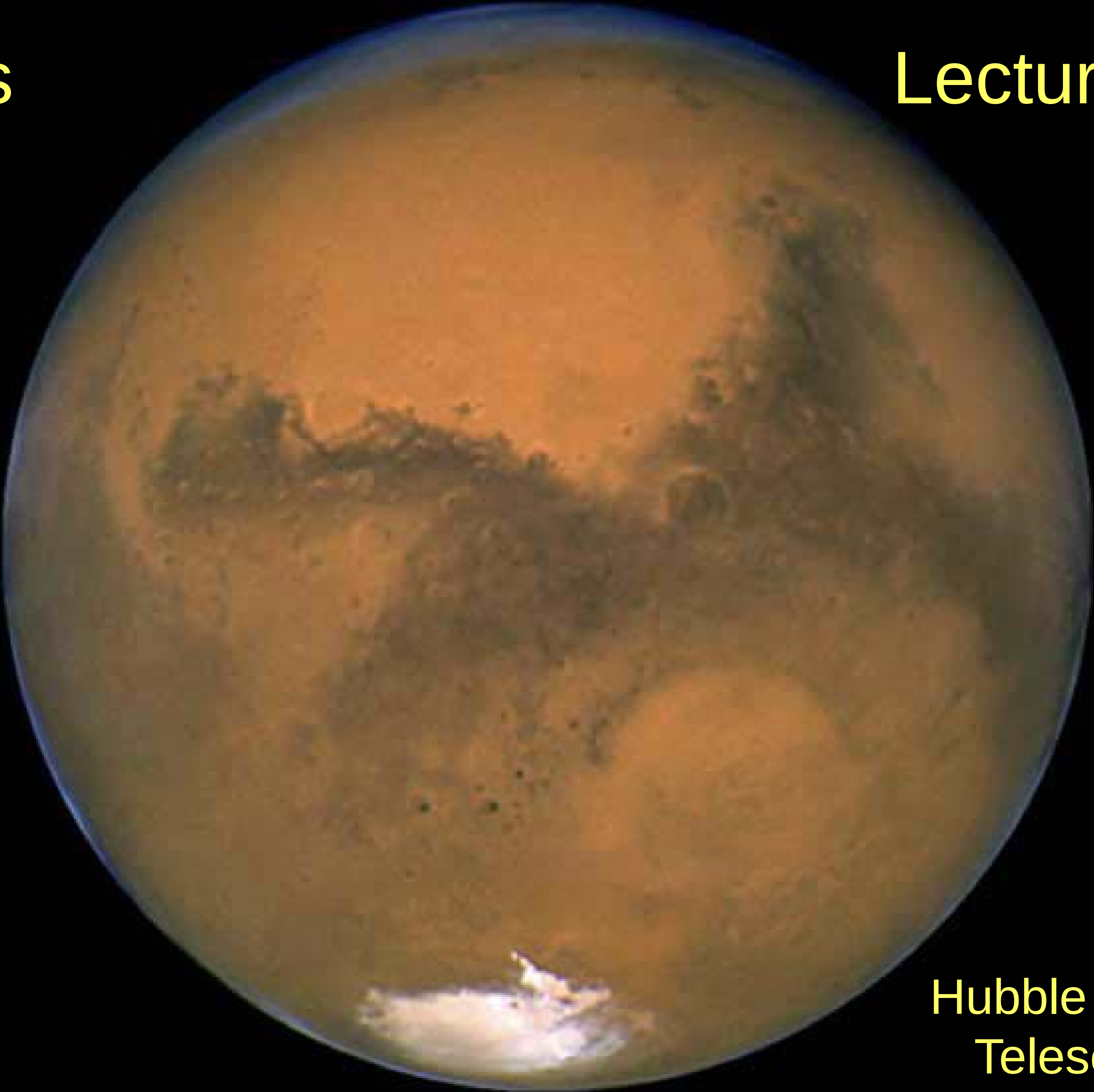
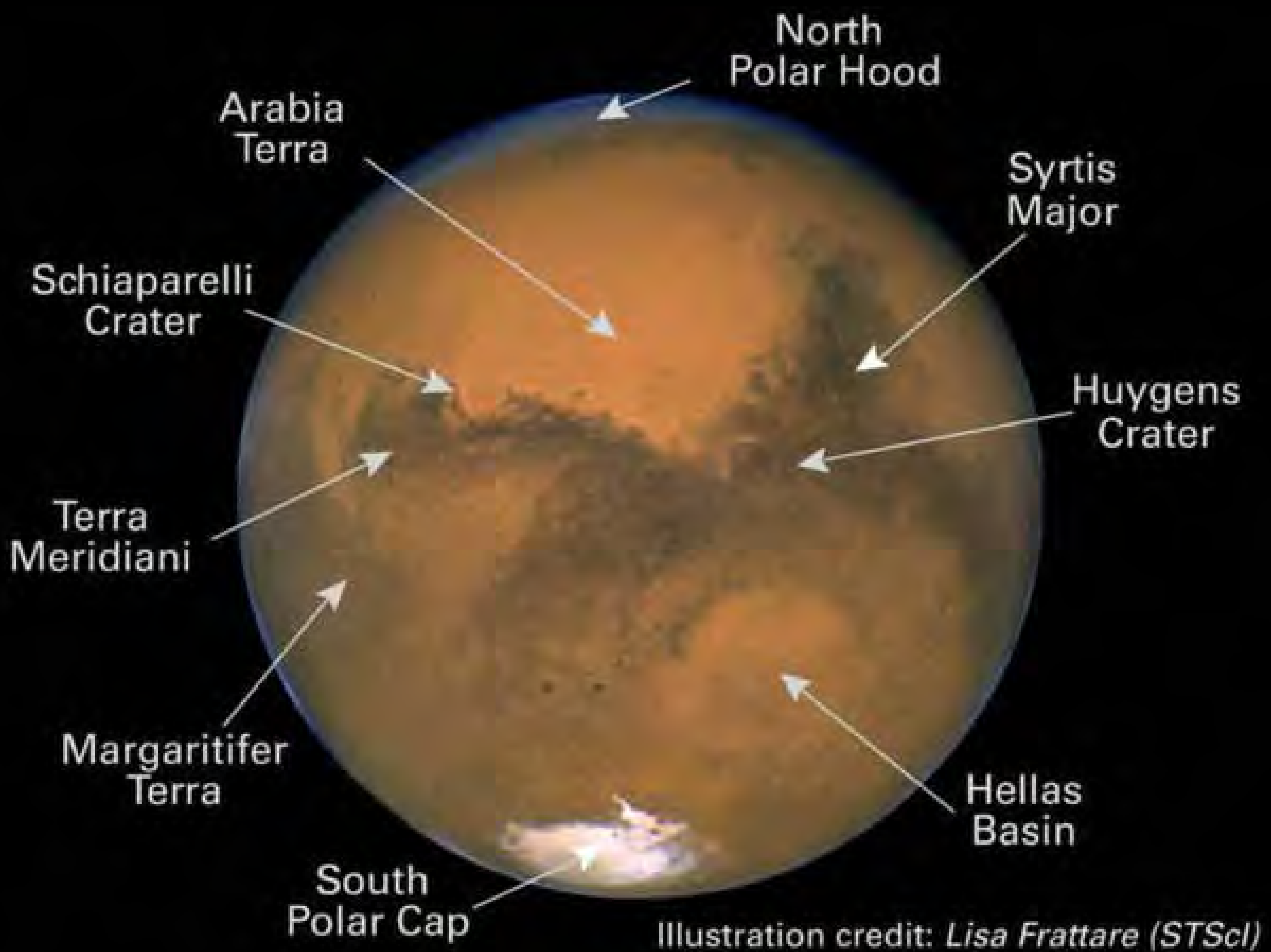
Mars Lecture 4



Hubble Space Telescope

The same image with feature names



Another view by Hubble Space Telescope

NASA, J. Bell (Cornell University) and M. Wolff (Space Science Institute)

The same image with feature names

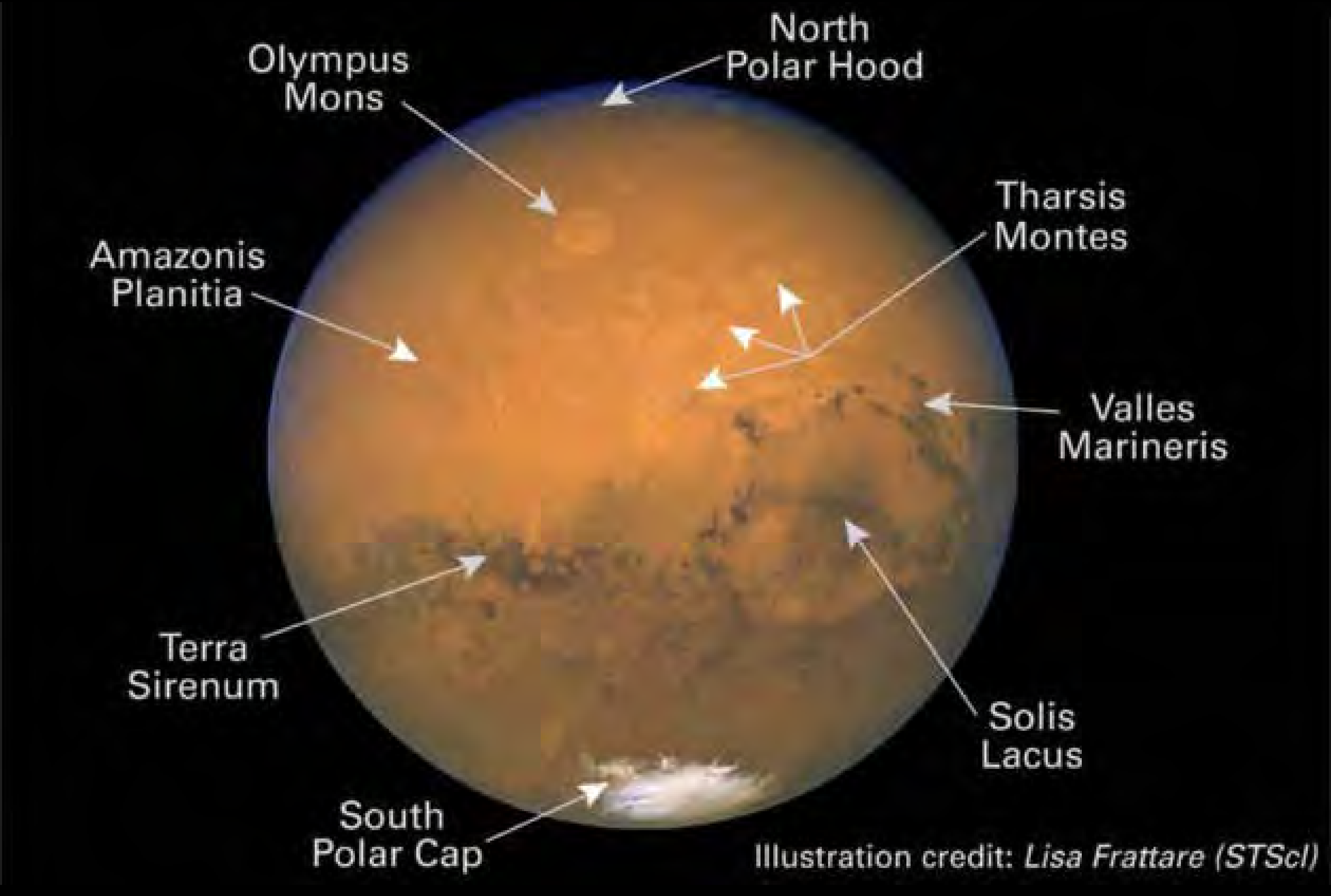
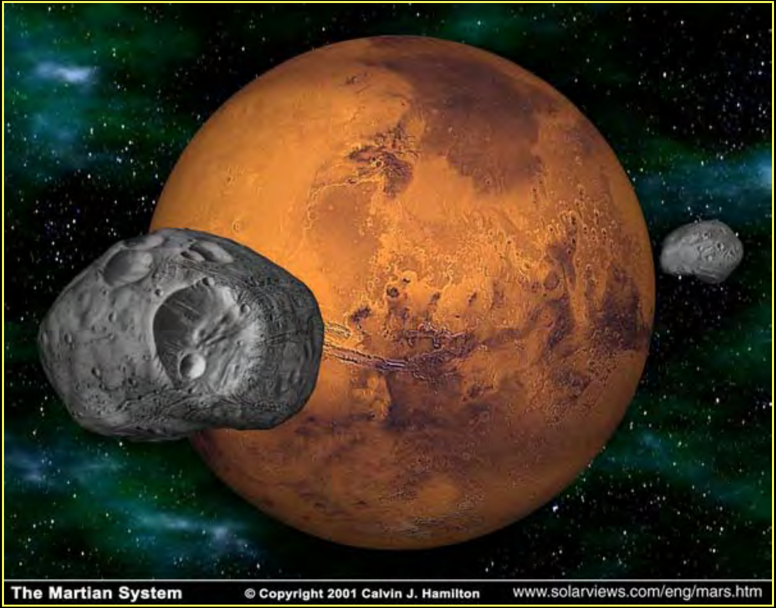


Illustration credit: *Lisa Frattare (STScI)*

General information



4th planet from the Sun
(mean distance **1.5** a.u.)

2 satellites: Phobos and Deimos

Martian year 687 Earth days

Rotation around axis – 24 h 39 min

Rotation axis 25.2º from ⊥ to the orbit plane (Earth 23.5º)

Seasons (north):
spring 199, summer 183, fall 147, winter 158 Earth days

Diameter 6792 km (0.53 D Earth)

Mass 0.11 M Earth (M Moon ~0.01 M Earth)

Mean density ρ = 3.9 g/cm^3 (ρ Earth = 5.52 g/cm^3)

Magnetic field – No obvious dipole, there is observed
from orbit remanent magnetisation of surface rocks

History of studies:

Before invention of telescope – red planet – God of war
Telescope – atmosphere, polar caps, canali
Space flights:
Past: Mariner 4, 6, 7 - Craters on Mars
Mariner 8 – ended in Atlantic Ocean
Mariner 9 – some similarities with Earth
Viking 1,2 – TV, UV, IR, magnetic measurements
Mars 2, 3 crashed, Mars 4, 5 gamma spectra, TV
Mars 6,7 missed Mars
Fobos 1 – lost in the way, Fobos 2 – TV, IR spectra
Mars 96 – ended in Pacific ocean
Mars Observer – lost in the vicinity of Mars
Mars Pathfinder – successful landing
Mars Climatic Orbiter – lost in the vicinity of Mars
Mars Polar lander – lost at landing
Mars Global Surveyor – successful
Phoenix
Spirit
Ongoing: Mars Odyssey, Mars Express, Opportunity, Mars Reconnaissance Orbiter, Mangalyaan, Curiosity, MAVEN

In some future:
Manned expedition to Mars

Now: Project «Mars-500»

Imitation of manned flight to Mars

520-days isolation (June 2010 – November 2011)

Ситёв Алексей Сергеевич
Comander

Камолов Сухроб Рустамович
Medical doctor

Смолеевский Александр Егорович
Researcher

Romain Charles
Engineer

Diego Urbina
Researcher

Wang Yue
Researcher

Surface environment:

Atmosphere – 95% CO_2, 3% N_2, 2% Ar (Earth 79% N_2, 21% O_2)

P atm average 7 mbar, from 3 mb on top of Olympus to 14 mb
at the floor of Valles Marinares

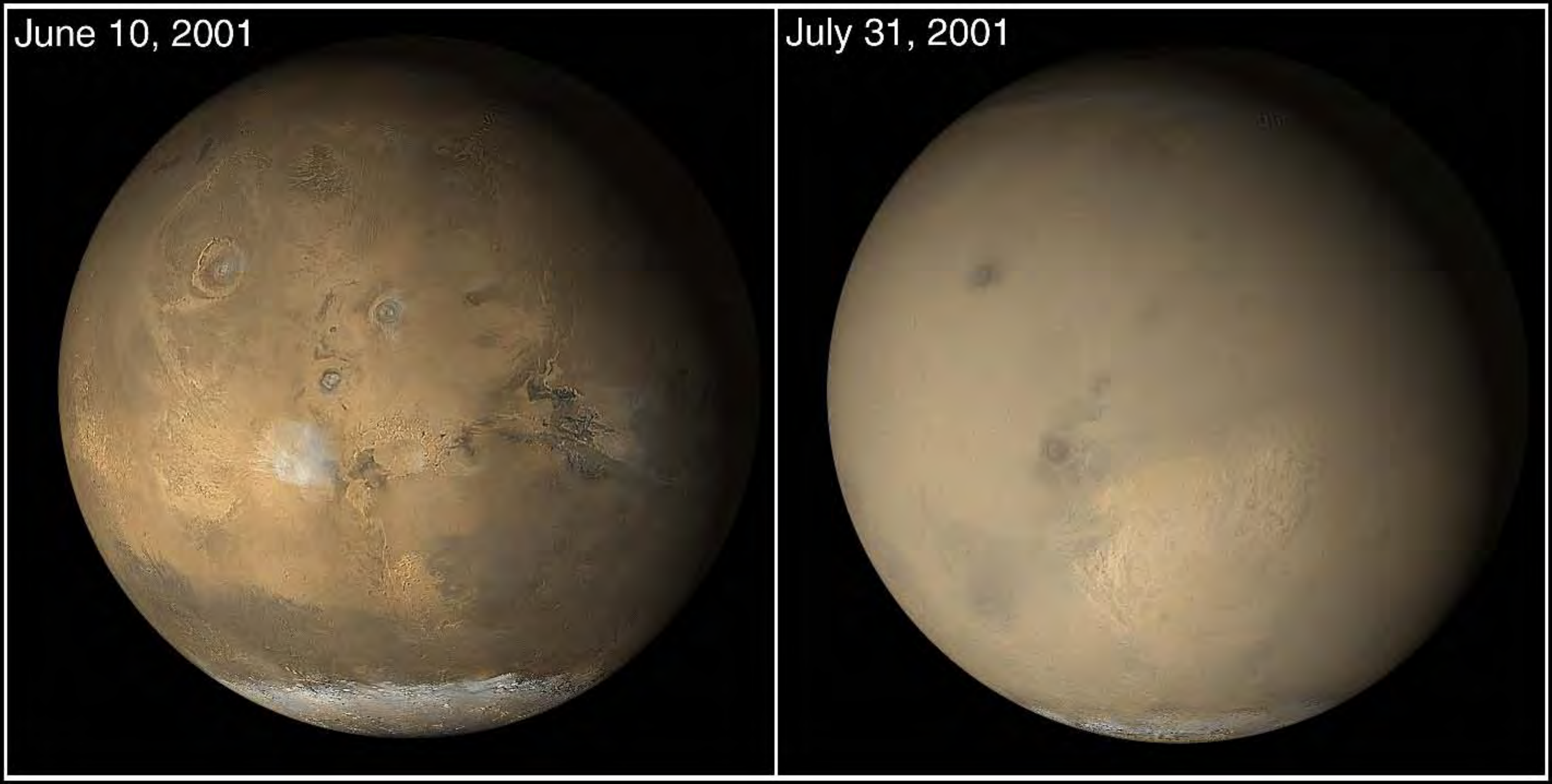
Surface temperature (±60 latitude): 180 K night, 290 K noon,
Poles in winter – down 150 K (condensation atmosph. CO_2)

Wind, yellow clouds 40-60 km/hour, dust devils

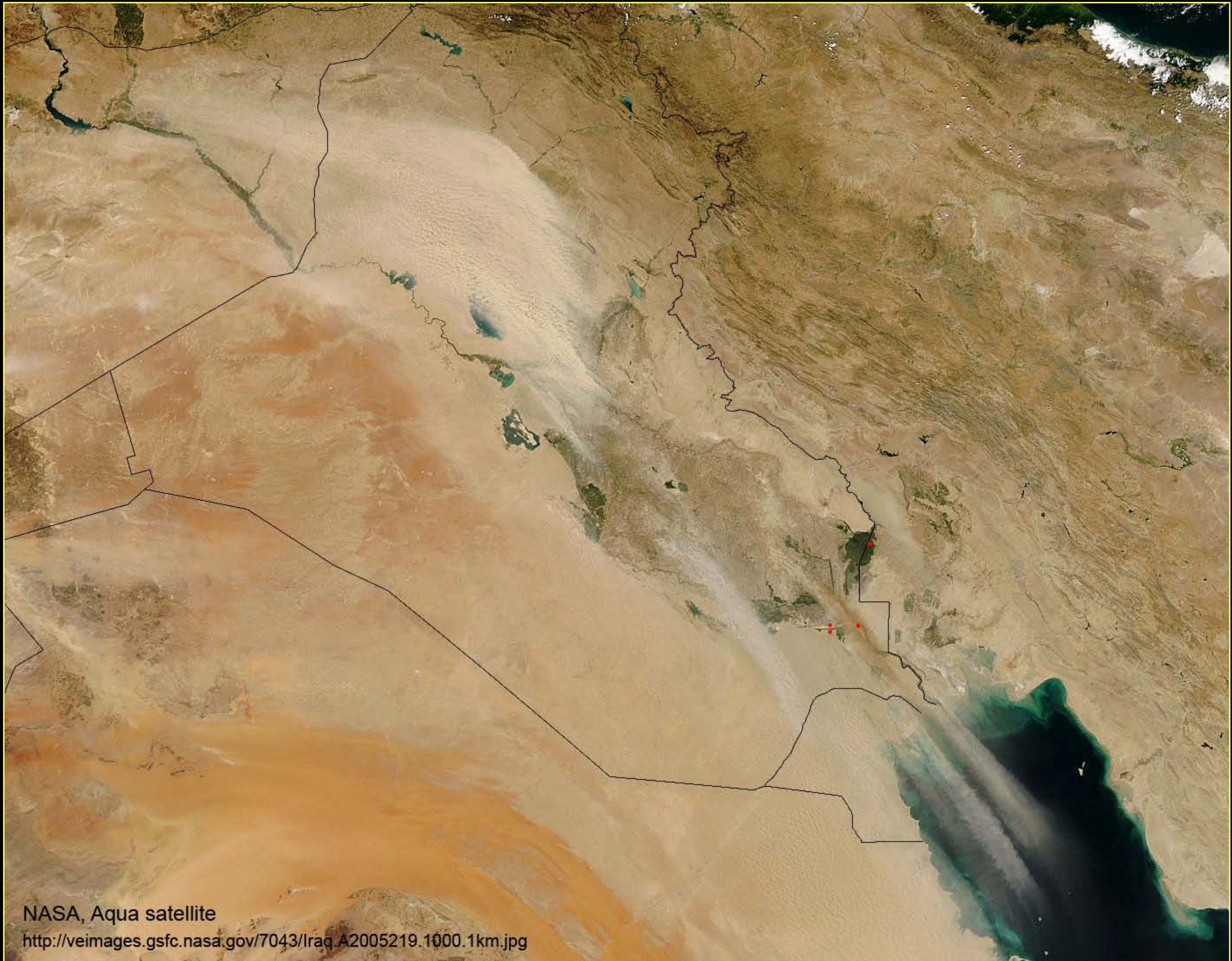
Surface gravity g = 0.38 g of Earth, 2.3 g of Moon

Dust devils in crater Gusev, Spirit landing site

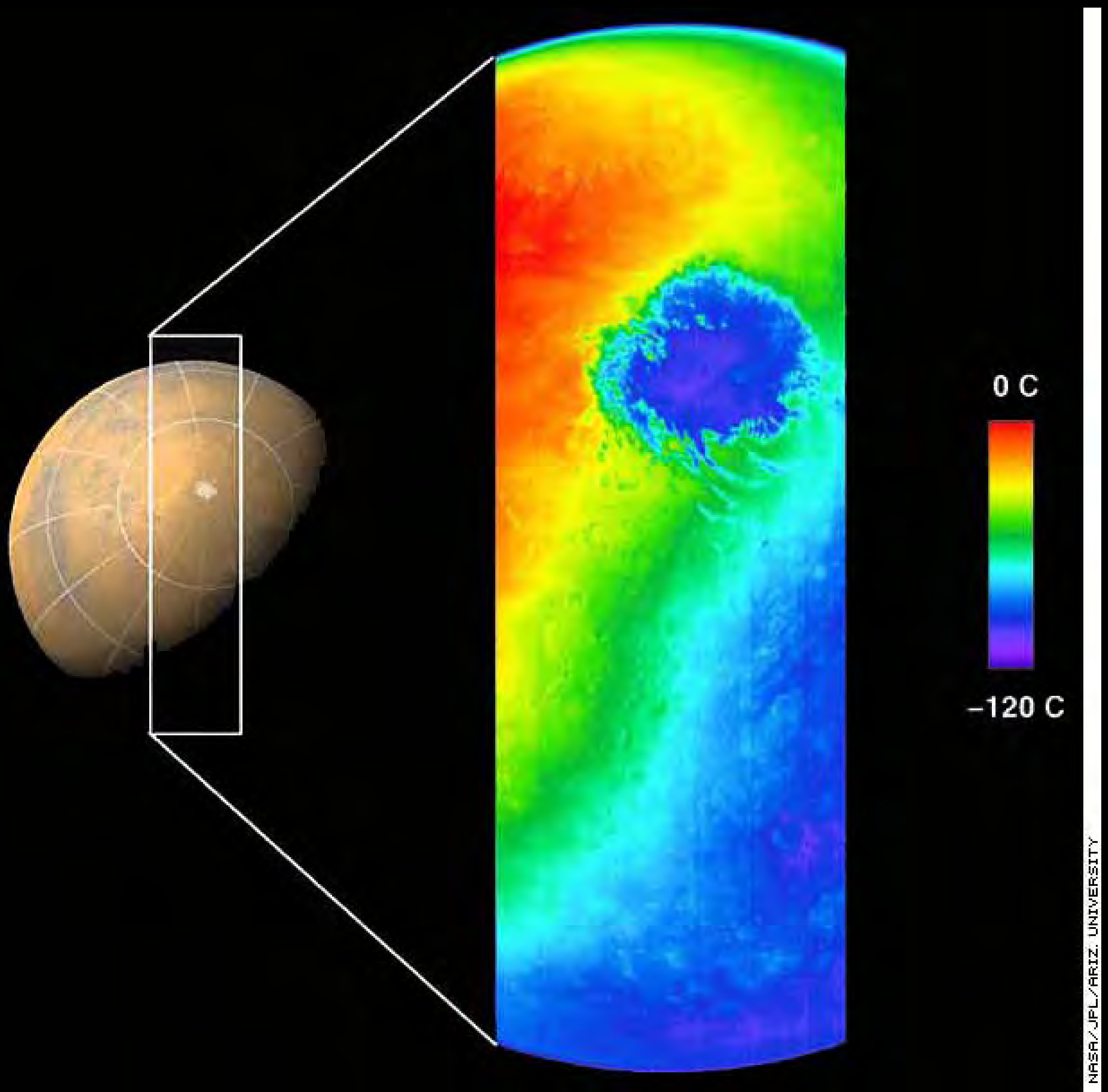
Global dust storms as effective mechanism of global averaging of composition of dusty soil



Earth: Dust storm in Iraq, August 8, 2005



Surface temperature at the South Pole



THEMIS,
Mars
Odyssey

Polar areas: Ices and frosts

Summer at south pole,
MGS Wide angle MOC

Late winter at south pole,
MGS Wide angle MOC

H_2O ice

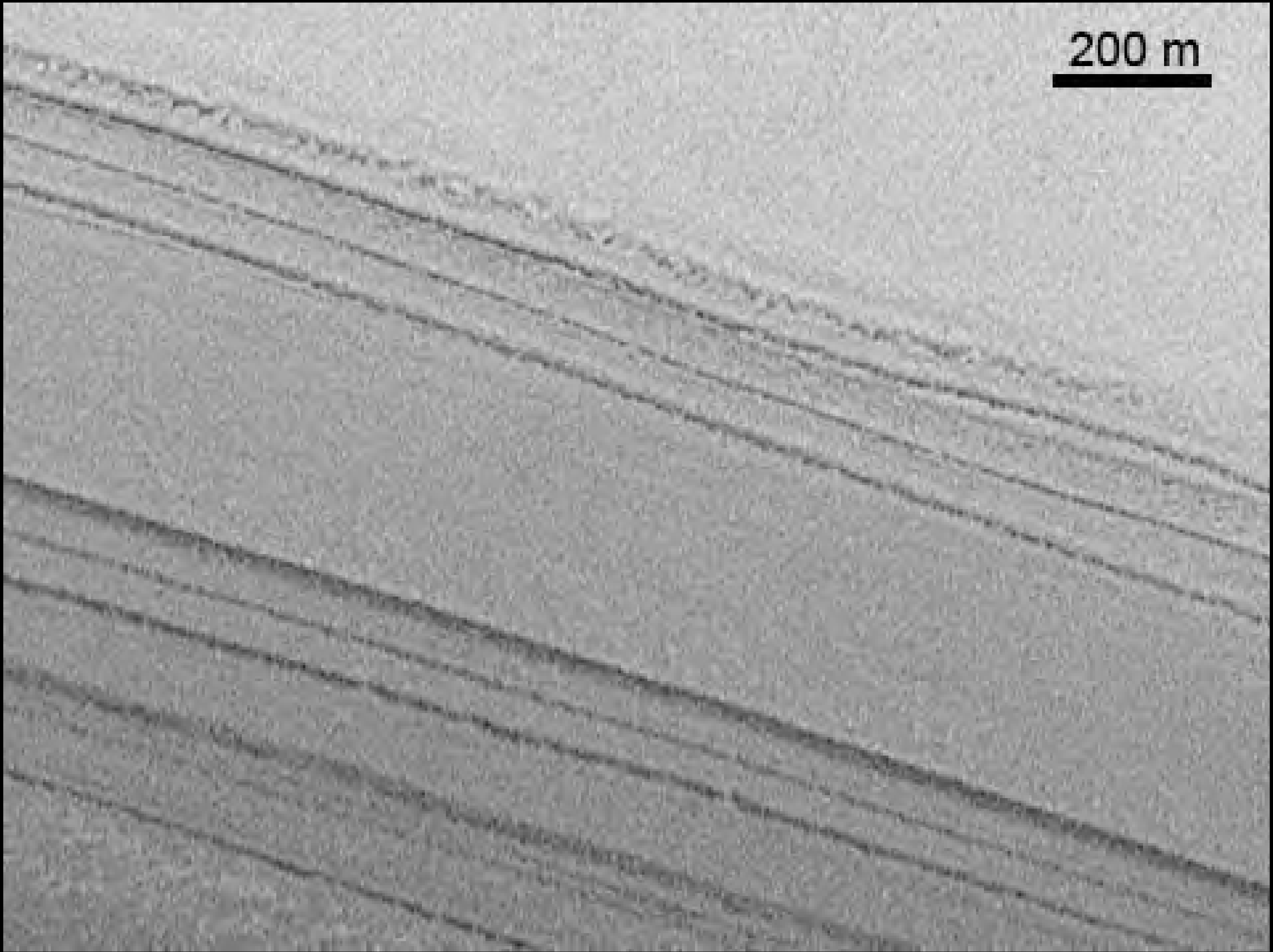
CO_2 ice

- white CO_2 ice
- "black" CO_2 ice

Clathrate CO_2 $6H_2O$

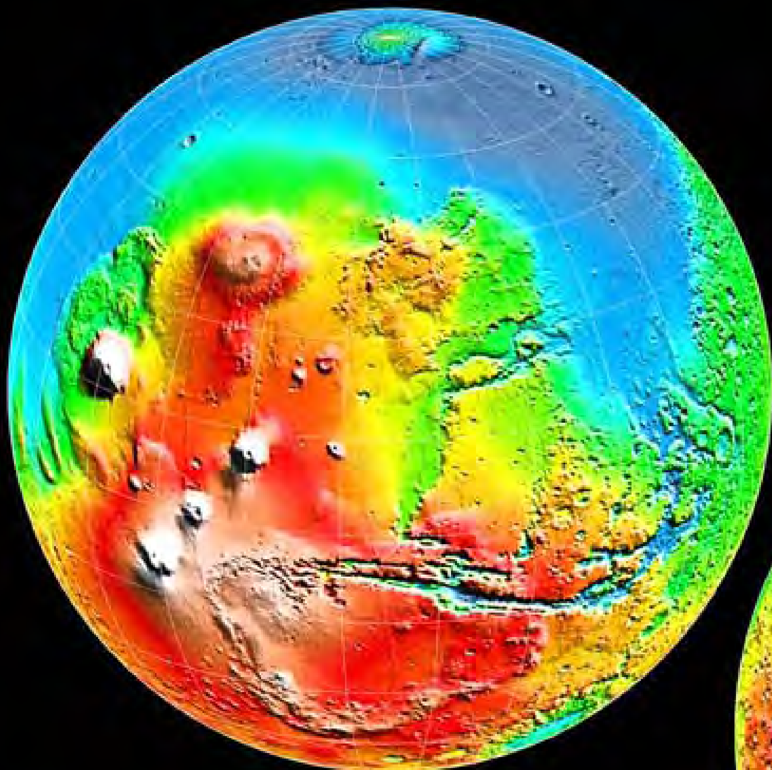
- expected,
- no signature found

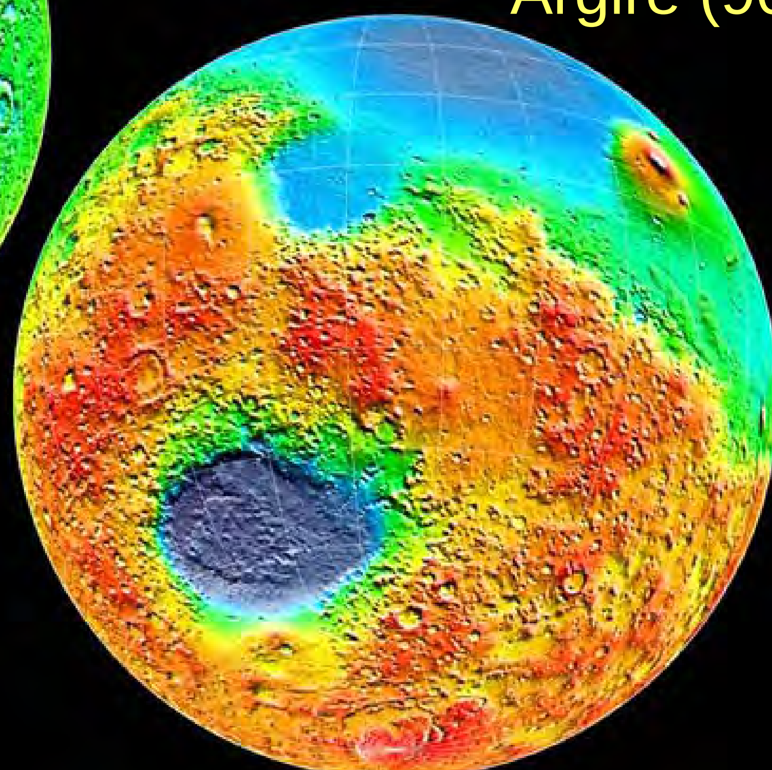
Mars polar layered deposits: North Pole



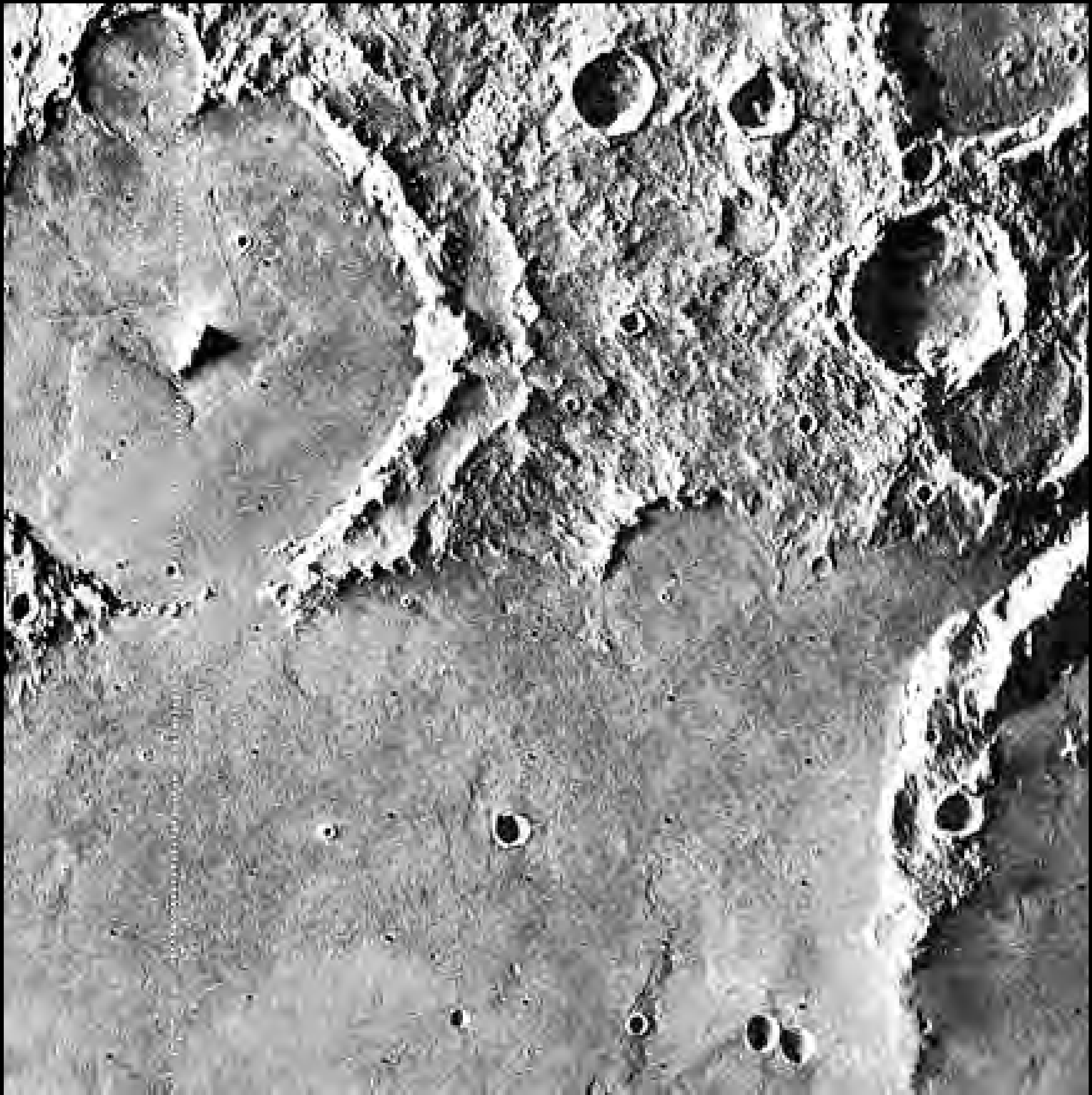
Surface morphology and topography

Lowland plains in the north
Cratered highland at the south
Transitional terrain
Tharsis bulge – inclined plains, giant volcanoes
Basins: Hellas (D = 2000 km), Argire (900 km)

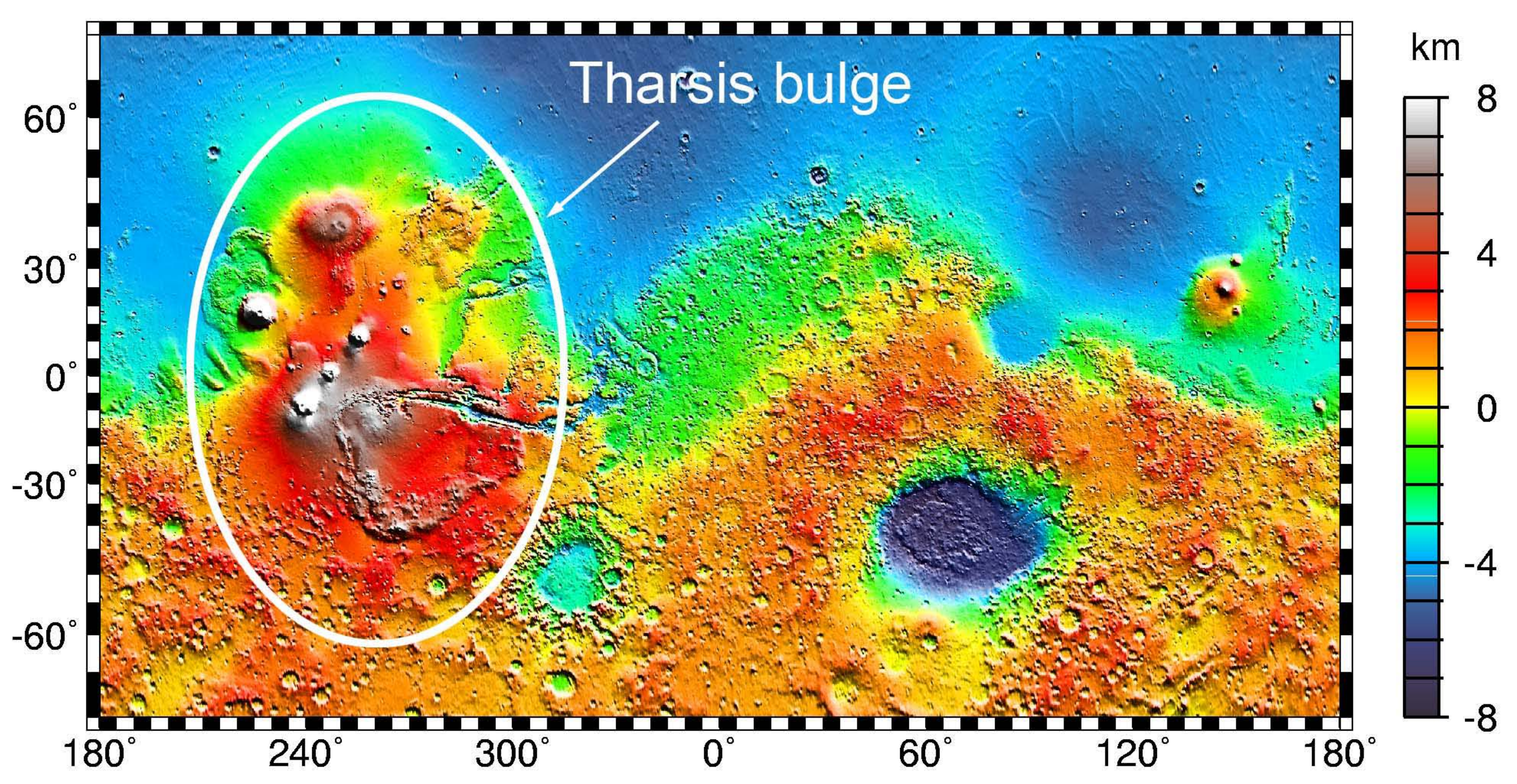




Highlands and plains

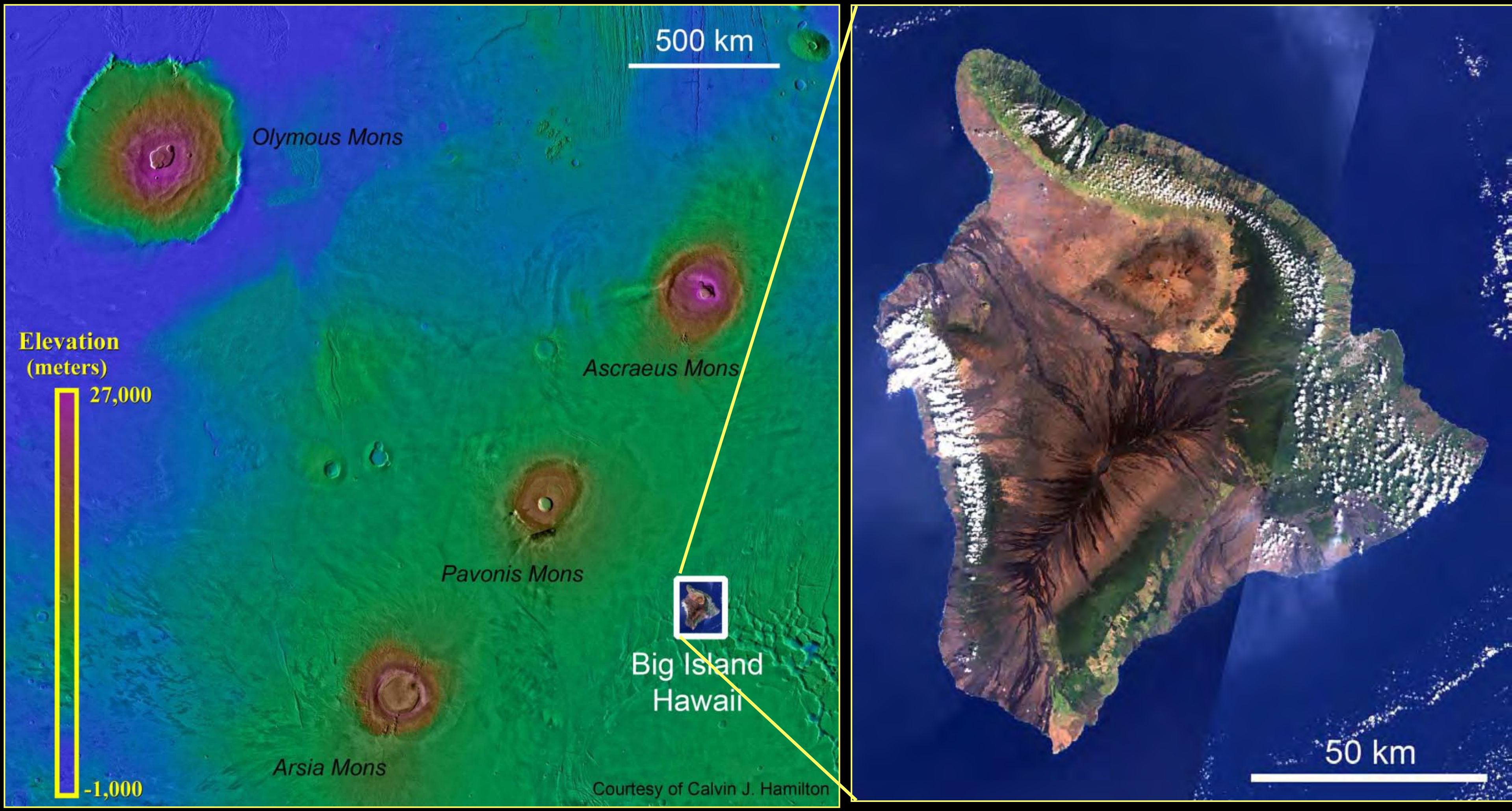


Tharsis topographic bulge bears several giant volcanoes



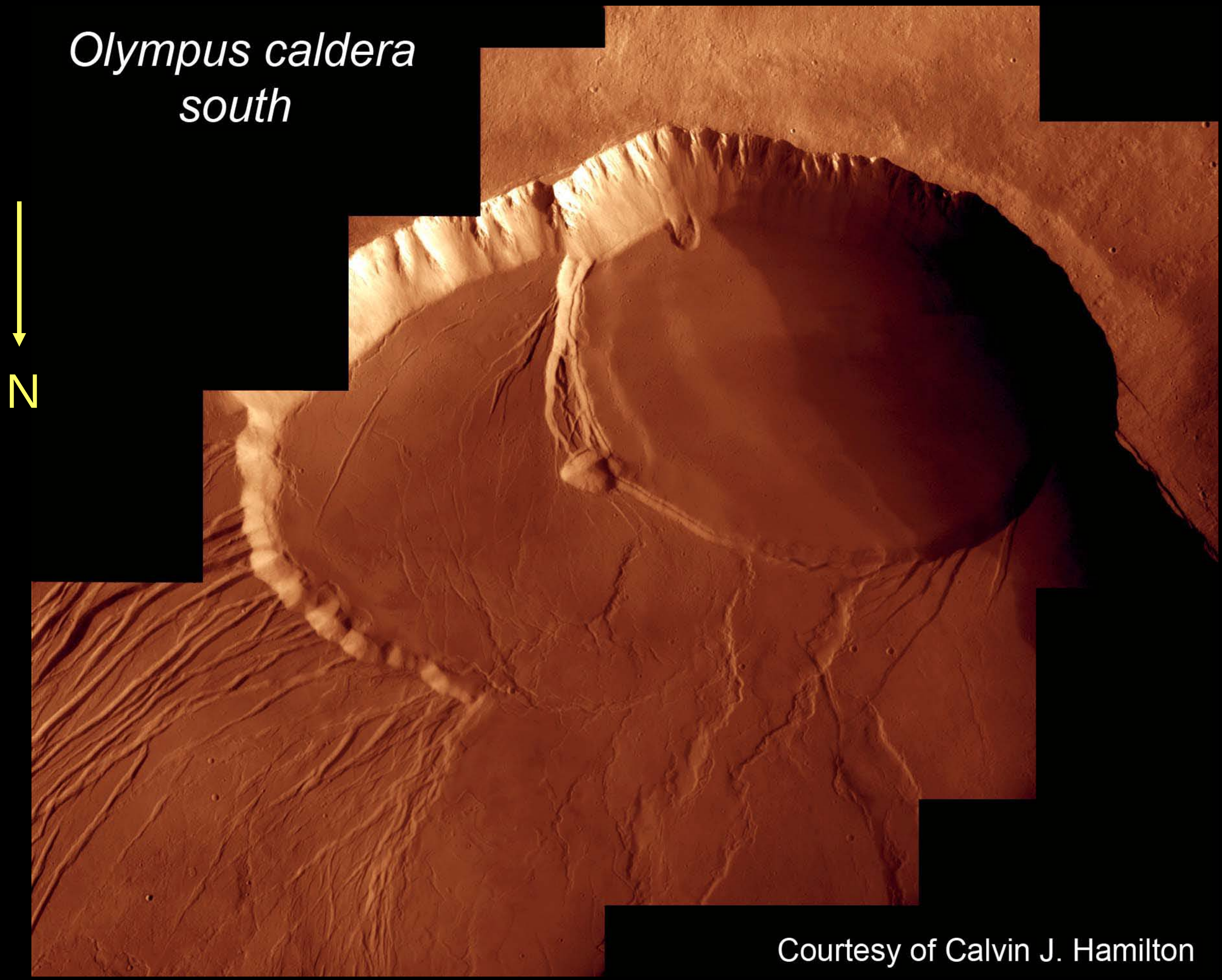
Case for Tharsis bulge?

Tharsis volcanoes in comparison with Big Island, Hawaii



Olympus Mons, 600 km across, 21 km high

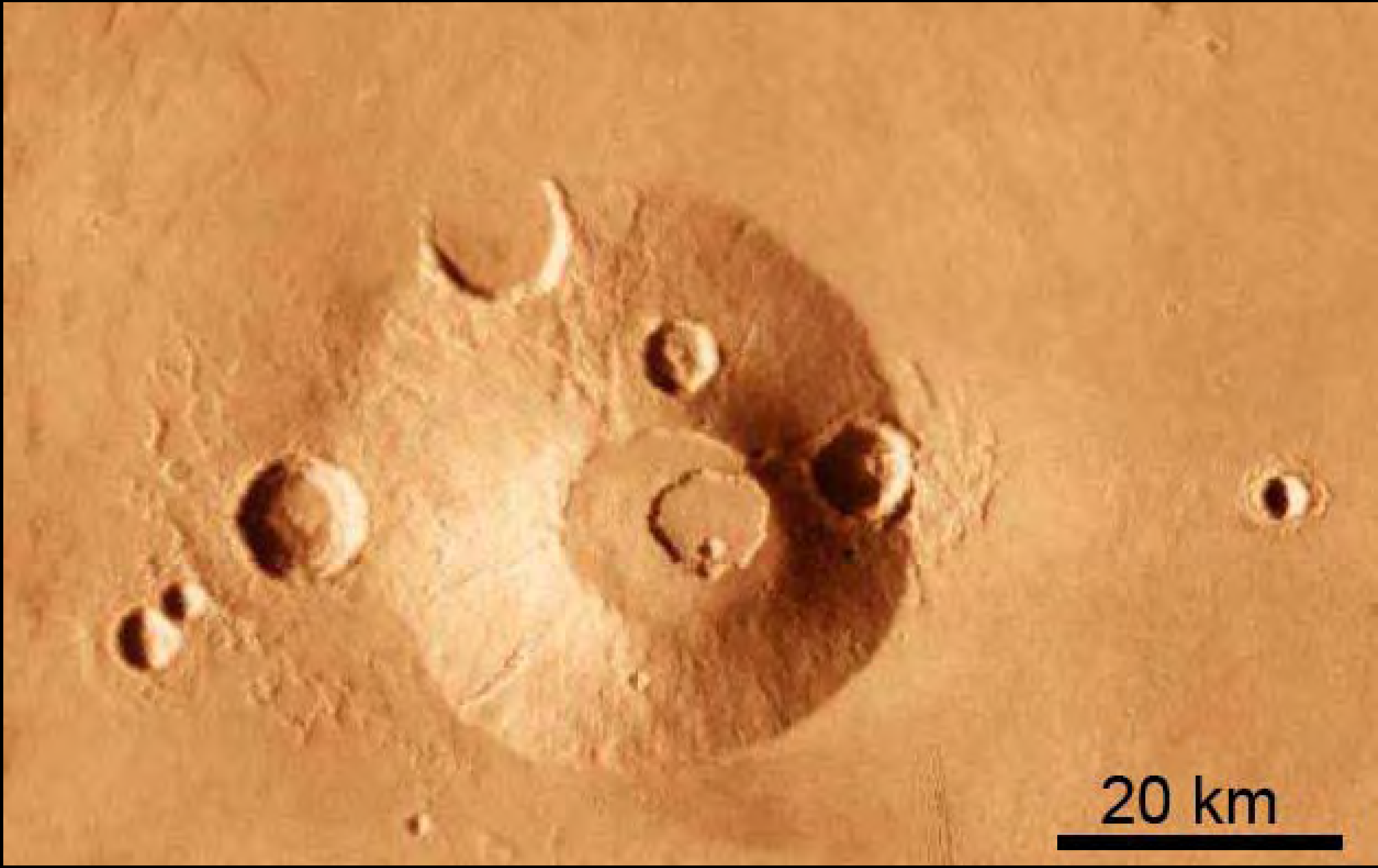
Southern part of Olympus caldera



Arsia Mons, the southmost of Tharsis volcanoes

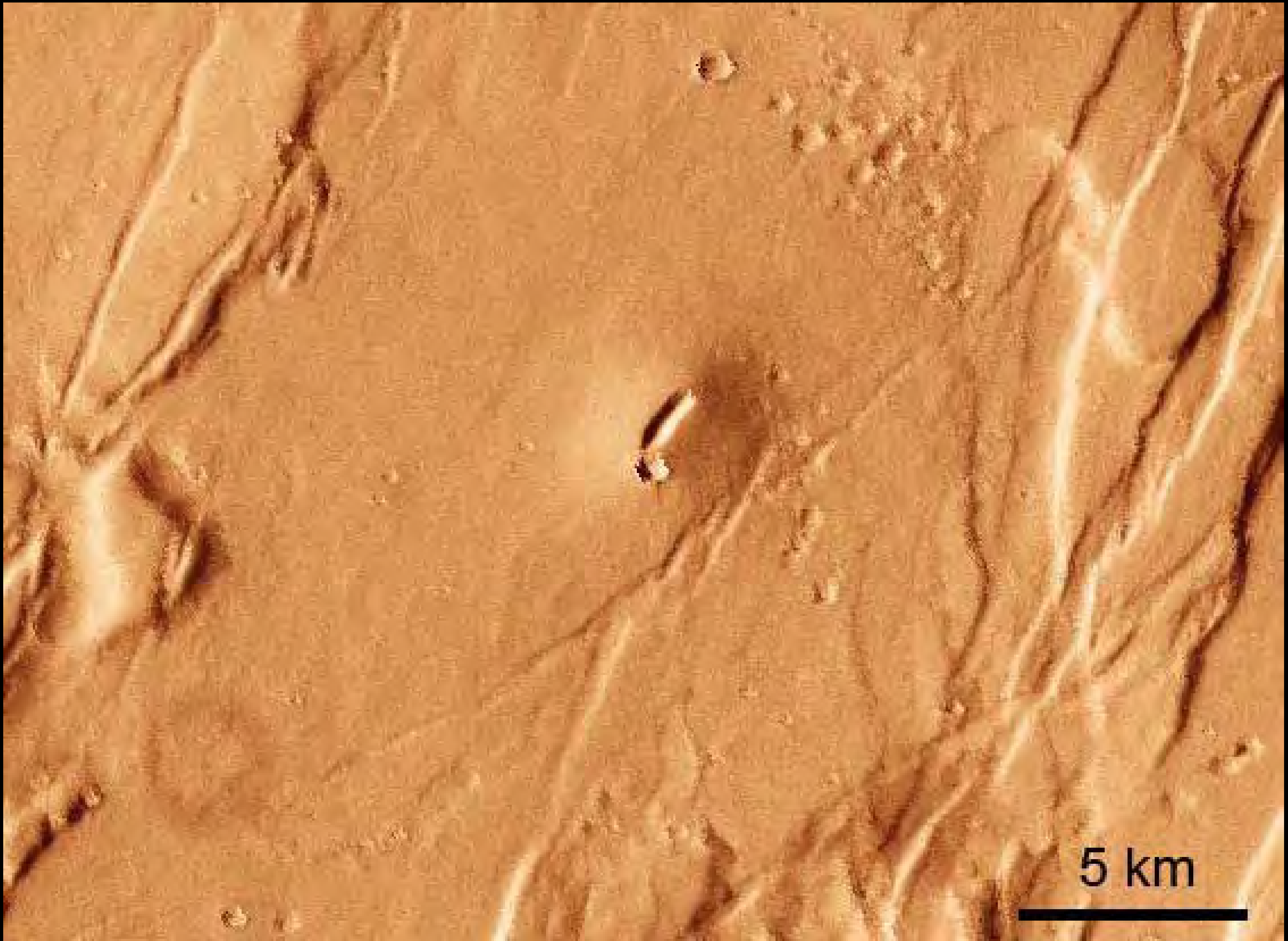
D = 450 km, H = 20 km above datum

Volcano of intermediate size, Uranius Tholus

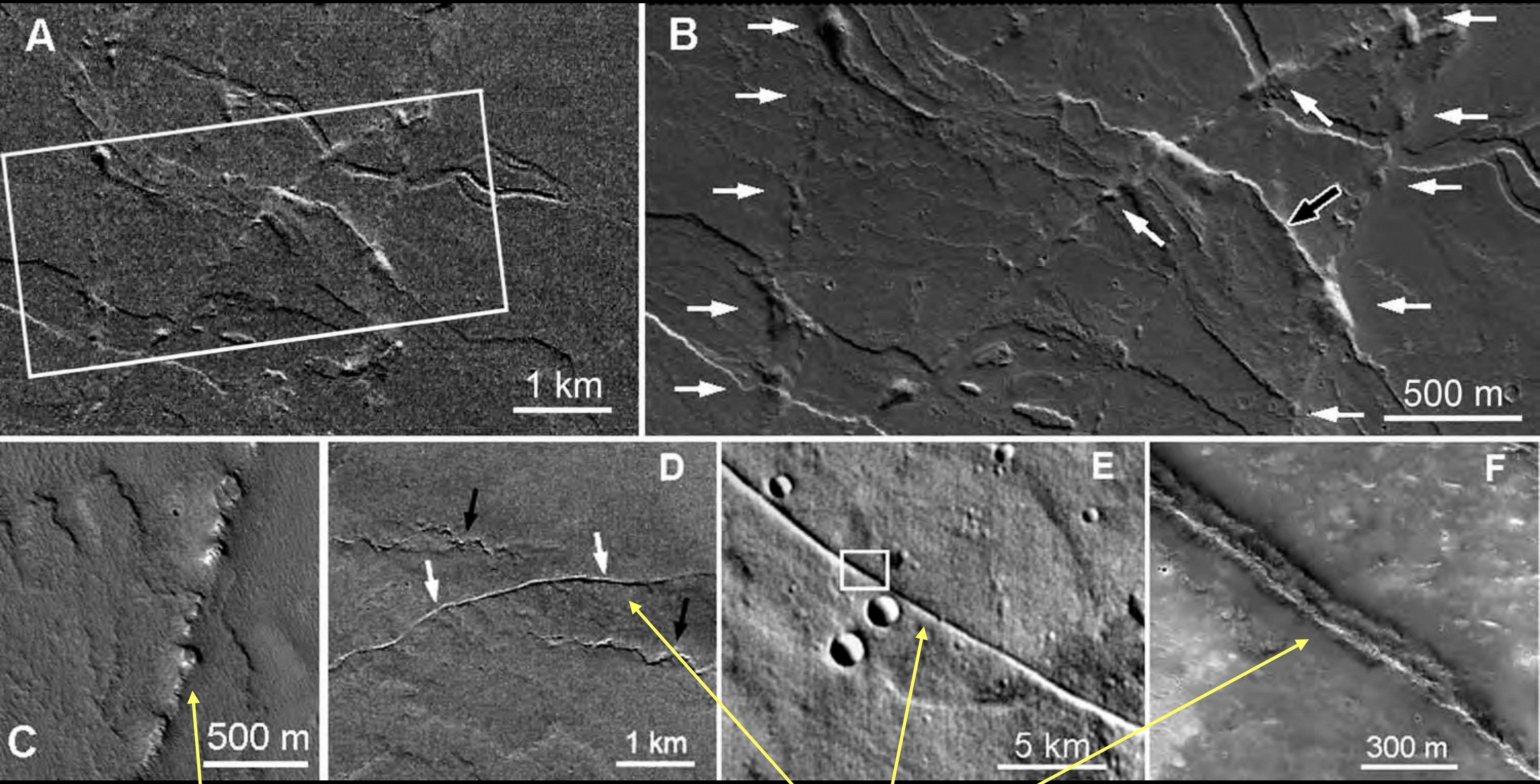


Pay attention on age relations between the volcano and surrounding plains

Small shield volcano in Tempe



Cinder cones and dike ridges of Martian volcanoes formed due to fissure eruption



Cinder cones

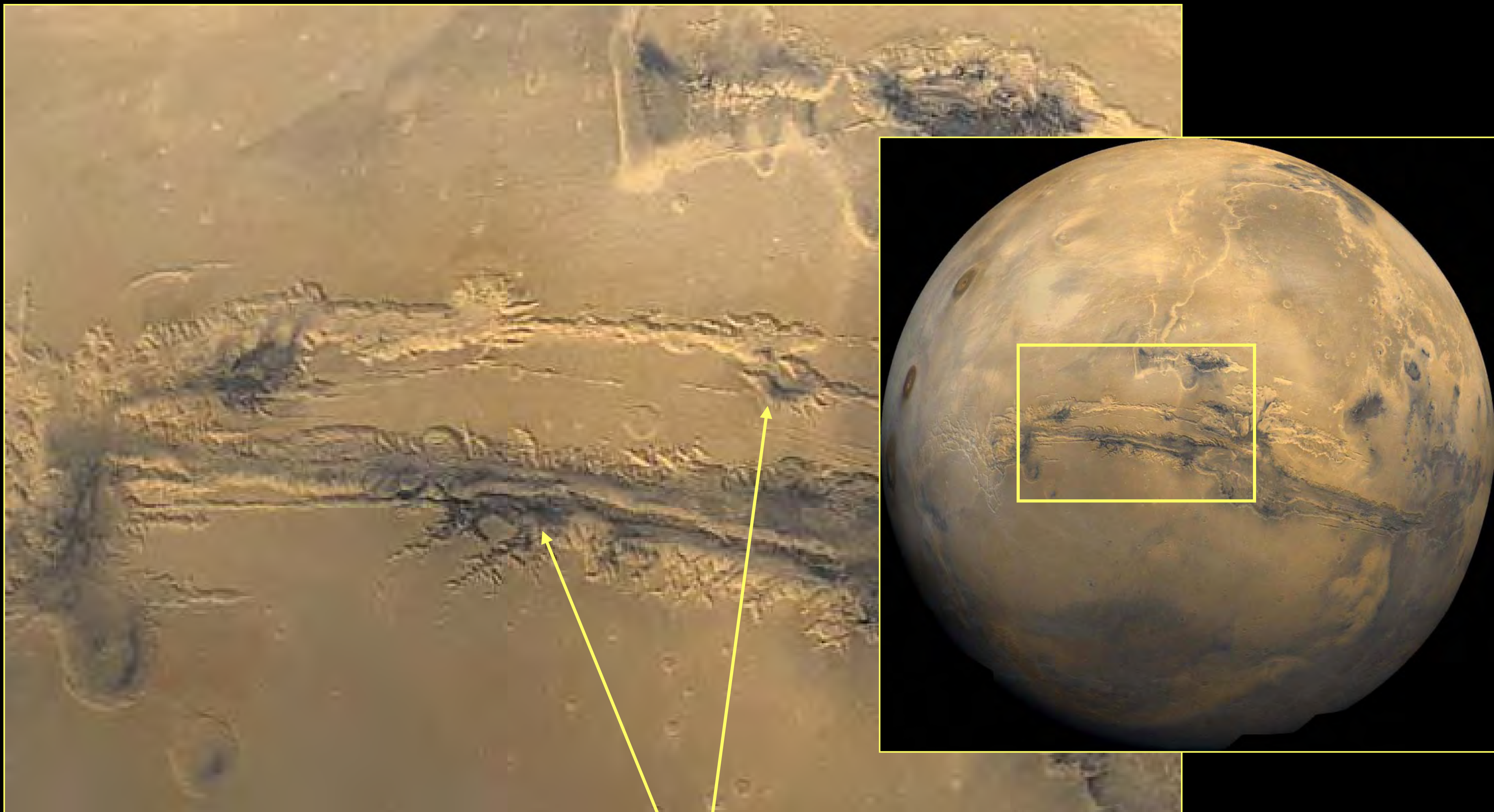
Dikes ridges

Fissure eruption, Etna, Sicily, Mediterranian, dawn

Fissure eruption, Etna, Sicily, Mediterranian, day

Cinder cone almost done, Etna, Sicily, Mediterranian

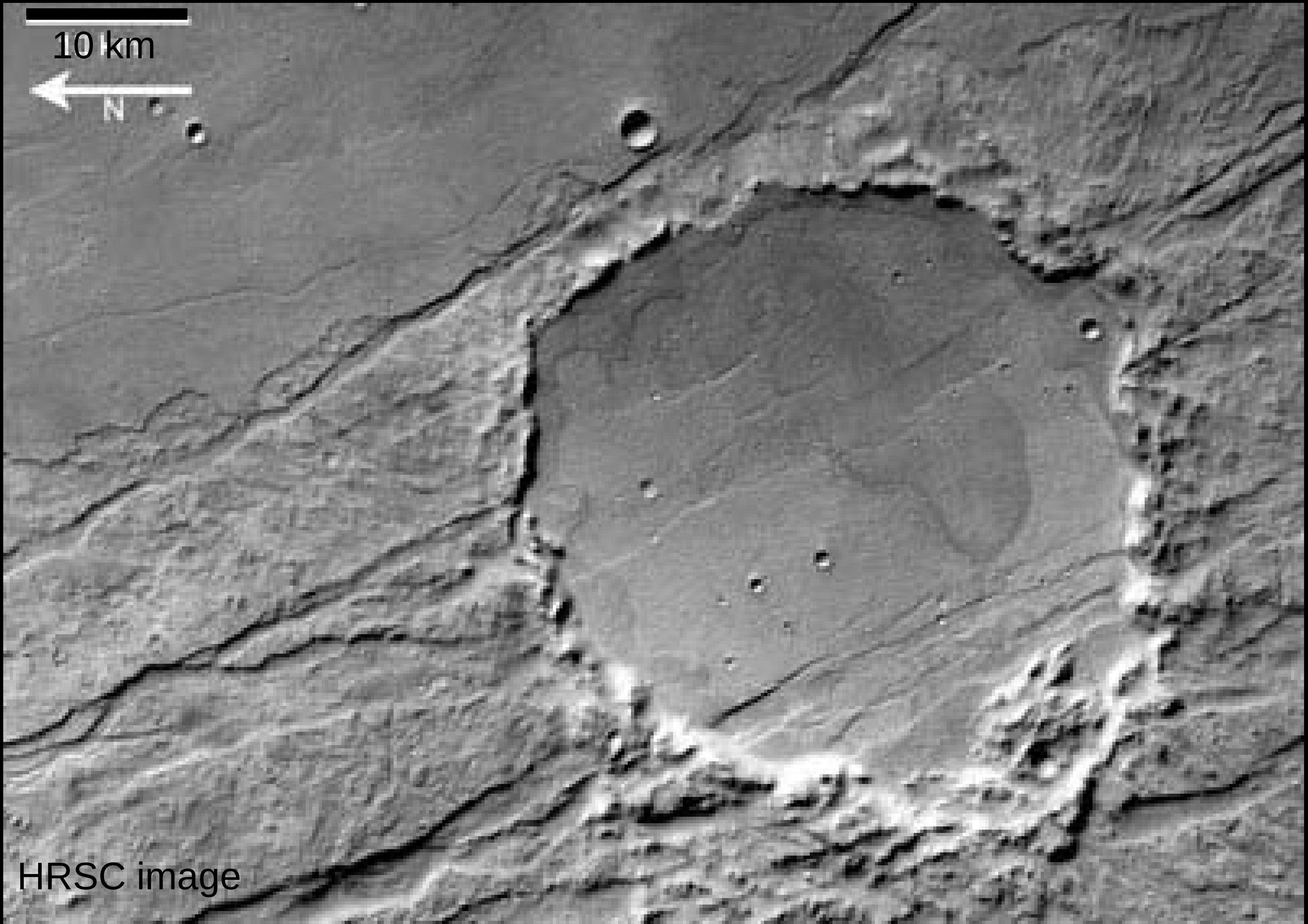
Tectonics, more extensional, partly compressional



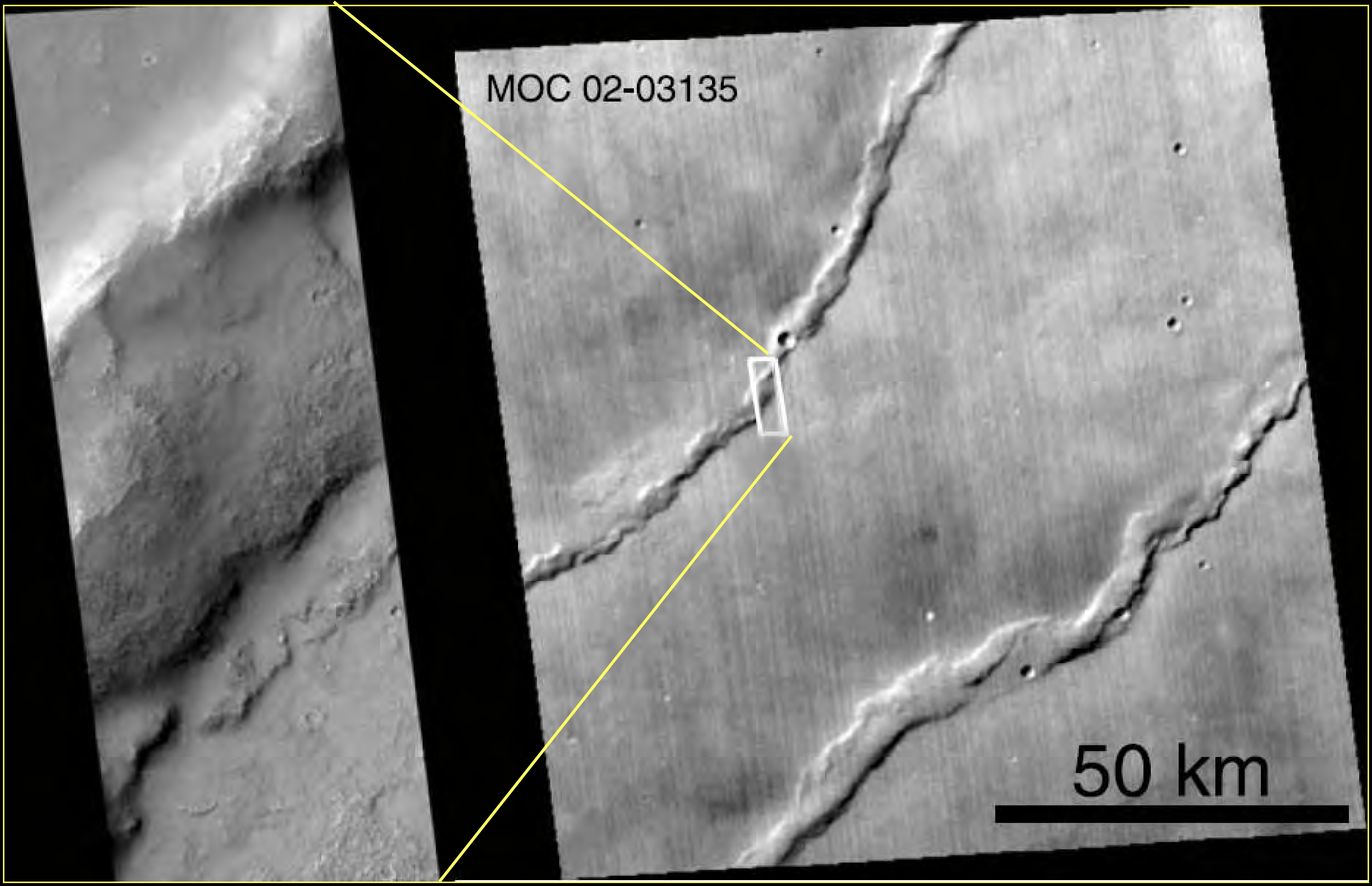
Valles Marinares – Martian rift zone

Grabens & pits of Phlegethon Catena suggest extension

Grabens of Claritas Fossae suggest extension

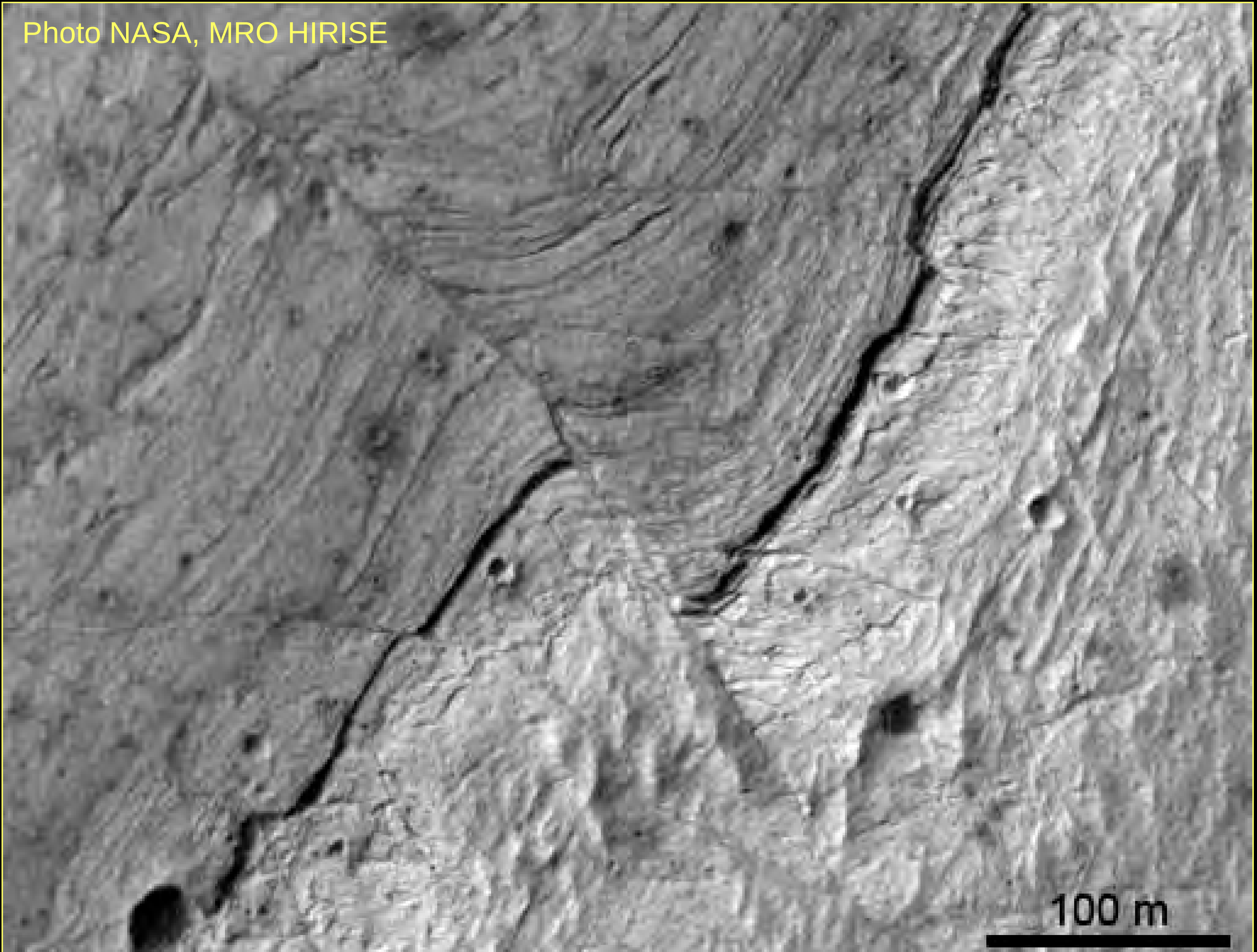


Wrinkle ridges suggest compression

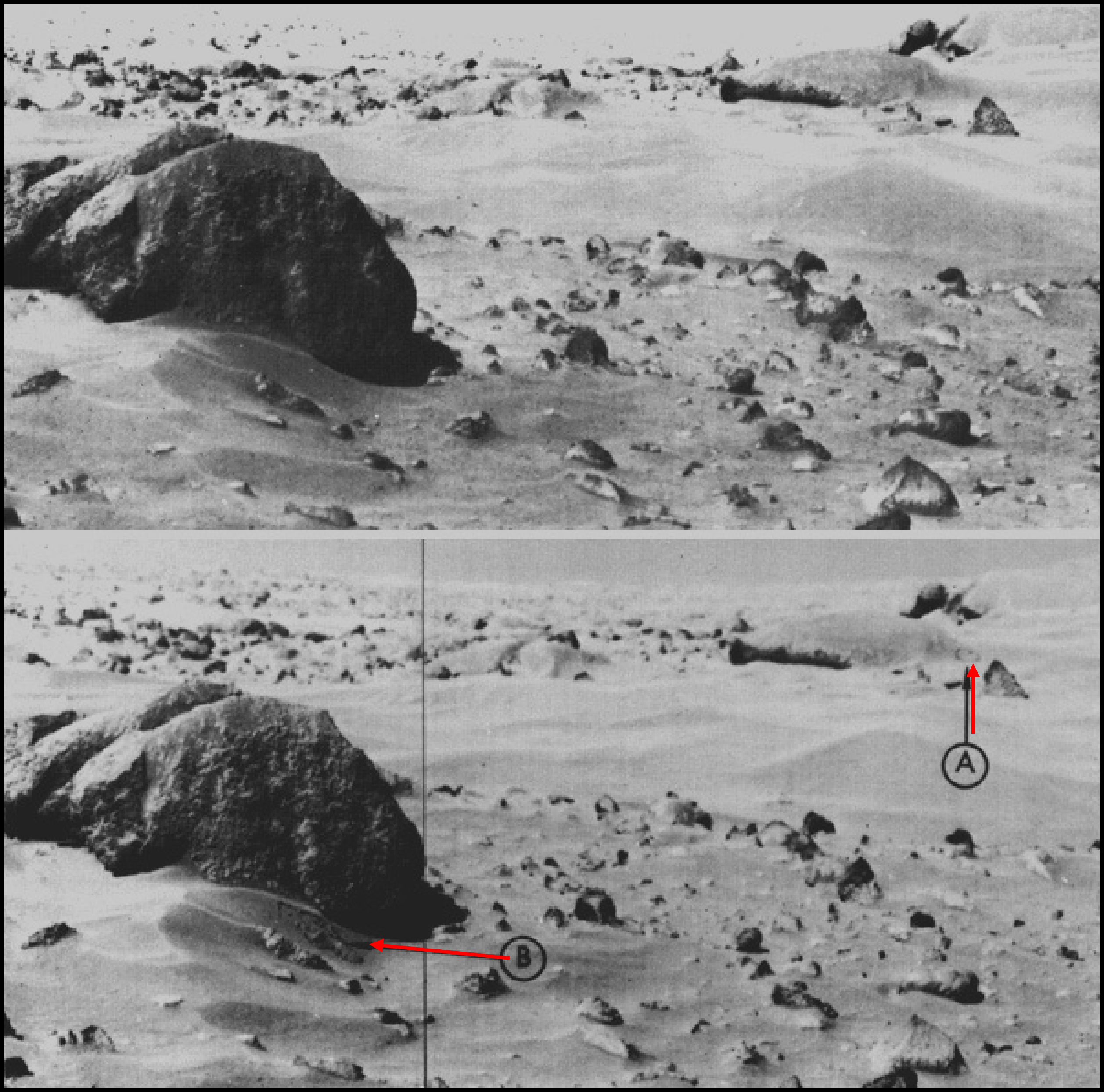


Similar in morphology and size to those of the Moon and Venus

Small faults and folds on Mars

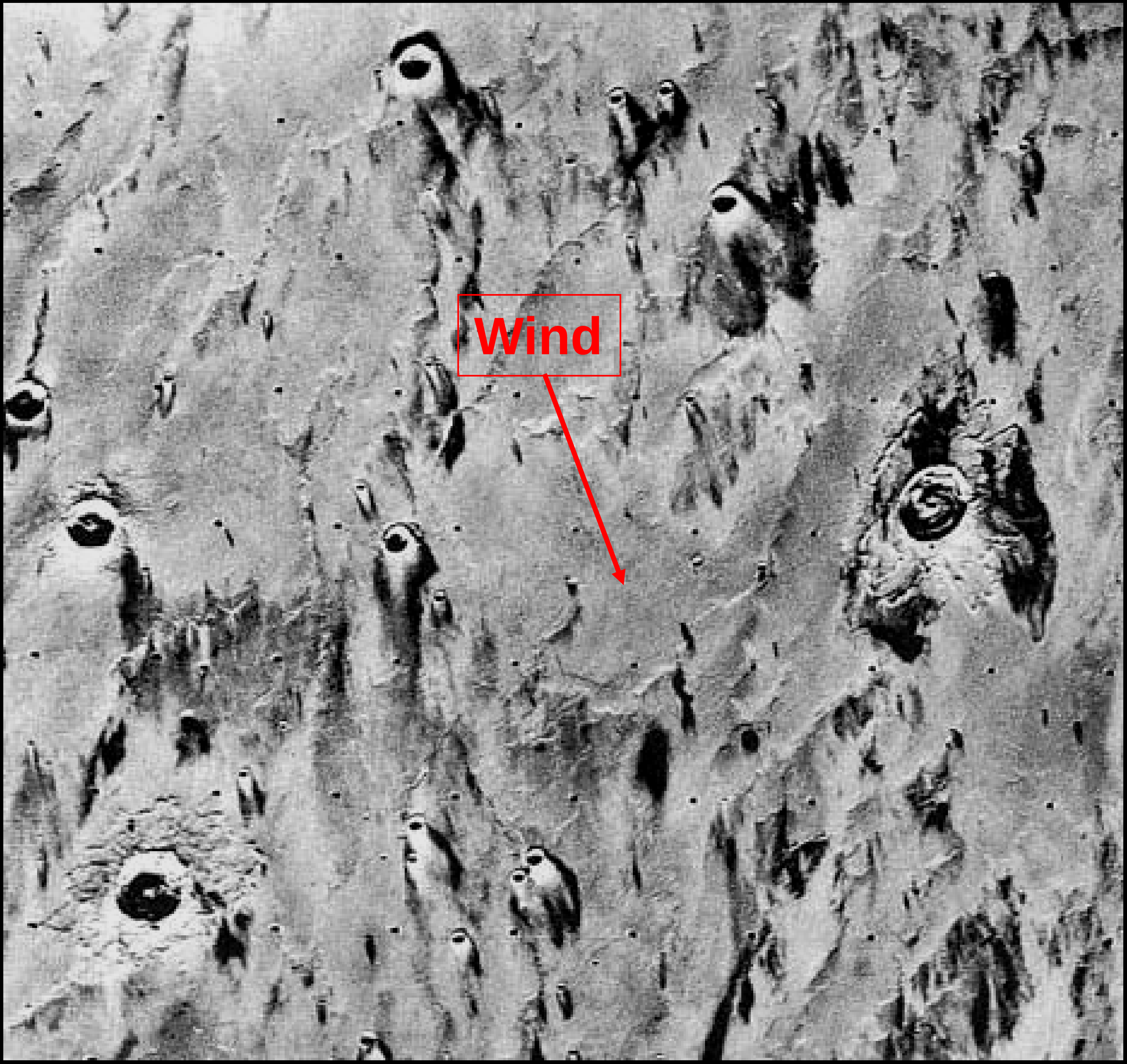


Eolian processes: Surface material moved by wind

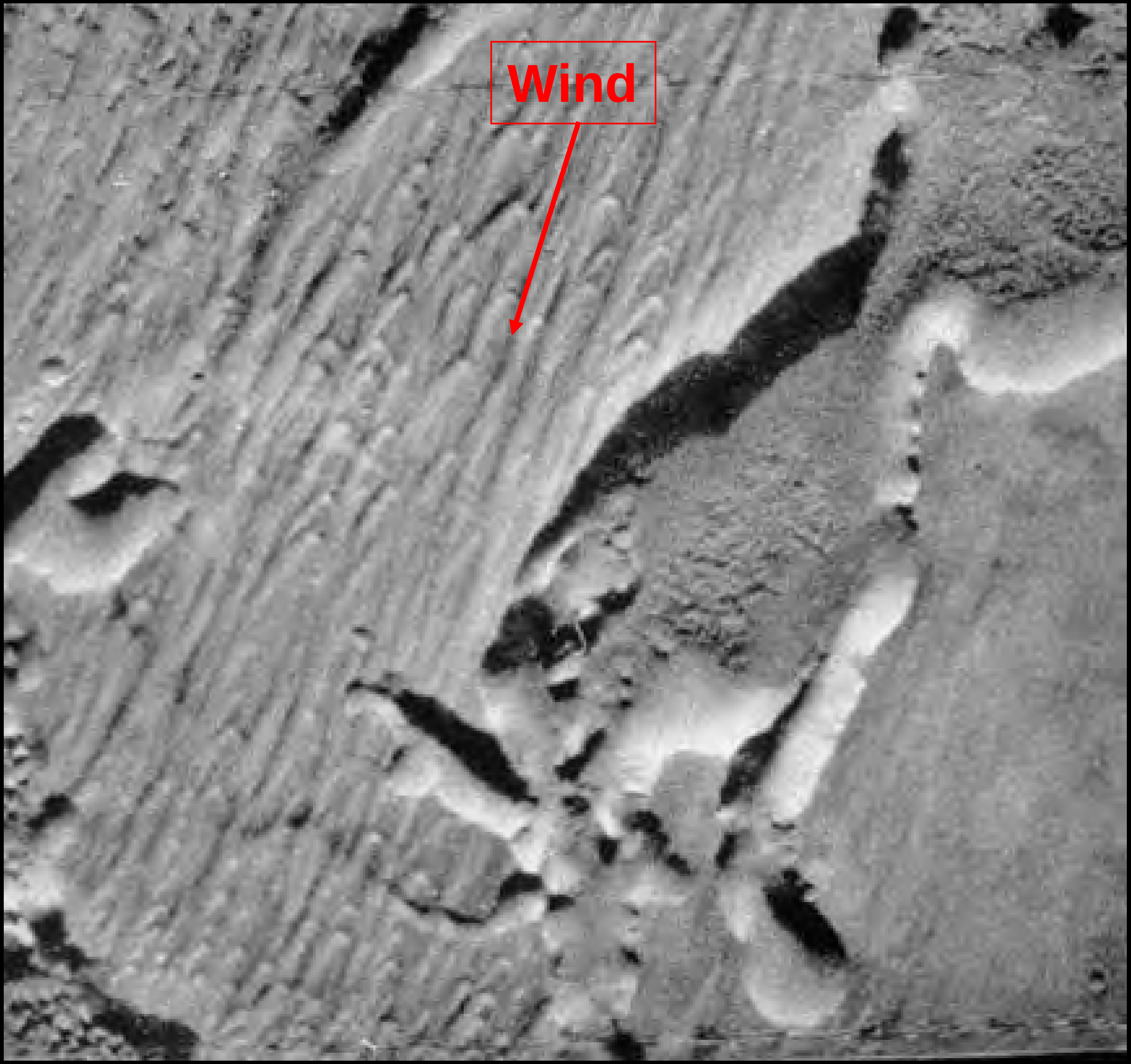


Viking 1 lander, one year time interval

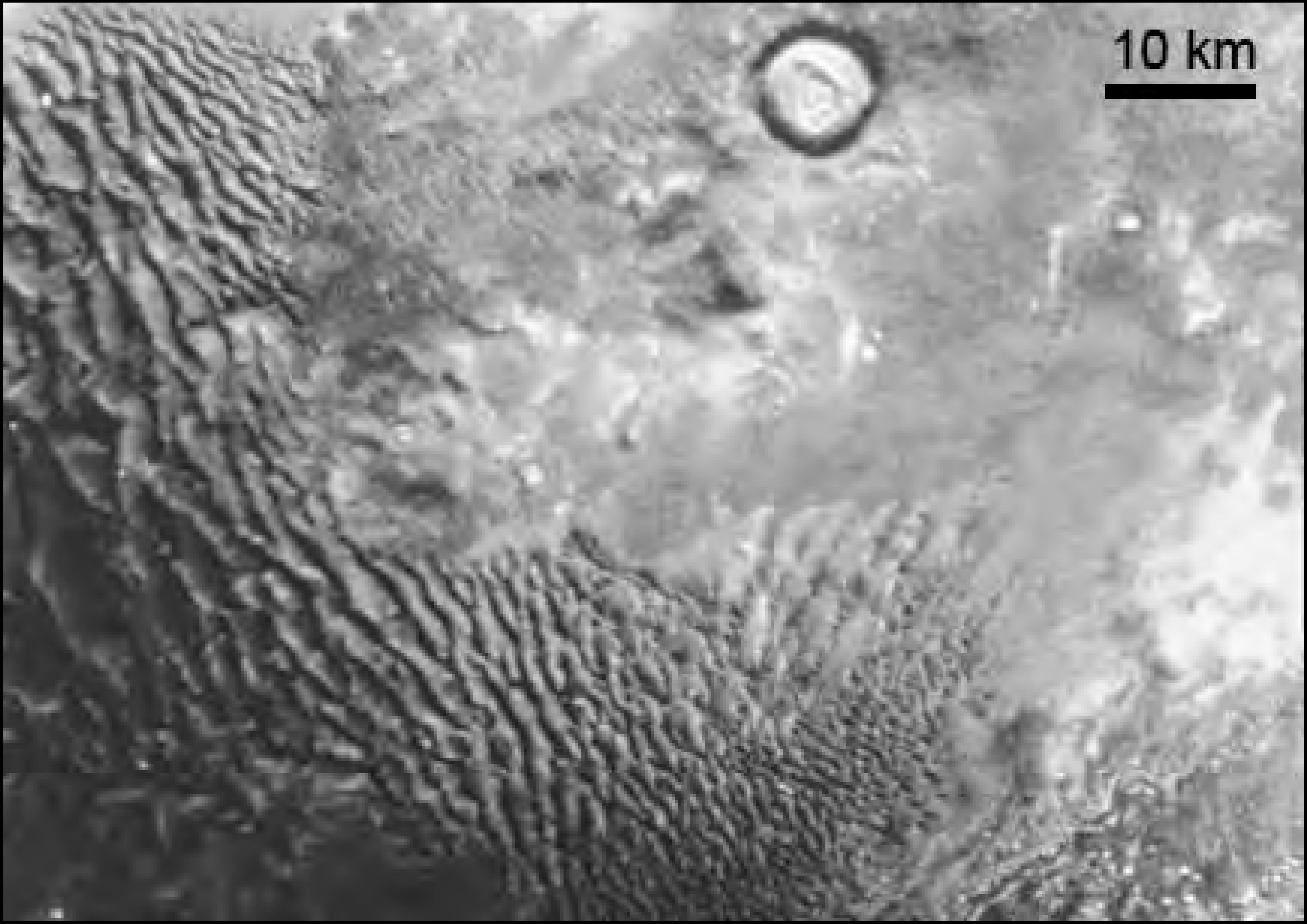
Eolian processes: Wind streaks dark (dust deflation)



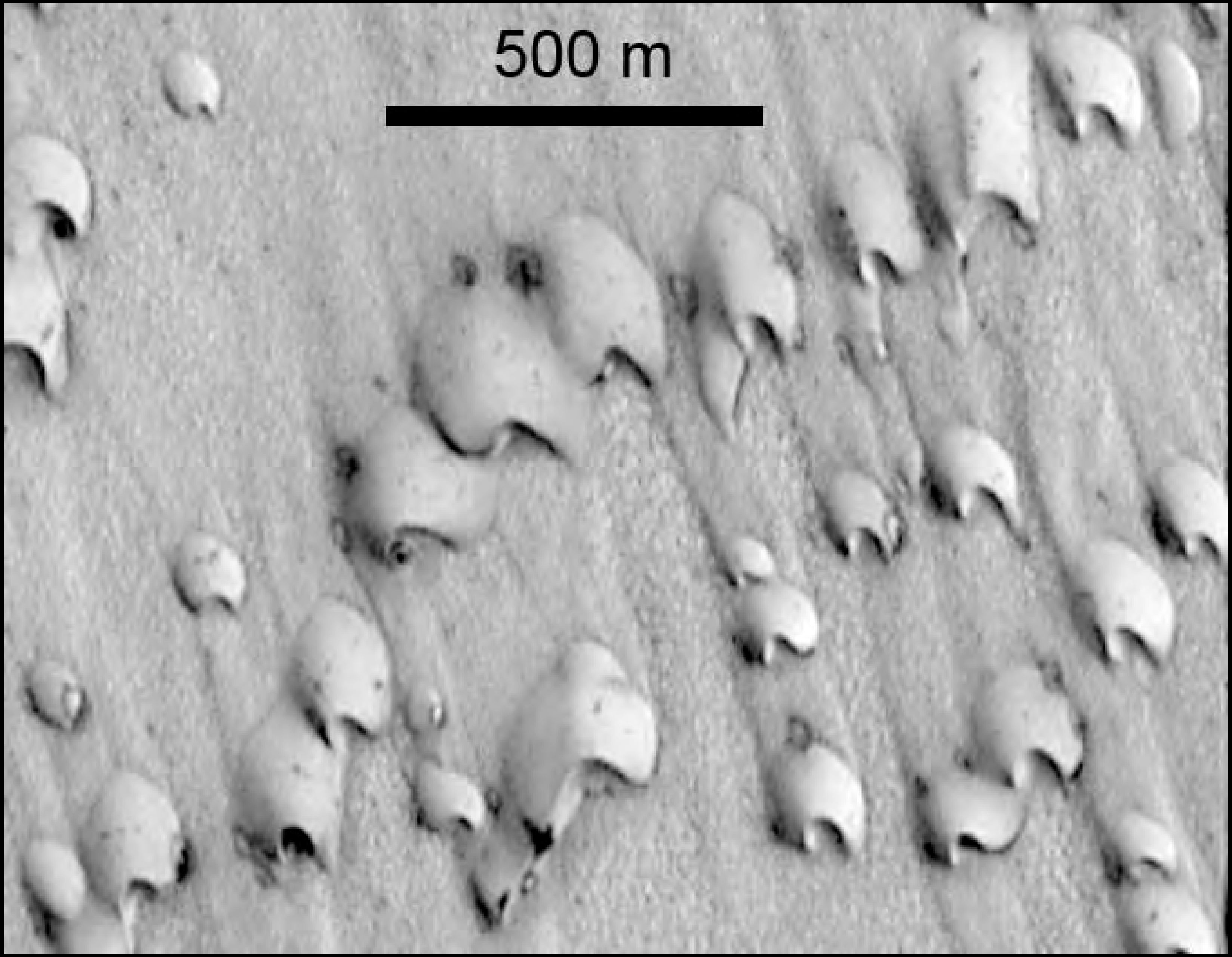
Eolian processes: Wind streaks bright (dust accumulation)



Eolian processes: Large dunes (sand saltation)

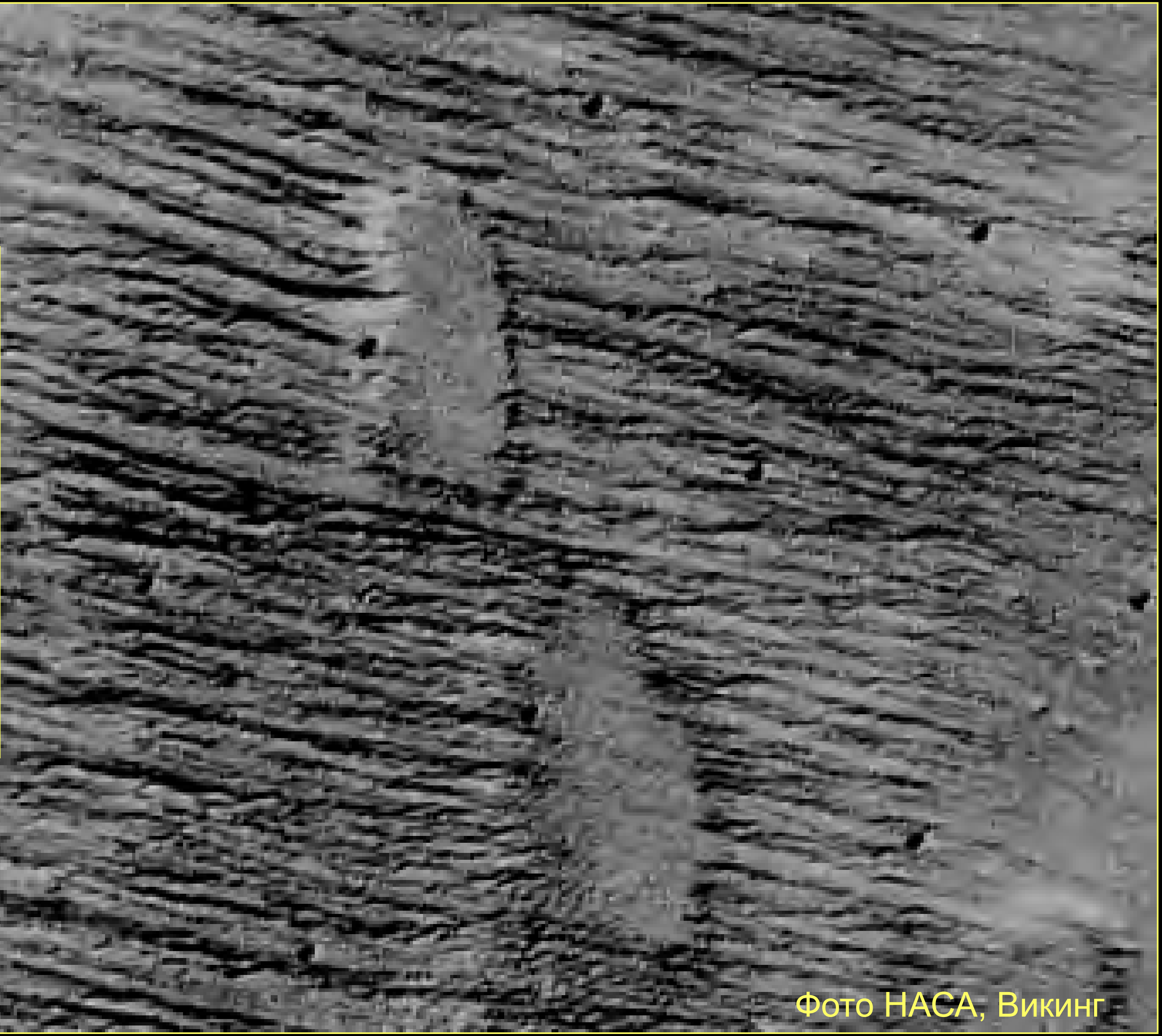


Eolian processes: Small dunes (saltation) covered by snow



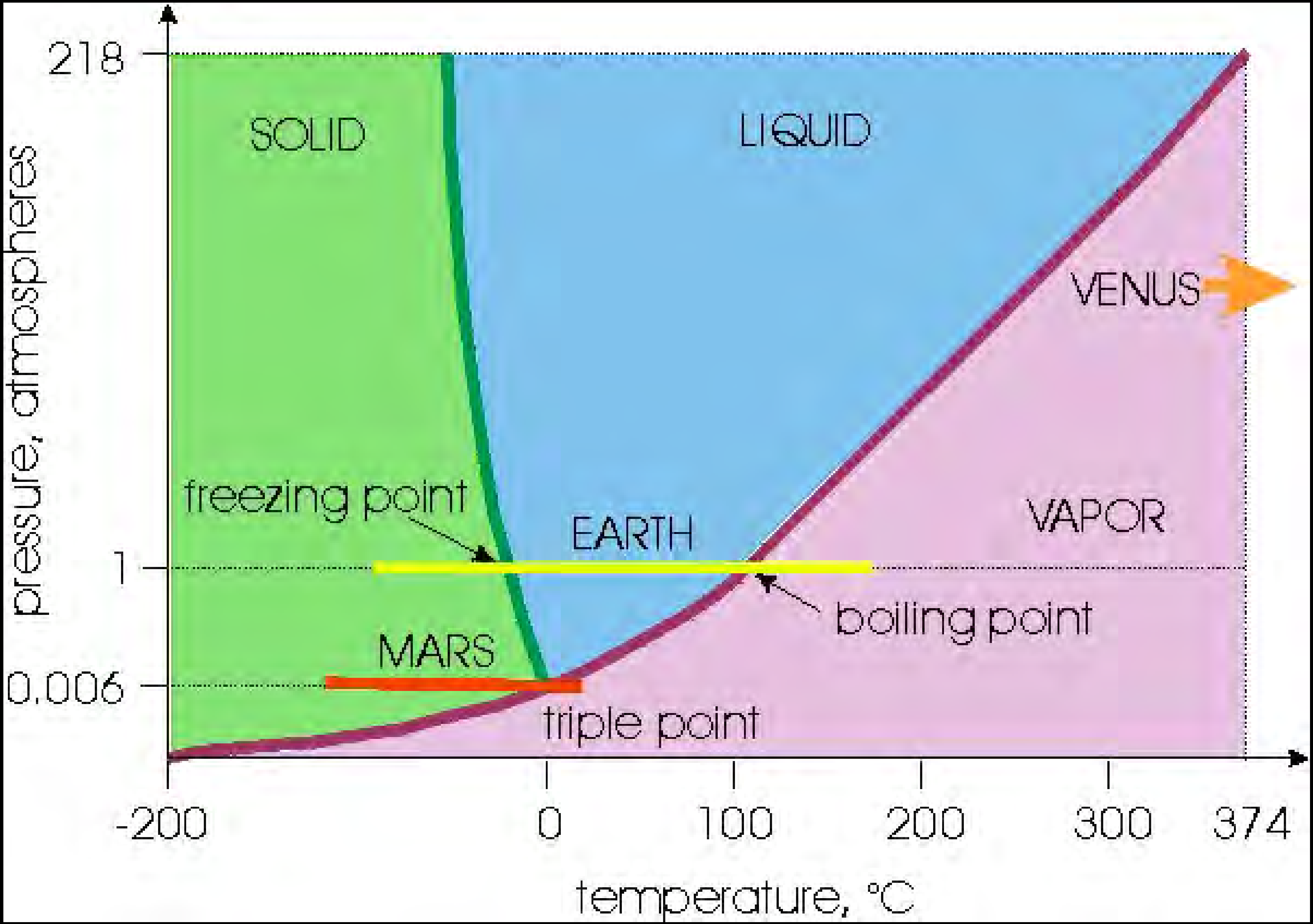
Eolian processes: Very small dunes (sand saltation)

Eolian processes: Yardangs – ridges carved by wind



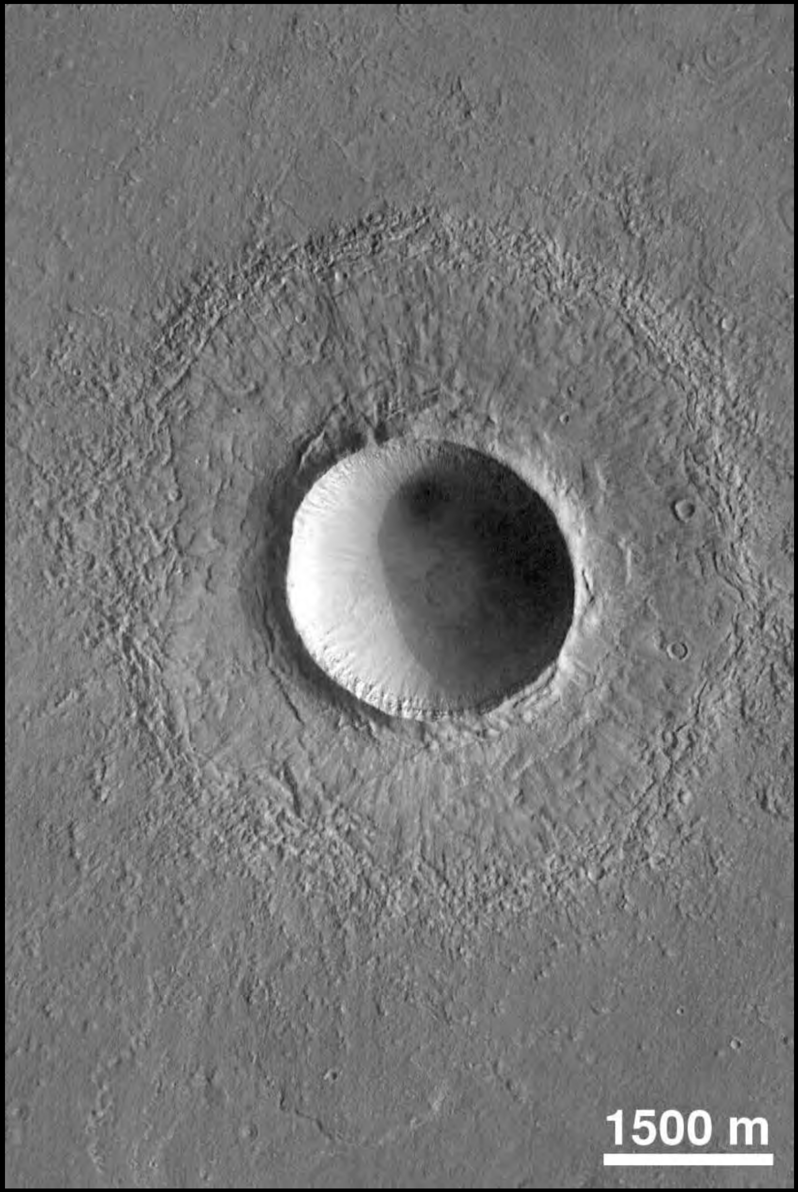
Eolian erosion,
White Desert, Egypt

Water on Mars: Water phase diagram

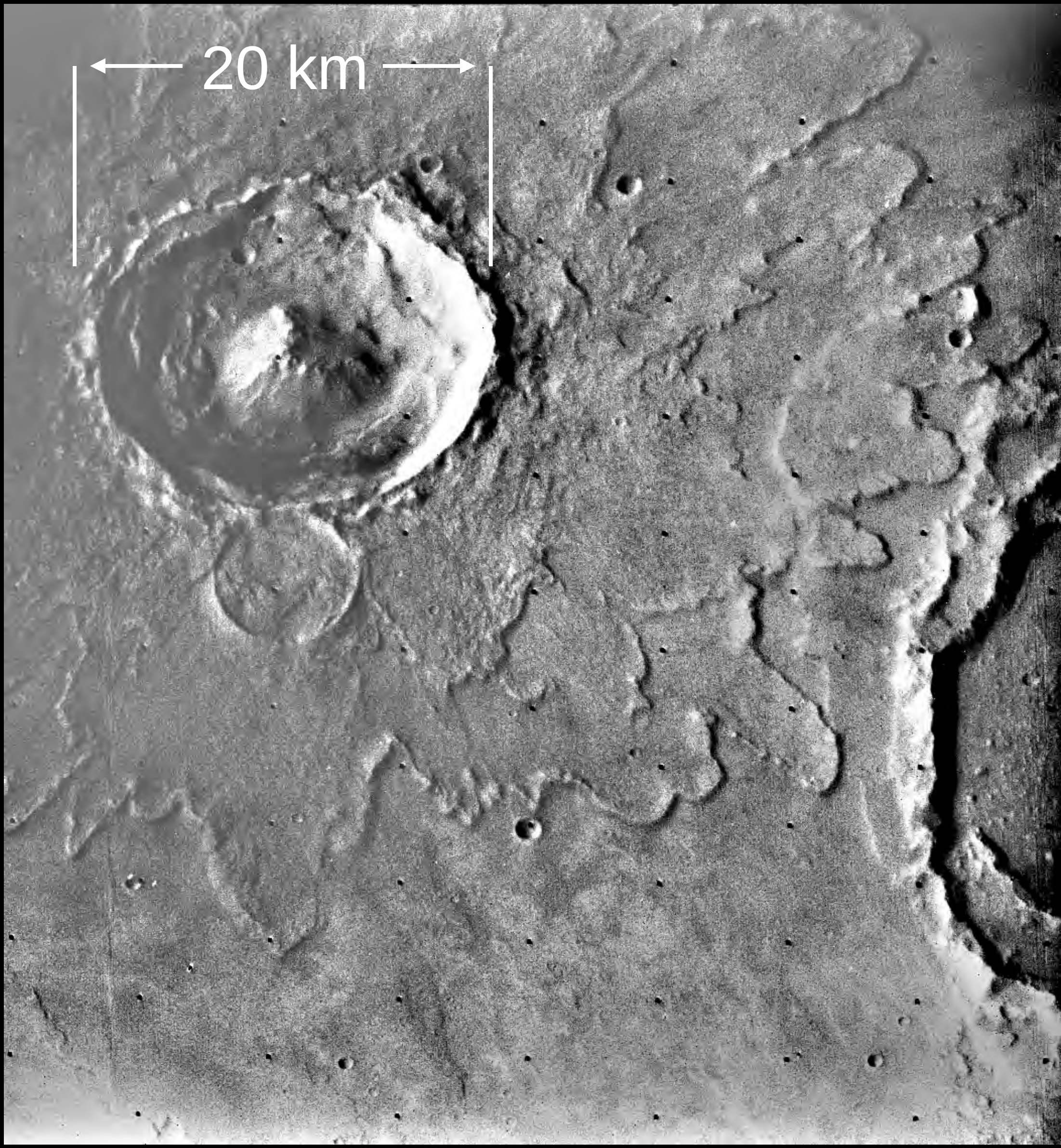


Water phase diagram suggests: No liquid water on surface of Mars

Impact cratering: Larger excavate ice-bearing material



Unnamed crater bowl-shaped

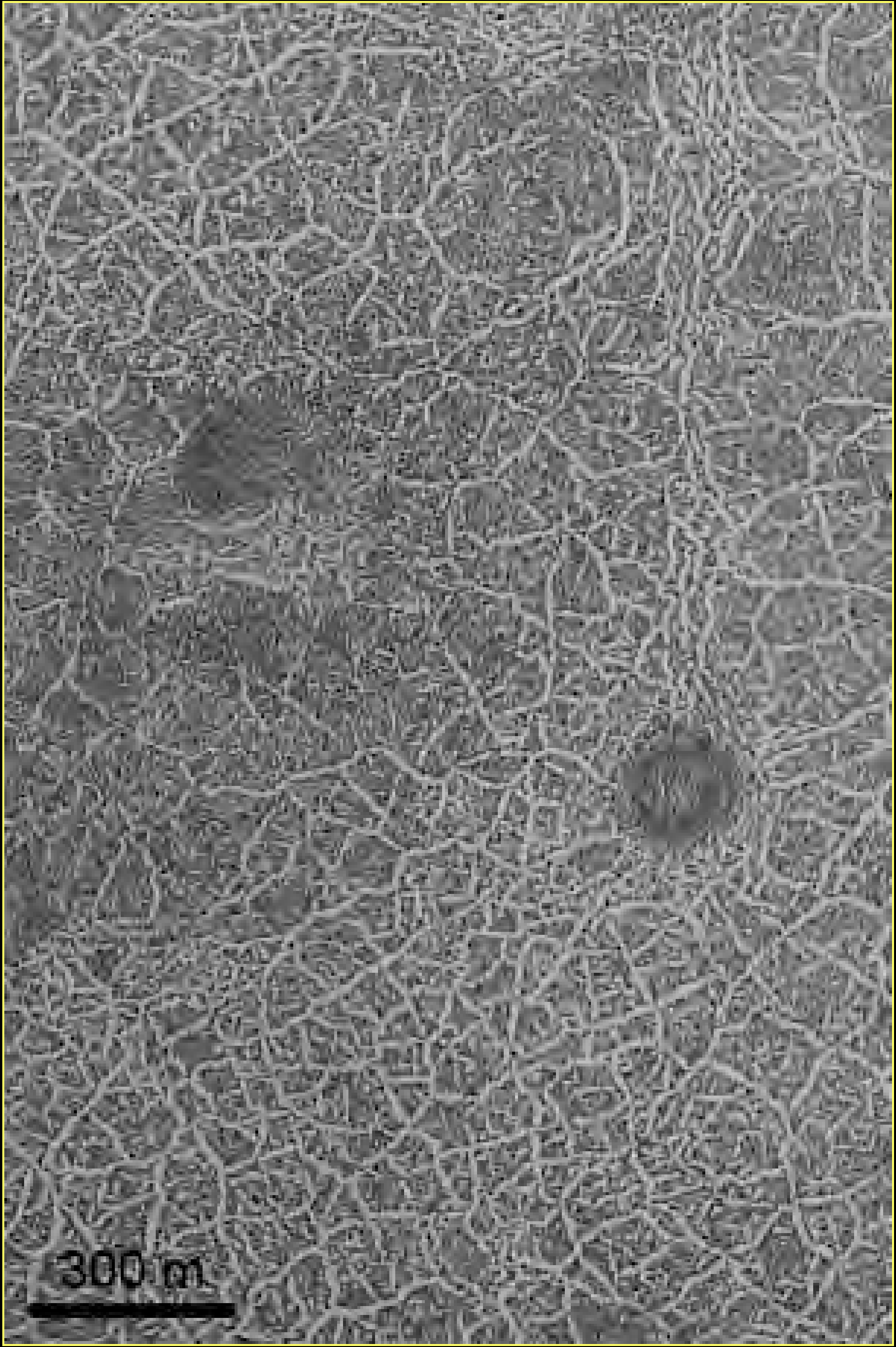


Crater Yuti central-peaked with fluidised ejecta

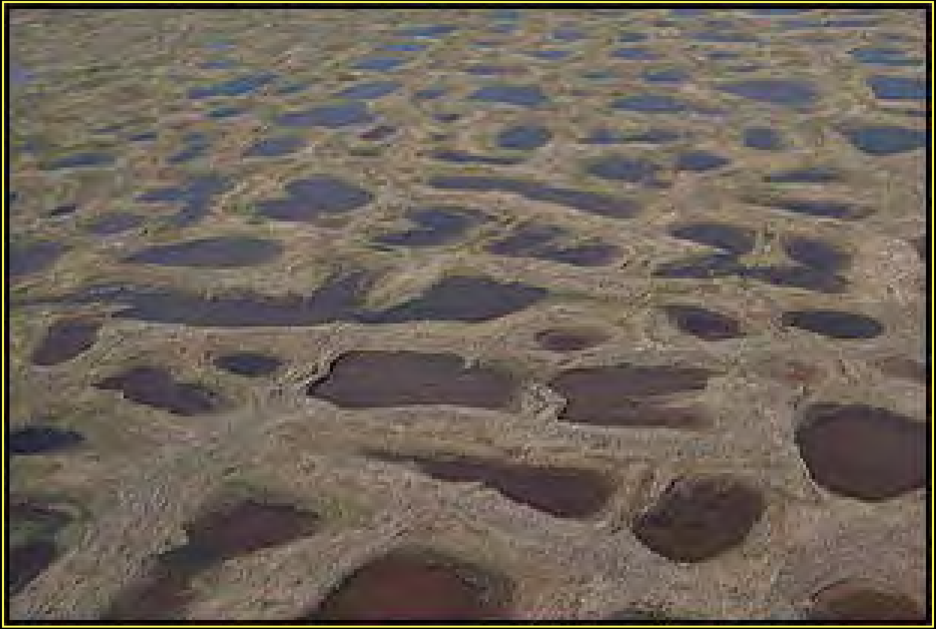
Mud flow deposits at the foot of Saint Helens volcano:

Hot volcanic ash deposited on ice on the slopes and mud flows formed.

Permafrost polygons in high latitudes of Mars & Earth

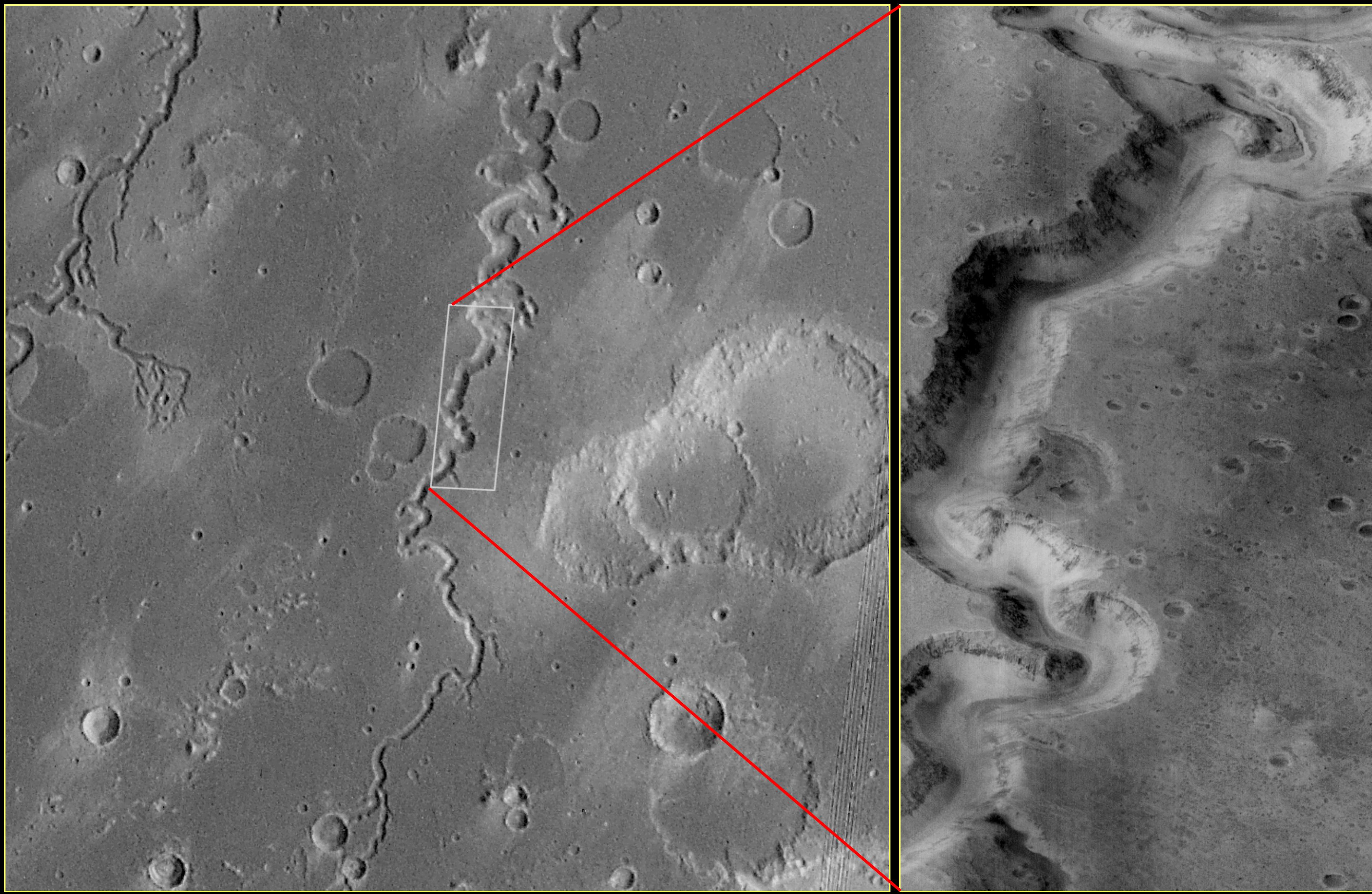


Mars



Canada

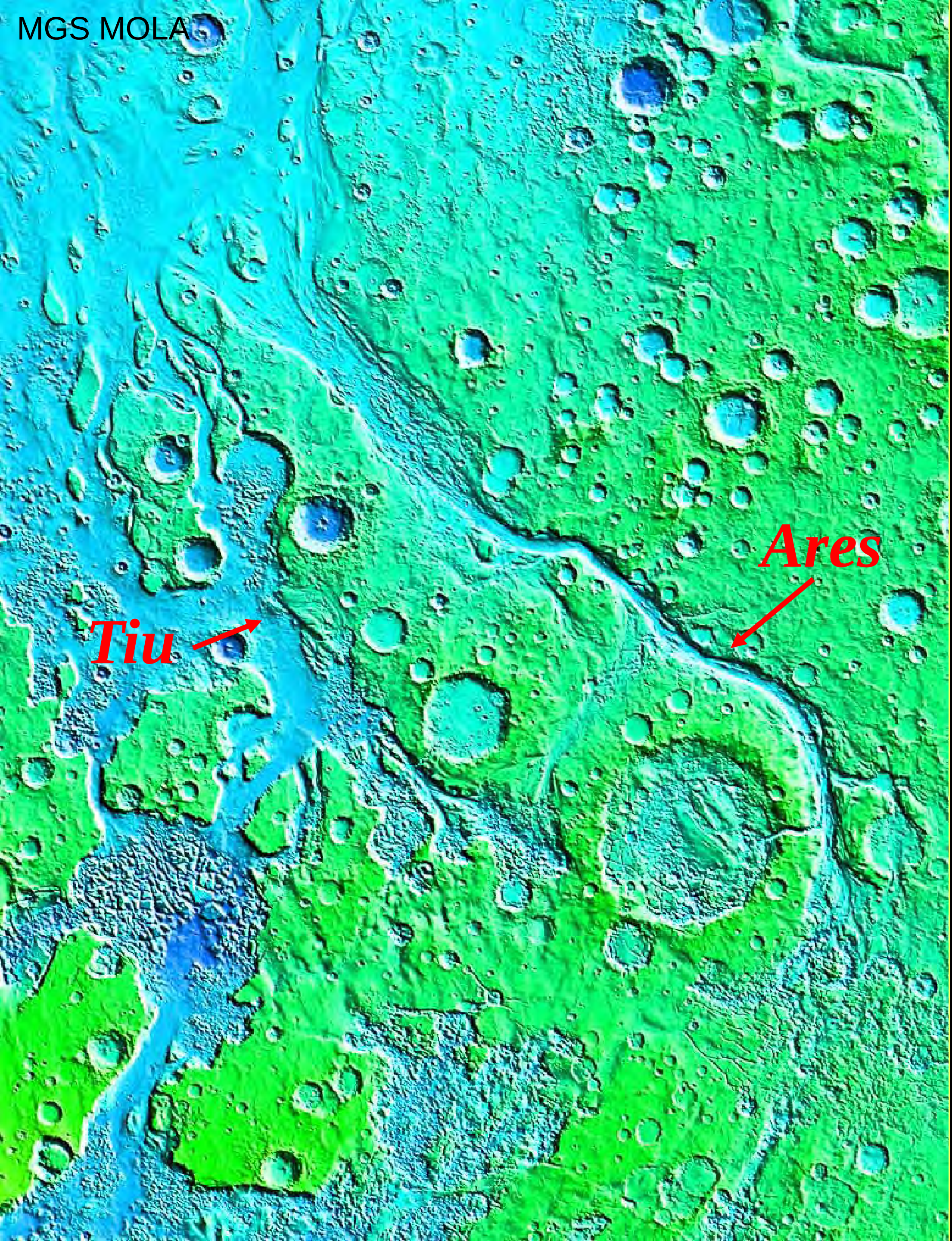
Fluvial processes: Nanedi Vallis - channel with tributaries



Fluvial processes: Channel networks suggest precipitation

River valleys of West Siberia, Russia

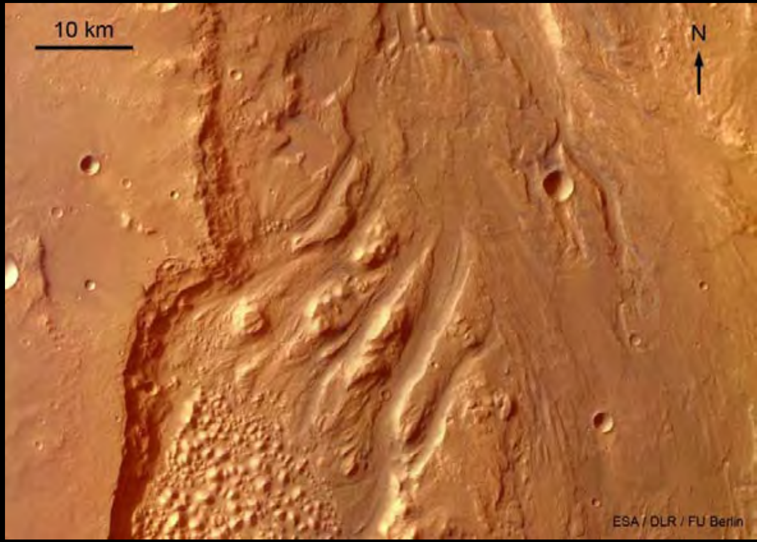
Dry valleys of California



Fluvial processes: Catastrophic flood channels Tiu & Ares:

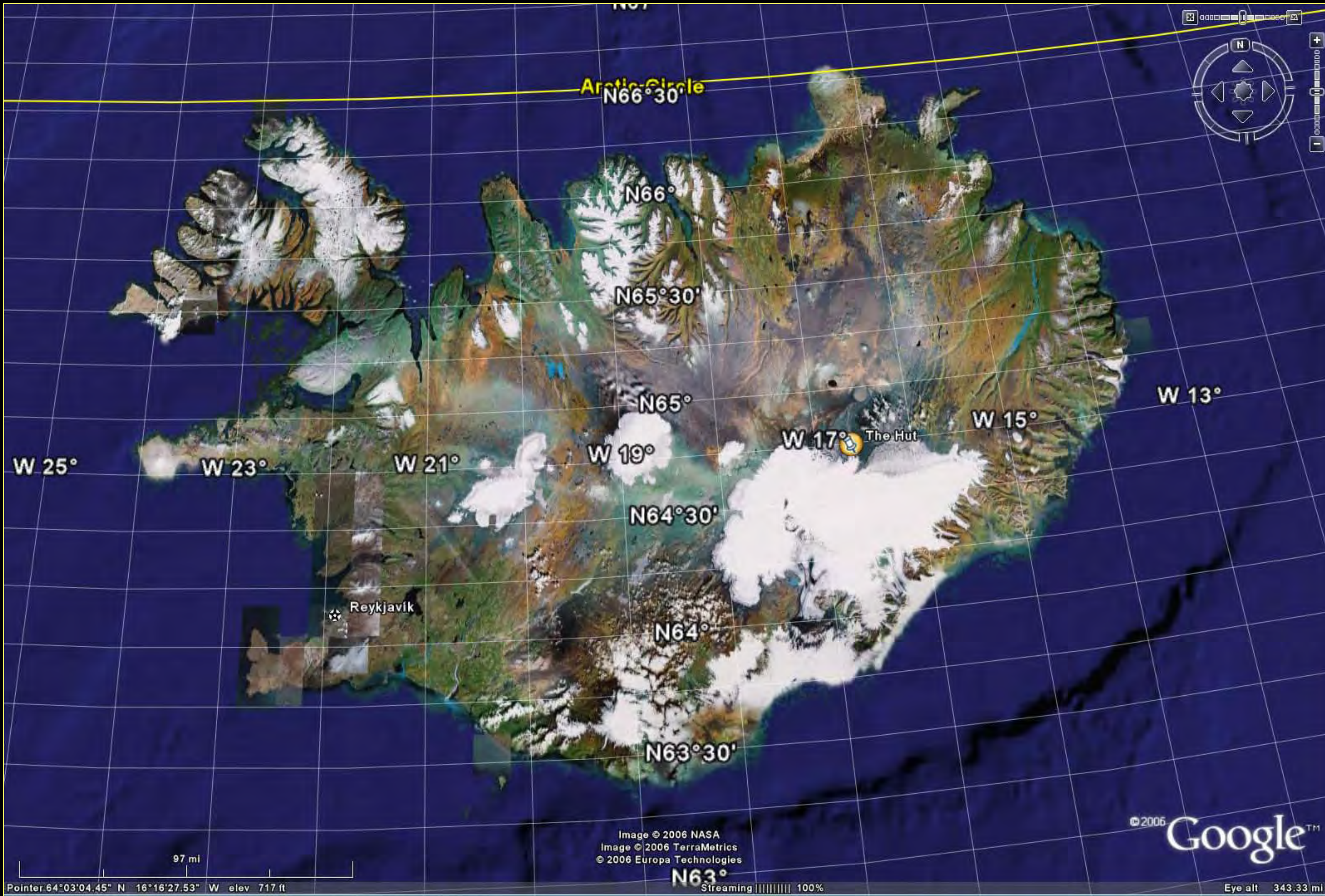
Water was released from underground leaving behind chaos

Could fill ocean?

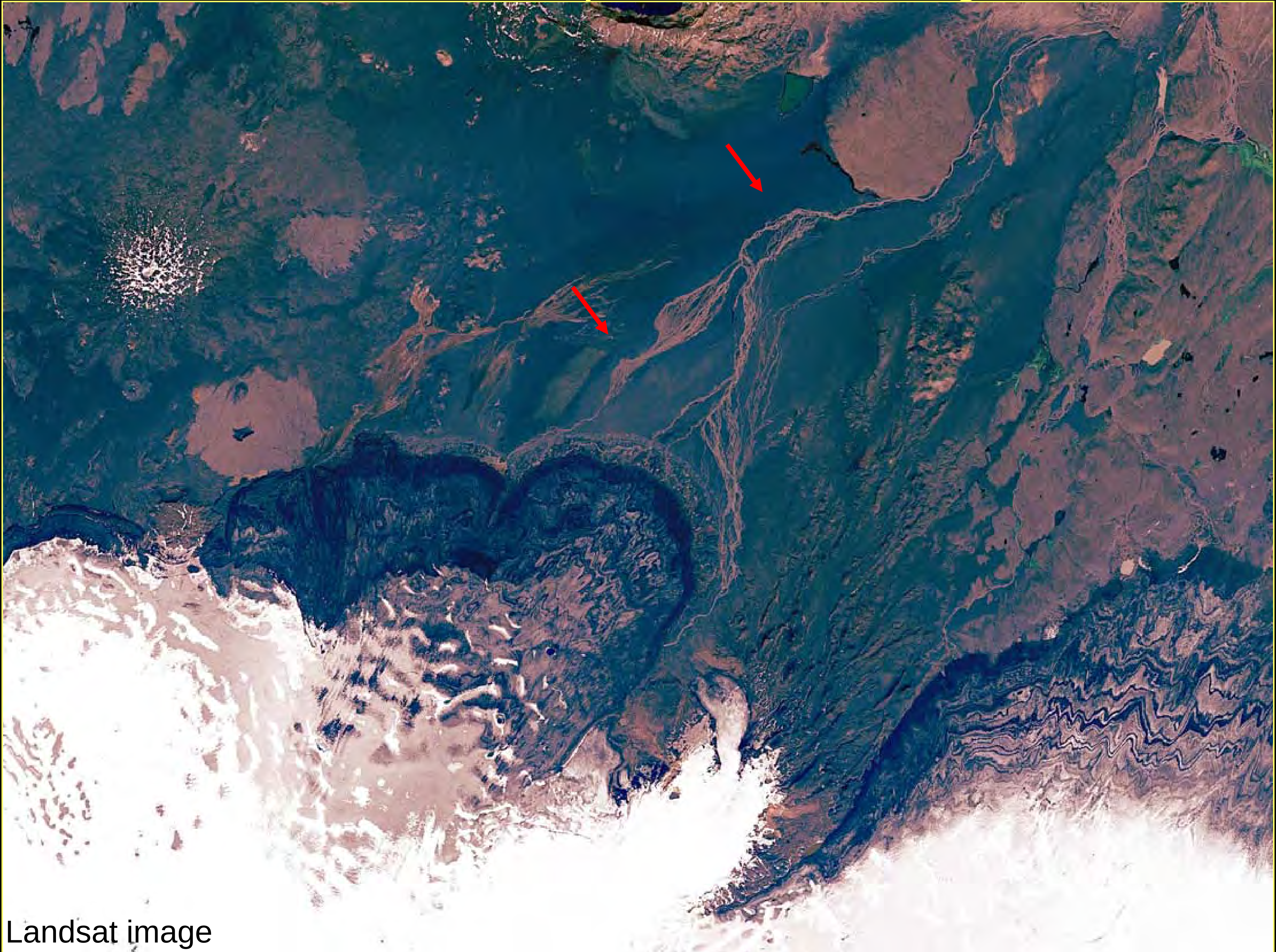


Iani Chaos one of sources of Ares Vallis

Iceland, where glaciers and active volcanoes coexist and catastrophic floods happen



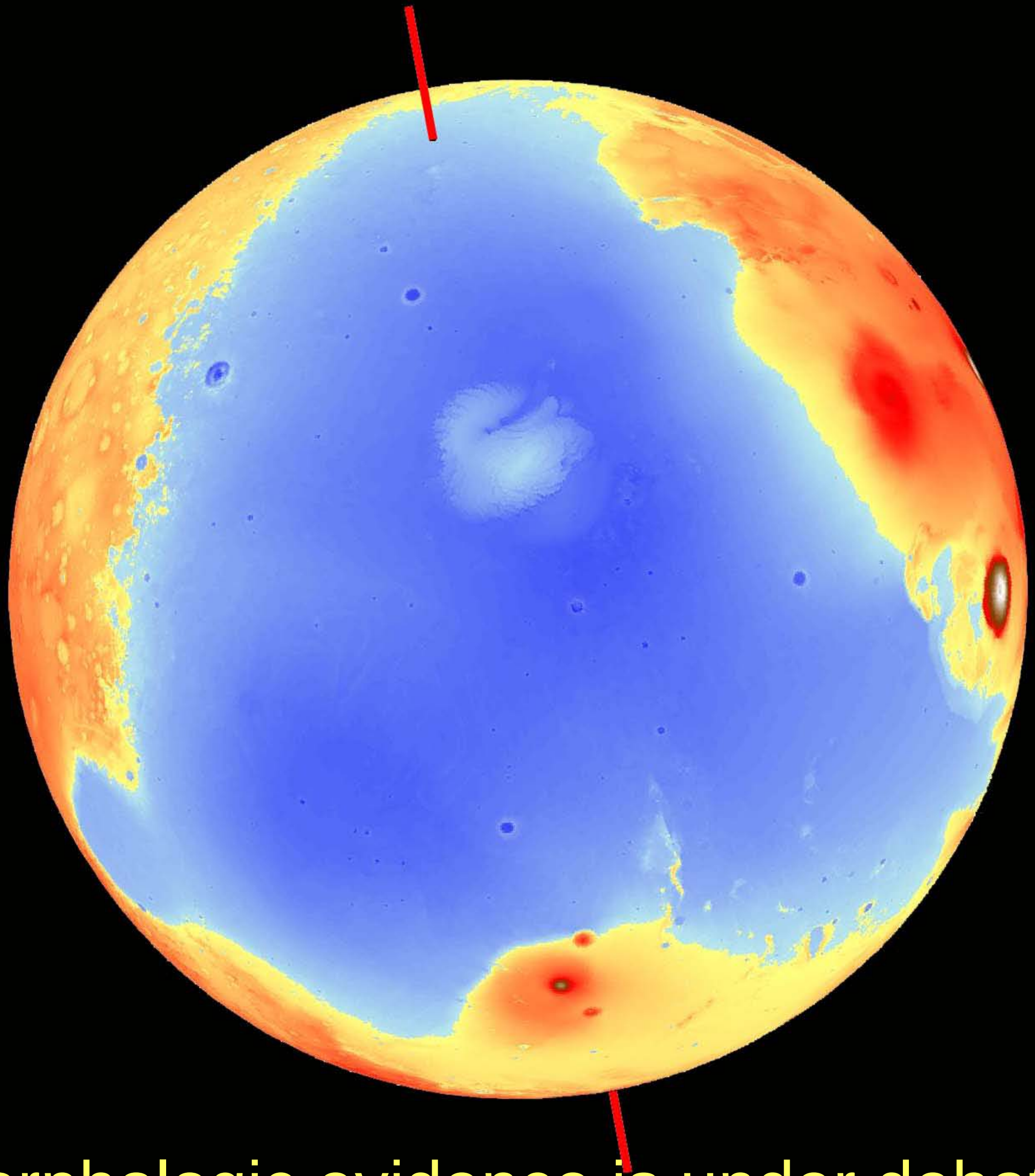
Iceland: traces of catastrophic floods, which happen when volcano erupts beneath the glacier



The valley after flood

Large ripples made of pebbles, formed by powerful flood

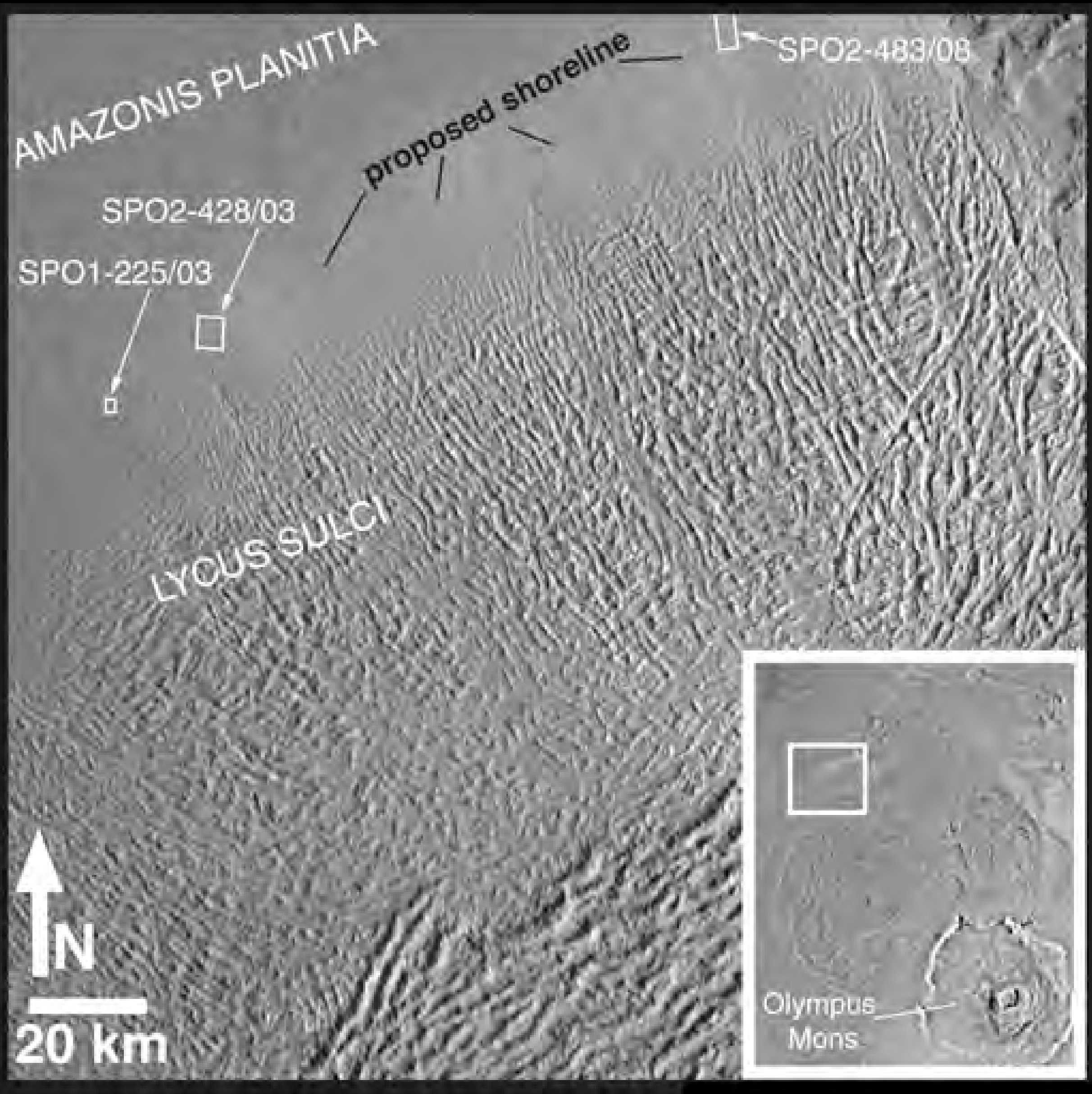
Hypothetic Mars ocean



Morphologic evidence is under debate

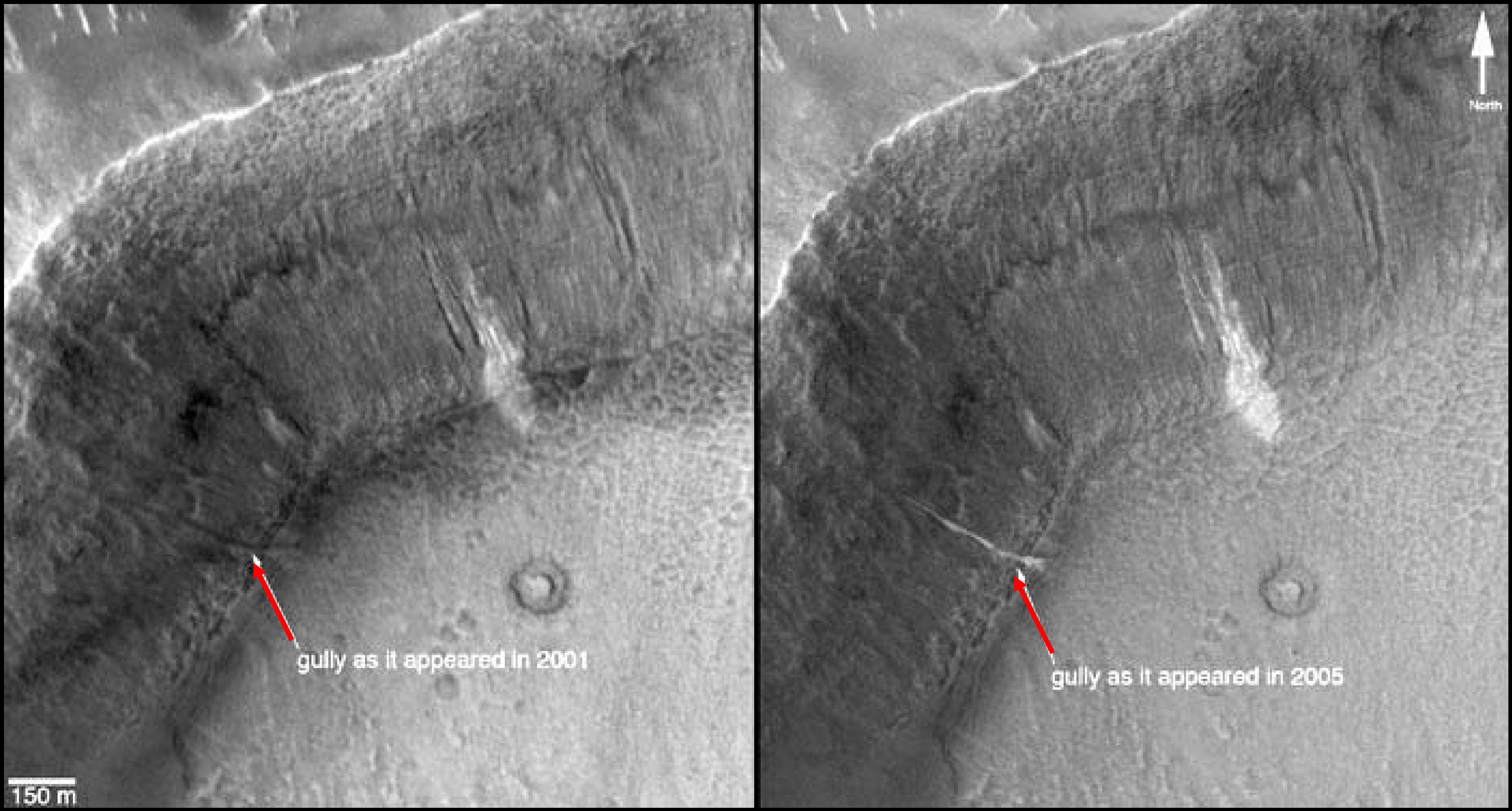
Real ocean on Earth

Search for ocean shoreline evidence

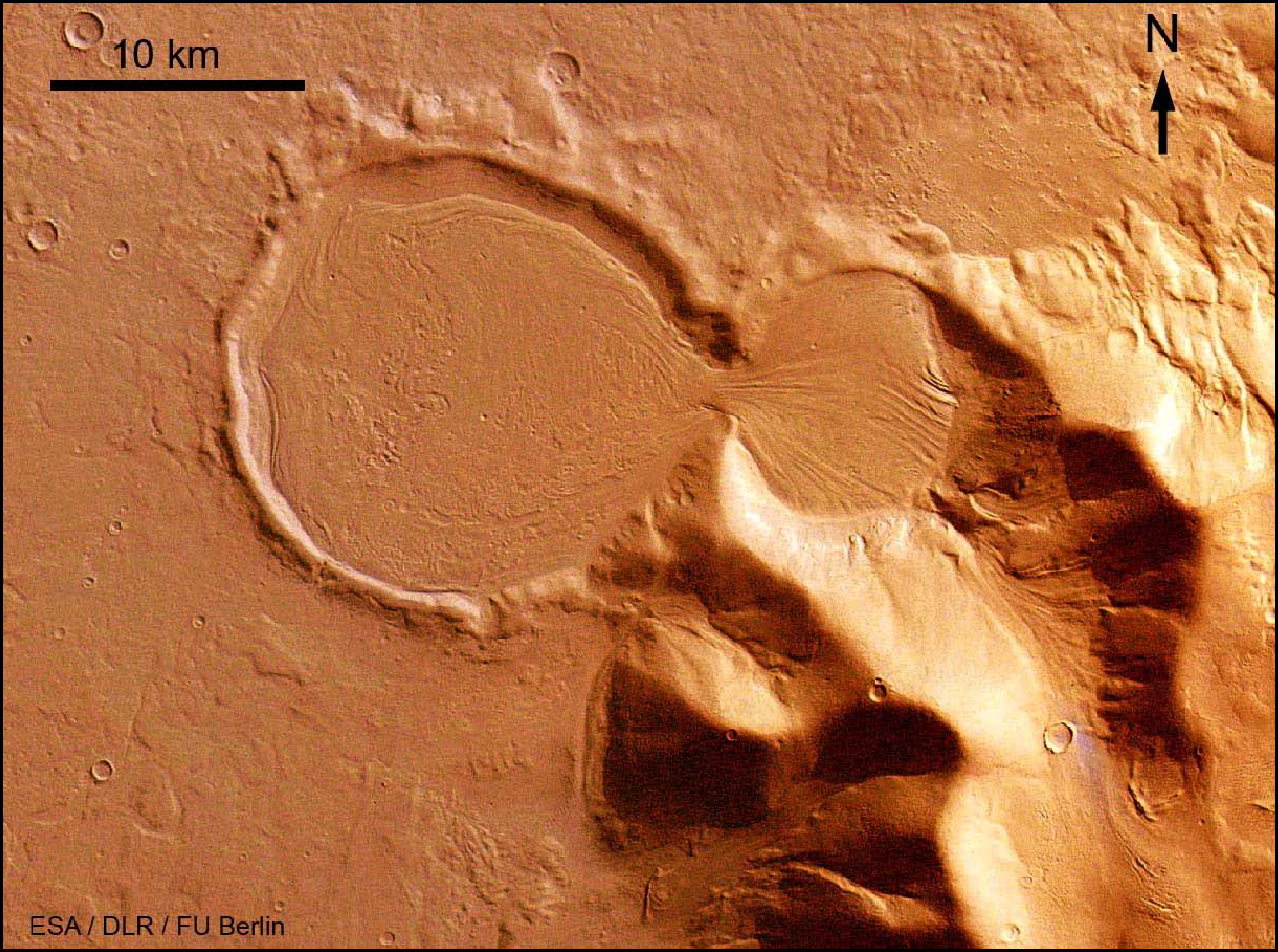


No expected cliff seen

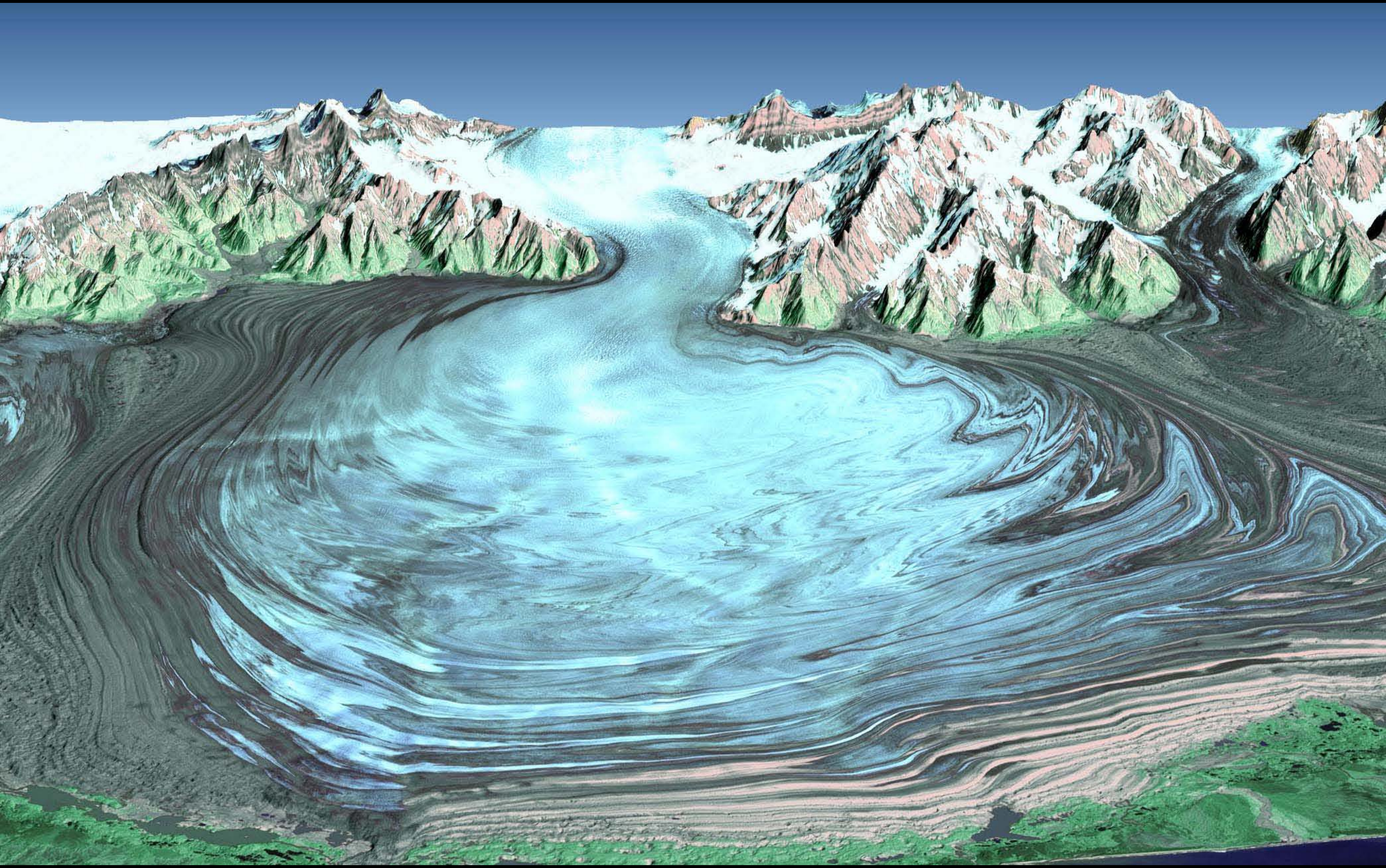
Gullies - small channels:
Some show evidence of recent water flow



Rock glacier on Mars



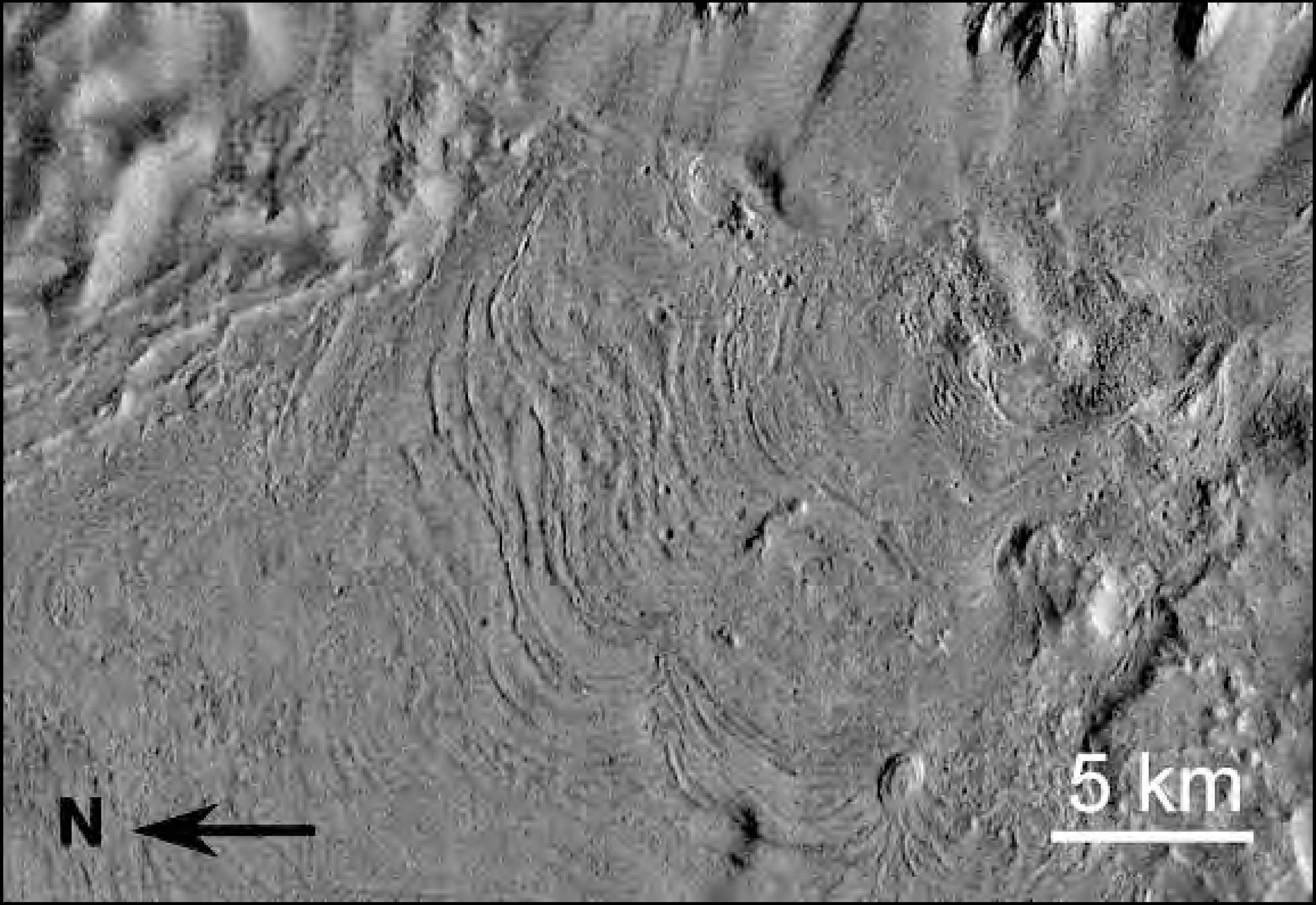
Glacier Malaspina, Alaska



65 km

Shuttle Radar Topography Mission

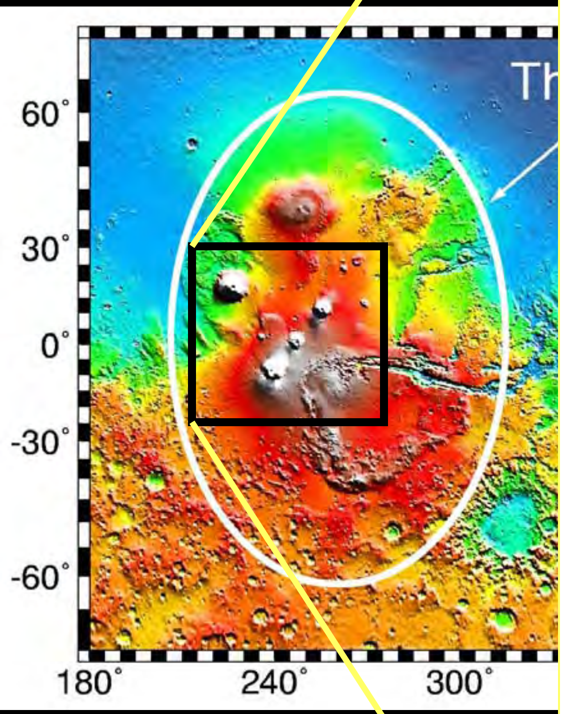
Rock glaciers on Mars

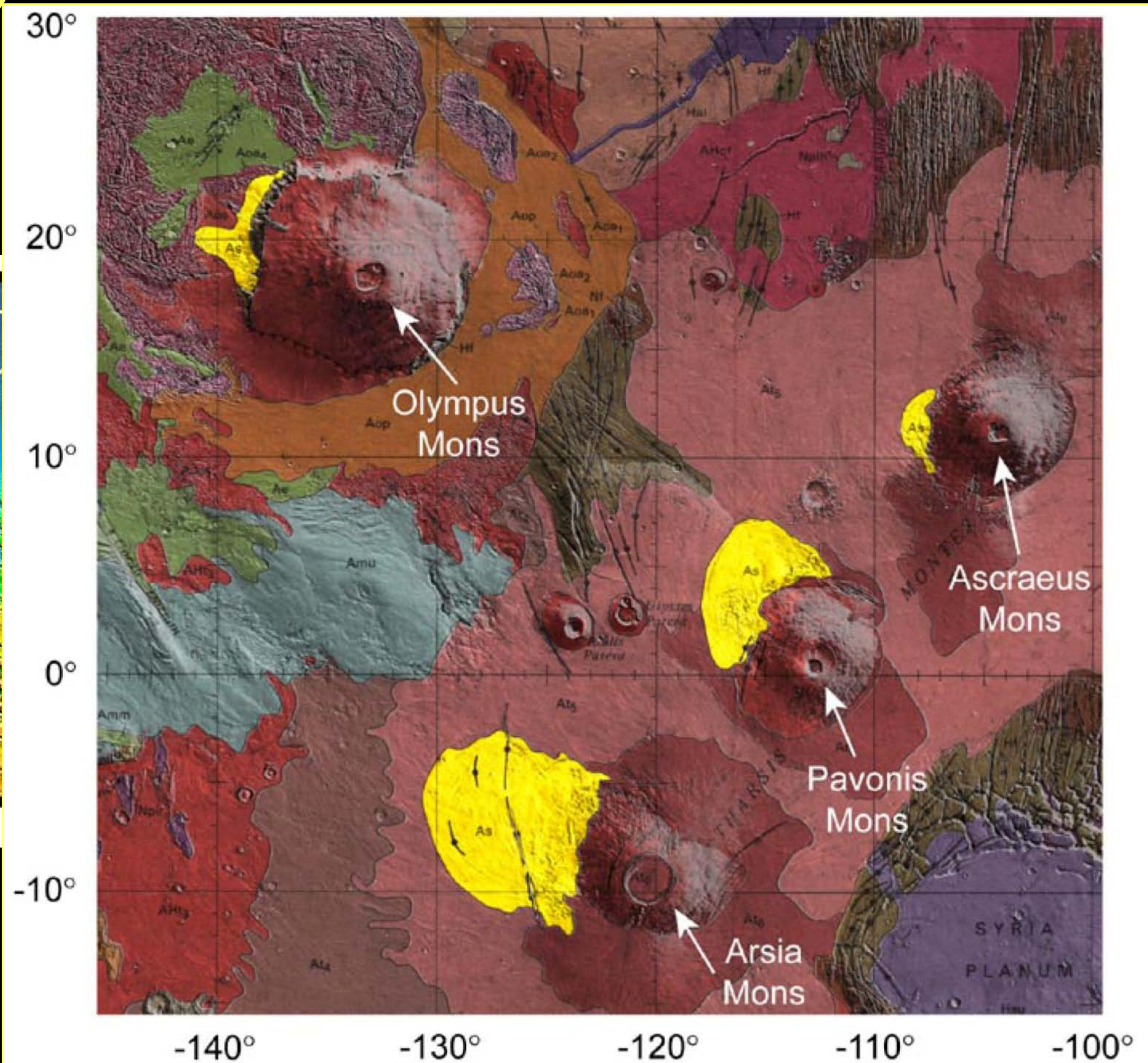


Western foot of Olympus Mons

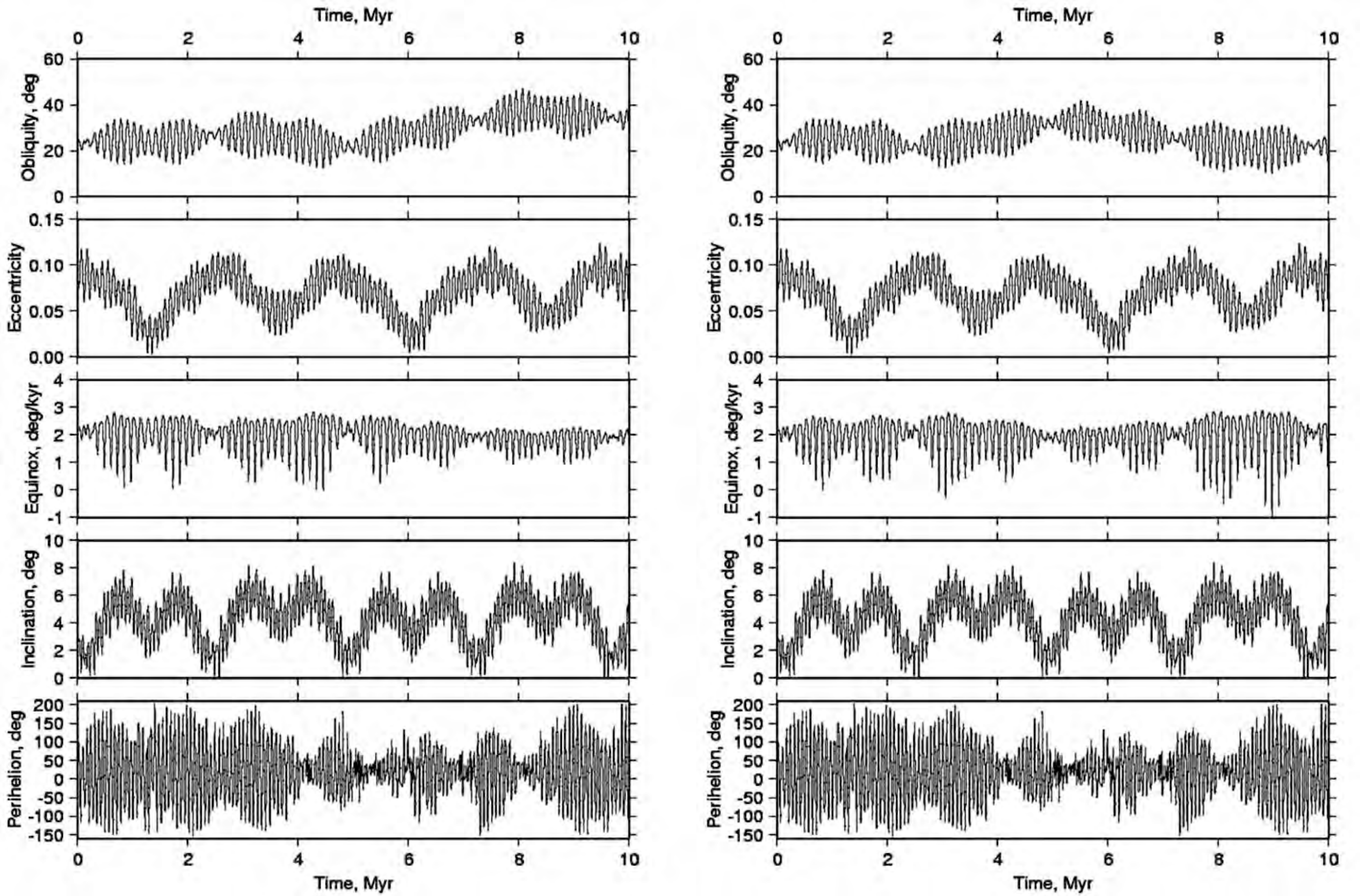
Rock glaciers at western foots of giant volcanoes of Mars

Head et al., 2003





Formation of glaciers on dry Mars was possible due to changes in tilt of the planet spin axis

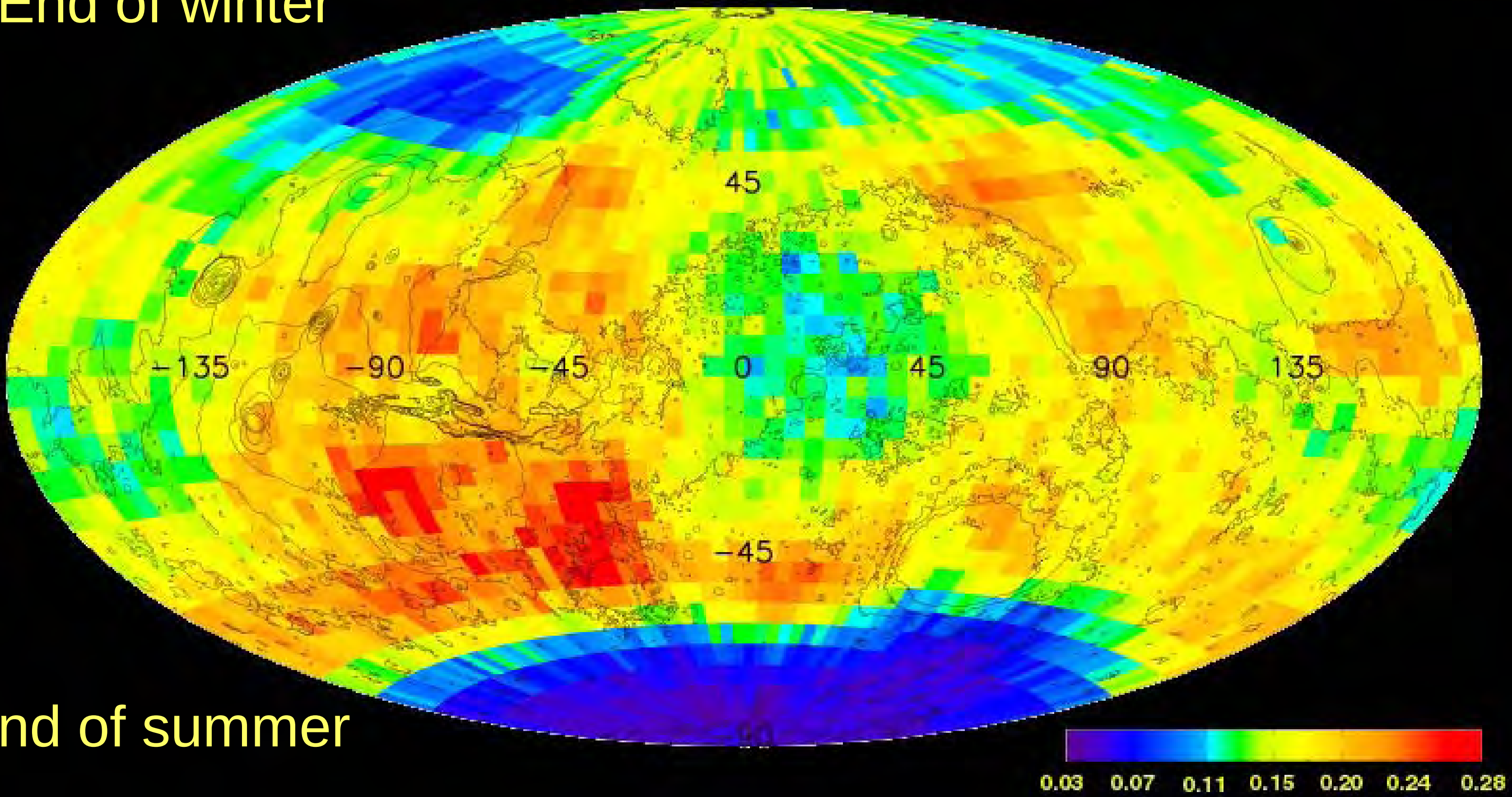


Prior to Tharsis | Armstrong ea. Icarus 2004 | Subsequent to Tharsis

MARS ODYSSEY HEND data: (0.4 eV-100 keV)

Mitrofanov et al., Science, 2002

End of winter



End of summer

Surface and ground ice (low neutron flux) at high southern latitudes

Higher flux at north pole due to CO_2 ice mantle

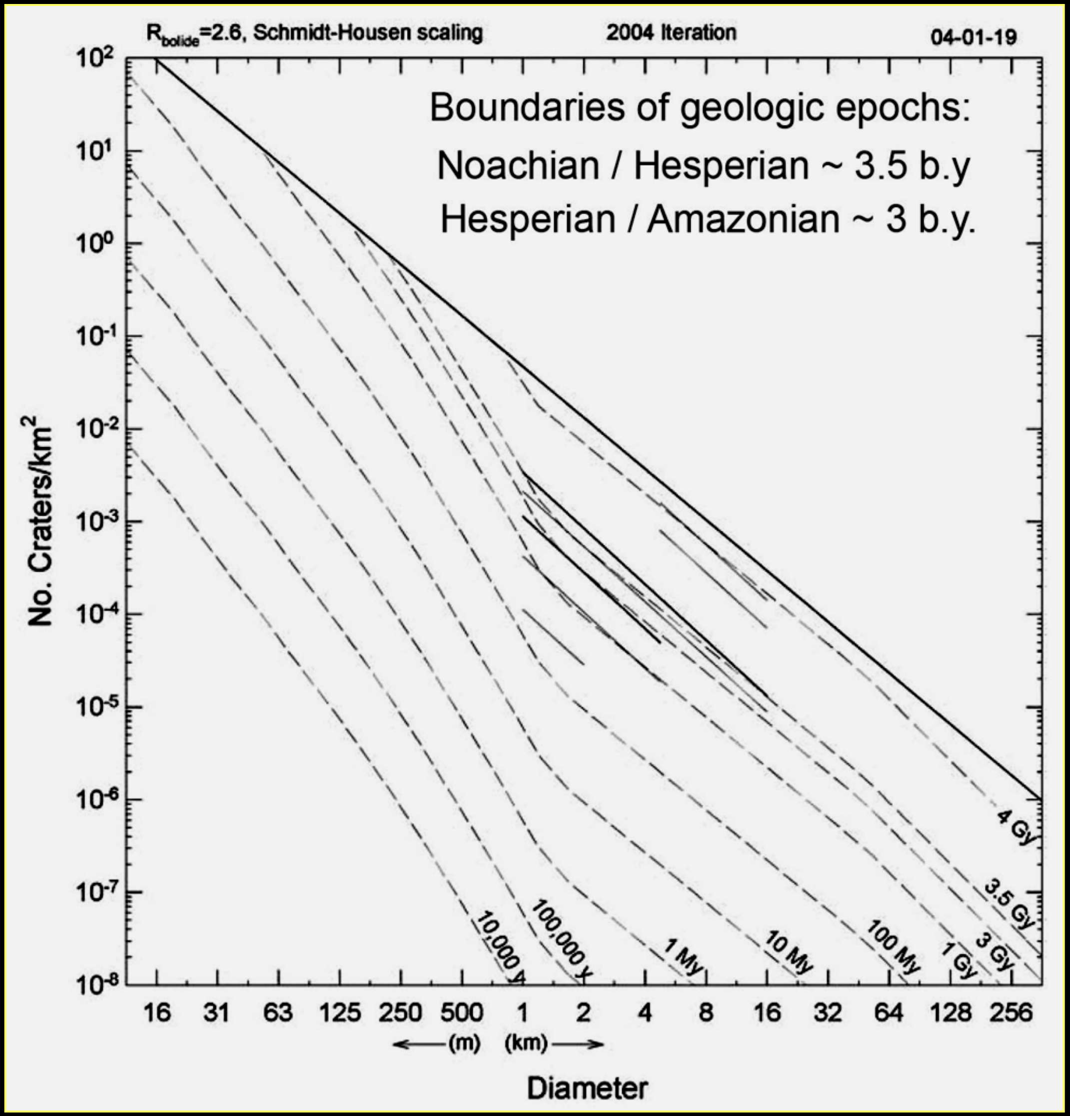
Low-flux (high-water) antipodal regions in equatorial part

Old craters

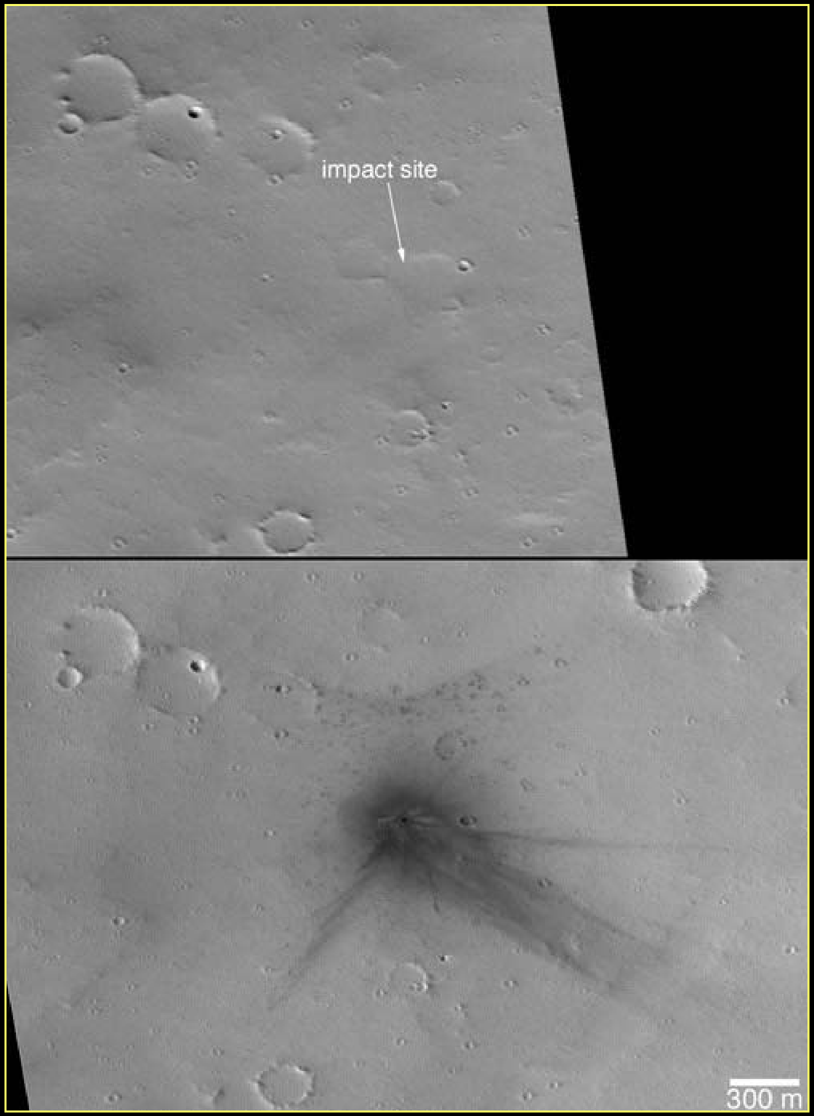
Huygens basin D = 460 km

Exhumed crater in valley

Crater chronology from Neukum and Hartmann



Hartmann, 2007
Isochron diagram

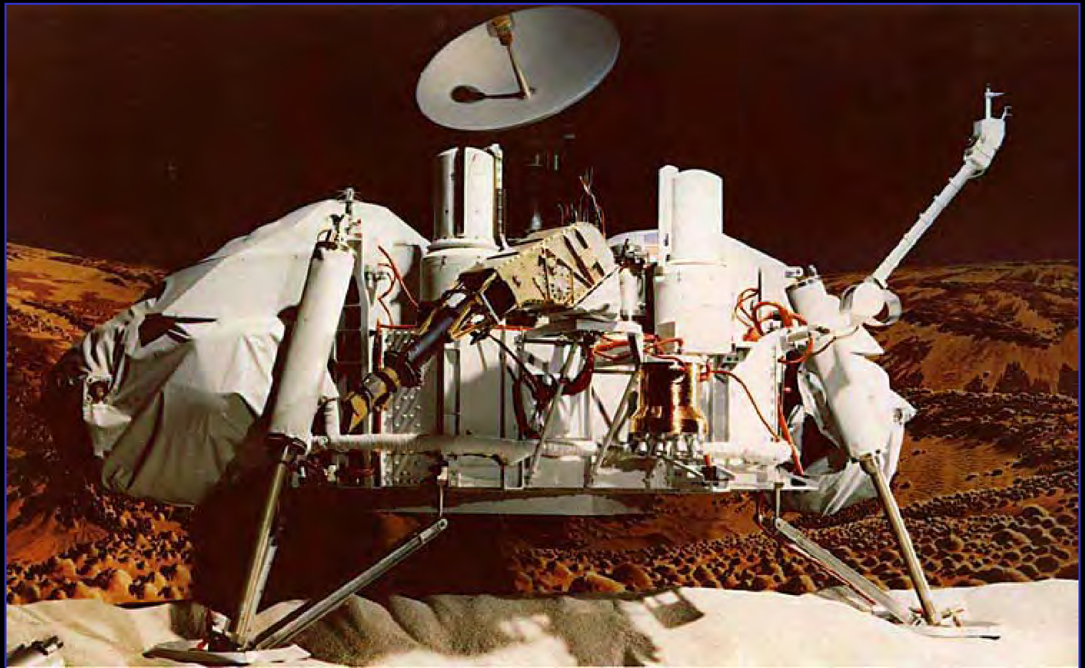


MOC discovery of
new-formed craters

Landing on Mars

Mars 3, 1971

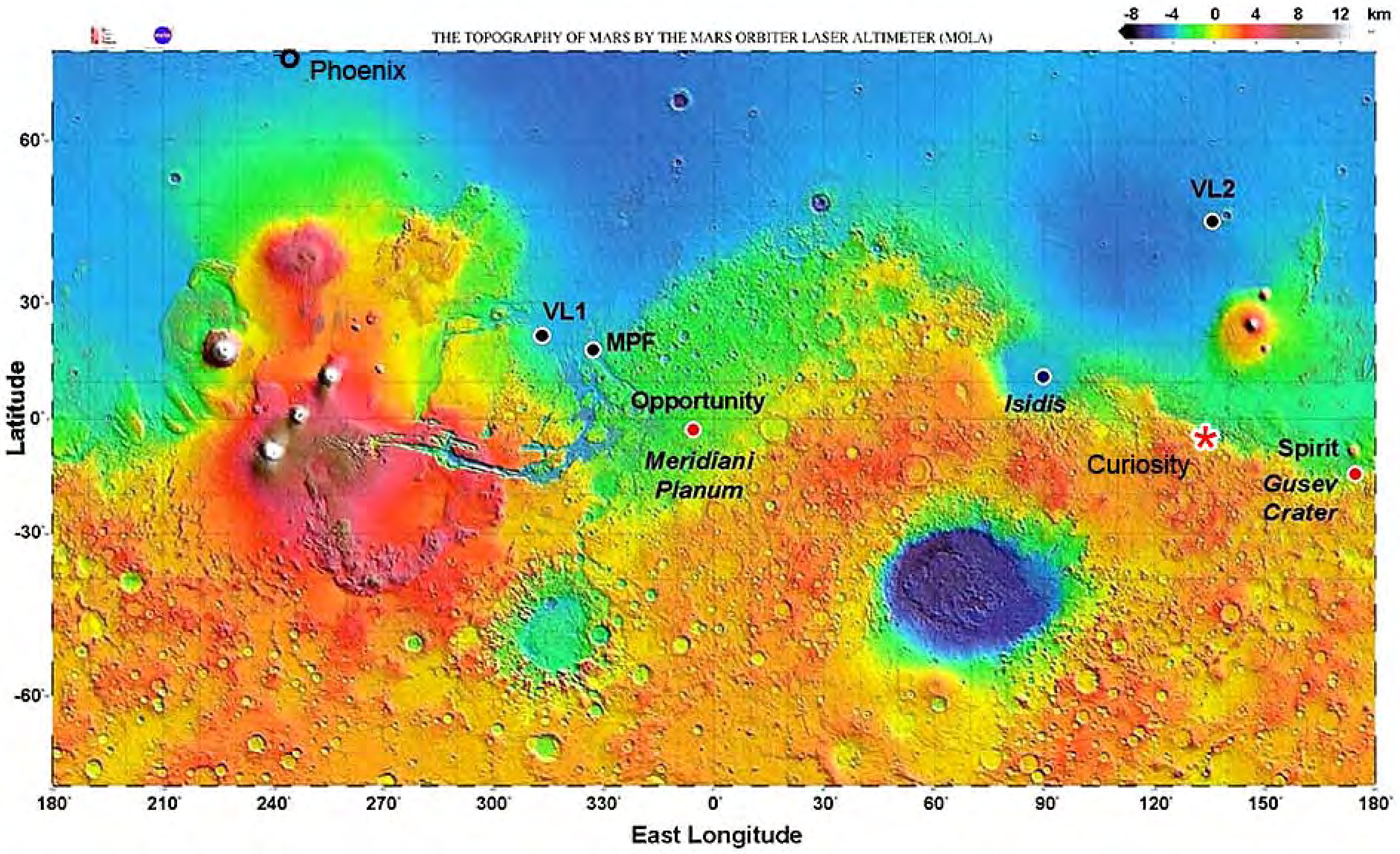
First successful landing on Mars. But after several seconds of data transmission communication lost



Viking 1, 1976

First successful and productive landing on Mars. Returned images and many data on atmosphere and soil composition

Landing sites



Fragment of Viking 1 lander panorama

Fragment of Viking 2 lander panorama

Viking landers: Surface composition

Soil: Viking results, % by weight: X-Ray Fluorescence Analysis

Gas Chr/ Mass Sp: H_2O up to 1

Const,	Chryse fines	Chryse soil	Utopia fines
SiO_2	43	42	43
Al_2O_3	7.3	7	43
Fe_2O_3	18.5	17.6	17.8
MgO	6	7	6*
CaO	5.9	5.5	5.7
K_2O	<0.15	<0.15	<0.15
TiO_2	0.66	0.59	0.56
SO_3	6.6	9.2	8.1
Cl	0.7	0.8	0.5

Multicomponent mixture of weathered and unweathered minerals:

Unweathered:	Mafic minerals
Weathered:	Smectite clays, palagonite and/or scapolite
Iron	Amorphous and crystalline oxyhydrates
Accessories	Sulfate and chloride salts
Carbonates	Very low, if any
Organic material	No

Banin et al., 1992

Surface material composition:

Reflection spectra resemble weathered basalt

Light / dark areas – much / little dust

Mars 5 gamma-spectrometry => mafic material

Viking in-situ X-ray fluorescence spectrometry (XRFS)
=> mafic, some presence of water => clays

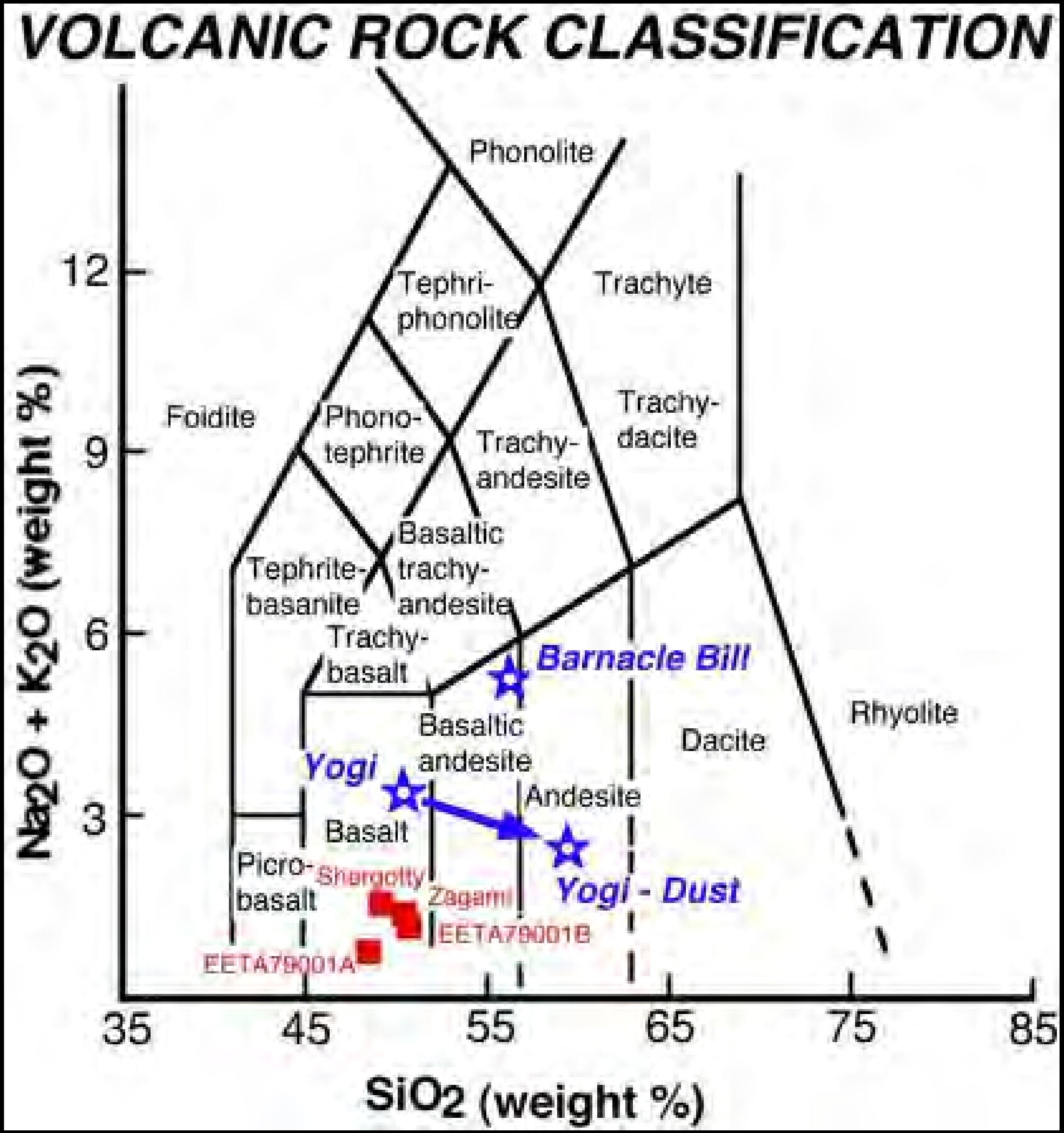
Mars Pathfinder XRFS => mafic soil, rocks andesito-basalt?

Mars Pathfinder - APXS Preliminary Results

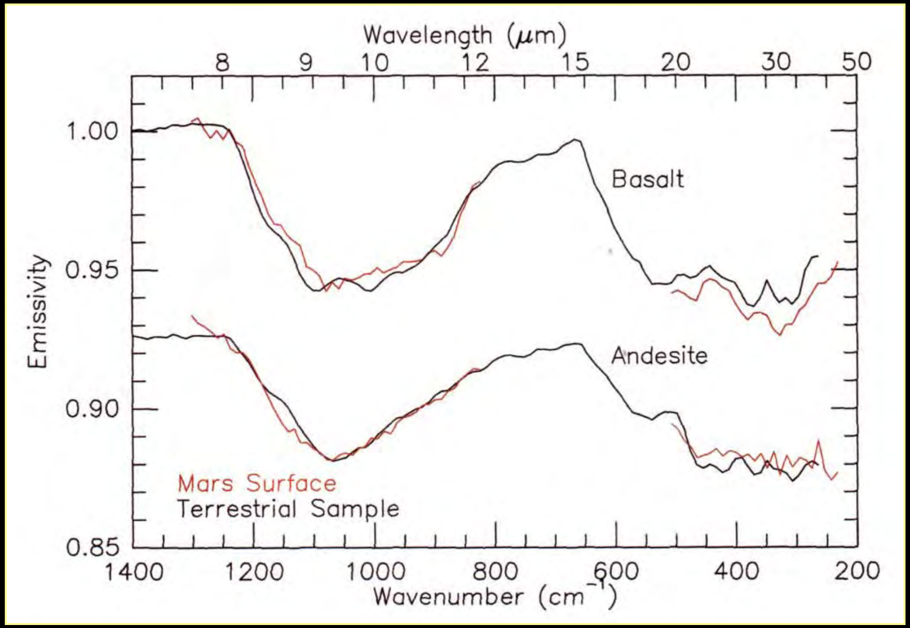
Oxide	A-2, Soil	A-4, Soil	A-5, Soil	A-3, Rock BB	A-7, Rock Yogi
SiO_2	46.1	43.3	43.8	55.0	50.9
Al_2O_3	8.0	10.4	10.1	12.4	11.4
FeO	19.5	14.5	17.5	12.7	13.8
MgO	8.7	9.0	8.6	3.1	6.3
CaO	6.3	4.8	5.3	4.6	5.8
Na_2O	4.3	5.1	3.6	4.2	2.5
K_2O	0.6	0.7	0.7	1.4	1.1
MnO	0.5	0.5	0.6	0.9	0.5
TiO_2	1.1	1.1	0.7	0.7	0.8
SO_3	4.3	6.2	5.4	2.2	4.2

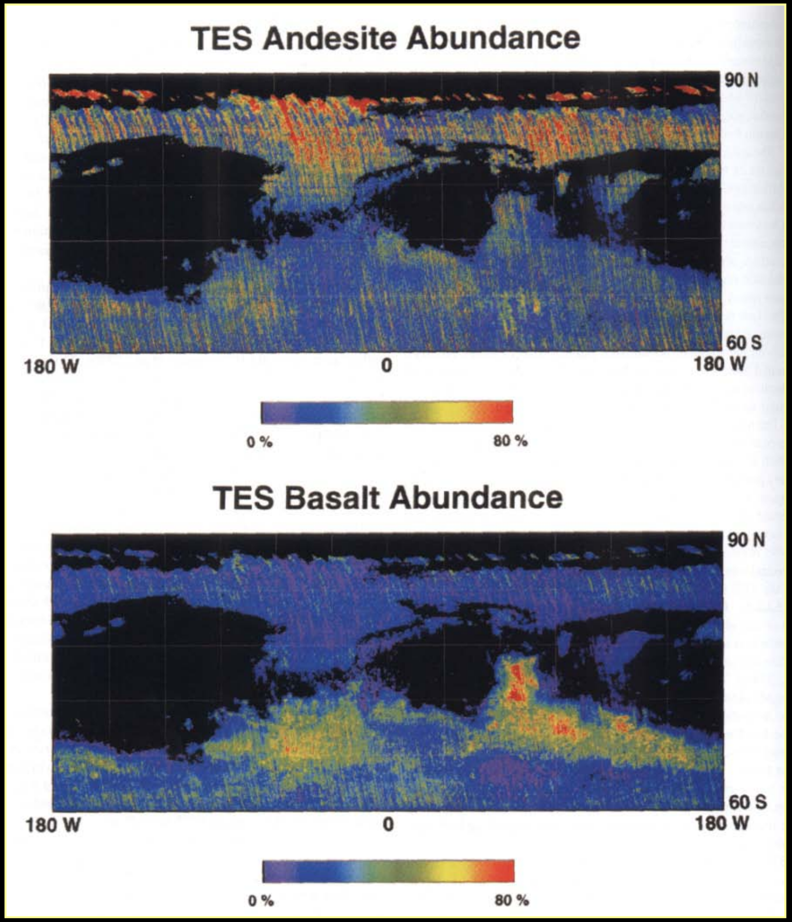
Notes:
Values for potassium and manganese are upper limits
Minor elements such as phosphorus, chlorine and chromium are omitted from this table.

Mars Pathfinder - APXS Preliminary Results



TES: Surface/igneous mineralogy
Basalt-andesite areal distribution



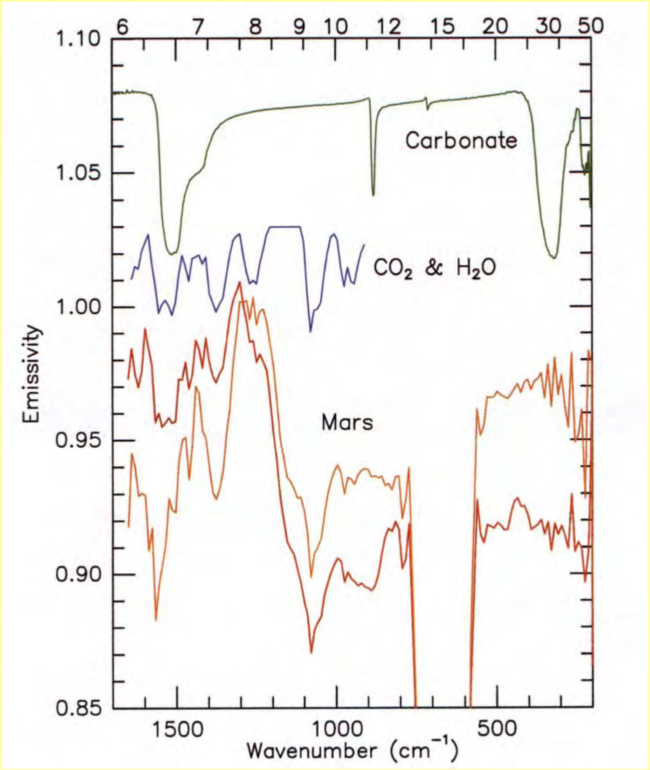


In dark regiones spectral signatures of basalts and andesites are seen. The surface can be separated into two geo-graphically distinct units with boundary along the planetary dichotomy:

The basaltic composition is confined to older surfaces and more silicic surface type concentrates in the younger northern plains.

Bandfield et al., 2000; Christensen et al., 2001.

TES: Surface mineralogy
Carbonates and weathering products



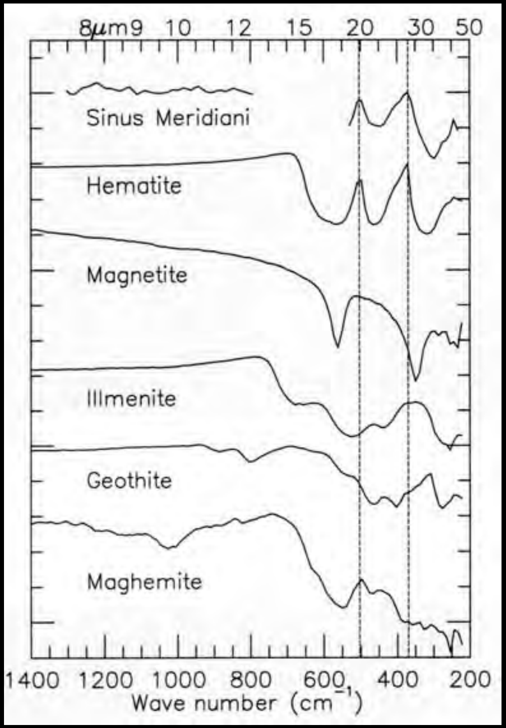
Carbonates, quartz and sulfates have not been identified at detection limit of 5, 5, and 10% respectively.

Christiansen et al., 2000, 2001

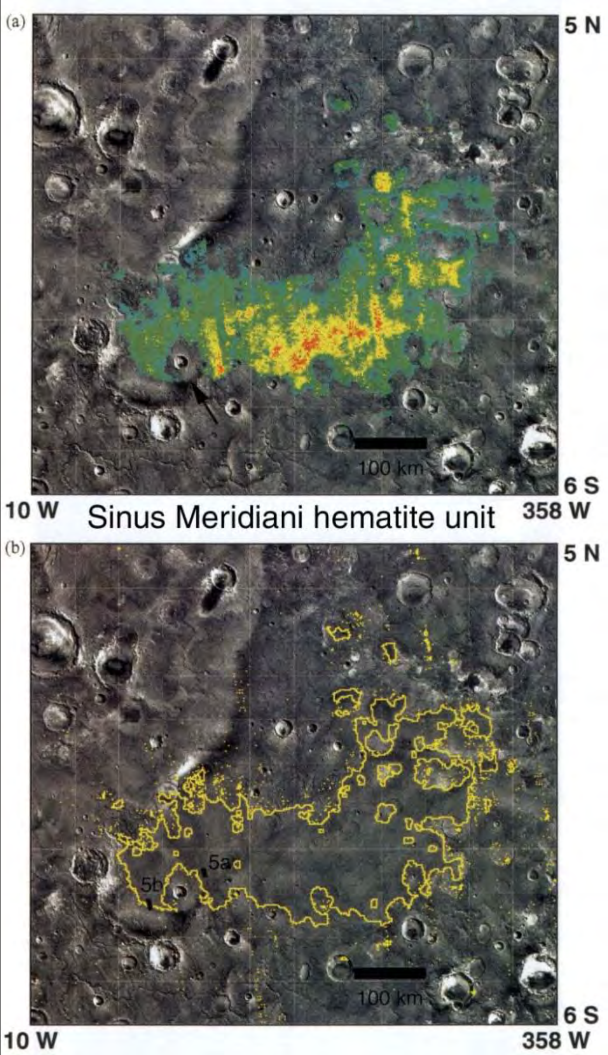
White Rock feature (8ºS, 335ºW), a place of expected evaporites was found to be not anomalously bright, with no signatures of sulfates and carbonates; spectrally flat halite can not be excluded

TES: Surface mineralogy

Hematite



Crystalline gray hematite has been uniquely identified from TES data and its occurrence has been mapped globally.
It is distinct from the fine-grained ,5-10 mkm, red, crystalline hematite considered to be a minor spectral component in Martian bright regions



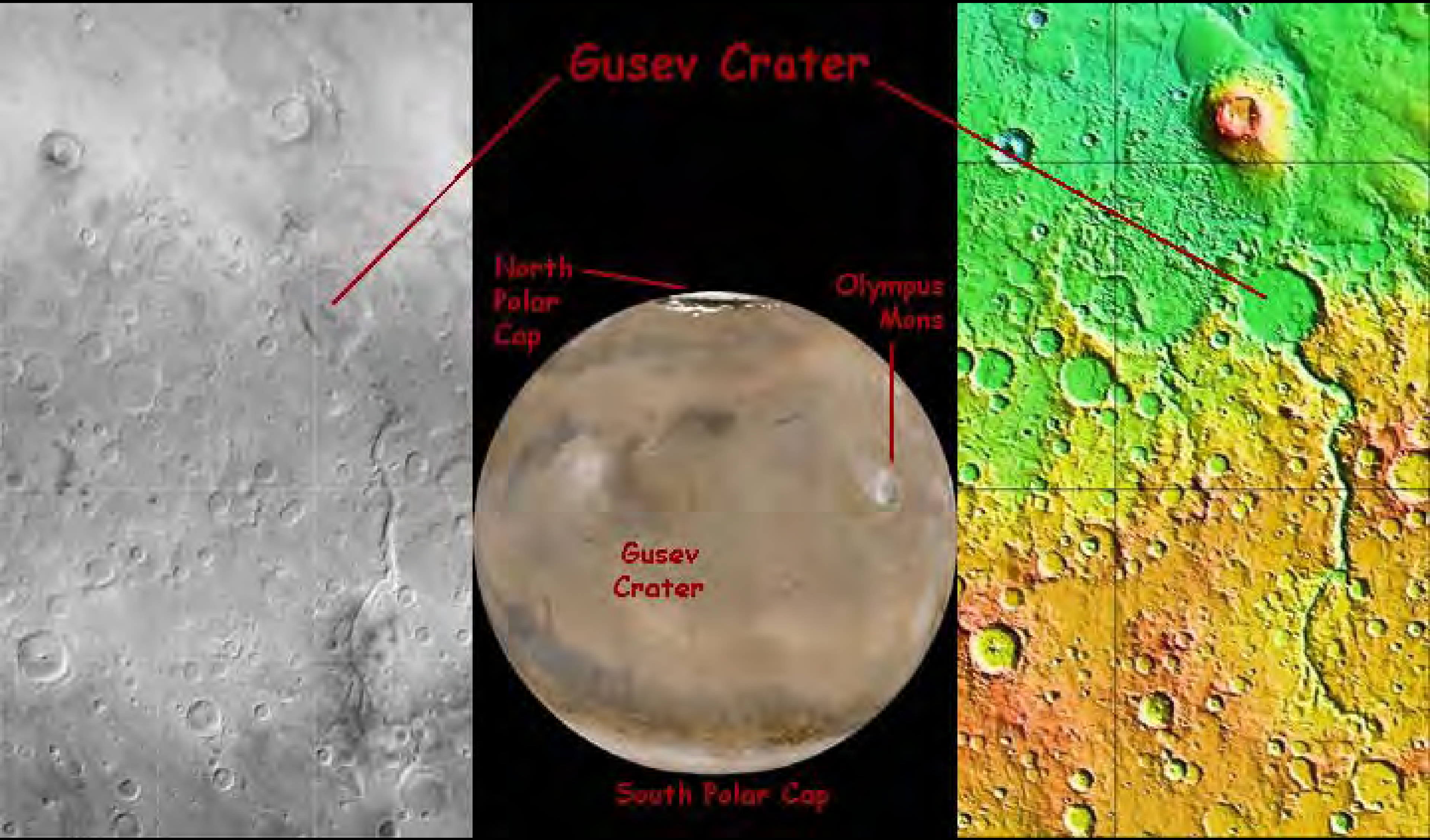
Three localities of crystalline gray hematite: Sinus Meridiani, Aram Chaos, Ophir/Candor small deposits.

Most likely formed by chemical precipitation from aqueous liquids under ambient or hydrothermal conditions.

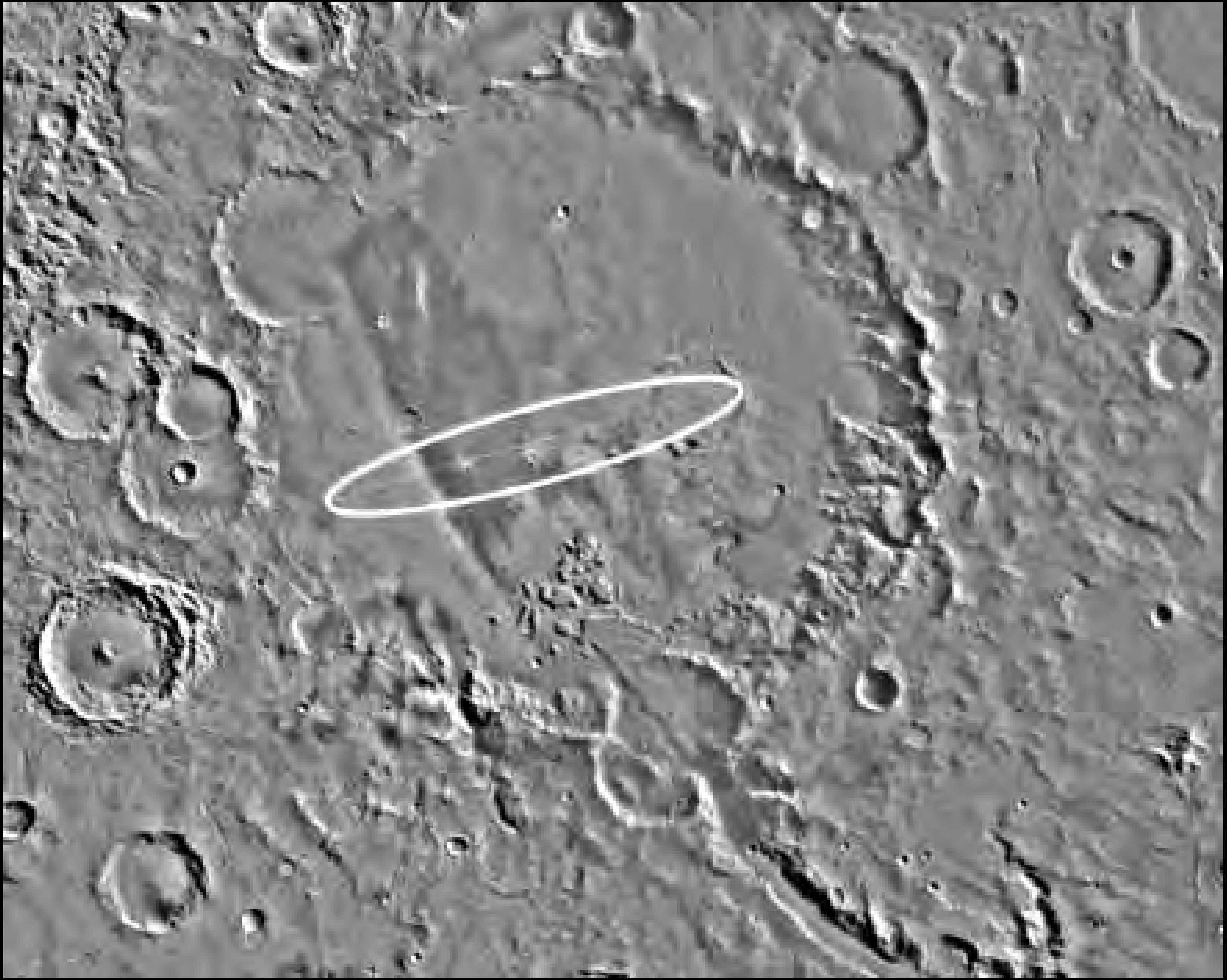
Christensen et al., 2000

MER – Mars Exploration Rover, artist presentation

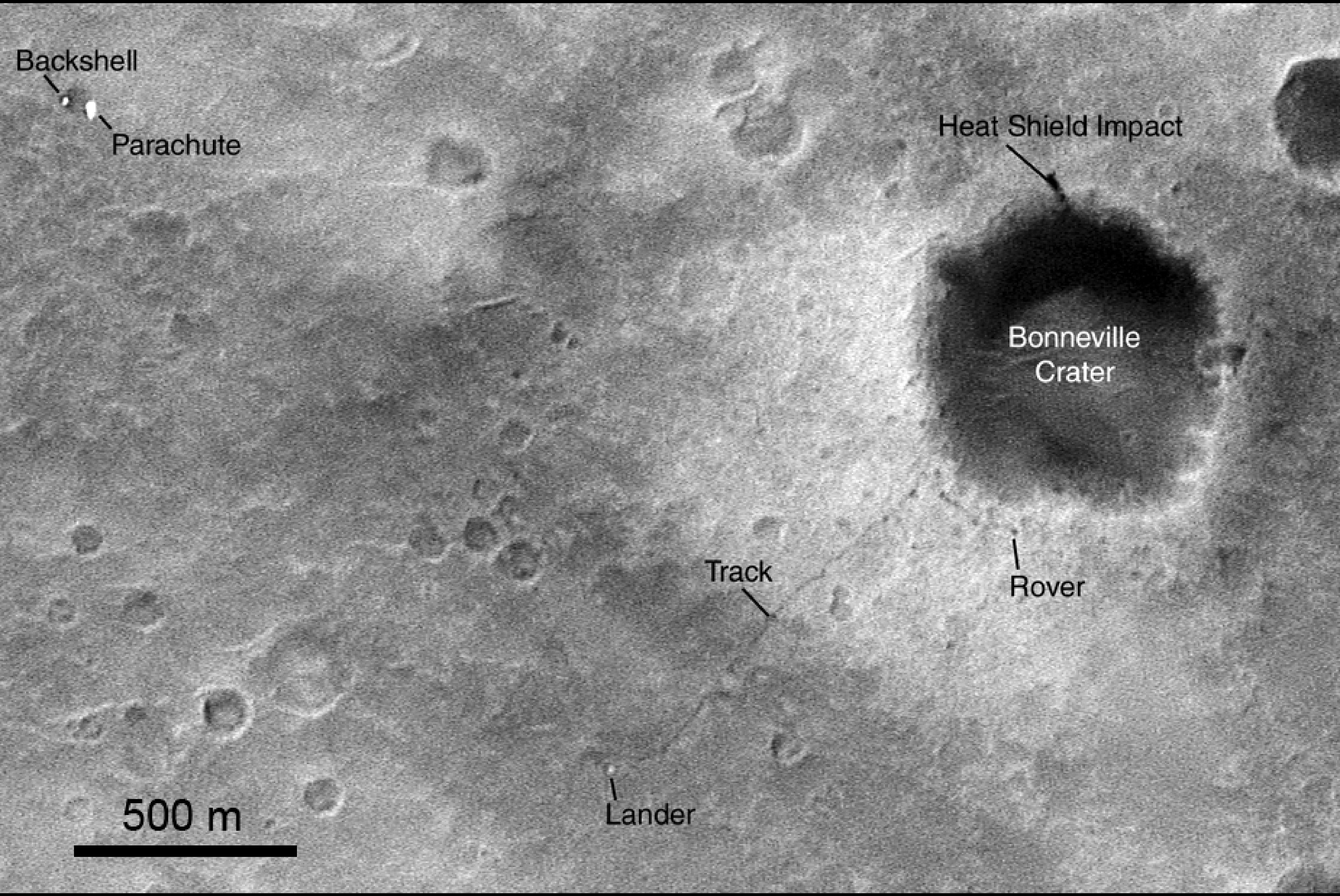
MER Spirit: Landing in crater Gusev expected old lake



Landing ellipse in crater Gusev

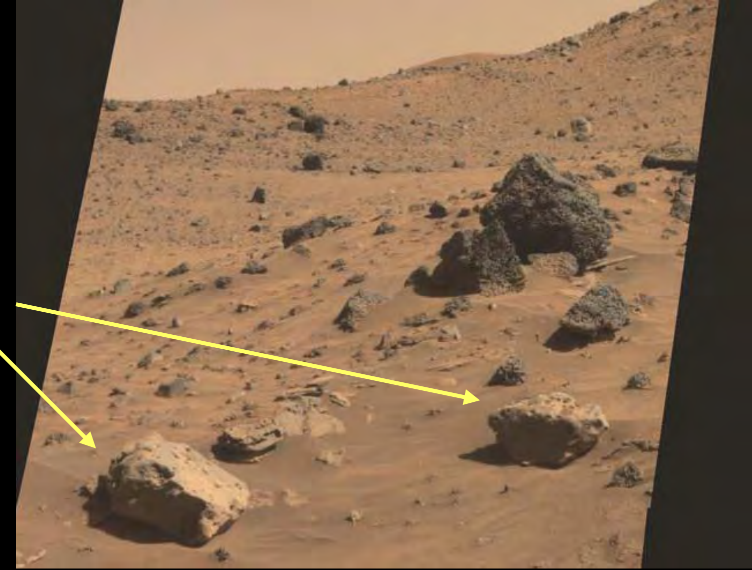


Spirit seen by MGS MOC on 85th sol



Surface material composition:
Mars Exploration Rovers, Spirit:

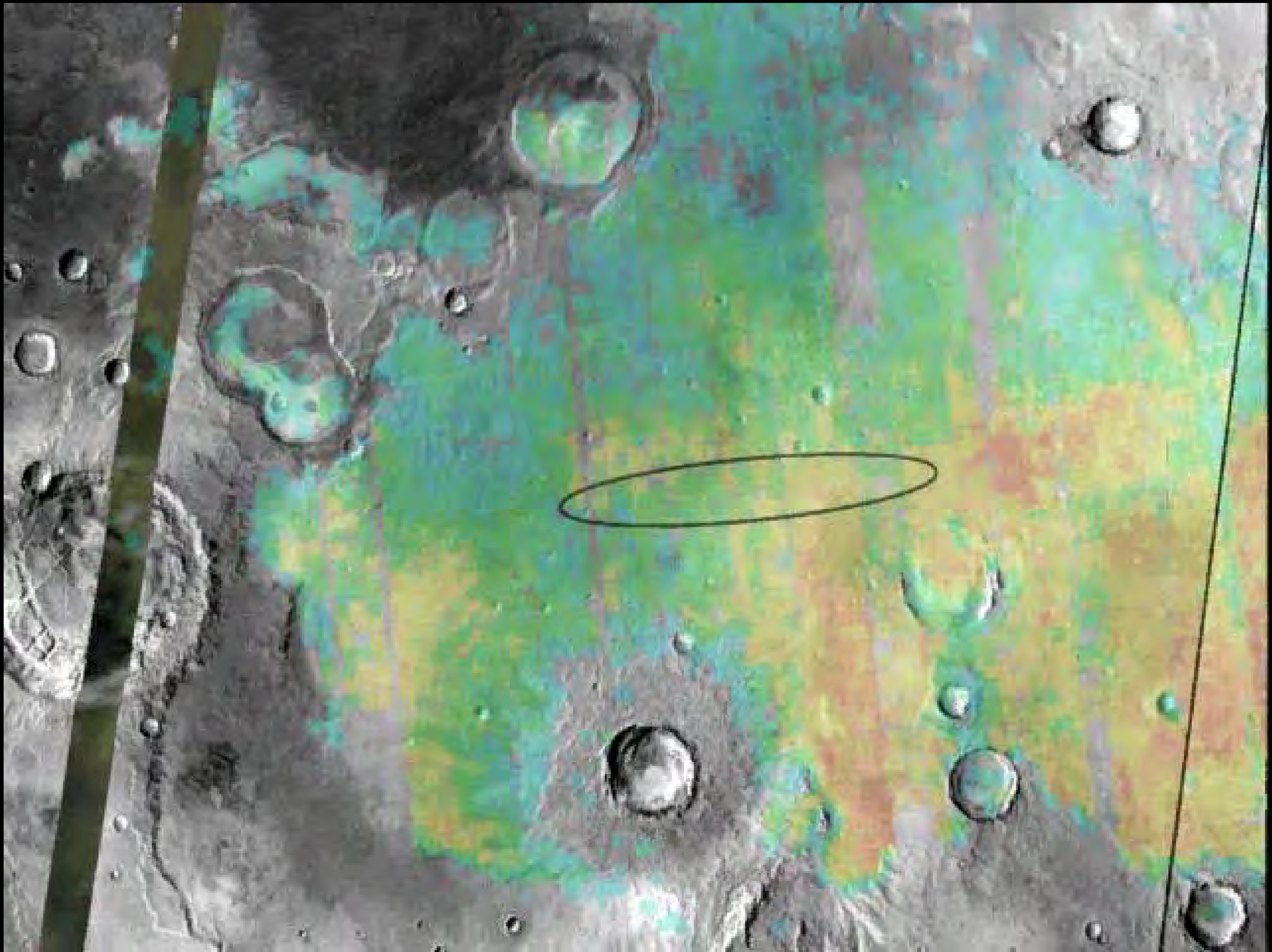
Possible meteorites



Mafic soil, bedrock basalts
No lacustrine deposits

Spirit robotic arm and grinding hole on the rock surface

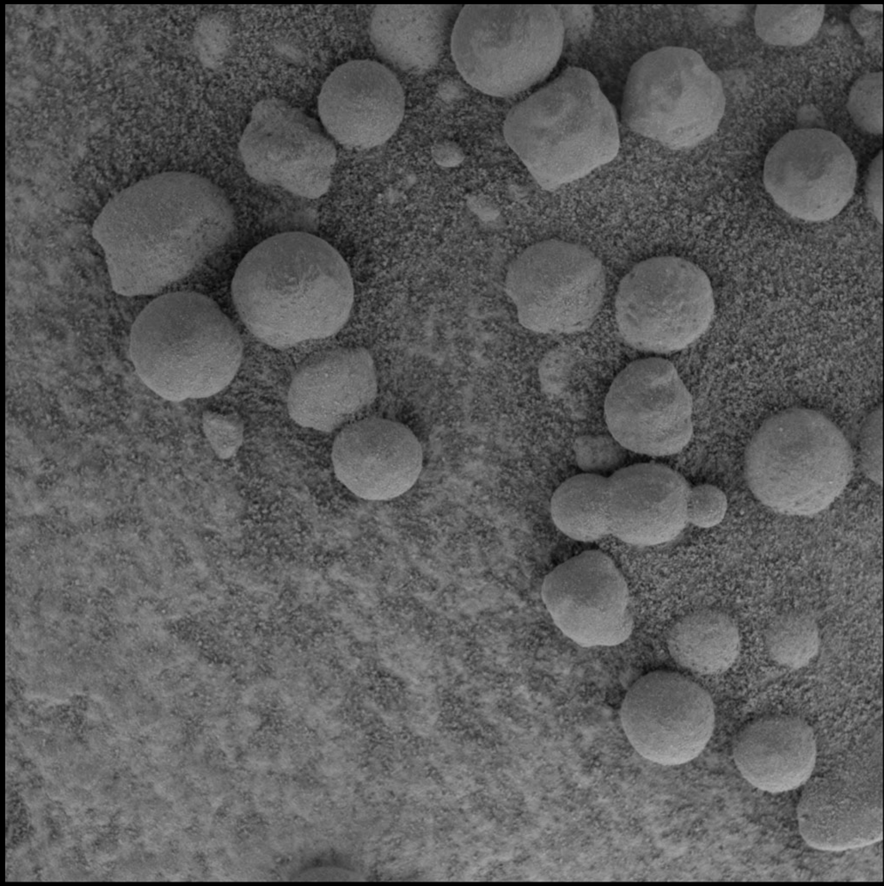
Opportunity landing ellipse on hematite abundance map



Surface material composition:
Mars Exploration Rovers, Opportunity:

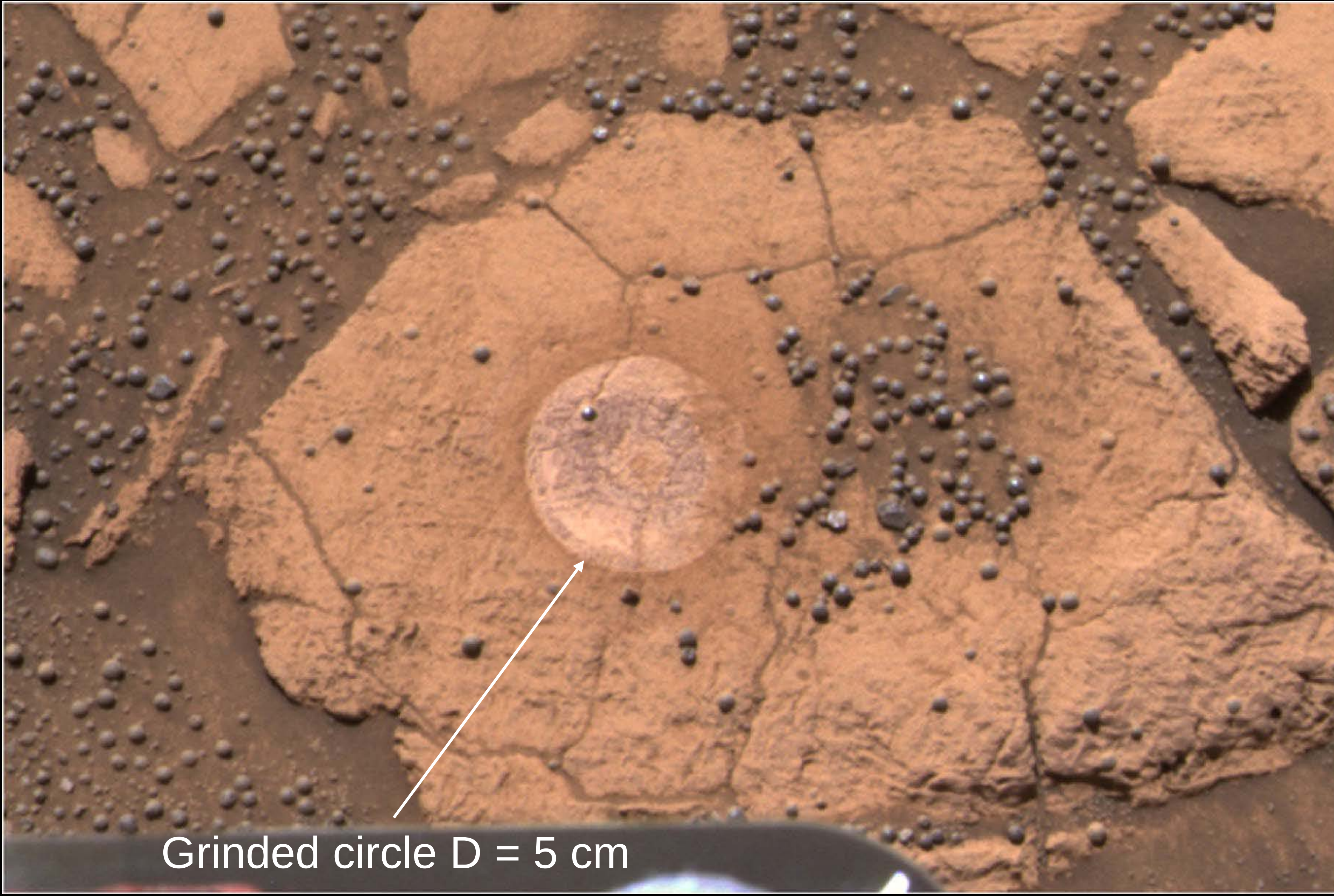
Soil - mafic with hematite spherules
Bedrock – finely bedded sulphates, including jarosite + hematite spherules = lacustrine sediments, water was acidic

El Capitan outcrop

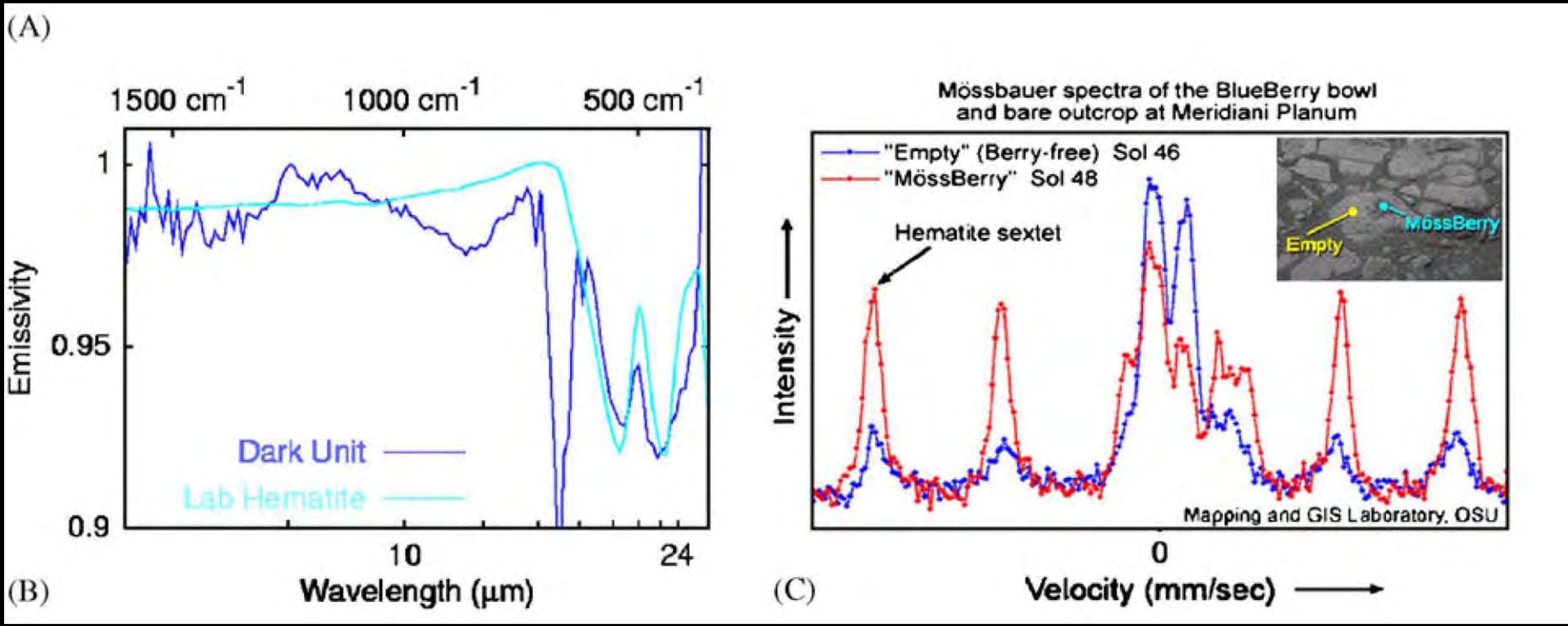


“Blueberries” in the soil

Opportunity, Berry bowl, Pancam image



Opportunity, Berry bowl

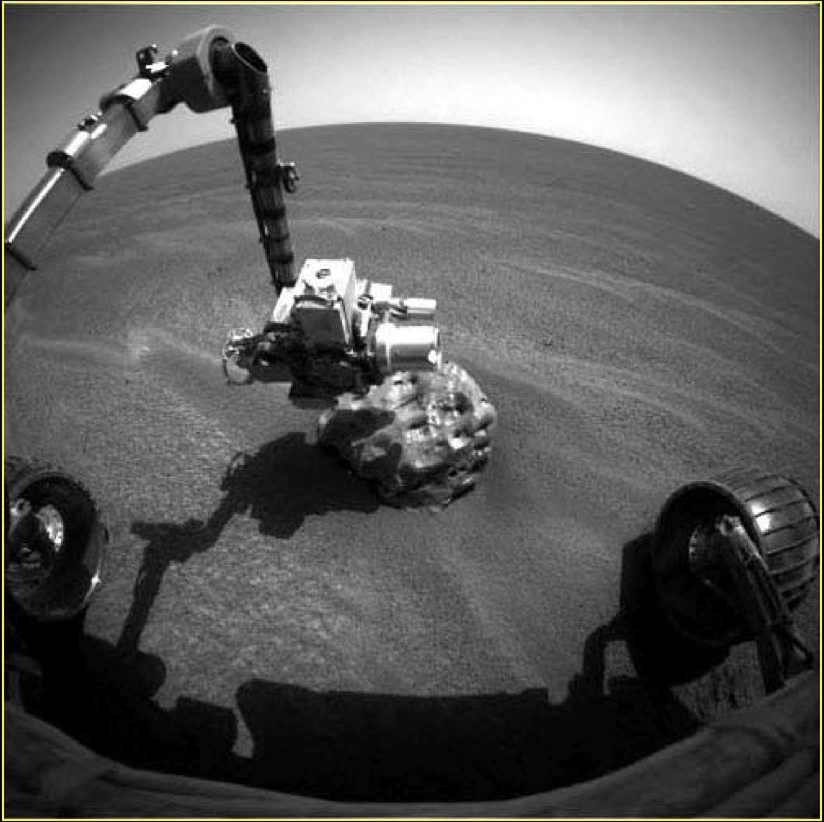


Laboratory spectra and MiniTES

Mossbauer spectra

These analyses show that the spherules are made of hematite

Opportunity found iron meteorite



Taking evidence that
this is meteorite

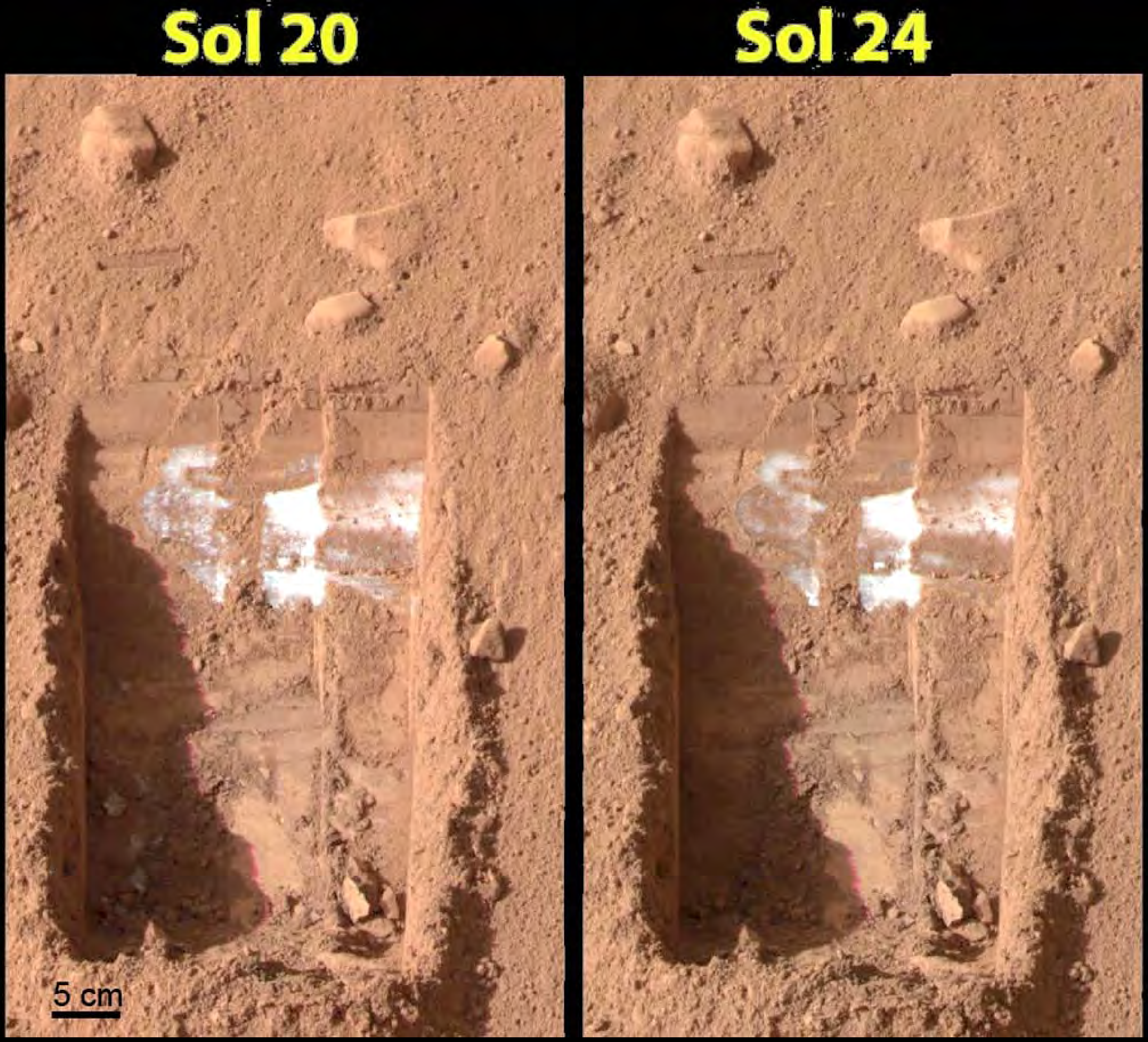
The Phoenix landing site is close to the North pole

Landscape of Phoenix site with permafrost polygons

Earth, Taimyr

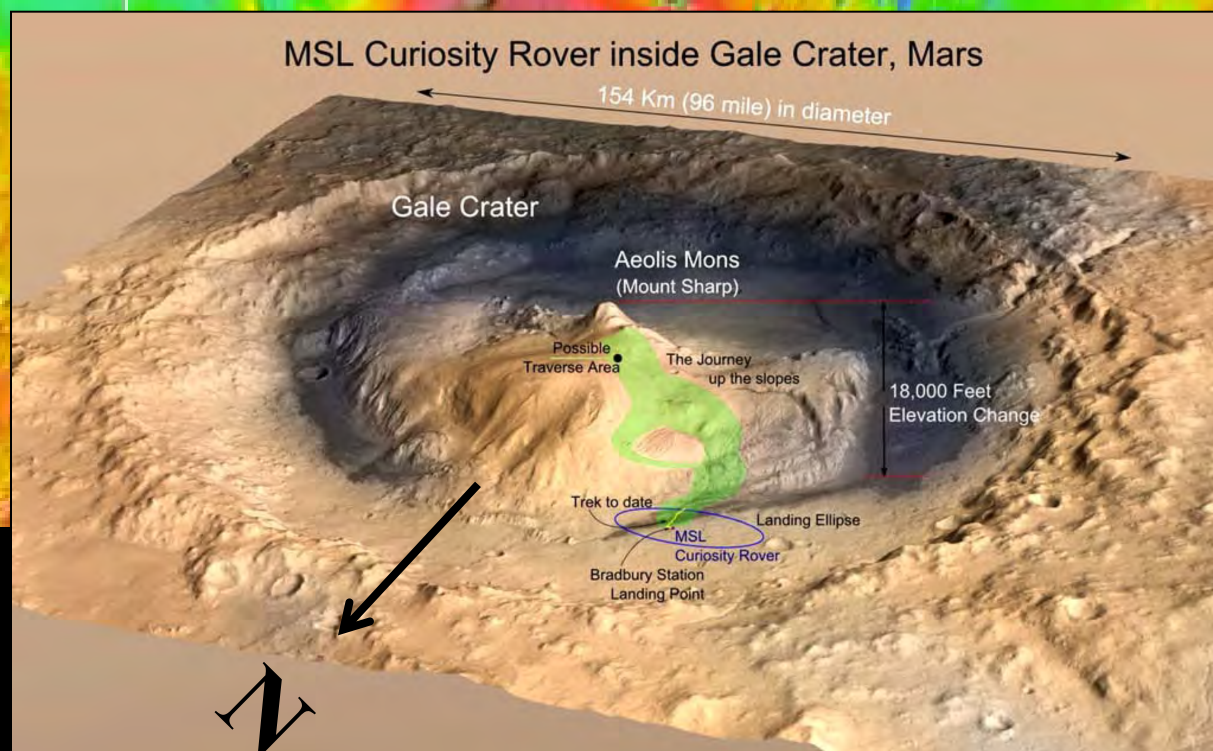
Earth, Altay

Robotic arm with scoop



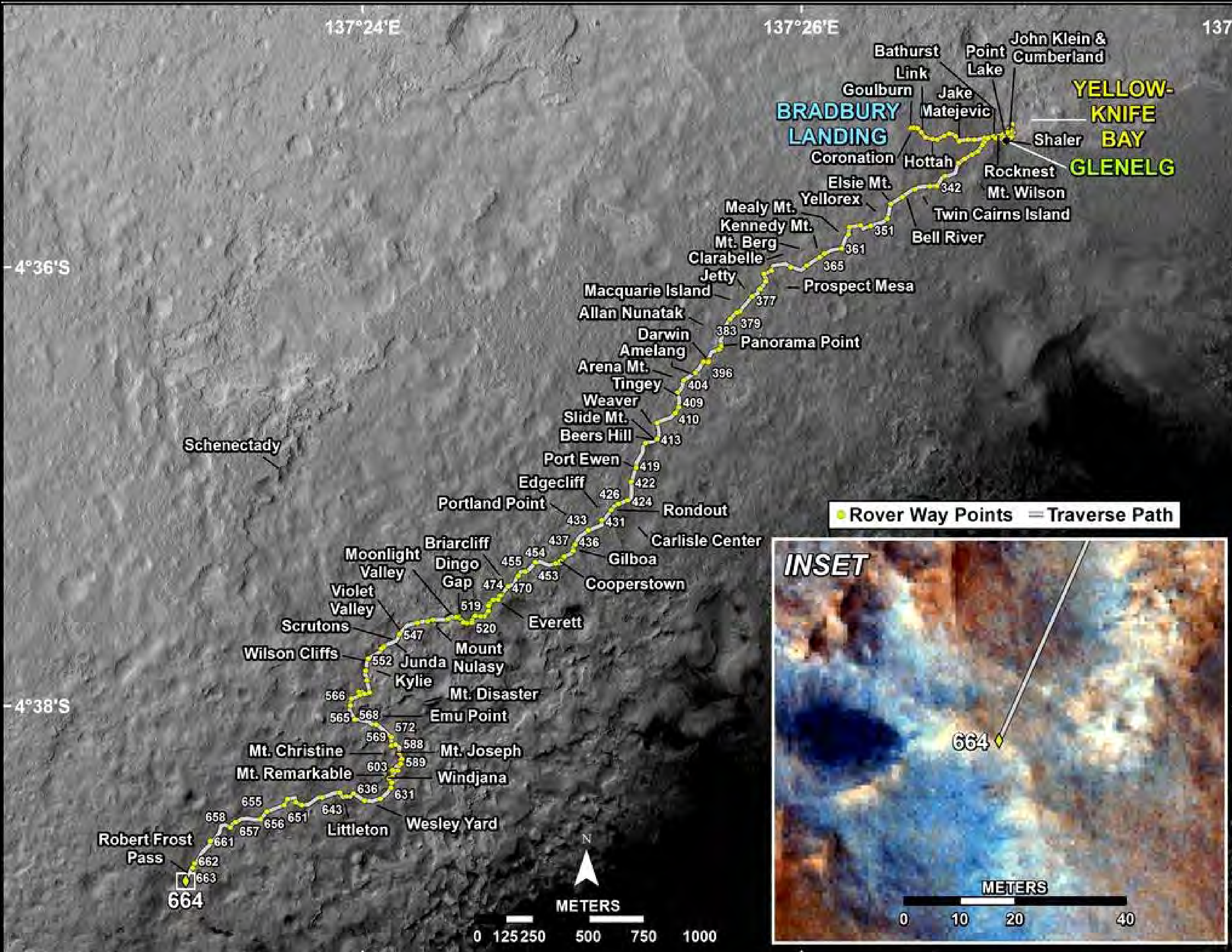
Trench with ice/frost subliming with time

Curiosity part done with the help of Walter Goetz, MPS

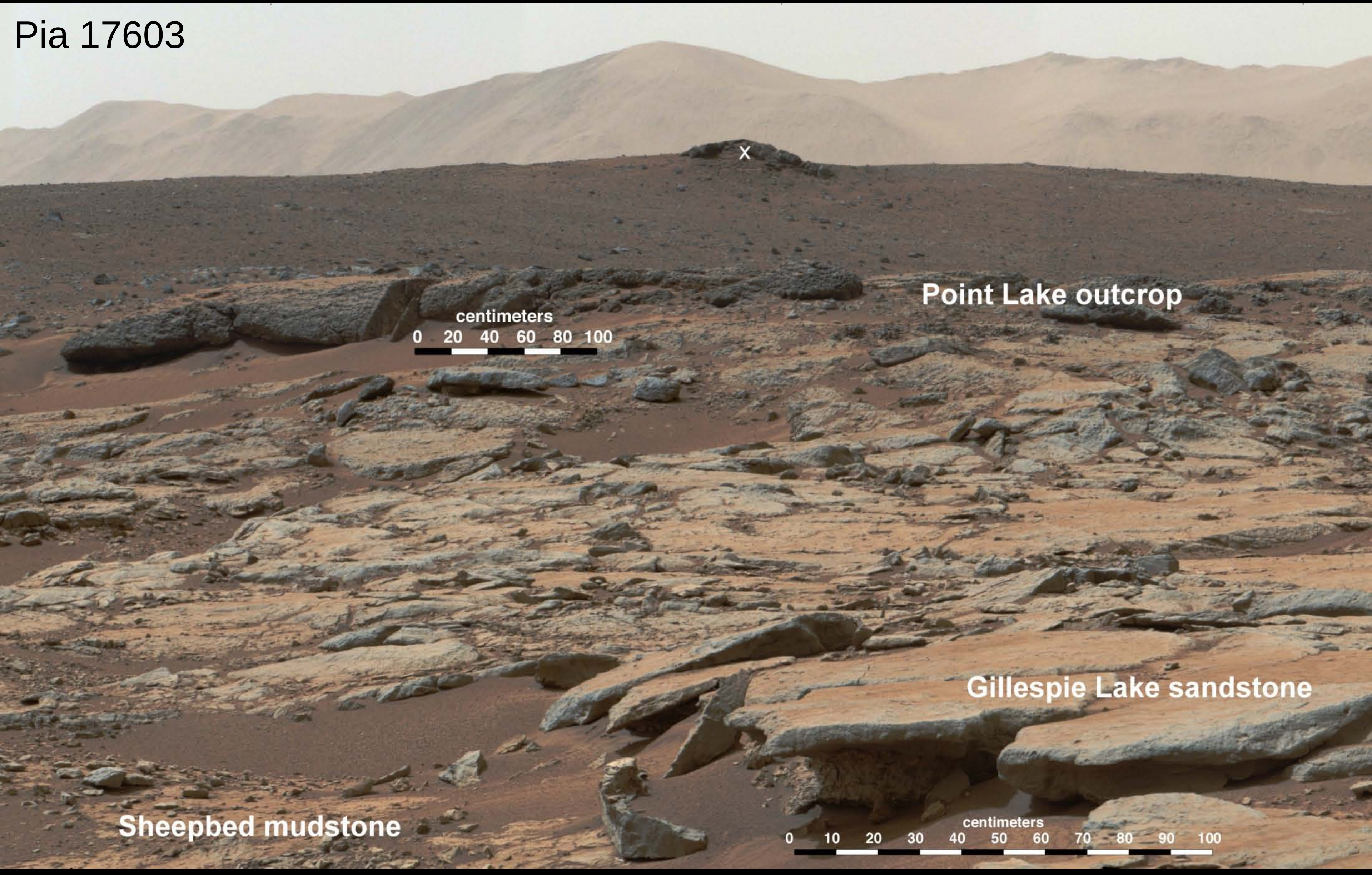


MSL Curiosity inside Gale crater

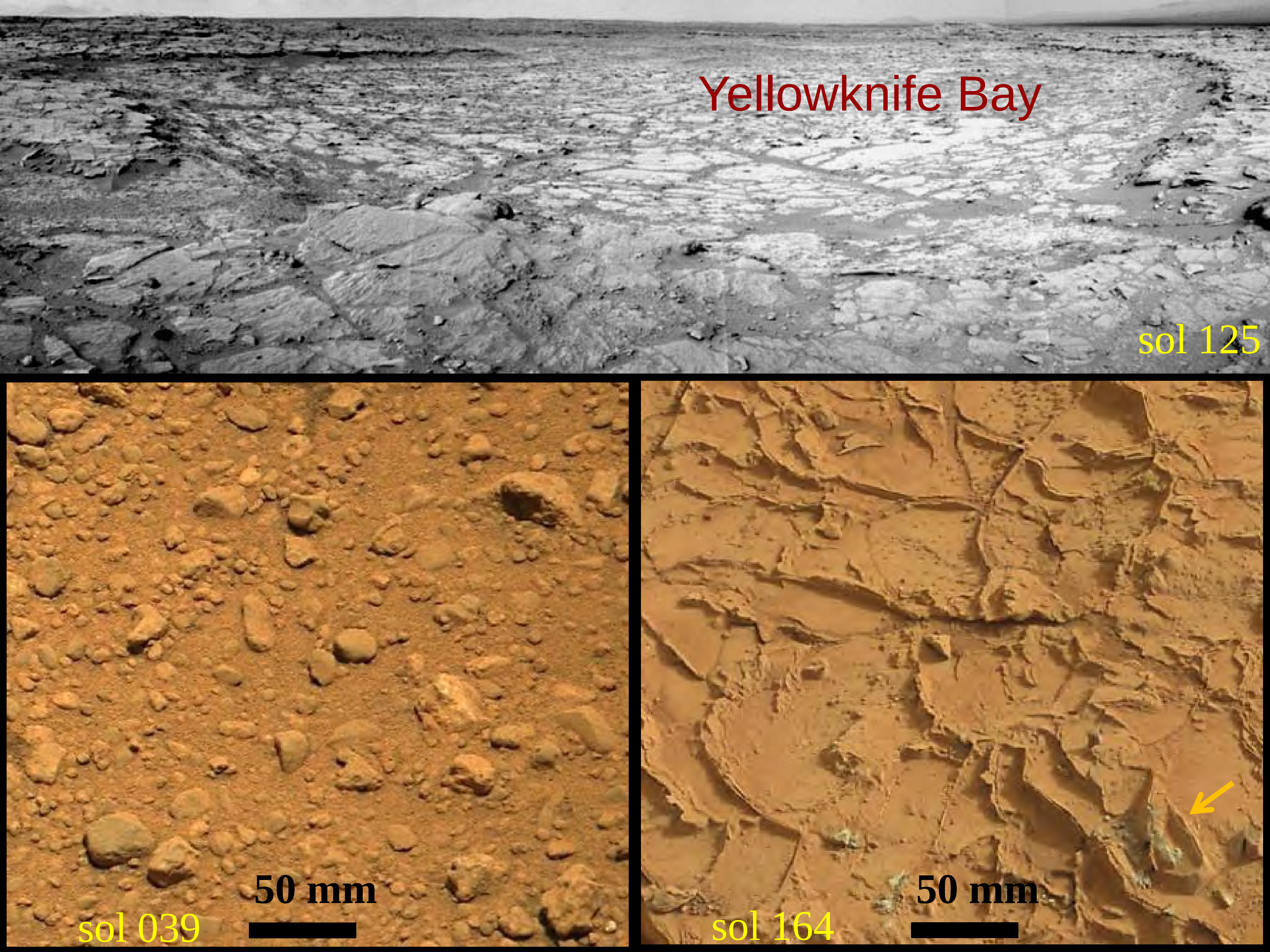
Large Mars rover Curiosity,
Search for evidence of past
environments favorable for life


137°24'E
137°26'E
137°
4°36'S
4°38'S
Bathurst
Point Lake
John Klein & Cumberland
Link
Goulburn
Jake Matejevic
YELLOW-KNIFE BAY
BRADBURY LANDING
Shaler
Coronation
Hottah
Rocknest
GLENELG
Elsie Mt.
342
Mt. Wilson
Mealy Mt.
Yellorex
Twin Cairns Island
Kennedy Mt.
351
Bell River
Mt. Berg
361
Clarabelle
365
Jetty
Prospect Mesa
Macquarie Island
377
Allan Nunatak
379
383
Darwin
Panorama Point
Amelang
396
Arena Mt.
404
Tingey
409
Weaver
410
Slide Mt.
Beers Hill
413
Schenectady
Port Ewen
419
422
Edgecliff
426
424
Rondout
Portland Point
433
431
Carlisle Center
437
436
Gilboa
Briarcliff
454
455
Moonlight Valley
Dingo Gap
453
Cooperstown
474
470
Violet Valley
519
Everett
520
Scrutons
547
Mount Nulasy
Wilson Cliffs
552
Junda
Kylie
566
Mt. Disaster
565
568
Emu Point
572
569
588
Mt. Christine
Mt. Joseph
589
Mt. Remarkable
603
Windjana
636
631
655
643
658
656
651
Littleton
Wesley Yard
657
Robert Frost Pass
661
662
663
664
N
METERS
0
125
250
500
750
1000
Rover Way Points
Traverse Path
INSET
664
METERS
0
10
20
40

Sedimentary deposits in Glenelg area



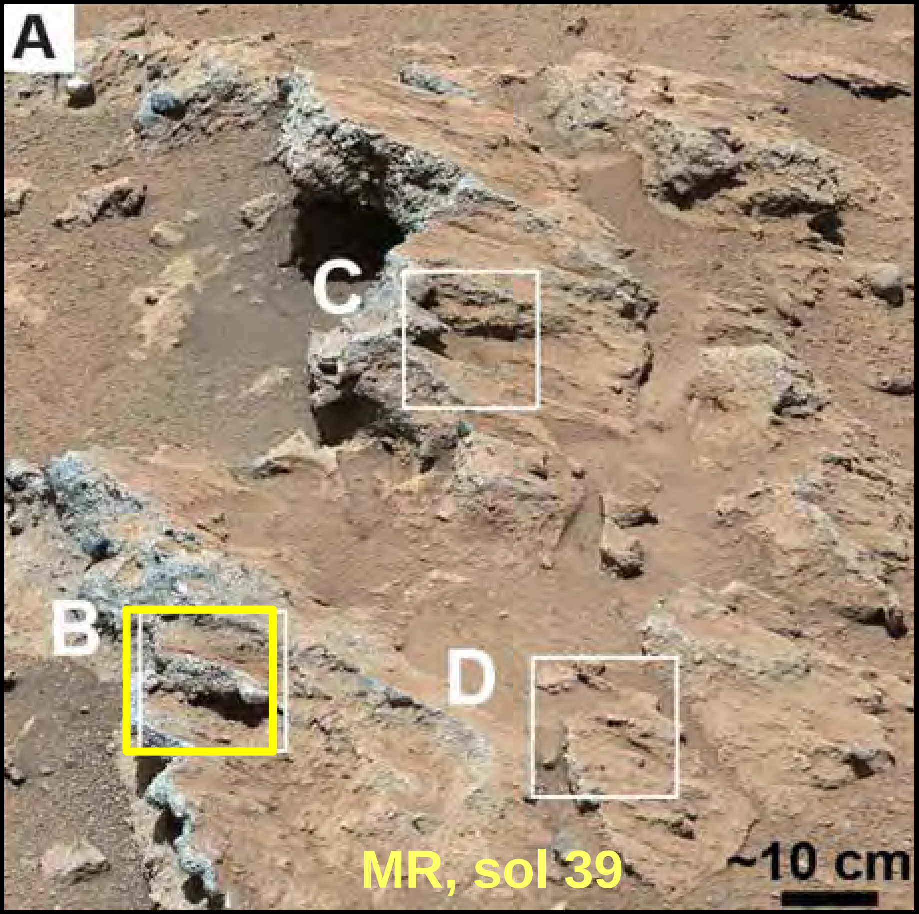
Pia 19074
Sol 712, Hidden Valley
centimeters
0 10 20 30 40 50

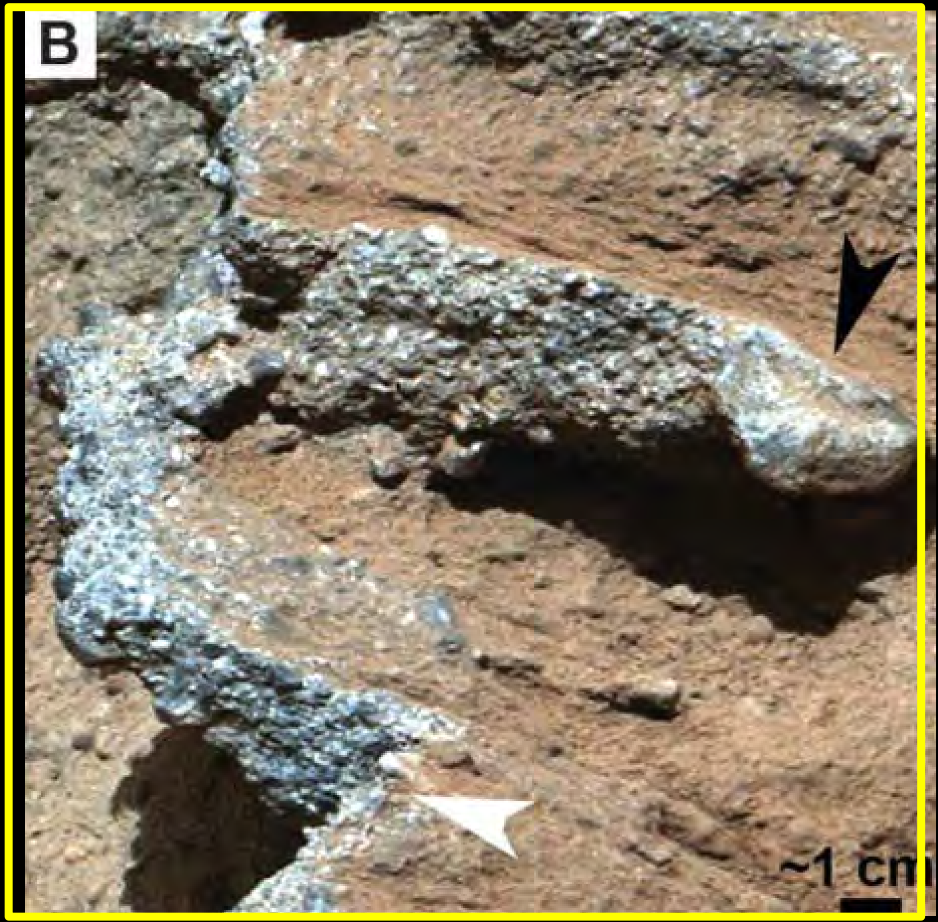


Yellowknife Bay
sol 125
50 mm
sol 039
50 mm
sol 164

Diagenetic Features at High Resolution

Hottah conglomerate

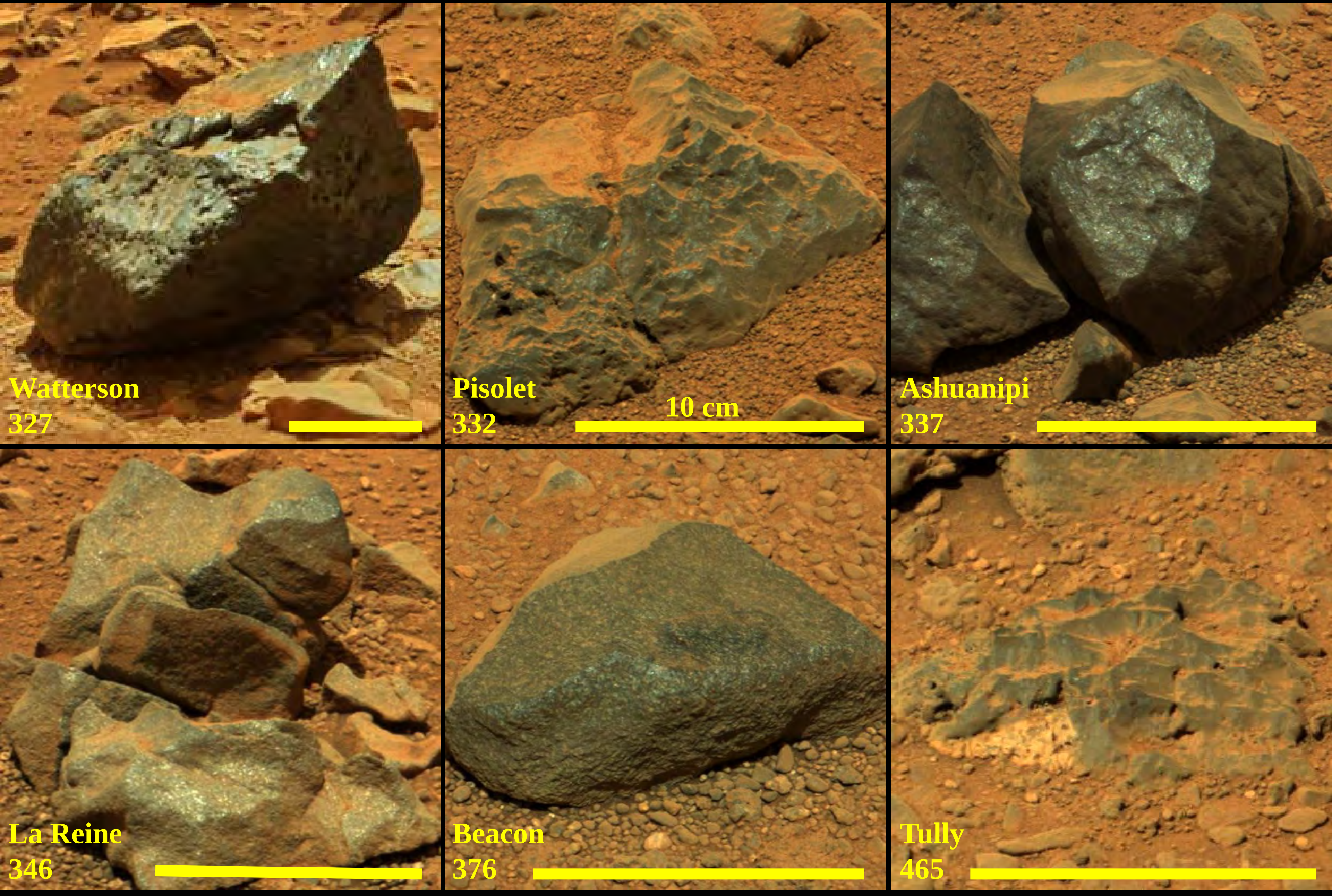




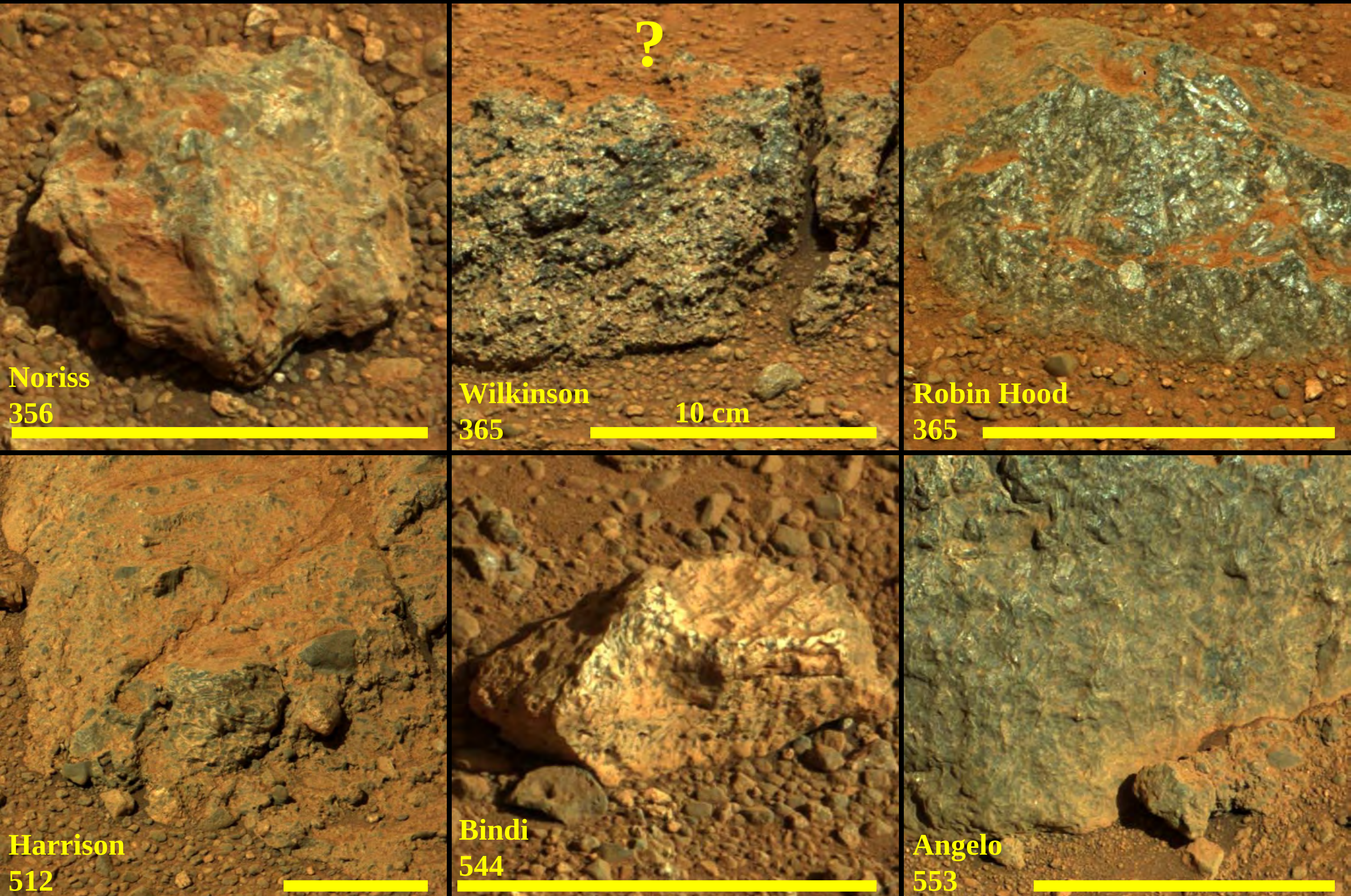
- cm-sized rounded clast
- weak laminations

(Williams et al., Sci, 2013

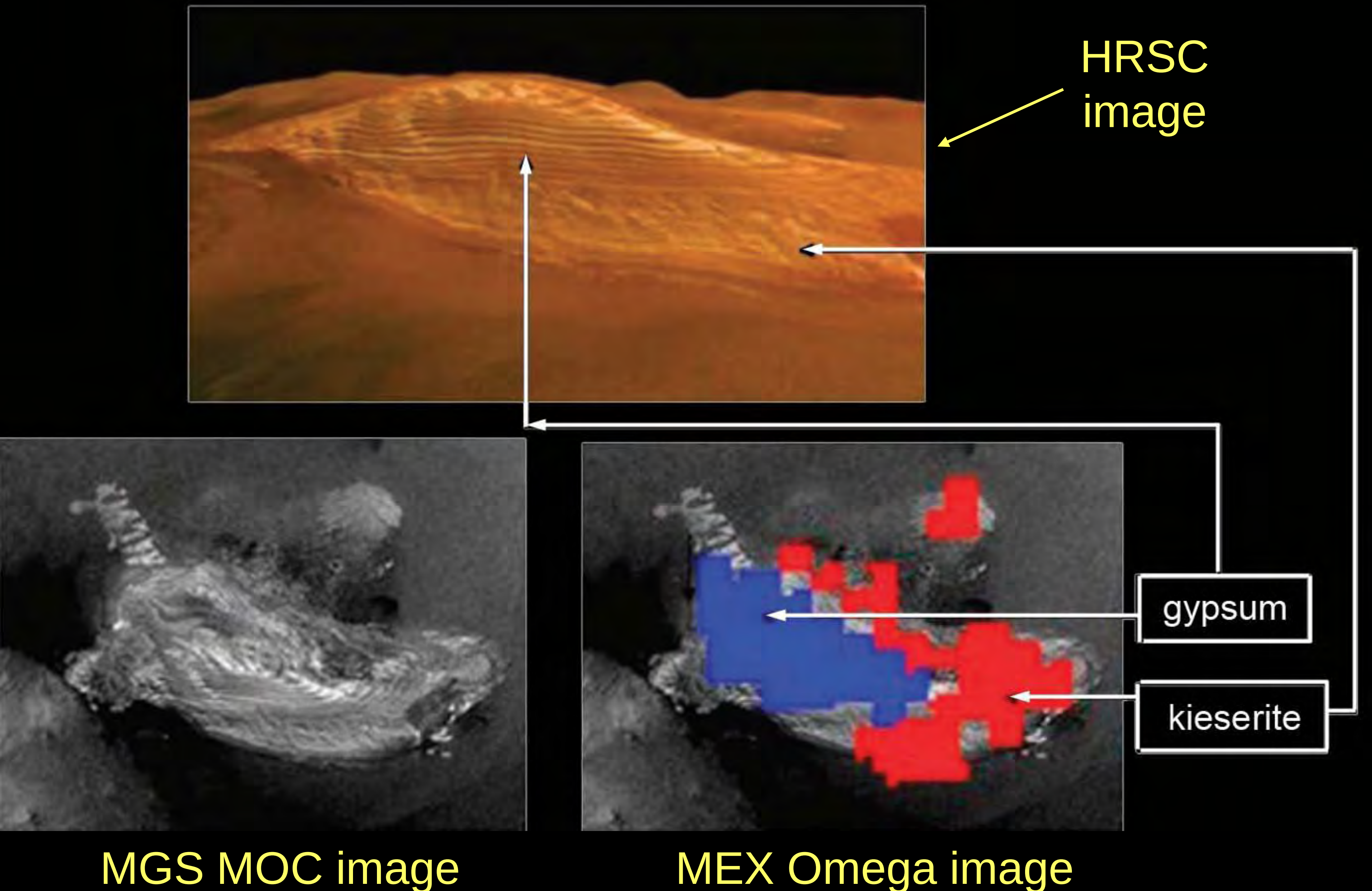
Mafic (< 53% SiO_2), mostly fine-grained (traditional?)



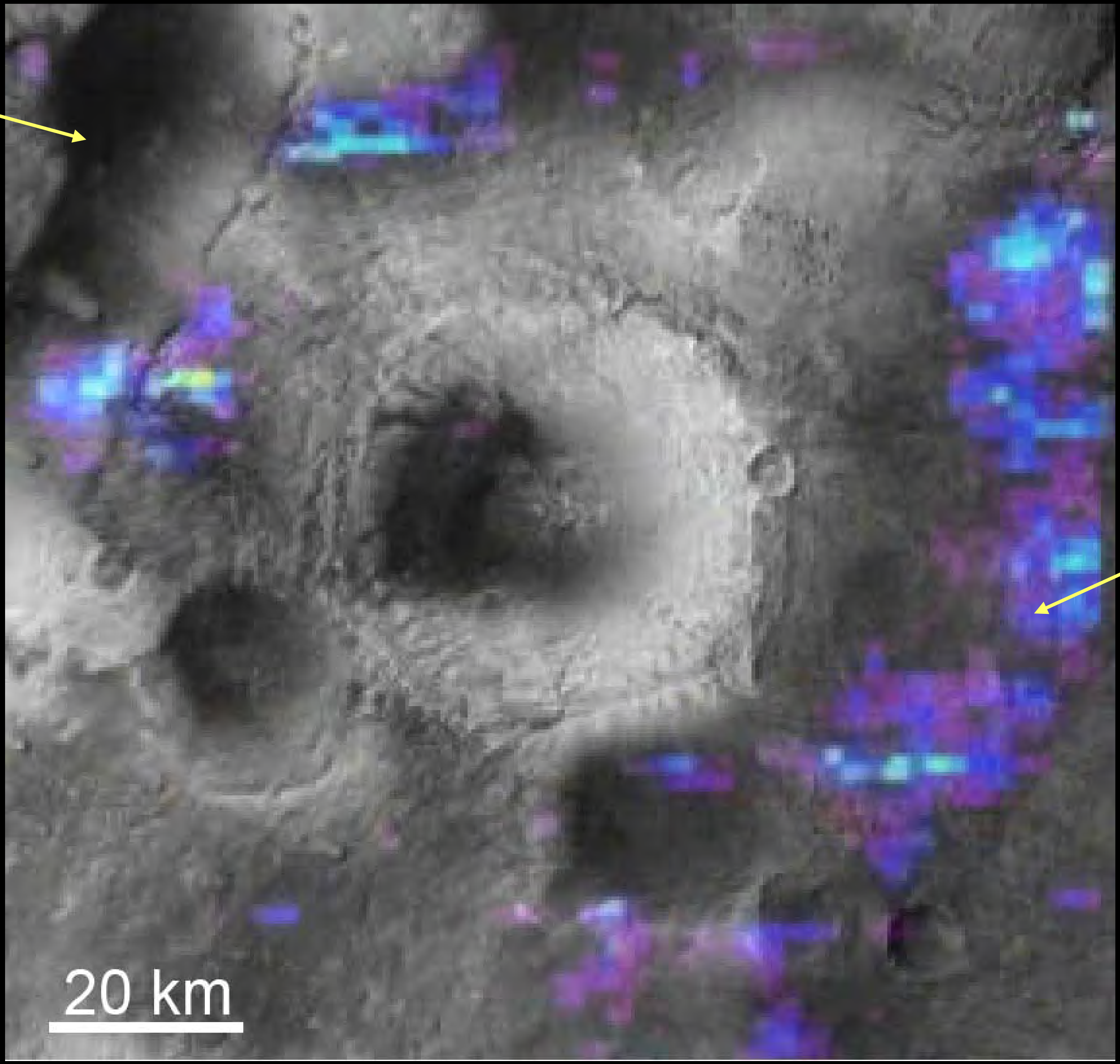
Felsic (> 53% SiO_2), plutonic or porphyritic



IR spectrometer Omega shows presence of sulfates



Phyllosilicates around 50 km crater

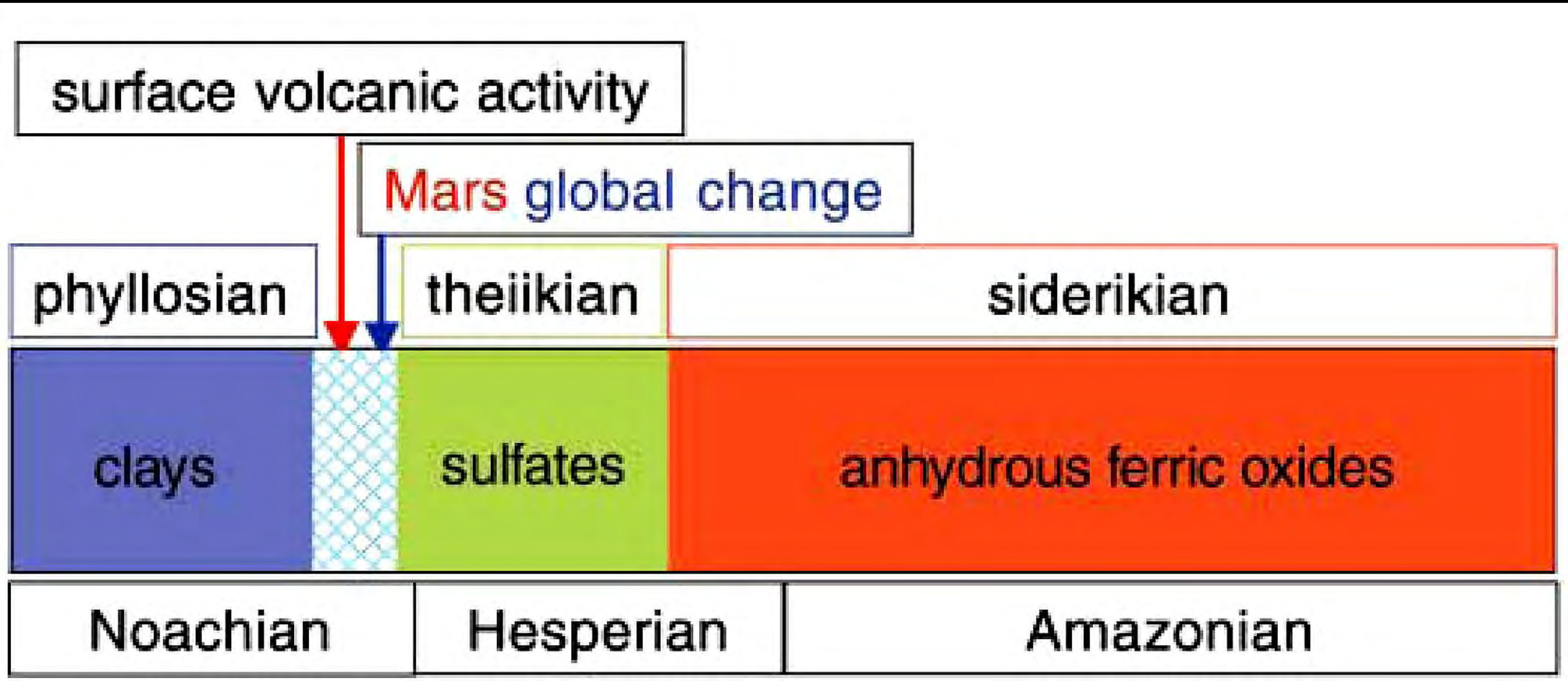


HRSC image

Color from Omega image

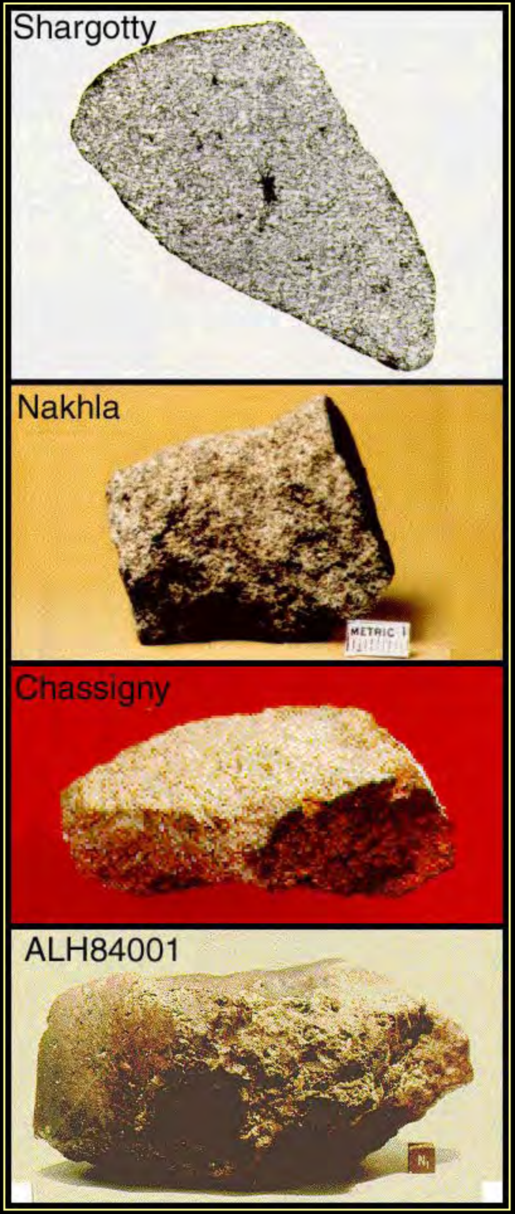
Mineralogical «eras» in history of Mars

Bibring et al., 2006



4.0 3.5 3.0 billion years ago

Igneous mineralogy



Shergotty-Nakhla-Chassigny (SNC) meteorites

Diabase Clinopyroxenite Dunite

= mafic/ultramafic accociation

Shergotty, Zagami, EETA 79001, ALHA 77005

Pyroxene pigeonite En60Fs28Wo12 - En21Fs61Wo28

Pyroxene augite En48Fs20Wo32 - En25Fs47Wo28

Maskelenite (plagioclase glass) An57Ab42Or1 - An43Ab53Or4

Olivine

Chromite

Nakhla, Lafayette, Governador Valadares

Pyroxene augite En38Fs23Wo39 dominant phase

Olivine Fa65-67

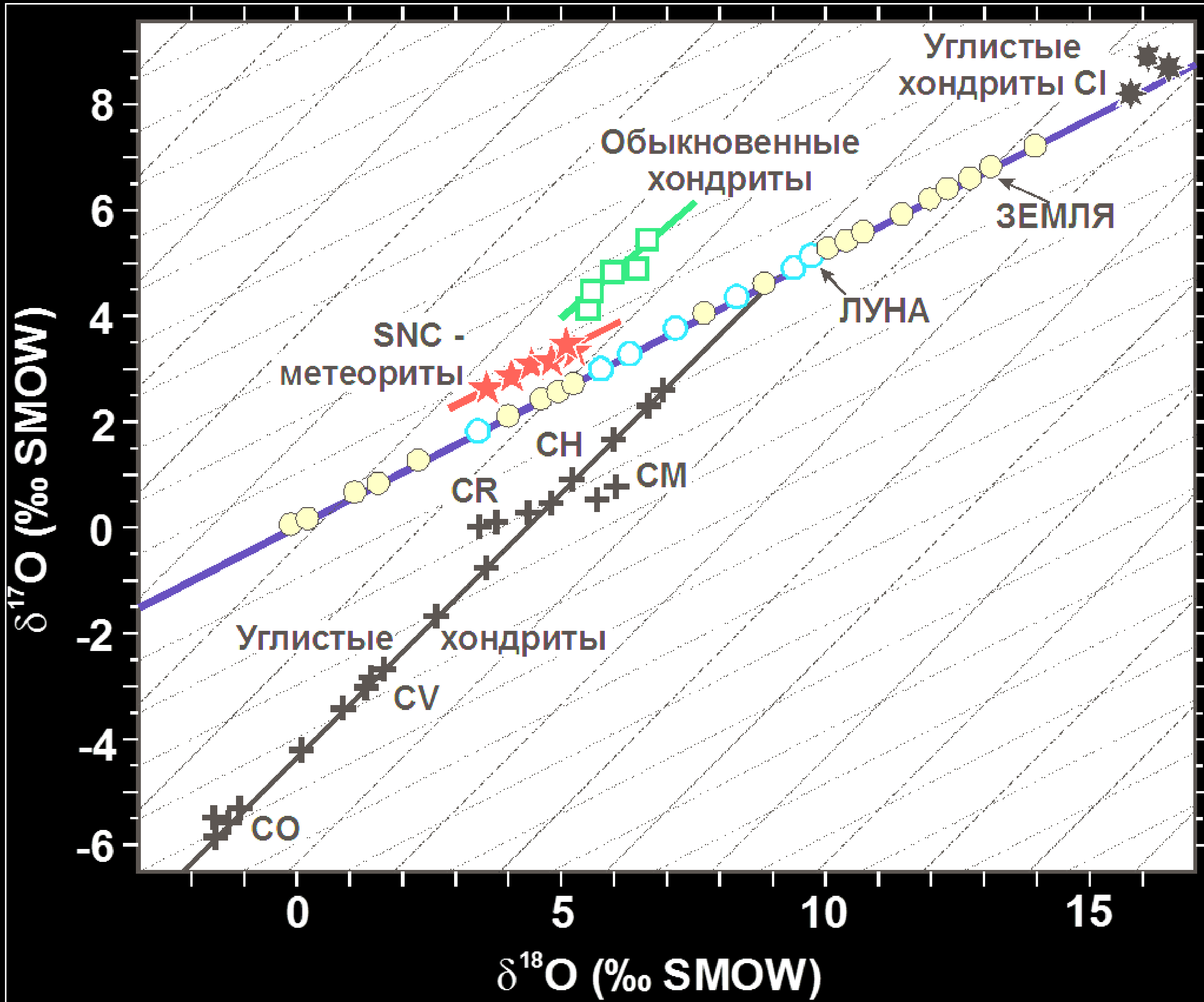
Chassigny

Olivine Fa32 dominant phase

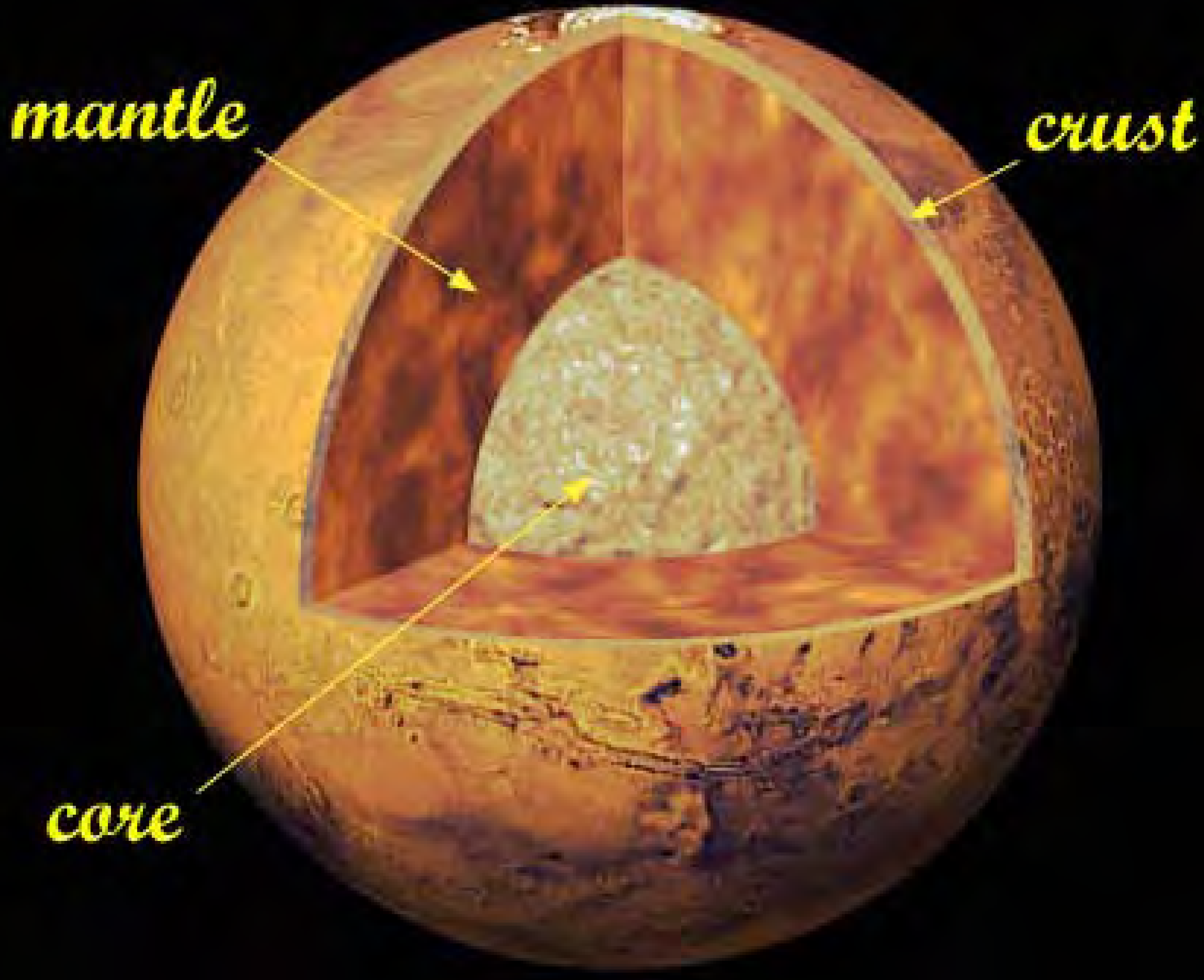
Augite, Orthopyroxene, Silica glass

If andesites are on Mars, low-Ca plagioclages may present

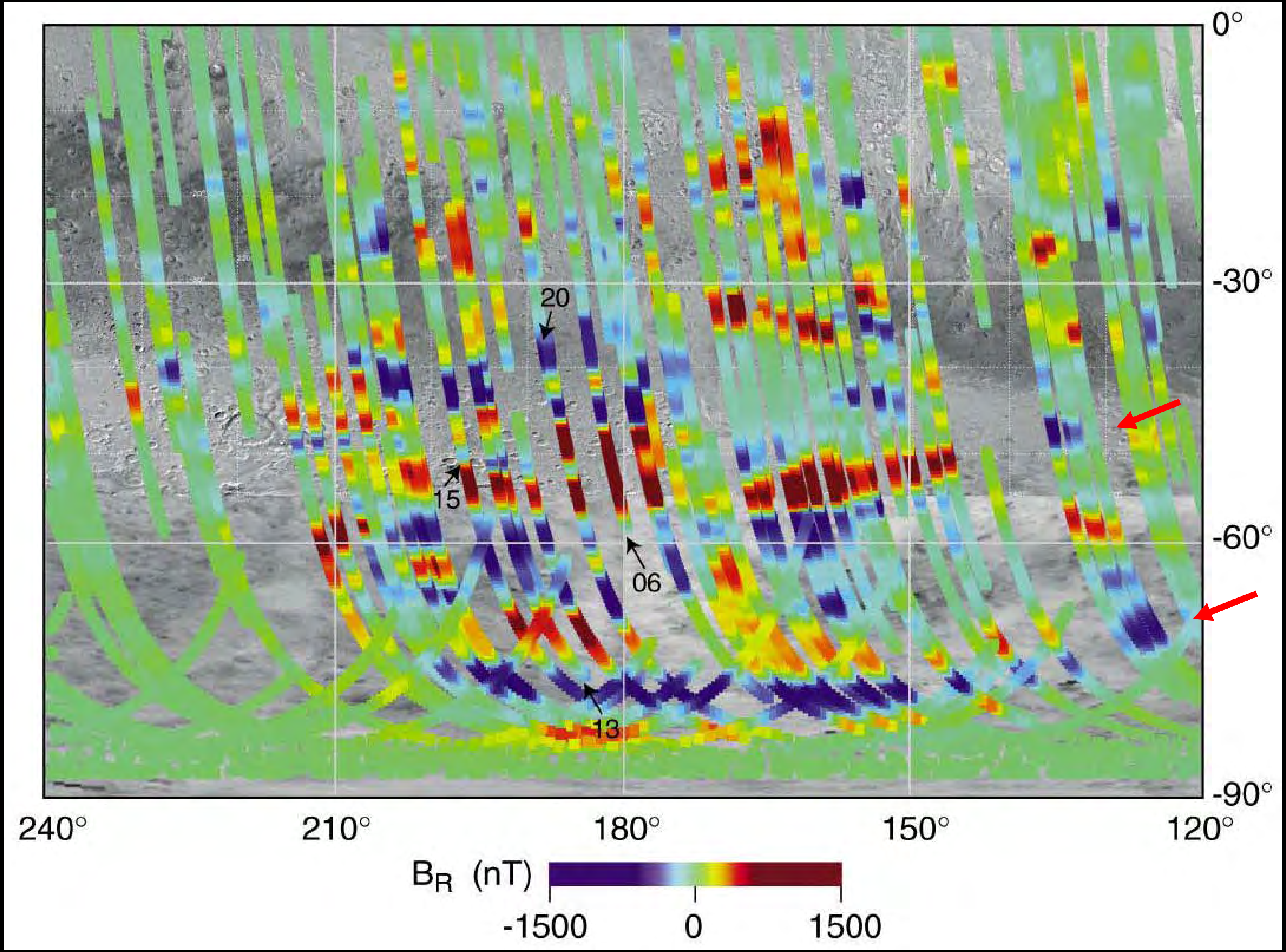
Oxygen isotopy diagram



Structure of Mars interiors

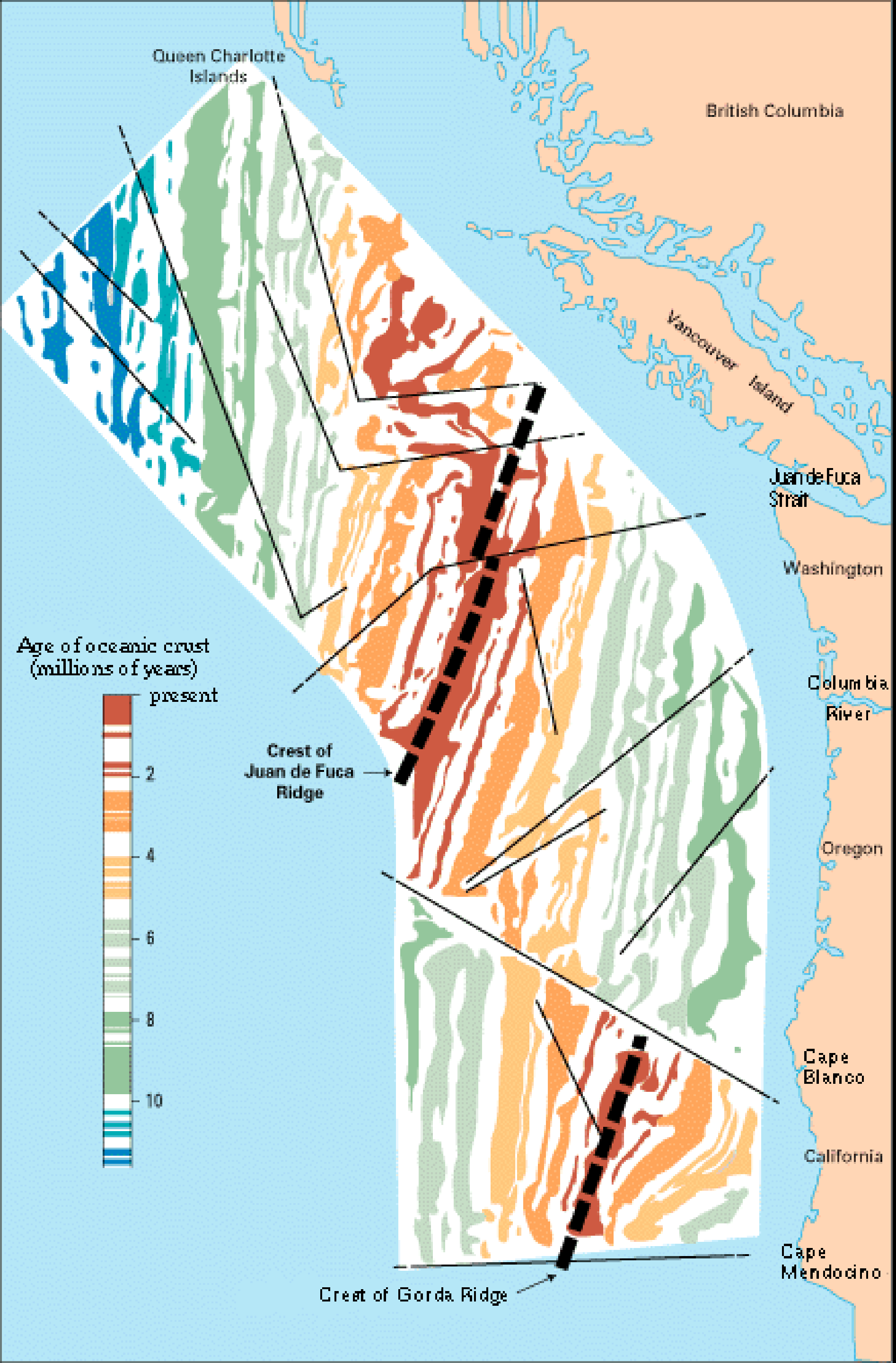


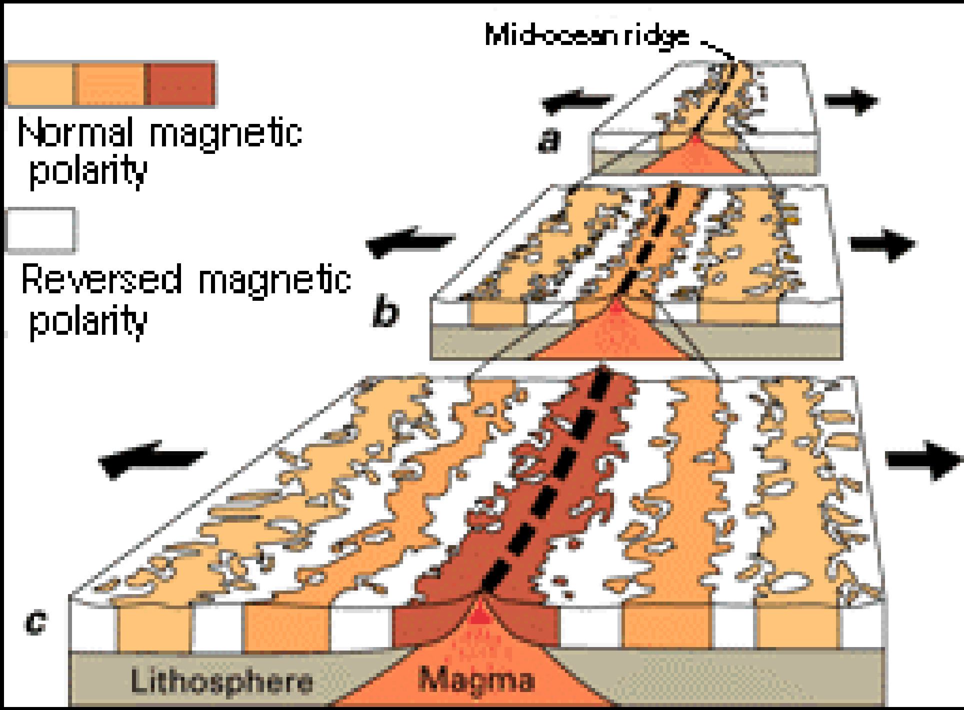
Mars magnetic anomalies



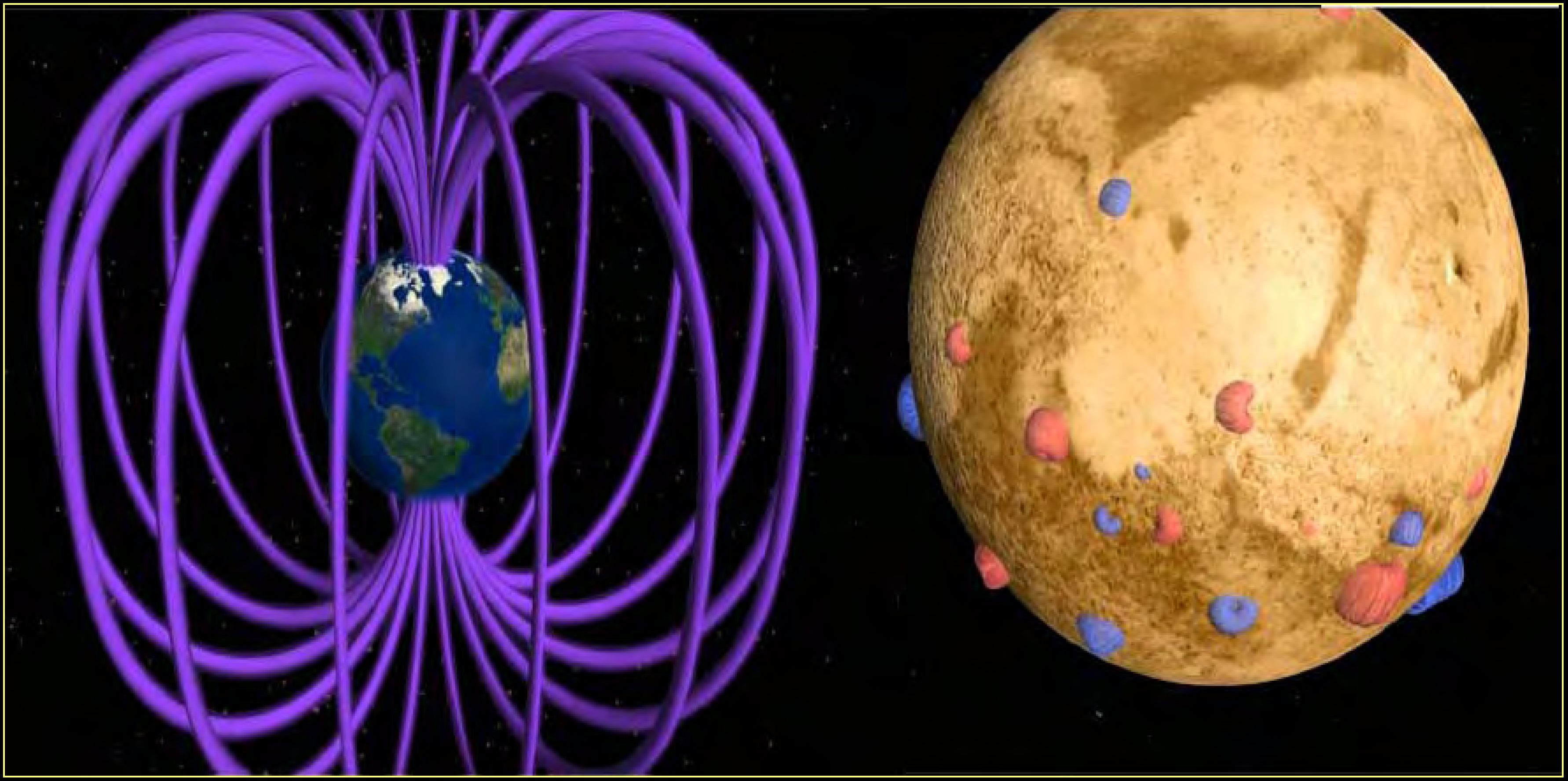
Banded pattern suggest plate tectonics in early history

Earth: Banded magnetic anomalies as evidence of sea-floor spreading





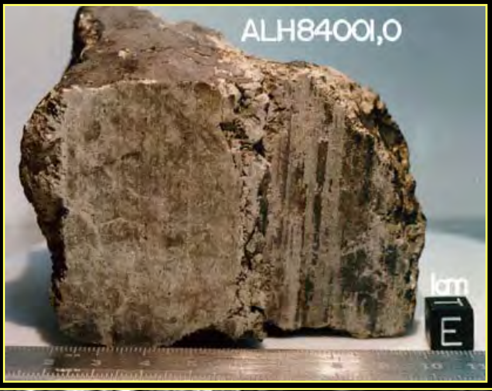
Earth’s dynamo and Mars’ remnant magnetism



Search for past or present Martian life

Originated on Mars or brought from Earth (or opposite)

Rock-spermia through meteoritic Earth-Mars ↔ exchange

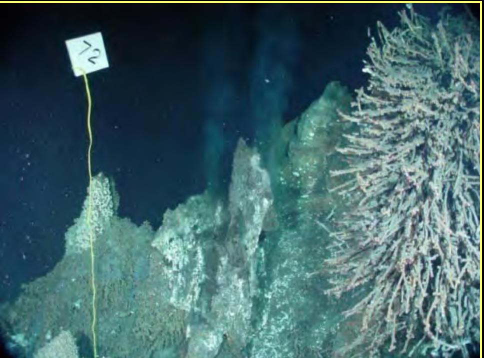


Search in Martian meteorites

Search in situ for fossil life
=> Study of subaqual sediments

Search in situ for present life
=> Study in potential life habitats
e.g. in hydrotherms ≈ “black smokers”

Martian meteorite
ALH840001,0



← Terrestrial black smokers creatures

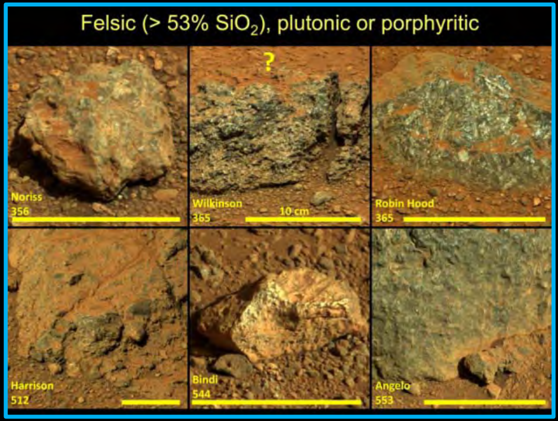
Face on Mars

Geologic history:

- Early bombardment ~ 4 b.y. ago?
- Noachian Wet Mars ~ 4 => 3.5 b.y.
- Hesperian plains forming volcanism ~ 3.5 => 3 b.y.
  Outflow channels,
  Ocean??
- Amazonian volcanism: Tharsis bulge and others
  Very dry environment,
  Equatorial glaciations due to axis inclination change
  Locally minor releases of liquid water
  ~ 3 b.y.=> now

Unresolved problems:

- Abundance and role of liquid water on Early Mars.
- When Mars got dry?
- Early volcanic history.
- Are there igneous rocks more evolved than basalts?
  Curiosity answered YES



- Late in time water-involved processes.
- Was life ever existed on Mars?

Thank you for your attention