POTENTIAL RESOURCES OF MARS
LECTURE 19 NEEP 533

HARRISON H. SCHMITT

NASA/JPL

DEFINITIONS

- **PLAGONITE / PLAGONITIC**
- **WEATHERING PRODUCT OF IRON-RICH ROCKS SUCH AS BASALT**
- **CLATHRATES**
- **ICE-LIKE HYDROUS COMPOUNDS OF METHANE AND CARBON DIOXIDE FORMED IN COLD, WATER-RICH ENVIRONMENTS**
- **CHEMOAUTOTROPIC**
- **METABOLICALLY SELF-SUPPORTIVE BASED ONLY ON AVAILABLE CHEMICALS**

RECENT WATER ACTIVITY

- **ALCOVE / GULLY / FAN FEATURES**
  - **NORTH POLE FACING, HIGH LATITUDE SITES (MOSTLY SOUTH)**
    - **EVIDENCE OF SNOW MELTING**
  - **"AQUIFERS" ~150 M BELOW SURFACE ON RELATIVELY YOUNG CLIFFS**
    - **TOO COLD FOR LIQUID WATER TODAY (CARR)**
  - **GEOGICALLY YOUNG, I.E., NO OVERLAPPING FEATURES**
  - **CHANGE IN AXIS INCLINATION IN LAST FEW MILLION YEARS**
    - **45º WOULD GIVE FULL SUN ON THESE SLOPES IN THE SUMMER**
    - **MELTING OF SOUTH POLAR CAP WOULD INCREASE ATMOSPHERIC DENSITY AND GREENHOUSE**

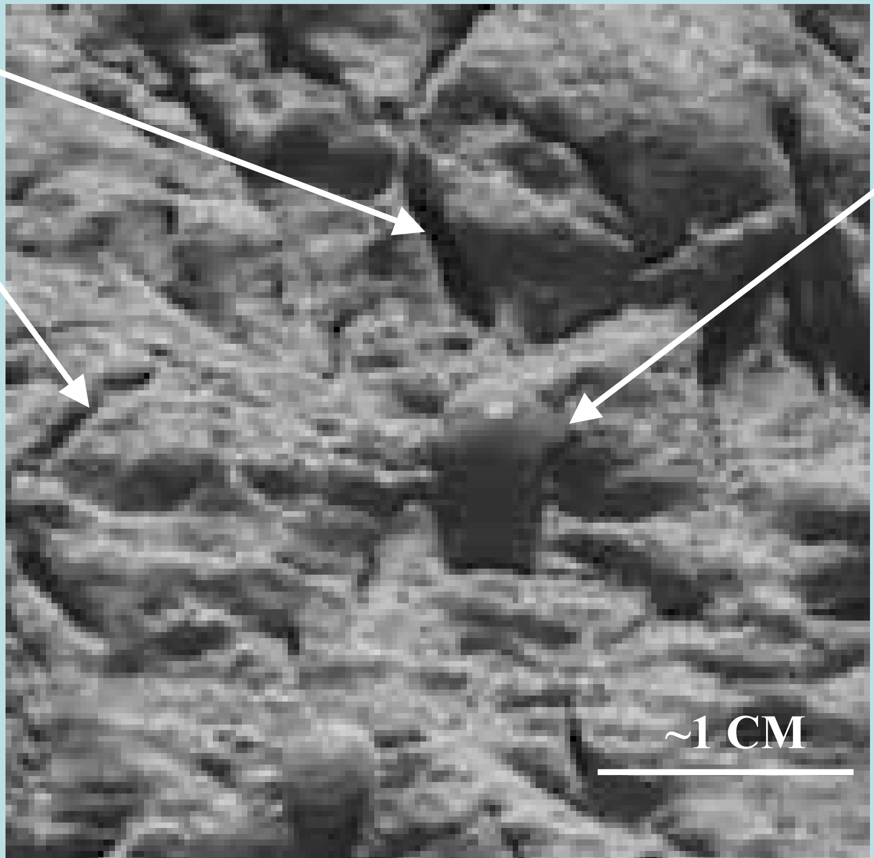
- **ALTERNATIVE FLUIDS**
  - **CO_2-H_20 OR CH_4-H_20 CLATHRATES**
  - **UNKNOWN THERMAL SOURCE IN CRUST**

WATER VOLUME ESTIMATES
(GLOBAL COVERAGE)

- **CARR:GEOLOGICAL EVIDENCE OF EROSION**
  - **10 M TO 1 KM**
- **CARR: POLAR CAPS**
  - **<30 M**
- **CARR: MEGAREGOLITH PORE SPACES**
  - **0.5 - 1.4 KM**

MARS ROVER “OPPORTUNITY” MAY HAVE DISCOVERED SULFUR-RICH EVAPORITES ORIGINALLY DEPOSITED IN WATER

CRYSTAL CASTS OF GYPSUM
($CaSO_4.2H_2O$)

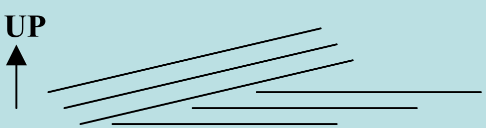


SPHERULES

CONCRETIONS OF IRON OXIDE

OOLITES ?

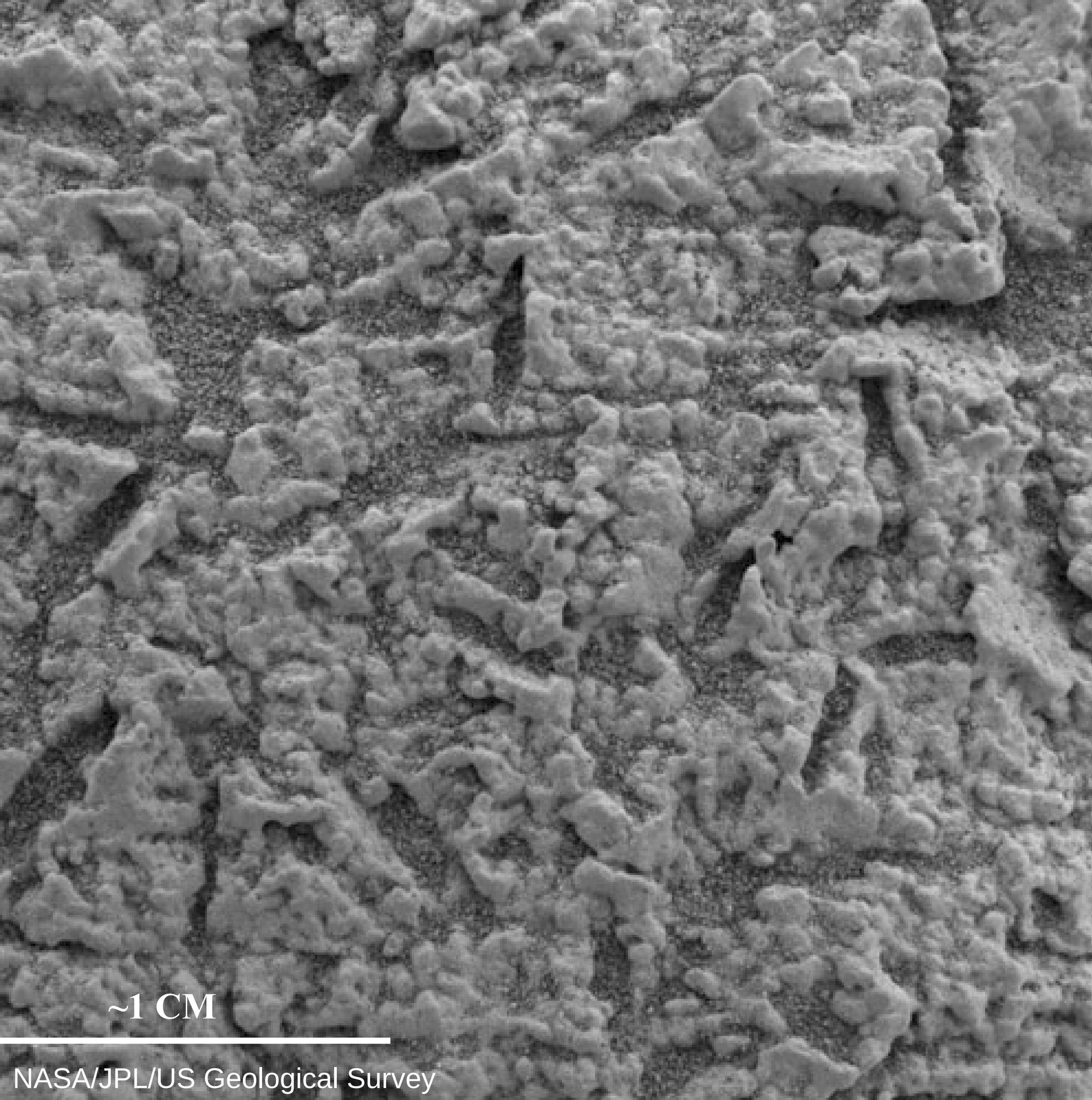
ELSEWHERE, JPL TEAM BELIEVES IT HAS OBSERVED CROSS-BEDDING



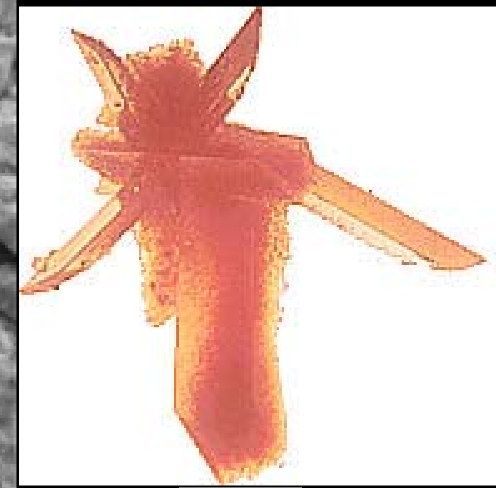
Jaroso Ravine, Aquilas, Sierra Almagrera, Murcia, Spain

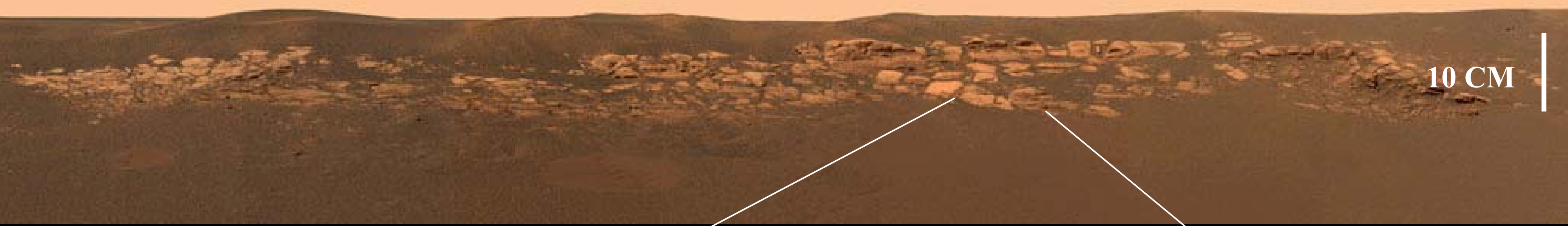
- **JAROSITE [$KFe^{+3}_3(SO_4)_2(OH)_6$] SIGNATURE IN MÖSSBAUER SPECTRA (NOT USUALLY AS EVAPORITE, HOWEVER)**
- **ALPHA BACKSCATTER SPECTRA ALSO INDICATES METALS THAT FORM HALOGEN SALTS**

OPPORTUNITY'S EL CAPITAN



NOTE: POSSIBLE CASTS OF TWINS OF CRYSTALLINE GYPSUM ($CaSO_4.2H_2O$ OR "SELENITE"

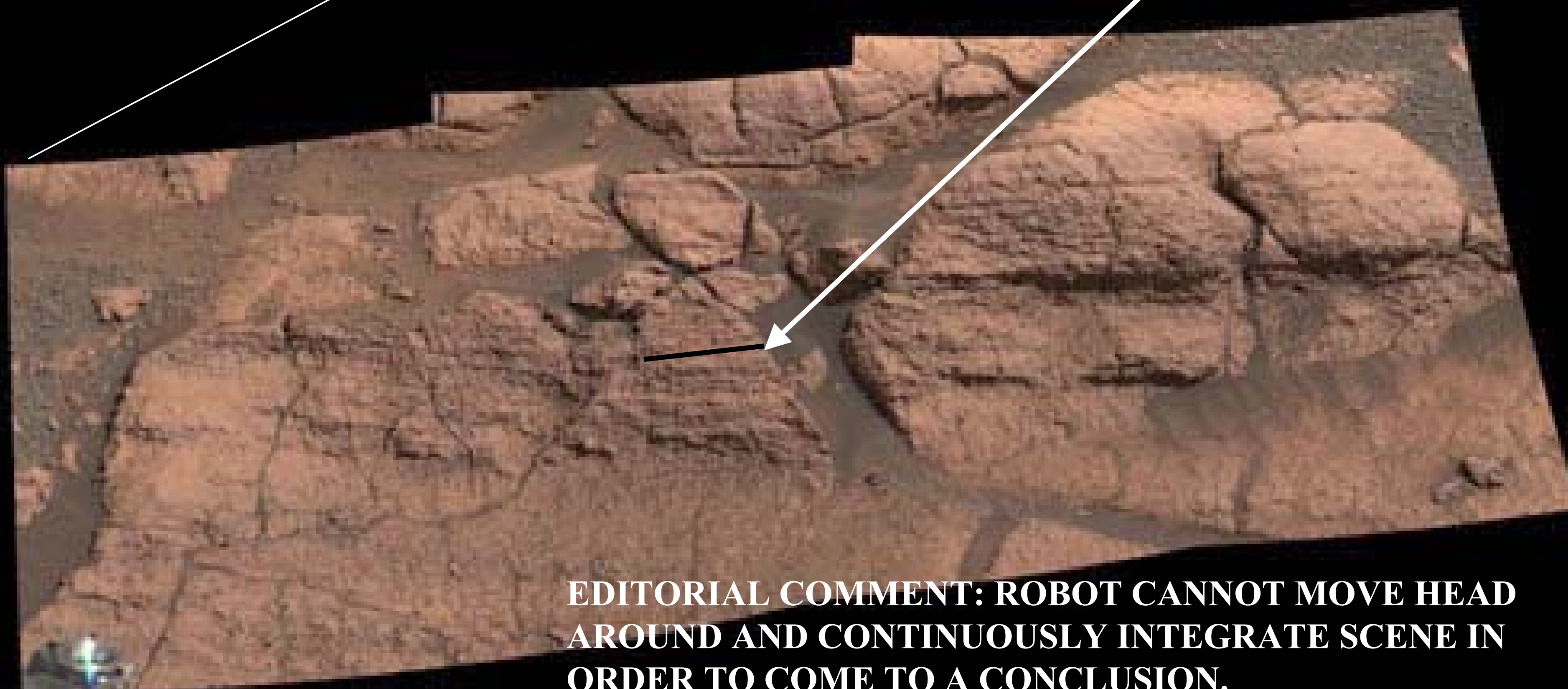




OPPORTUNITY'S LAYERS

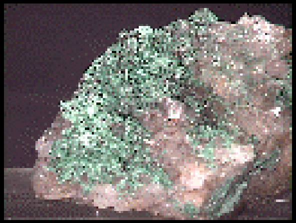
NASA/JPL/Cornell

CROSS-BEDDING ?



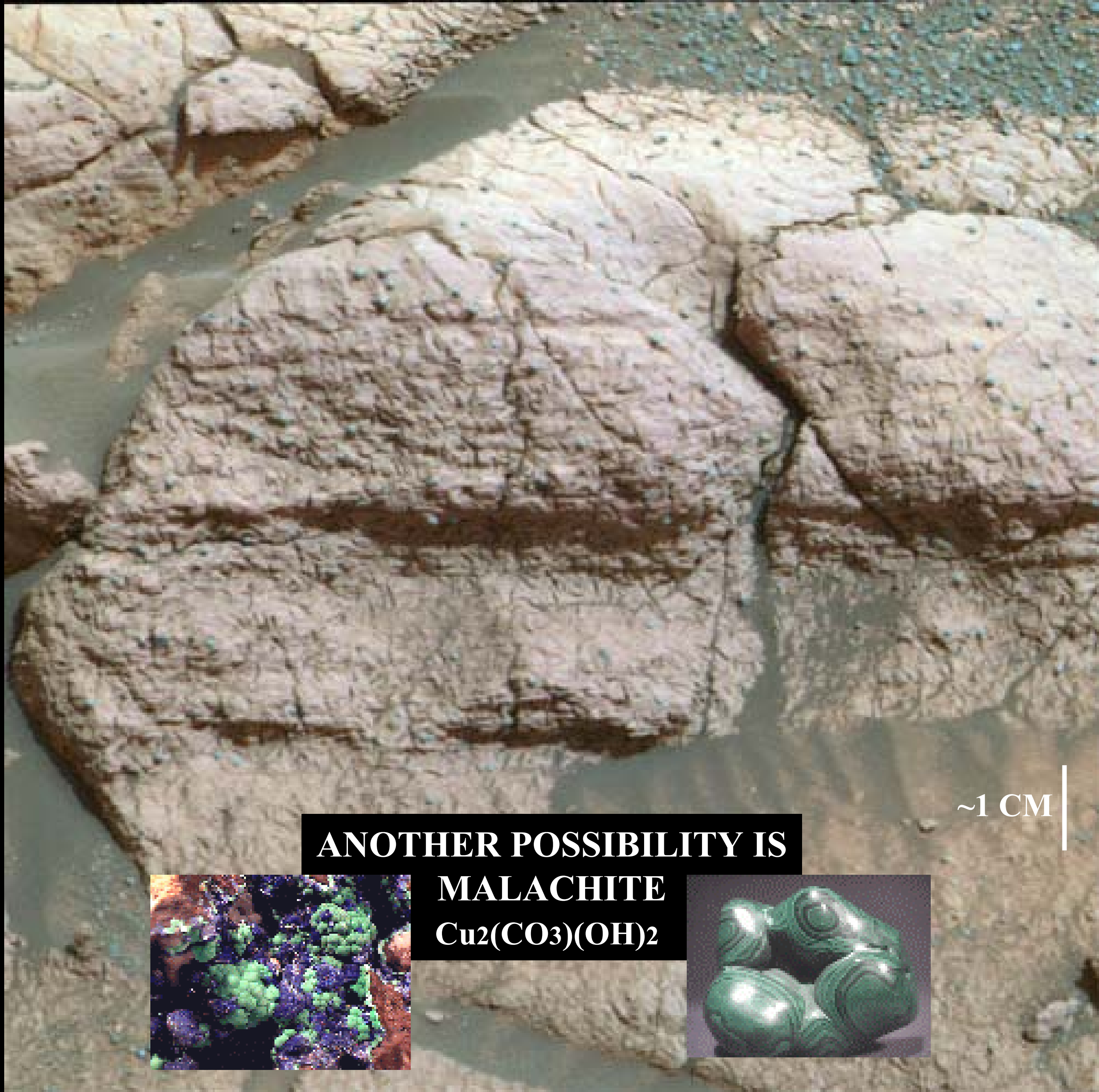
OPPORTUNITY'S "EL CAPITAN" SPHERULES AND LAYERING

IF COLOR OF SPHERULES IS REAL, THEY MAY BE COPPER SULFATE CONCRETIONS OF ANLERITE $Cu_3SO_4(OH)_4$



OR BROCHANTITE $Cu_4SO_4(OH)_6$

NASA/JPL

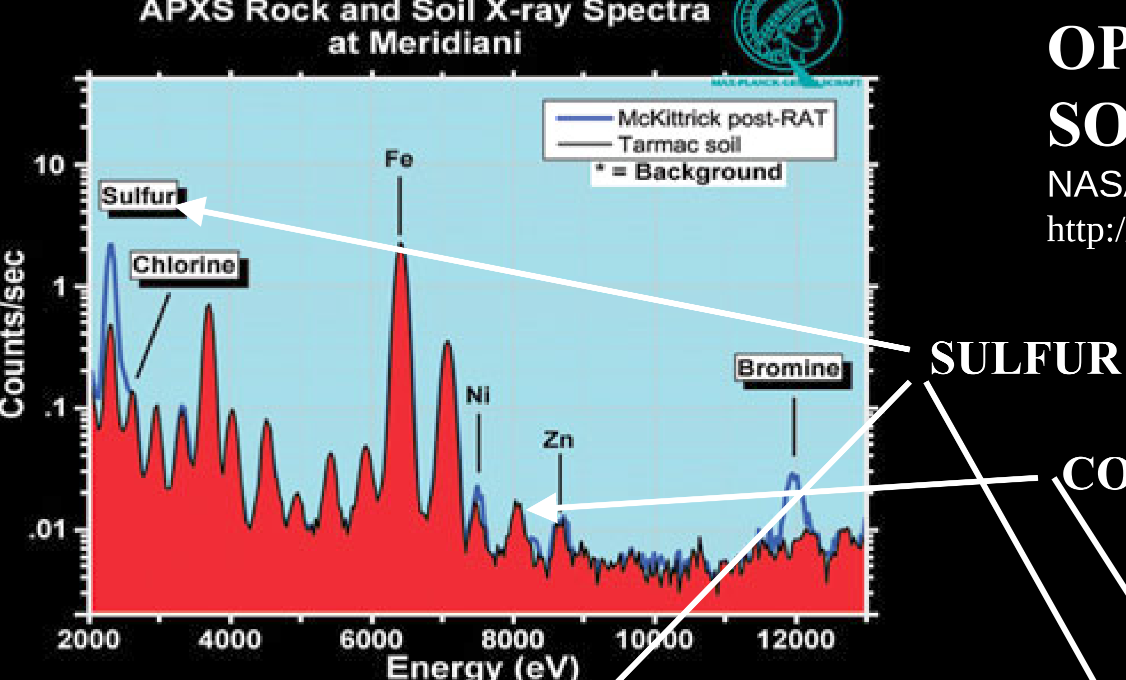


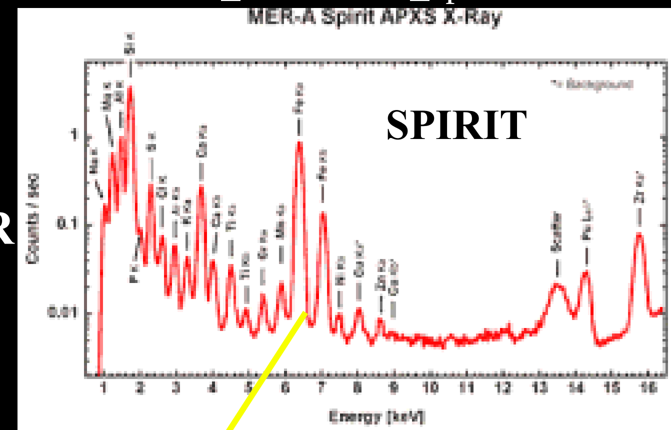
ANOTHER POSSIBILITY IS MALACHITE $Cu_2(CO_3)(OH)_2$

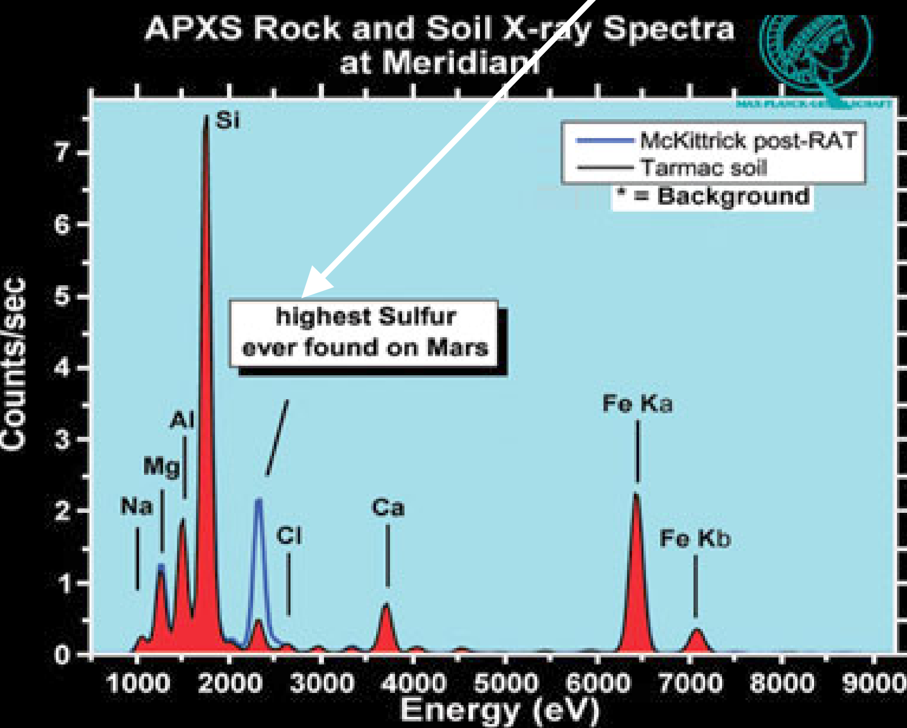
OPPORTUNITY ROCK AND SOIL COMPOSITIONS

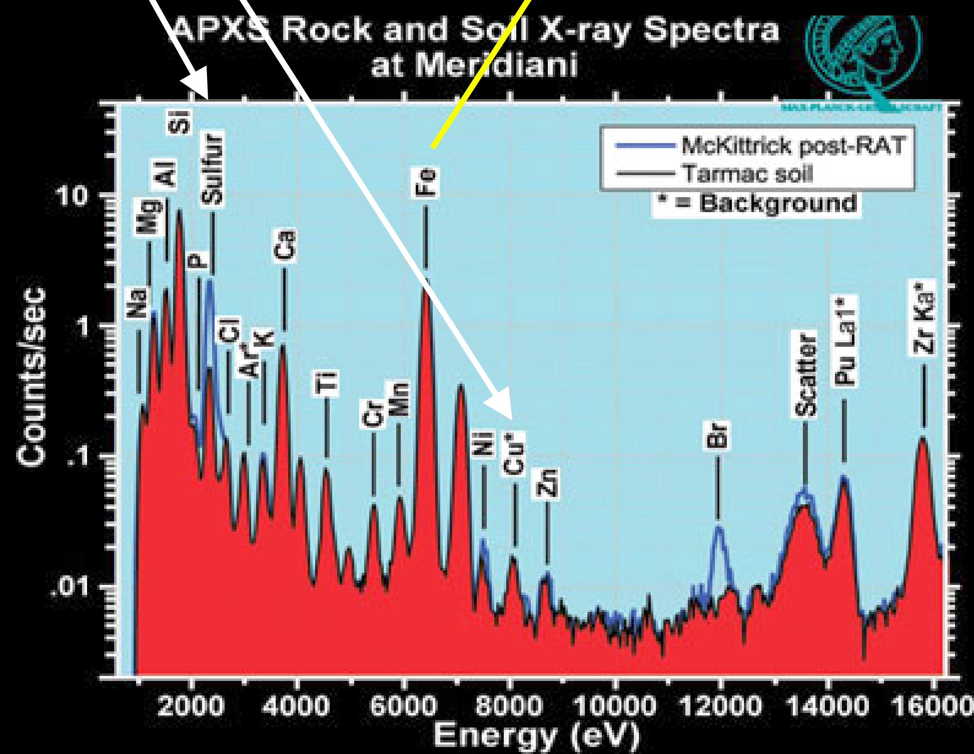
NASA/JPL/Cornell/Max Planck Institute

http://athena.cornell.edu/the_mission/ins_apxs.html





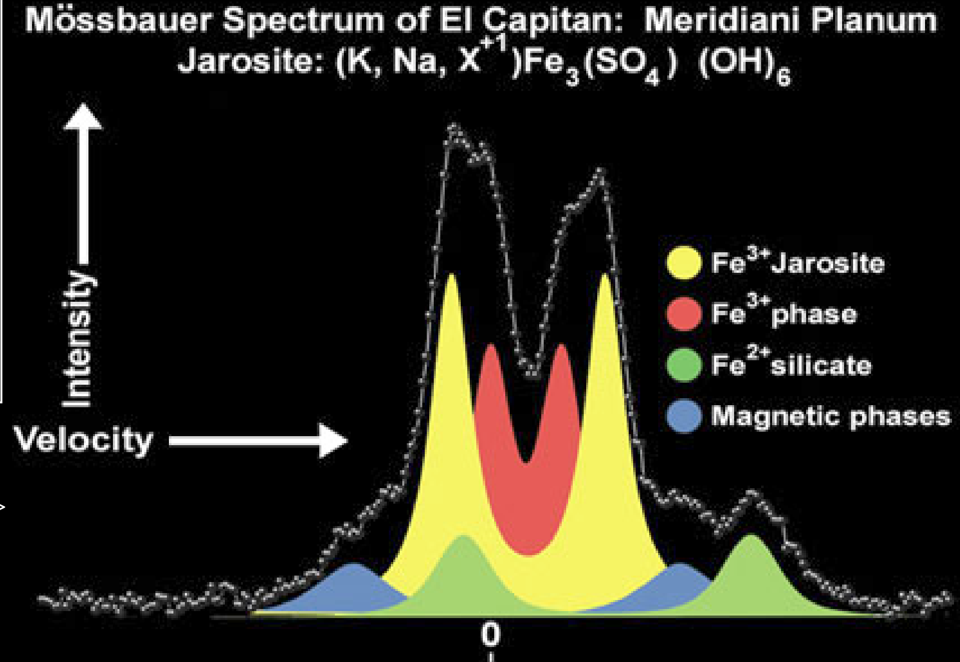




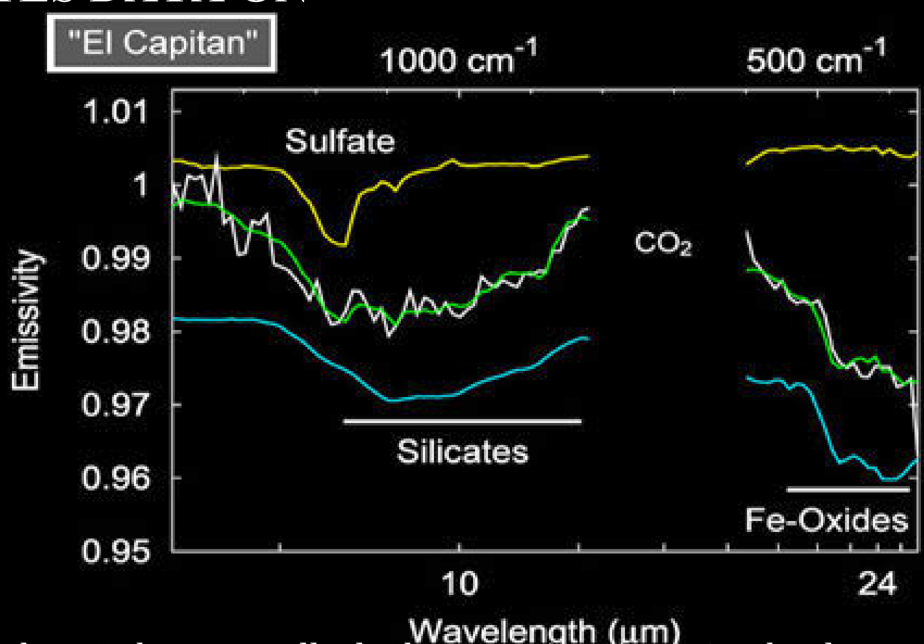
OPPORTUNITY ROCK IRON-BEARING MINERALS

NOTE: PRESENCE OF FE-BEARING SILICATE AND CROSS-BEDDING SUGGESTS SEDIMENTS CEMENTED BY SULFATES, SALTS, AND HEMATITE.

NASA/JPL/University of Mainz
See <http://athena.cornell.edu/pdf/tb_moss.pdf>

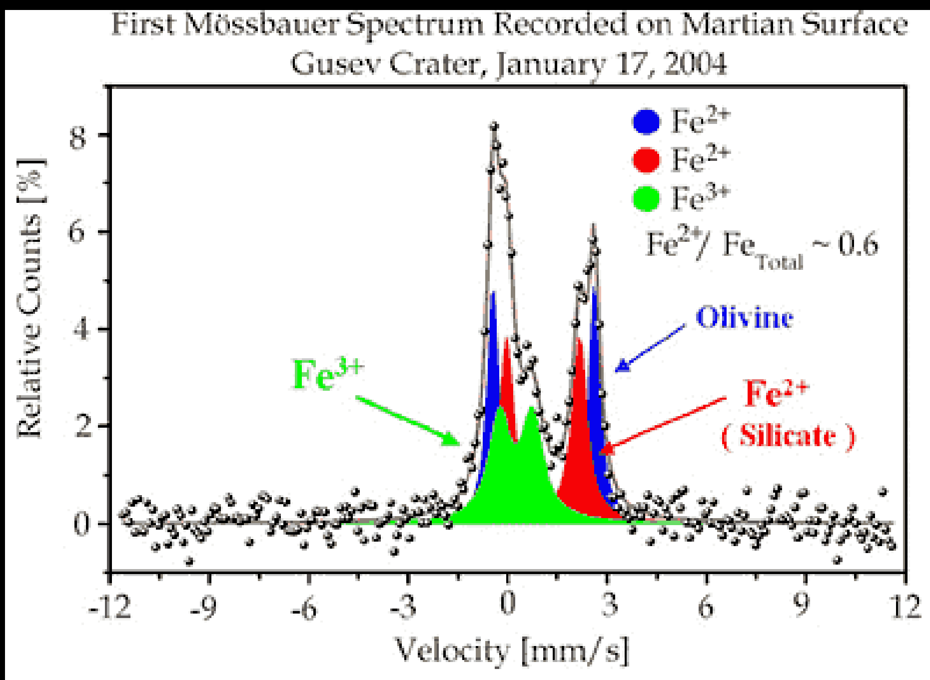


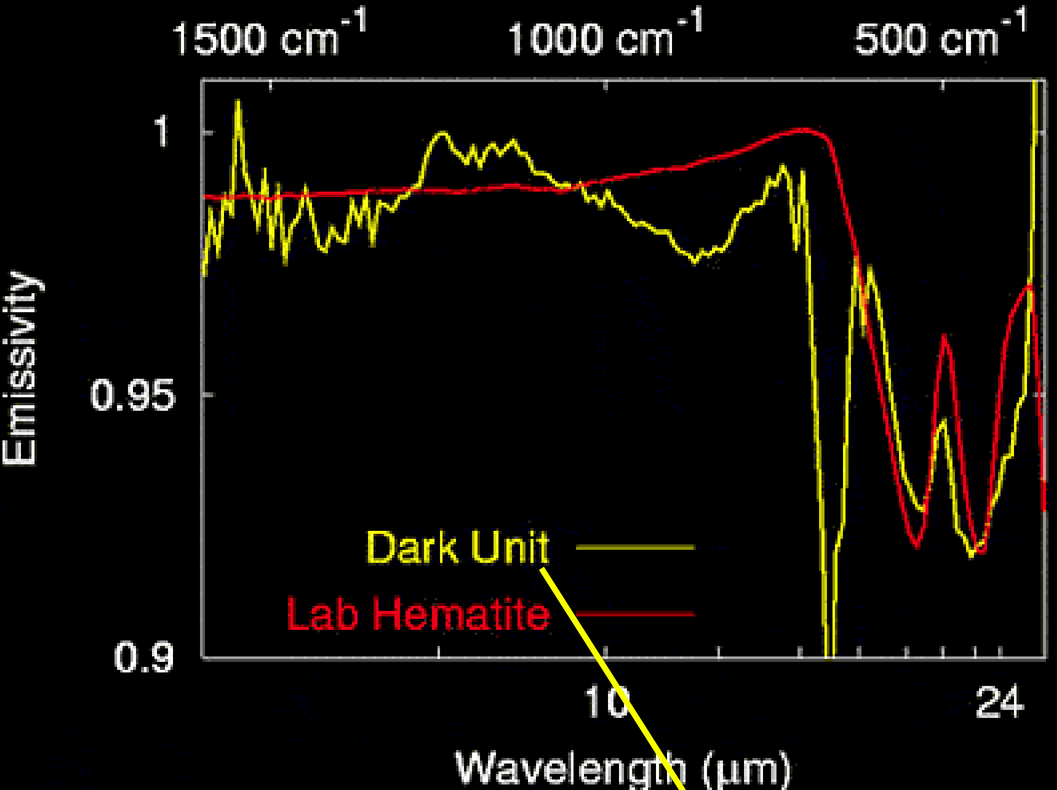
TES DATA ON



<http://athena.cornell.edu/the_mission/ins_minites.html>

SPIRIT ROCK, IRON-BEARING MINERALS

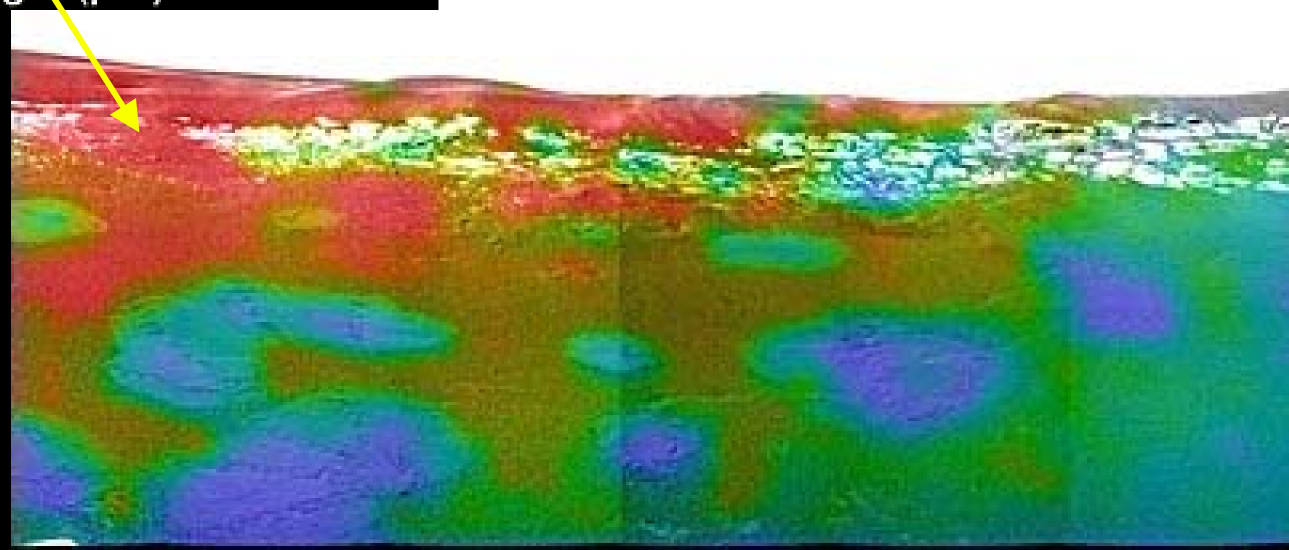




OPPORTUNITY ROVER SITE

TES DATA ON CRATER WALL

NASA/JPL/Cornell/ASU



RED AND ORANGE PATCHES INDICATE HIGH LEVELS OF CRYSTALLINE HEMATITE.
BLUE AND GREEN INDICATE LOW LEVELS OF THE IRON-BEARING MINERAL.

WHAT MIGHT BE GOING ON HERE?

1. JAROSITE IS NOT NORMALLY AN EVAPORITE MINERAL

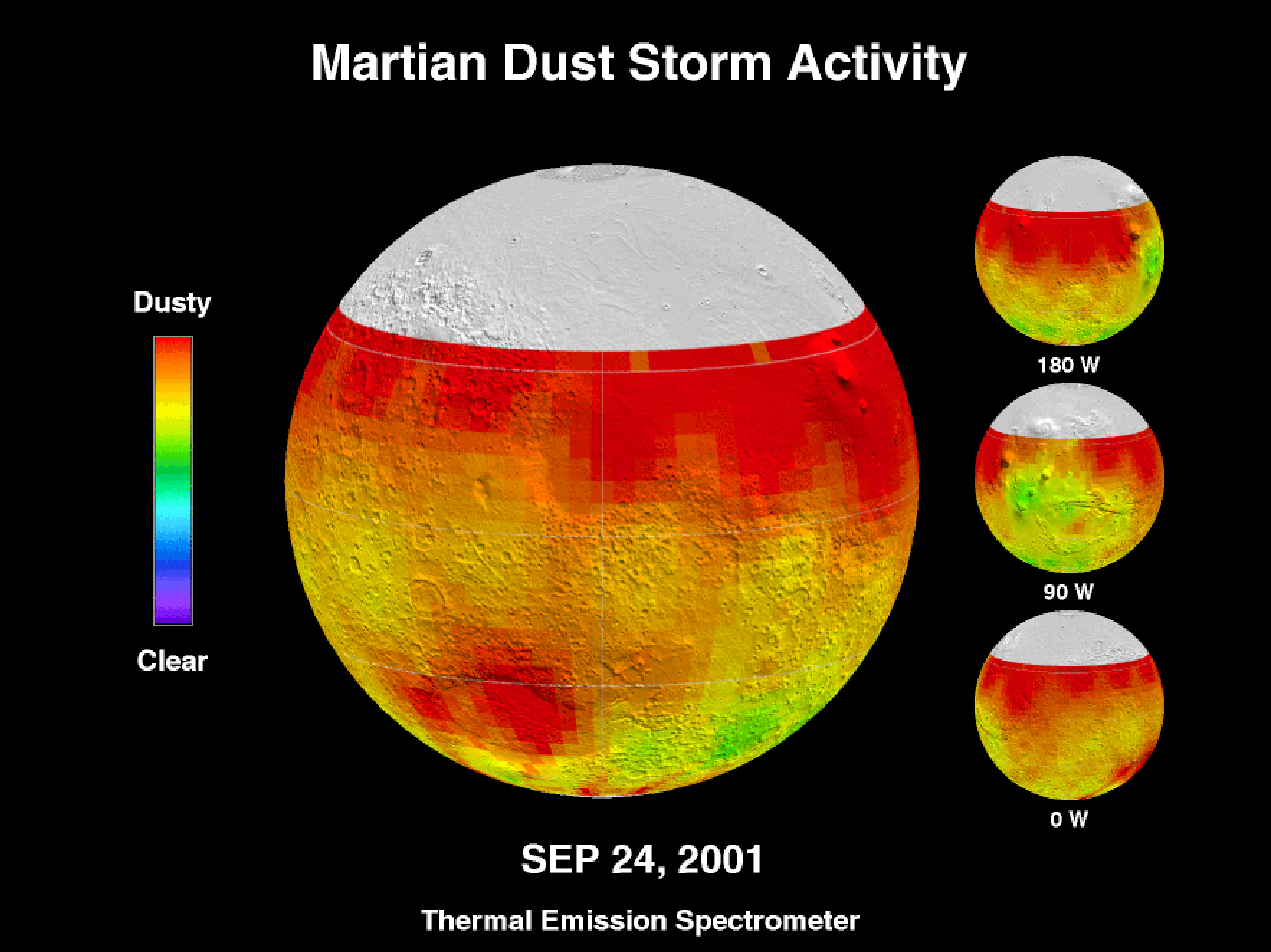
   OXIDATION PRODUCT OF IRON SULFIDES

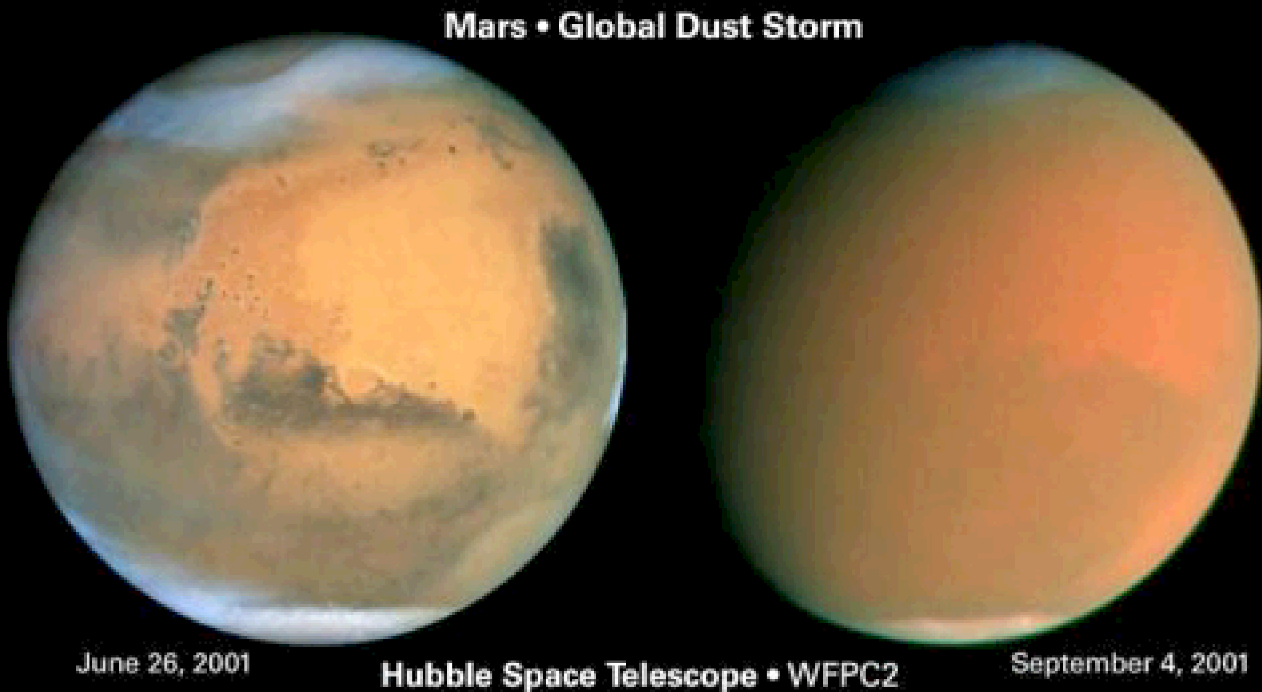
2. ASSOCIATION OF CROSS-BEDDING AND Fe-SILICATES AND POSSIBLY MAGNETITE WITH HALOGENS, HEMATITE, JAROSITE, GYPSUM AND POSSIBLE METAL SULFATES SUGGEST:

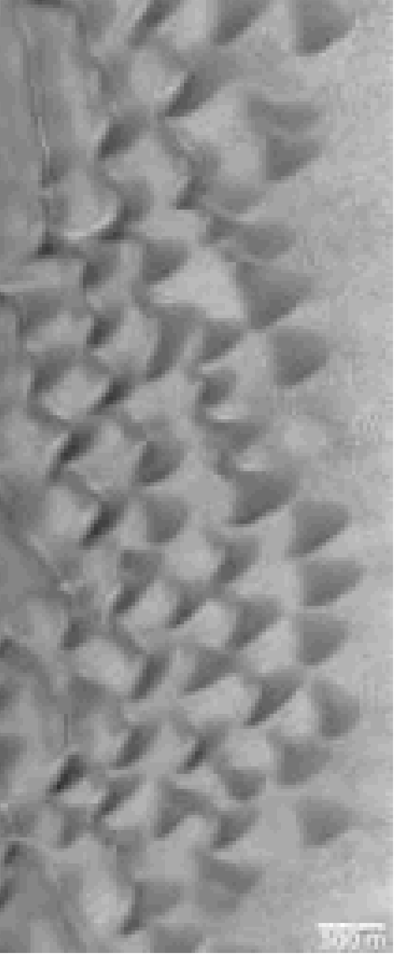
   ? OXIDIZED RESIDUALS OF A SULFIDE DEPOSIT AT A HOT SPRING OR VOLCANIC FUMEROLE SUBJECT TO PERIODIC FLOODING AND EVAPORATION

MARTIAN ODDS AND ENDS

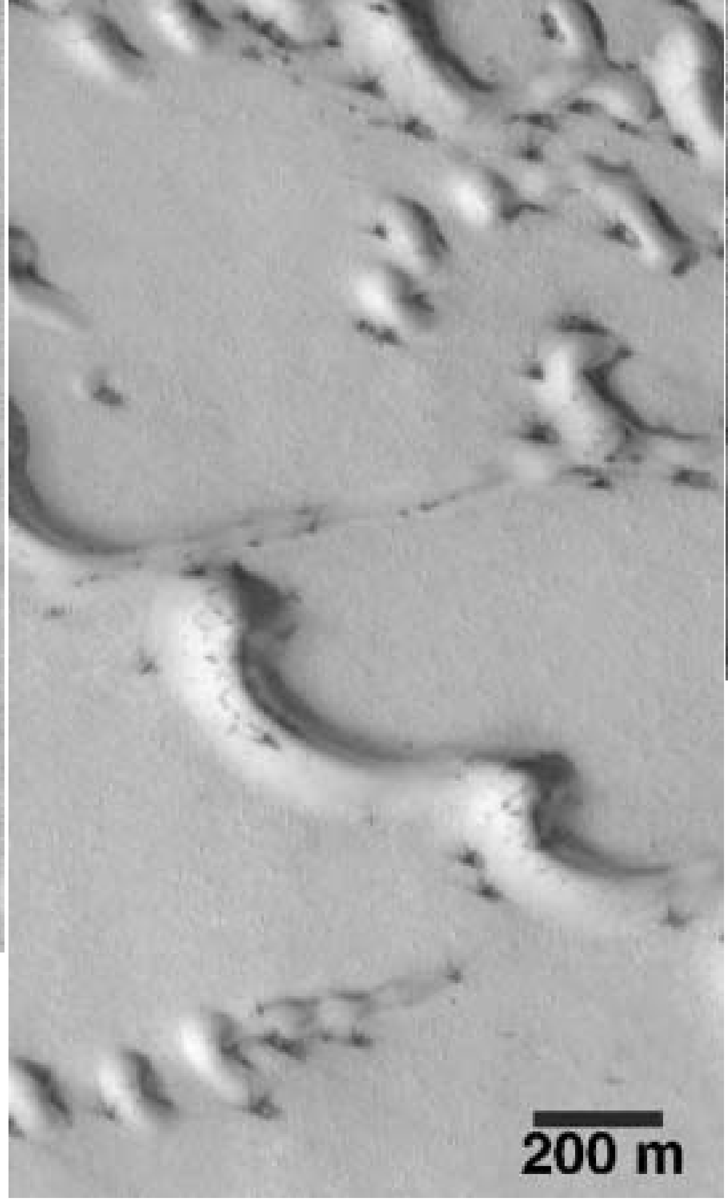
- LAVAS NO OLDER THAN 100 M.Y.
  - CRATER COUNTS IN THARSIS ARSIA MONS CALDERA
- LAVAS < 10 M.Y.
  - ELYSIUM PLAINS
- ESTIMATES THAT 10-20% OF SURFACE < FEW 100 M.Y. ???
- NAKHLITE WEATHERING ~650 M.Y.
- SEASONAL EXCHANGE OF CO_2 BETWEEN SURFACE AND ATMOSPHERE CONFIRMED
  - 1.5 - 2 M ELEVATION CHANGE AT HIGH LATITUDES


Martian Dust Storm Activity
Dusty
Clear
180 W
90 W
0 W
SEP 24, 2001
Thermal Emission Spectrometer

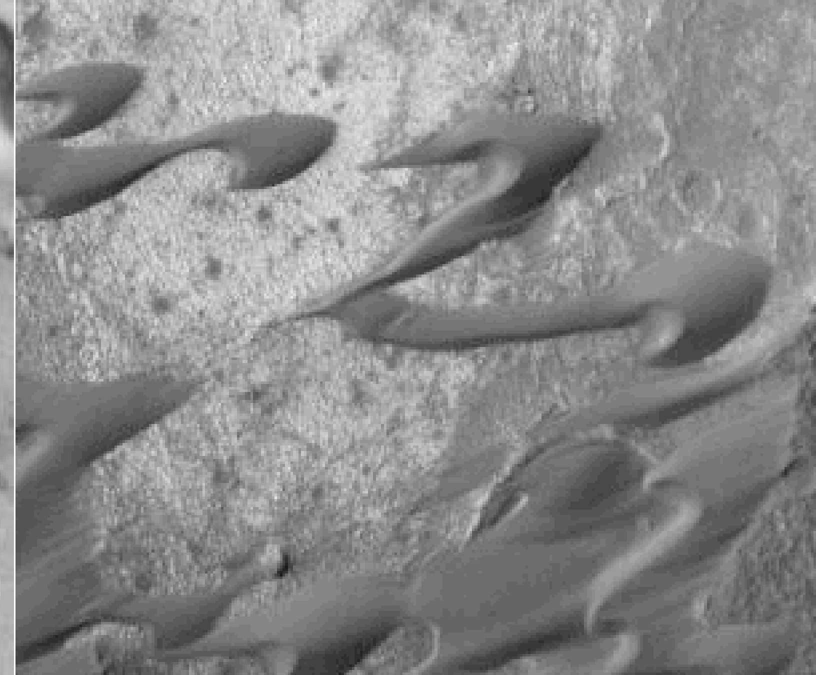

Mars • Global Dust Storm
June 26, 2001
Hubble Space Telescope • WFPC2
September 4, 2001



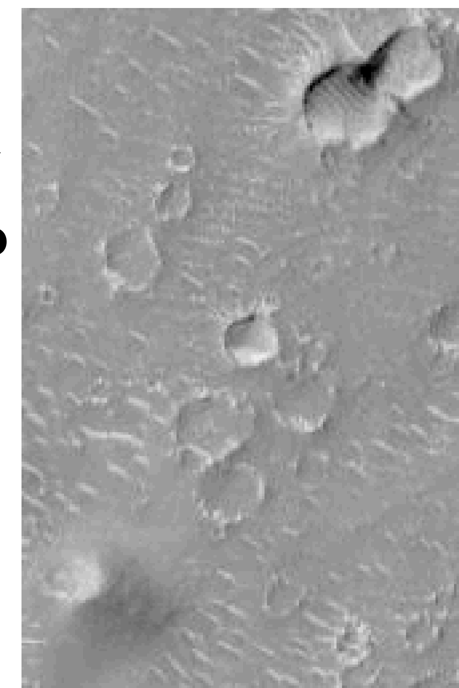
PROTOR CRATER DUNES



FROST ON NORTH POLAR DUNES

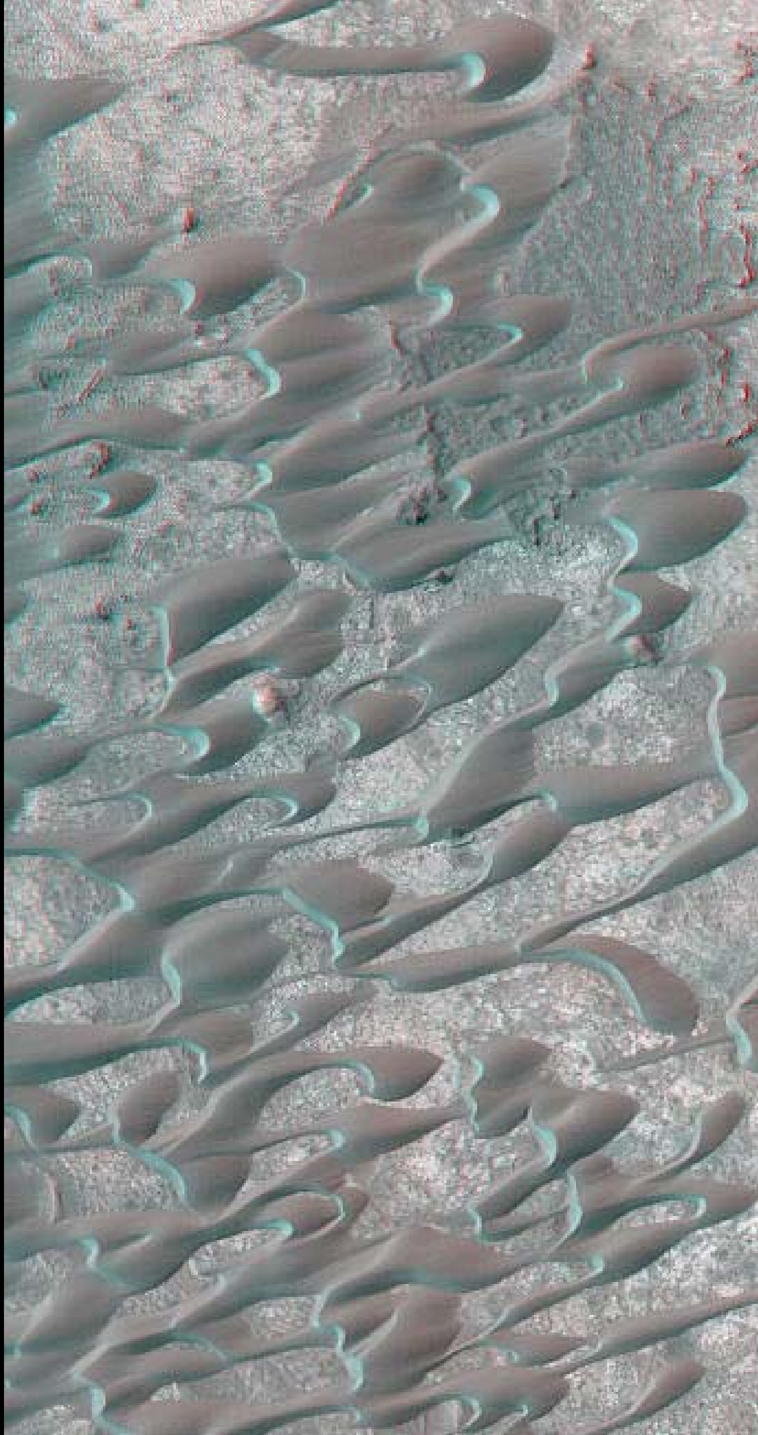


NILI PATERA, SYRTIS MAJOR DUNES



ISIDIS PLANITIA LIGHT COLORED DUNES

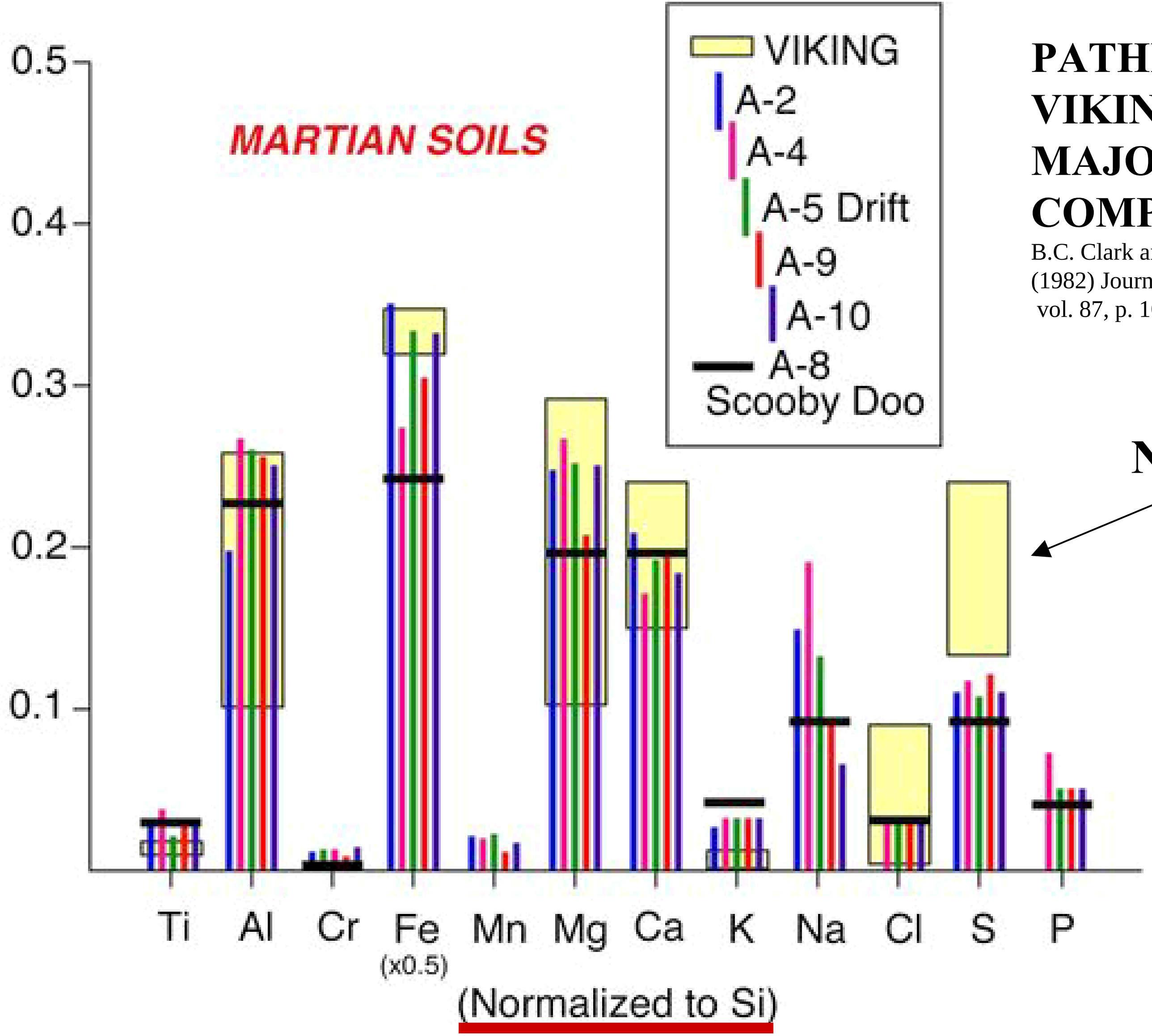
NILI PATERA DUNES IN 3D



NASA/JPL MALIN SCIECE SYSTEMS

X-Ray Fluorescence Analyses of Different Samples at the Two Viking Landing Sites (Carr et al., 1984)

	Chryse Fines	Chryse Duricrust (1)	Chryse Duricrust (2)	Utopia Fines	Estimated Absolute Error	Pathfinder
SiO_2, wt %	44.7	44.5	43.9	42.8	5.3	~50
Al_2O_3, wt %	5.7	N/A	5.5	N/A	1.7	~8
Fe_2O_3, wt %	18.2	18.0	18.7	20.3	2.9	~16
MgO, wt %	8.3	N/A	8.6	N/A	4.1	~8
CaO, wt %	5.6	5.3	5.6	5.0	1.1	~6
K_2O, wt %	<0.3	<0.3	<0.3	<0.3	---	~0.3
TiO_2, wt %	0.9	0.9	0.9	1.0	0.3	~1.1
SO_3, wt %	7.7	9.5	9.5	6.5	1.2	~5.5
Cl, wt %	0.7	0.8	0.9	0.6	0.3	~0.6
Sum	91.8	N/A	93.6	N/A	---	
Rb, ppm	<30			<30		
Sr, ppm	60 ± 30			100 ± 40		
Y, ppm	70 ± 30			50 ± 30		
Zr, ppm	<30			30 ± 20		



PATHFINDER / VIKING MAJOR ELEMENT COMPARISON

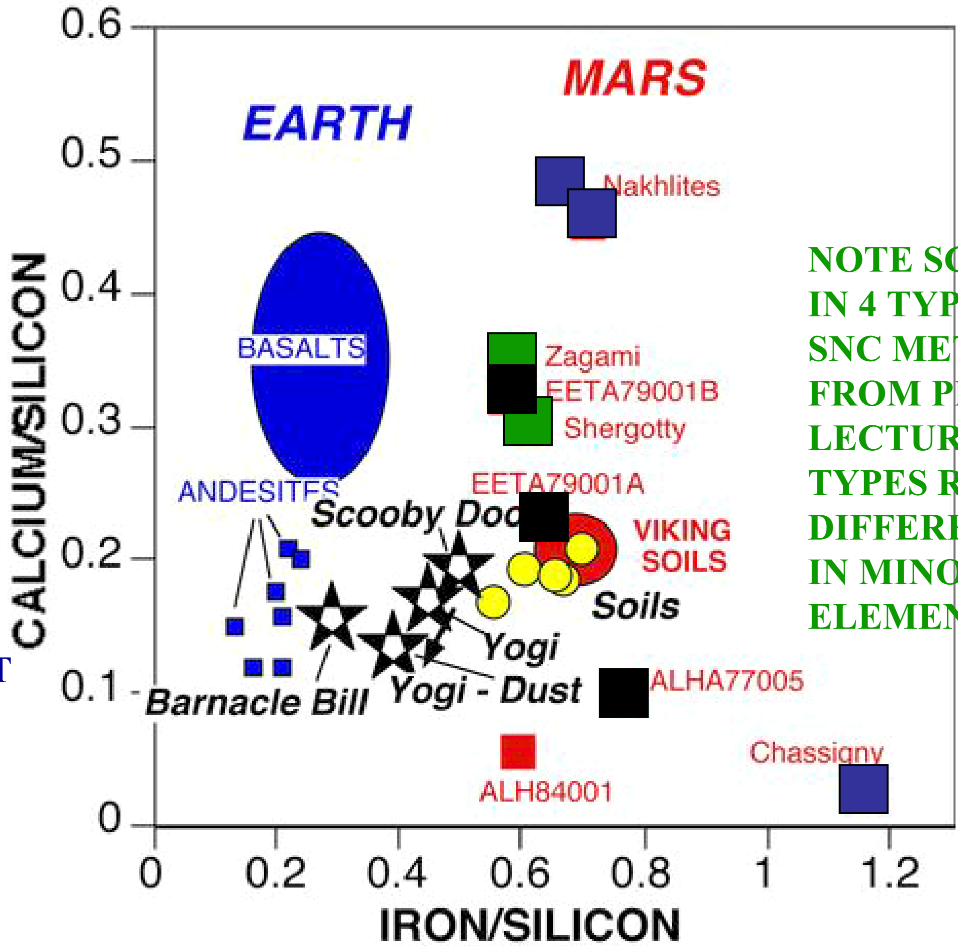
B.C. Clark and others (1982) Journal of Geophysical Research, vol. 87, p. 10,064

NOTE:

Soils at the Pathfinder site generally have higher aluminum and magnesium, and lower iron, and chlorine relative silicon. Scooby Doo, which appears to be a sedimentary rock composed primarily of compacted soil, also exhibits a few chemical differences form the surrounding soils. Analysis A-5 represents a deposit of windblown dust (called drift), whereas the other soil analyses may be cemented materials.

PATHFINDER AND VIKING ANALYSES RELATIVE TO SNC METEORITES, ETC.

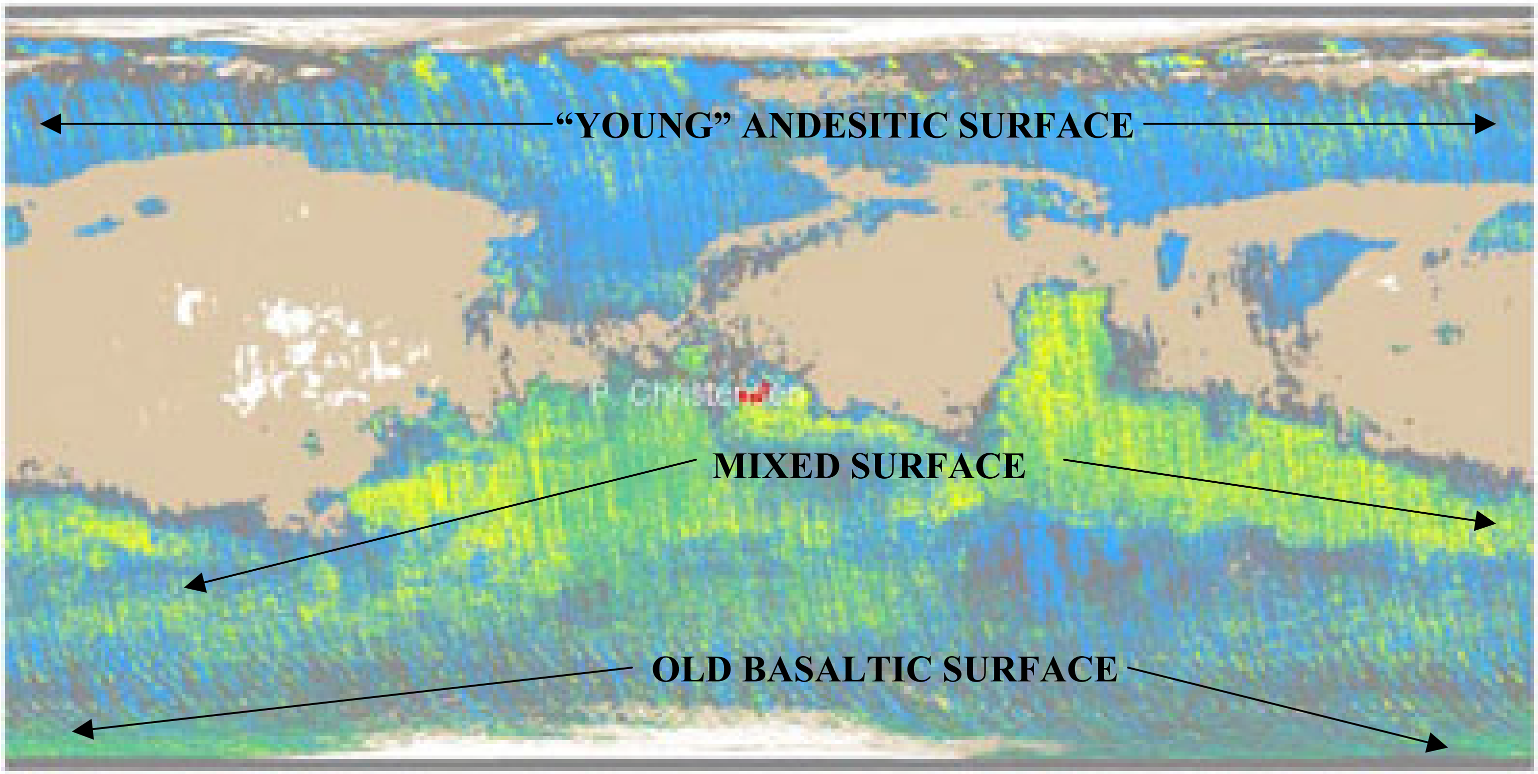
NOTE DIFFERENCES BETWEEN EARTH BASALTS AND ANDESITES RE. THE GLOBAL SURVEYOR TES ANALYSES SUGGEST SIMILAR DISTINCTIONS ON MARS.



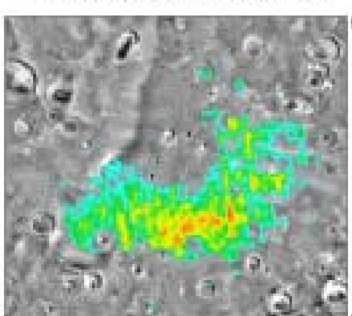
NOTE SCATTER IN 4 TYPES OF SNC METEORITES FROM PREVIOUS LECTURE. TYPES REFLECT DIFFERENCES IN MINOR ELEMENTS.

The analysis of Yogi appears to be contaminated by dust adhering to the rock's surface. The rock composition can be estimated by subtracting a portion of dust; the resulting Yogi composition is very similar to that of Barnacle Bill (we assumed 50% dust having the composition of drift analysis A-5 and used a linear mixing model to subtract the dust which is only strictly valid if the dust, where present, is thicker than the APXS penetration depth). Barnacle Bill is also contaminated by dust, but to a lesser extent. Much of the finer dust is slightly magnetic with two mineralogical alternatives proposed (Hviid, et al., 1997): (1) Clay phase + Maghemite (gamma-Fe_2O_3) which may imply previous leaching of Fe^{2+} by liquid water and (2) titanomagnetite or titanohaghemite in palagonite from direct weathering of glassy basalt.

TES Geologic Map of Mars



TES Hematite Abundance



Map Units

- Basalt
- Andesite
- Basalt/Andesite
- Other
- Dust
- Hematite-rich
- Ice/Clouds

P. Christensen

MARTIAN SOILS CHEMISTRY

- **EVIDENCE FOR CLAY MINERALS AT THE SURFACE**
  - **Viking and Pathfinder suggest that the soil has been produced by palogonitic weathering of iron rich silicate and include poorly crystalline, Fe+-rich gels, containing nanophase ferric oxide (Stoker, et al., 1993, Rieder, et al, 1997).**
  - **Actual clay minerals, such as iron-rich montmorillonites, could be up to 15% and not be detected by present spectral techniques.**
  - **Spectral studies also indicate some water bound in mineral crystal structures, such as clay.**
  - **Weathering near freezing 10^5 slower than on Earth (Burns and Fisher, 1993) but may have been much more rapid during cyclic wet periods.**
  - **Soils also include minor sulfates, carbonates and oxides (Stoker, et al., 1993; Viking and Opportunity analyses).**
- **EVIDENCE OF SURFACE CRUSTS ("DURICRUST") DUE TO CHEMICAL PRECIPITATION**
  - **Possibly Mg, Fe, Na, Ca sulfates; Ca, Mg, Fe carbonates; and Na, K chlorine and bromine salts**
  - **Modeling of spectral data indicates that atmospheric dust may include 0-3% carbonate and 10-15% sulfate-bearing compounds.**
  - **Crustal carbonates are indicated by some of the Martian meteorites**
- **VIKING SOILS APPEAR TO BE OXIDIZING (1-10 PPB OF REACTING OXIDANTS) RATHER THAN REDUCING (NASA, 1988)**

ACTUAL SOIL MINERALS - 1

VIKING, PATHFINDER AND OPPORTUNITY ANALYSES

- SUGGEST WEATHERED BASALT (ANDESITE?)
  - SULFATES, CARBONATES, AND OXIDES

- EARTH-BASED SPECTRA INDICATE WATER IS BOUND IN MINERALS
  - CLAY, E.G. FE-RICH MONTMORILLONITES, COULD BE UPTO 15%
  - HYDROUS SULFATES JAROSITE AND GYPSUM ?

- SPECTRA ALSO INDICATE DUST MAY INCLUDE 10-15% SULFATES BUT <3% CARBONATE

- PATHFINDER MAGNETS AND MGS TES DATA SHOW MUCH IRON IS OXIDIZED (Fe_2O_3)

- SURFACE CRUST "(DURICRUST" OR MARTIAN “CALICHE”)
  - CA, MG, FE AND NA SULFATES
  - CA, MG, AND FE CARBONATES SUBSURFACE
    - CARBONATES APPARENTLY DECOMPOSED BY UV RADIATION
  - FE CARBONATE (SIDERITE) IN MARTIAN METEORITES
  - HALOGEN SALTS

SOIL MINERALS - 2

VIKING AND PATHFINDER ANALYSES

- **MODEL MARTIAN "SOIL" COMPOSITION (VIKING) [STOKER, ET AL, 1984]**
  - **SILICATE MINERALS 84-79%**
  - **MAGNETIC MINERALS 3%**
  - **SULFATE SALTS 12%**
  - **CHLORIDE SALTS 1%**
  - **CARBONATES 0%**
  - **NITRATES 0-1%**
  - **WATER (MAY BE MUCH HIGHER) >1%**

- **SOIL COMPOSITION FROM PATHFINDER**
  - **HIGHER SiO_2 AT PATHFINDER THAN FOR VIKING SITES**
    - **GREATER WEATHERING OR WATER SORTING (?)**
- **SOIL COMPOSITION FROM SPIRIT AND OPPORTUNITY**
  - **IN WORK, BUT LOCALLY HIGH IN HYDROUS SULFATES, IRON OXIDES, AND HALOGEN SALTS**

MARTIAN ATMOSPHERE
VIKING DATA

NAS9-17779 - Phase III
Final Report

Average Composition of the Martian Atmosphere (Carr et al., 1984)

Gas	Mole fraction
Carbon dioxide (CO_2)	95.32%
Nitrogen (N_2)	2.7%
Argon (Ar)	1.6%
Oxygen (O_2)	0.13%
Carbon Monoxide (CO)	0.07%
Water vapor (H_2O)	0.03%
Neon (Ne)	2.5 ppm
Krypton (Kr)	0.3 ppm
Xenon (Xe)	0.08 ppm
Ozone (O_3)	0.03 ppm

Isotope Ratios

Ratio	Earth	Mars
$^{12}C/^{13}C$	89	90
$^{16}O/^{18}O$	499	500
$^{14}N/^{15}N$	277	165
$^{40}Ar/^{36}Ar$	292	3000
$^{129}Xe/^{132}Xe$	0.97	2.5

VOLATILE RESOURCES -1 ATMOSPHERE

- CARBON DIOXIDE
  - CH_4 DERIVED FROM THE ATMOSPHERE COULD BE PARTICULARLY IMPORTANT AS A PROPULSION FUEL SOURCE EVEN ON EARLY EXPLORATION MISSIONS (ZUBRIN AND BAKER, 1991).
    - METHANE PRODUCED BY THE WELL-KNOWN INDUSTRIAL REACTION:
      - $CO_2+4H_2 = CH_4+2H_2O$
      - EXOTHERMIC AND SPONTANEOUS WITH A NICKEL CATALYST WITH 99% FIRST PASS CONVERSION
    - OXYGEN CAN BE PRODUCED, AND SOME HYDROGEN RECOVERED AND RECYCLED, BY ELECTROLYSIS OF H_2O
      - HYDROGEN MAY INITIALLY COME FROM LUNAR OR TERRESTRIAL SOURCES UNTIL WATER-ICE CAN BE REFINED
- NITROGEN (3%)
- WATER (VERY MINOR FROM ATMOSPHERE BUT ABUNDANT FROM ICE)

VOLATILE RESOURCES -2 NEAR SURFACE

- **CHLORINE, BROMINE AND FLUORINE FROM SOILS**
- **COPPER, ZINC, LEAD, PRECIOUS METALS, ETC. FROM PYROCLASTICS AND VOLCANIC HOT SPRING DEPOSITS**
- **SULFUR FROM FeS (TROILITE) IN BASALTIC REGOLITH AND FROM VOLCANIC FUMEROLE DEPOSITS**
- **CHLORINE, SULFUR, AND OTHER ELEMENTS FROM SOIL CRUSTS**
- **HYDROCARBON COMPOUNDS DEPENDING ON THE EXISTENCE AND EXTENT OF EARLY LIFE AND / OR PRESENT LIFE FORMS**
  - **DARK FLOWS DOWN SLOPES OBSERVED BY MGS AND THOUGHT TO BE LANDSIDES BUT MIGHT BE OIL SEEPS**
  - **EVIDENCE FOR LIFE FORMS AT THE VIKING LANDER SITES "NOT" PRESENT (HOROWITZ, 1988)**
    - **LOW CONCENTRATIONS OF LICHEN-LIKE FORMS ARE A POSSIBILITY (LEVIN AND STRAAT, 1988)**
  - **DEBATE OVER RELIC LIFE FORMS IN SNC METEORITE ALH84001**

EXTREME LIFE ON EARTH

LITHOPHILE WITH WATER (BACTERIA)

DEEP IN OCEAN BOTTOM SEDIMENTS (1 KM)

DEEP BASALTIC ROCKS (1.5 KM) (C AND H+)

OLD, OIL-BEARING SEDIMENTS (3.5 KM)

DEEP GRANITE (207 M)

THERMOPHILE (VERY COMPLEX COMMUNITIES)

BLACK SMOKERS

BOILING HOT SPRINGS (>110ºC)

CRYOPHILE (BACTERIAL AND ALGAE)

ICE/BRINE/WATER INTERFACE (-20 ºC)

ARIDOPHILE (ALGAE, BACTERIA, PHYTOFLAGELLATES, PROTOZOA, VIRUSES)

ANTARCTIC DRY VALLEYS

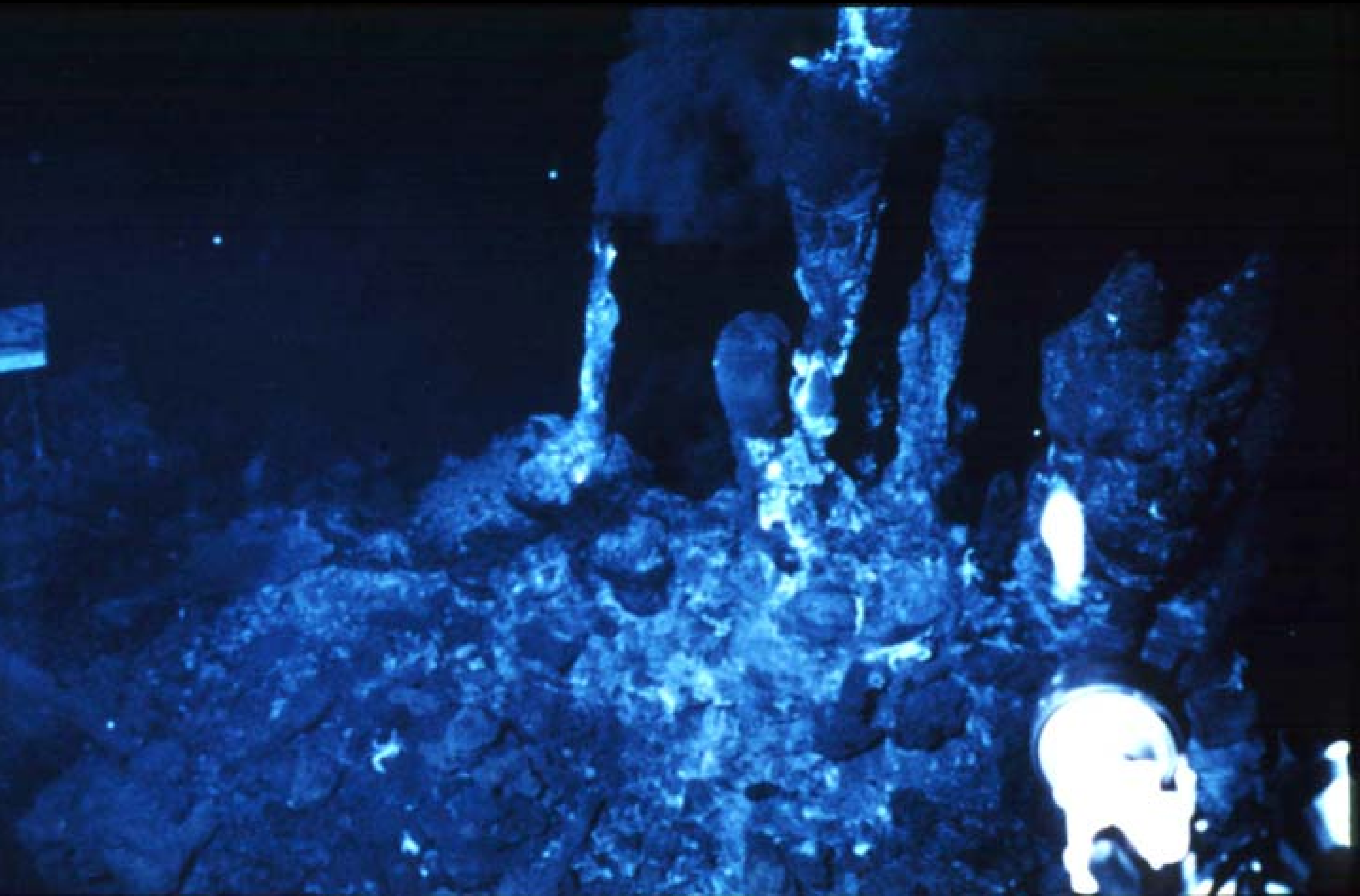
LICHEN / FUNGI

BACTERIAL SPORES IN BEES IN AMBER

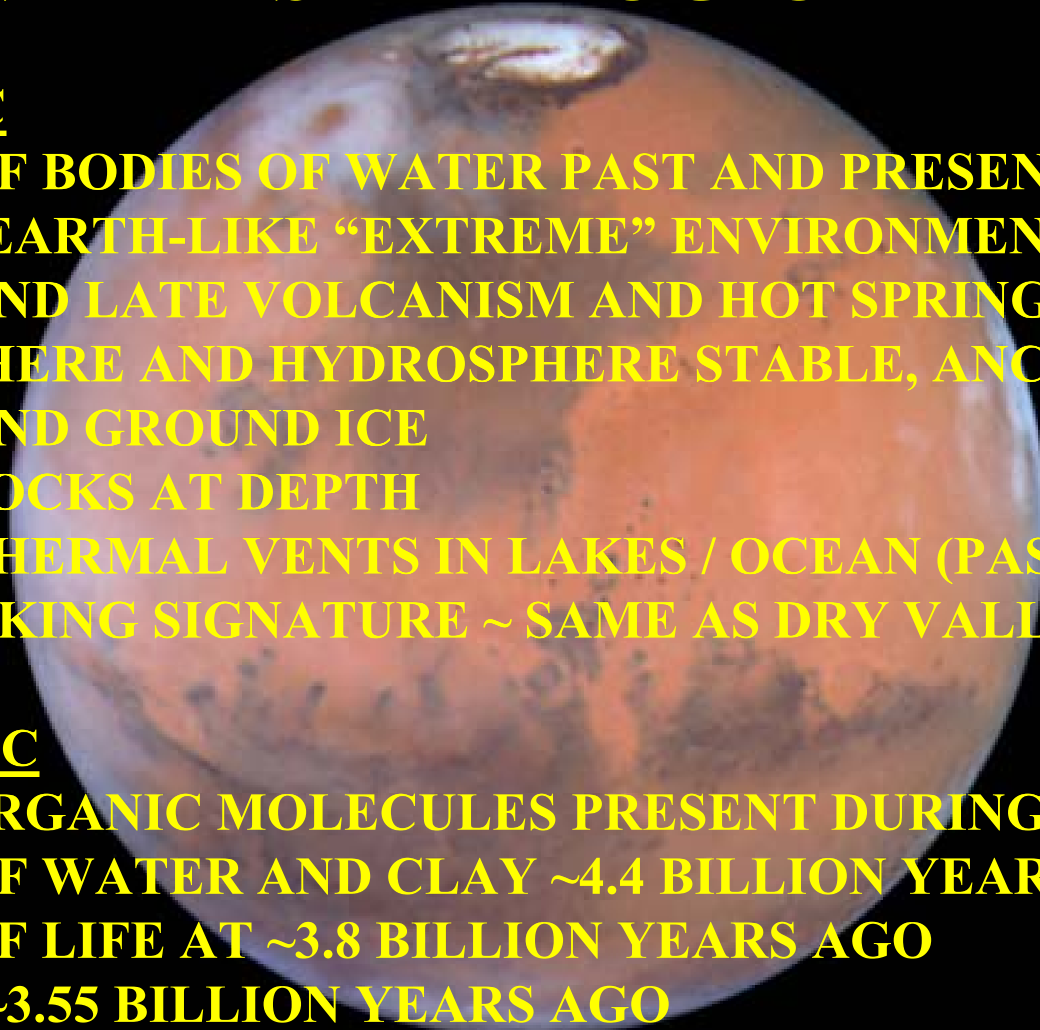
DARKOPHILE (CHEMOAUTOTROPIC BACTERIA)

DEEP CAVES (C AND H_2S)

BLACK SMOKER AT MID-OCEAN RIDGE VENT



EXISTING LIFE ON MARS?
WHAT IS THE LOGIC PATH?



MARS LOGIC

EVIDENCE OF BODIES OF WATER PAST AND PRESENT

PROBABLE, EARTH-LIKE "EXTREME" ENVIRONMENTS

- **EARLY AND LATE VOLCANISM AND HOT SPRINGS**
- **CYROSPHERE AND HYDROSPHERE STABLE, ANCIENT FEATURES**
- **POLAR AND GROUND ICE**
- **"WET" ROCKS AT DEPTH**
- **HYDROTHERMAL VENTS IN LAKES / OCEAN (PAST) ?**
- **LEVIN VIKING SIGNATURE ~ SAME AS DRY VALLEY TEST**

EARTH LOGIC

COMPLEX ORGANIC MOLECULES PRESENT DURING ACCRETION

EVIDENCE OF WATER AND CLAY ~4.4 BILLION YEARS AGO

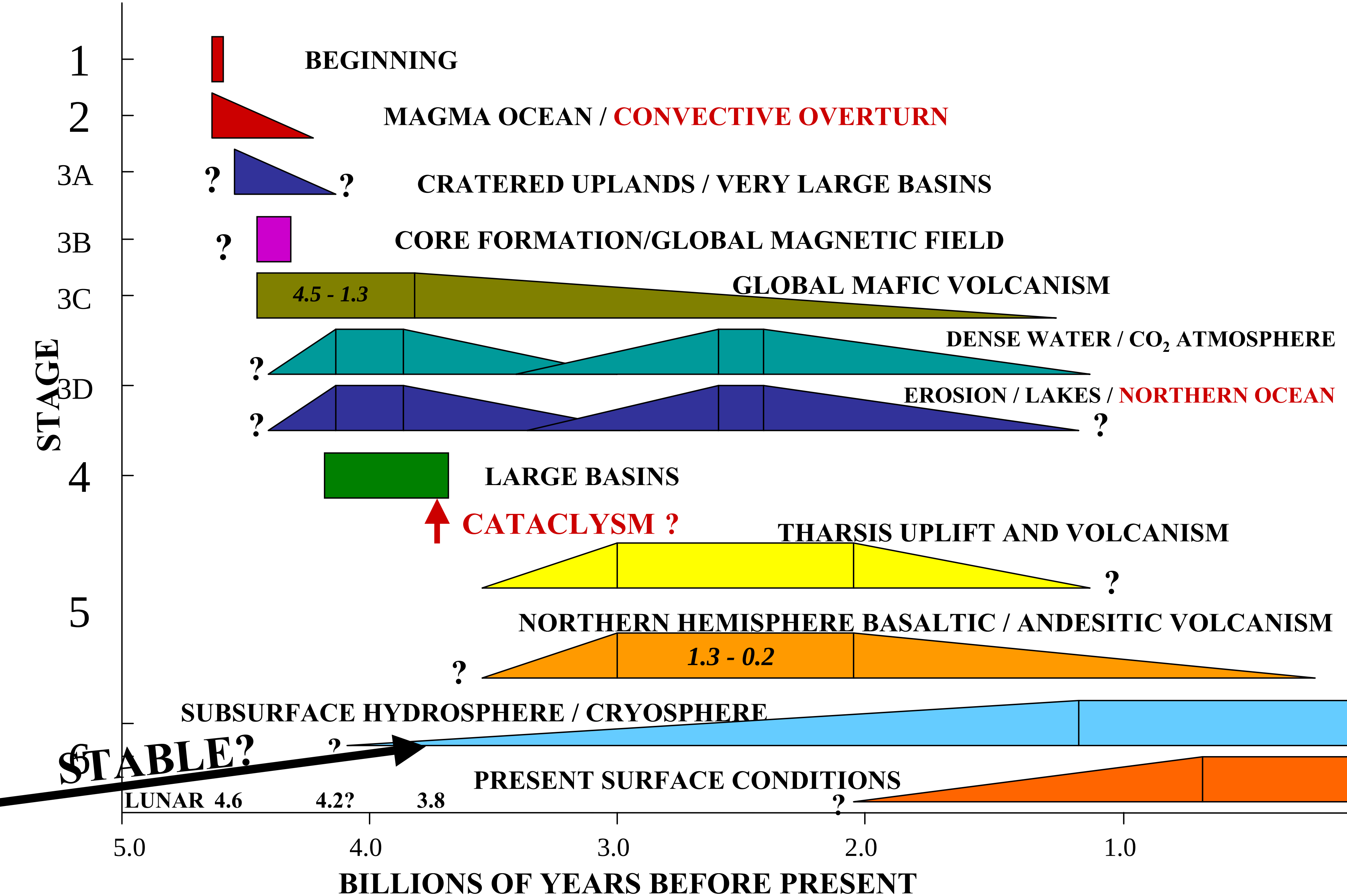
EVIDENCE OF LIFE AT ~3.8 BILLION YEARS AGO

FOSSILS AT ~3.55 BILLION YEARS AGO

"SIMPLE" LIFE FORMS IN TODAY'S EXTREME ENVIRONMENTS

NASA HST IMAGE

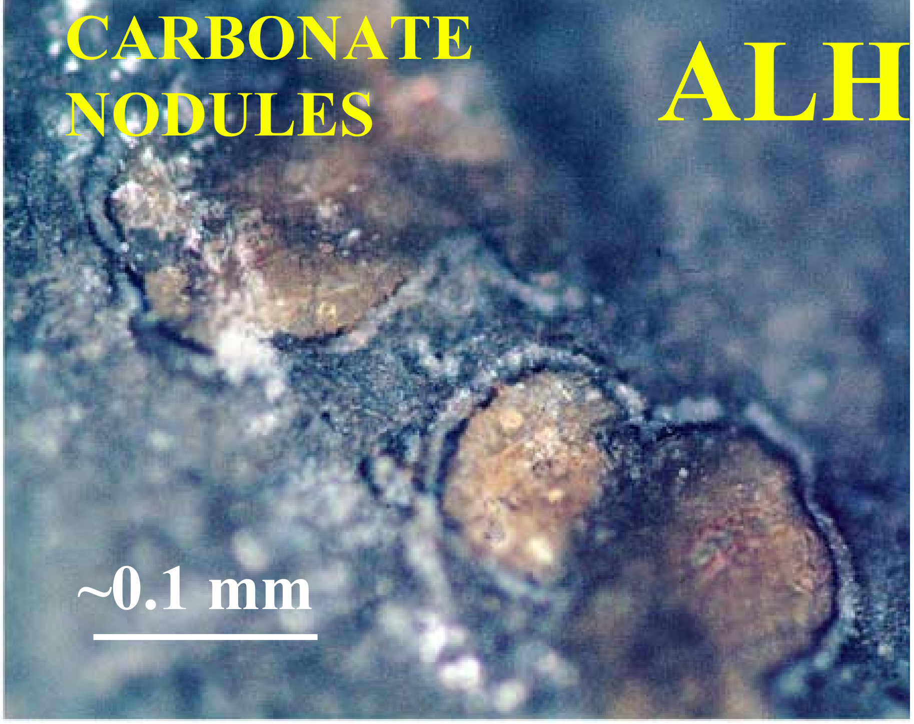
MAJOR STAGES OF MARS' EVOLUTION

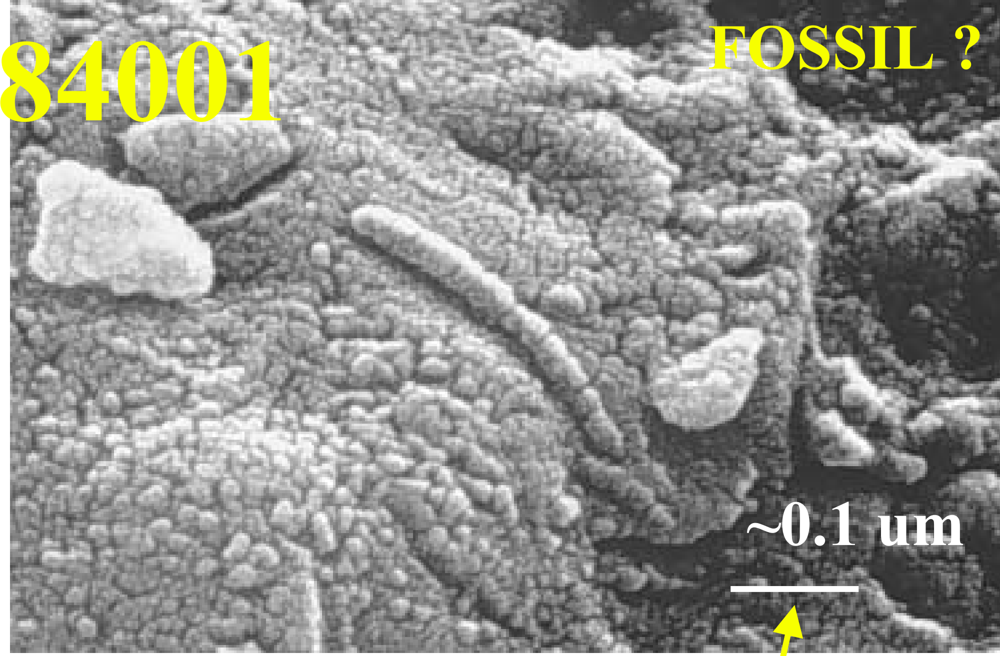


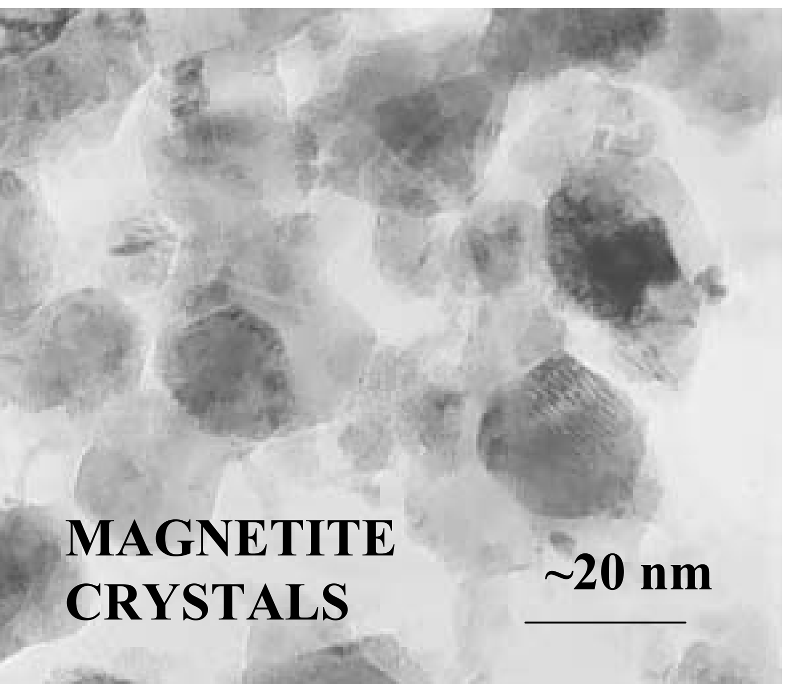
ITALICS = SNC DATES

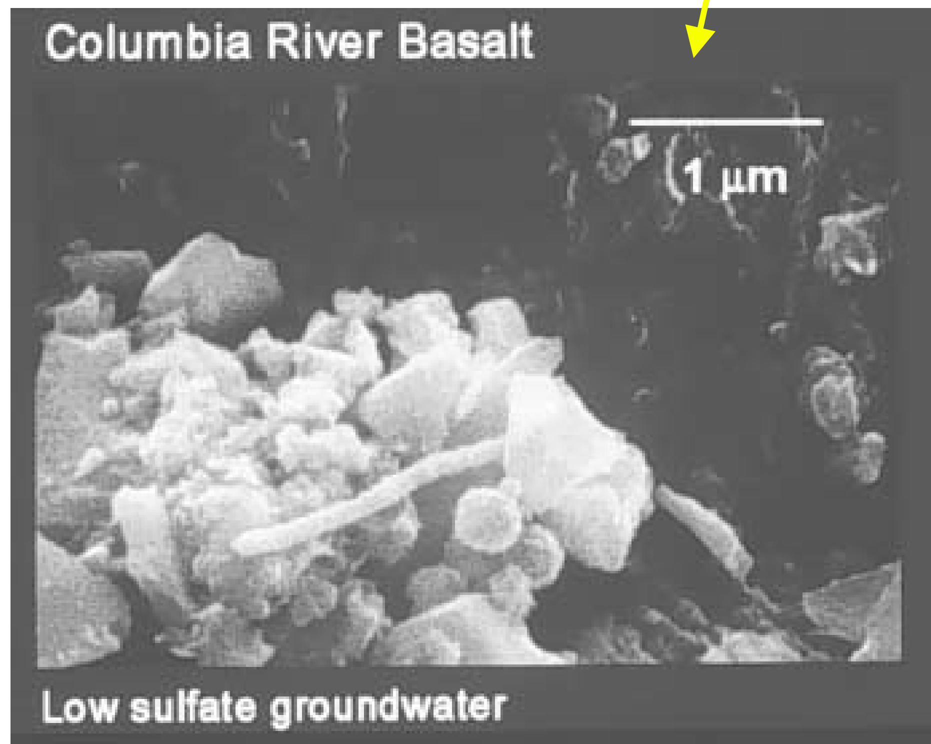
RED = MAJOR UNCERTAINTY

ALH84001


CARBONATE
NODULES
~0.1 mm


FOSSIL ?
~0.1 um


MAGNETITE
CRYSTALS
~20 nm


Columbia River Basalt
1 µm
Low sulfate groundwater

EVIDENCE OF LIFE IN ALH84001???

- **EACH OF MCKAY, ET AL'S PIECES OF EVIDENCE HAS BEEN DUPLICATED INORGANICALLY**
  - **PAH'S COULD BE CONTAMINATION**

- **ALL EVIDENCE TAKEN TOGETHER IS STILL STRONG ARGUMENT**

- **TIME WILL TELL…………**

RESOURCES RESULTING FROM PRESENCE OF WATER AND AIR

- **DENSITY CONTRASTS**
  - **SORTING OF HEAVY AND LIGHT MINERALS FROM SAND AND GRAVEL BY WATER**
  - **SORTING OF CLAYS AND SILICA FROM SAND BY WIND**
  - **SORTING OF CLAYS FROM SAND BY SETTLING RATES IN LAKES (LAYERED SEDIMENTS)**

- **CHEMICAL PRECIPITATION IN WATER**
  - **CHEMICAL EVAPORITE PRECIPITATES OF CARBONATE, IRON OXIDES, AND VARIOUS CHLORIDE SALTS (SODIUM, POTASSIUM, ETC.) IN LAKES**
  - **METAL SULFIDE PRECIPITATES IN LAKE BEDS**
  - **"BLACK SMOKER" SULFIDE DEPOSITS IN OCEAN BEDS**

- **PRODUCTS OF ANCIENT WEATHERING**
  - **BAUXITE (ALUMINUM), IRON OXIDES, COBALT, NICKEL**

- **HYDROTHERMAL PRECIPITATION**
  - **VEINS OF METALS, SULFIDES, CARBONATES, ETC. NEAR VOLCANOS**
    - **LEAD, ZINC, COPPER, GOLD, SILVER, ETC.**
  - **VEINS AND DISSEMINATED METAL DEPOSITS IN THE UPLANDS CRUST**

METALLIC RESOURCES (NEAR SURFACE)

- METALLIC MATERIALS REQUIRED FOR MARTIAN MANUFACTURING AND OPERATIONS
  - SILICON FROM QUARTZ IN SORTED SEDIMENT OR DUNES
  - TITANIUM FROM ILMENITE IN SORTED SEDIMENTS OR DUNES
    - OXYGEN AND IRON CAN BE BY-PRODUCTS
  - ALUMINUM WITH BY-PRODUCT SILICON
    - PLAGIOCLASE ($CaAl_2Si_2O_8$)
    - SCAPOLITE ($Na_4Al_3Si_9O_2$ [4Cl]-$Ca_4Al_6Si_6O_2$ [4(CO_3,SO_4)]
    - CLAY MINERALS
  - CHROMIUM
    - CHROME-SPINEL (Cr_2O_3 FROM $(Fe,Mg)(Cr,Al,Ti)_2O_4$ IN BASALT)
  - MANGANESE, IRON, ALUMINUM, COBALT, NICKEL
    - OXIDES AND CLAYS IN WEATHERING OR SHALLOW HYDROTHERMAL DEPOSITS
  - MAGNESIUM
    - MgO FROM $(Mg,Fe)_2SiO_4$ (OLIVINE) IN BASALT AND MG-CARBONATE
  - IRON AND NICKEL FROM METEORITE DEBRIS IN REGOLITH
    - COBALT
    - PLATINUM GROUP, AND OTHER SIDEROPHILE ELEMENTS, E.G., Au
- MANY ELEMENTS FROM SULFATES AND HALOGEN SALTS

RESOURCES RESULTING FROM MAGMA FRACTIONAL CRYSTALLIZATION

- LAYERED EXTRUSIVES AND INTRUSIVES (REMEMBER TES IMAGE OF OLIVINE LAYER)
  - TITANIUM (ILMENITE)
  - CHROMIUM (CHROMITE)
  - IRON AND SULFUR (TROILITE)
  - NICKEL, IRON, AND COPPER (SULFIDES)
  - PLATINUM GROUP METALS
  - REFRACTORY MINERALS (OLIVINE)

- PEGMATITES (LATE STAGE SILICA- AND WATER-RICH FLUIDS)
  - LITHIUM
  - URANIUM
  - BORON
  - OTHER "INCOMPATIBLE" ELEMENTS

- MARTIAN "KREEP" IF CONCENTRATED
  - PHOSPHOROUS, RARE EARTH ELEMENTS AND POSSIBLY K

NON-METALLIC RESOURCES

- DUNE MATERIAL FOR INSULATION AND ZENITH RADIATION PROTECTION
- ROAD AGGREGATE FROM NATURALLY SORTED MATERIALS (GRAVEL)
- SINTERED DUNE MATERIAL FOR CONSTRUCTION APPLICATIONS
- SILICA SAND FOR SOLAR CELLS AND GLASS
- CLAY MINERALS FOR CERAMICS
- PLANT GROWTH MEDIUM
  – PROBABLY CONSISTENT PLANET-WIDE AND MAY REQUIRE SPECIAL TREATMENT

MARS DIFFERENCES NEAR SURFACE (RELATIVE TO THE MOON)

- ATMOSPHERE (1% OF EARTH)
  - MOVES FINE PARTICLES AND ERODES ROCKS AND SOILS
- GROUND ICE
- UNDERGROUND WATER
- POLAR ICE (MAY BE SOME ON MOON)
  - PERIODIC GLACIER ACTIVITY
- WATER AND WIND SORTED MATERIALS

- FINELY PULVERIZED REGOLITH ABSENT
  - ATMOSPHERE PROTECTS (NOTE VIKING LANDERS AND PATHFINDER BOULDER FIELDS)
    - SMALL METEORS: CURRENTLY CRATERS <~30 M NOT FORMED
    - SOLAR WIND (EXCEPT AROUND ZENITH)
  - MARTIAN "REGOLITH"
    - COARSE ROCK DEBRIS MIXED WITH EXTREMELY FINE WIND-BLOWN DUST
    - NO MICROMETEOR “TAMPING”
    - LOCAL WATER-BOURNE MATERIALS
    - NO MICROMETEOR INDUCED NANOPHASE IRON
    - GENERALLY LESS DENSE
      - DUNES HAVE VERY LOW BEARING STRENGTH
    - GENERALLY MORE PORUS
      - ~60% VS. ~25%

MARS RESOURCES: CONCLUSIONS

- SELF-SUFFICIENCY IS ASSURED FOR FUTURE SETTLERS
- BUT NO KNOWN RESOURCES, STANDING ALONE, JUSTIFY EXPORT TO EARTH
  - NO NET PROFIT FOR "MARS ROCKS!, LIMITED"
- SOME CASH-FLOW IN MARS ECONOMY COULD BE REALIZED
  - BY-PRODUCTS OF OTHER NECESSARY ACTIVITIES
  - SOME EXPORTS TO DEEP SPACE USERS ARE LIKELY, I.E., LAUNCHES FROM MARS,
- REMEMBER, HOWEVER, THE STATEMENT IN RED, ABOVE, WAS SAID ABOUT THE MOON UNTIL 1985
  - BEFORE IMPORTANCE OF LUNAR ^{3}HE WAS IDENTIFIED AT WISCONSIN

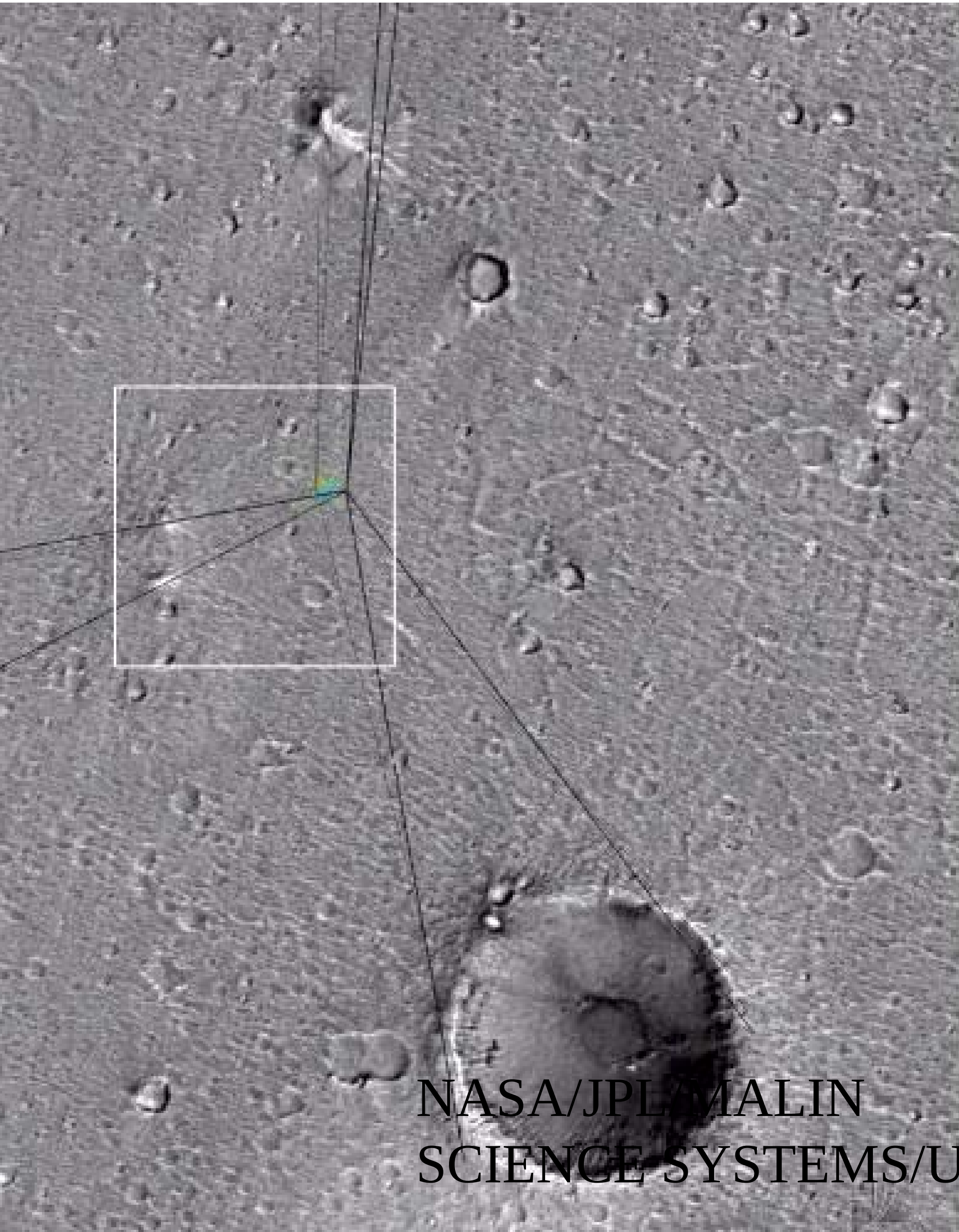
ENJOY THE VIEW WHEN YOU GET THERE!!!!!

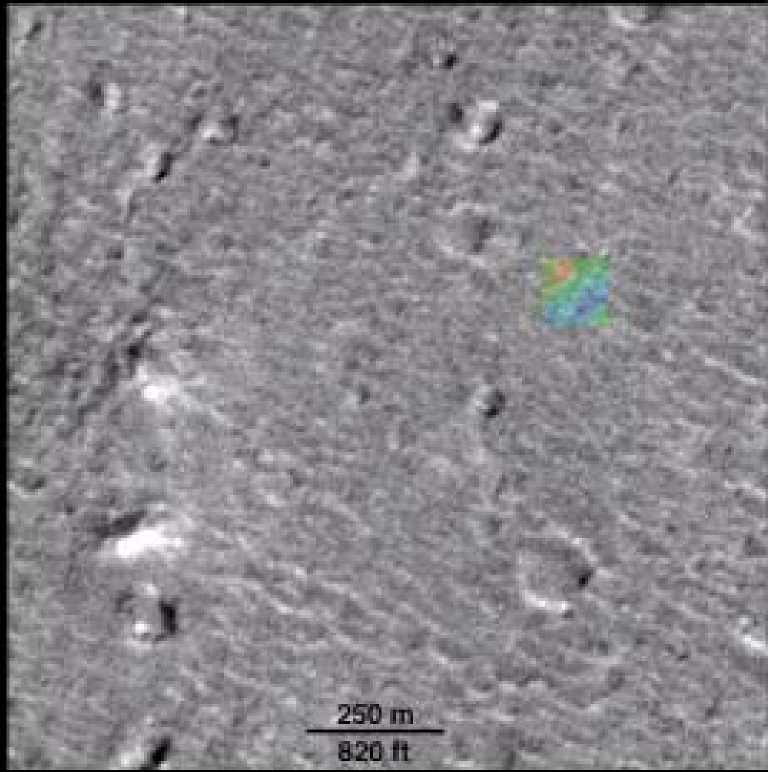
"TRUE COLOR OF MARS"
PATHFINDER LANDER VIEW
NASA/JPL

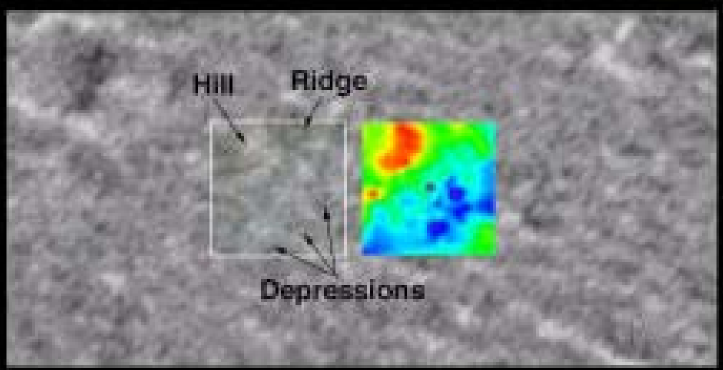
TERM PAPER TOPICS

- **MARTIAN RESOURCES IN THE "BILL OF MATERIALS" FOR <u>FIRST</u> PERMANENT MARTIAN HABITAT**
- **EARTH'S EXTREME LIFE ENVIRONMENTS THAT MAY BE FOUND ON MARS**
- **PROS AND CONS FOR EVIDENCE OF LIFE IN MARS METEORITE ALH84001**
- **√ MARS SURFACE RADIATION CONSIDERATIONS**

PATHFINDER LOCATION

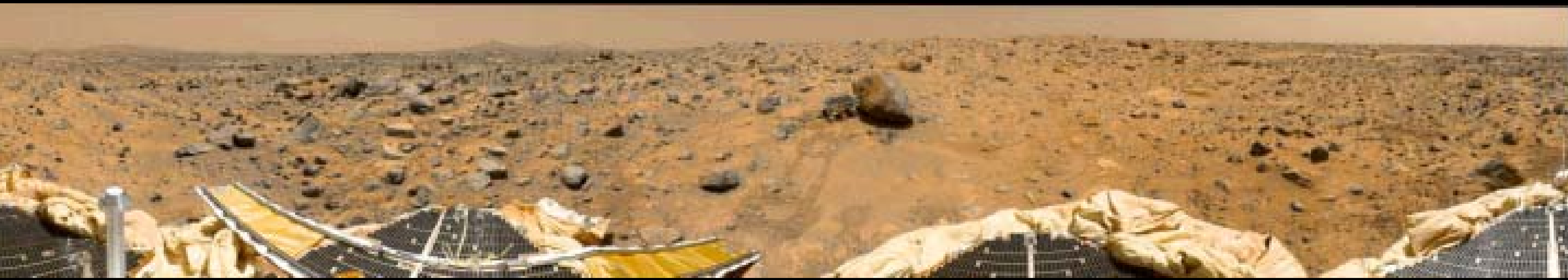


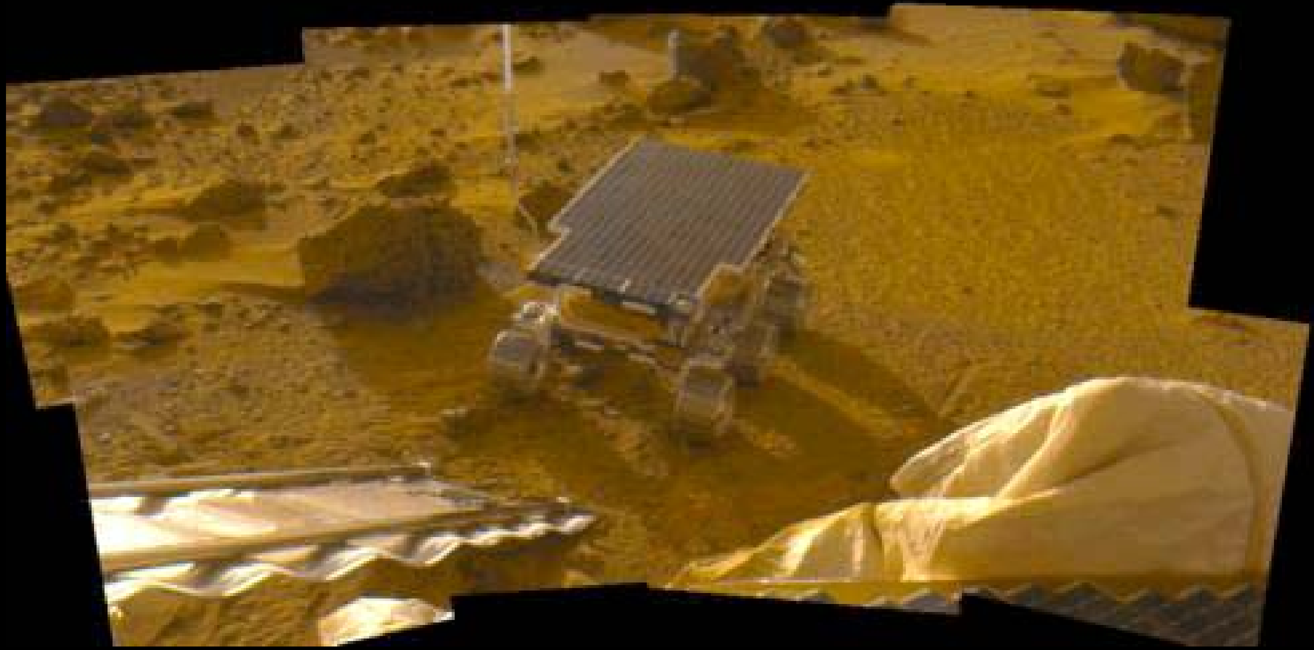




NASA/JPL/MALIN SCIENCE SYSTEMS/USGS

PATHFINDER/SOUJOURNER





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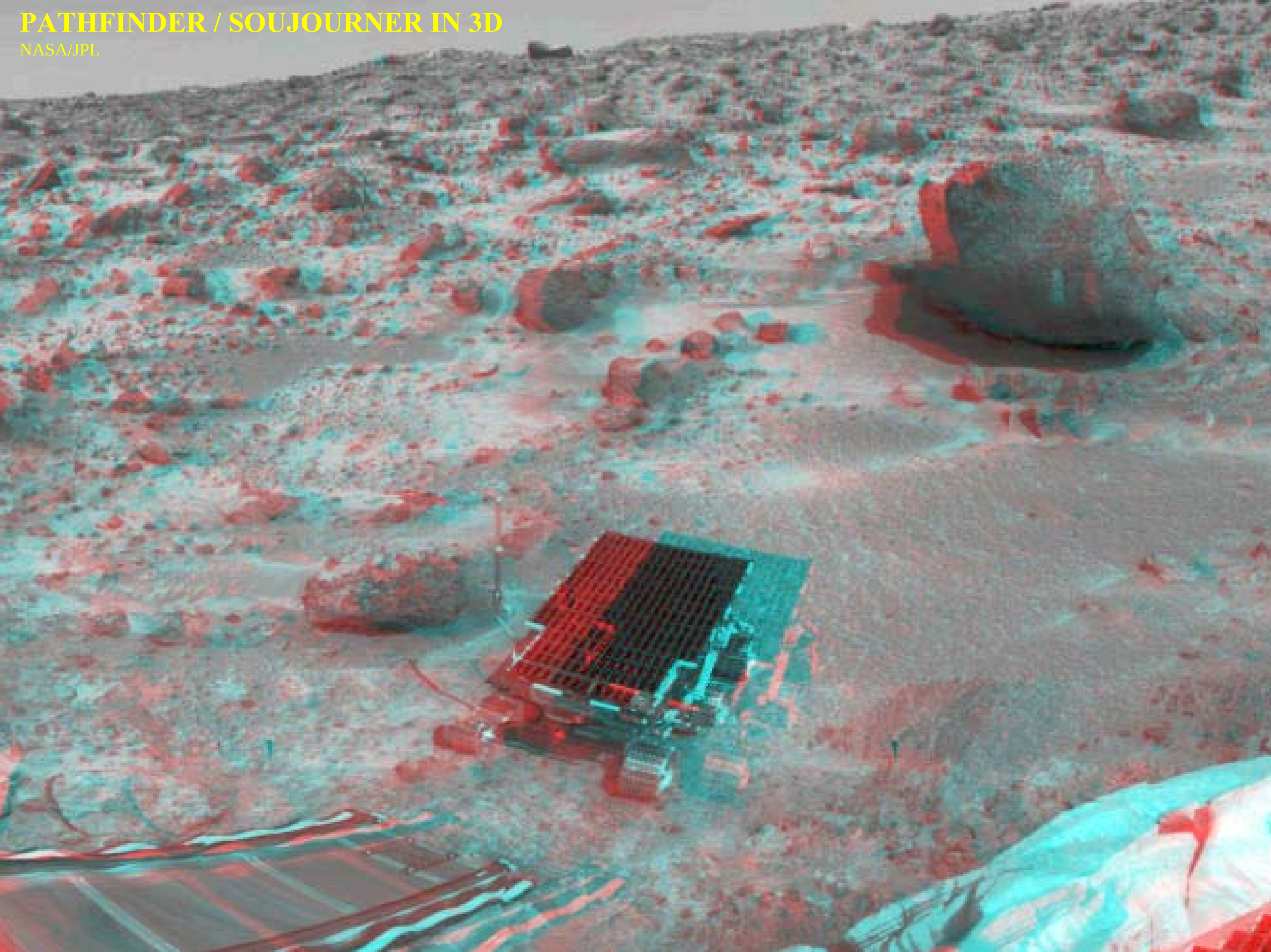
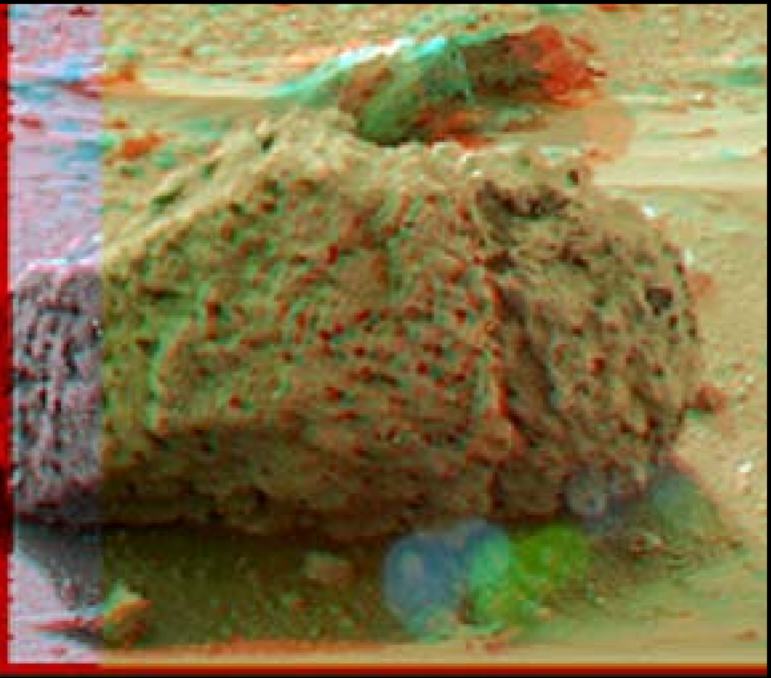
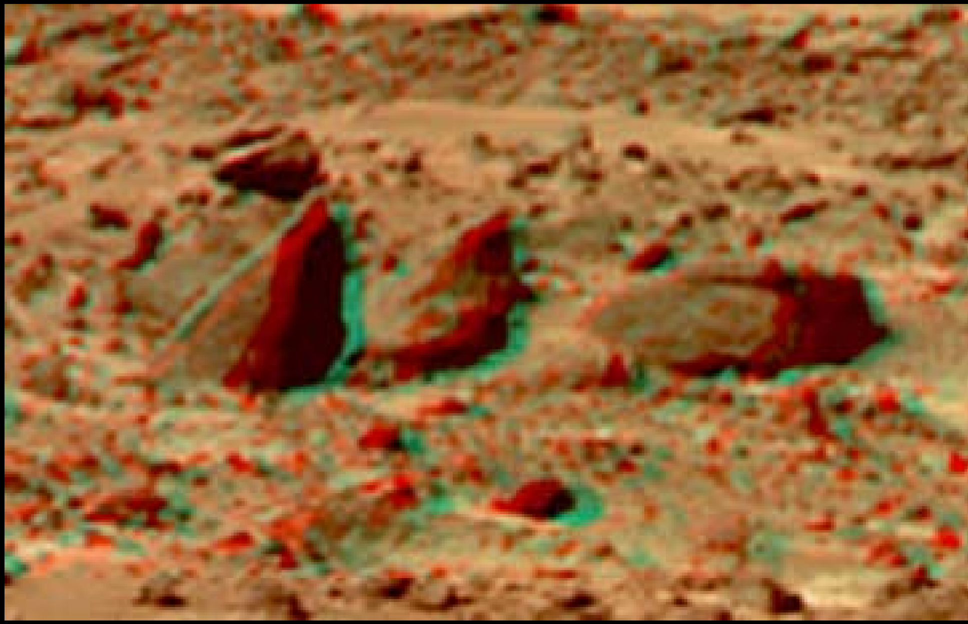
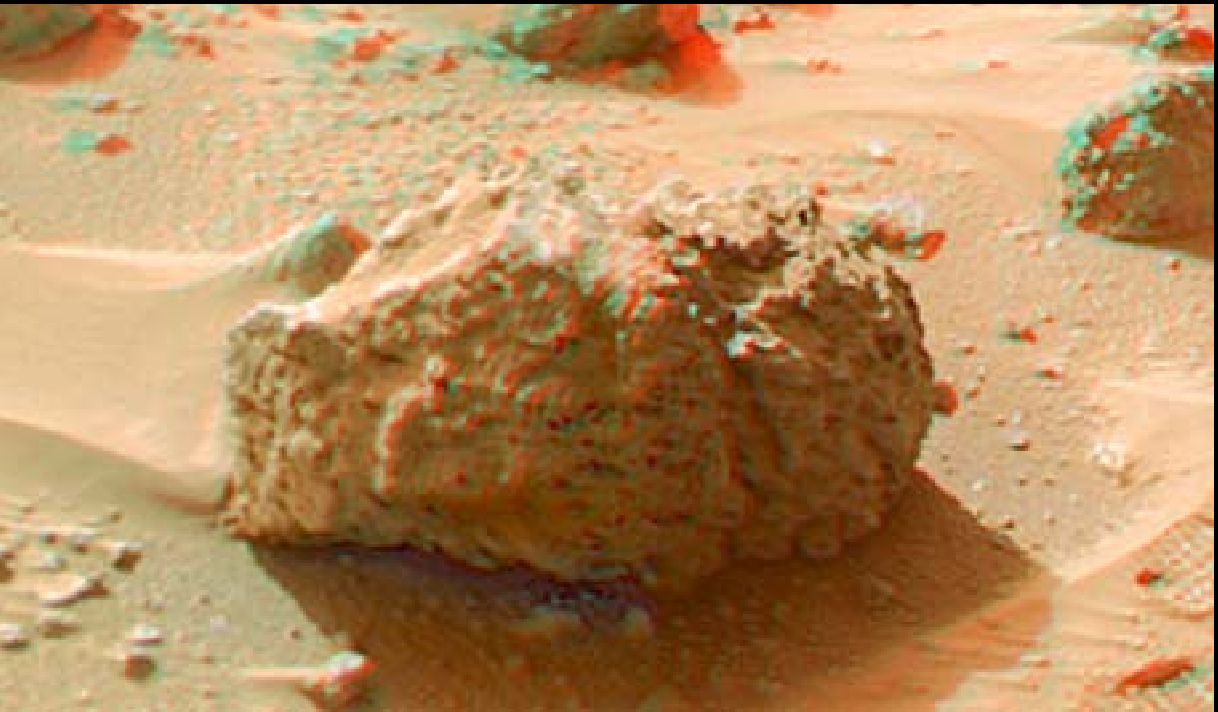
PATHFINDER / SOUJOURNER IN 3D

NASA/JPL



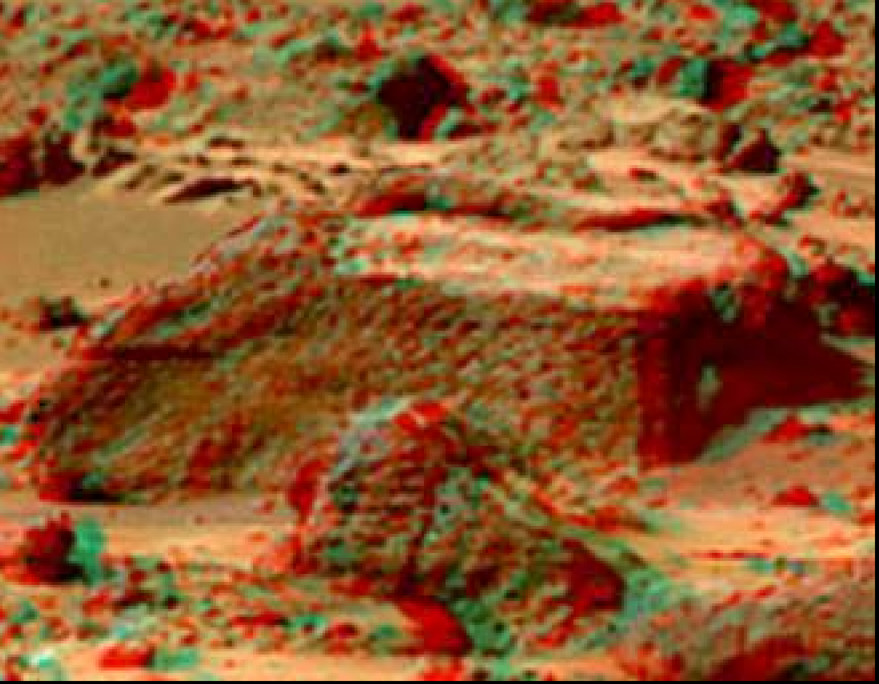


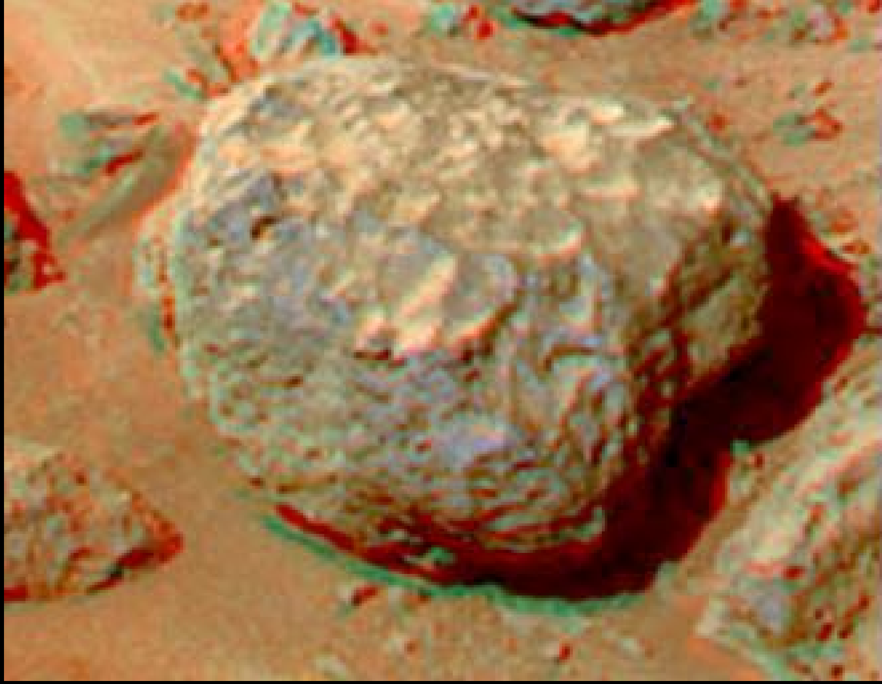




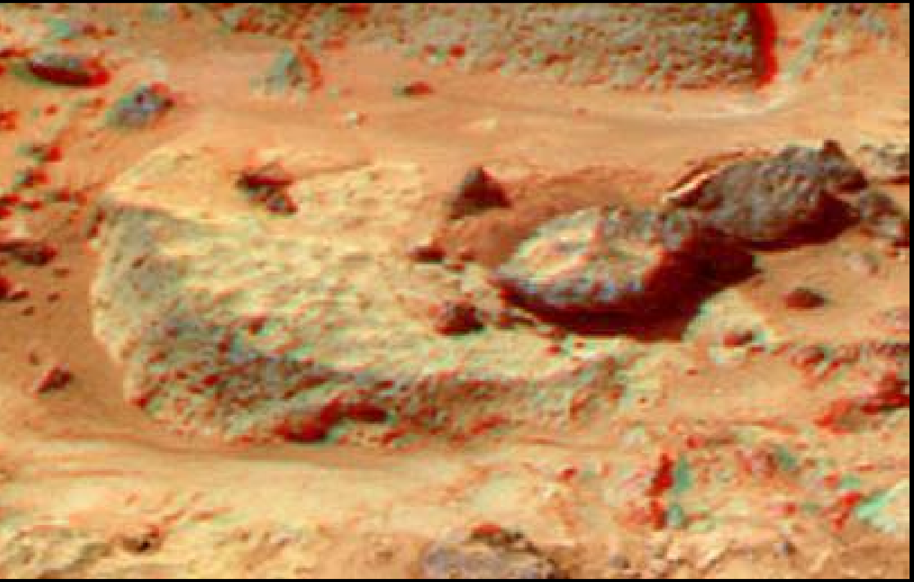
PATHFINDER ROCKS AND SURROUNDINGS IN 3D

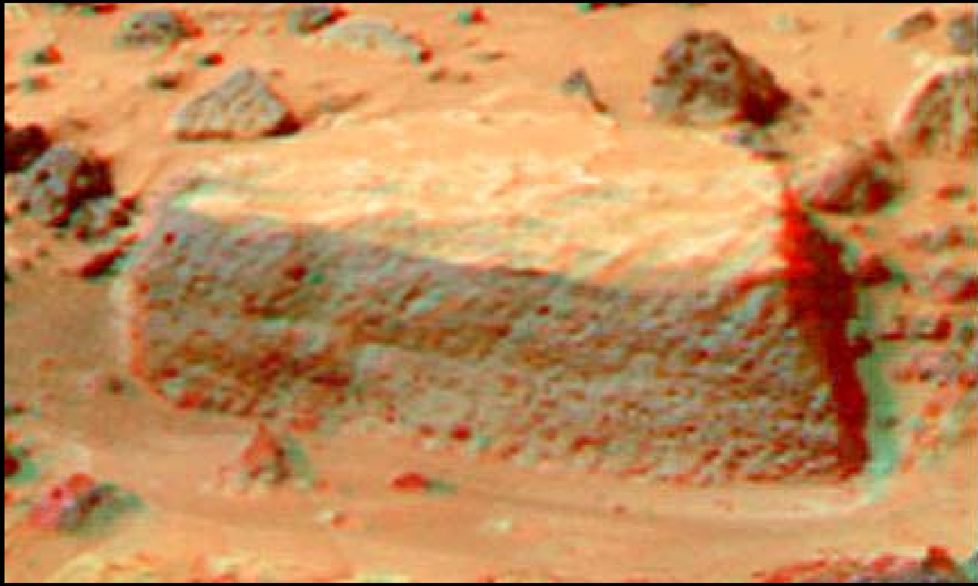
NASA/JPL





MORE PATHFINDER ROCKS IN 3D





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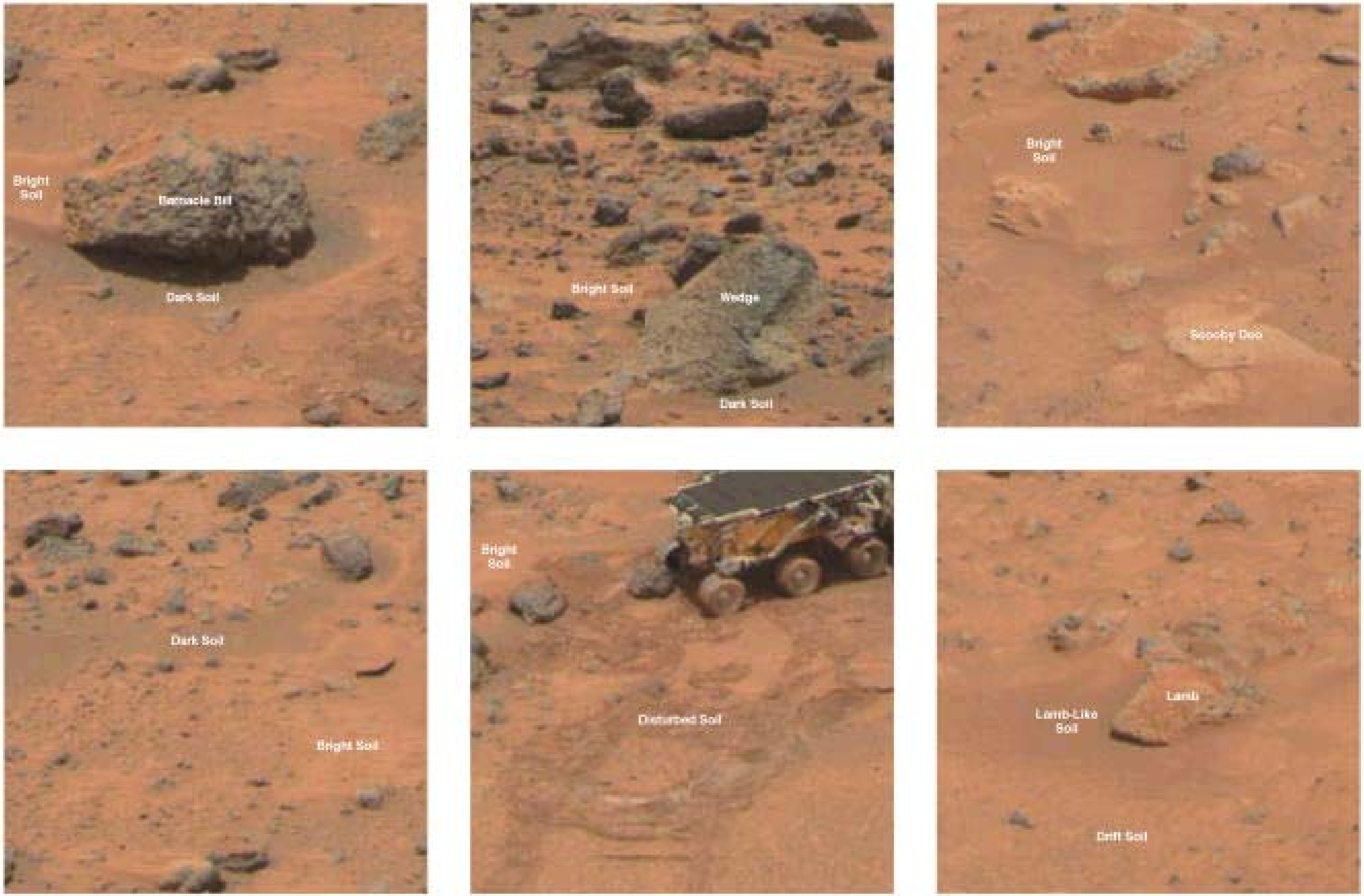
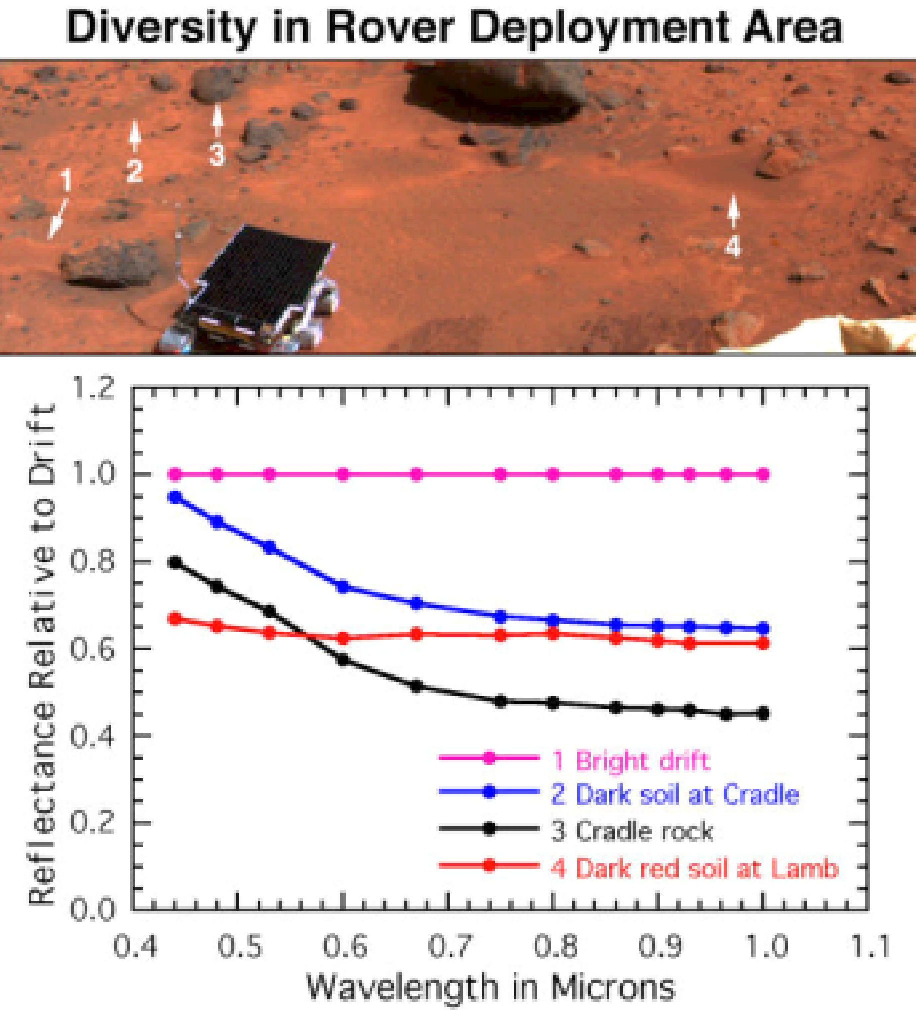
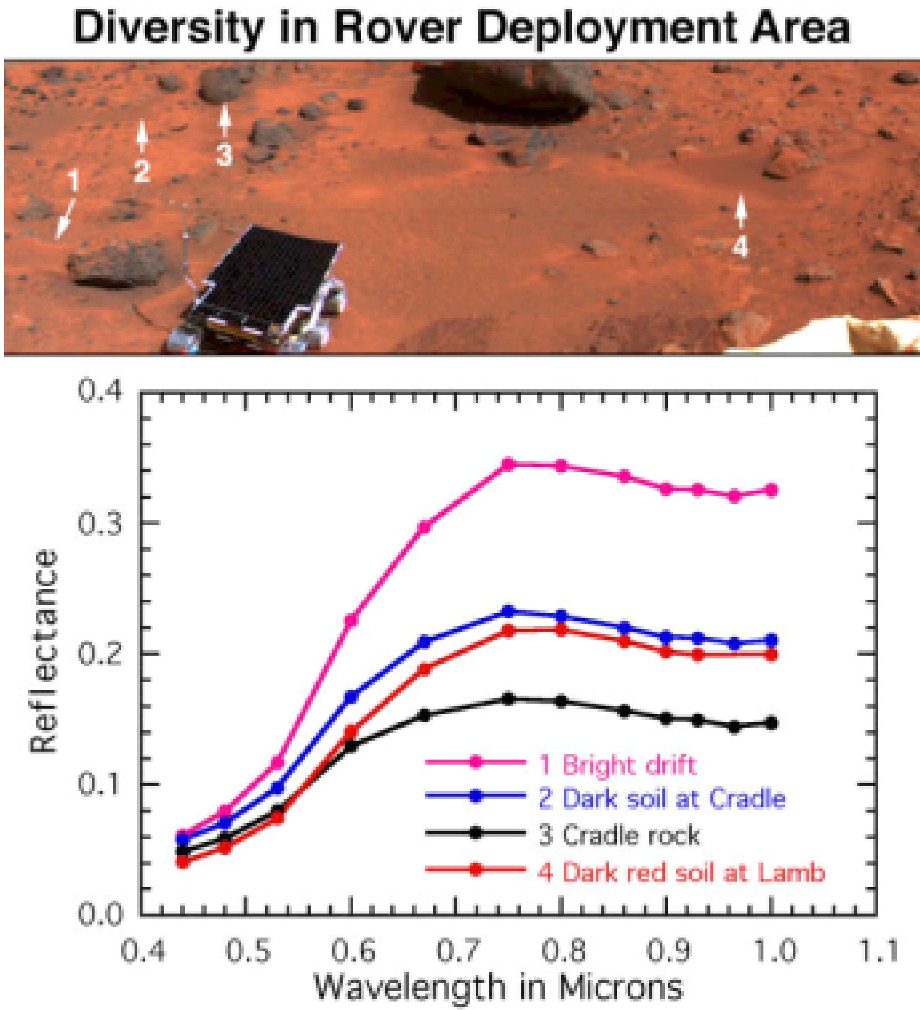
SOIL TYPES AT PATHFINDER SITE

NASA/JPL



PATHFINDER SOIL





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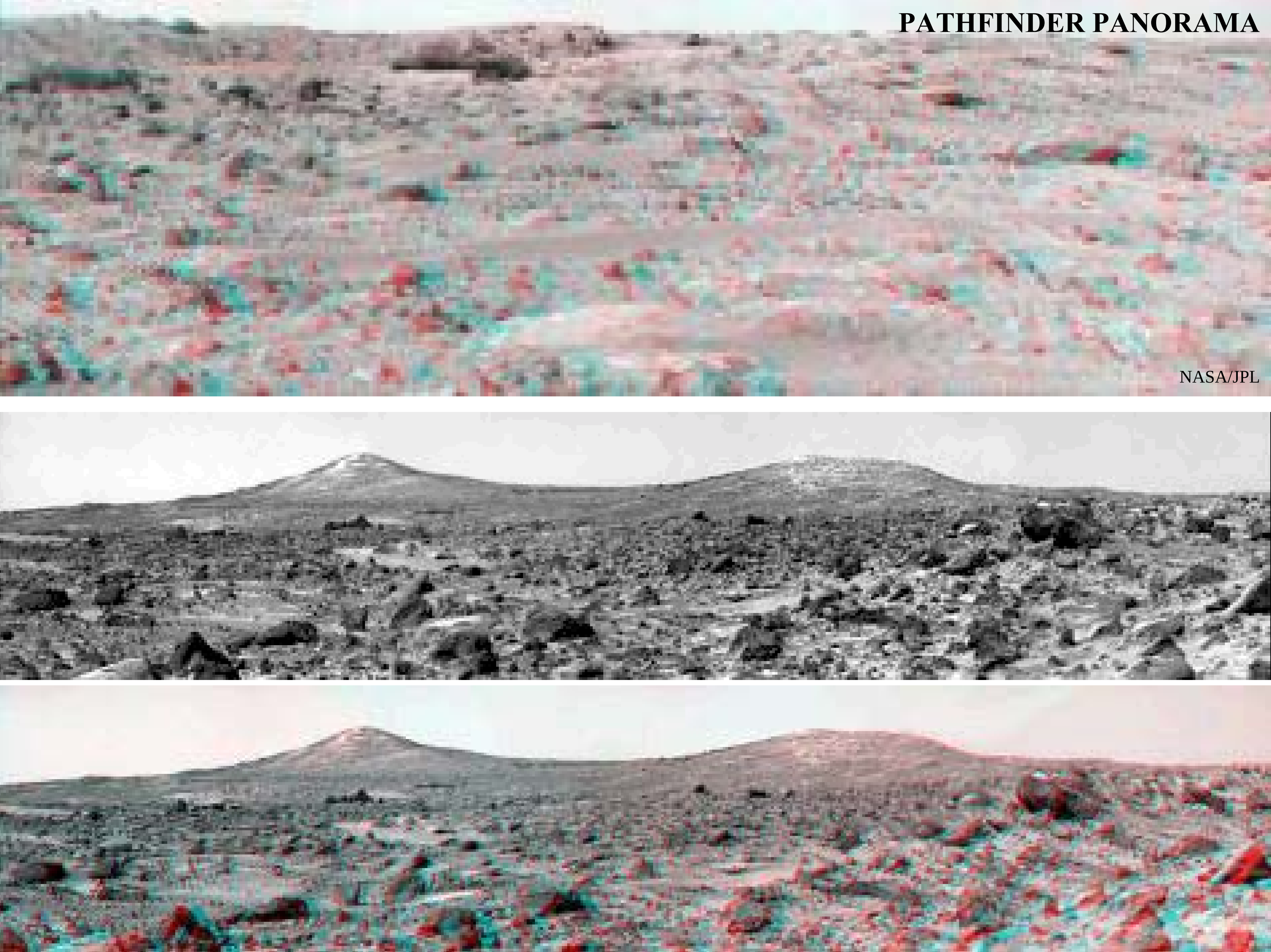
PATHFINDER PANORAMA
NASA/JPL



VIKING 1 LANDER VIEWS, CHRYSE, 7500 KM SW OF VIKING 2 SITE NASA/JPL
(IN OUTFLOW REGION, ~1200 KM FROM PATHFINDER SITE)

VIKING 2 LANDER VIEWS UTOPIA, NORTHERN LOWLANDS 7500 KM NE OF VIKING 1 SITE

NASA/JPL