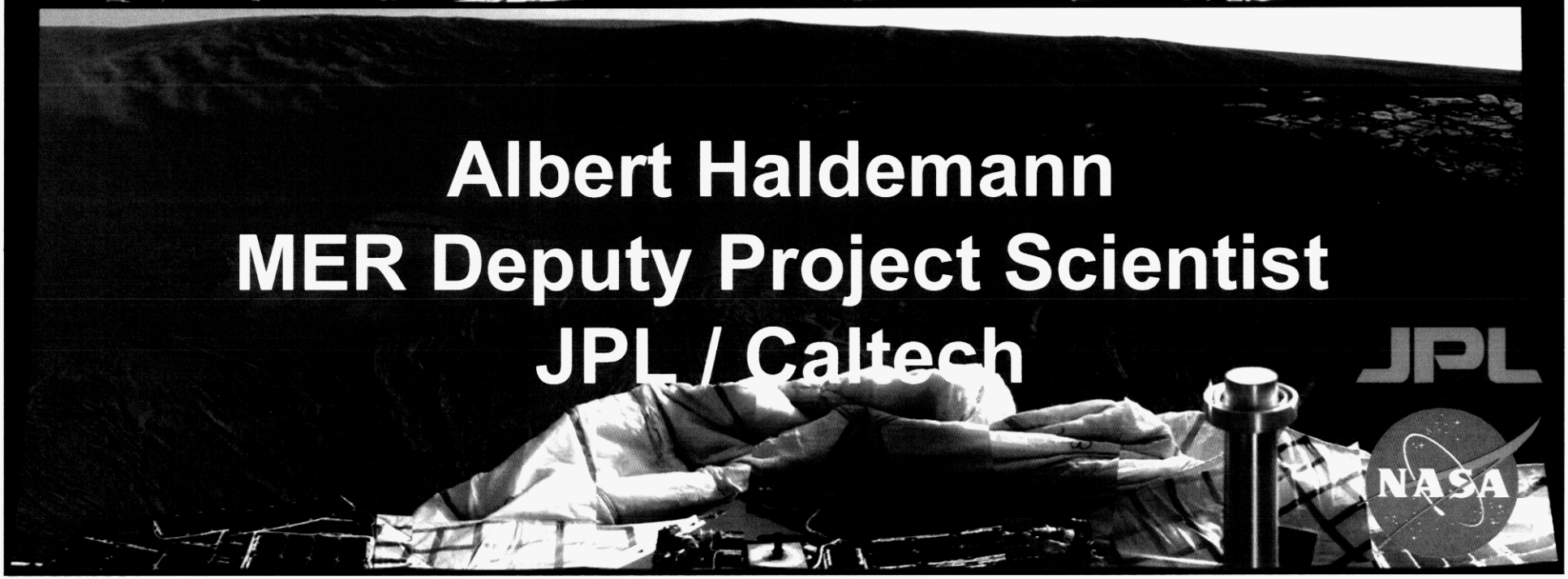
Colloque de Physique,
Institut de Physique de l'Université de Neuchâtell
Neuchâtel, Switzerland, January 23, 2006.

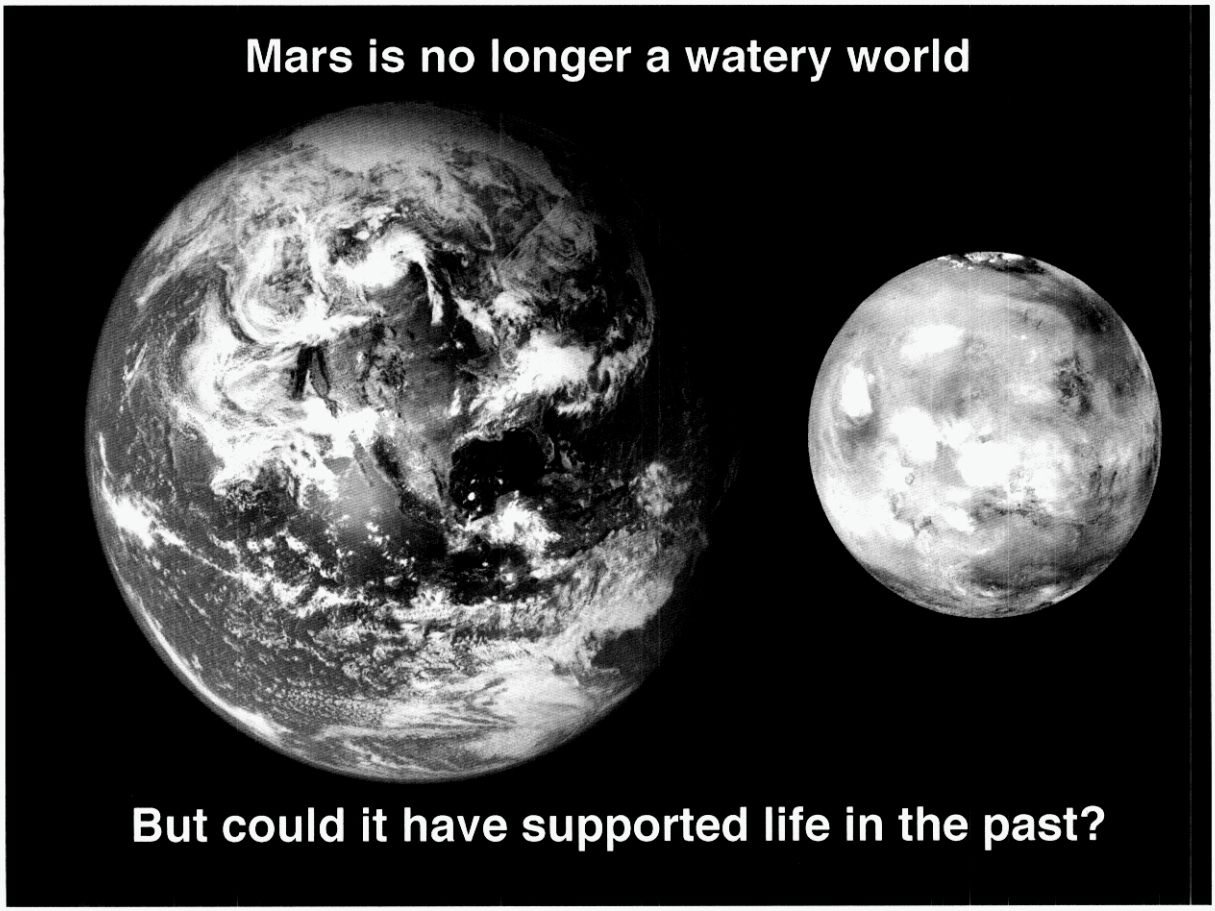
The Science from *Spirit* and *Opportunity*

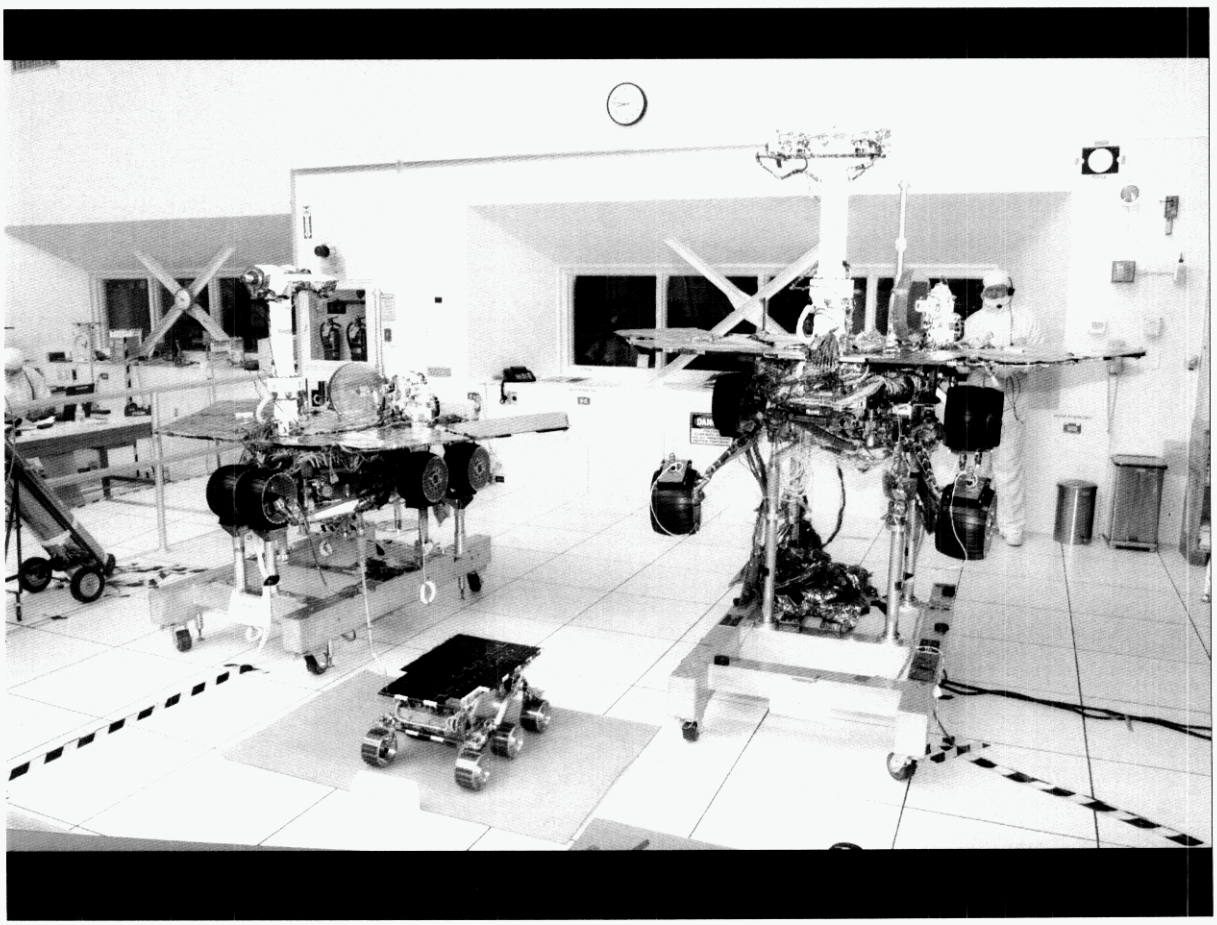


Albert Haldemann
MER Deputy Project Scientist
JPL / Caltech

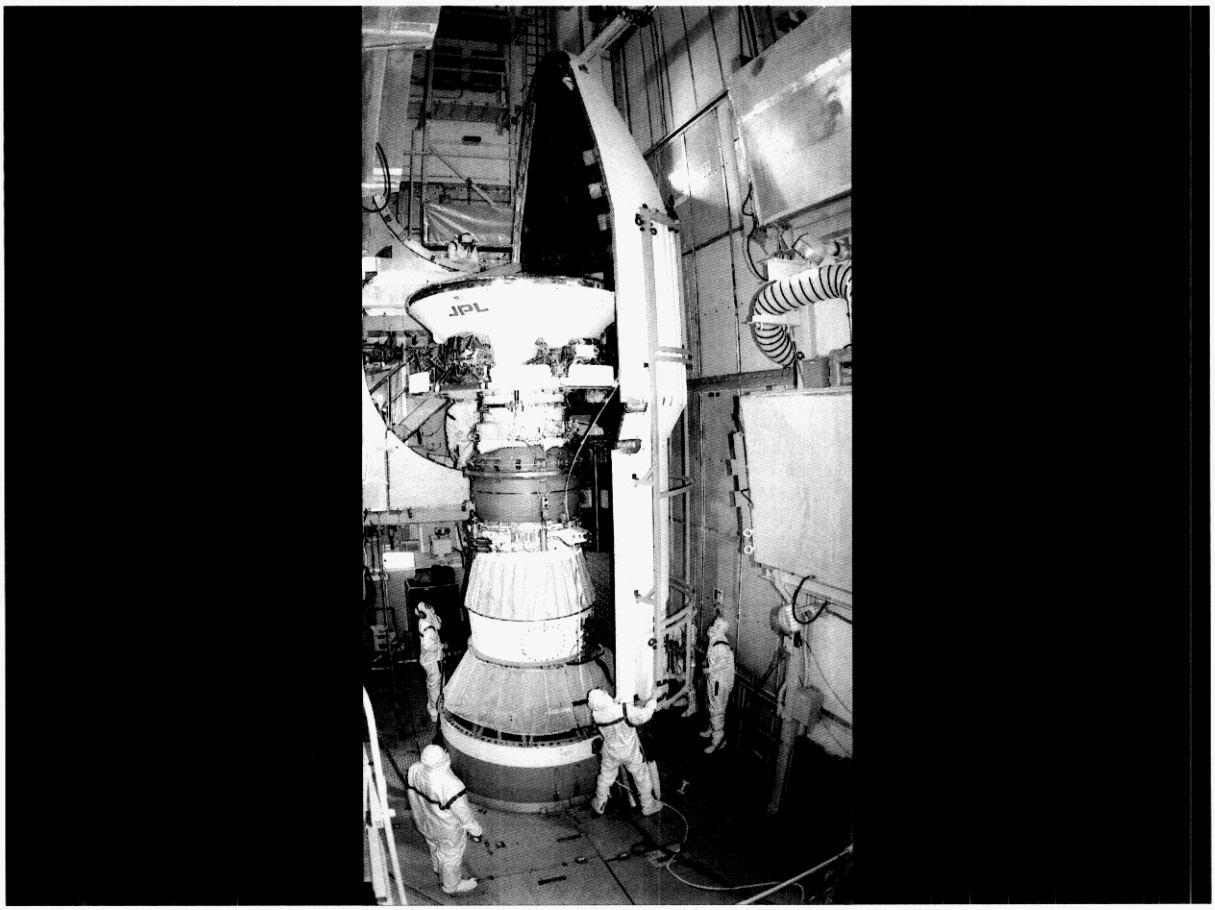
JPL

NASA

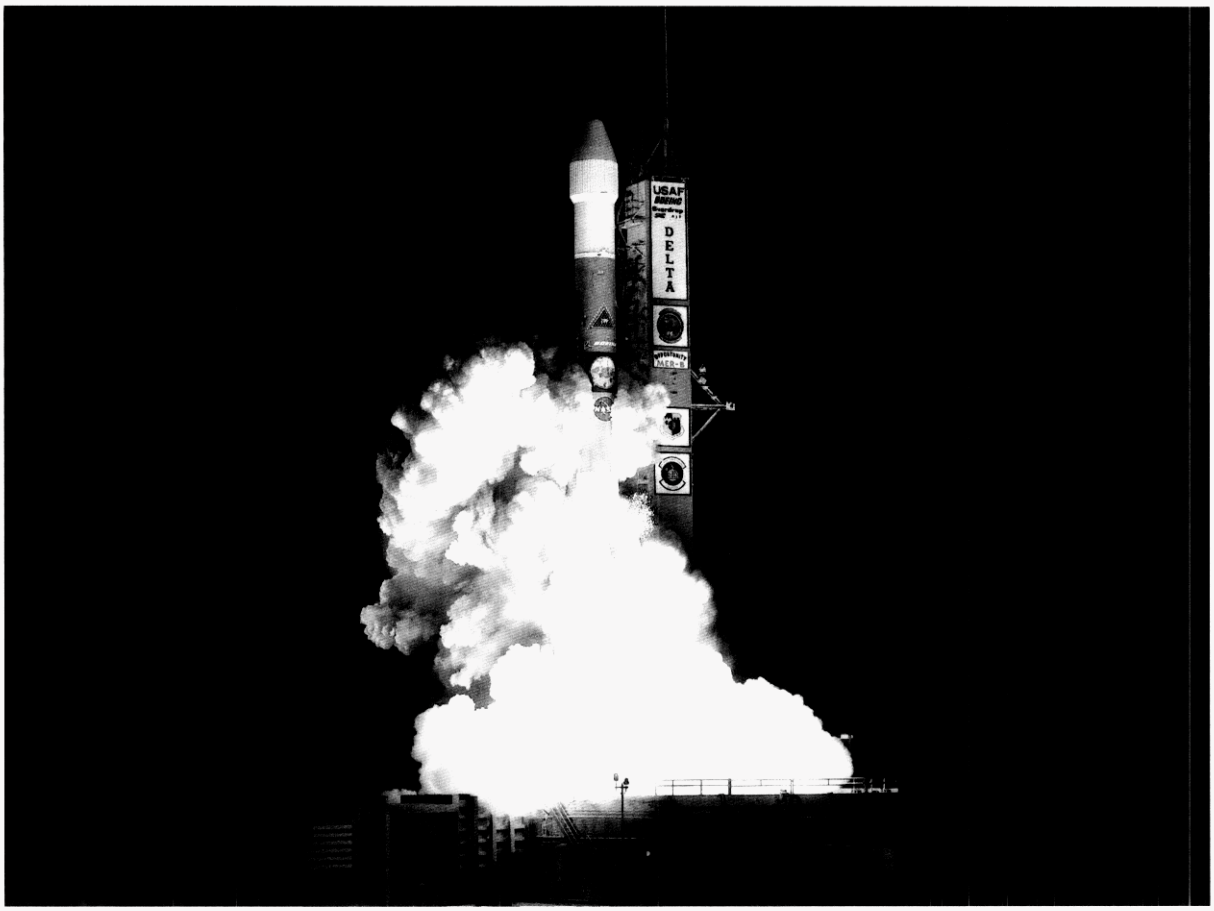

Mars is no longer a watery world
But could it have supported life in the past?

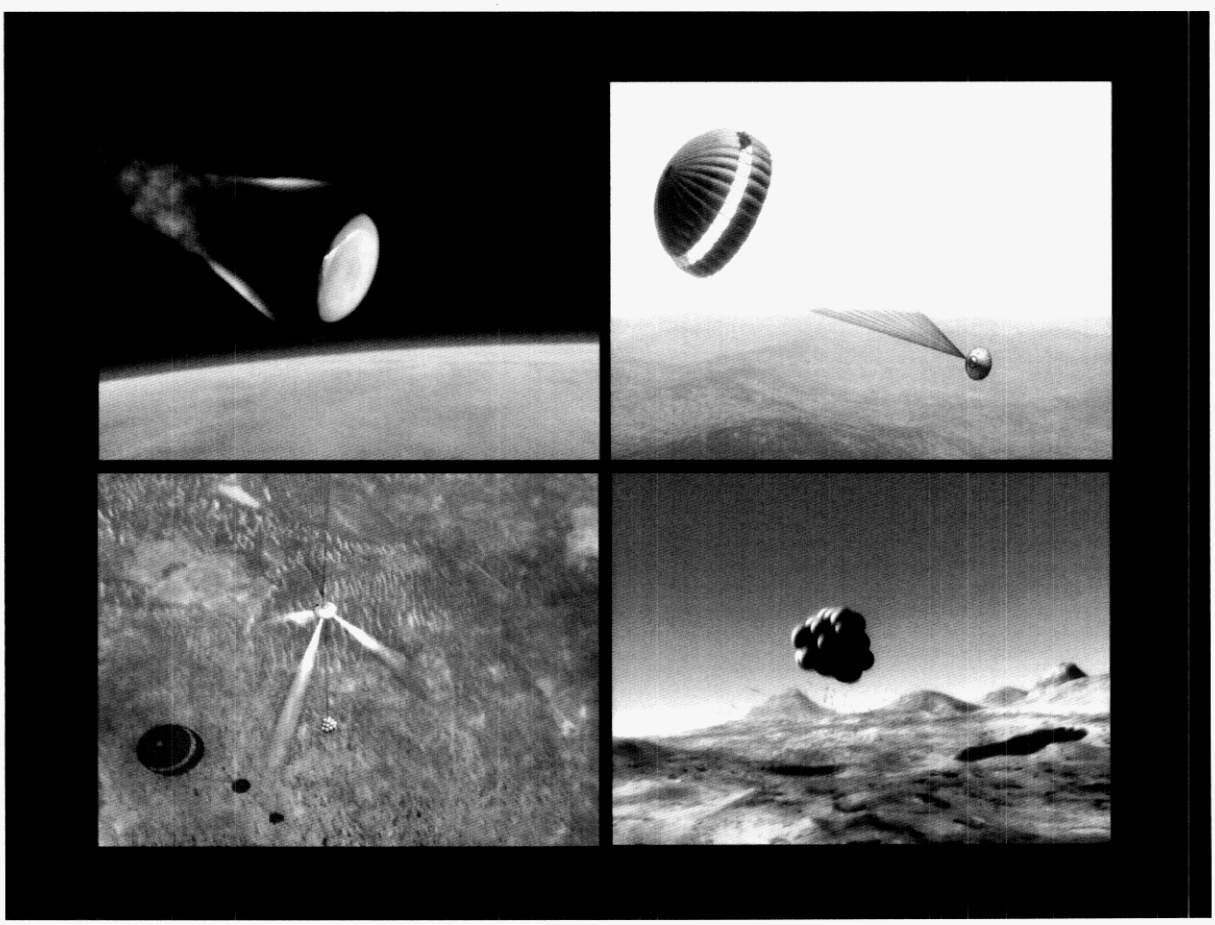


JPL


JPL

USAF
DELTA
MEP-A

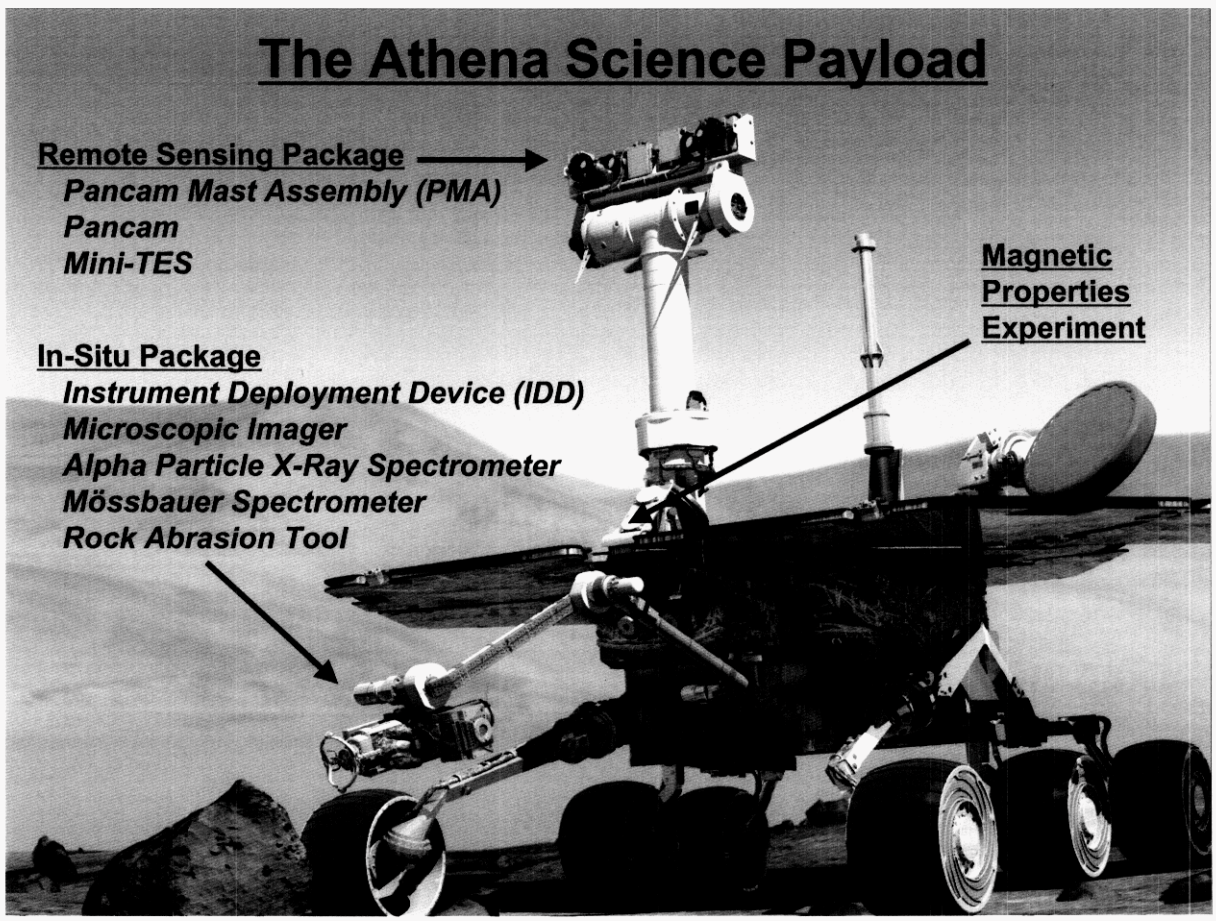

USAF
DELTA

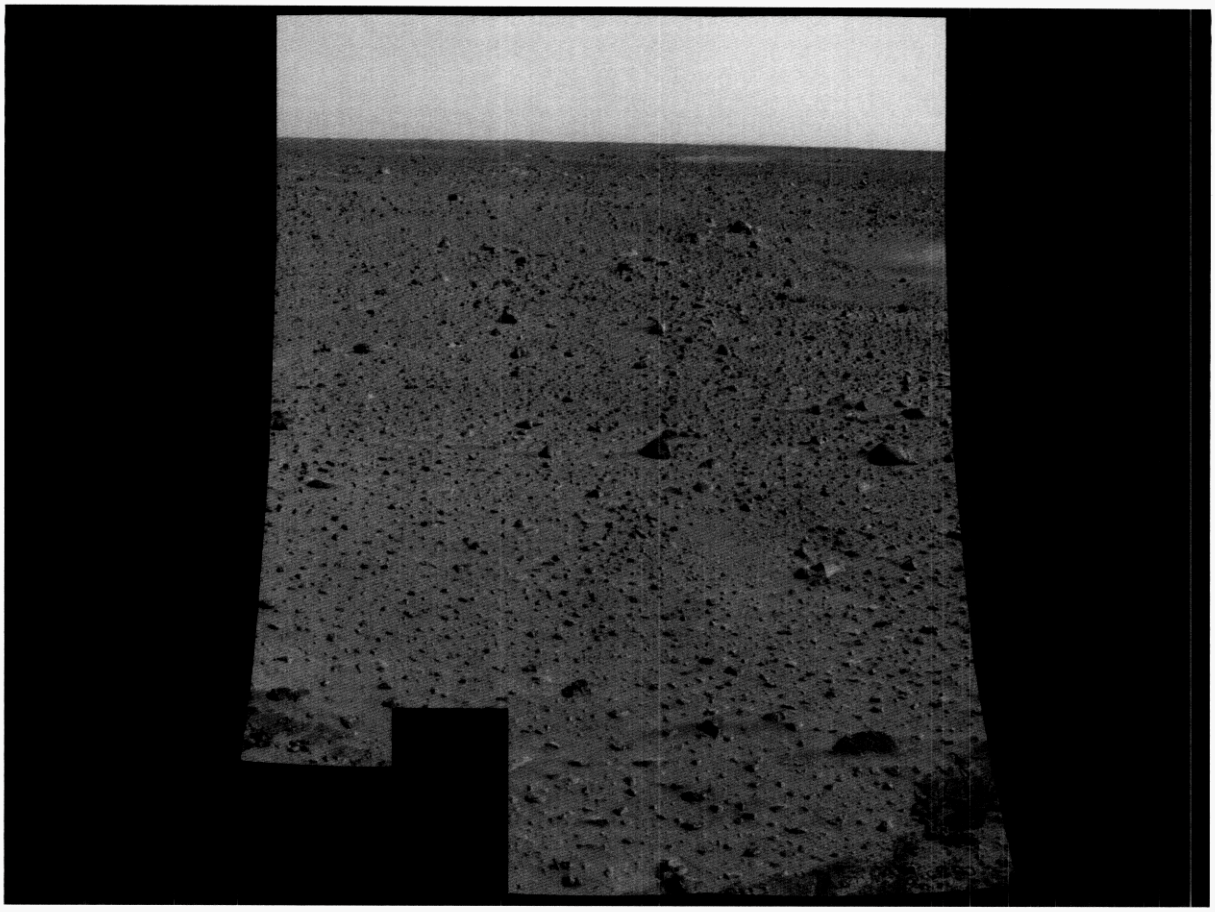


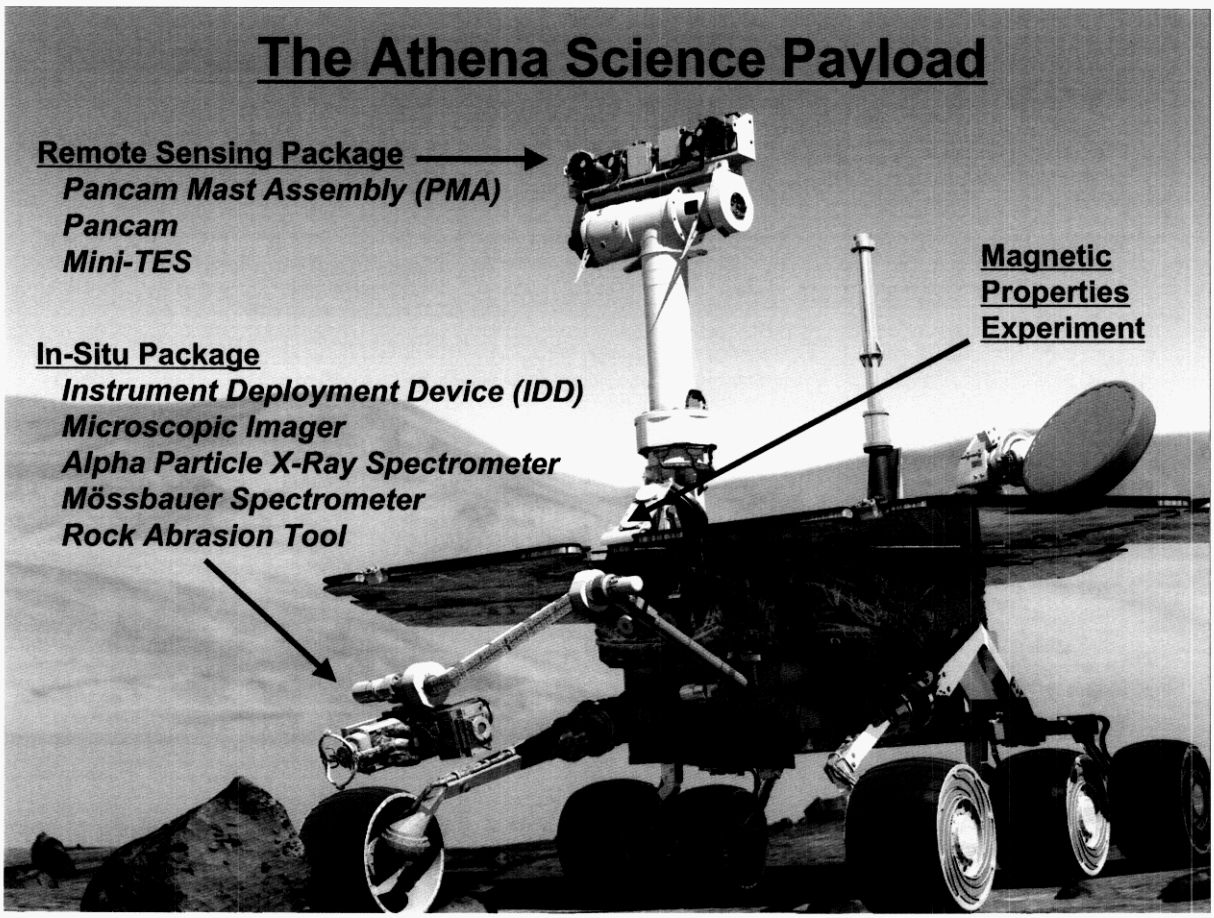
Science Objective

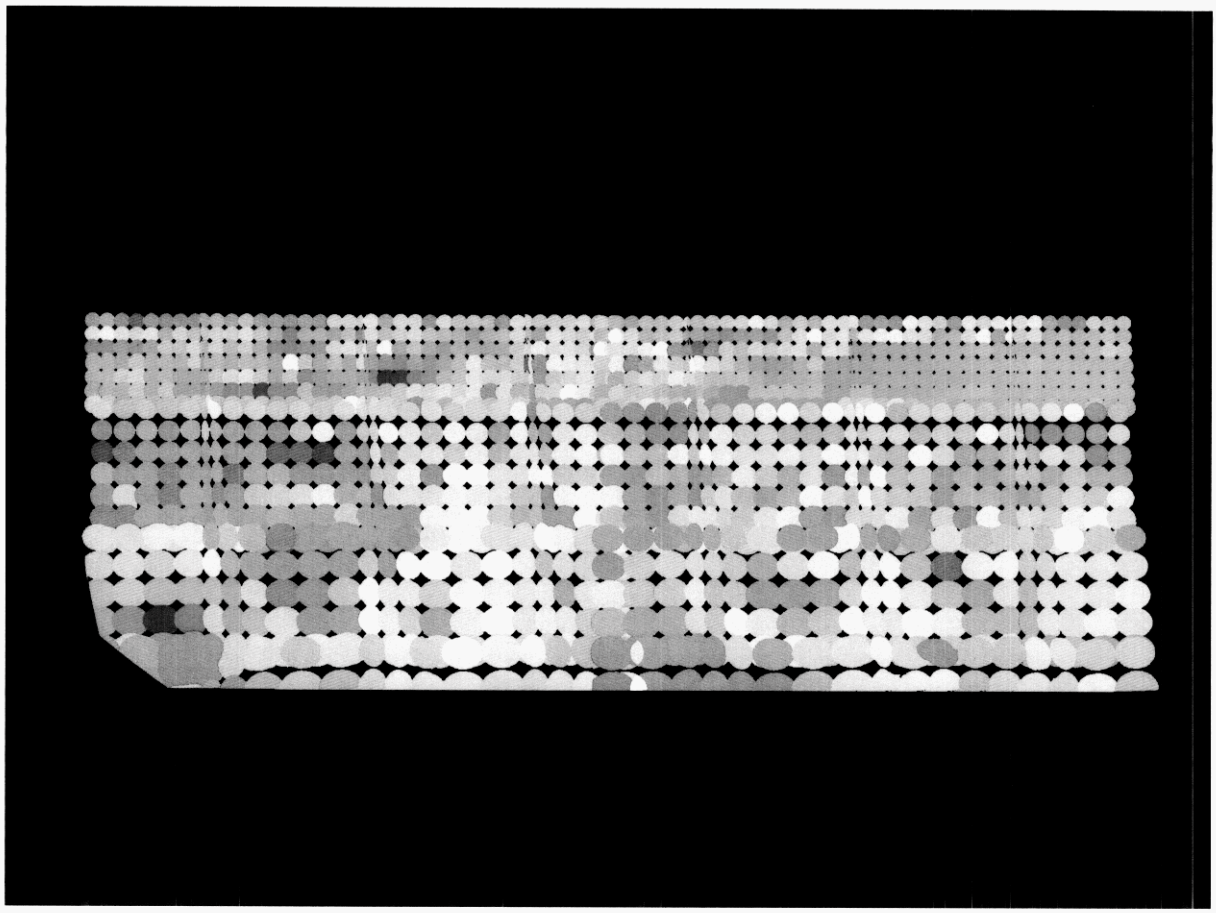
To determine the water, climate, and geologic history of two sites on Mars where evidence has been preserved for past and persistent liquid water activity that may have supported biotic or pre-biotic processes.

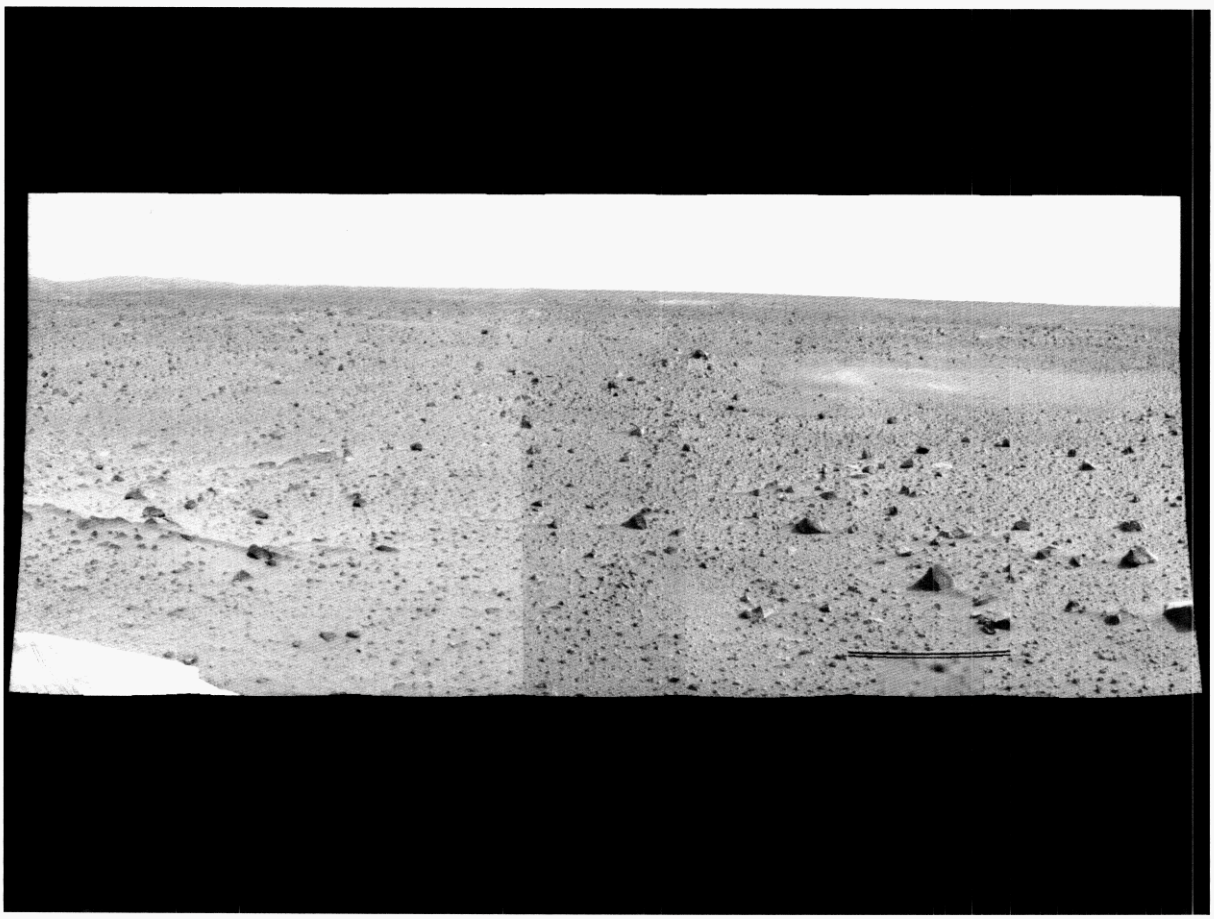
The Athena Science Payload

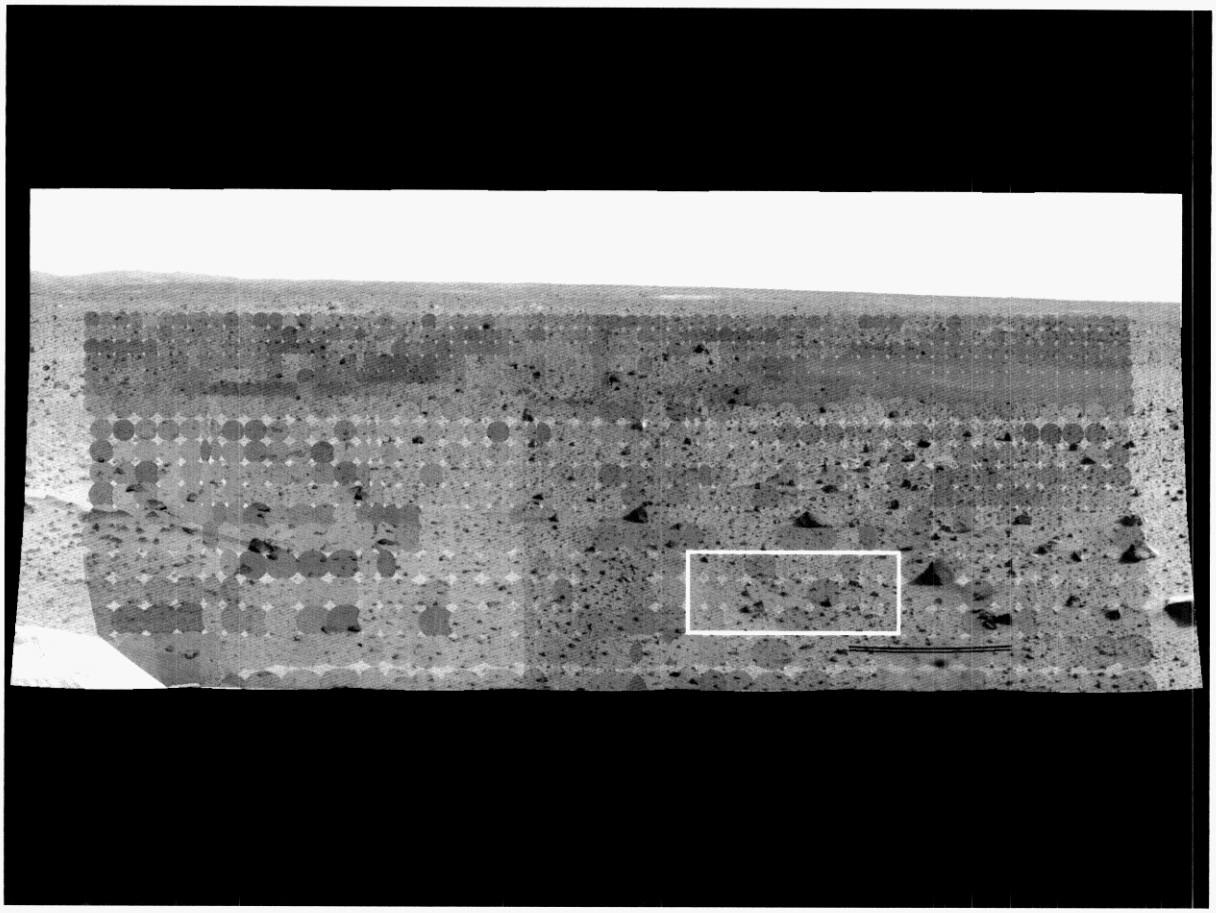


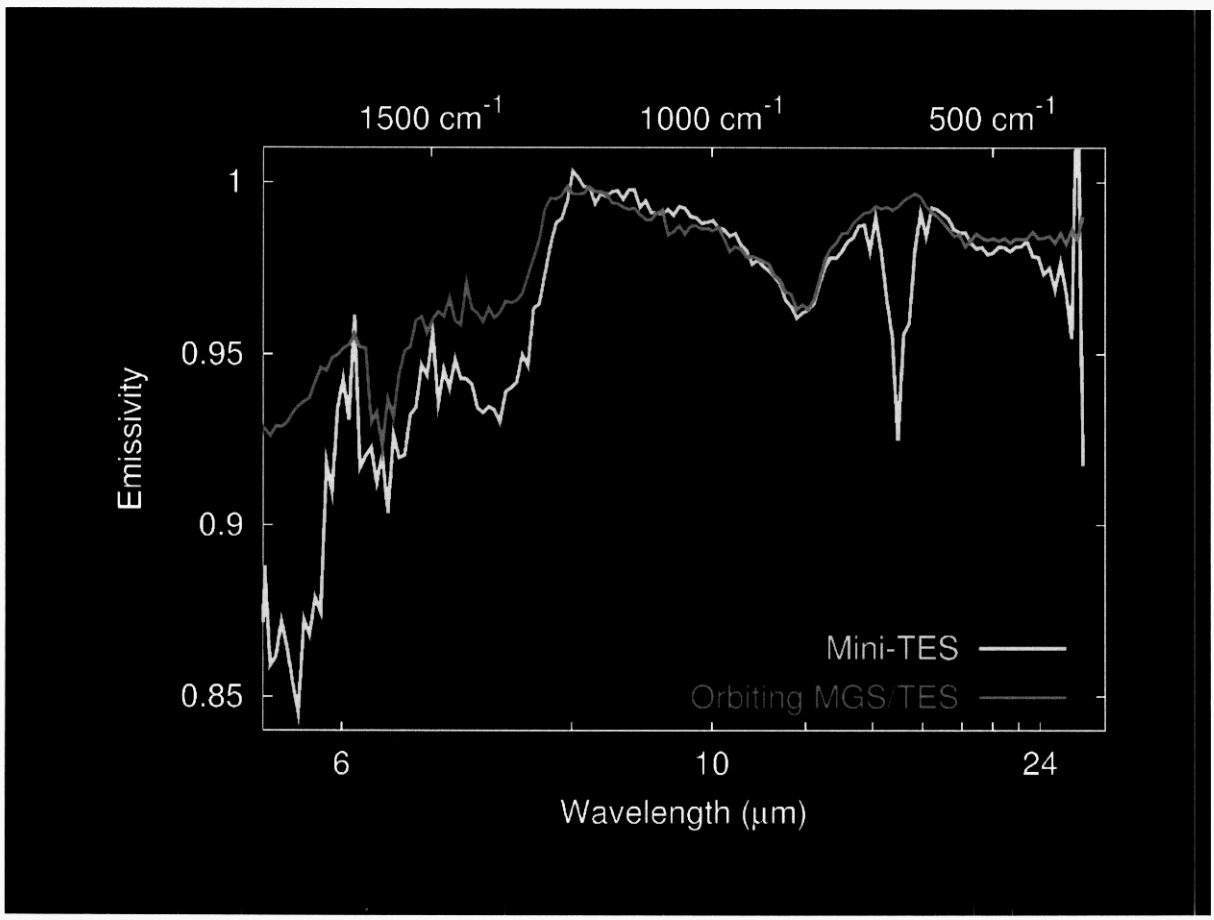


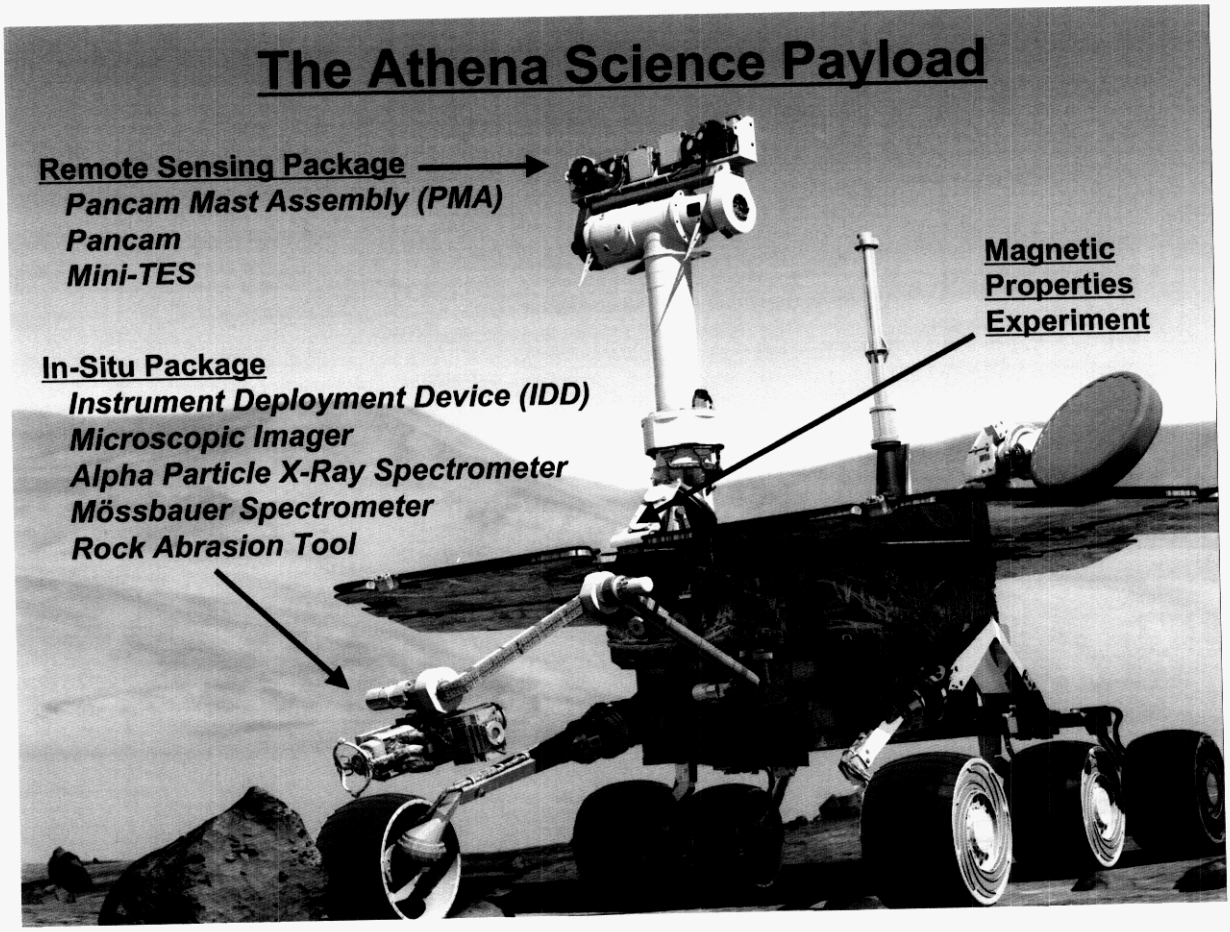

The Athena Science Payload
Remote Sensing Package
Pancam Mast Assembly (PMA)
Pancam
Mini-TES
In-Situ Package
Instrument Deployment Device (IDD)
Microscopic Imager
Alpha Particle X-Ray Spectrometer
Mössbauer Spectrometer
Rock Abrasion Tool
Magnetic Properties Experiment

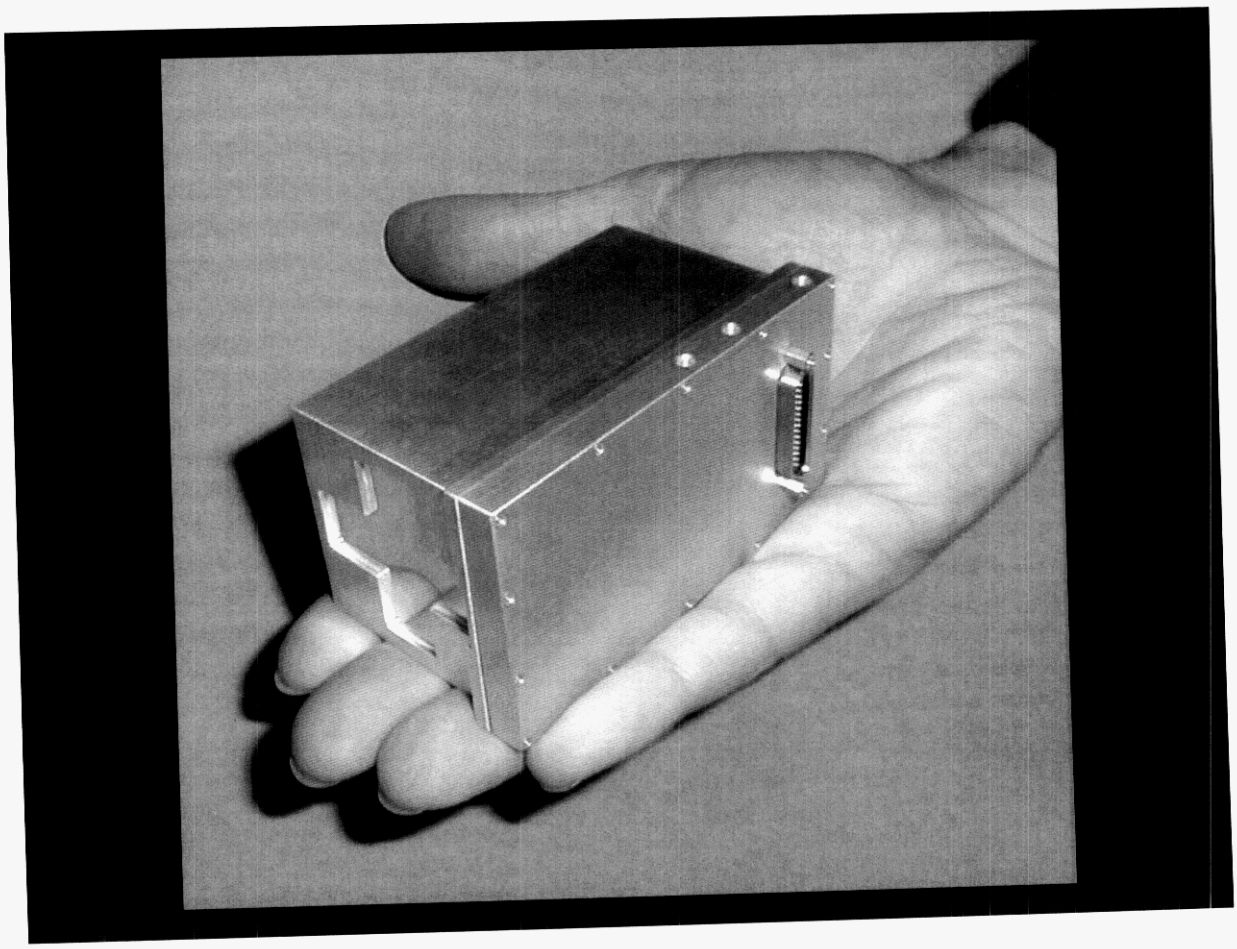


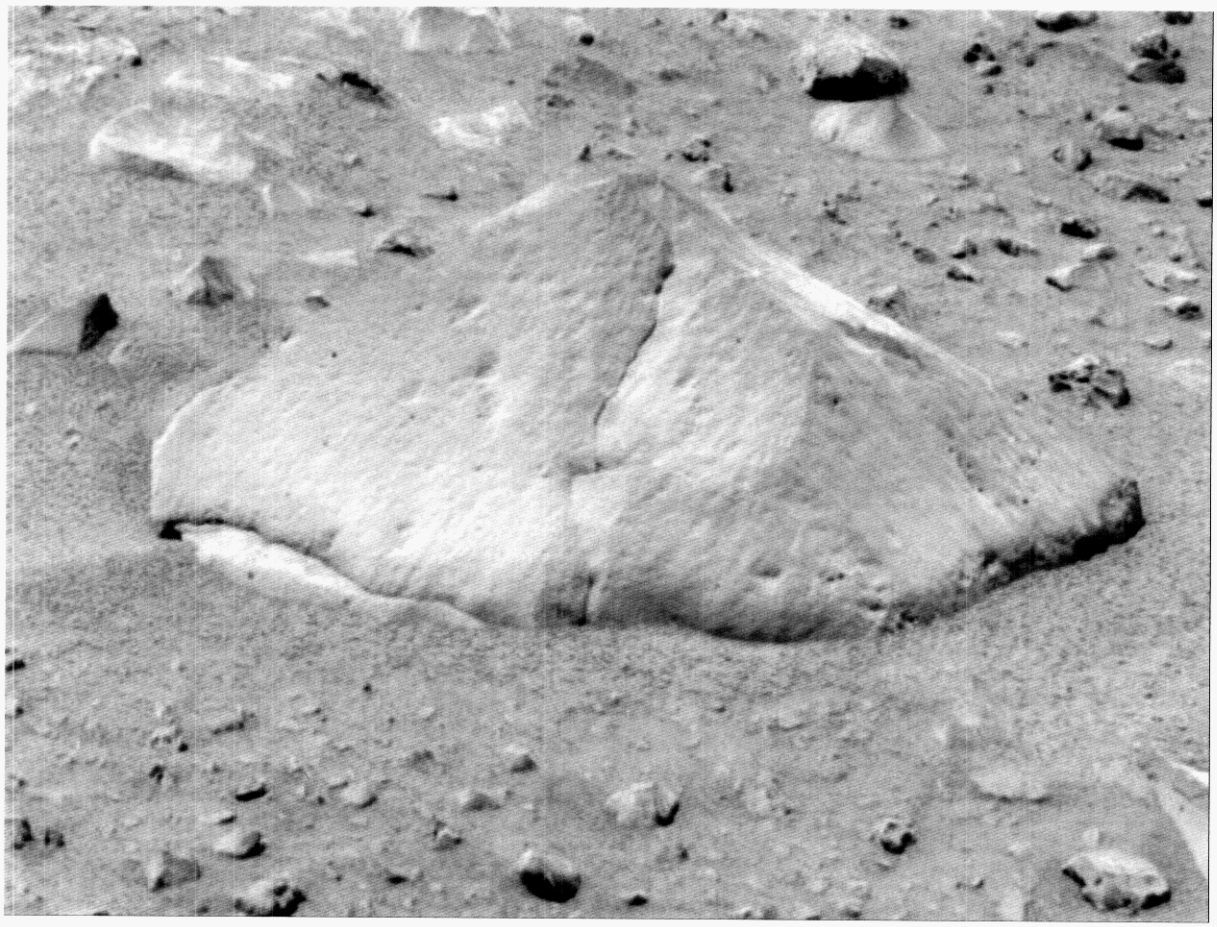


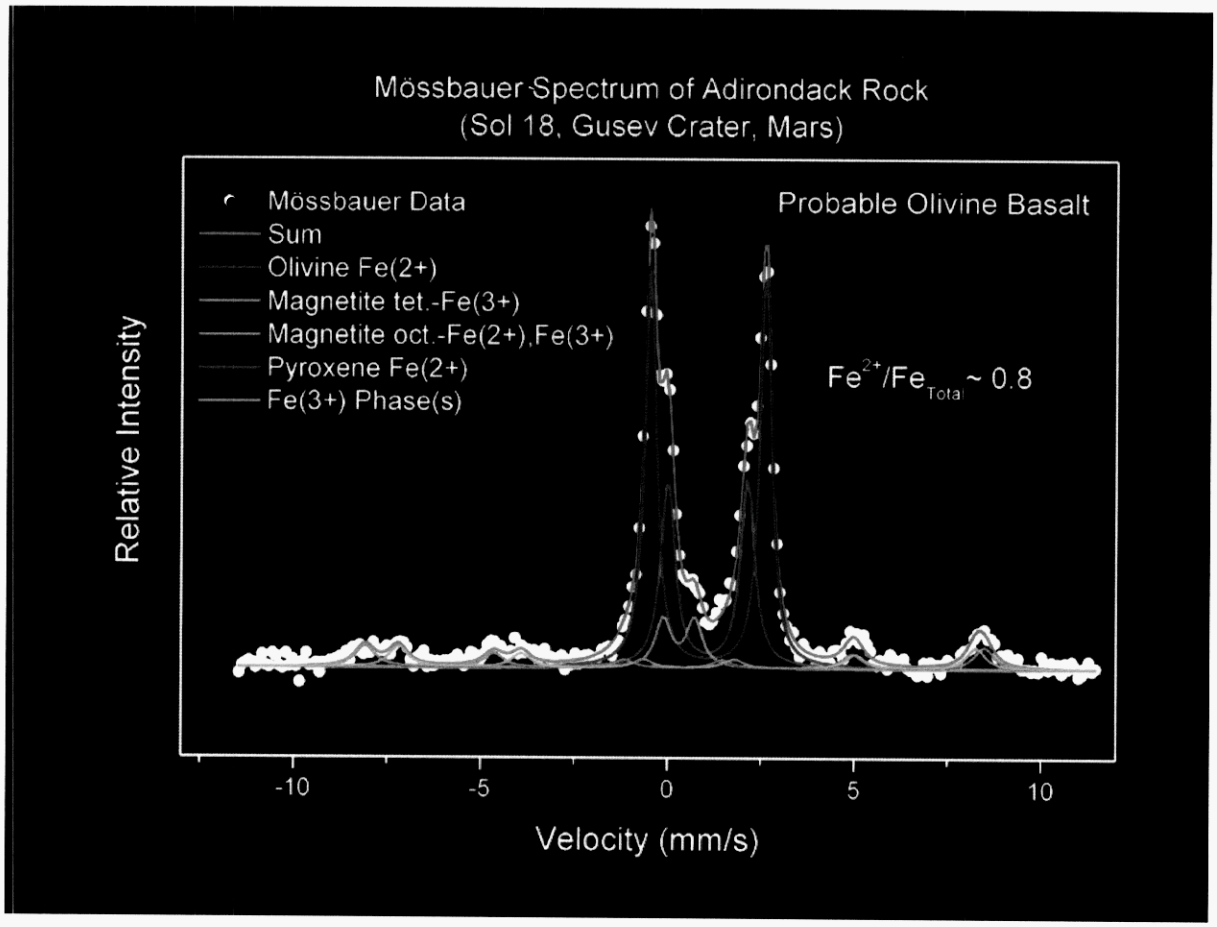


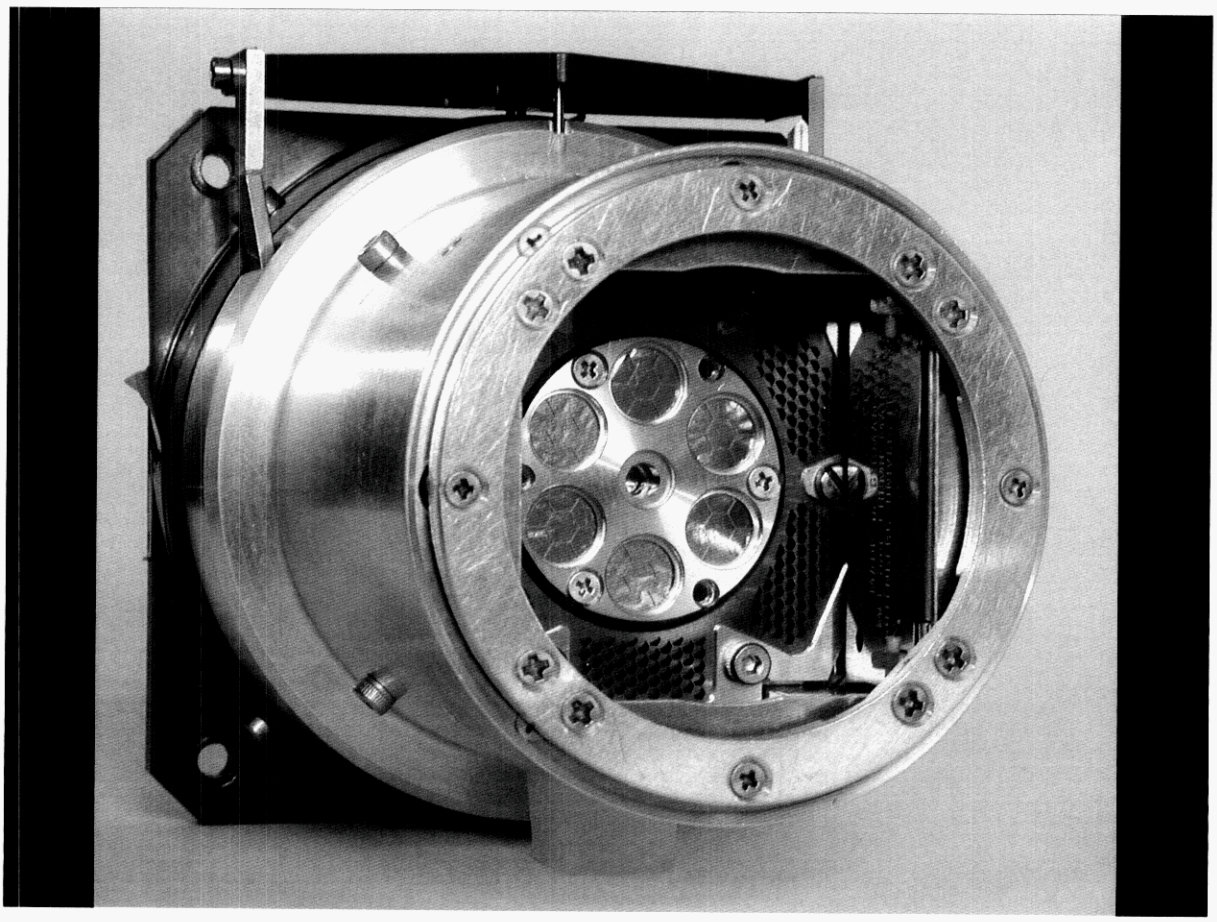

1500 cm-1
1000 cm-1
500 cm-1
1
0.95
0.9
0.85
Emissivity
Mini-TES
Orbiting MGS/TES
6
10
24
Wavelength (μm)

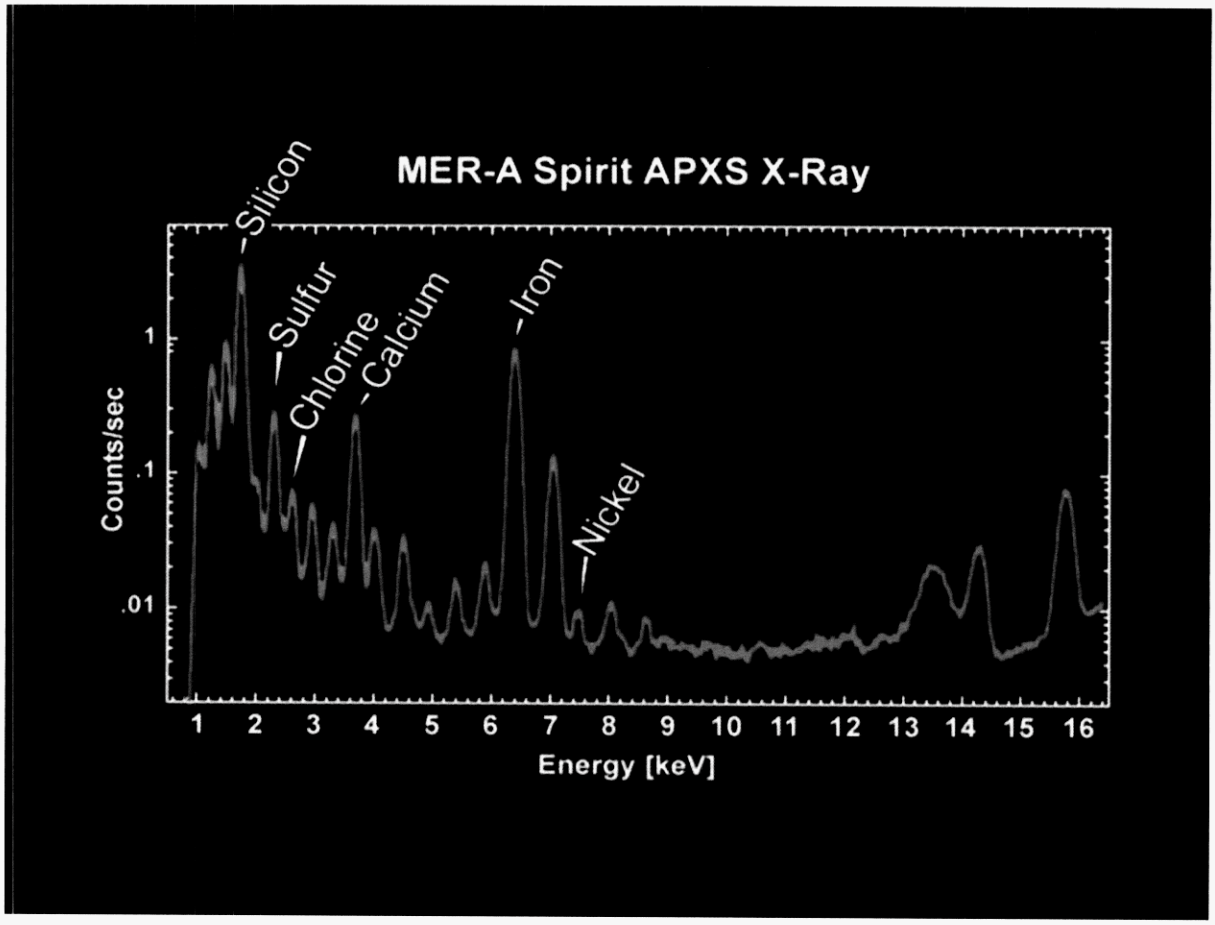

The Athena Science Payload
Remote Sensing Package
Pancam Mast Assembly (PMA)
Pancam
Mini-TES
Magnetic Properties Experiment
In-Situ Package
Instrument Deployment Device (IDD)
Microscopic Imager
Alpha Particle X-Ray Spectrometer
Mössbauer Spectrometer
Rock Abrasion Tool

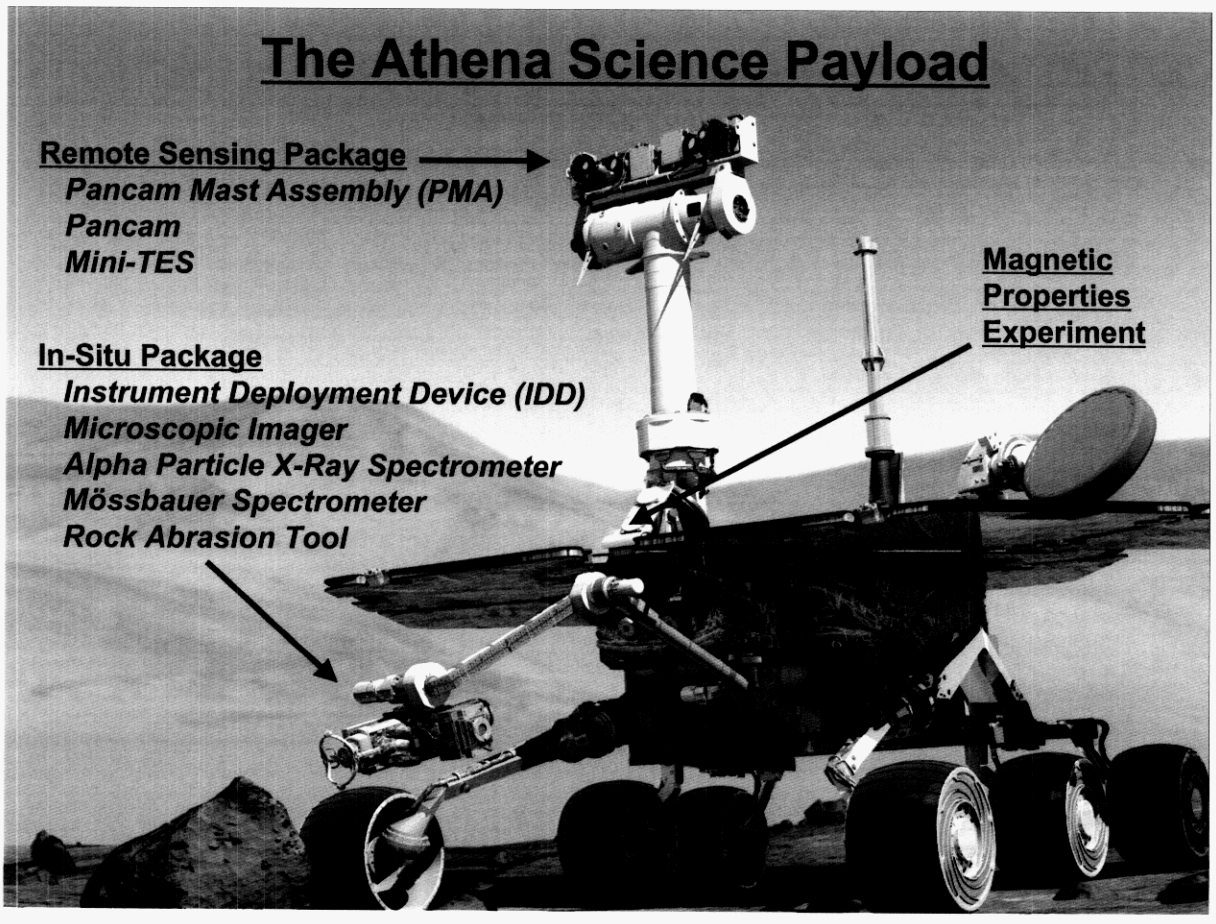


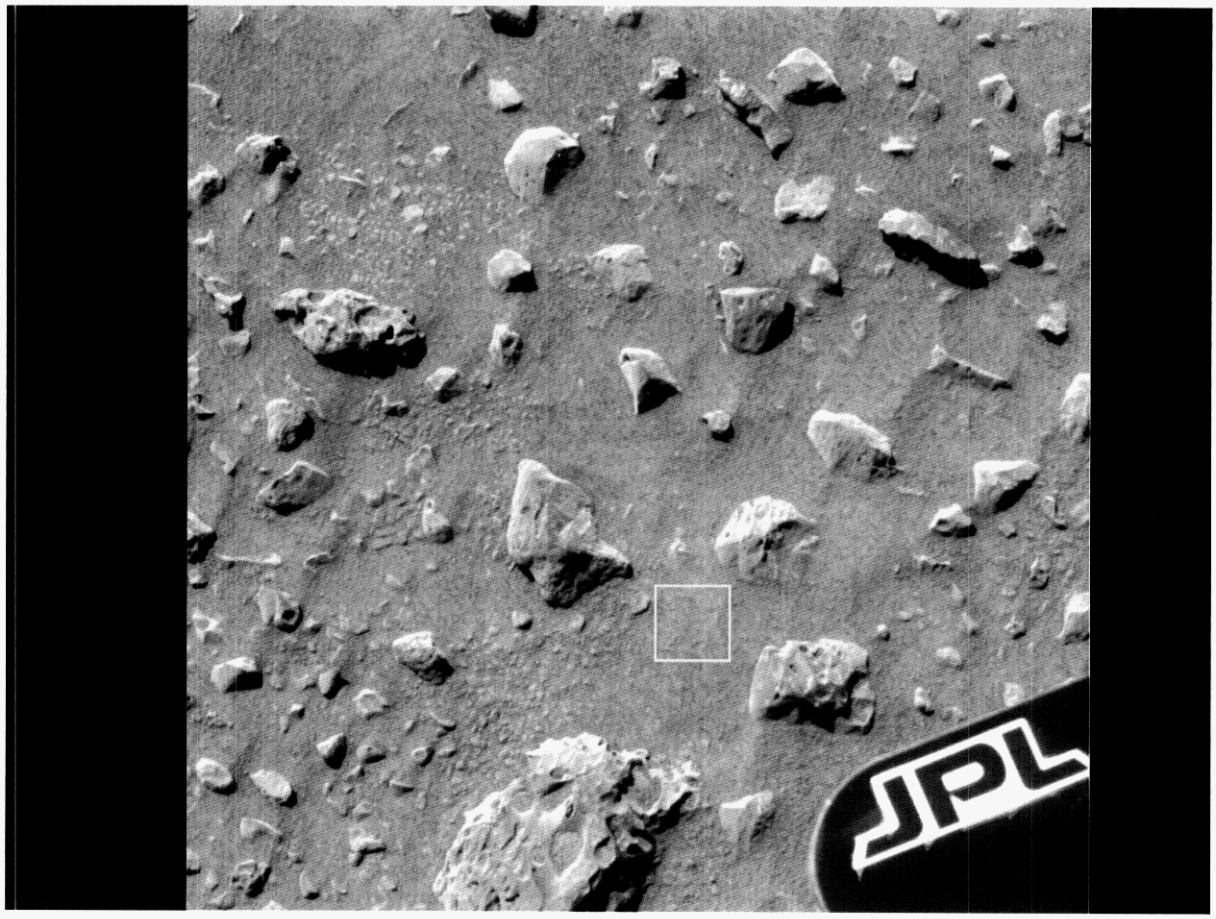


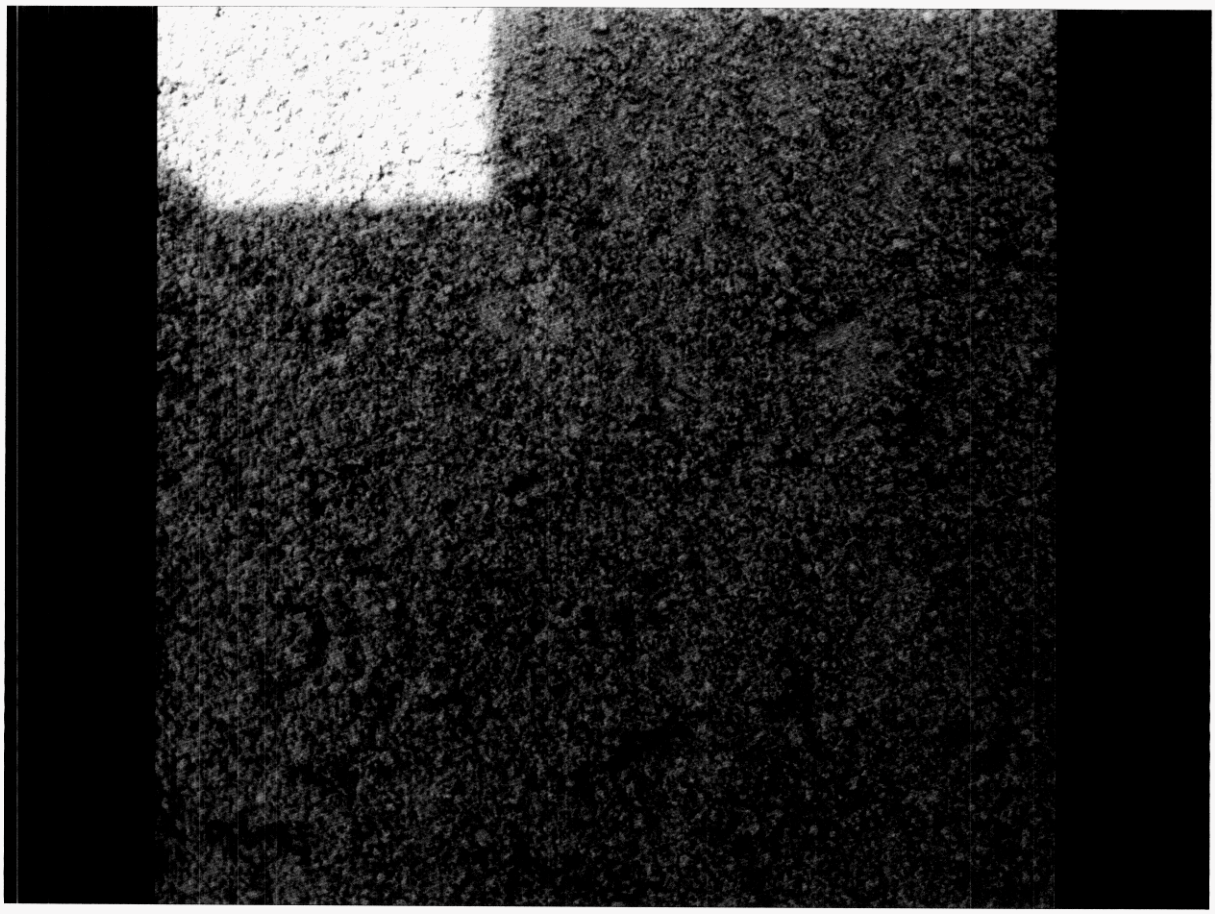

Mössbauer Spectrum of Adirondack Rock
(Sol 18, Gusev Crater, Mars)
Mössbauer Data
Sum
Olivine Fe(2+)
Magnetite tet.-Fe(3+)
Magnetite oct.-Fe(2+),Fe(3+)
Pyroxene Fe(2+)
Fe(3+) Phase(s)
Probable Olivine Basalt
$Fe^{2+}/Fe_{Total} \sim 0.8$
Relative Intensity
-10
-5
0
5
10
Velocity (mm/s)

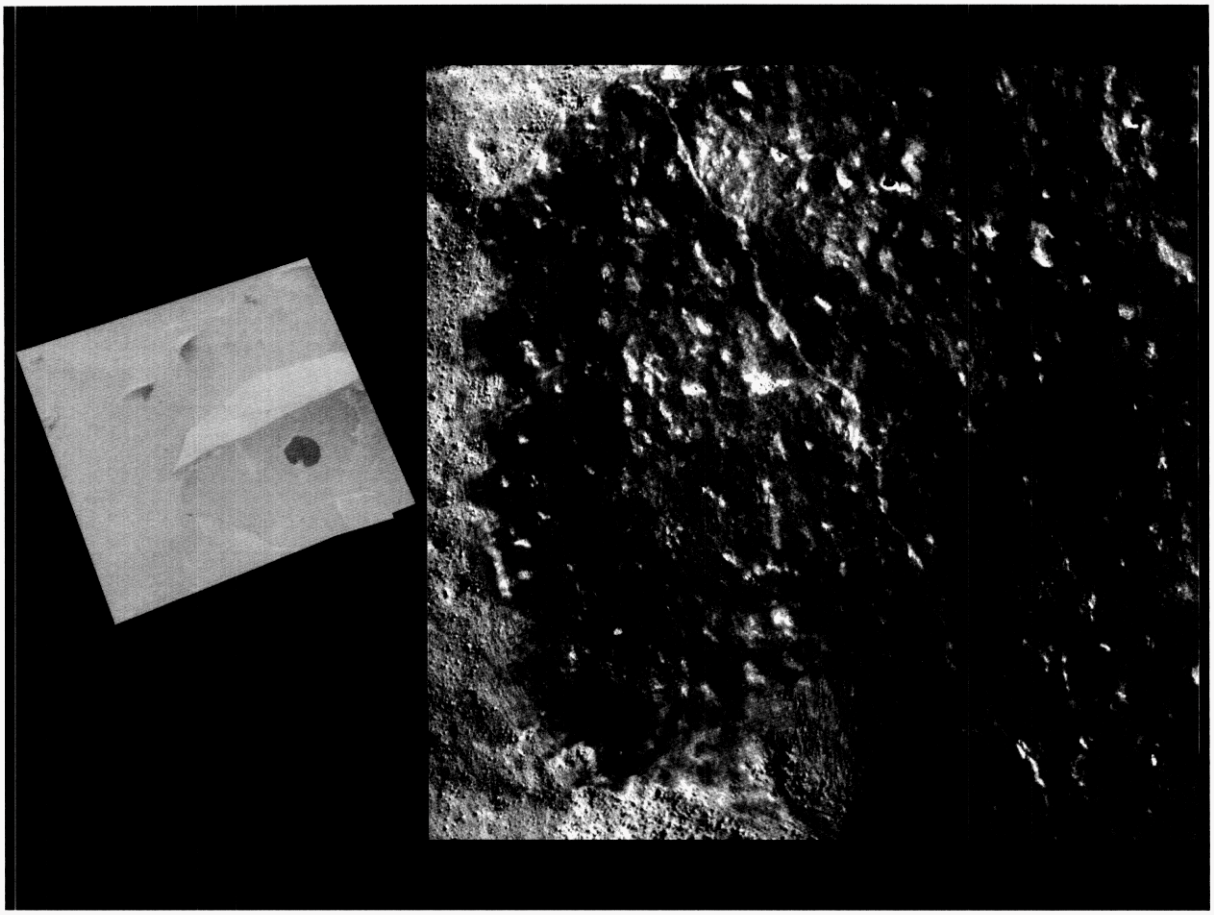


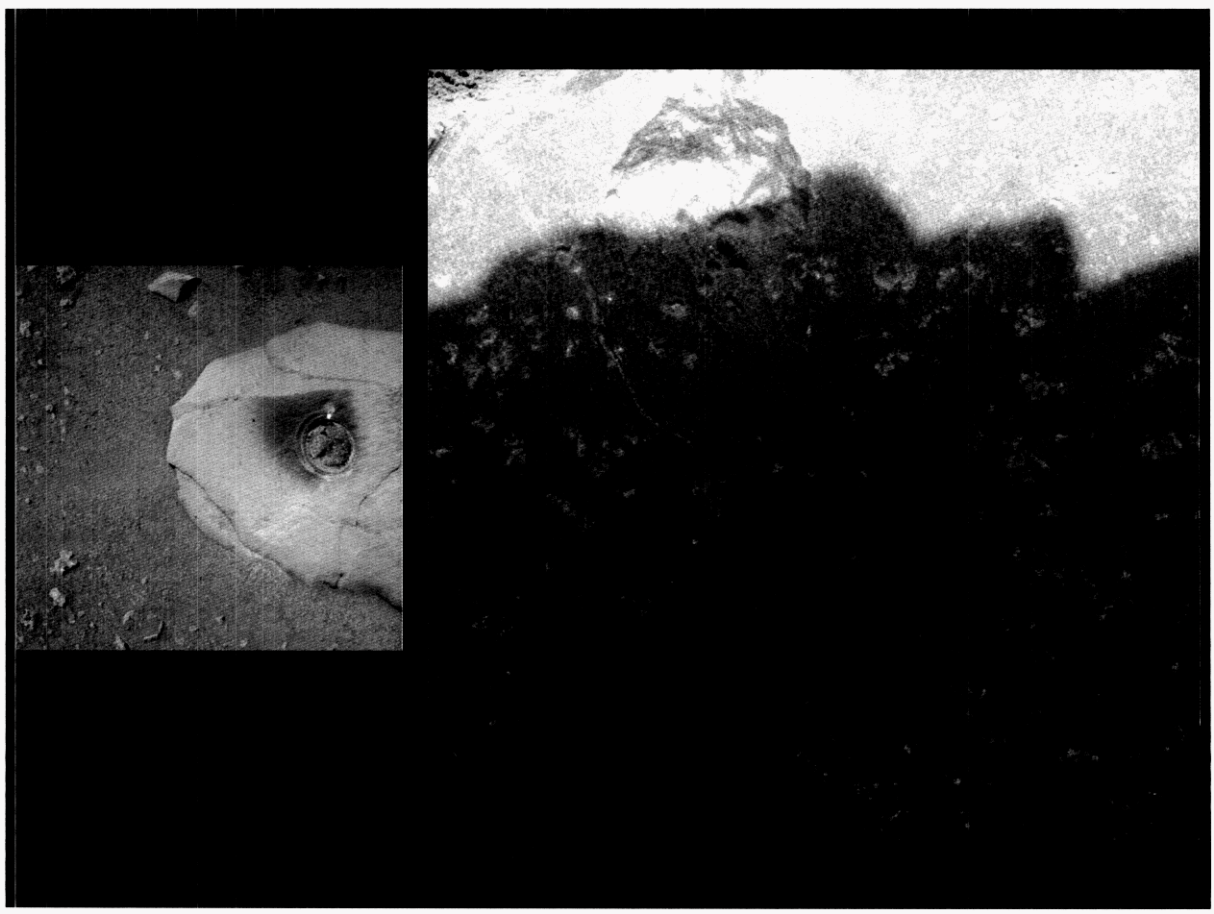

MER-A Spirit APXS X-Ray
Silicon
Sulfur
Chlorine
Calcium
Iron
Nickel
Counts/sec
1
.1
.01
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Energy [keV]


The Athena Science Payload
Remote Sensing Package
Pancam Mast Assembly (PMA)
Pancam
Mini-TES
In-Situ Package
Instrument Deployment Device (IDD)
Microscopic Imager
Alpha Particle X-Ray Spectrometer
Mössbauer Spectrometer
Rock Abrasion Tool
Magnetic Properties Experiment


JPL

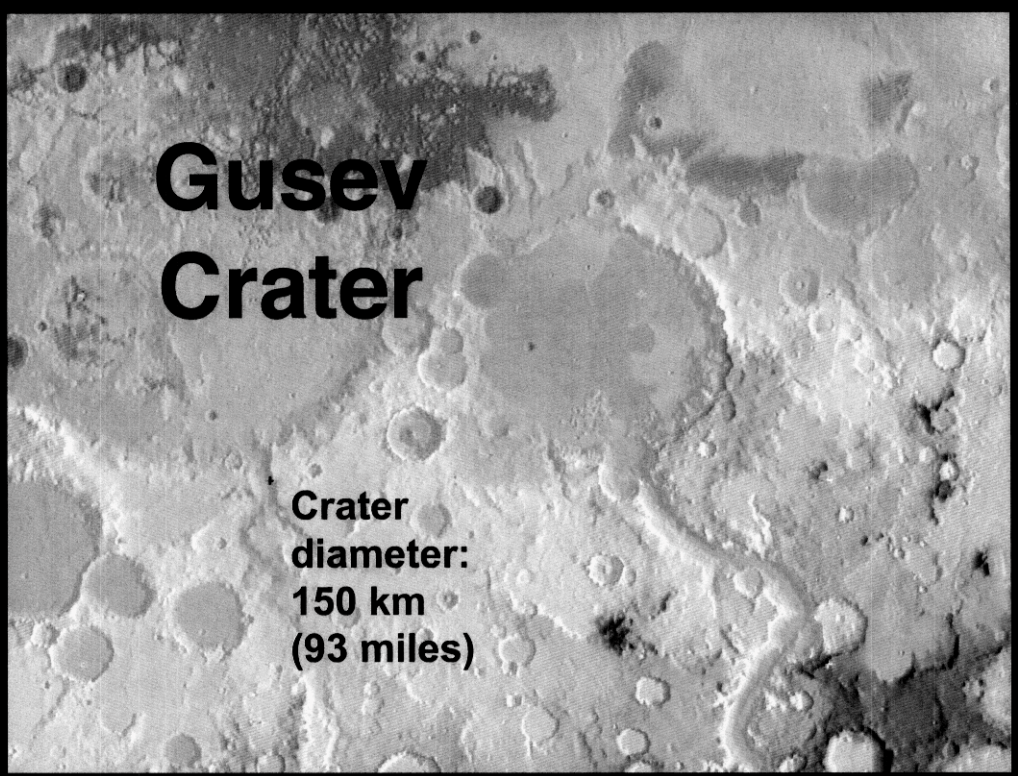


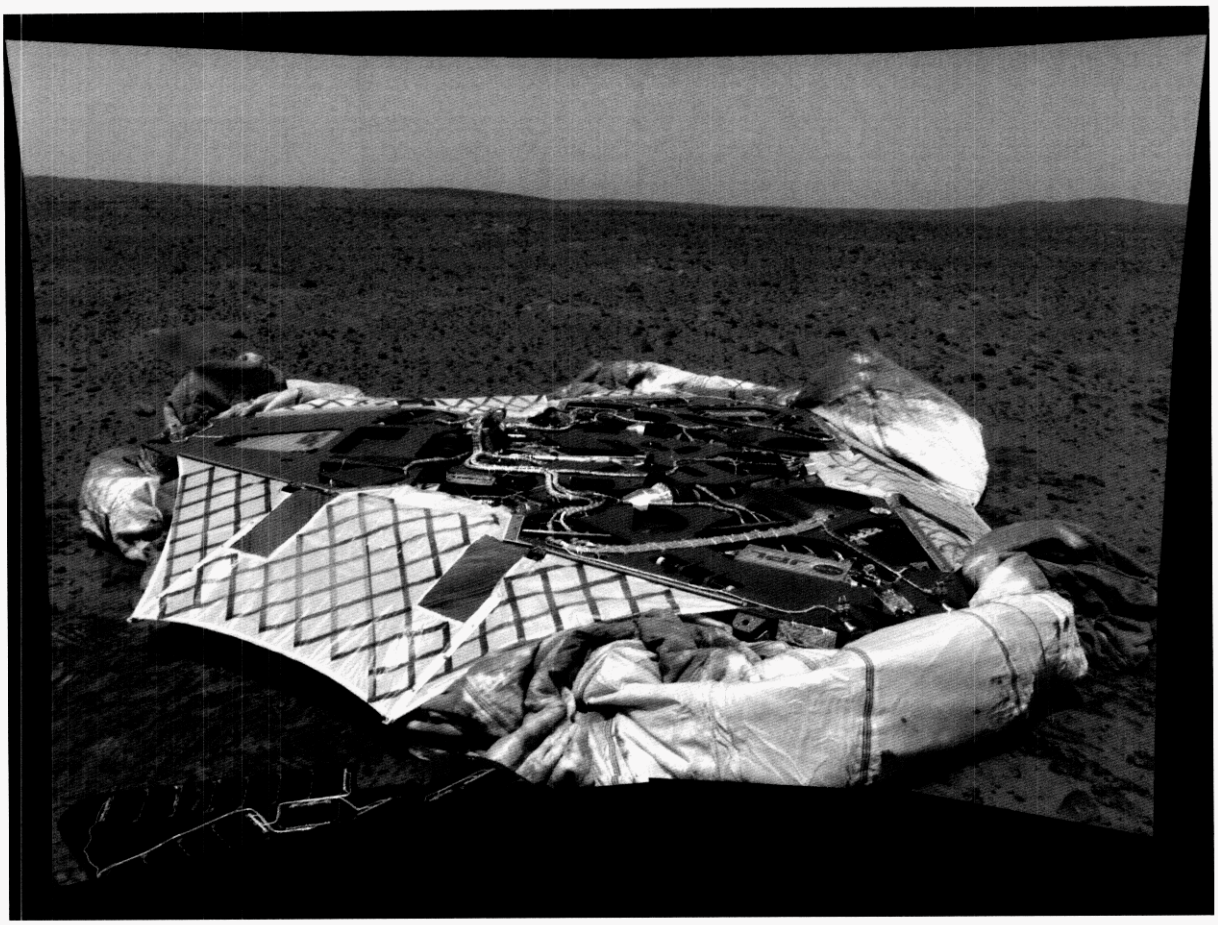


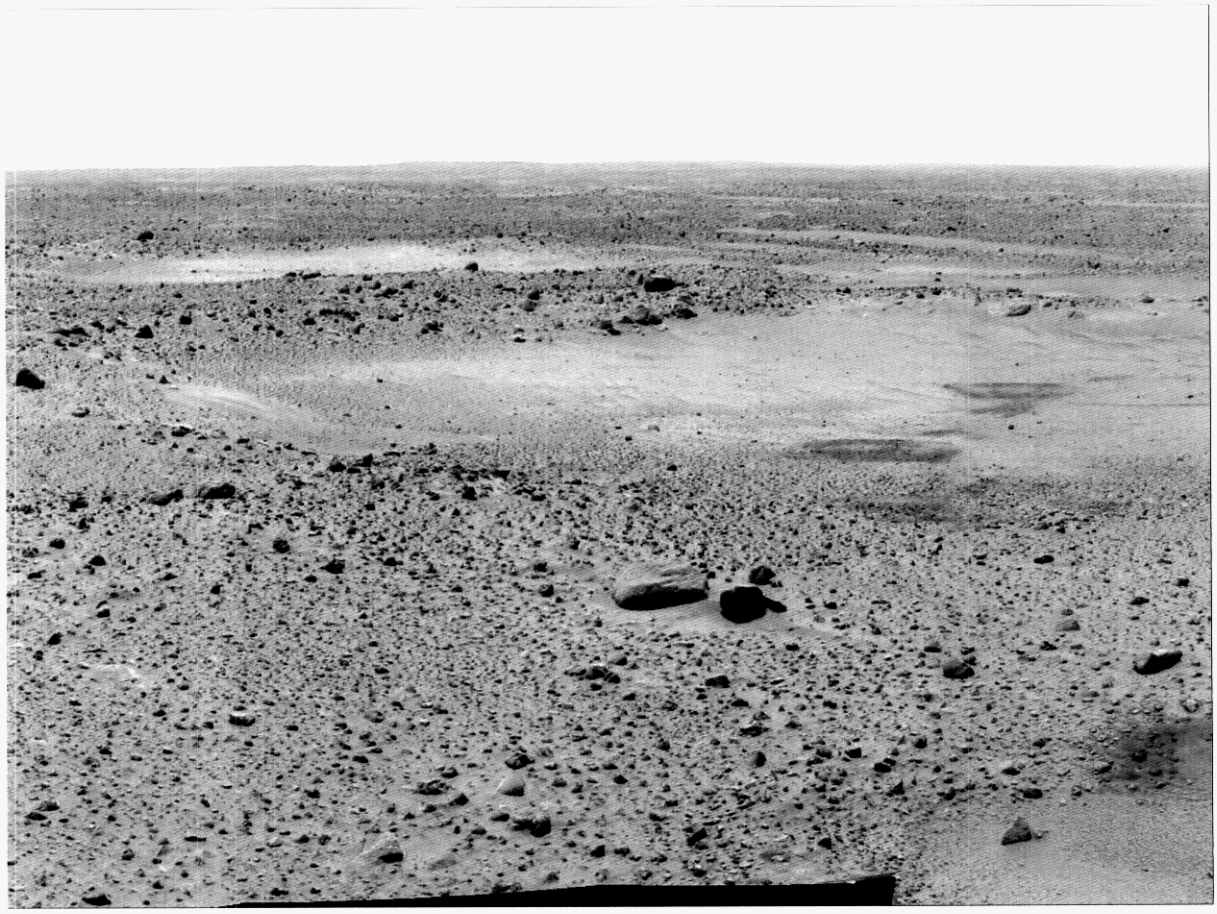


Spirit

20:40 PDT = Sol 612 11:36 LST-A

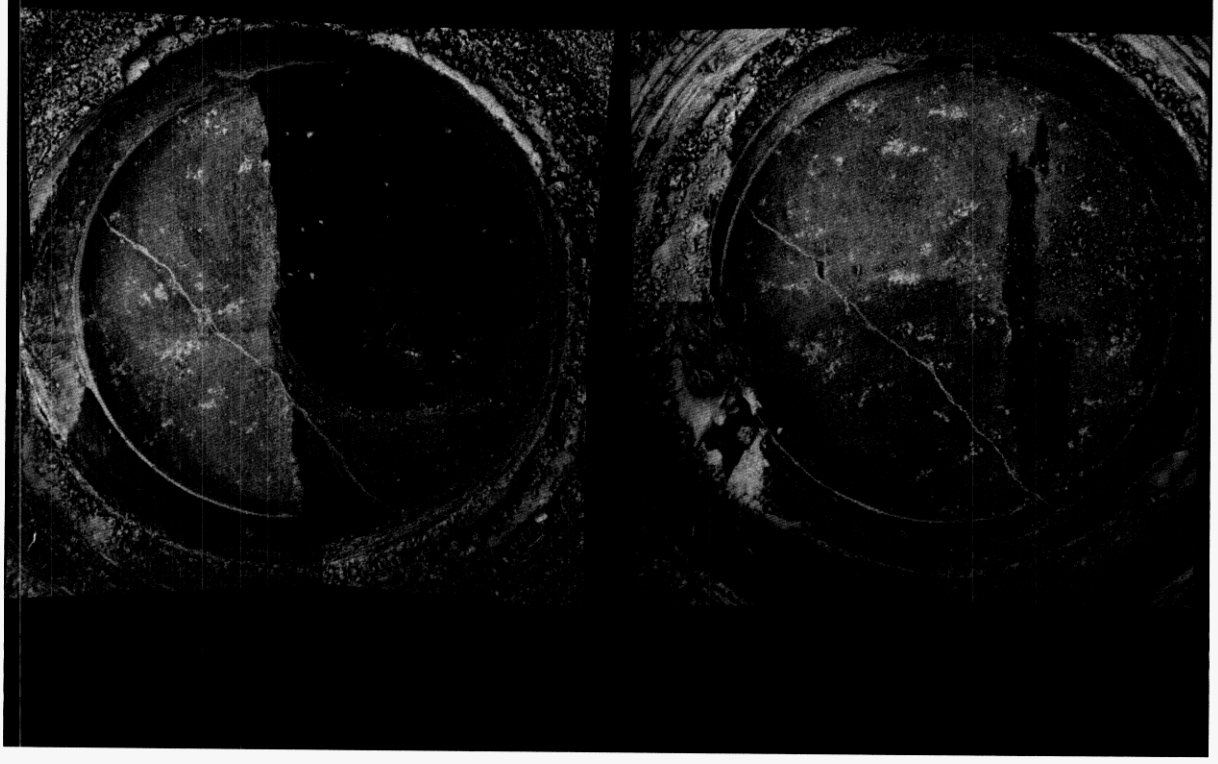


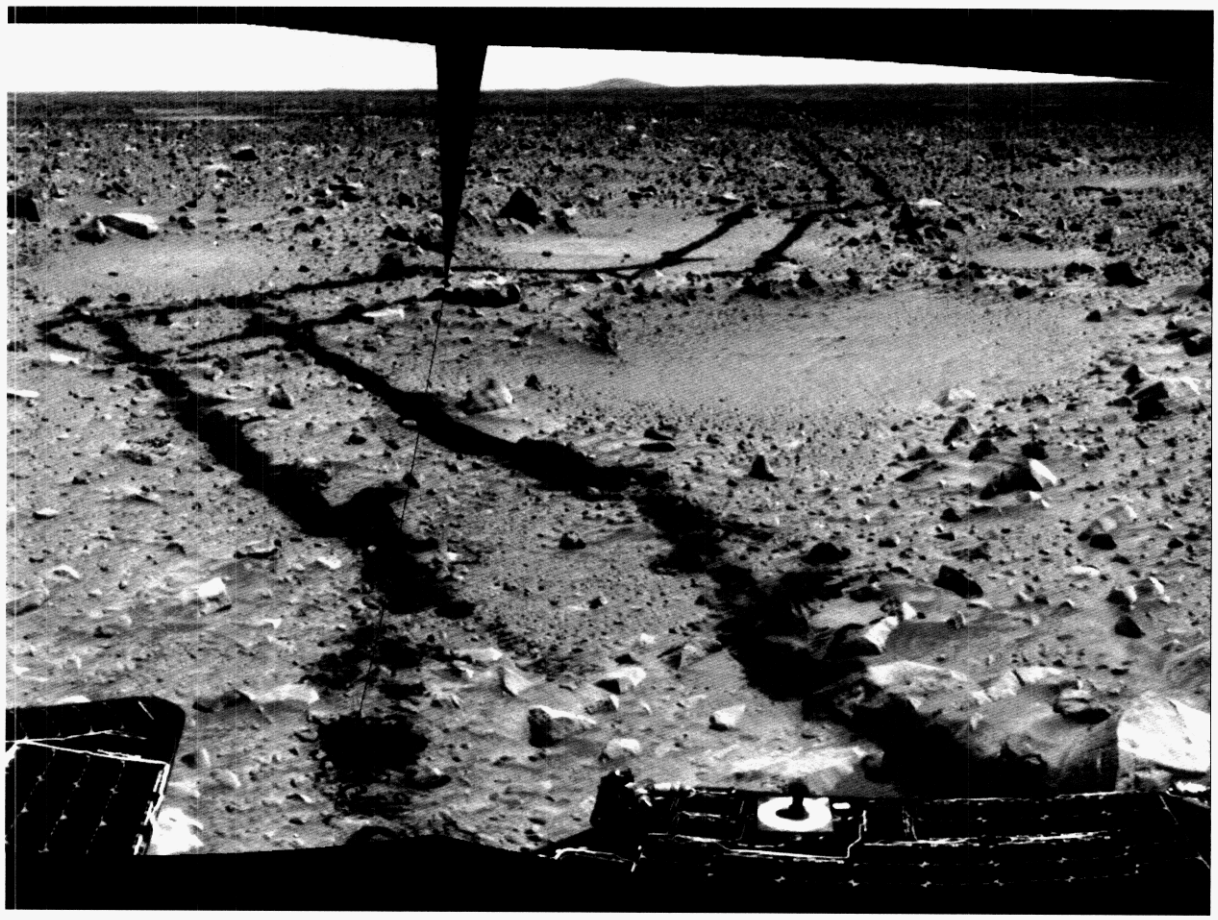


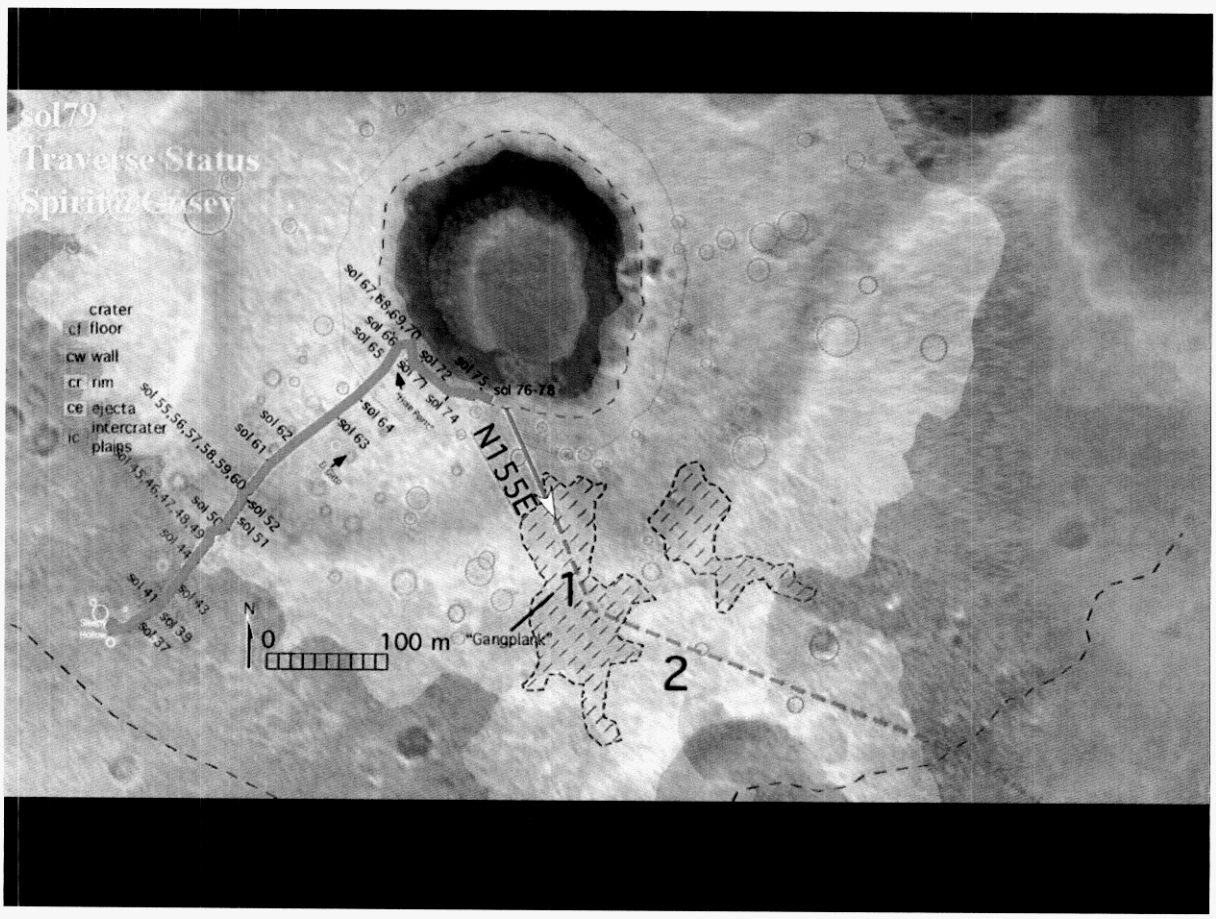


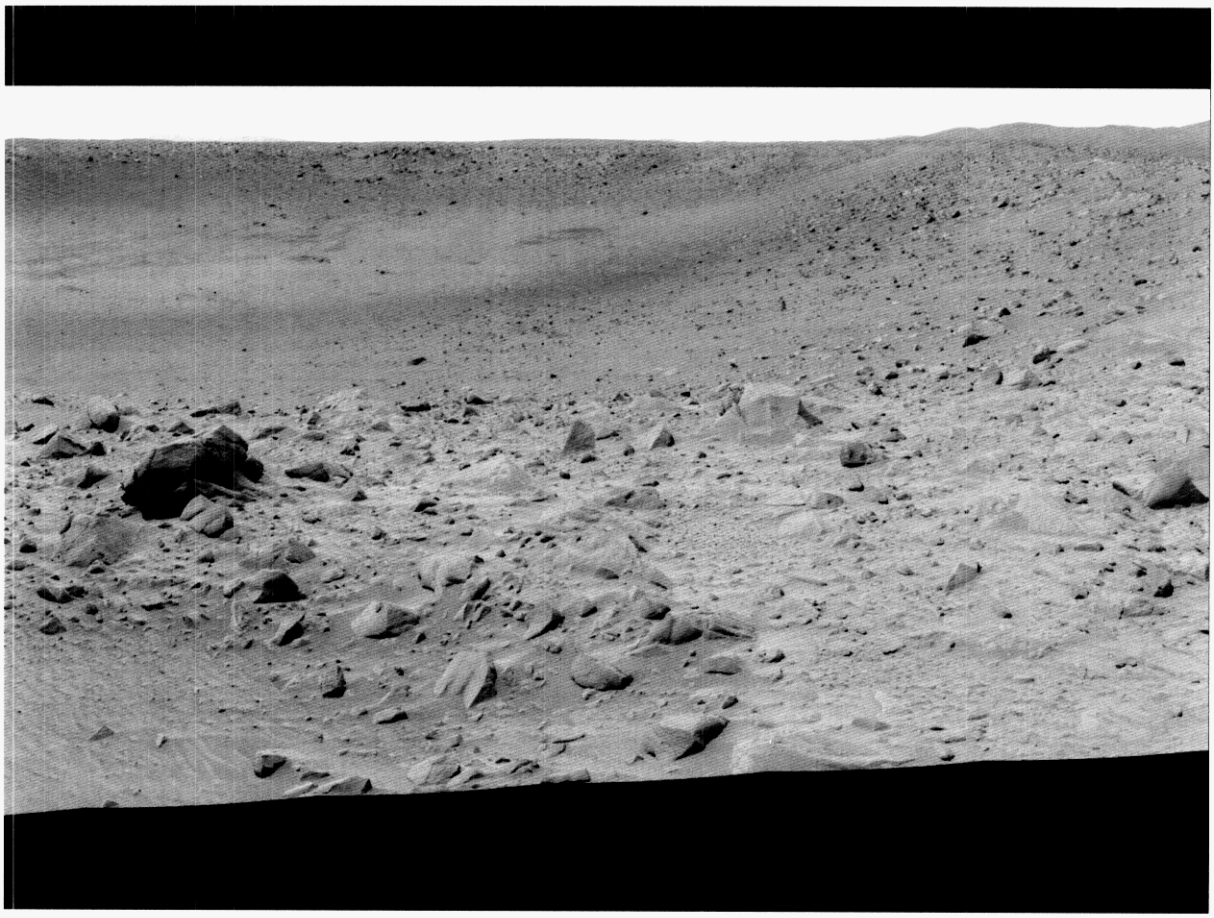
Gusev (B011 soil?)
Adirondack "as is", 5min
Adirondack after Brush
Adirondack after RAT
Crest, morning
Mimi
Track
Trench Floor
100
10
1
0.1
0.01
wt %
MgO
Al2O3
SiO2
SO3
Cl
K2O
CaO
FeO

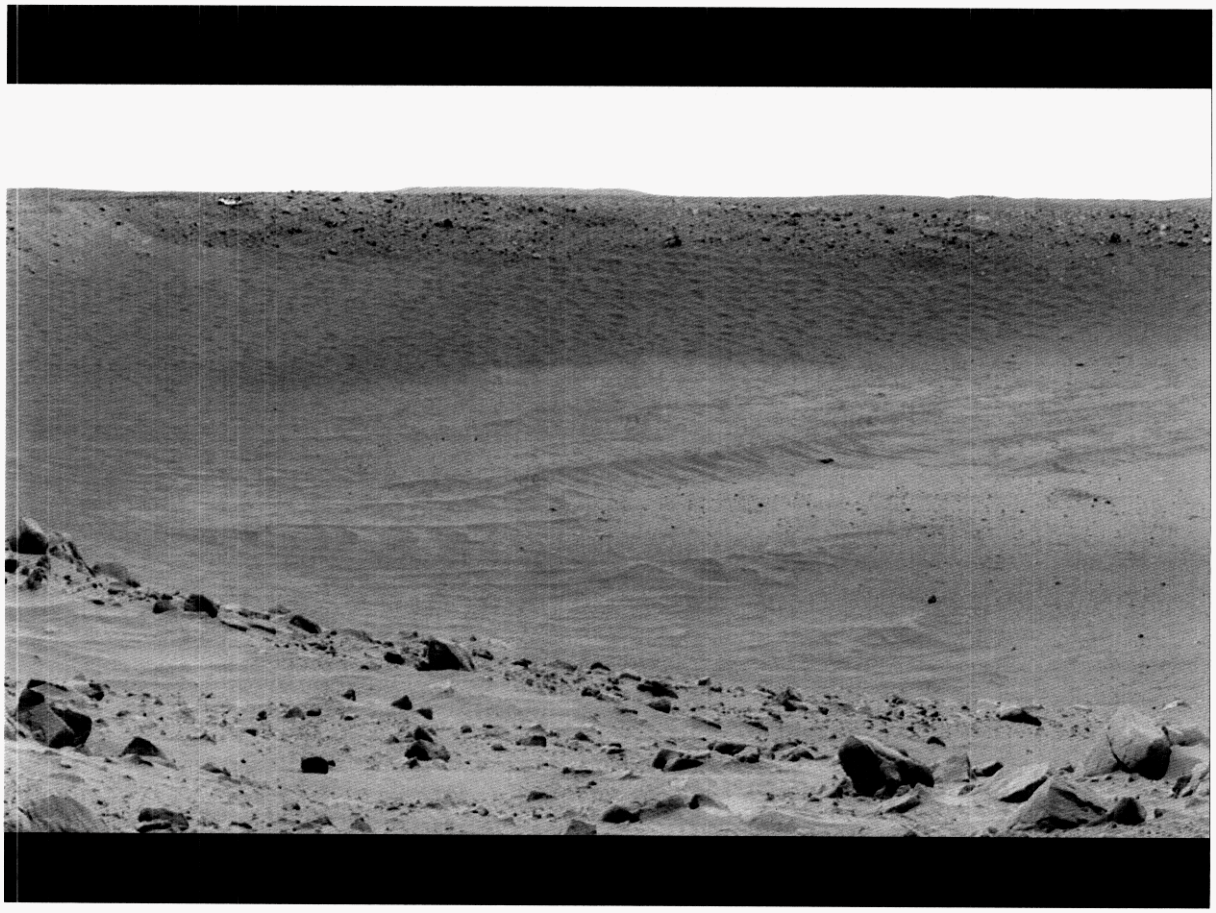
Mazatzal

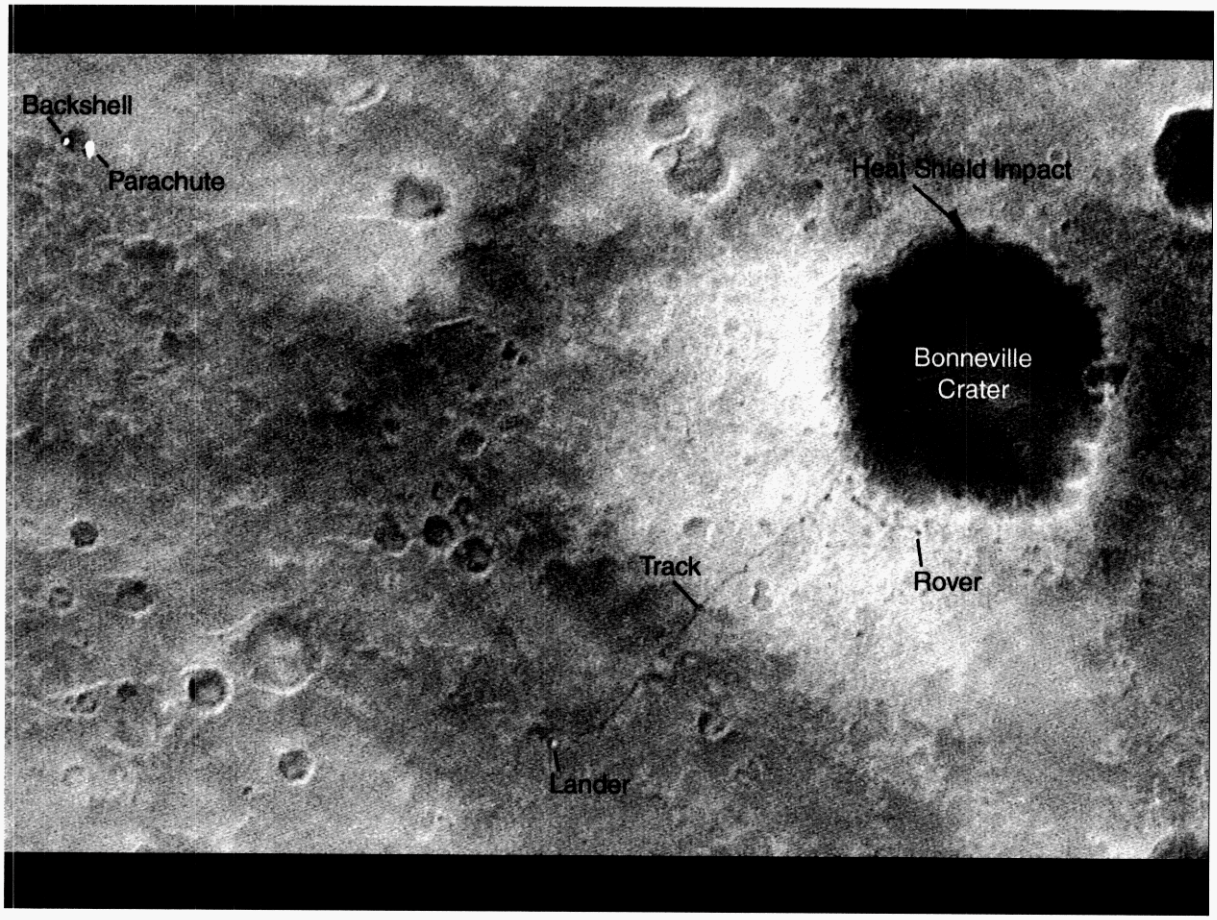


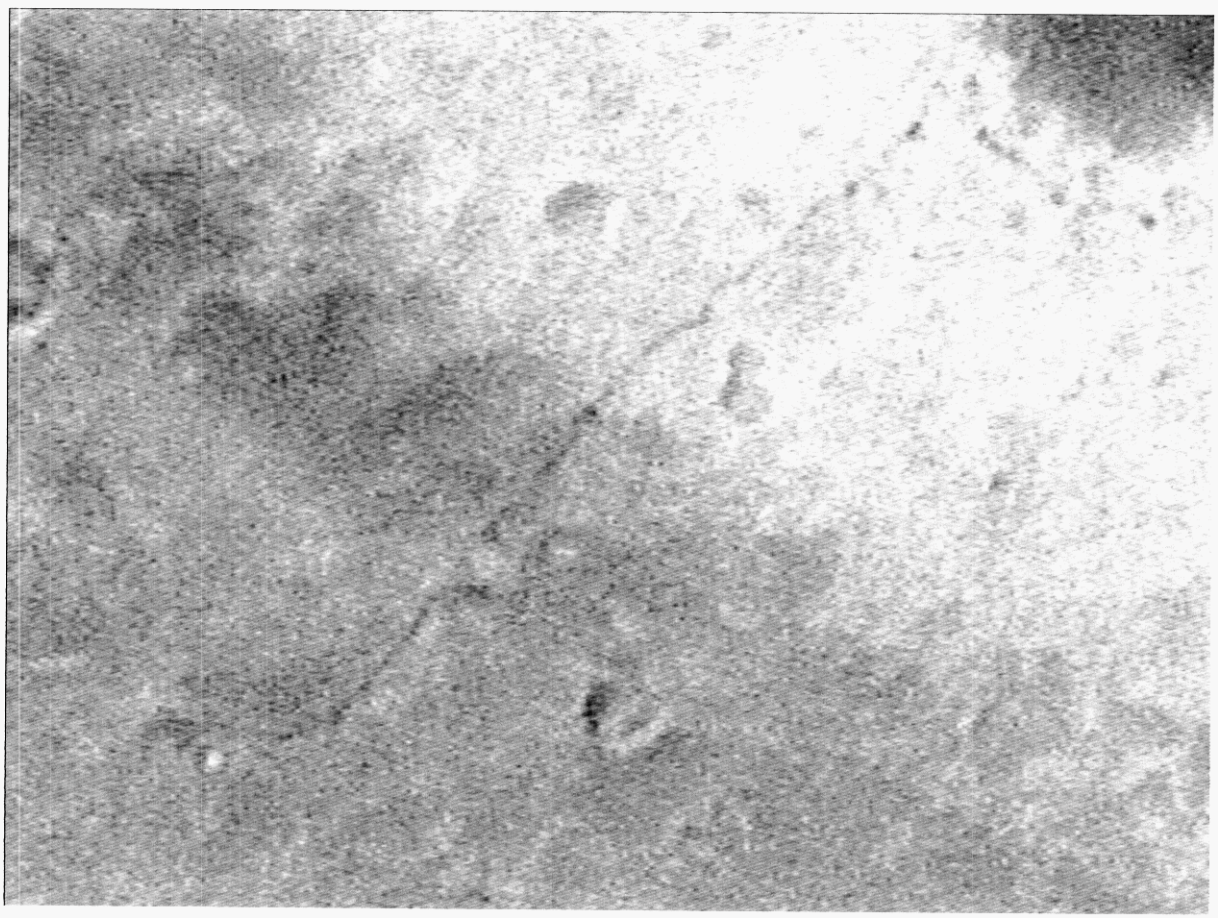


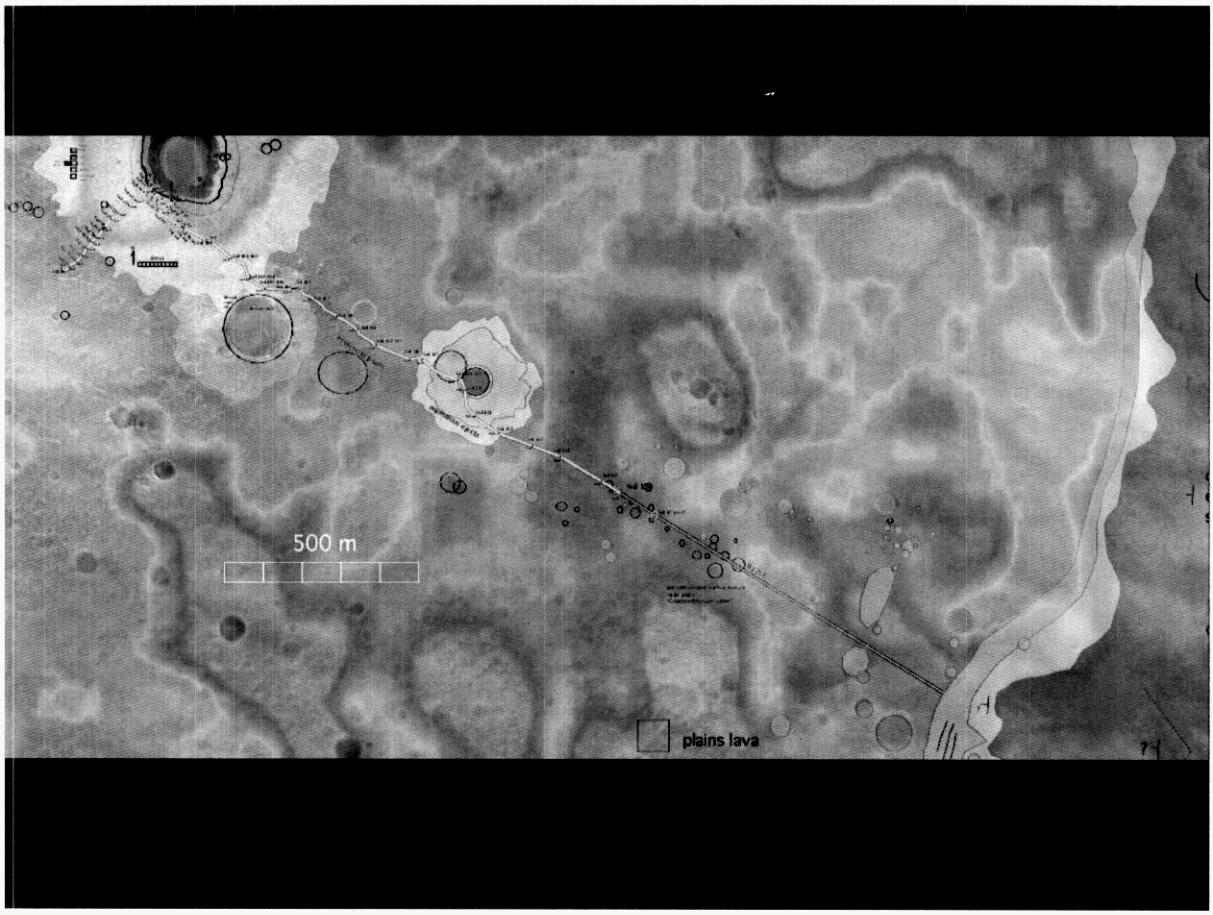

sol79
Traverse Status
Spirit@Gusev
crater
cf floor
cw wall
cr rim
ce ejecta
ic intercrater plains
sol 67,68,69,70
sol 66
sol 65
sol 72
sol 75
sol 76-78
sol 71
sol 74
sol 64
sol 63
sol 62
sol 61
sol 55,56,57,58,59,60
sol 45,46,47,48,49
sol 50
sol 52
sol 51
sol 44
sol 41
sol 43
sol 39
sol 37
N155E
1
2
N
0
100 m
"Gangplank"

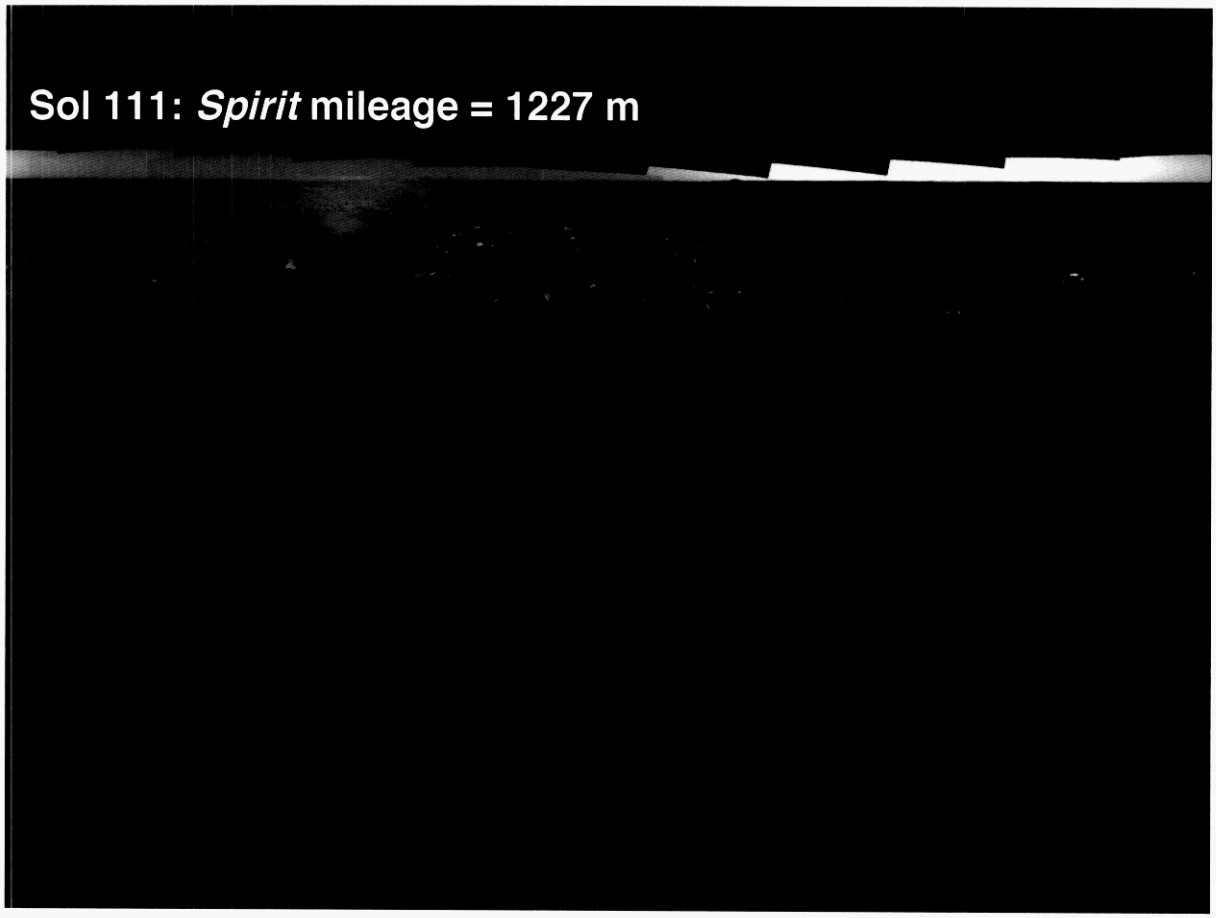




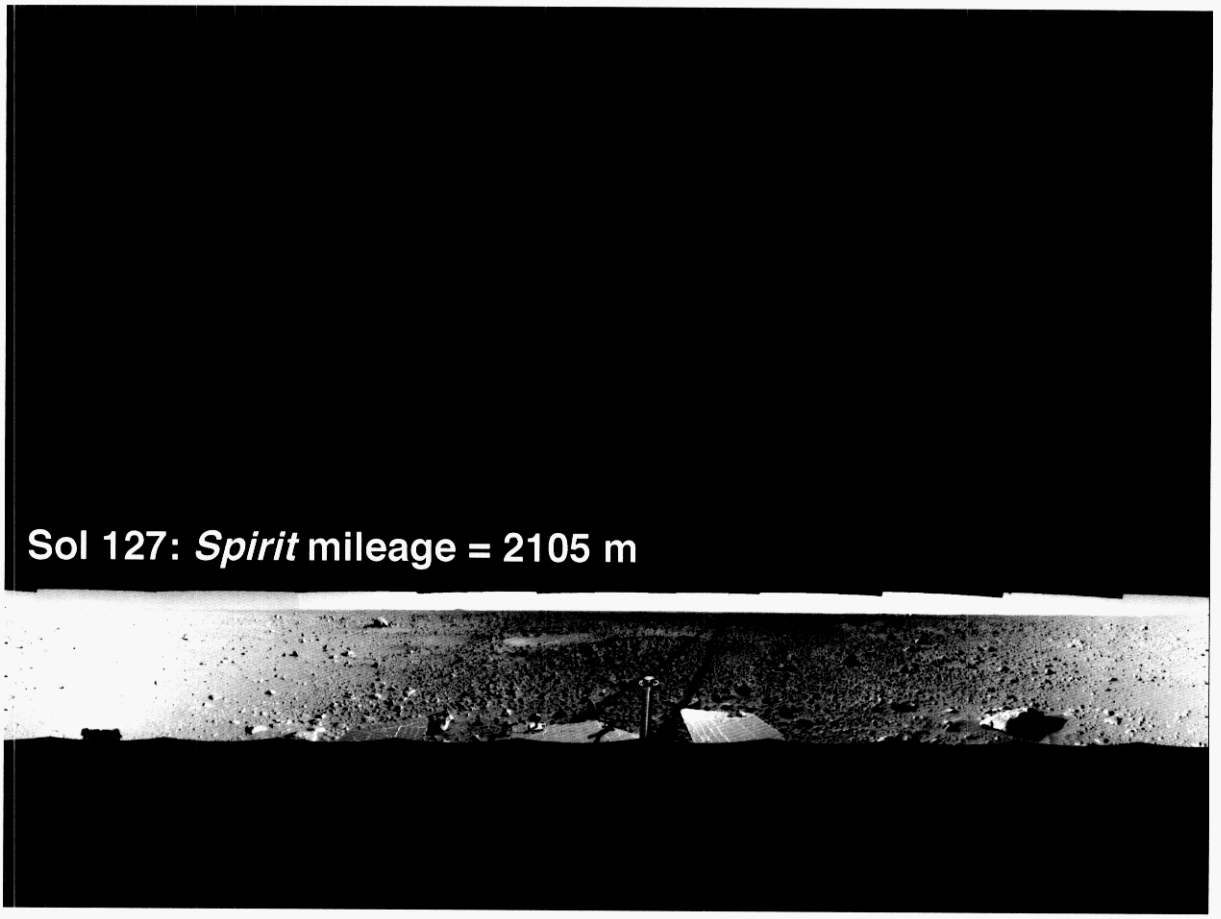

Backshell
Parachute
Heat Shield Impact
Bonneville
Crater
Track
Rover
Lander

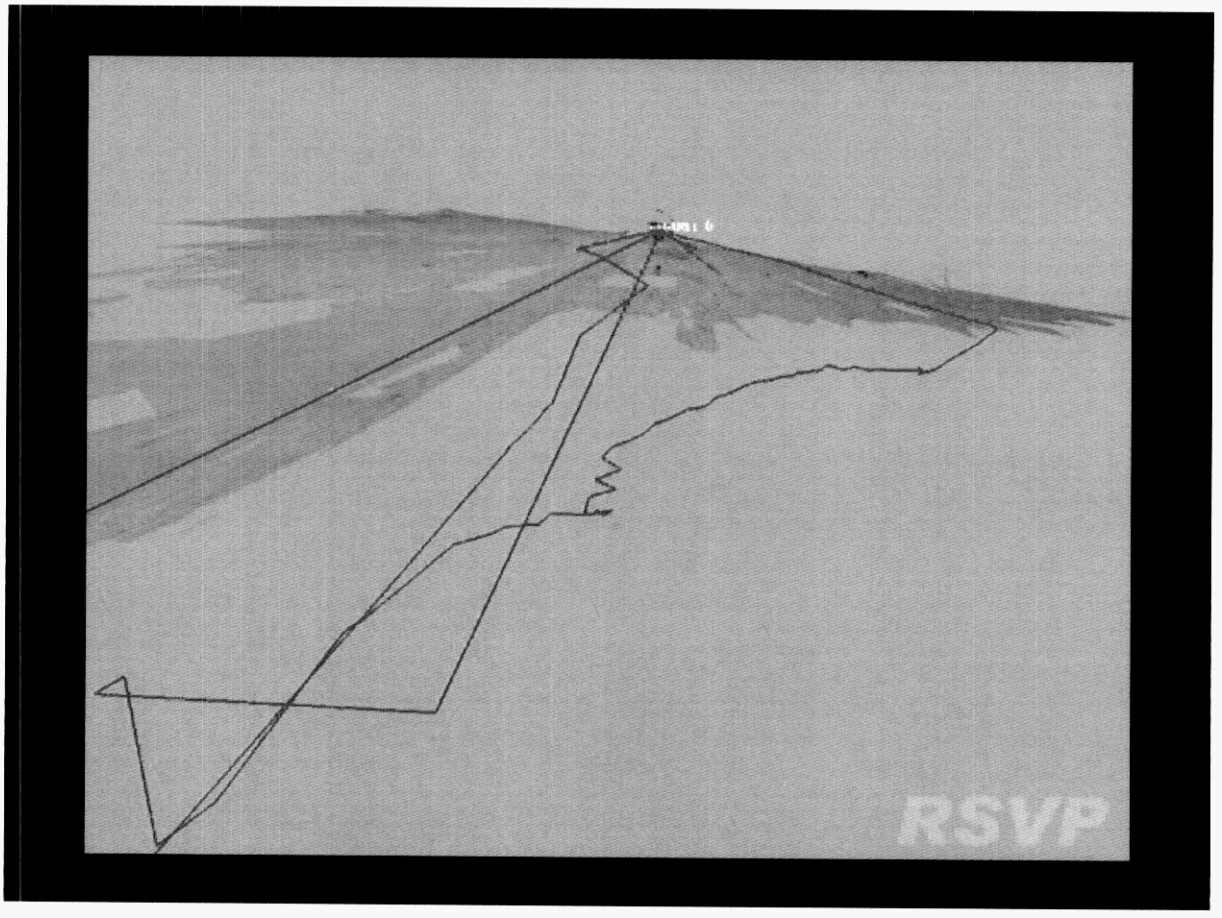



500 m
plains lava

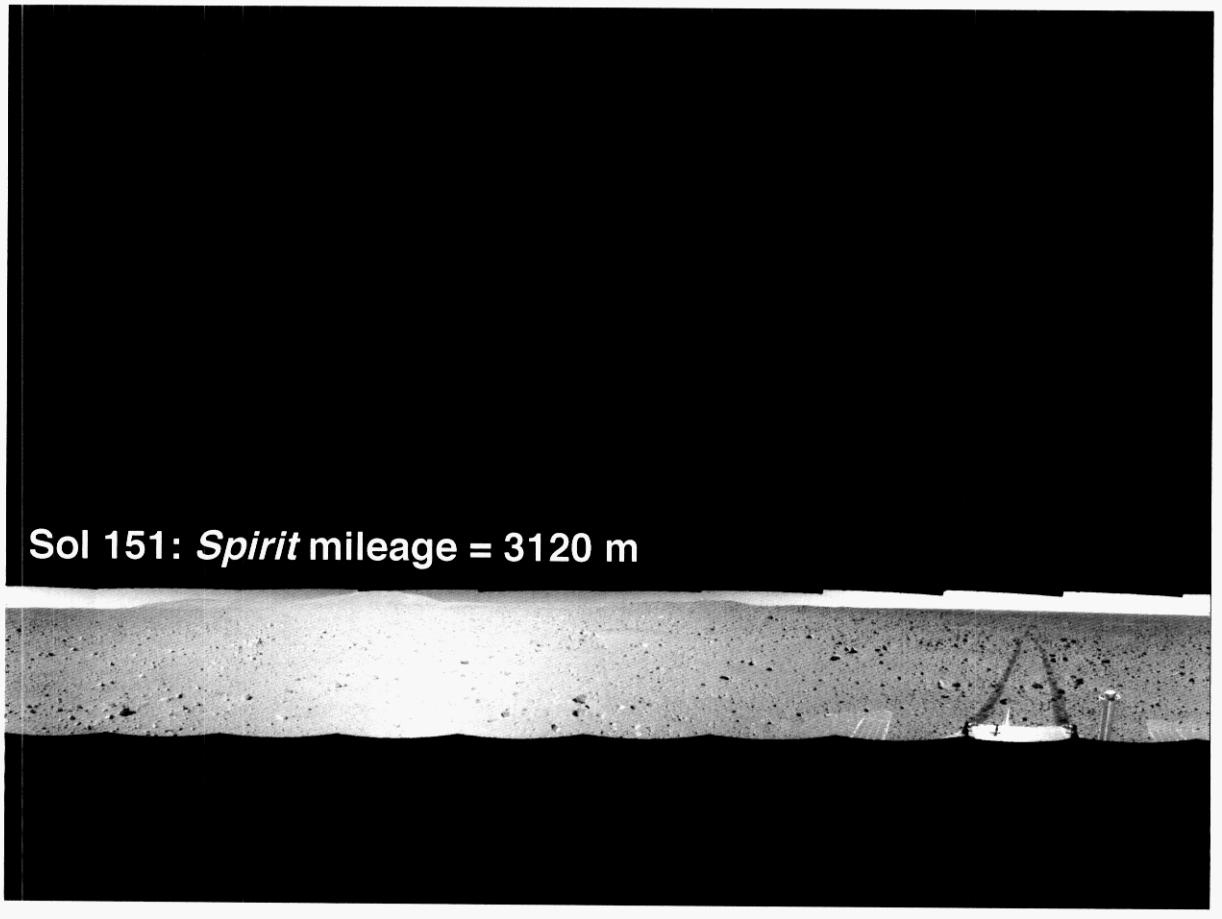

Sol 111: *Spirit* mileage = 1227 m

Sol 124: *Spirit* mileage = 1910 m


Sol 127: *Spirit* mileage = 2105 m


RSVP

Sol 148: *Spirit* mileage = 3047 m

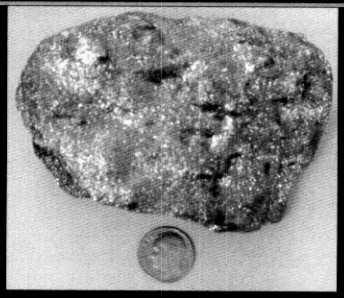

Sol 151: *Spirit* mileage = 3120 m

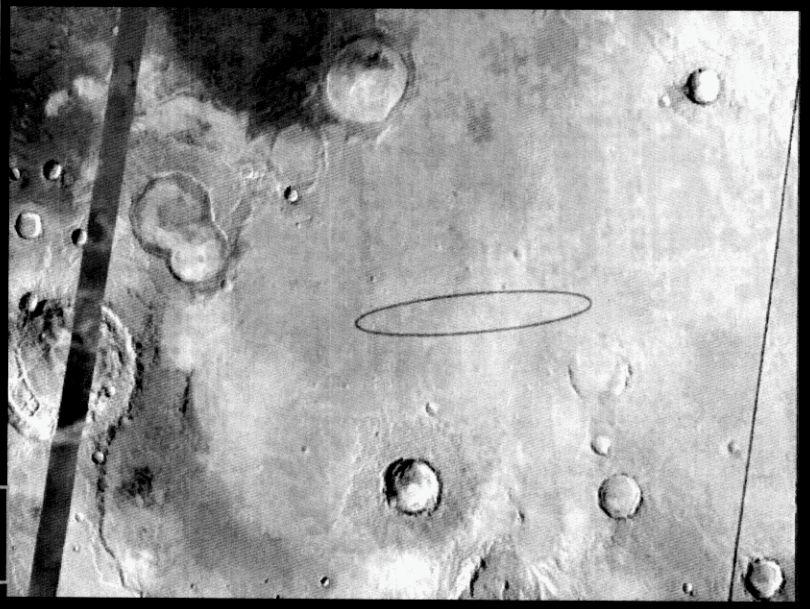
Opportunity

20:50 PDT = Sol 591 23:45 LST-B

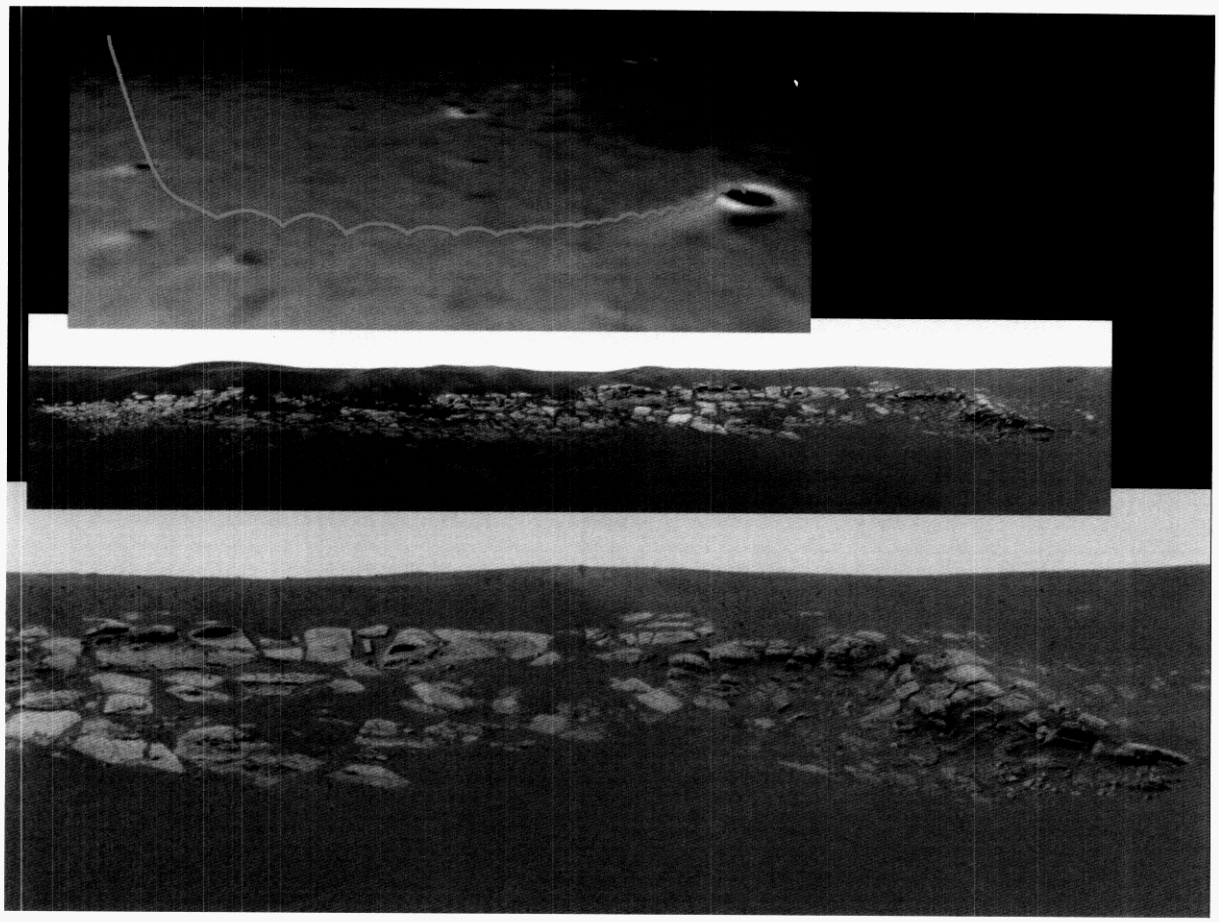
Meridiani Planum

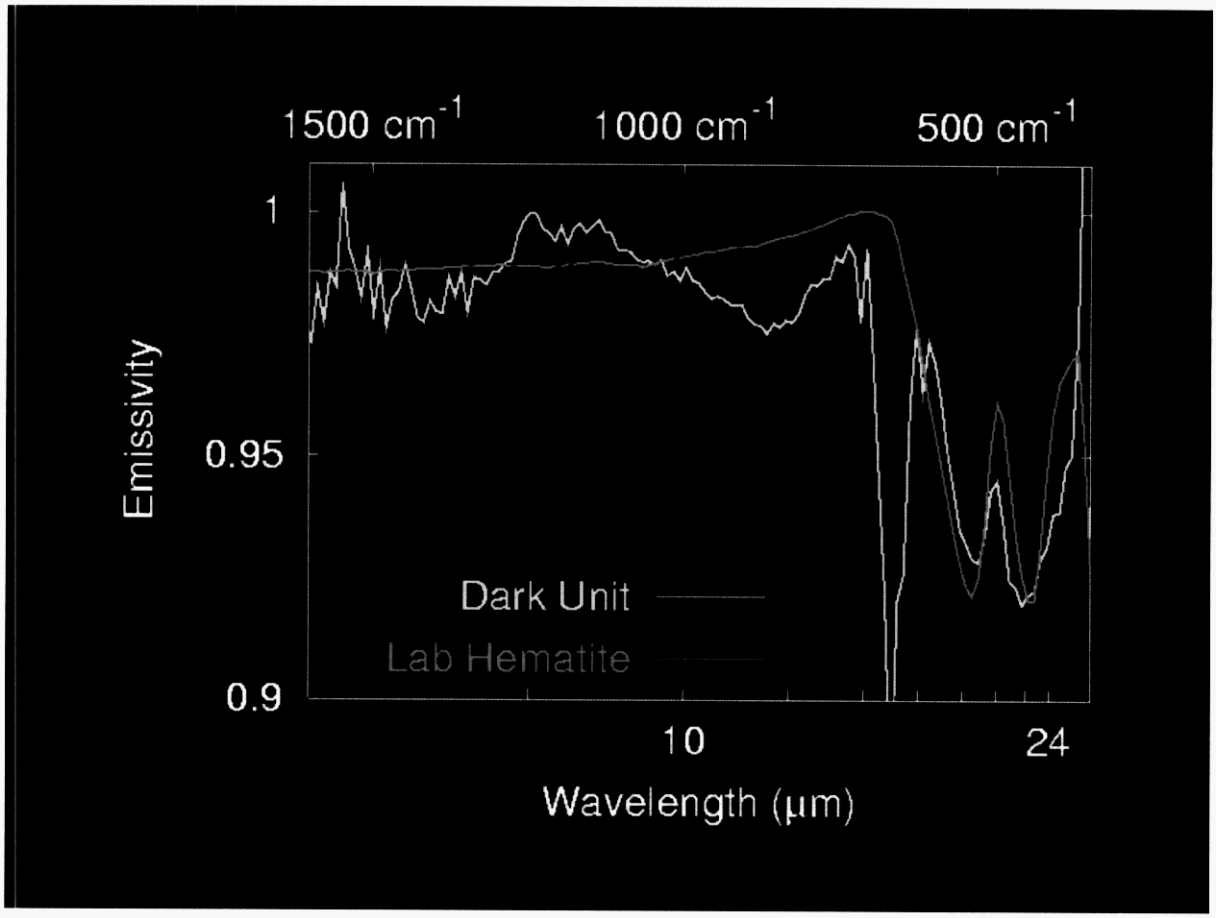
Gray crystalline hematite

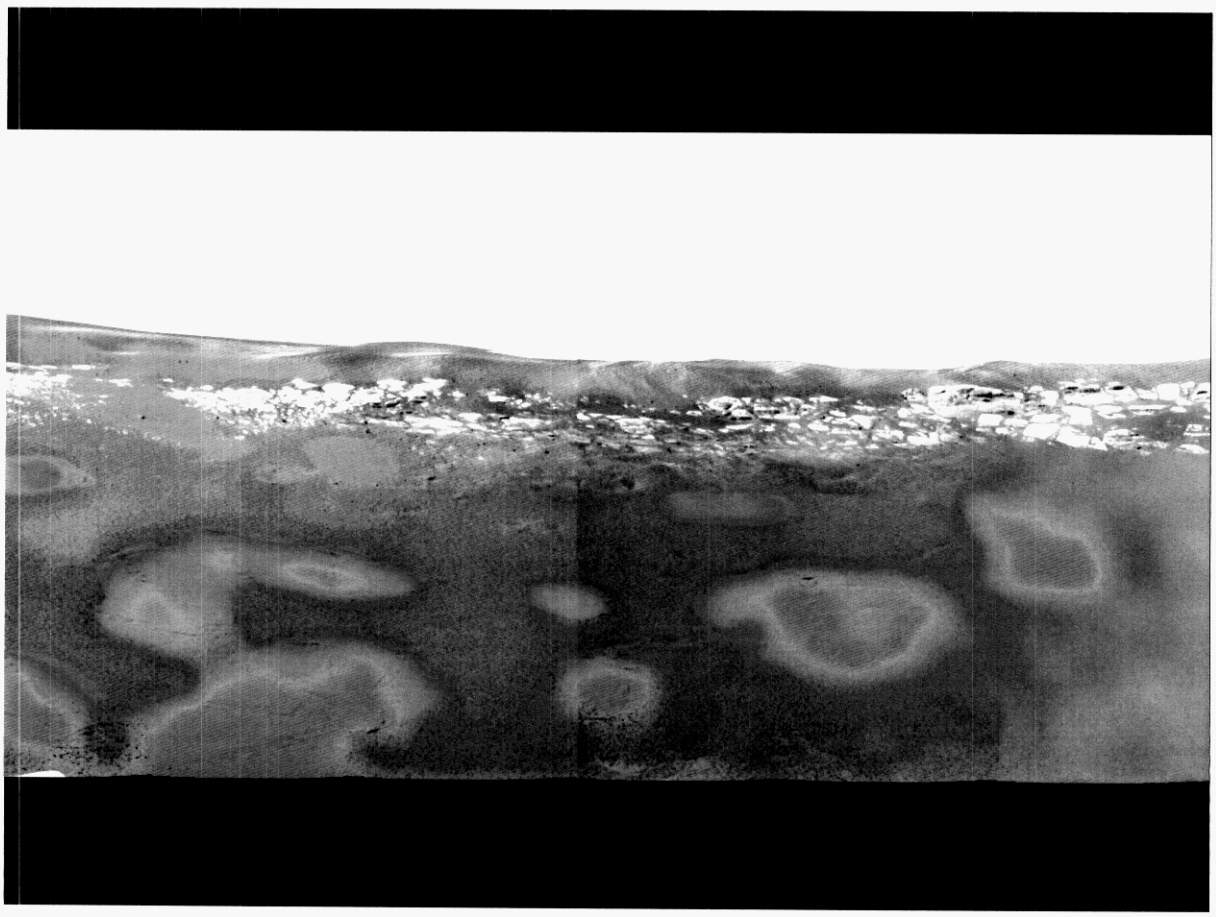


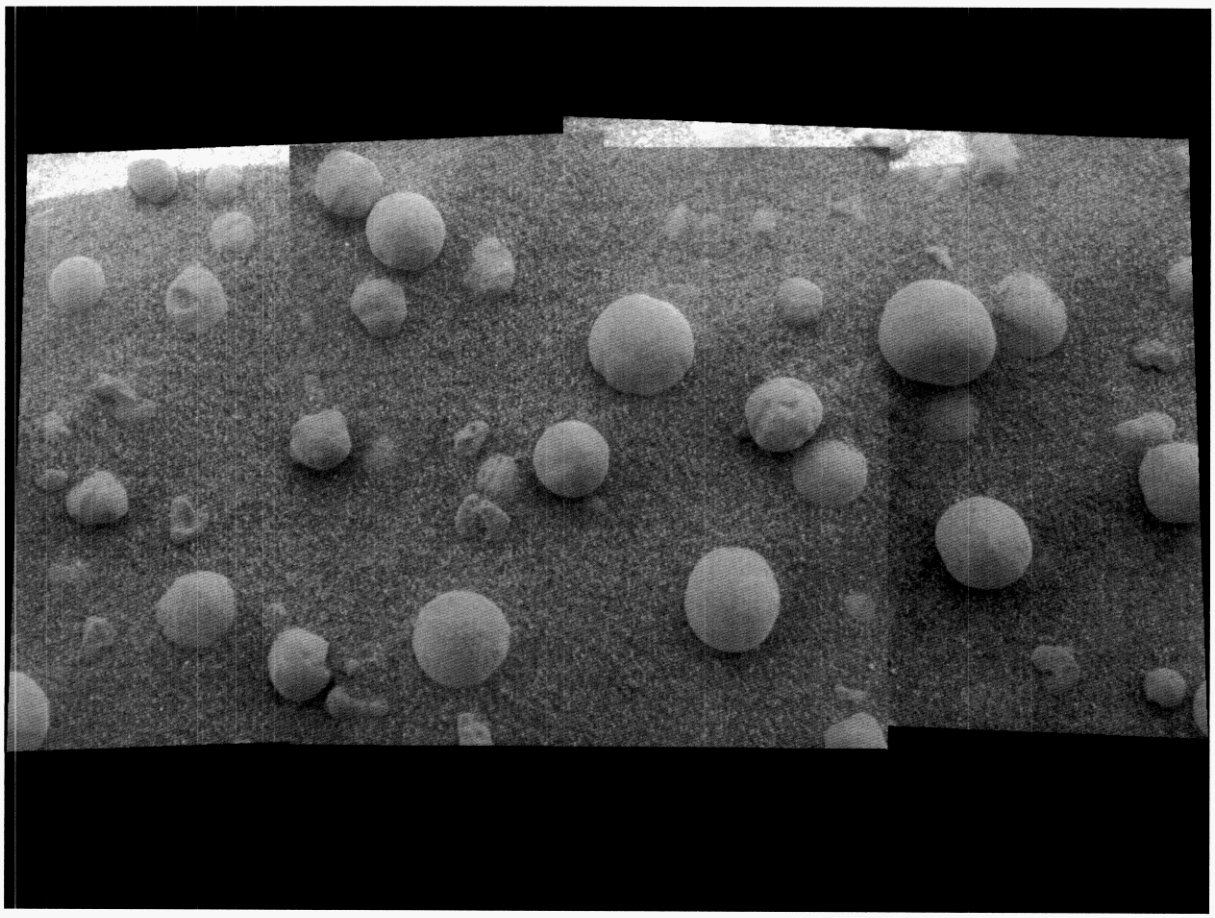


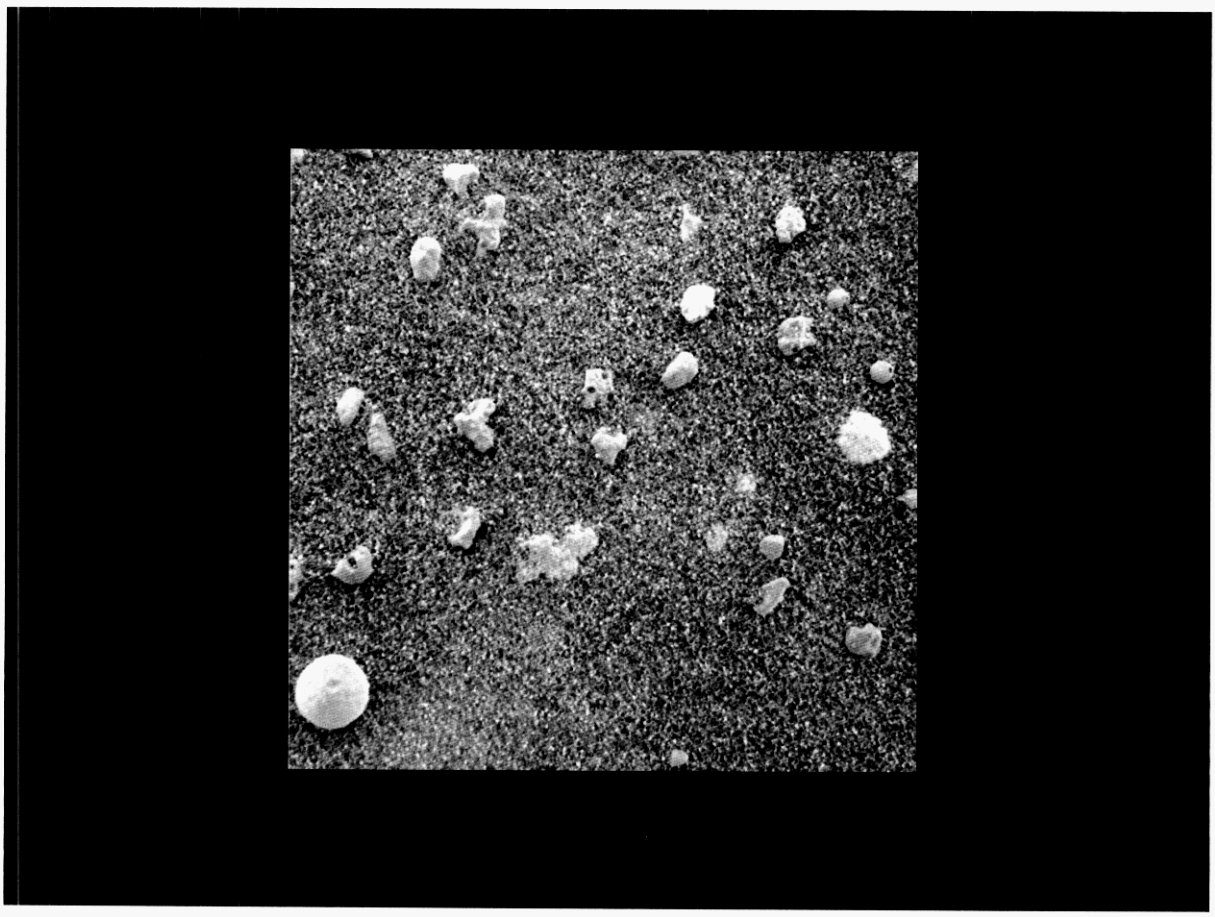
71 km x 9 km landing ellipse

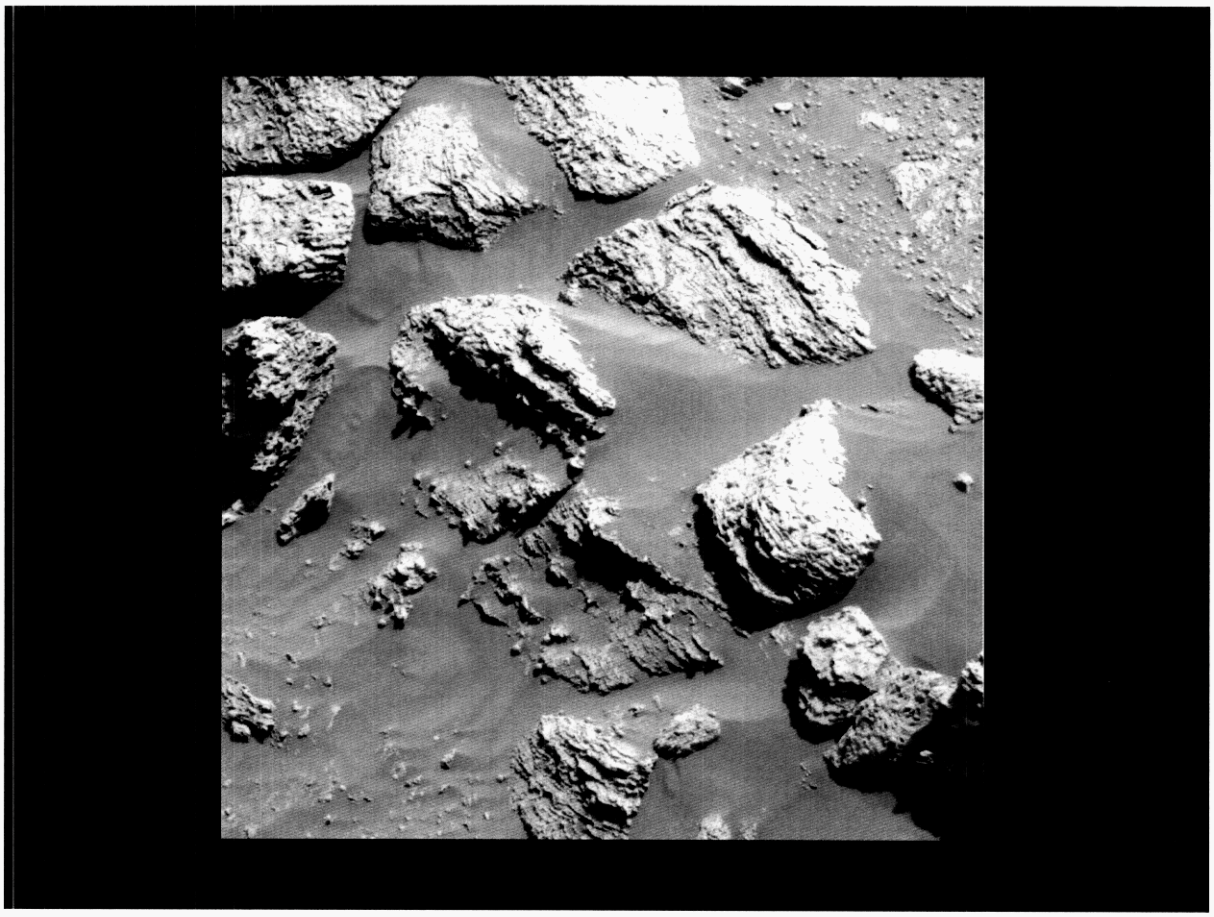


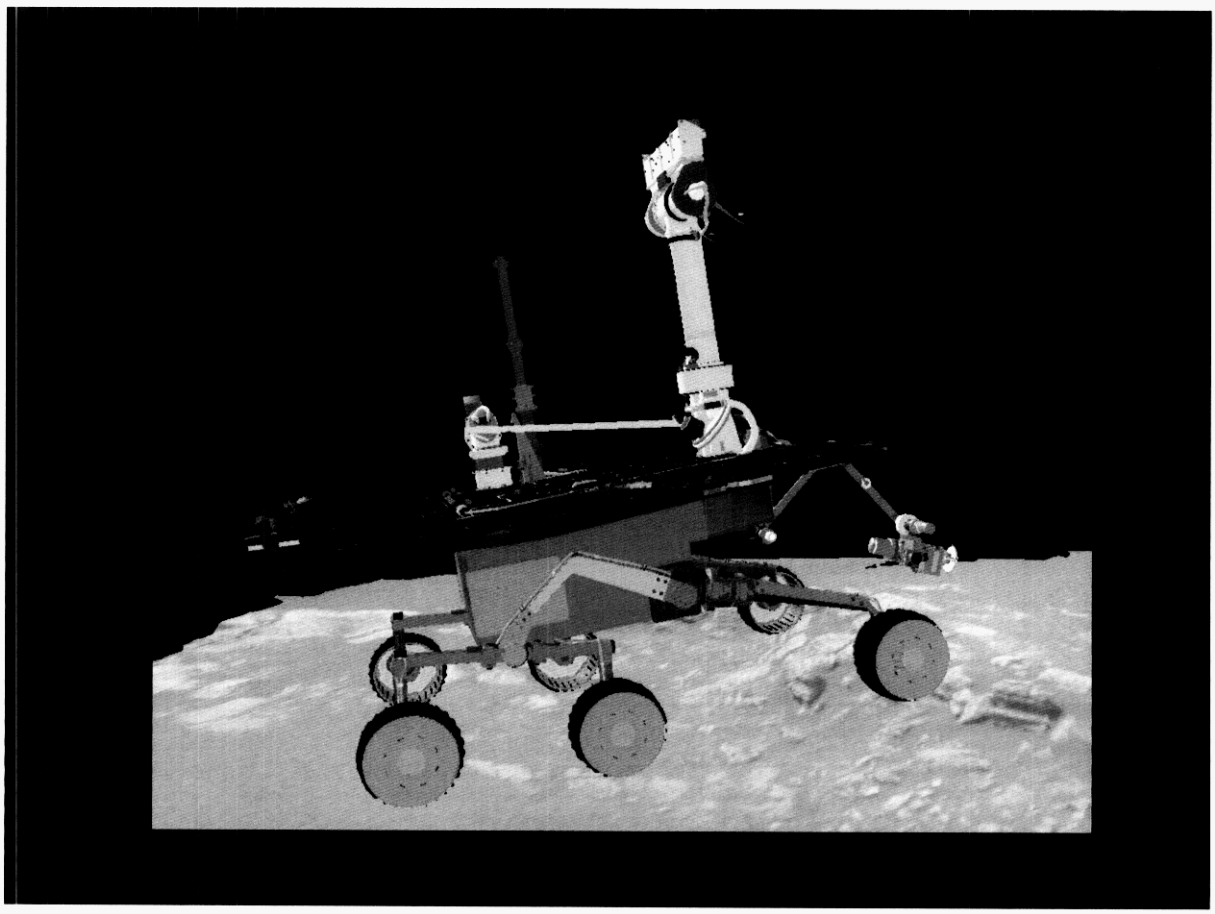

1500 cm-1
1000 cm-1
500 cm-1
1
0.95
0.9
Emissivity
Dark Unit
Lab Hematite
10
24
Wavelength (μm)

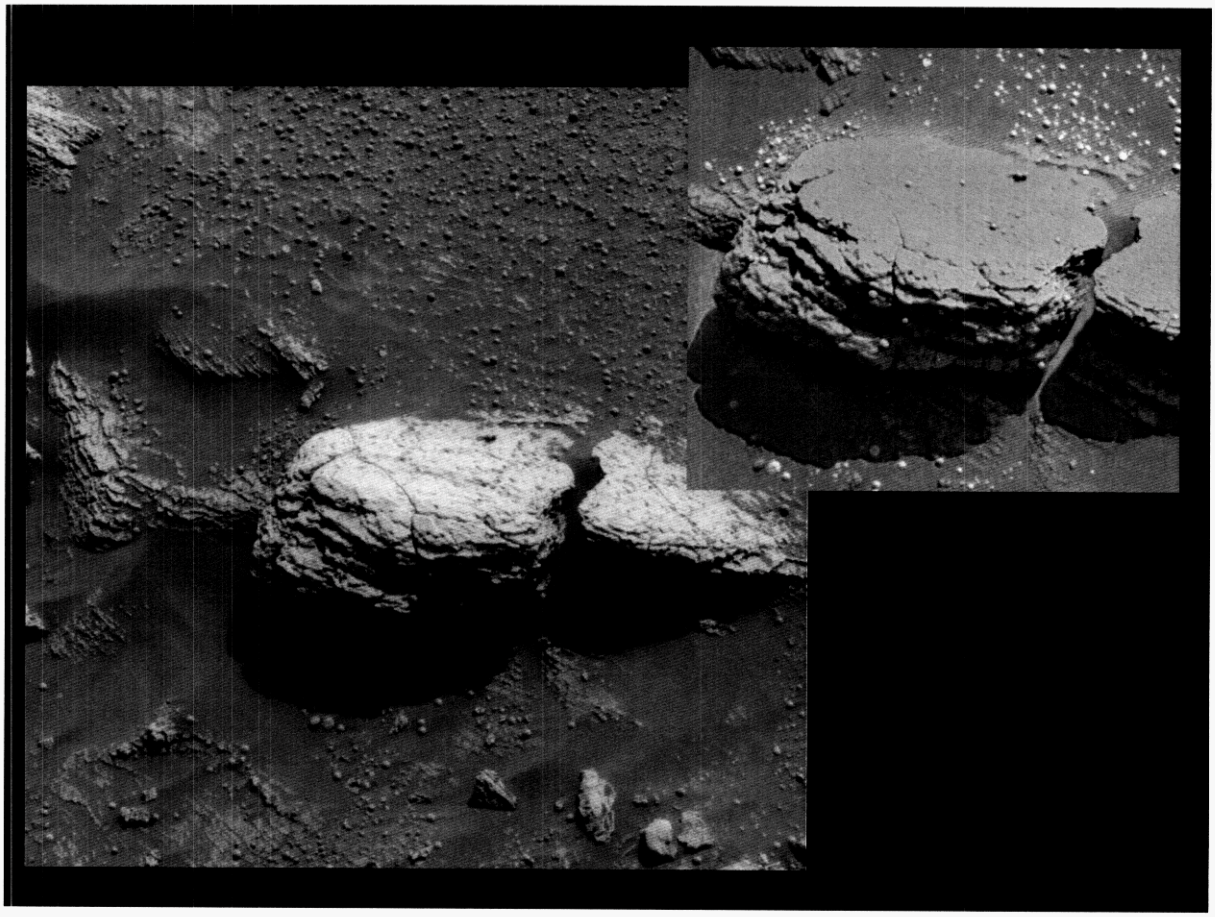


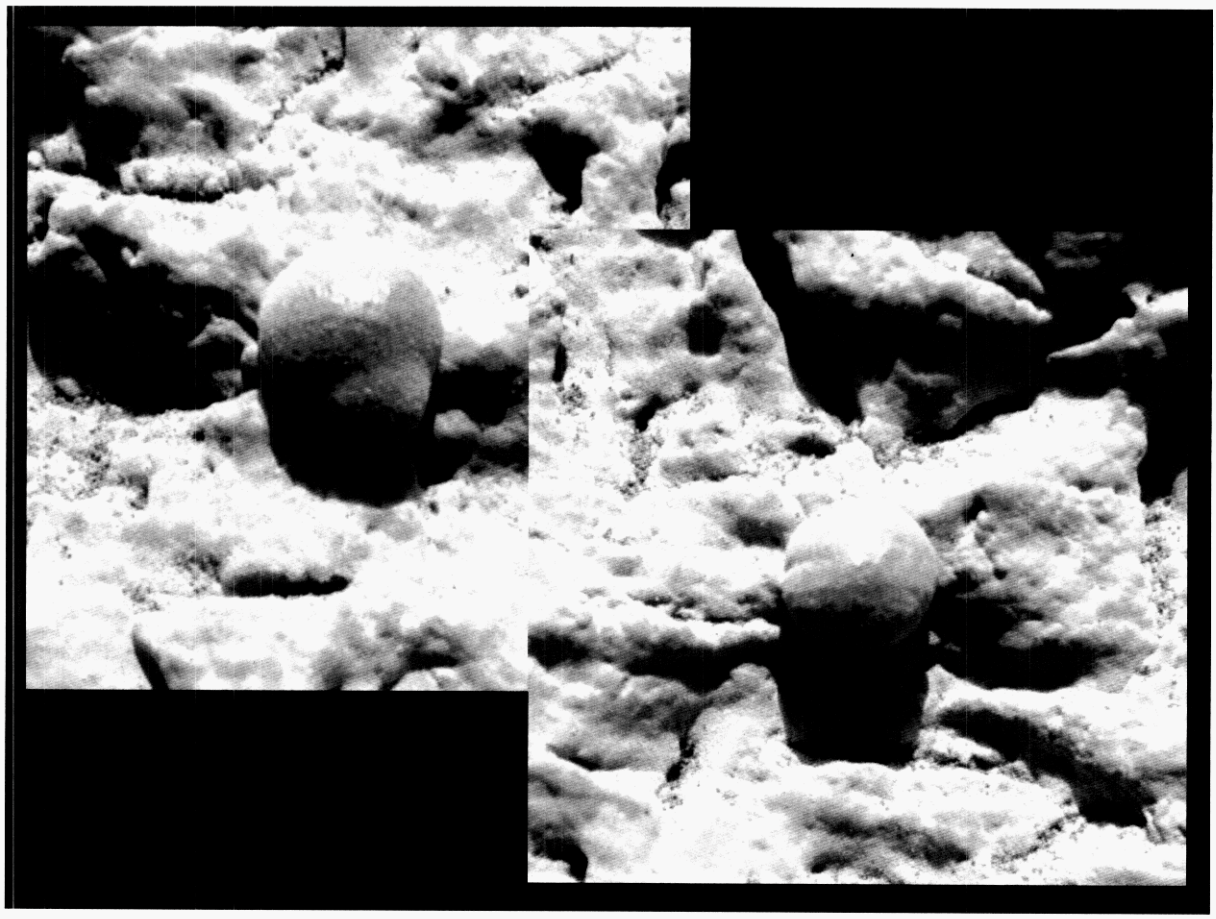


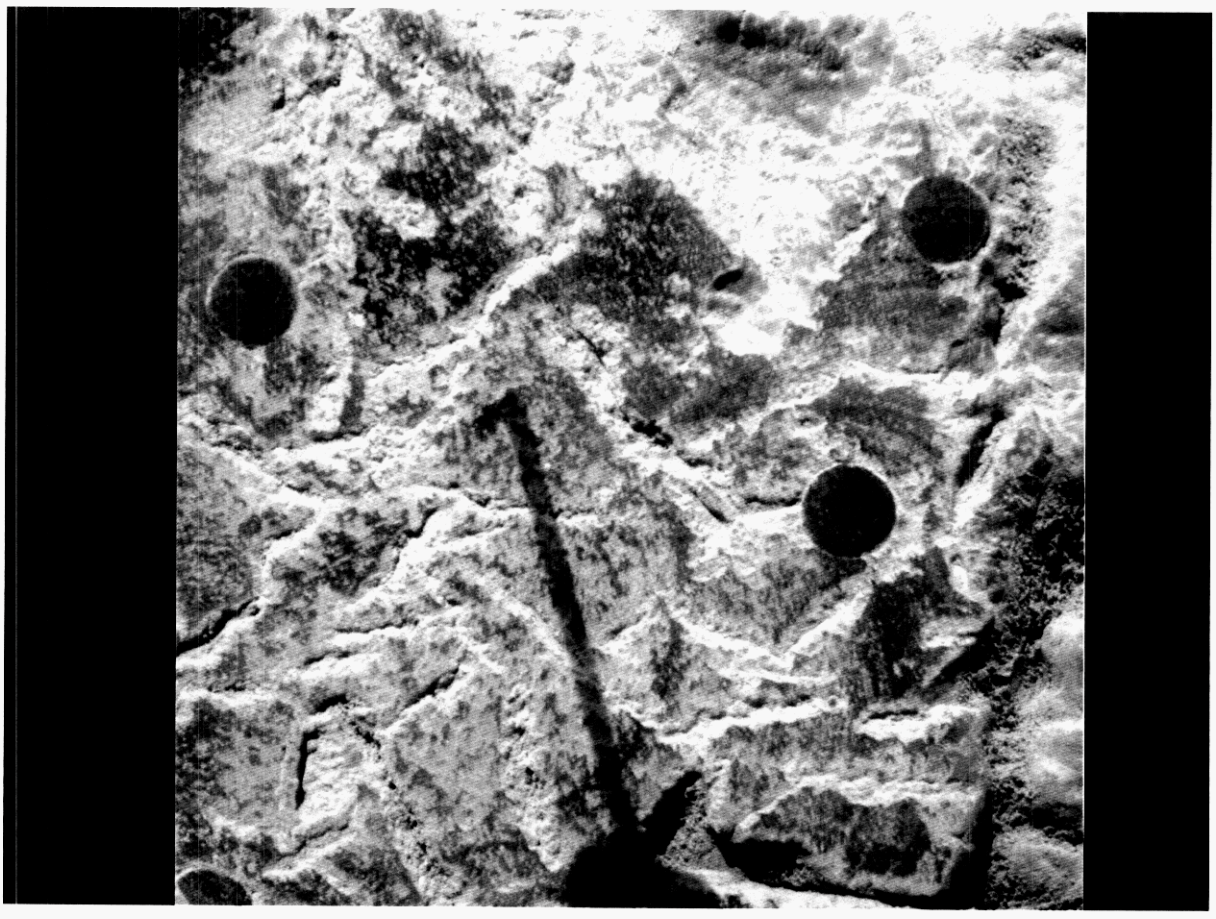


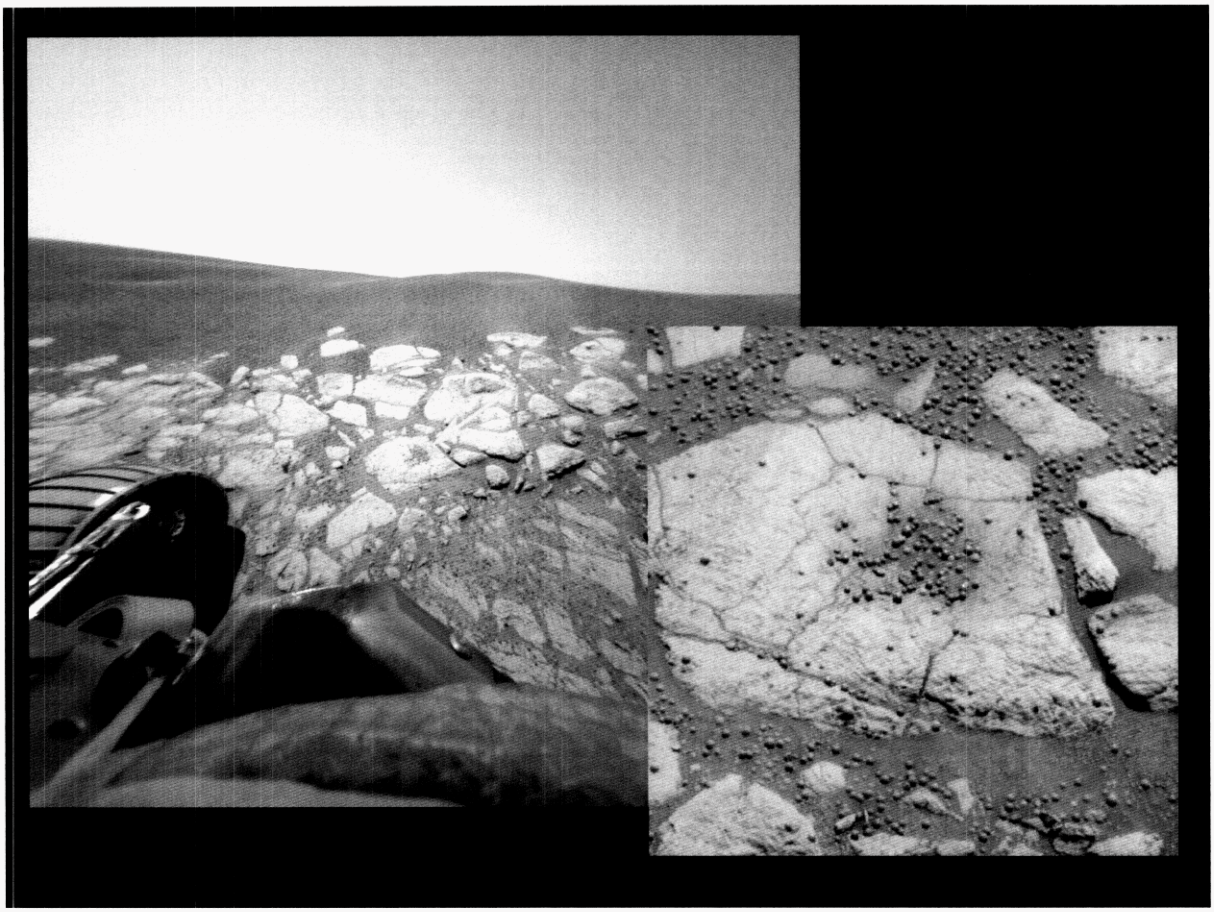


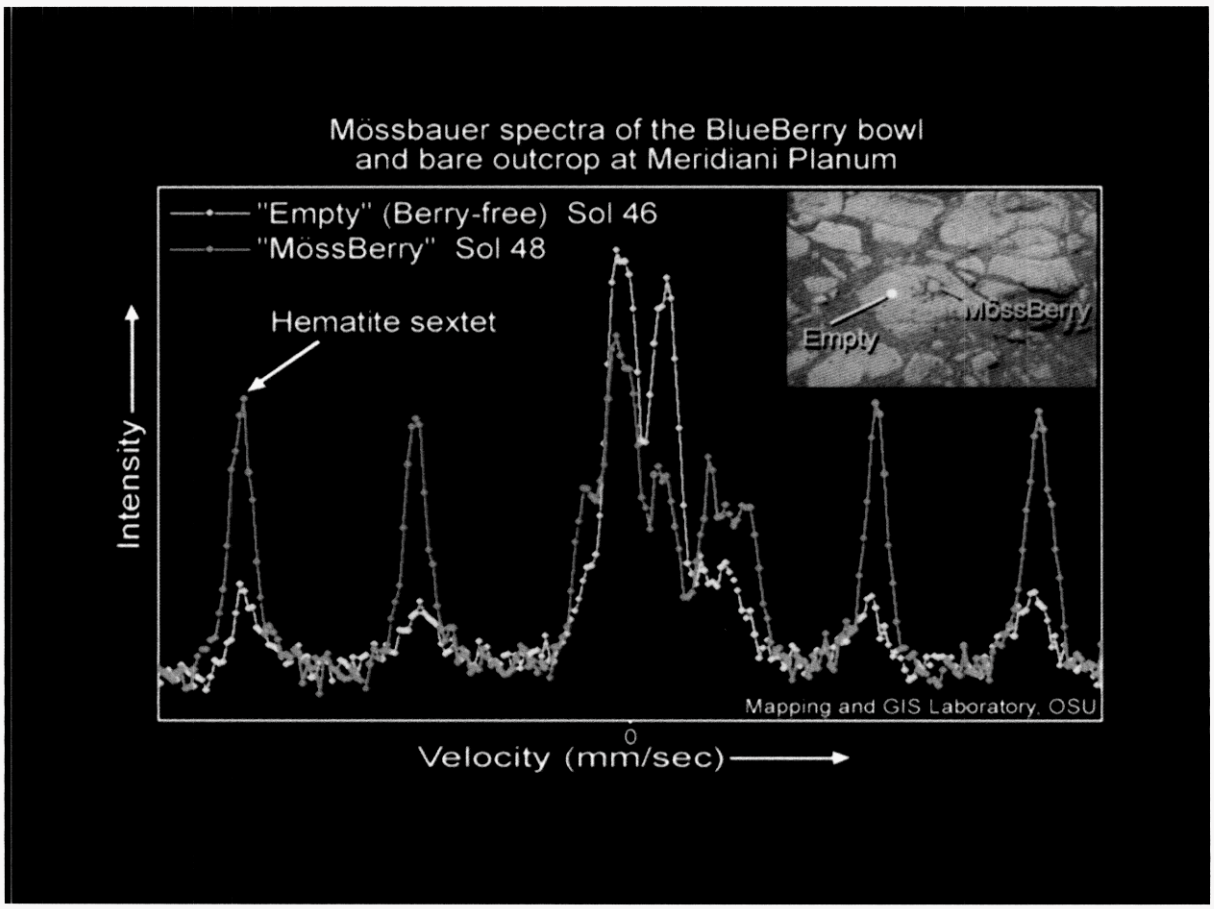


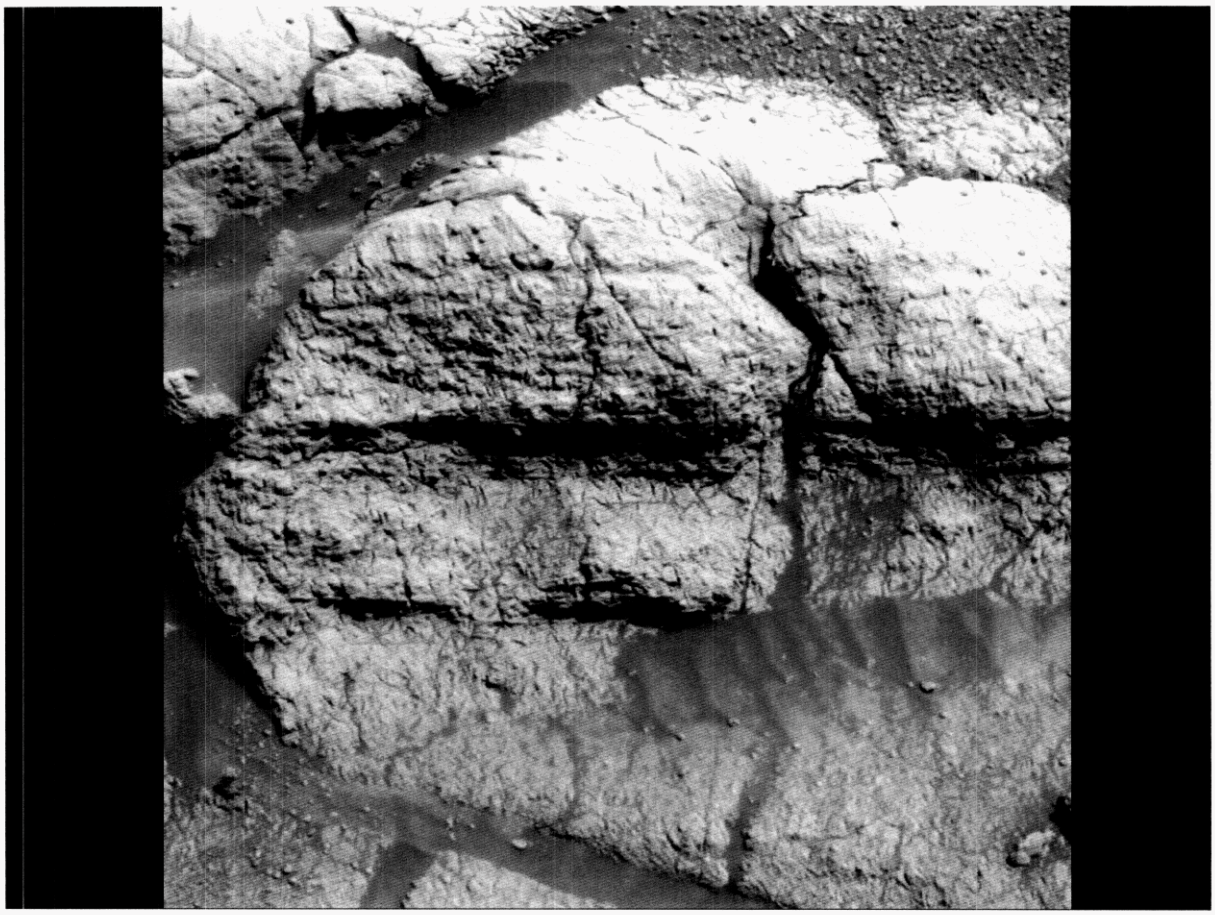


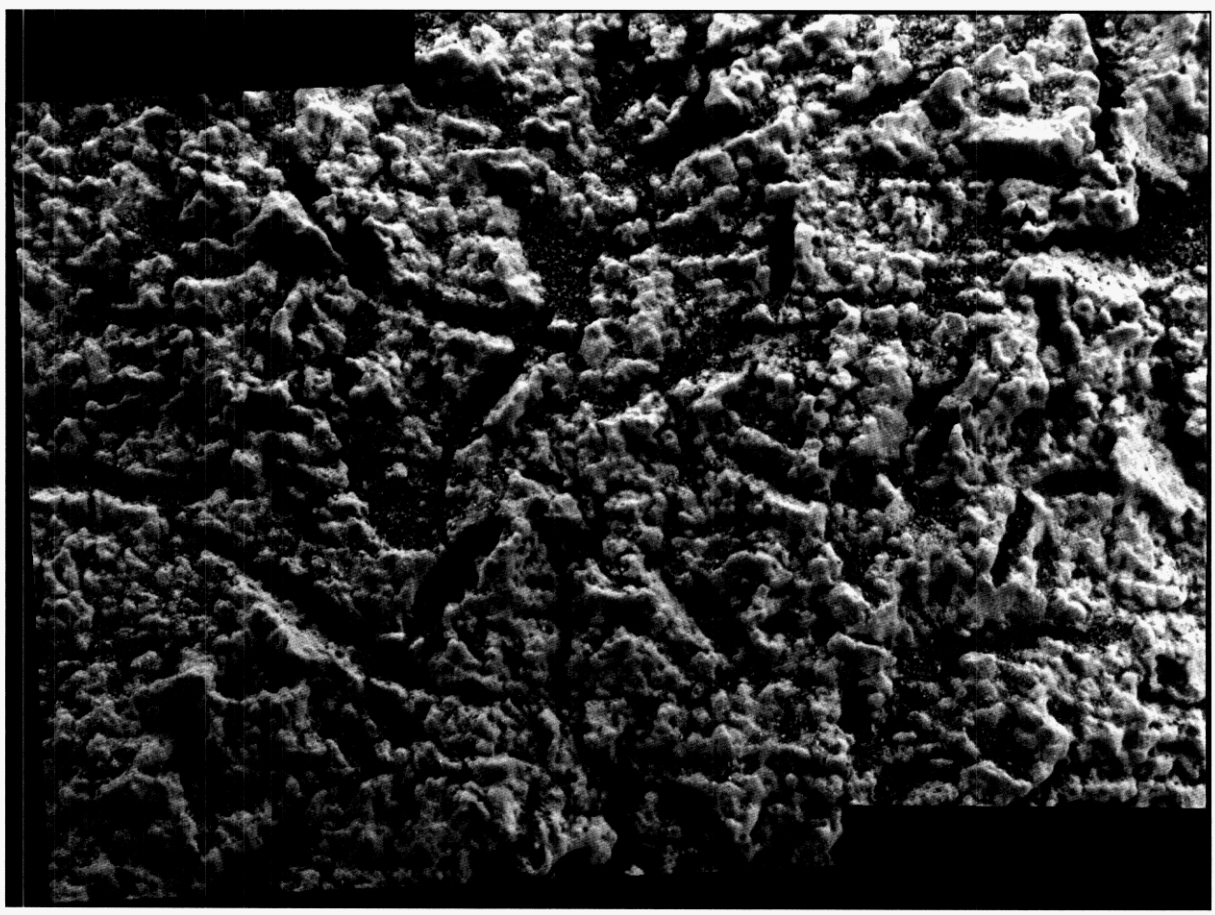


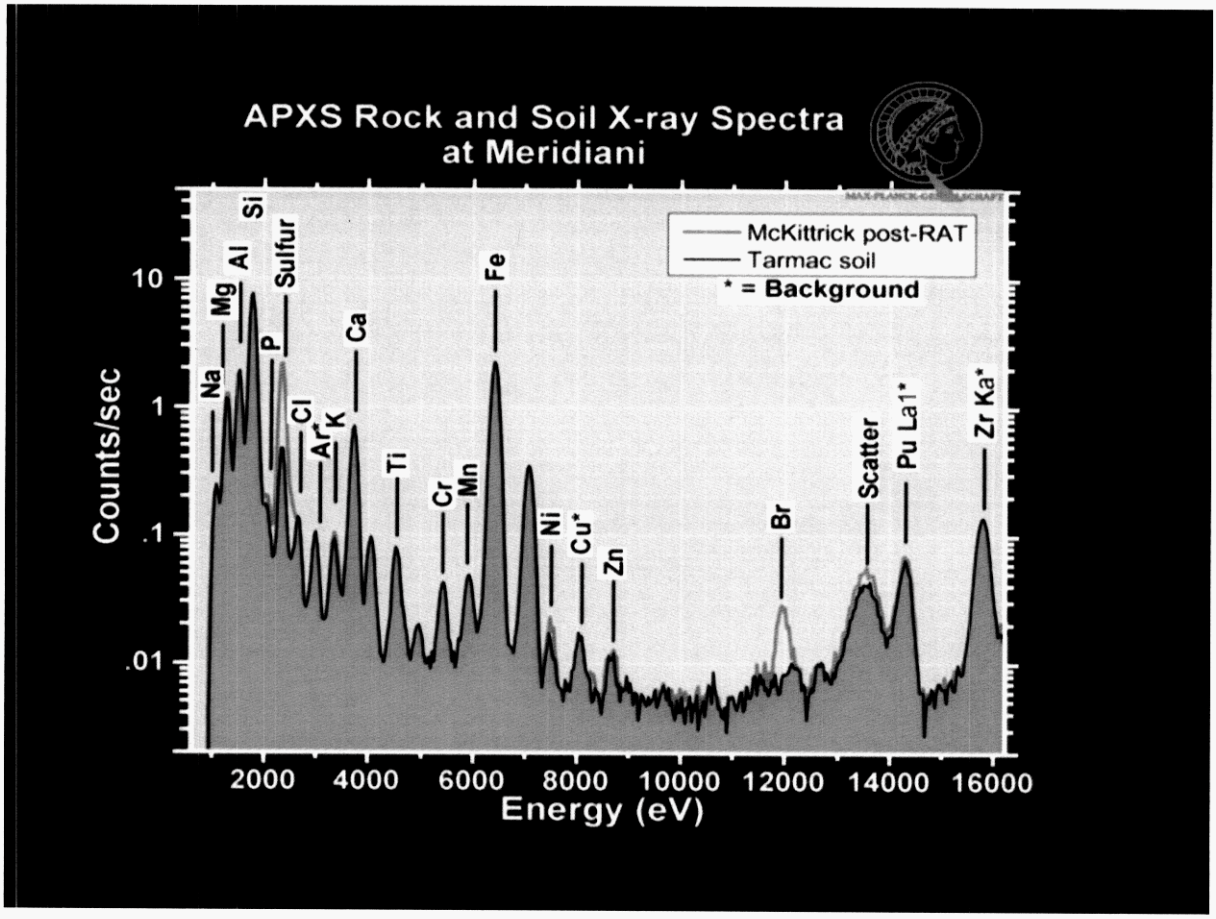


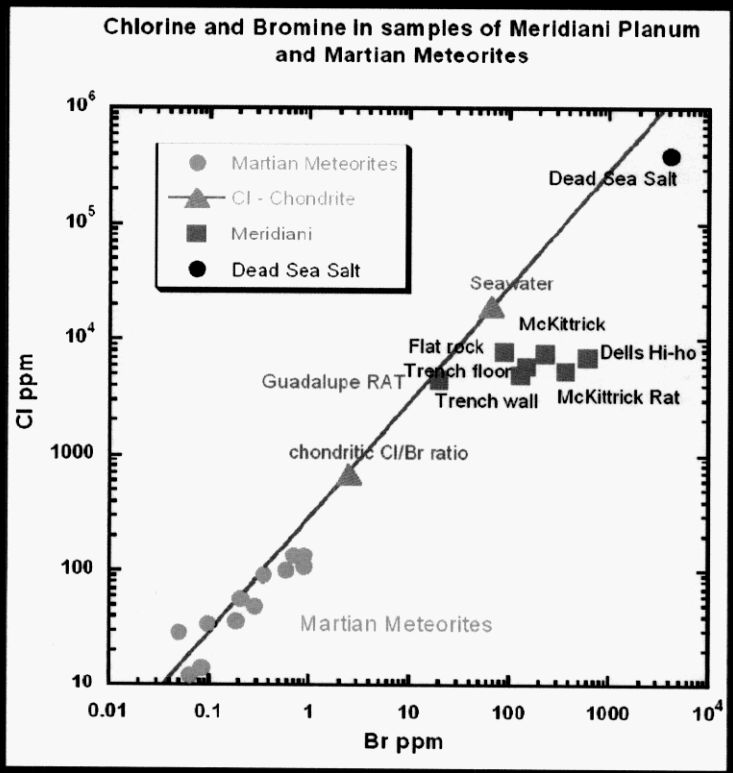


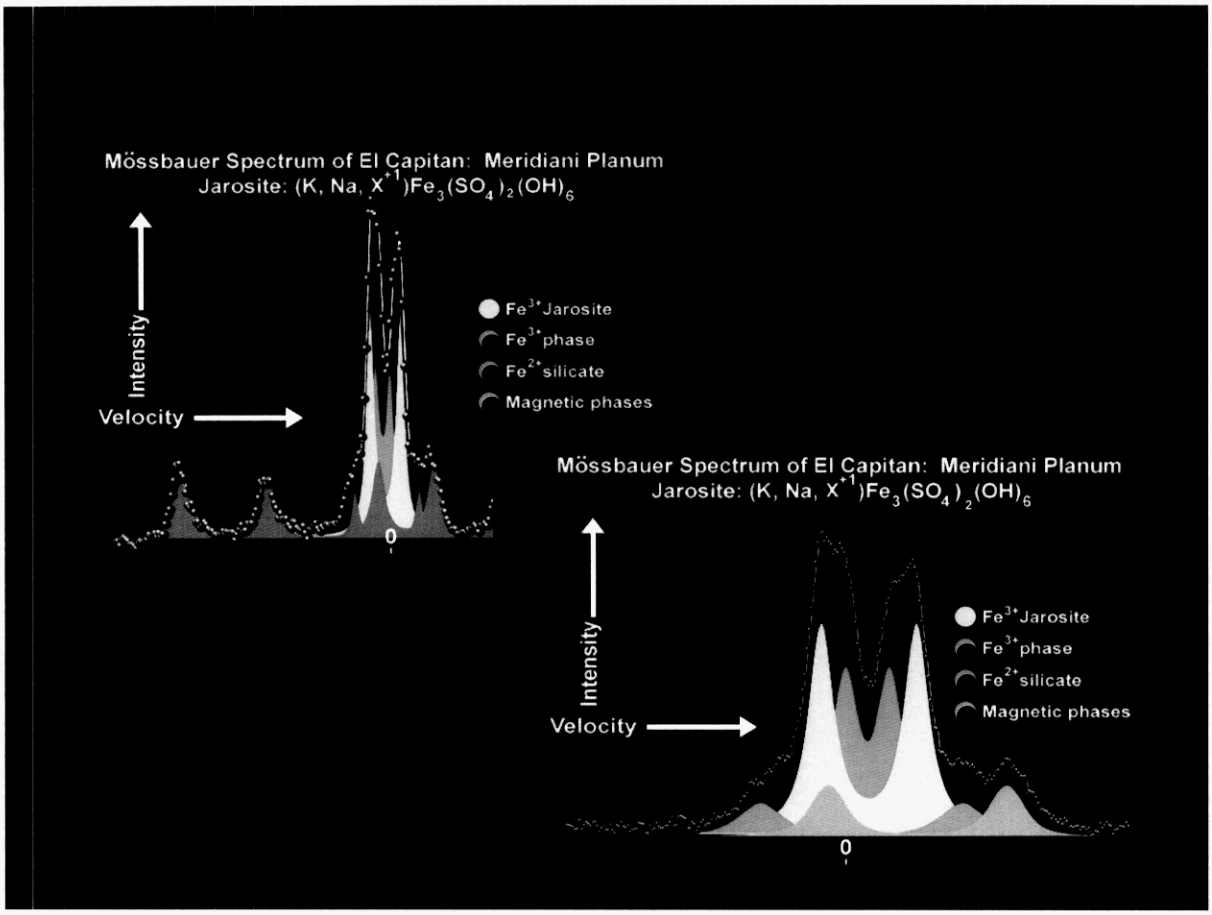

Mössbauer spectra of the BlueBerry bowl
and bare outcrop at Meridiani Planum
"Empty" (Berry-free) Sol 46
"MössBerry" Sol 48
Hematite sextet
Empty
MössBerry
Intensity
Mapping and GIS Laboratory, OSU
0
Velocity (mm/sec)

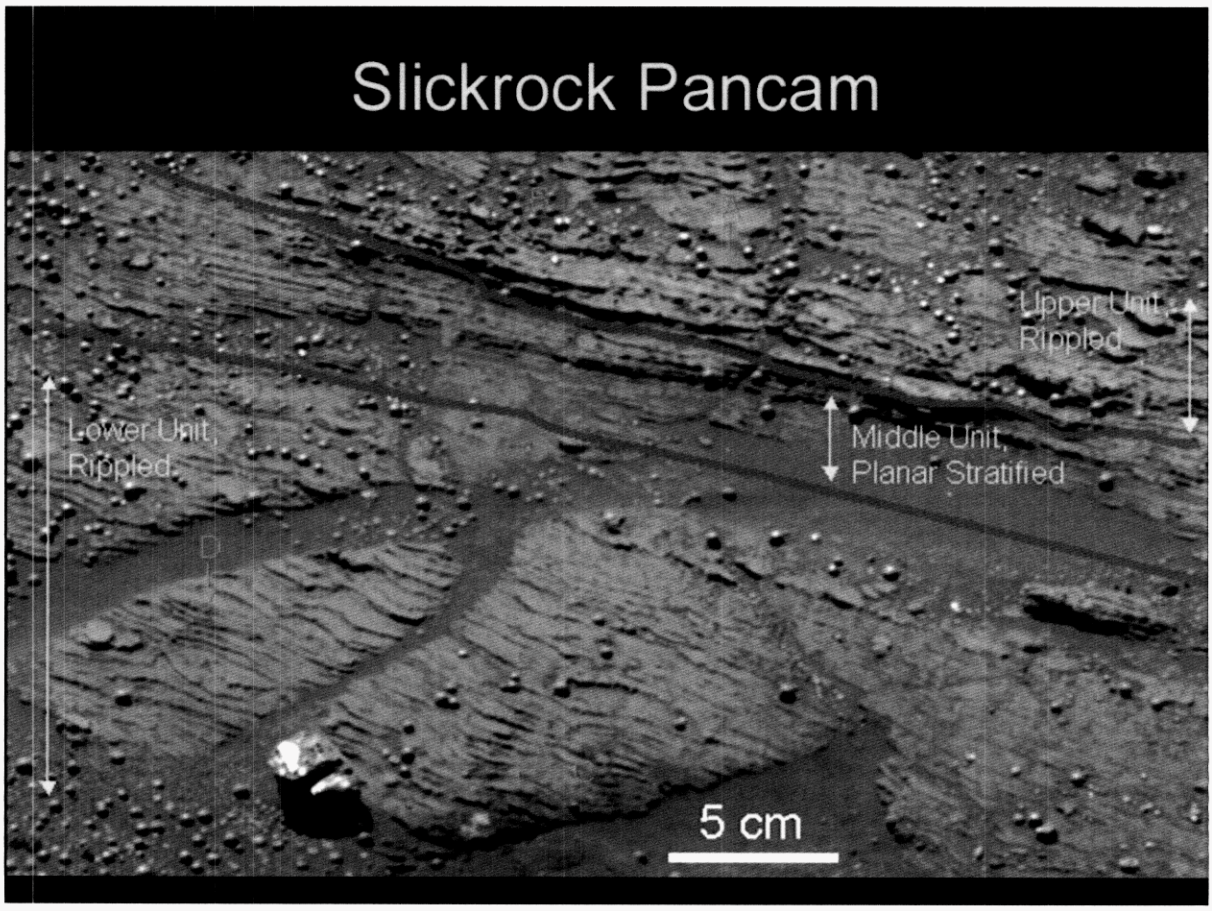


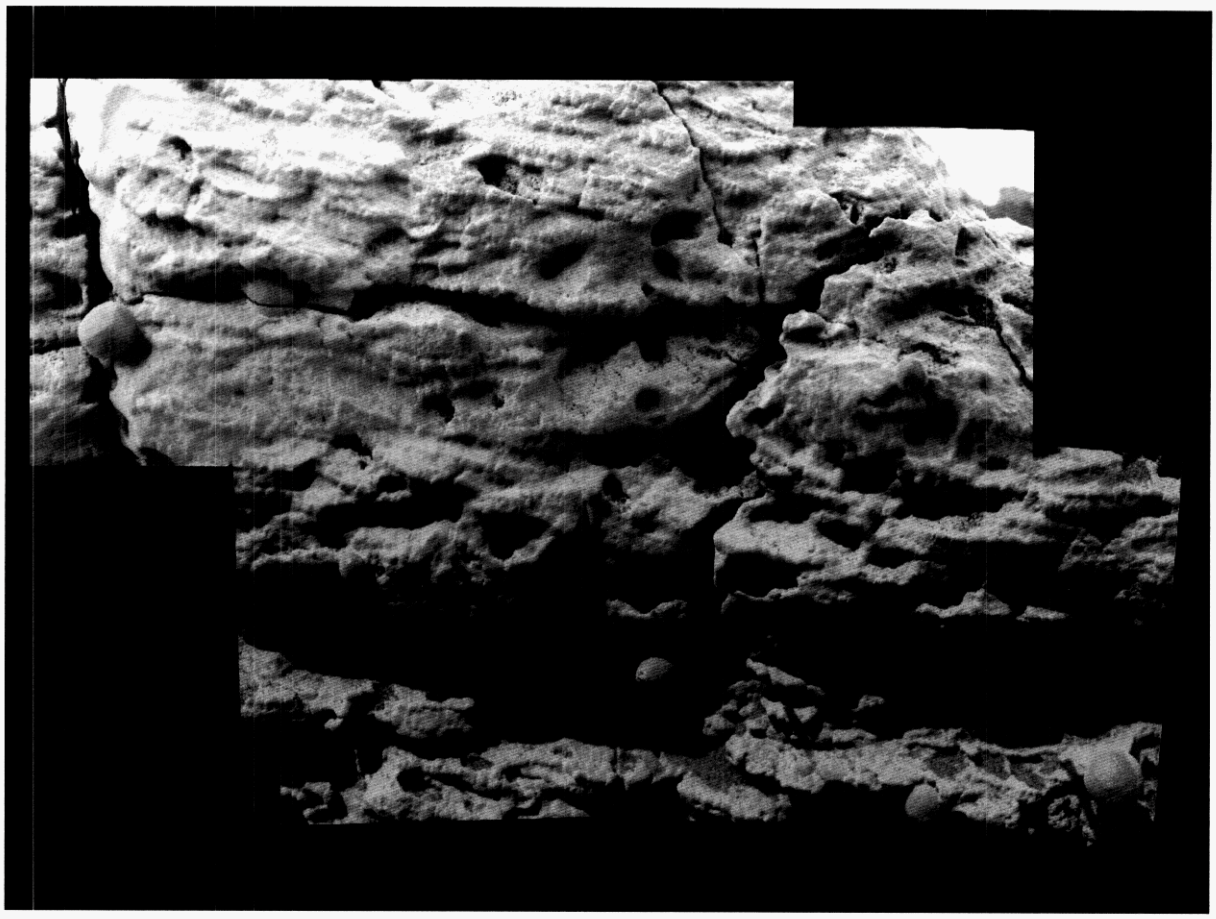


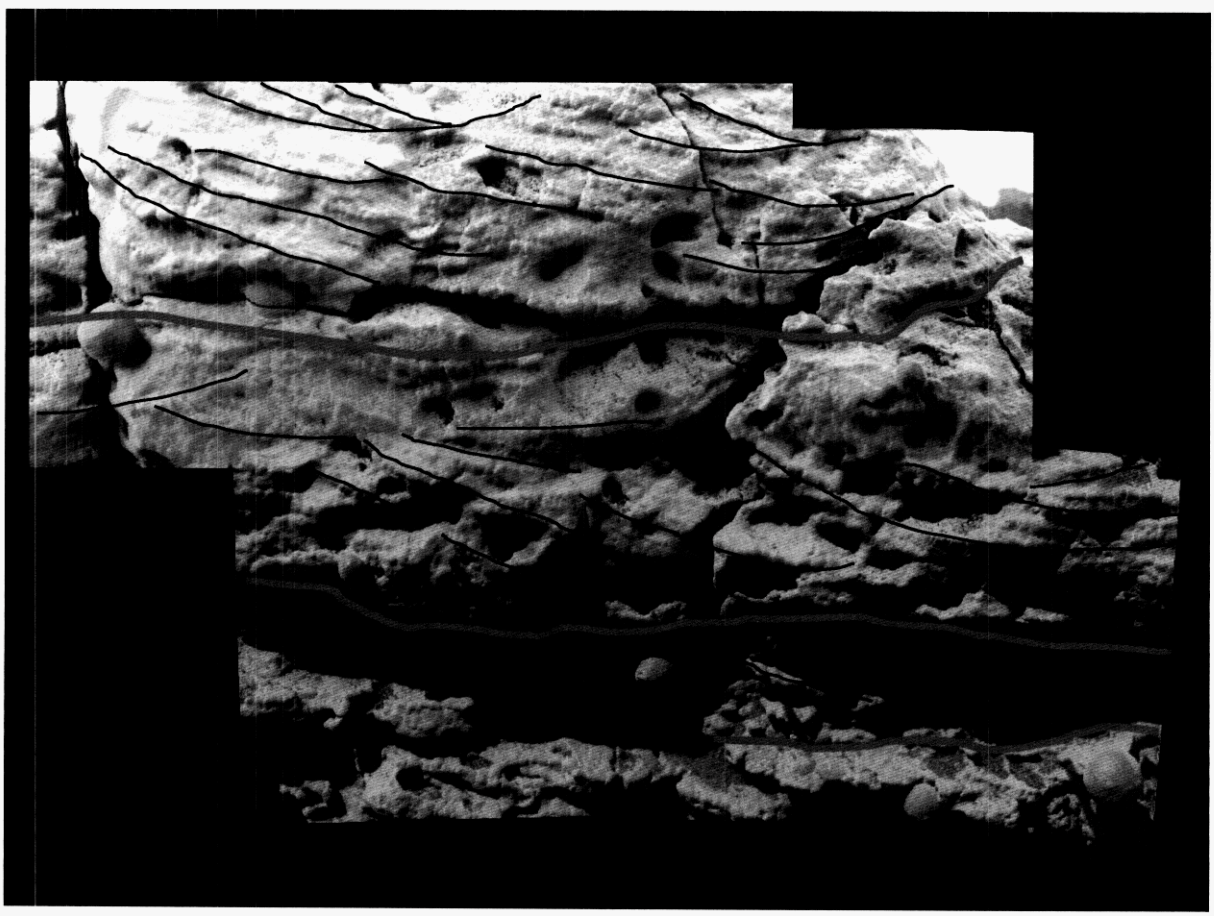

APXS Rock and Soil X-ray Spectra
at Meridiani
McKittrick post-RAT
Tarmac soil
* = Background
Counts/sec
10
1
.1
.01
Na
Mg
Al
Si
Sulfur
P
Cl
Ar*
K
Ca
Ti
Cr
Mn
Fe
Ni
Cu*
Zn
Br
Scatter
Pu La1*
Zr Ka*
2000
4000
6000
8000
10000
12000
14000
16000
Energy (eV)


Chlorine and Bromine in samples of Meridiani Planum
and Martian Meteorites
Martian Meteorites
CI - Chondrite
Meridiani
Dead Sea Salt
Cl ppm
10^6
10^5
10^4
1000
100
10
Dead Sea Salt
Seawater
McKittrick
Flat rock
Trench floor
Trench wall
Dells Hi-ho
McKittrick Rat
Guadalupe RAT
chondritic Cl/Br ratio
Martian Meteorites
0.01
0.1
1
10
100
1000
10^4
Br ppm

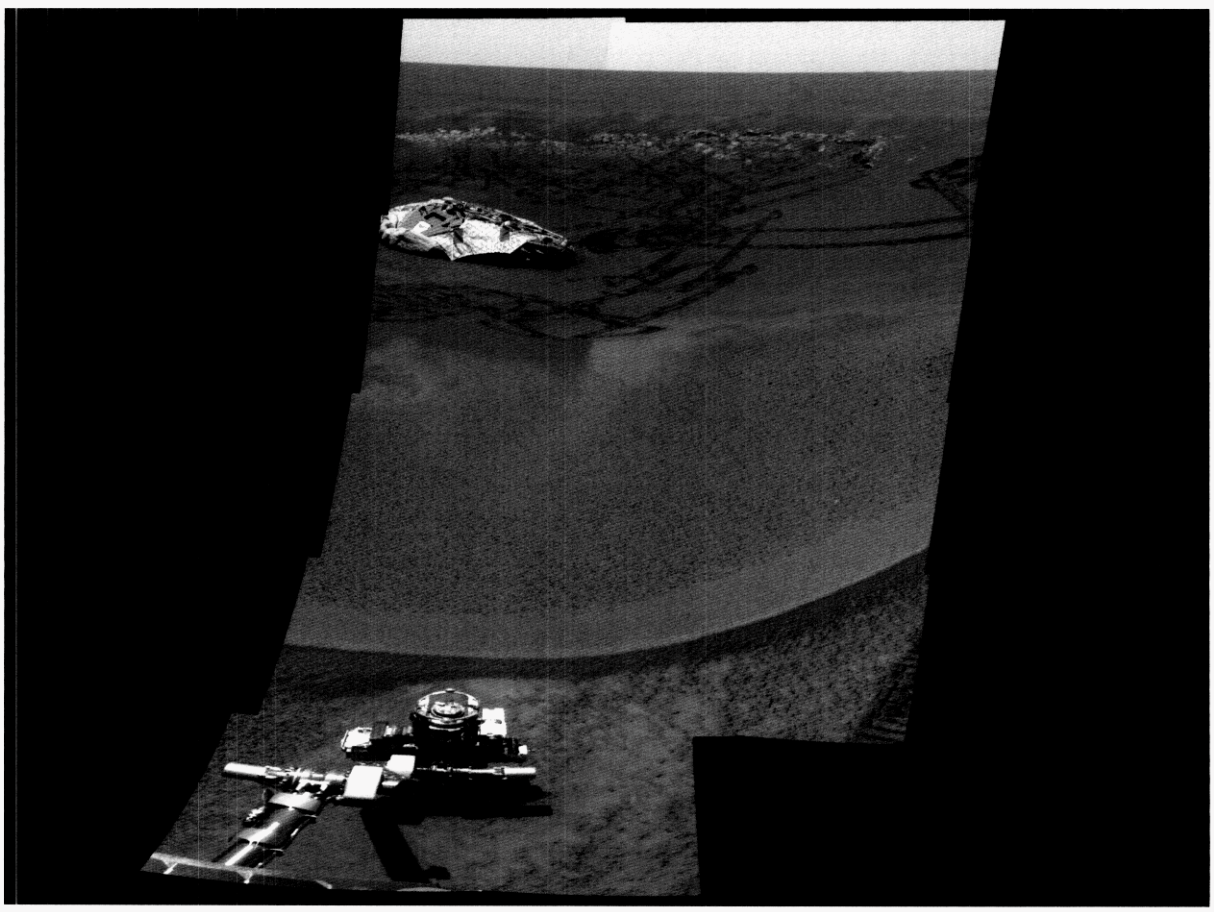

Mössbauer Spectrum of El Capitan: Meridiani Planum
Jarosite: (K, Na, X^{+1})$Fe_3(SO_4)_2(OH)_6$
Intensity
Velocity
0
Fe^{3+} Jarosite
Fe^{3+} phase
Fe^{2+} silicate
Magnetic phases
Mössbauer Spectrum of El Capitan: Meridiani Planum
Jarosite: (K, Na, X^{+1})$Fe_3(SO_4)_2(OH)_6$
Intensity
Velocity
0
Fe^{3+} Jarosite
Fe^{3+} phase
Fe^{2+} silicate
Magnetic phases

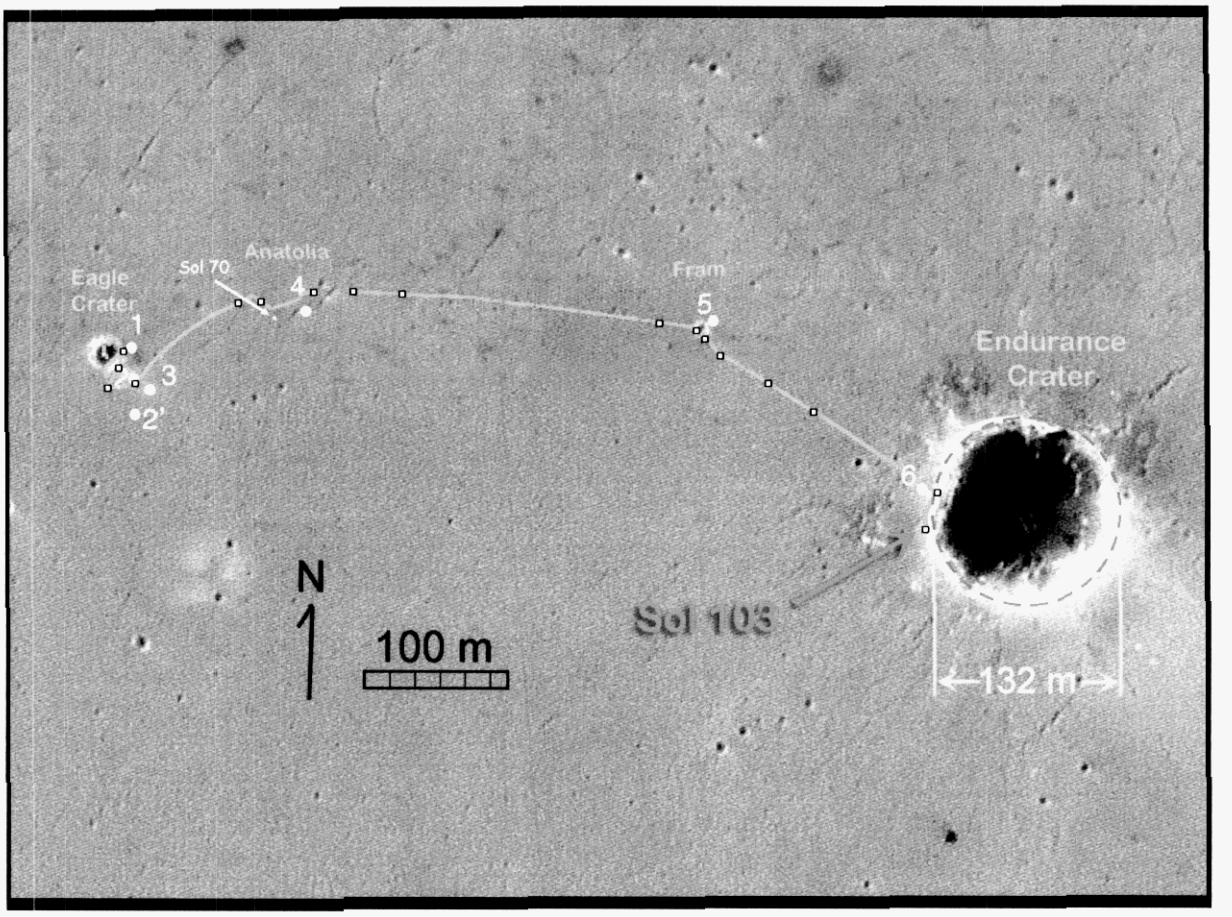

Slickrock Pancam
Upper Unit, Rippled
Middle Unit, Planar Stratified
Lower Unit, Rippled
5 cm

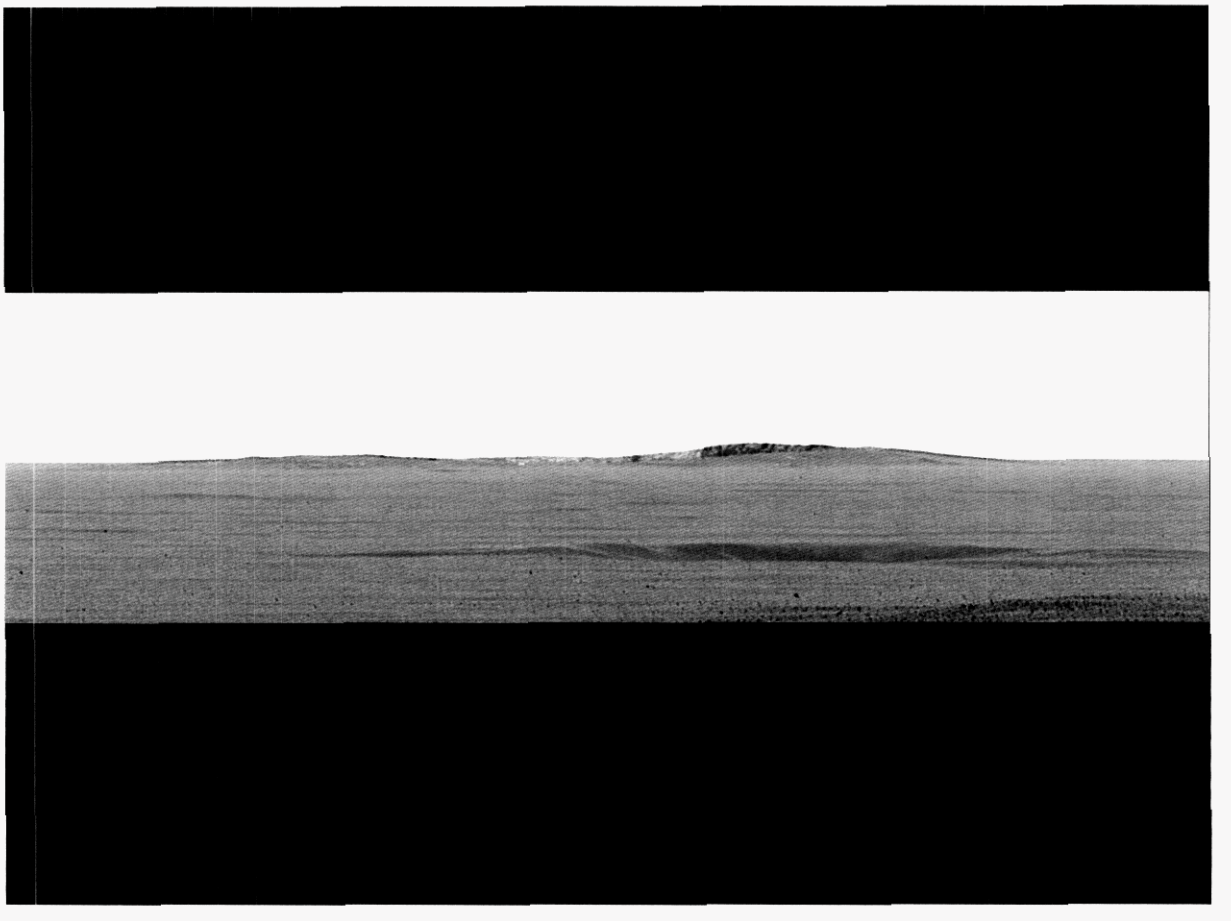


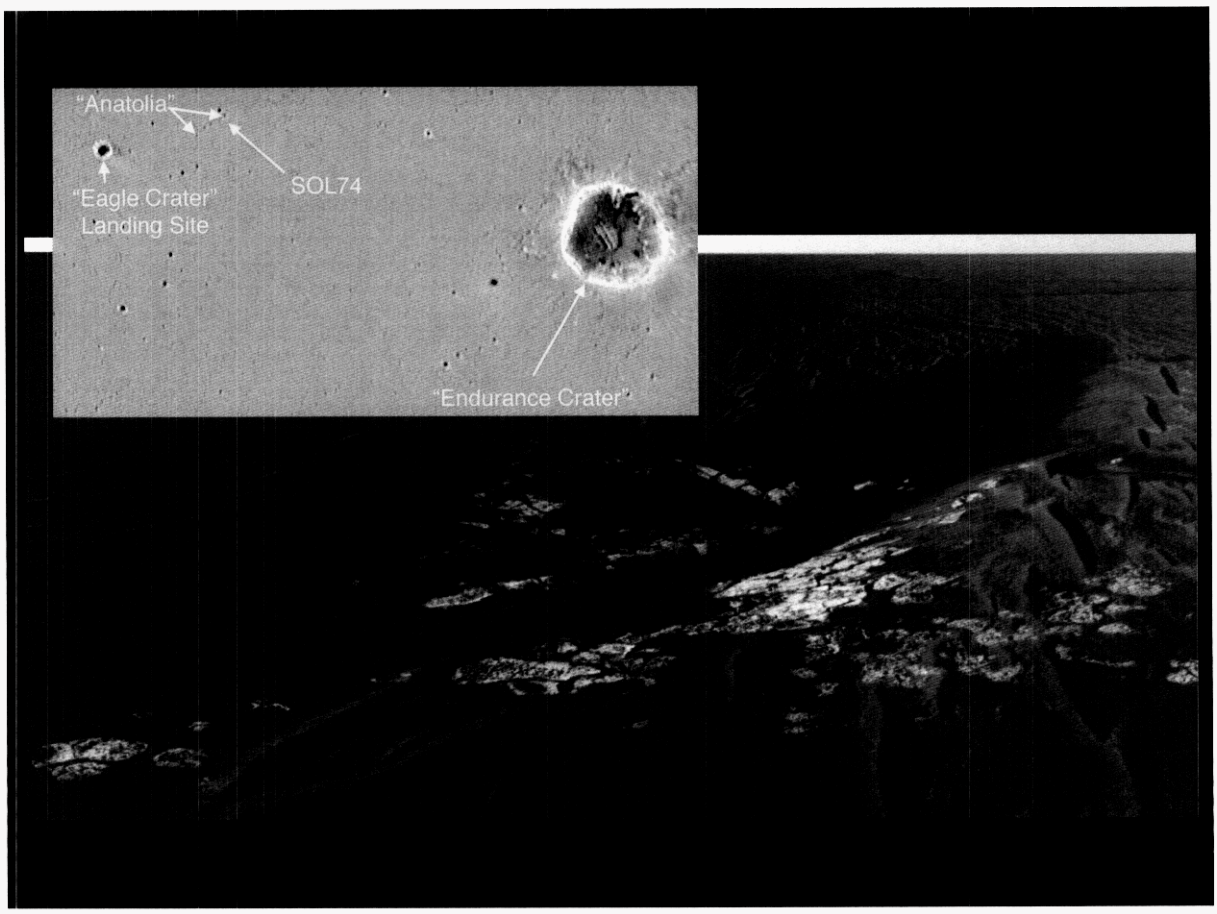


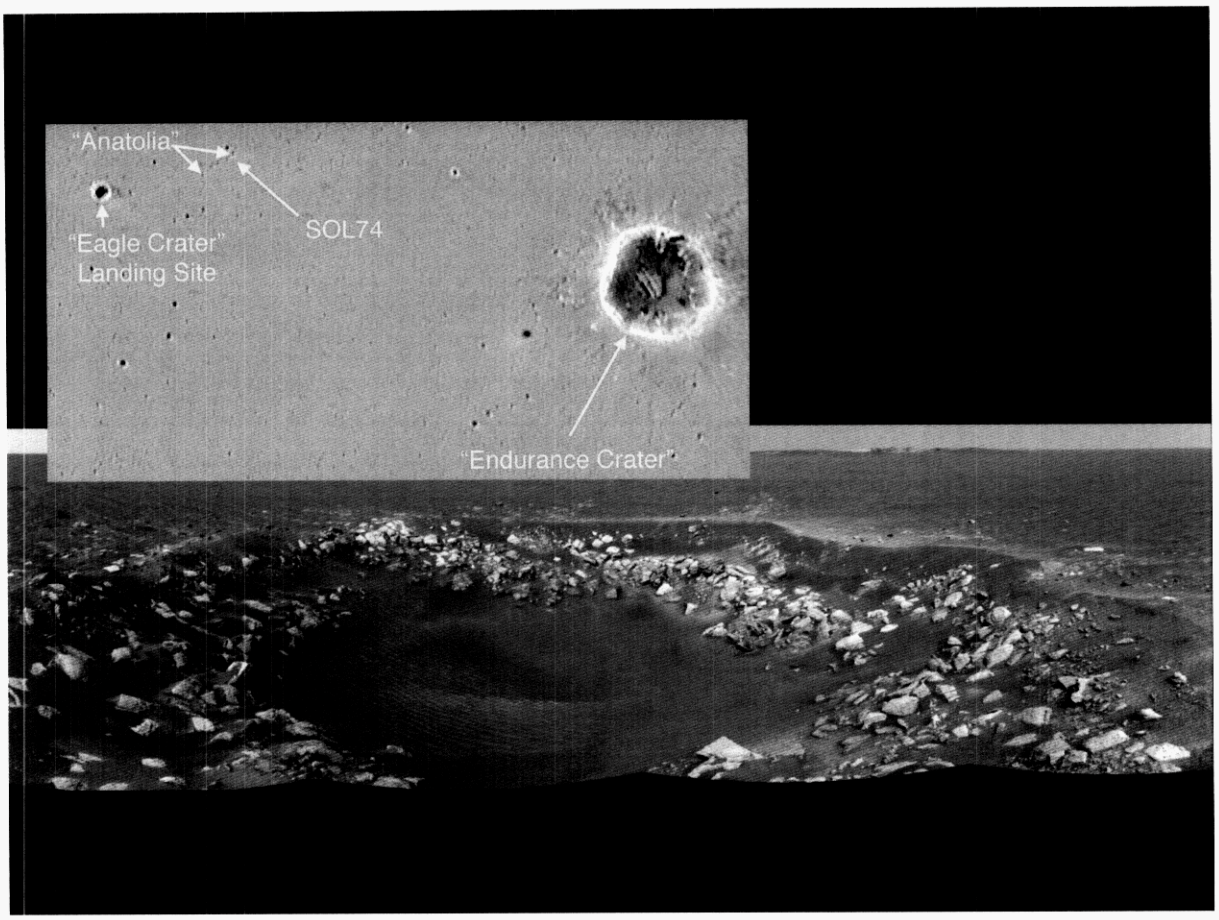
Courtesy Dave Rubin, USGS

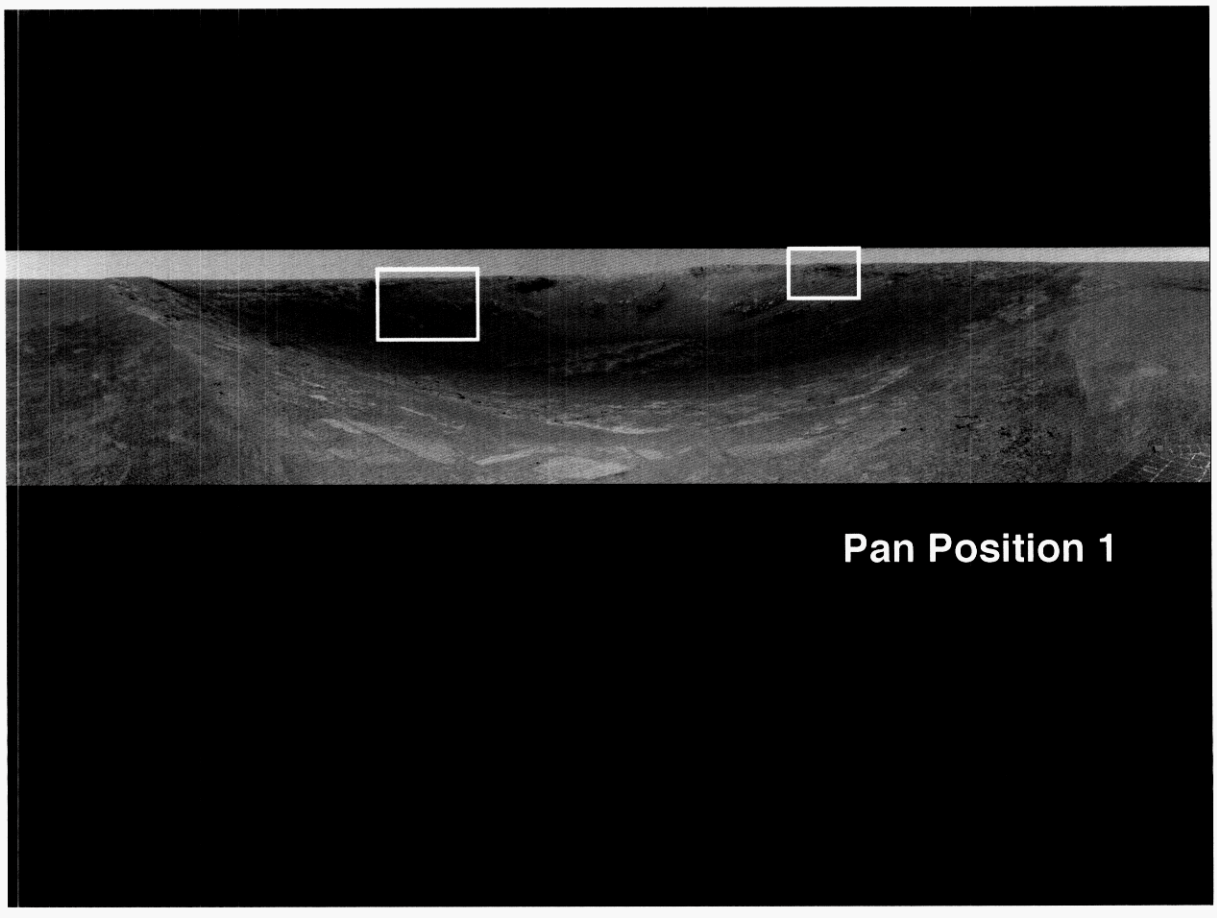


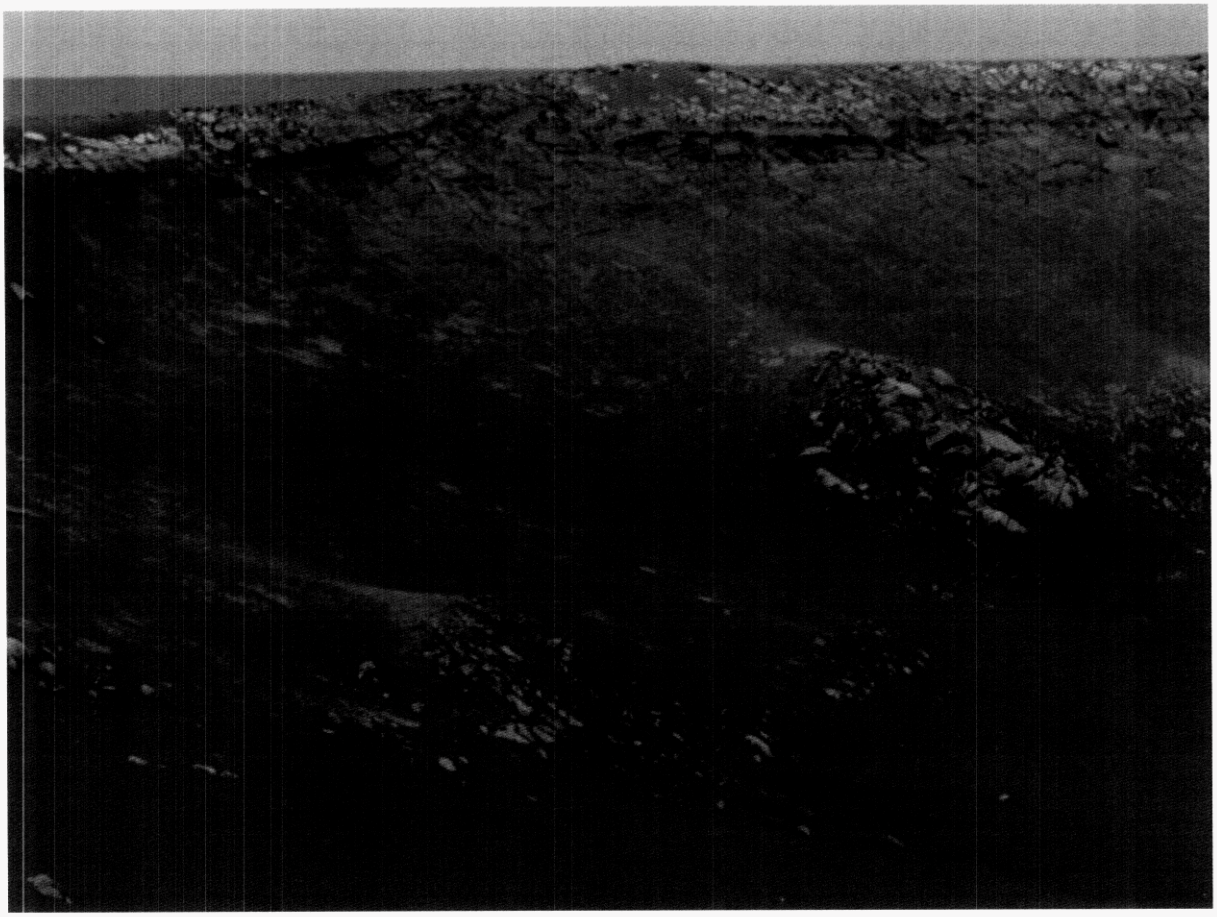

Eagle Crater
Sol 70
Anatolia
Fram
Endurance Crater
1
2
2'
3
4
5
6
N
100 m
Sol 103
132 m

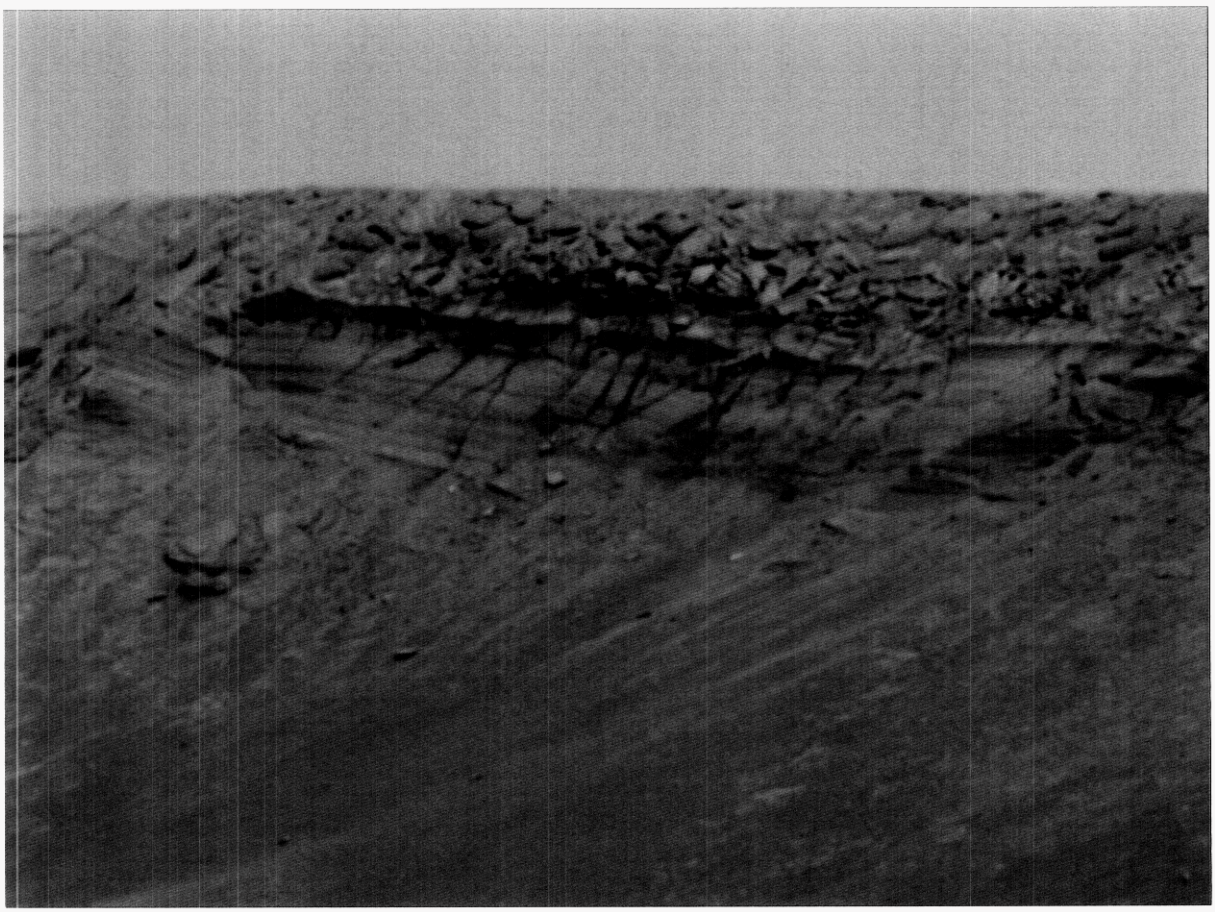


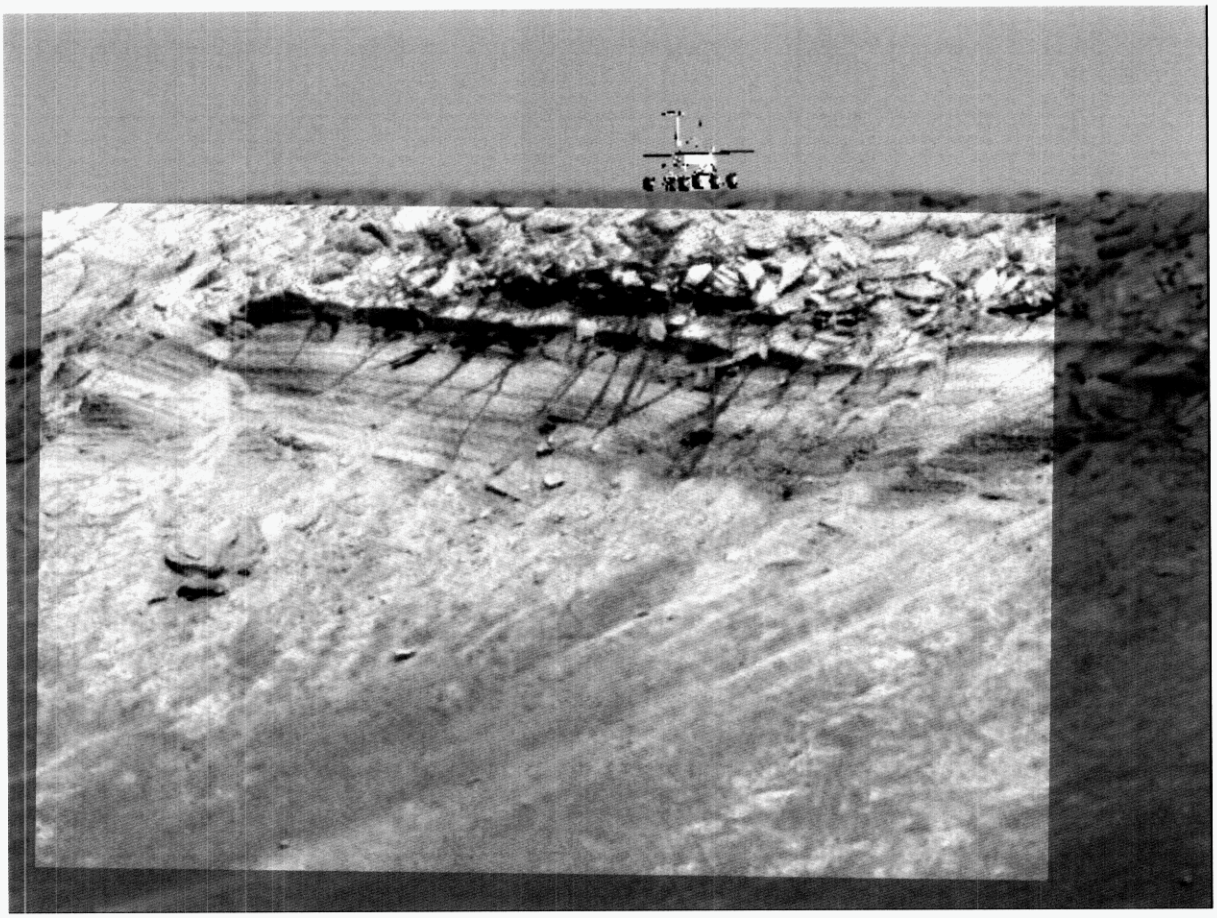

"Anatolia"
"Eagle Crater"
Landing Site
SOL74
"Endurance Crater"

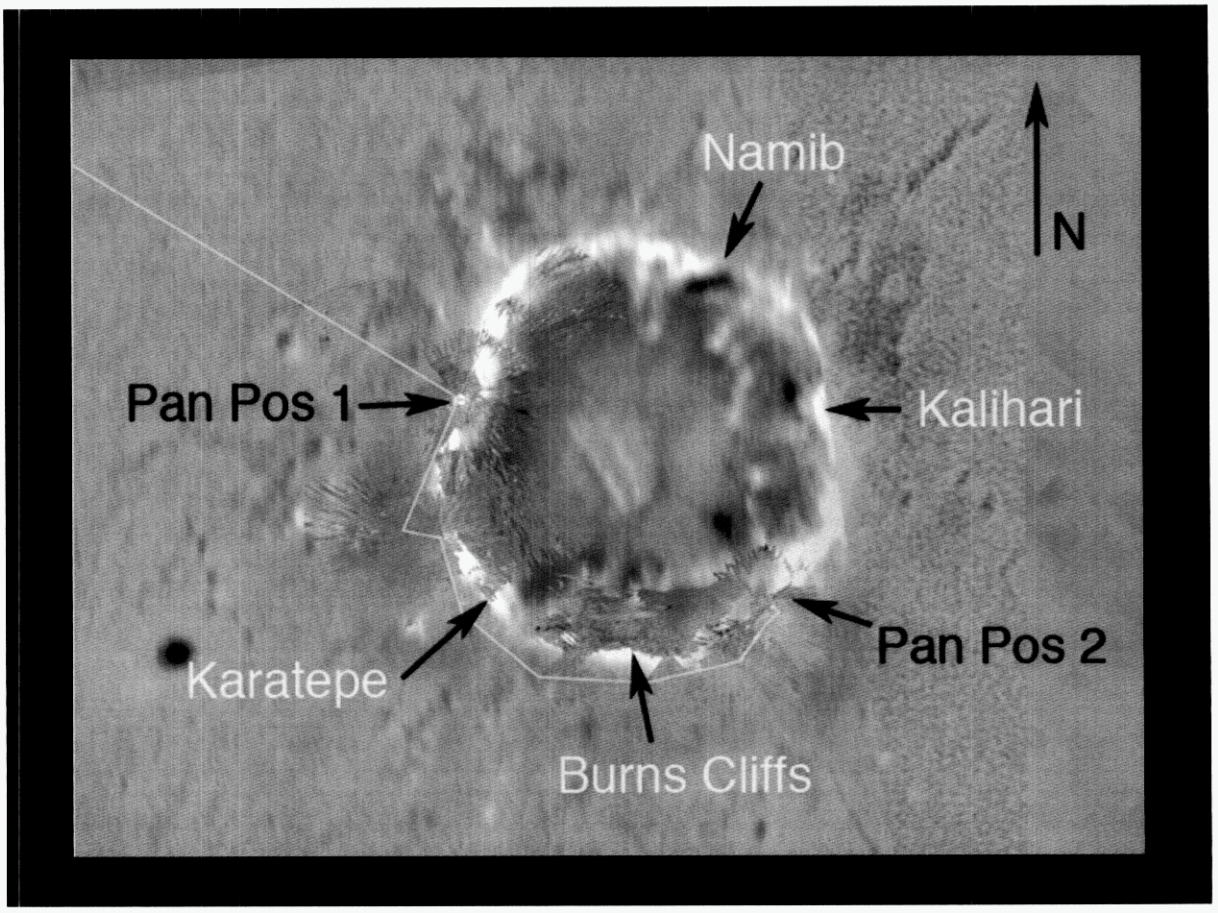

"Anatolia"
"Eagle Crater"
Landing Site
SOL74
"Endurance Crater"

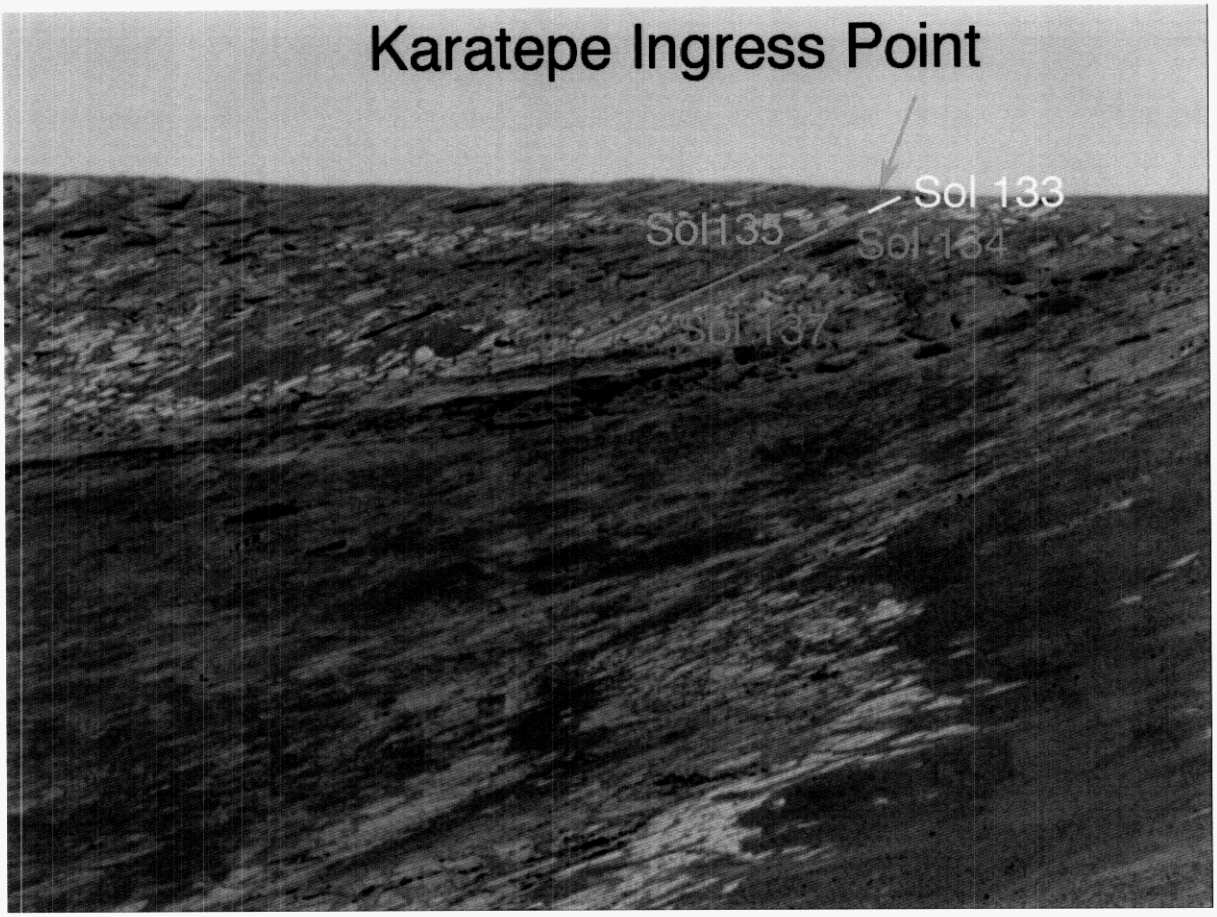

Pan Position 1

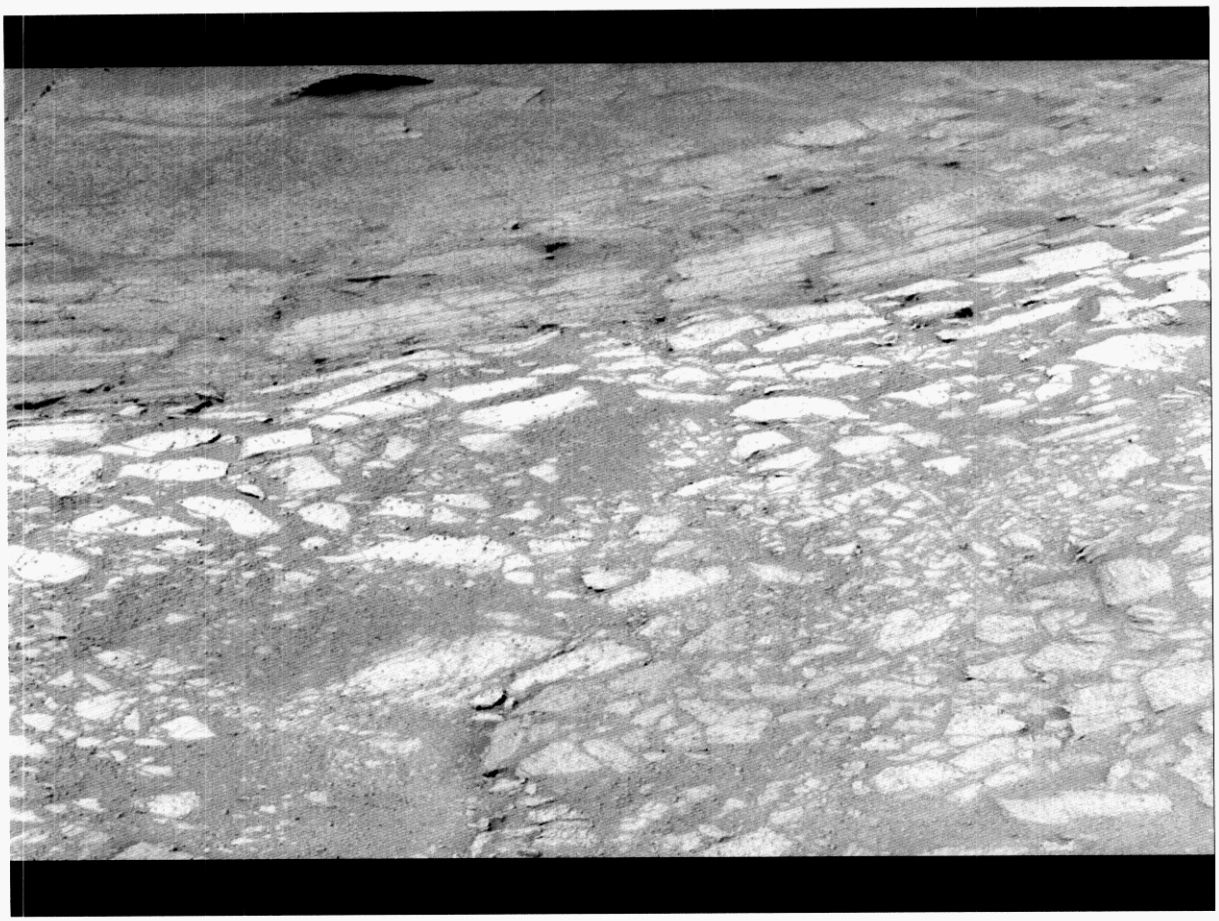


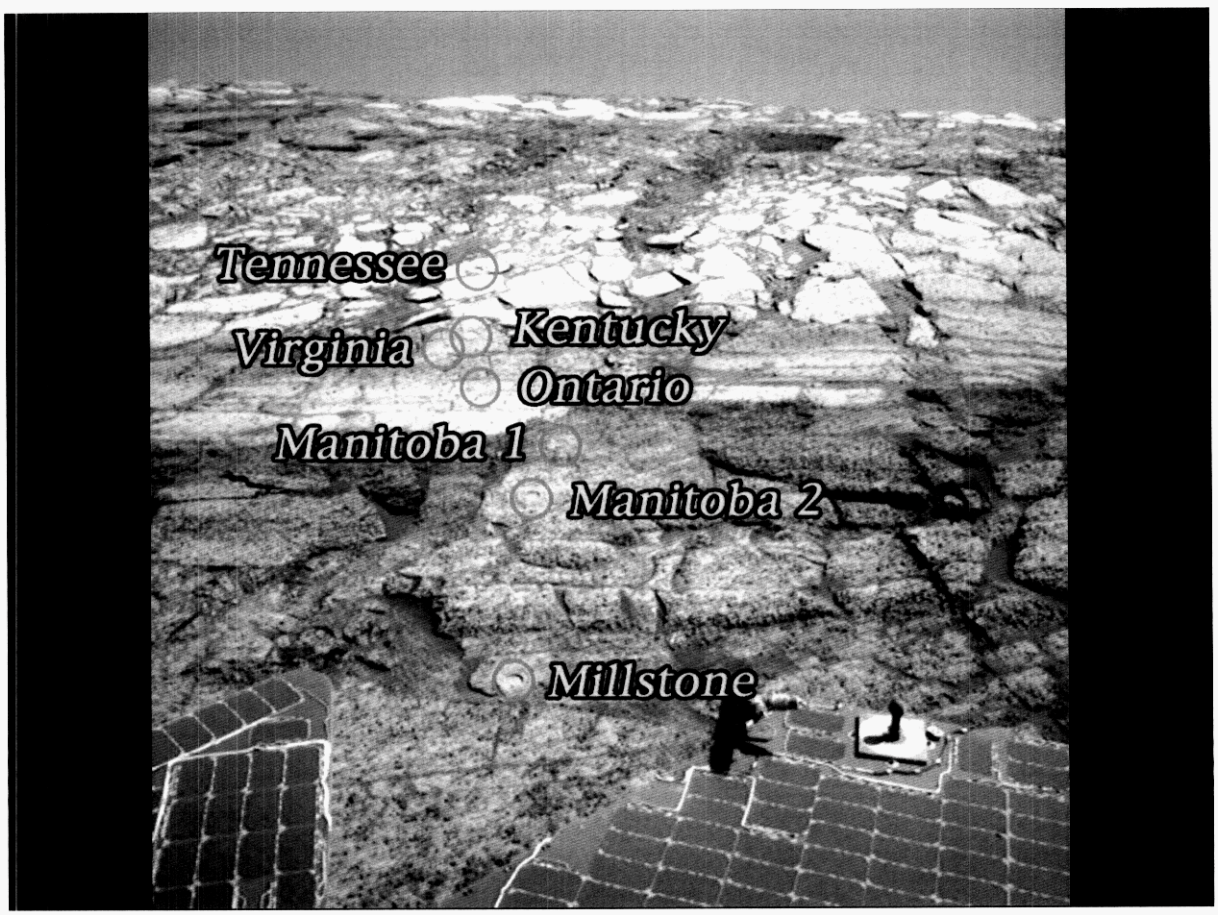


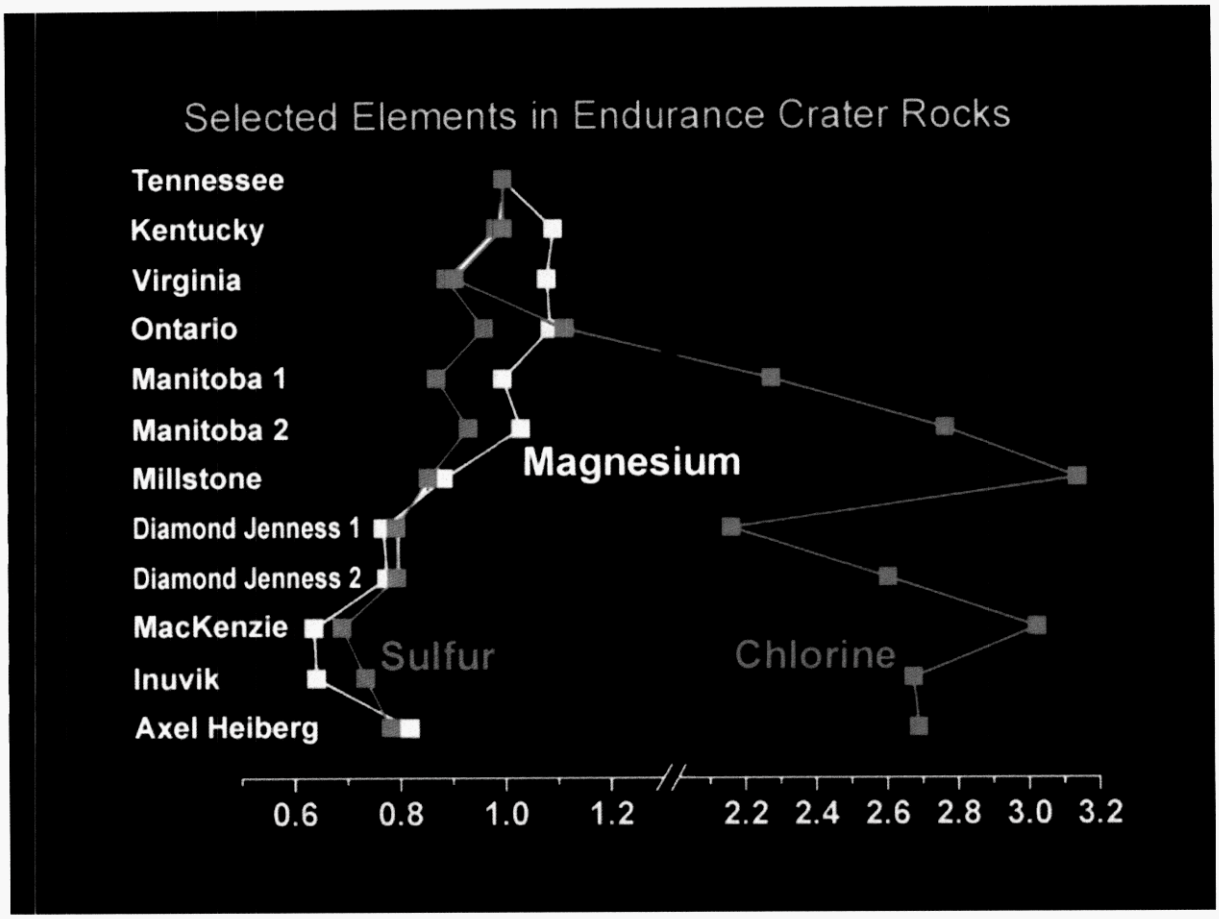


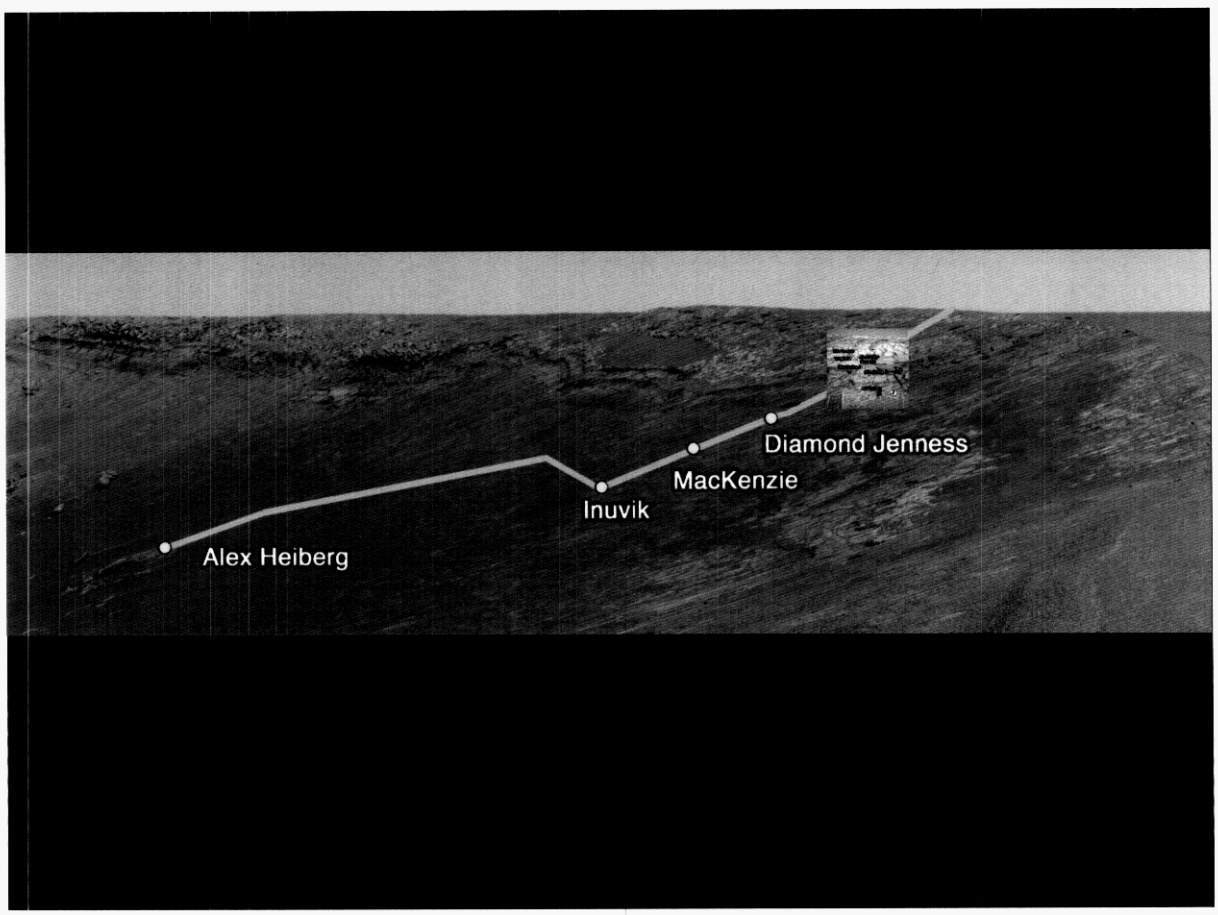

Namib
N
Pan Pos 1
Kalihari
Karatepe
Pan Pos 2
Burns Cliffs

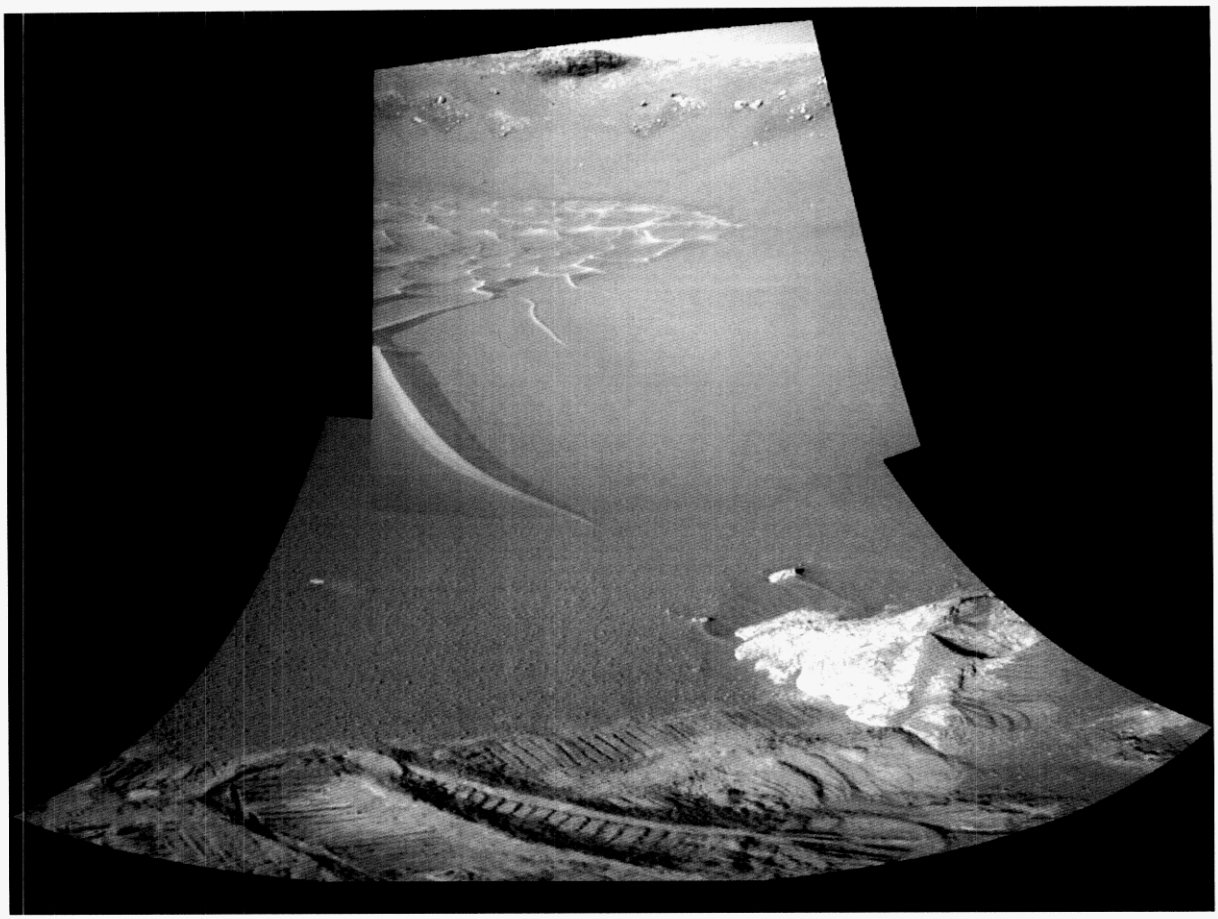

Karatepe Ingress Point
Sol 133
Sol135
Sol 164
Sol 137

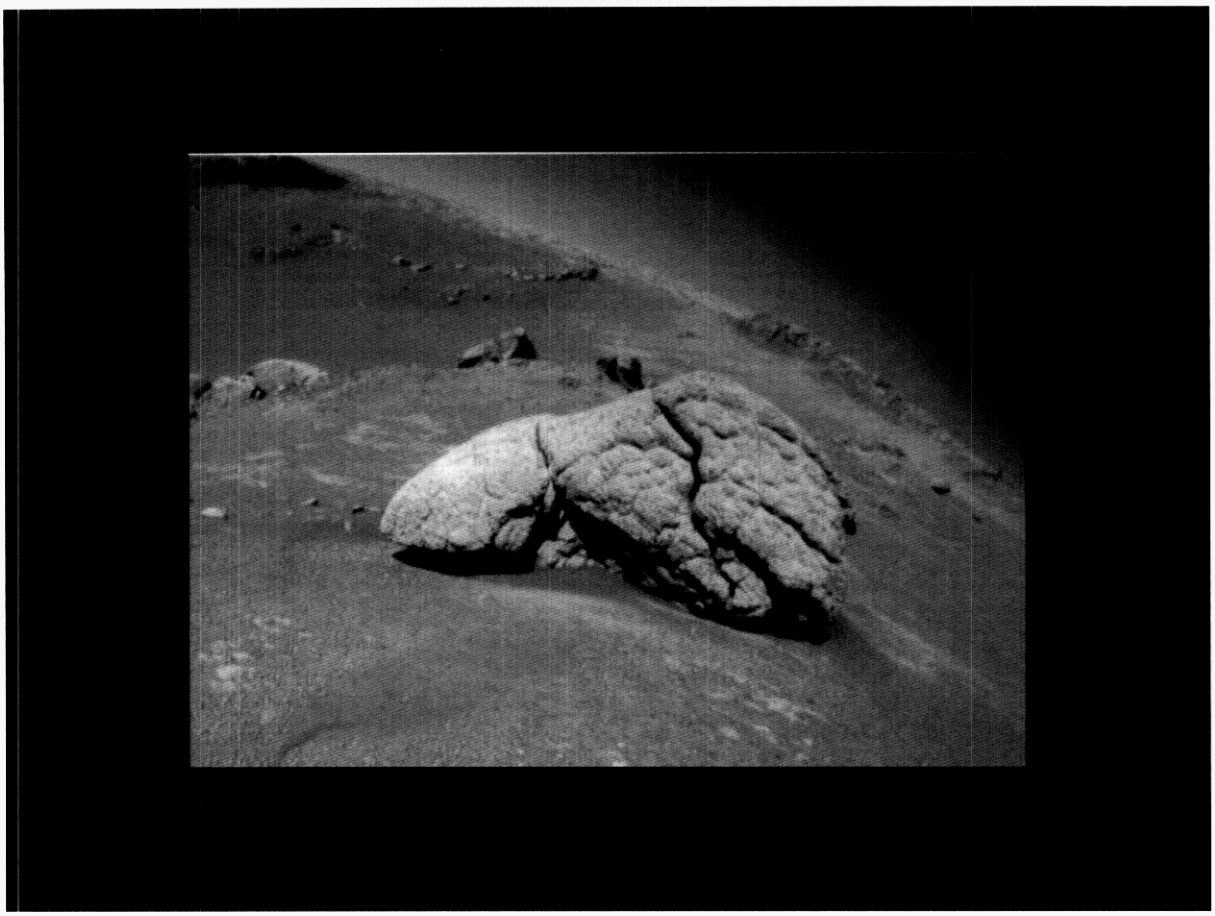


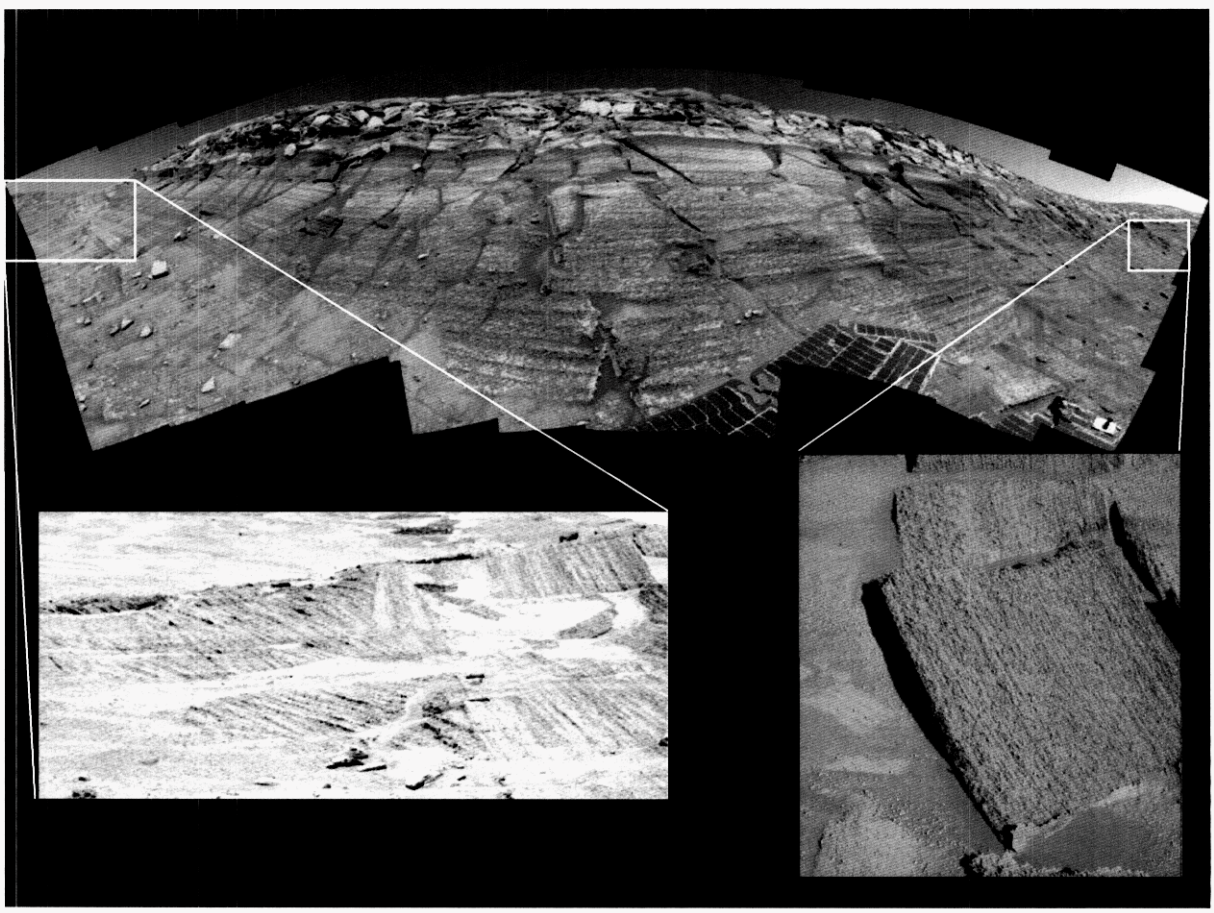

Tennessee
Virginia
Kentucky
Ontario
Manitoba 1
Manitoba 2
Millstone

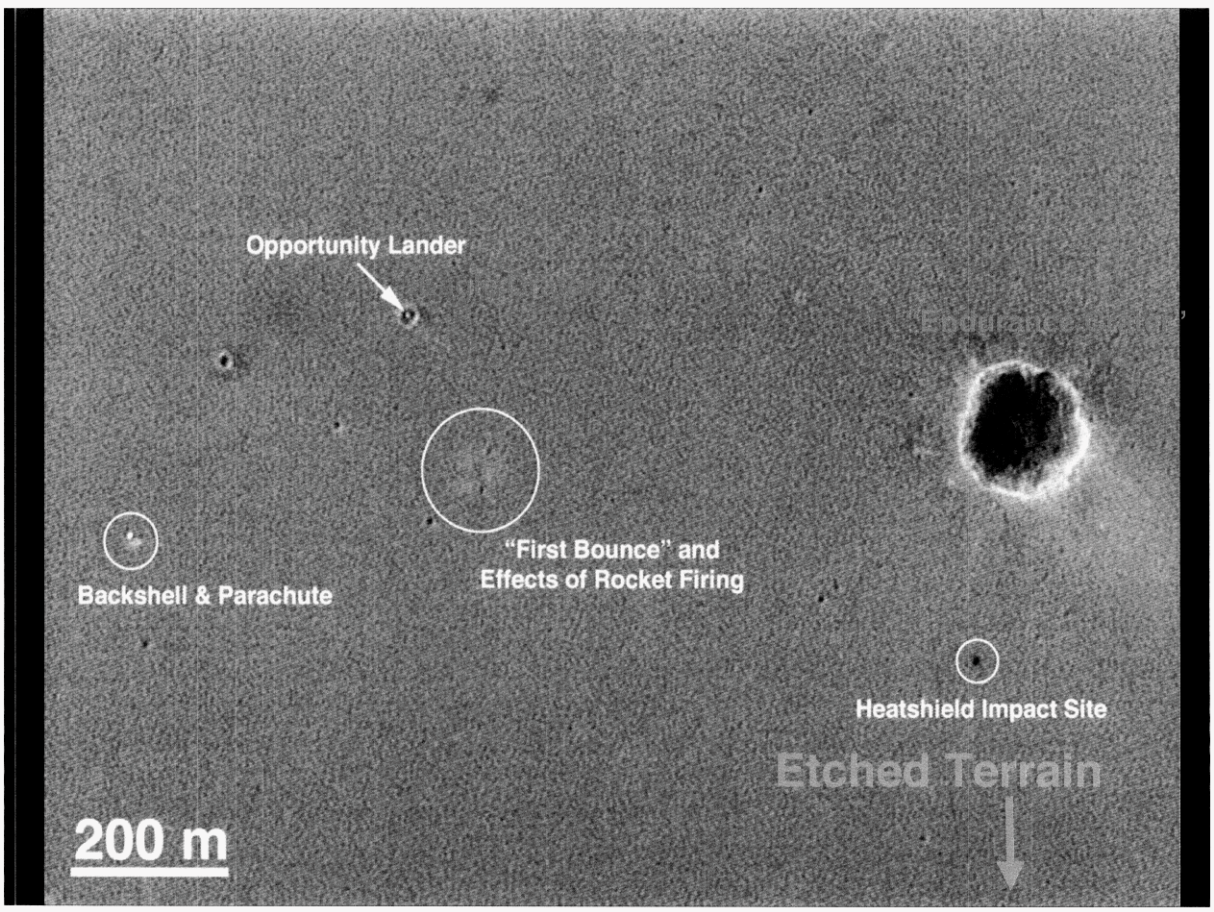

Selected Elements in Endurance Crater Rocks
Tennessee
Kentucky
Virginia
Ontario
Manitoba 1
Manitoba 2
Millstone
Diamond Jenness 1
Diamond Jenness 2
MacKenzie
Inuvik
Axel Heiberg
Magnesium
Sulfur
Chlorine
0.6
0.8
1.0
1.2
2.2
2.4
2.6
2.8
3.0
3.2

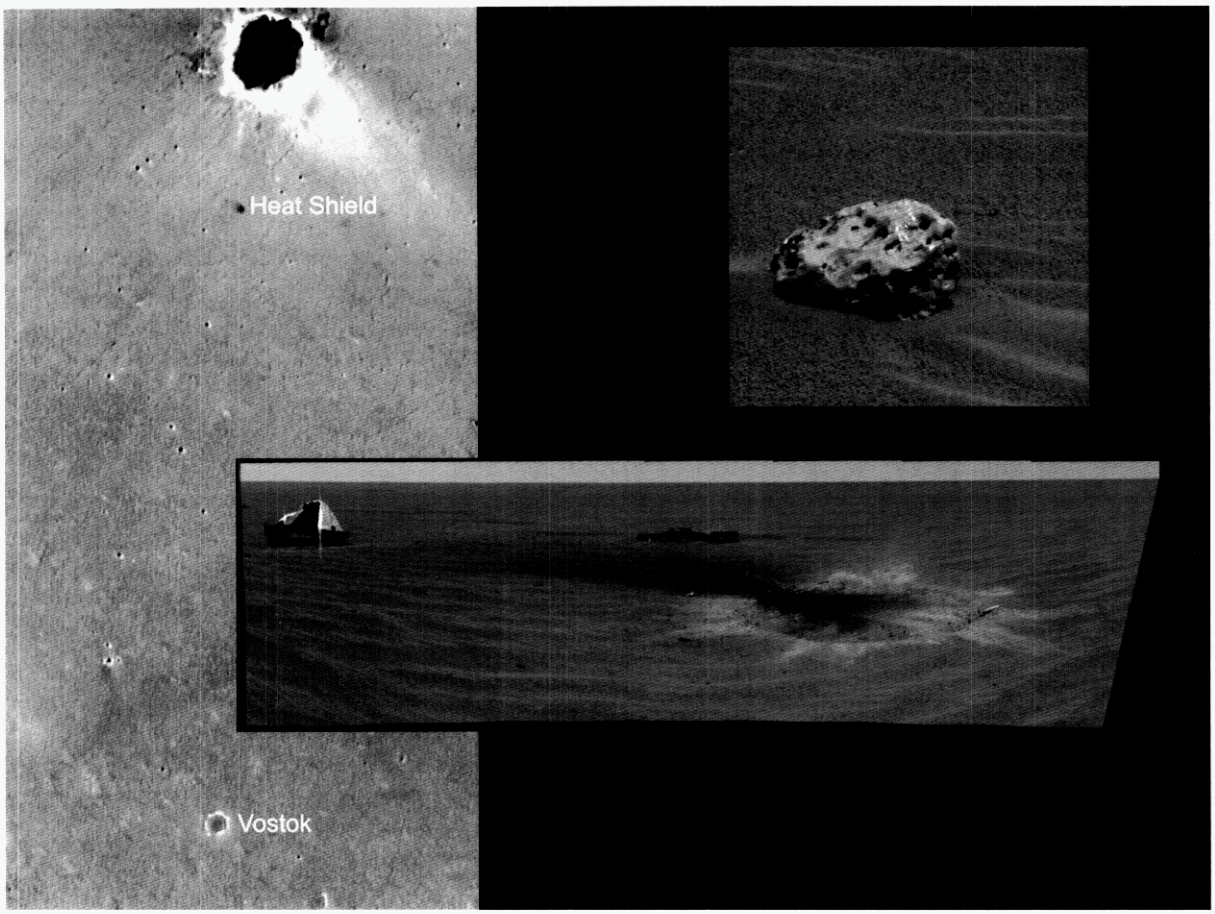

Diamond Jenness
MacKenzie
Inuvik
Alex Heiberg



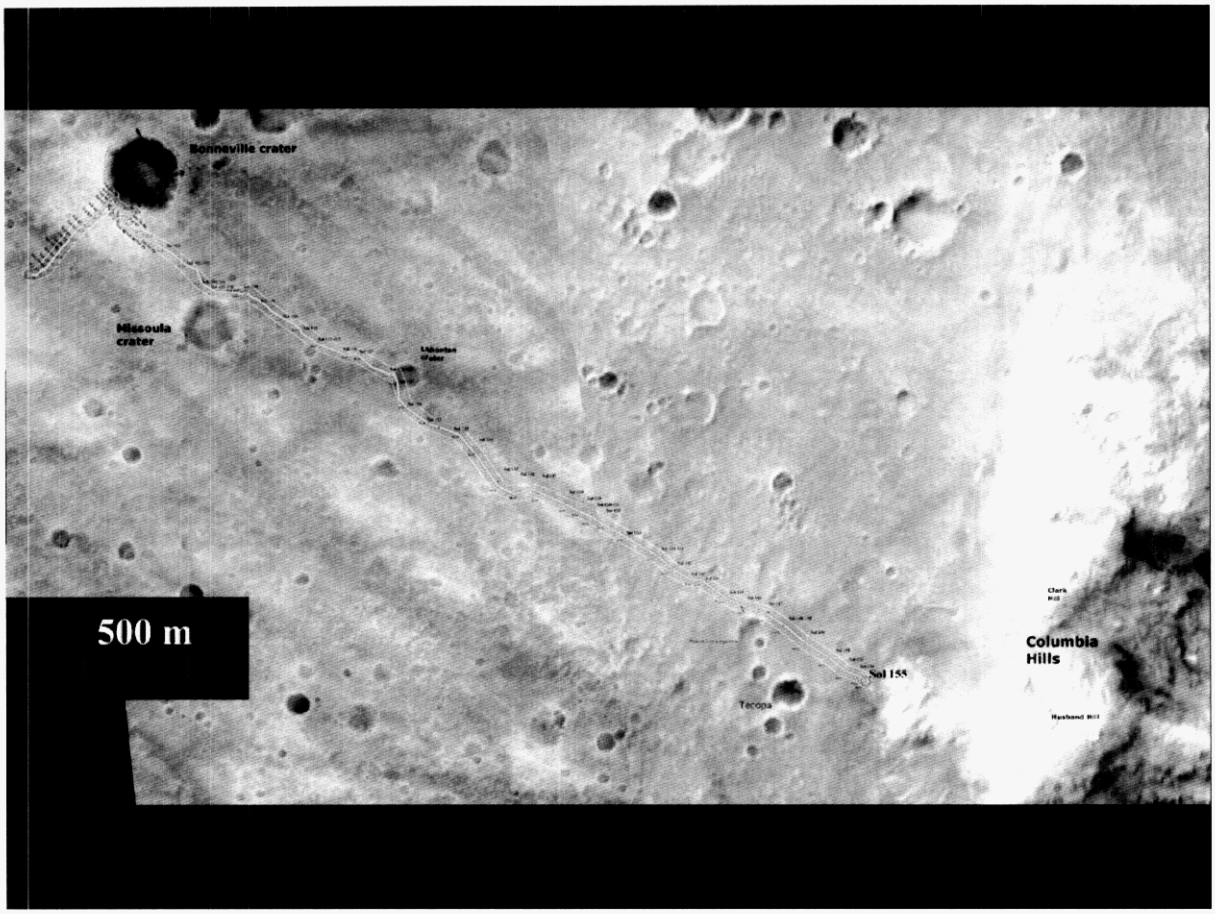


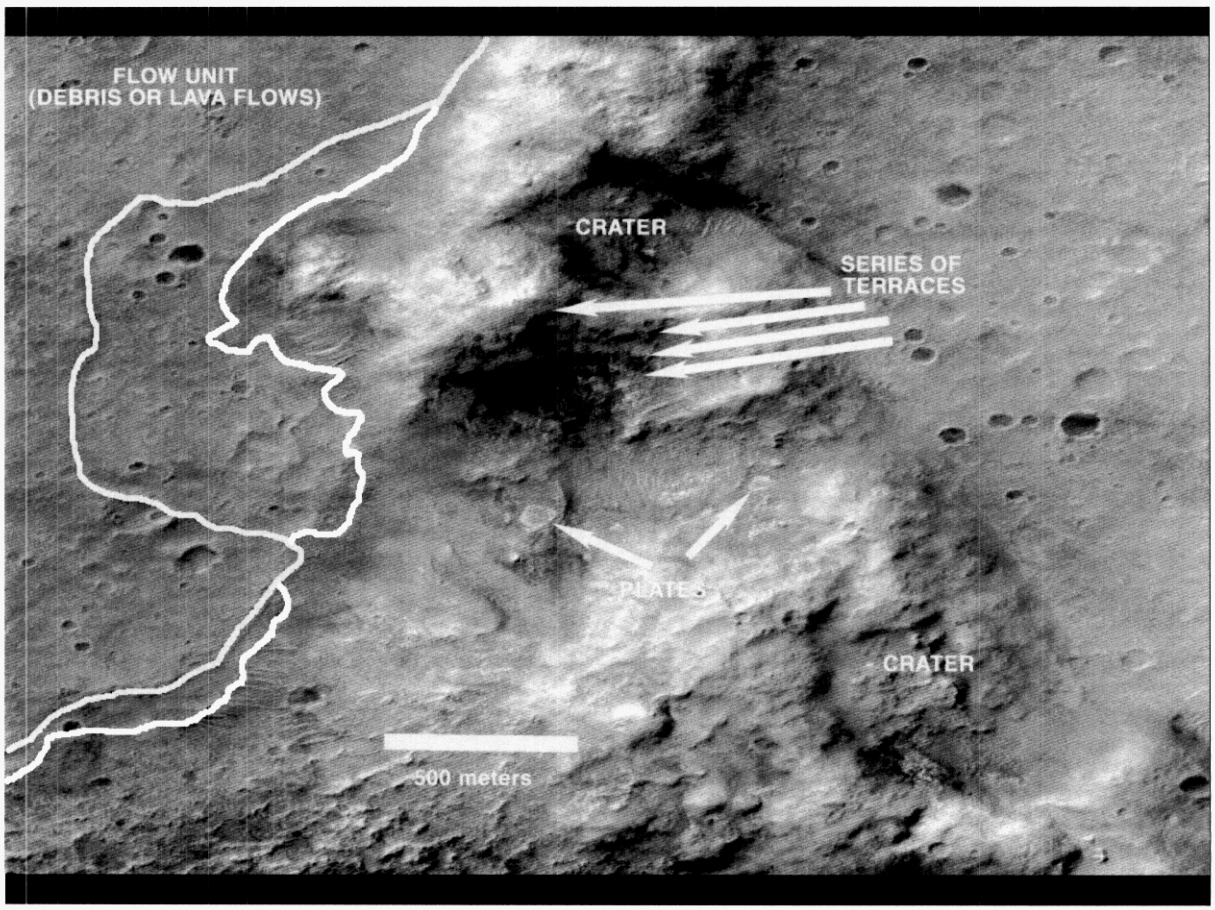


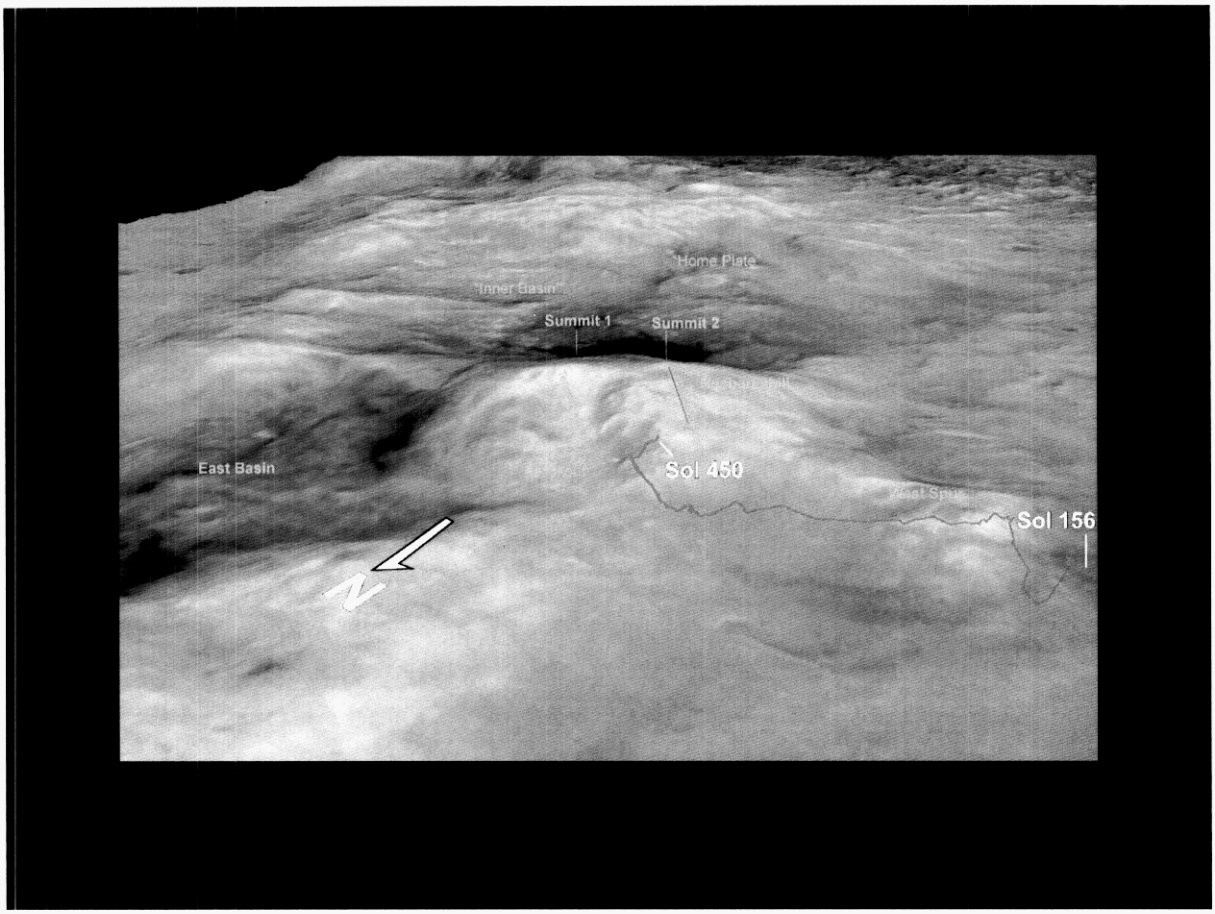

Opportunity Lander
Ejecta
"First Bounce" and
Effects of Rocket Firing
Backshell & Parachute
Heatshield Impact Site
Etched Terrain
200 m

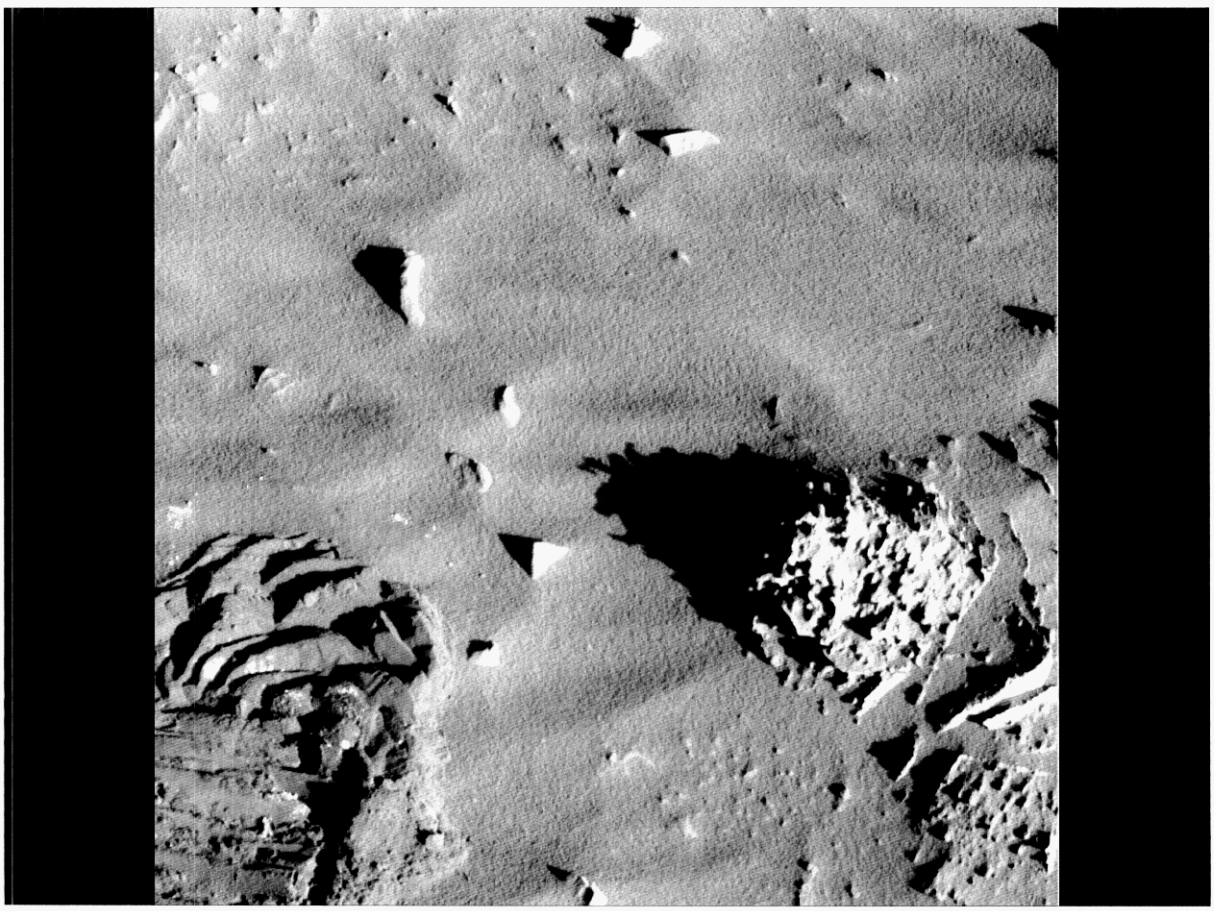

Heat Shield
Vostok

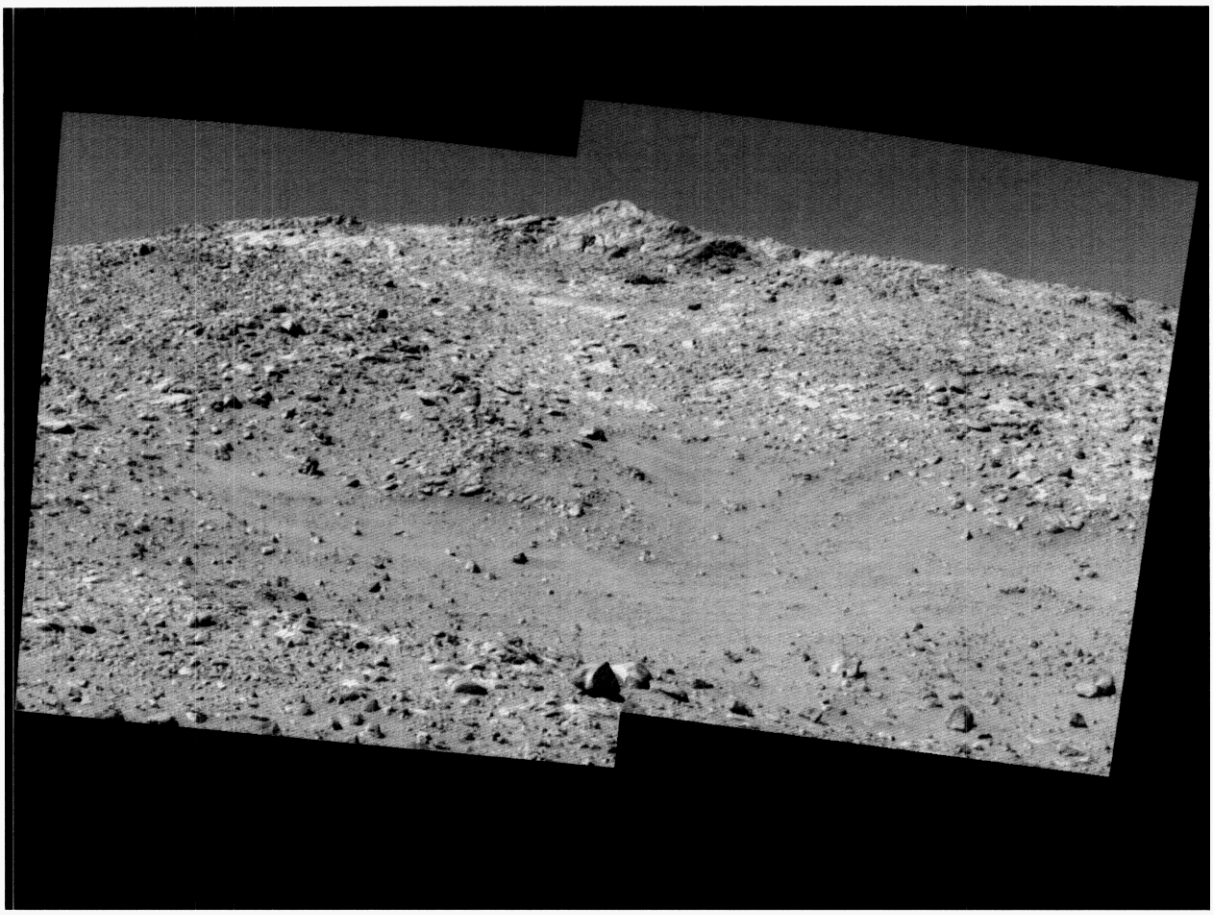
Columbia Hills

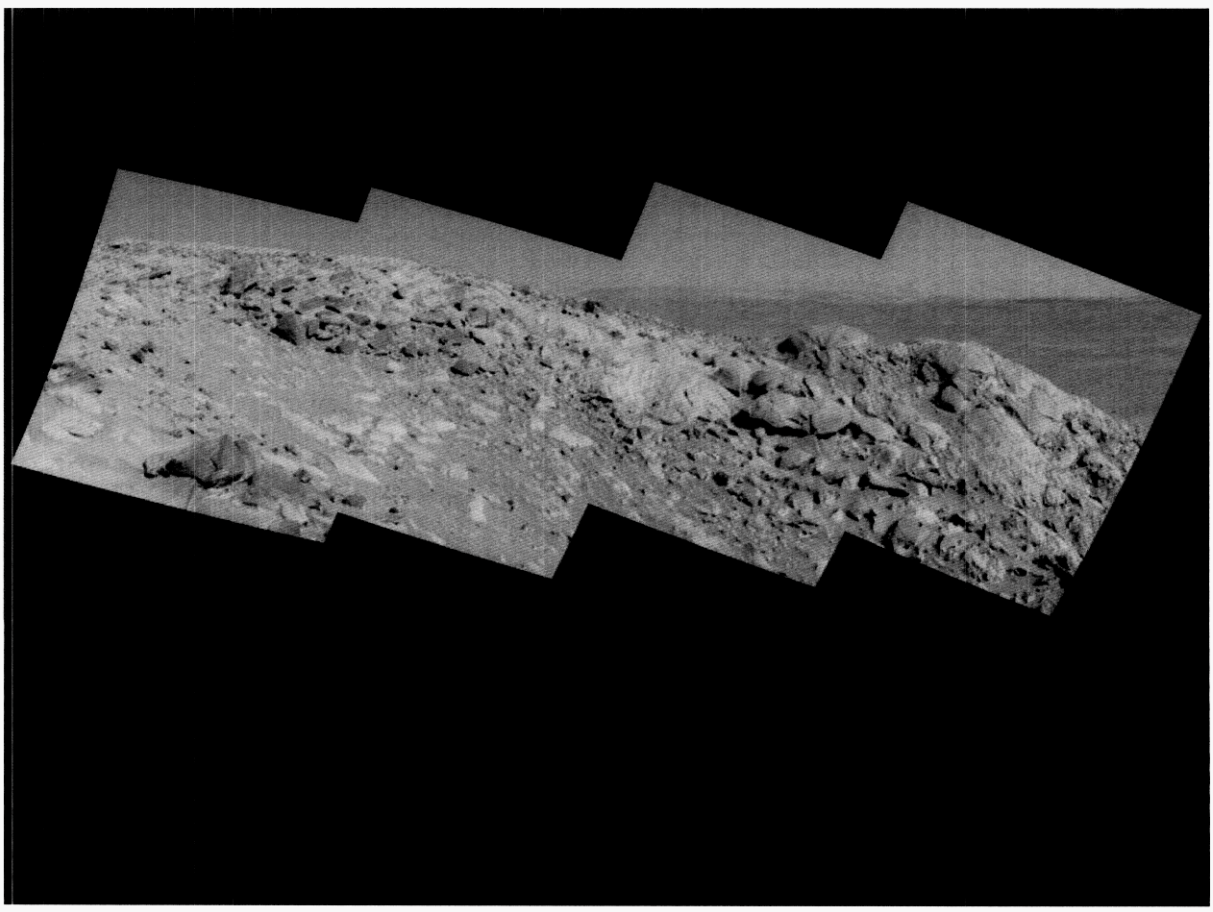

Bonneville crater
Missoula crater
500 m
Columbia Hills
Sol 155
Tecopa

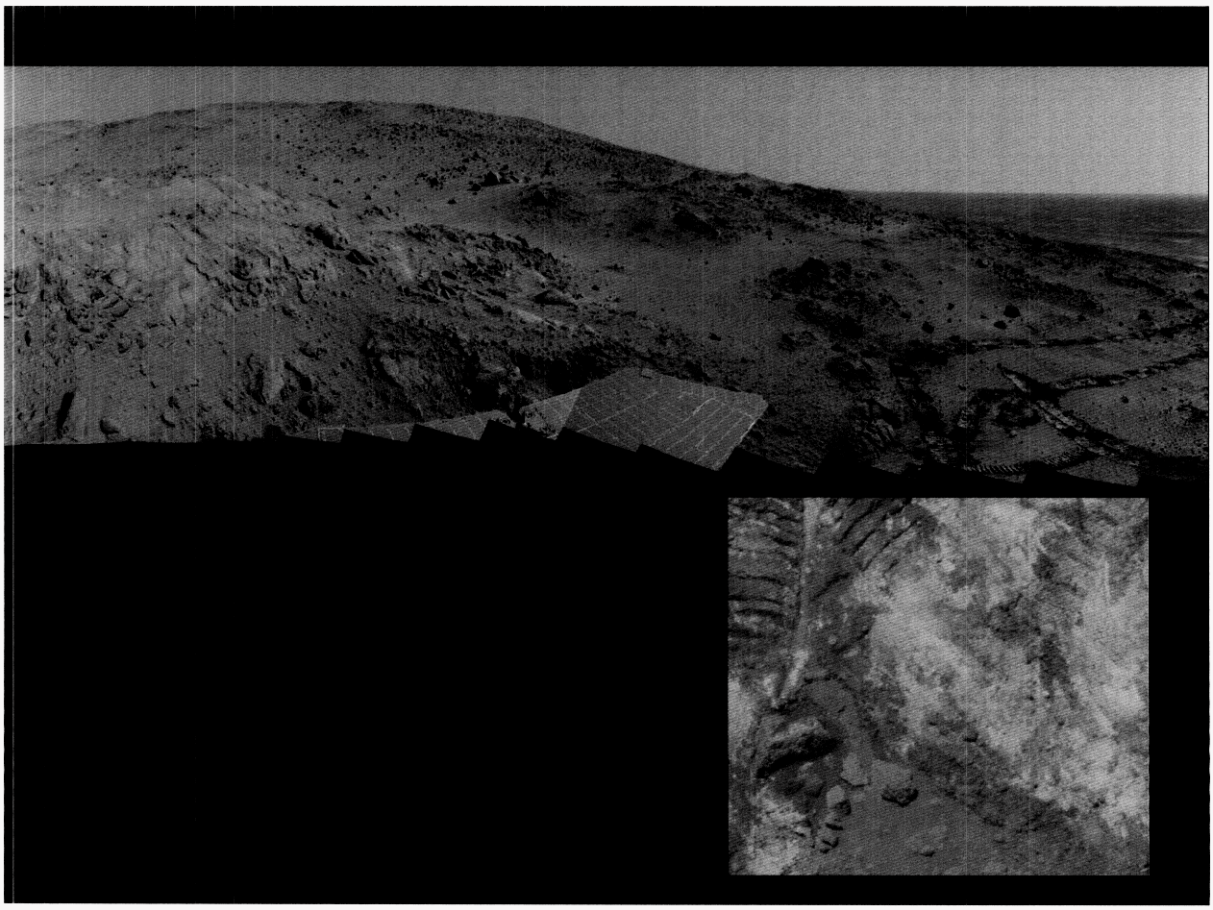

FLOW UNIT
(DEBRIS OR LAVA FLOWS)
CRATER
SERIES OF TERRACES
PLATES
CRATER
500 meters

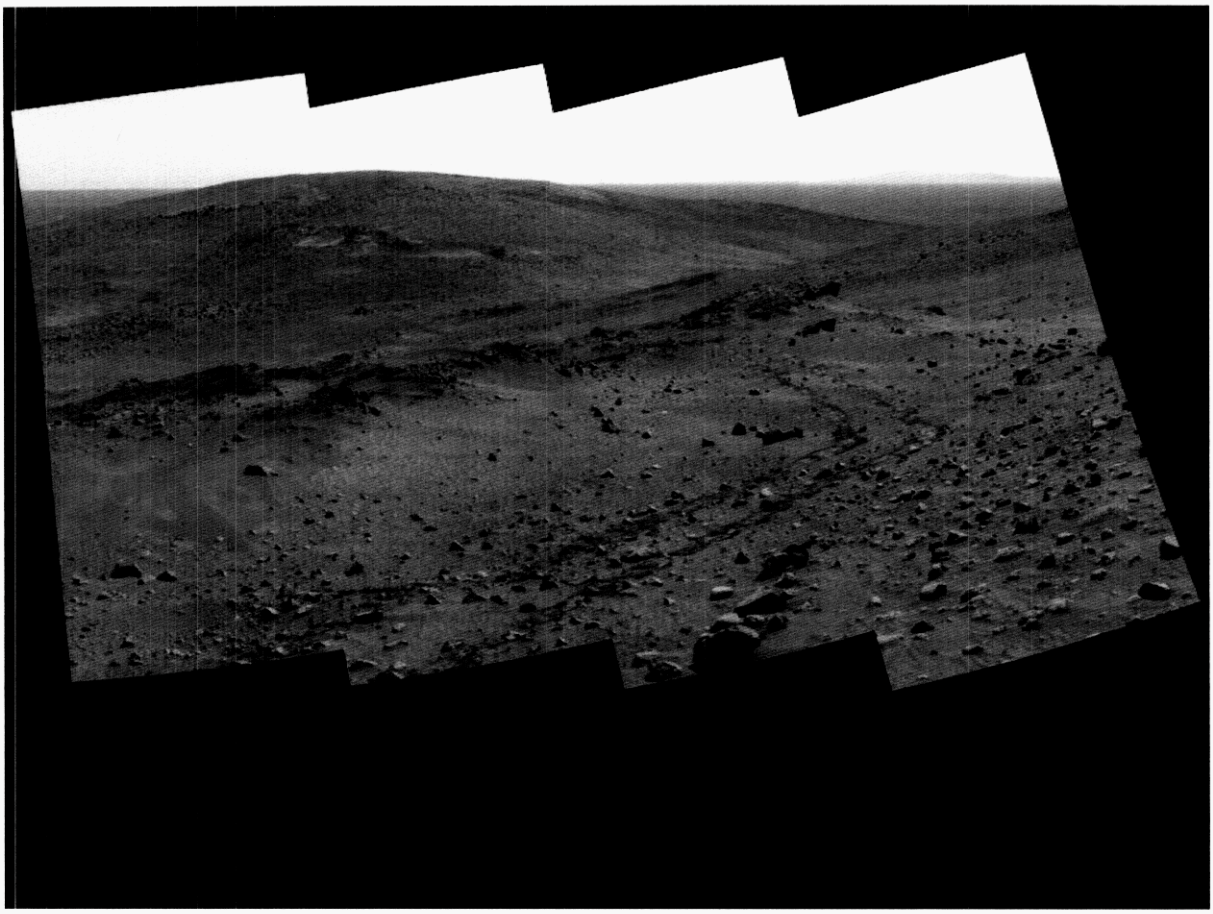

Home Plate
Inner Basin
Summit 1
Summit 2
East Basin
Sol 450
Sol 156
N

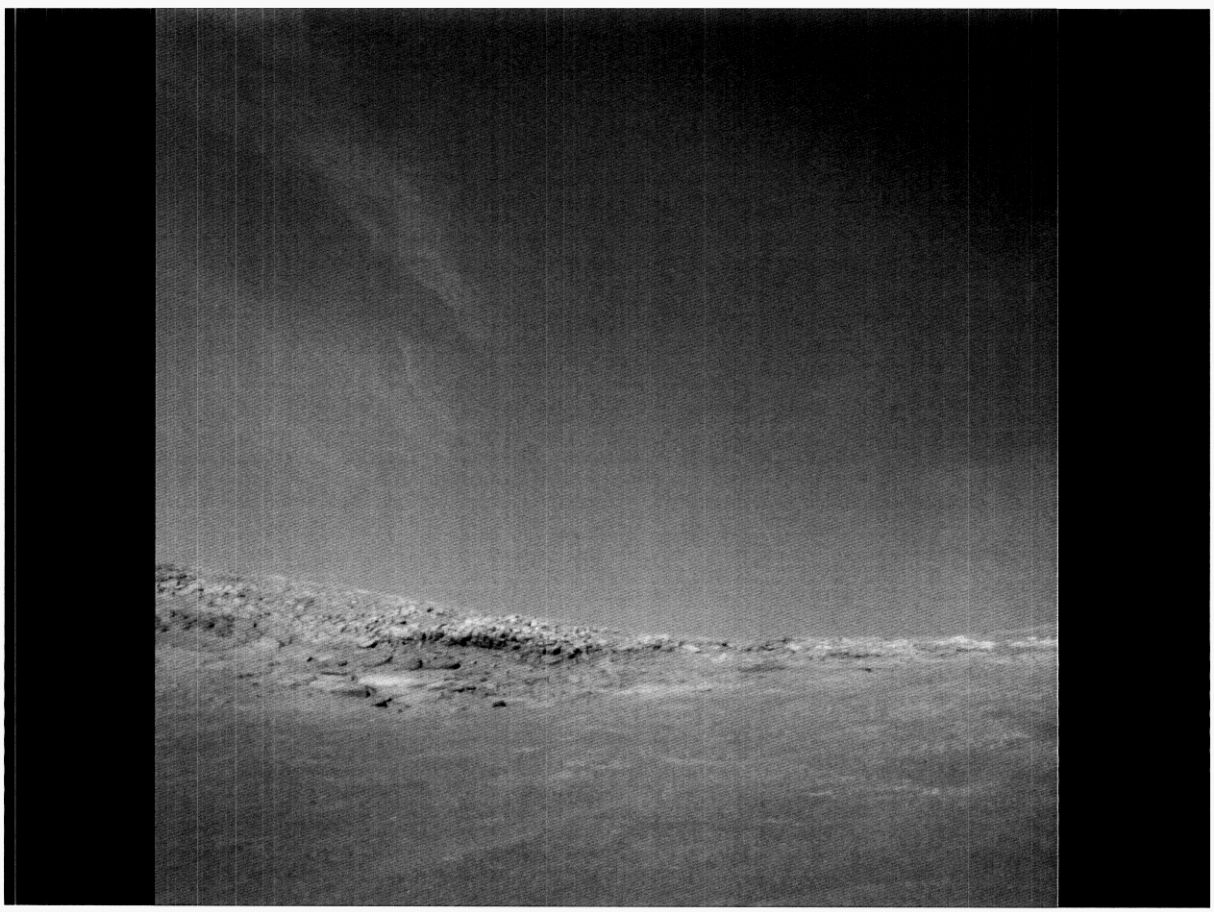


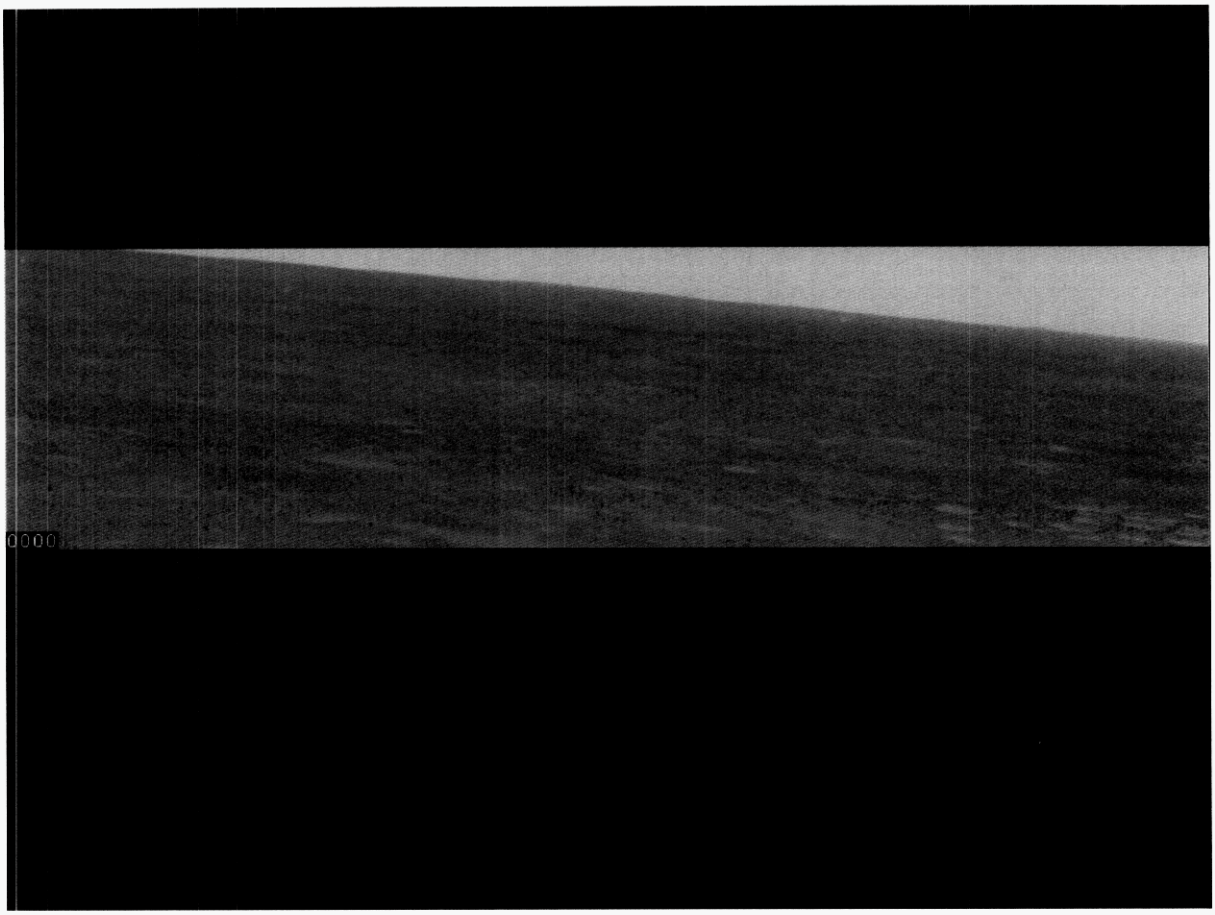


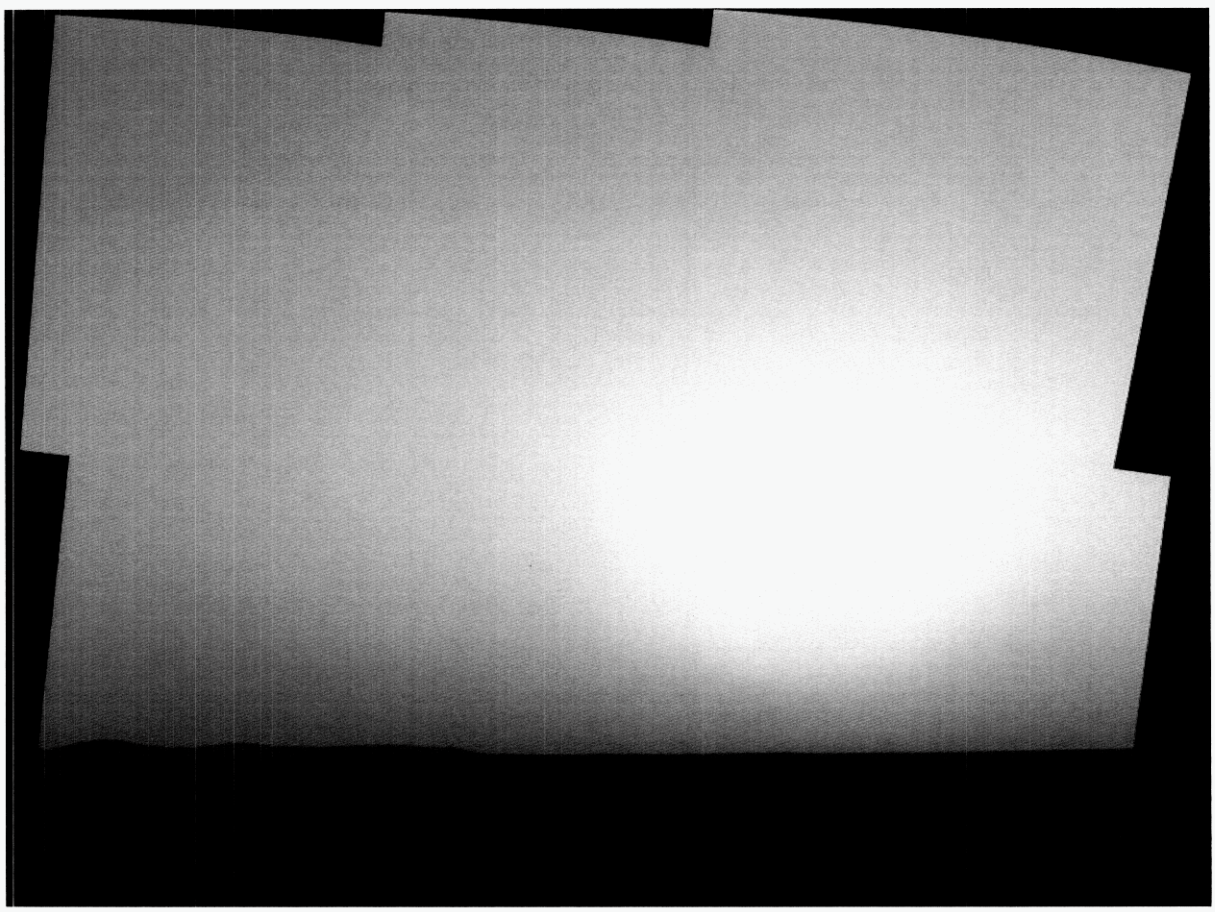


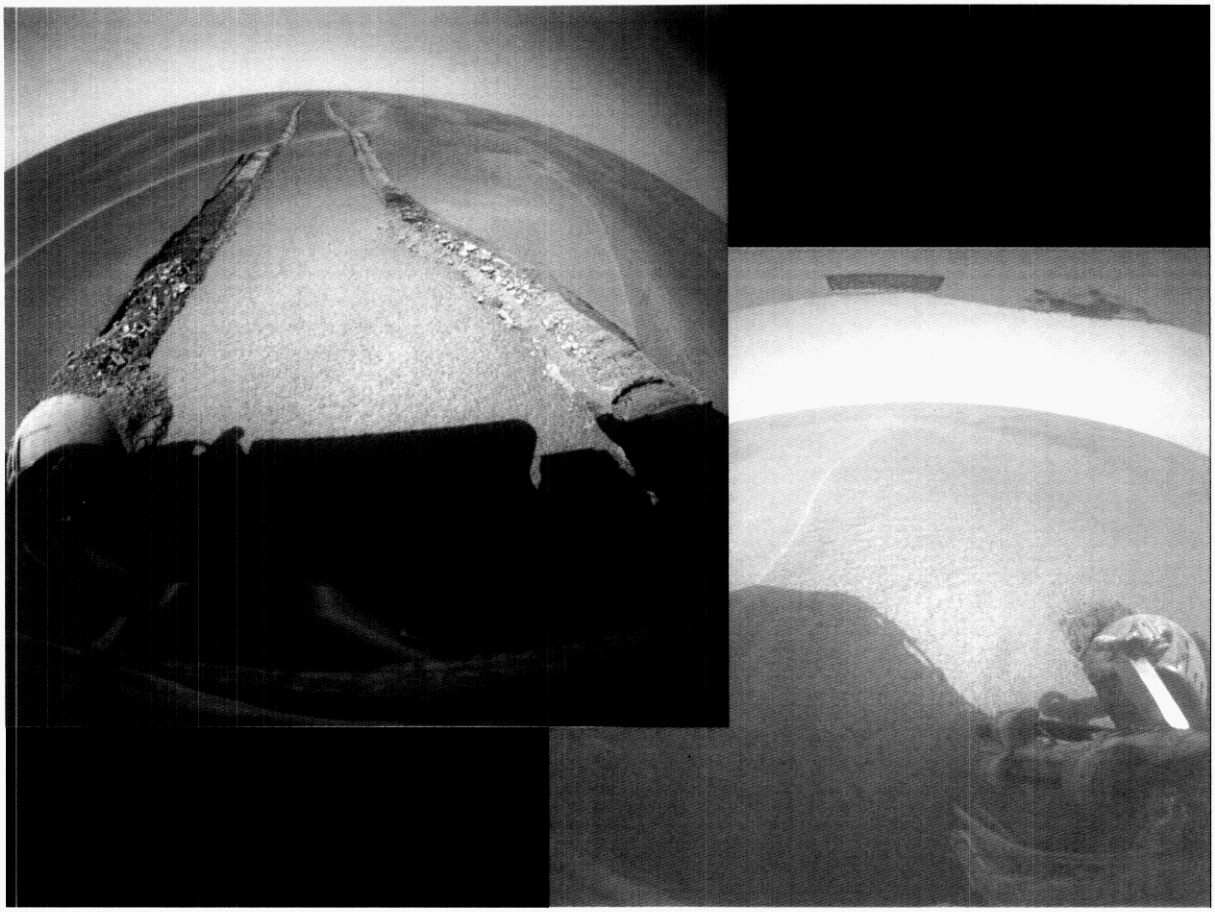








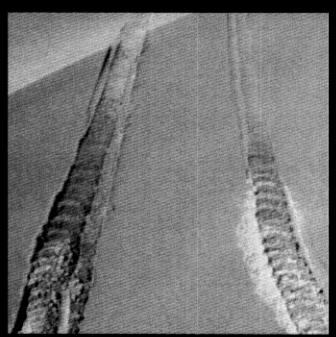




Opportunity Sol 465

Front Left

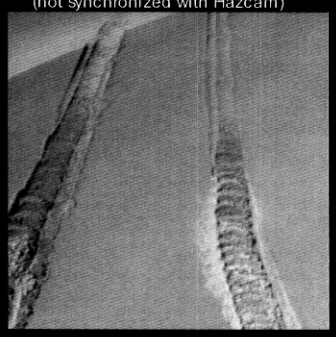
Front Right



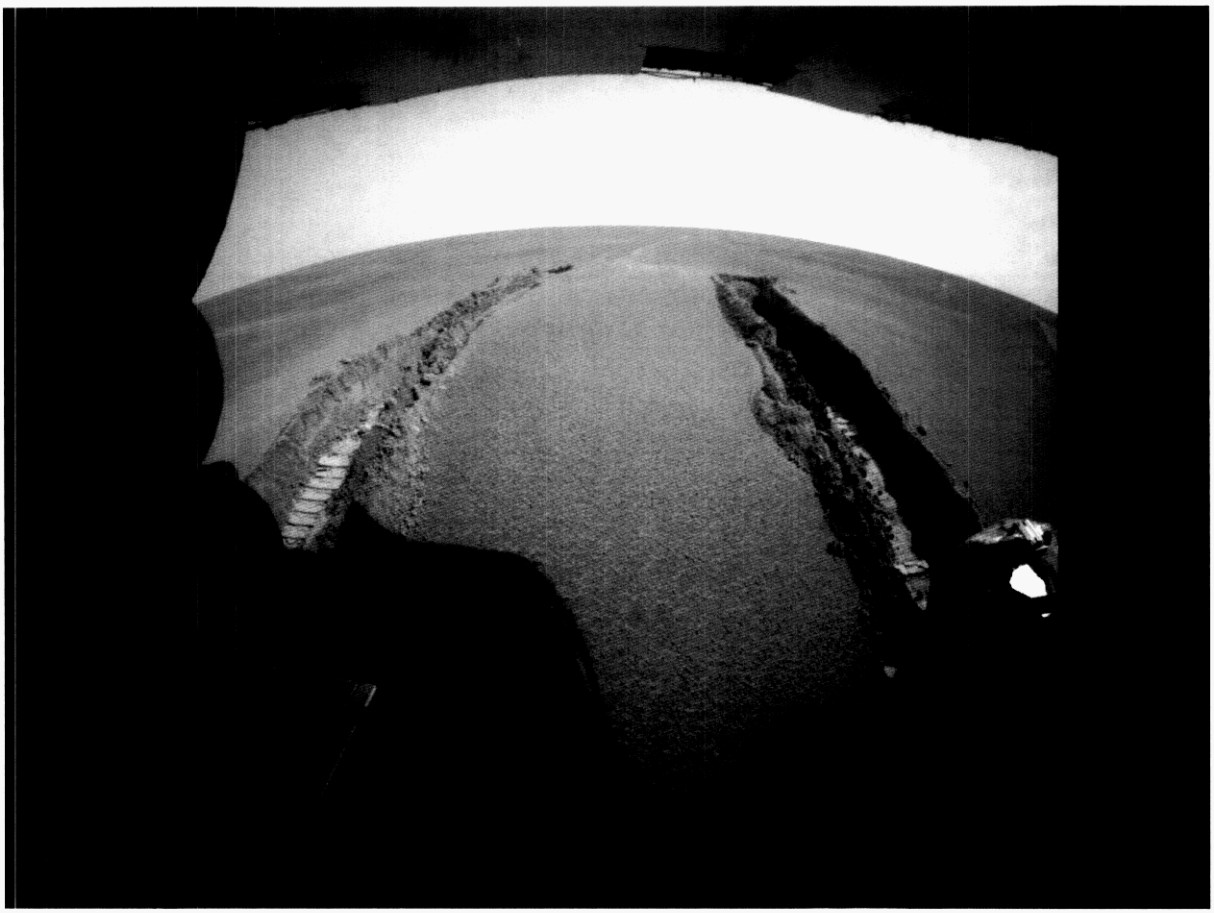
Nav Left
(not synchronized with Hazcam)

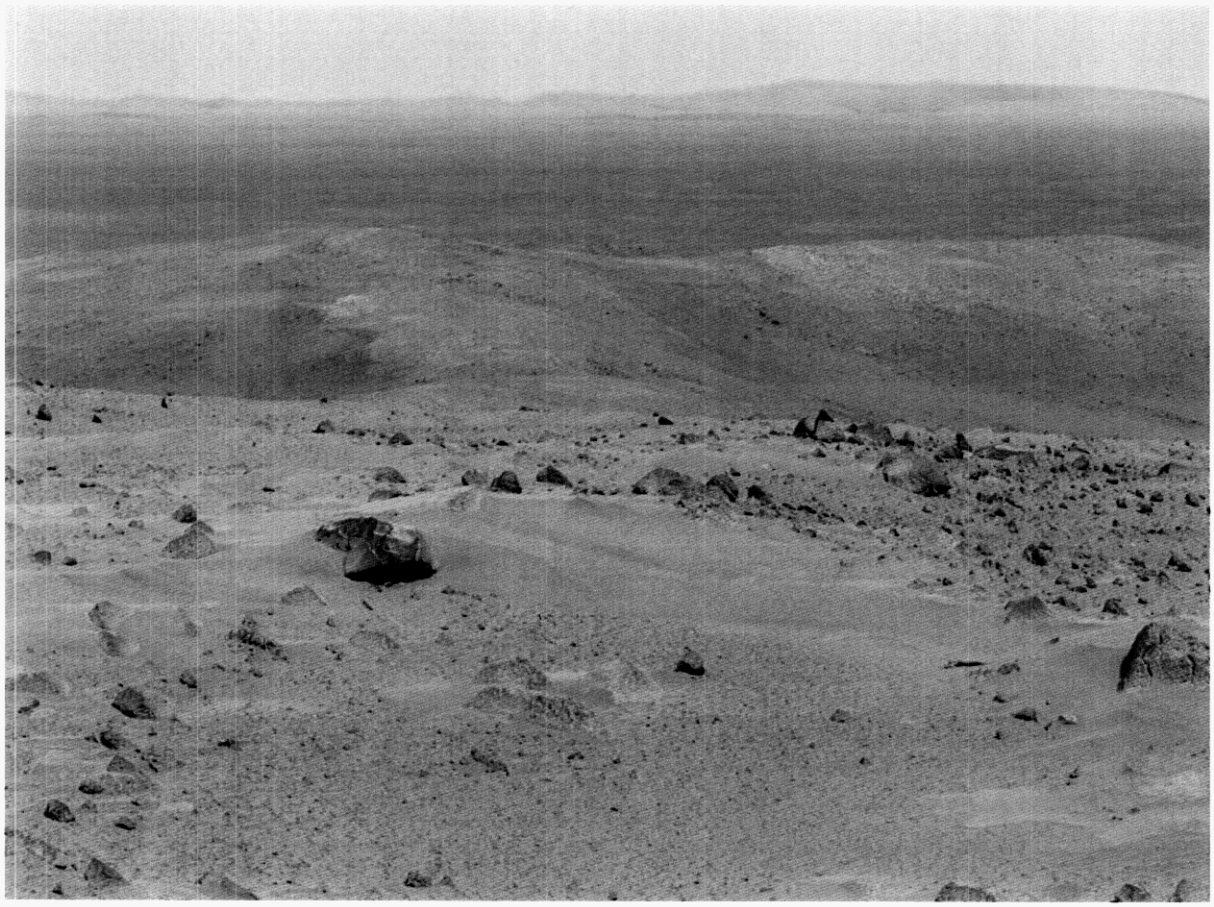
Rear Right

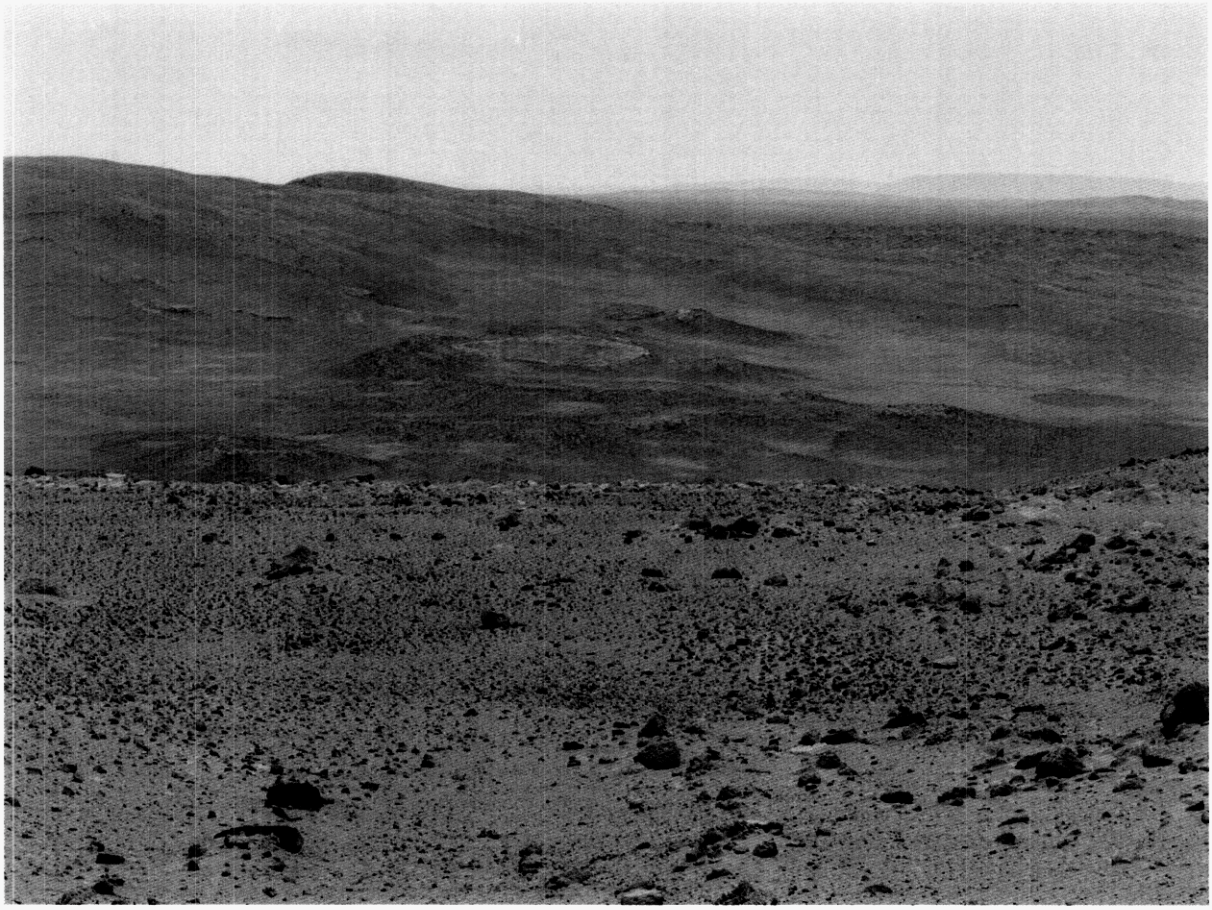
Rear Left

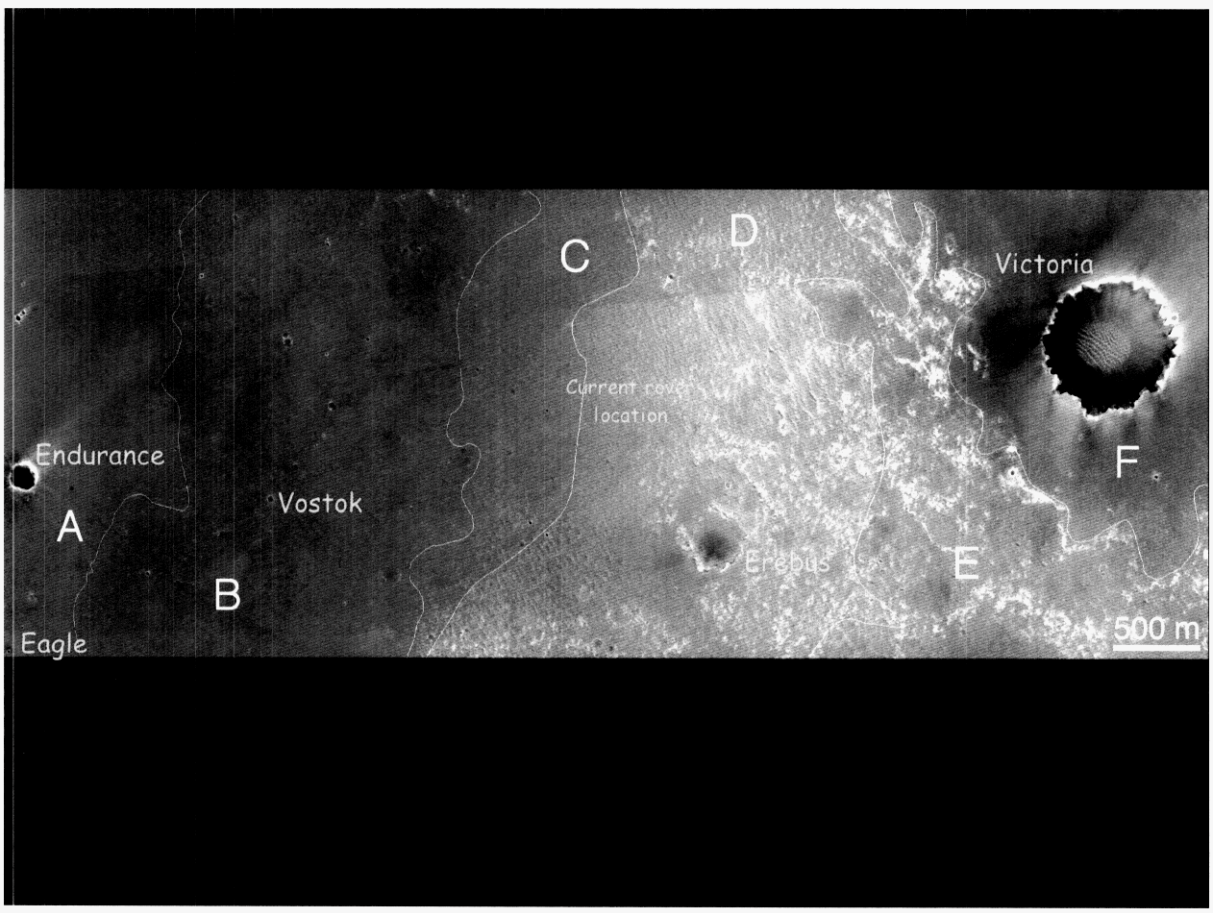


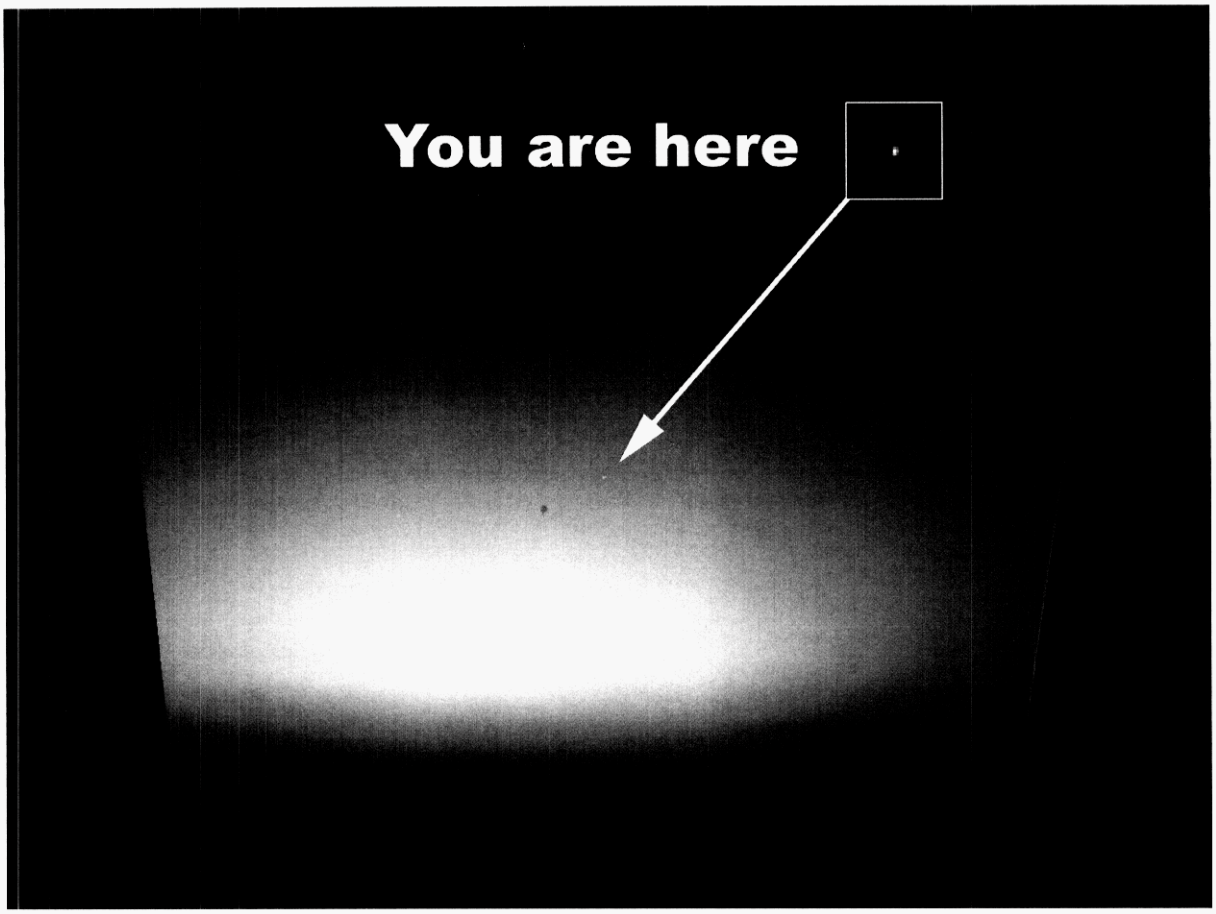
Nav Right
(not synchronized with Hazcam)








C
D
Victoria
Current rover location
Endurance
A
Vostok
B
Eagle
Erebus
E
F
500 m


You are here