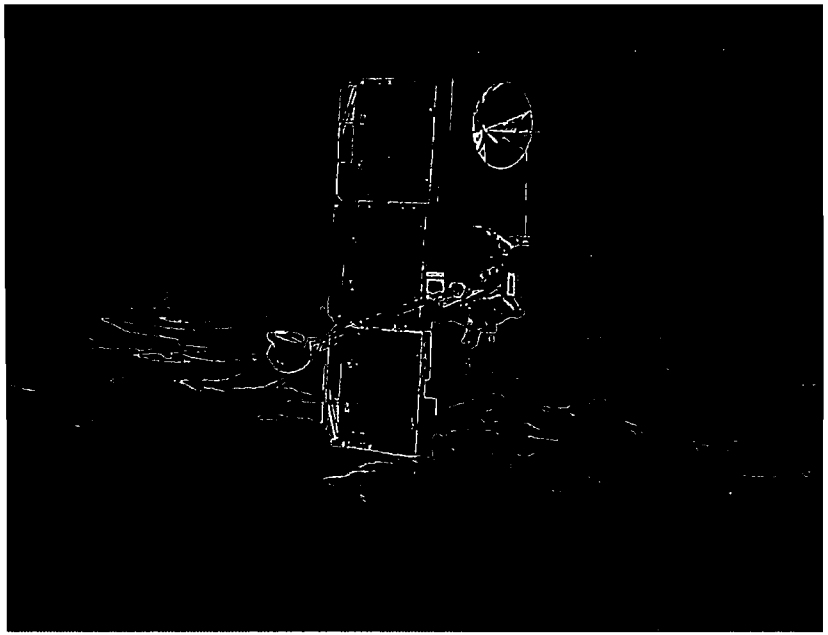
2001 Mars Odyssey: Overview of Science through Extended Mission 2

D. A. Senske
Jet Propulsion Laboratory/
California Institute of Technology
HEND Workshop
18-21 June 2007



2001 Mars Odyssey

Odyssey E2 Mission

- Science Goals
- Results from the GRS Suite
- Results from THEMIS
- Planning for Extended Mission 3 (E3)

Odyssey - Extended Mission 2

- The E2 mission pursues the following science goals:
  - Monitor interannual and secular variations of the Mars climate system and surface processes
  - Improve the resolution of existing elemental maps and generate maps of additional key elements
  - Expand the capability of the THEMIS camera system by implementing off-nadir pointing
  - Acquire data complementary to those obtained by other spacecraft at Mars, especially MRO
- The E2 Mission provides the following operational support to other Program missions:
  - UHF relay support to MER
  - Landing site reconnaissance for PHX and MSL

Results from the GRS Suite

GRS Results

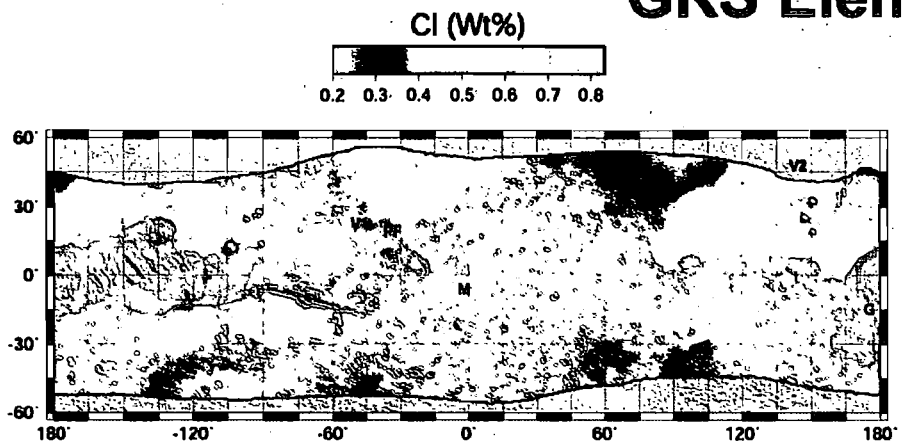
- The GRS team has compiled, calibrated, analyzed, released and published global maps of the following elements:

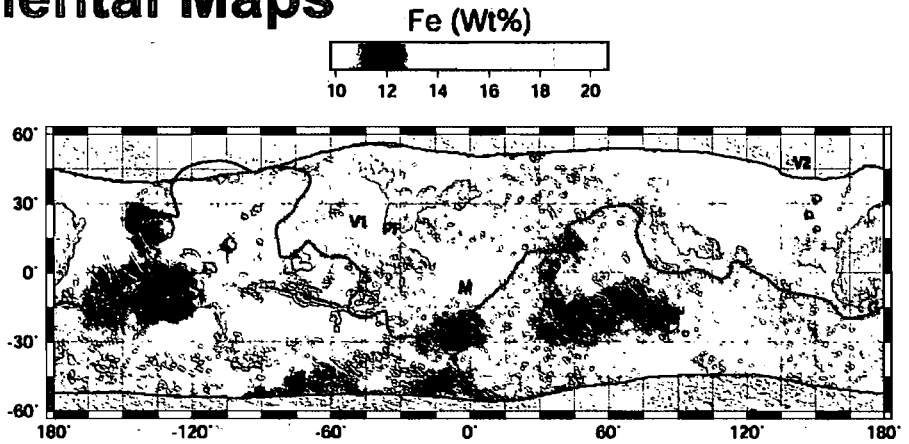
  H, Si, Cl, K, Fe and Th

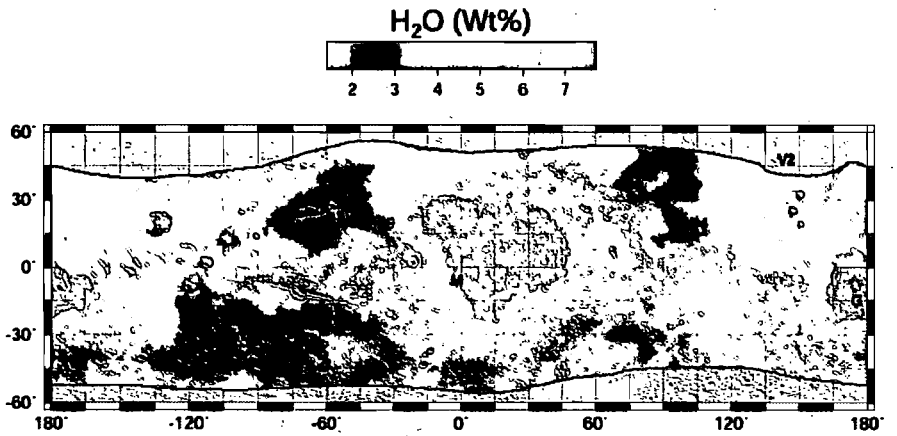
- Maps of additional elements, at lower resolution are in work for:

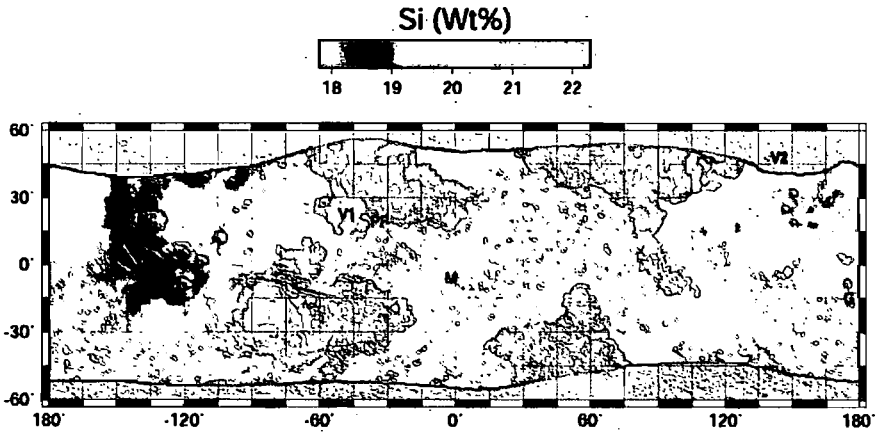
  Ca, Al, S, U

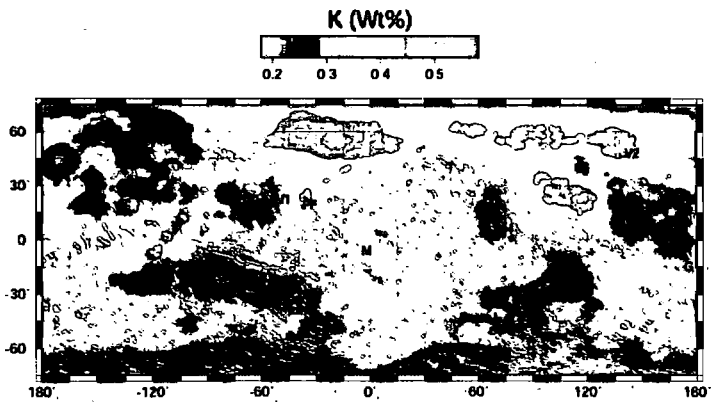
GRS Elemental Maps

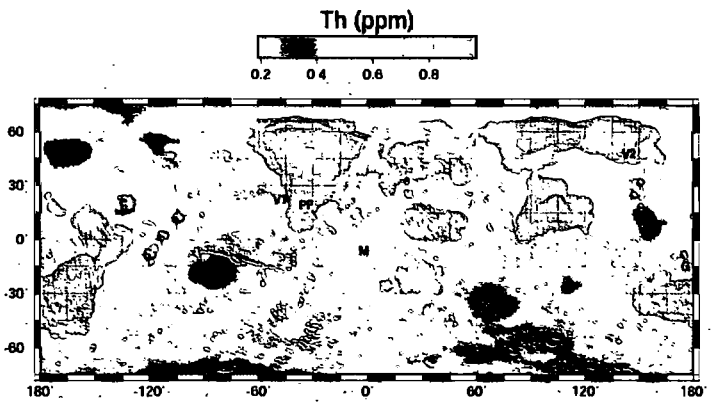












GRS JGR Special Issue

2001 Mars Odyssey

GRS Special JGR Issue December 2006/January 2007

Analysis of gamma ray spectra measured by Mars Odyssey, Evans, L. G., R. C. Reedy, R. D. Starr, K. E. Kerry, and W. V. Boynton

Mars Odyssey Gamma Ray Spectrometer elemental abundances and apparent relative surface age: Implications for Martian crustal evolution, Hahn, B. C., et al.

Composition of northern low-albedo regions of Mars: Insights from the Mars Odyssey Gamma Ray Spectrometer, Karunatillake, S., et al.

Equatorial and midlatitude distribution of chlorine measured by Mars Odyssey GRS, Keller, J. M., et al.

Seasonal polar carbon dioxide frost on Mars: CO_2 mass and columnar thickness distribution, Kelly, N. J., W. V. Boynton, K. Kerry, D. Hamara, D. Janes, R. C. Reedy, K. J. Kim, and R. M. Haberle

Theoretical fluxes of gamma rays from the Martian surface, Kim, K. J., D. M. Drake, R. C. Reedy, R. M. S. Williams, and W. V. Boynton

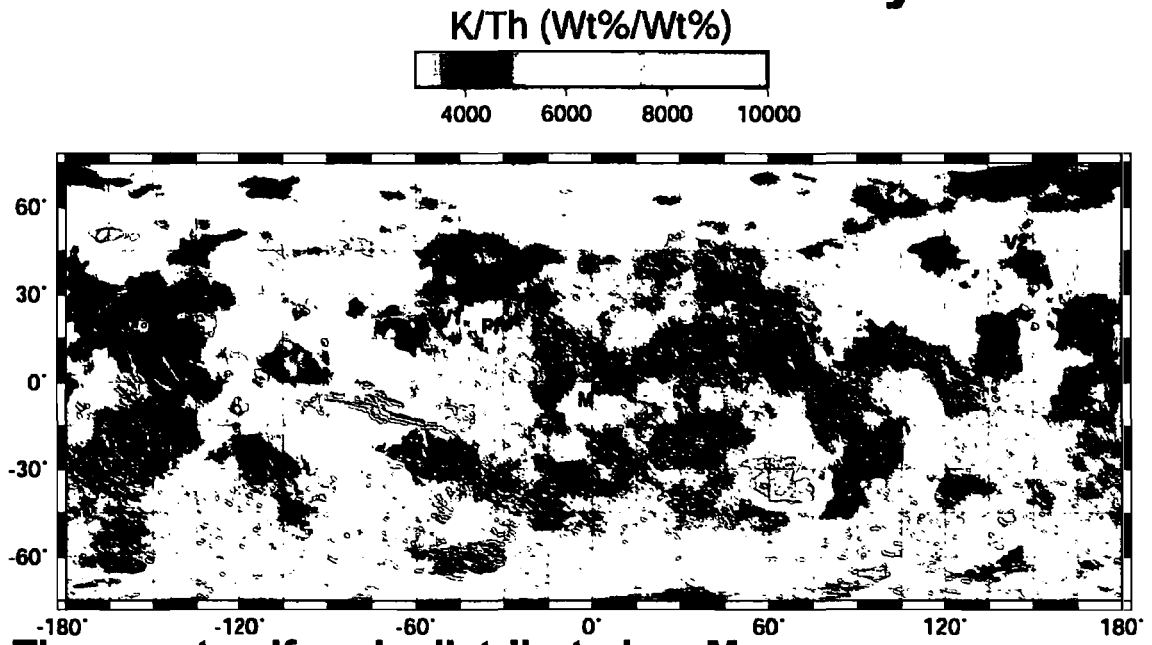
Geochemistry of Martian soil and bedrock in mantled and less mantled terrains with gamma ray data from Mars Odyssey, Newsom, H. E., et al.

Mars' atmospheric argon: Tracer for understanding Martian atmospheric circulation and dynamics, Sprague, A. L., et al.

Variations in K/Th on Mars, Taylor, G. J., et al.

Bulk composition and early differentiation of Mars, Taylor, G. J., et al.

Bulk Martian Chemistry



K and Th are not uniformly distributed on Mars.

Concentrations of K and Th are generally higher than those in basaltic Martian meteorites indicating that Martian meteorites are not representative of the bulk crust.

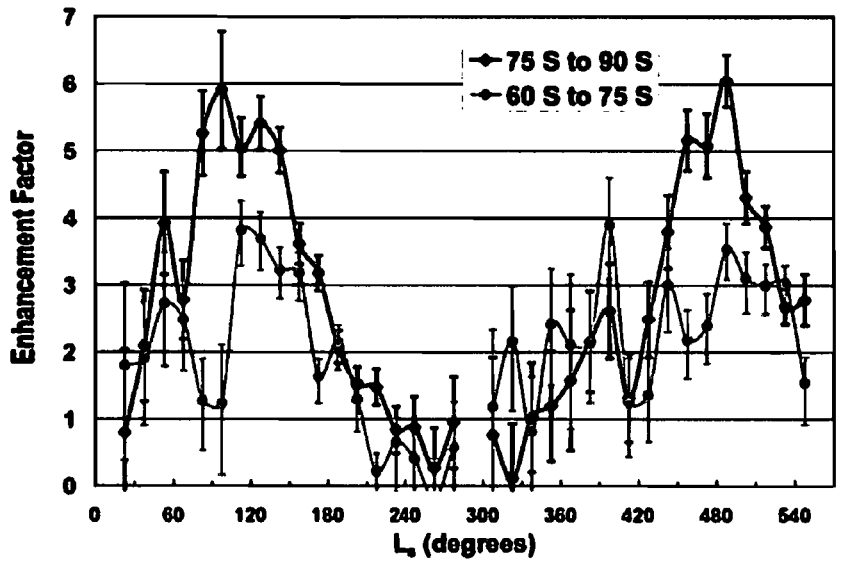
Fe concentrations support the idea that bulk Mars is enriched in FeO compared to Earth.

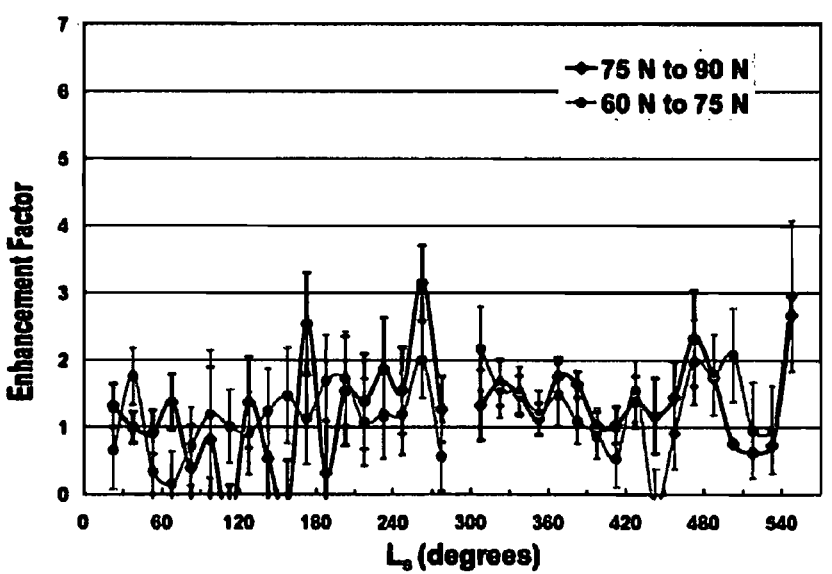
The differences in K/Th and FeO between Earth and Mars are consistent with the planets accreting from narrow feeding zones.

The concentration of Th on Mars does not vary as much as it does on the Moon suggesting that the primary differentiation of Mars differed from that of the Moon.

(Taylor et al., 2006)

Argon Variation in the Polar Regions





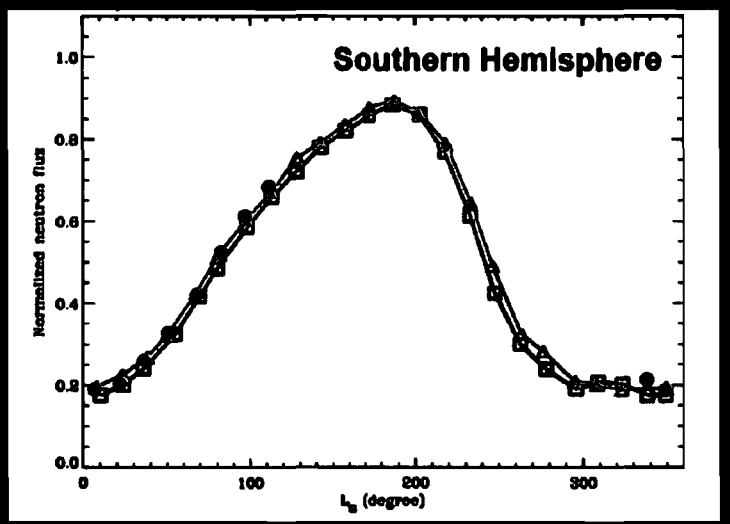
(1) There is a factor of 6 enhancement of Ar measured over south polar latitudes for 2 consecutive Mars years
(2) There is no similar strong enhancement of Ar over north polar regions during northern winter.
(3) Rapid seasonal fluctuations in Ar abundance from 60 S to 90 S may be evidence for wave activity at the perimeter of the southern seasonal polar cap.
(4) The magnitude of the Ar enhancement over the south polar region lacks spatial coincidence with either the relatively dark "cryptic terrain" or the relatively bright albedo regions

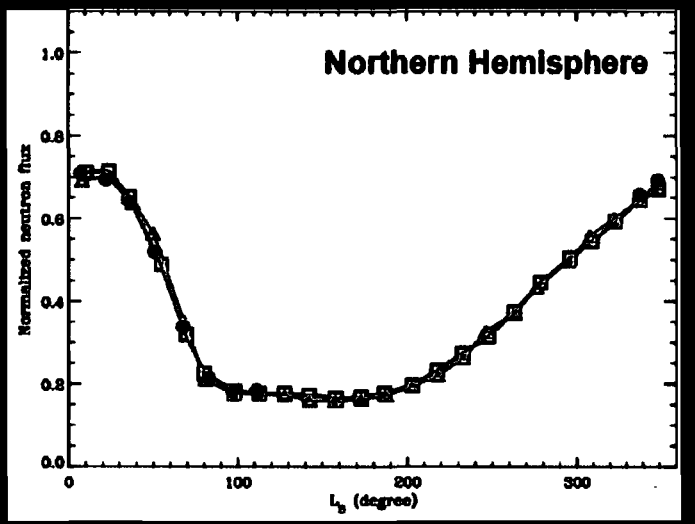
(Sprague et al., 2007)

2001 Mars Odyssey

HEND Monitoring of Seasonal CO_2

Now focused on observation of long term observation of CO_2:

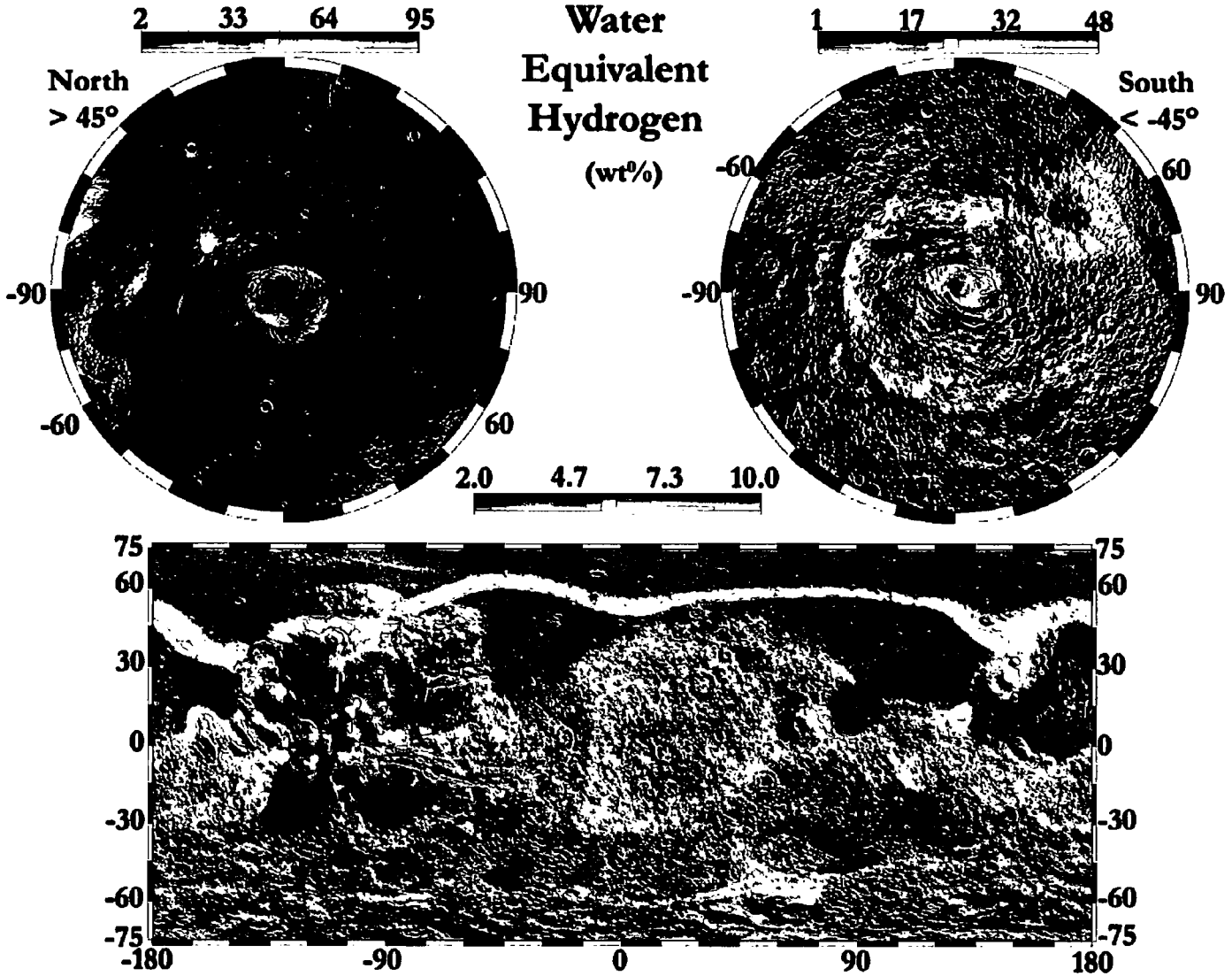




- First orbital Martian year (flux of epithermal neutrons)
- Second orbital Martian year (flux of epithermal neutrons)
- Third orbital Martian year (flux of epithermal neutrons)

2001 Mars Odyssey

Neutron Spectrometer



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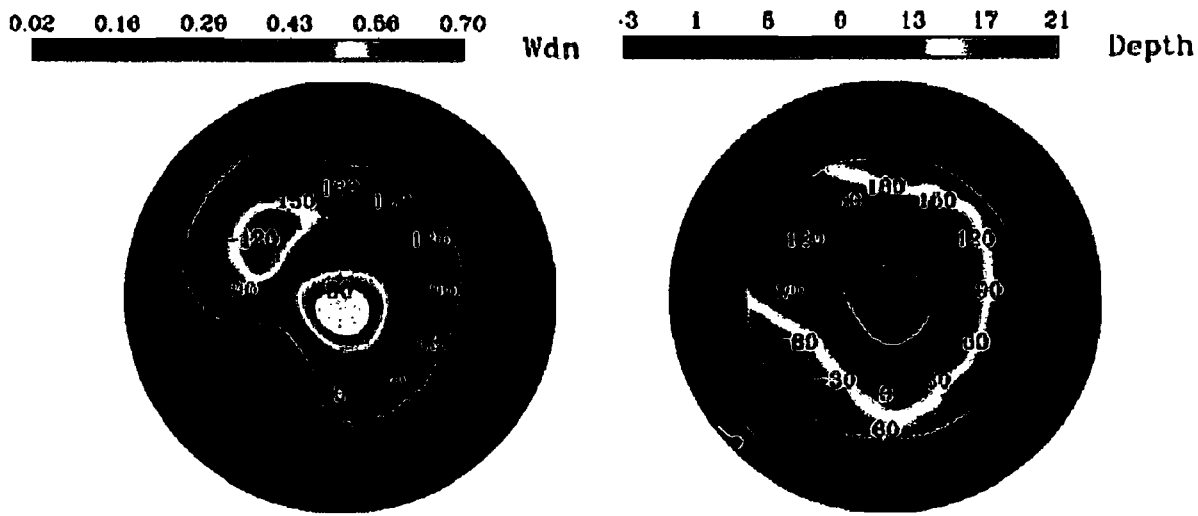
Two Layer Model



Two layer model of the distribution of hydrogen at high northern latitudes.

The WEH abundance in the upper layer was found to range between 1% and about 5%.

The maximum value of the apparent thickness of the upper layer peaks at about 60° latitude

The maximum is consistent with an expected transition from WEH contained solely in hydrous minerals at lower latitudes, to WEH contained both in the forms of water ice and water of hydration at high latitudes.

(Feldman et. al. 2007)

2001 Mars Odyssey

Results from THEMIS

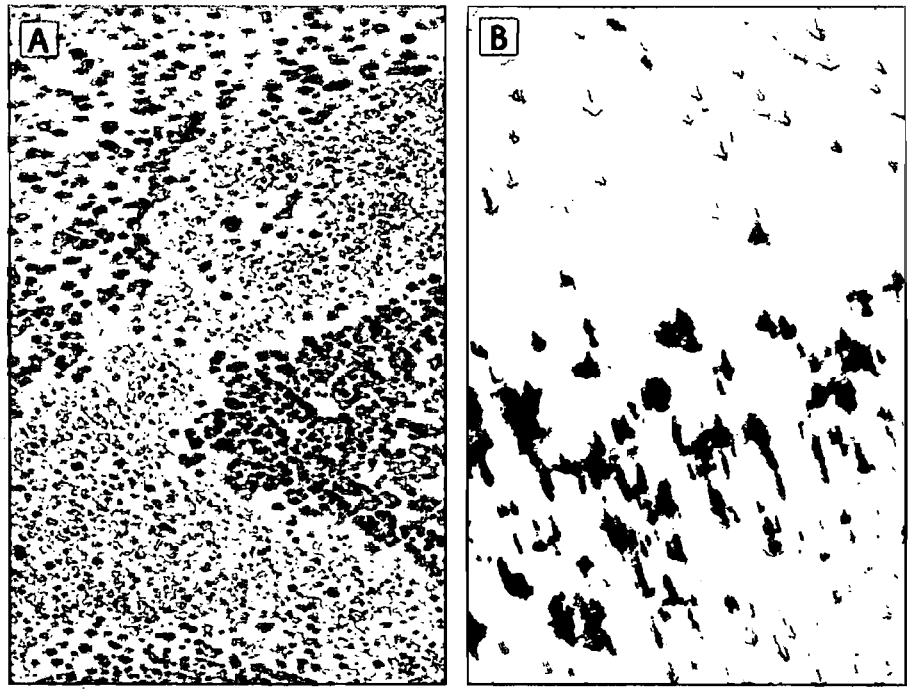
THEMIS Discoveries & Accomplishments

- THEMIS data used to hypothesize the cause of dark markings that appear every spring on Mars' south polar cap
- Water ice confirmed at Mars south polar cap
- Data used to hypothesize that Water from melting snow eroded many of the geologically recent gullies on Mars
- Aram Chaos is an ancient impact crater containing a thick stack of sediments deposited underwater
- Granite-like rocks discovered
- Olivine-rich rocks point to cold, dry martian past
- Discovery of evolved lavas in Syrtis Major
- Mars has more channels than previously thought
- Mars has large expanses with exposed bedrock

THEMIS Results

CO_2 jets formed by sublimation beneath translucent slab ice in Mars' seasonal south polar ice cap

Hugh H. Kieffer, Philip R. Christensen & Timothy N. Titus



Subsurface water-ice distributions

nature Vol 447|3 May 2007|doi:10.1038/nature05781

LETTERS

High-resolution subsurface water-ice distributions on Mars

Joshua L. Bandfield[1]

[1]School of Earth and Space Exploration, Arizona State University, Tempe, Arizona 85287-6305, USA.

2001 Mars Odyssey

Using observations by Mars Odyssey's THEMIS, scientists have discovered that water ice lies at variable depths over small-scale patches on Mars.

The new approach uses thermal imaging as a thermometer to measure how fast the ground changes temperature during local spring, summer and fall. The dense, icy layer retains heat better than the looser soil above it. Where the icy layer is closer to the surface, the surface temperature changes more slowly.

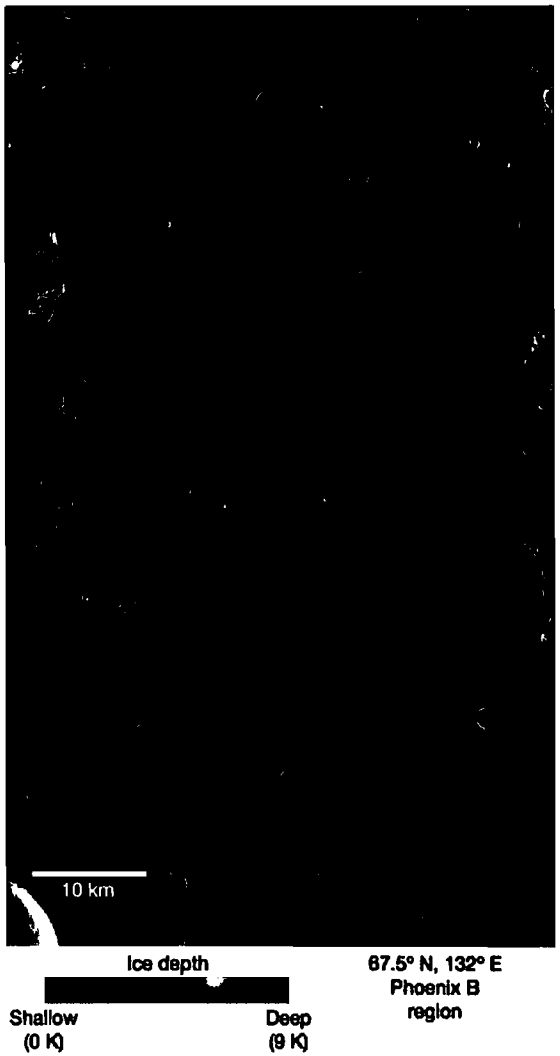
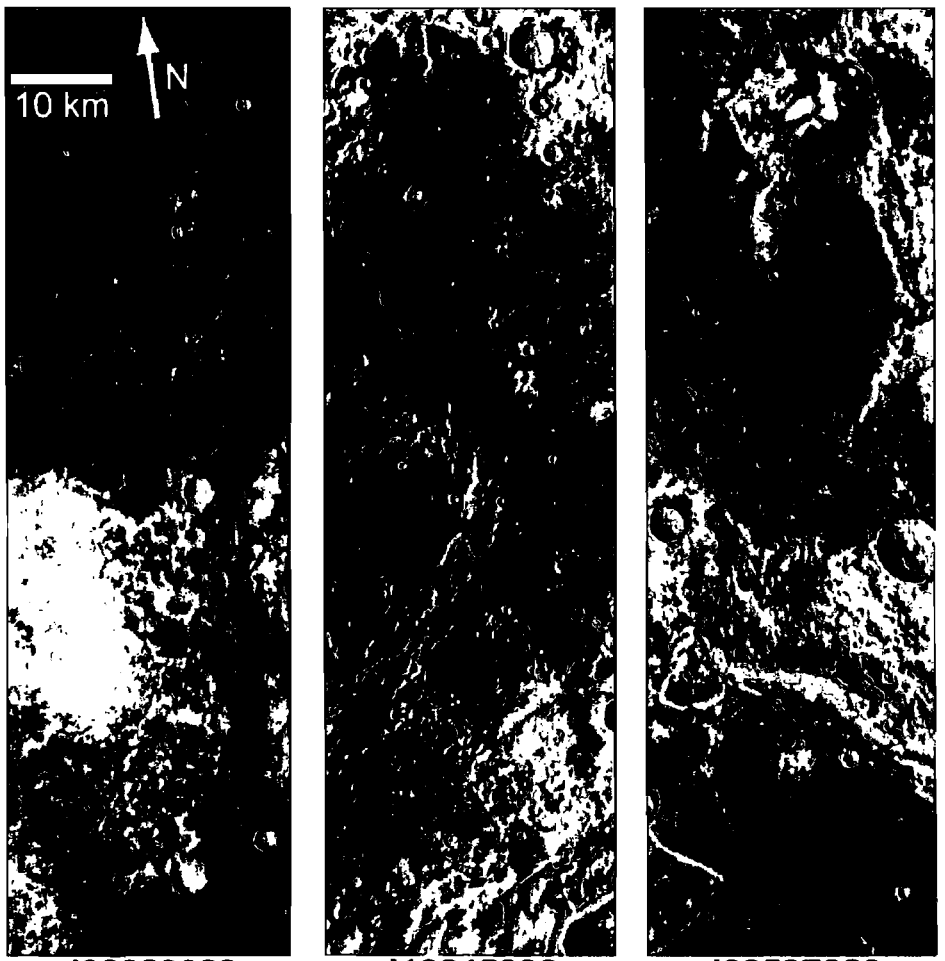


Figure 2 | Ice depth map centred near 67.5° N, 132° E (Phoenix B region proposed landing site). This map was produced by differencing the relative surface temperatures present in THEMIS night-time images

Granitoid Outcrops

Identification of additional exposures of Granitoid rock in Syrtis Major (Banfield, GRL 2006)

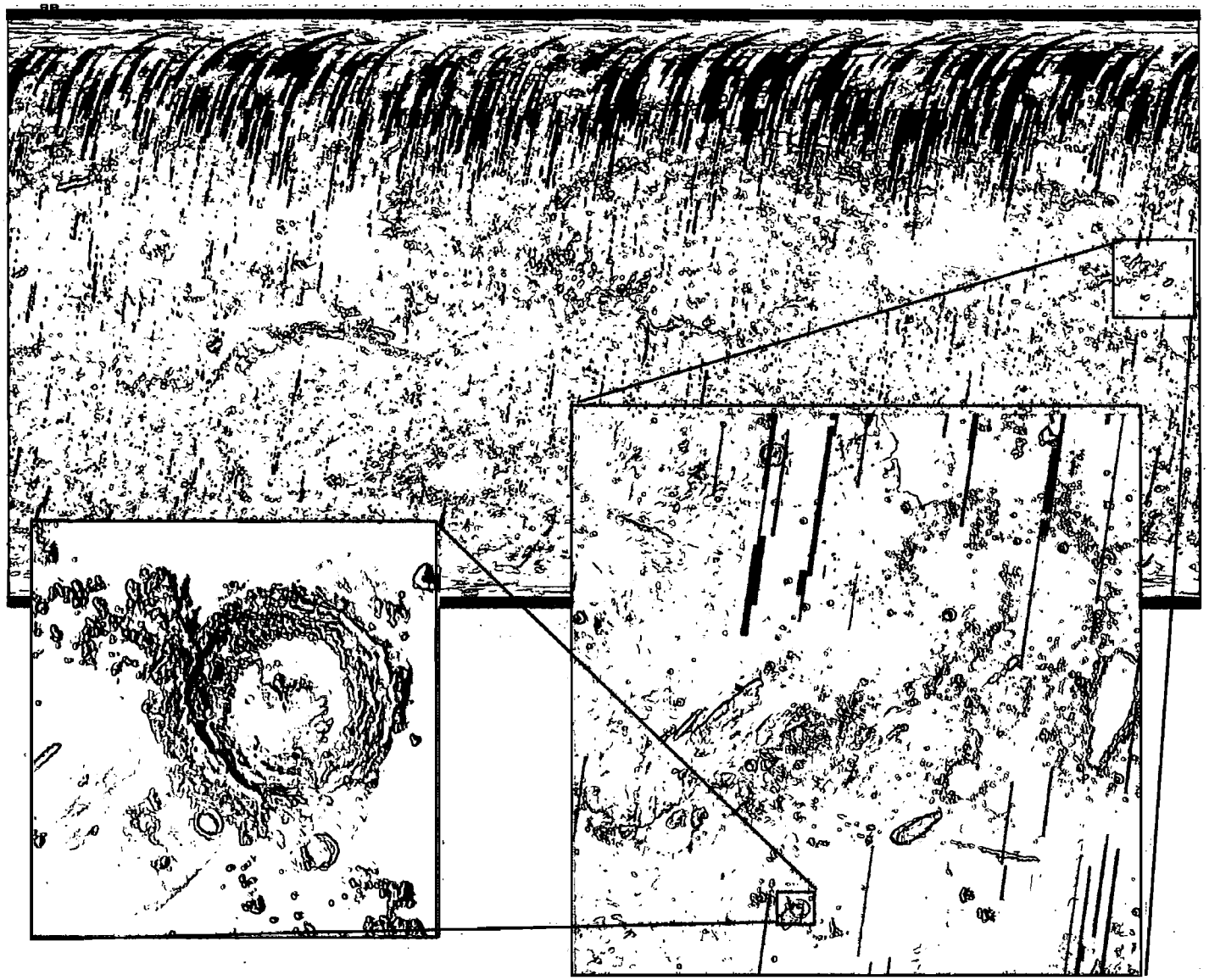


I02020009 I10845006 I09597020

Decorrelation stretched THEMIS images. Yellow colors coincide with higher band 8 and 7 and lower band 5 emissivities, consistent with surfaces that contain quartz and feldspar.

2001 Mars Odyssey

Global Day IR Map



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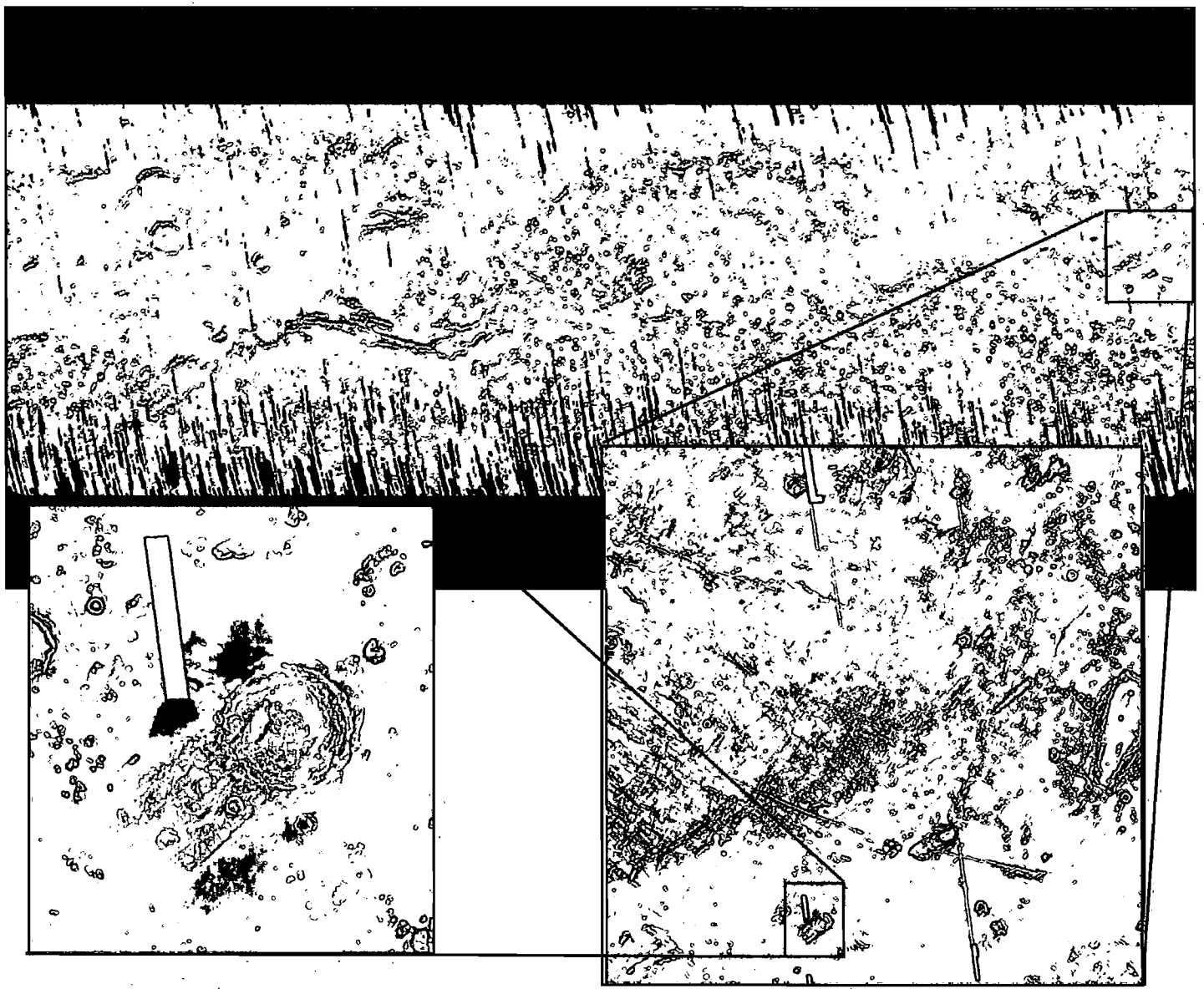
Global Night IR Map



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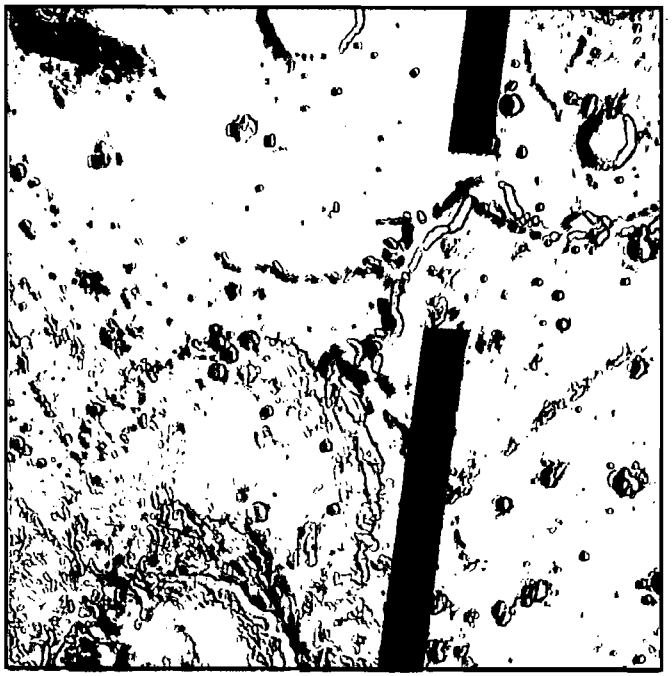
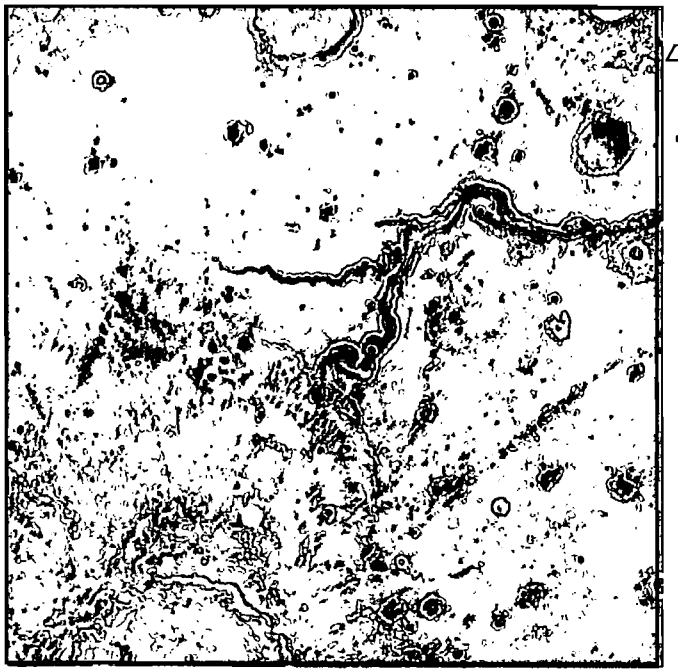


THEMIS

Day IR
Mosaic

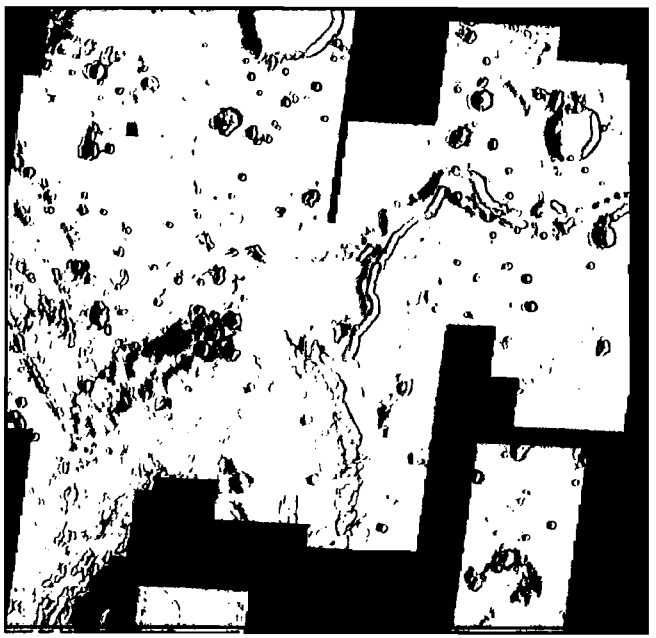
100m/pixel



THEMIS

Night IR
Mosaic

100m/pixel



THEMIS

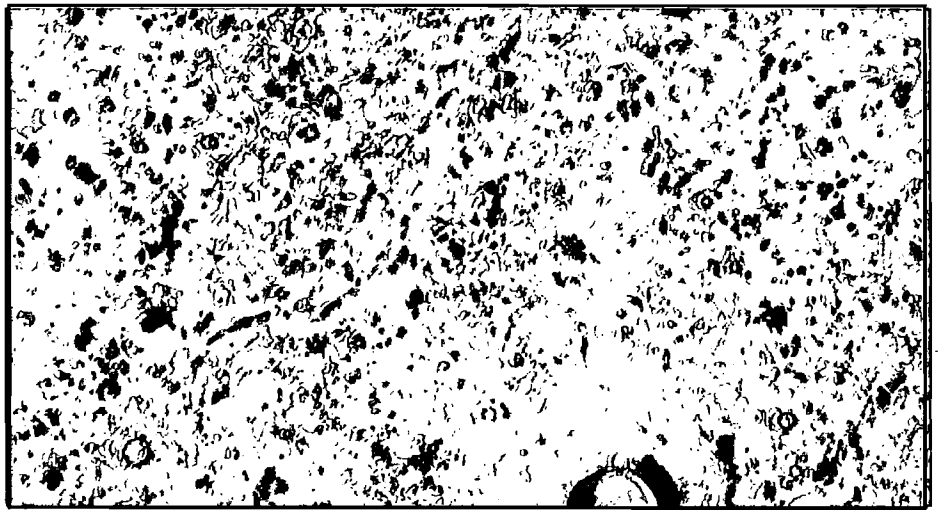
Visible Mosaic

18 m/pixel

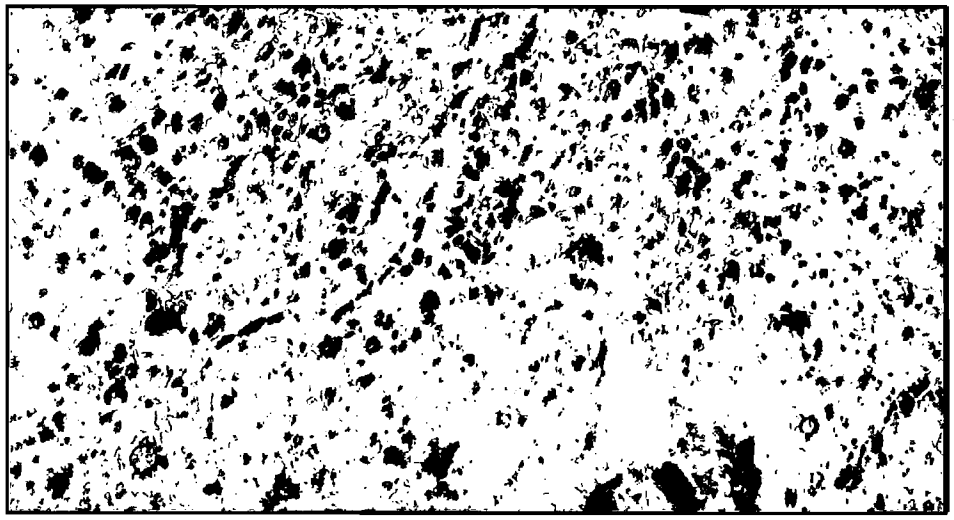
Off-nadir imaging (<4°) will allow more rapid filling of image gores

Assessment of Phoenix Landing sites

THEMIS Visible image of Phoenix landing Site 1



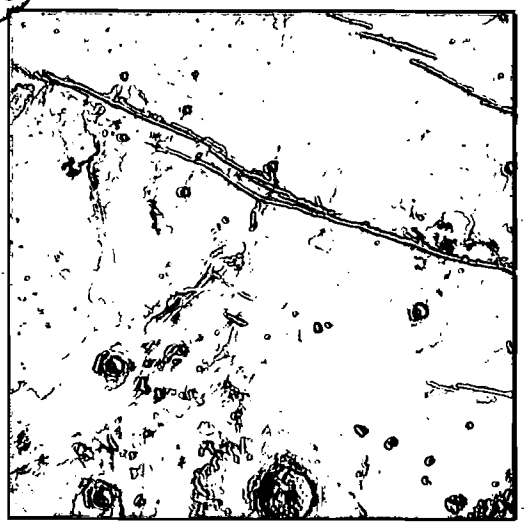
THEMIS Night IR on Visible image



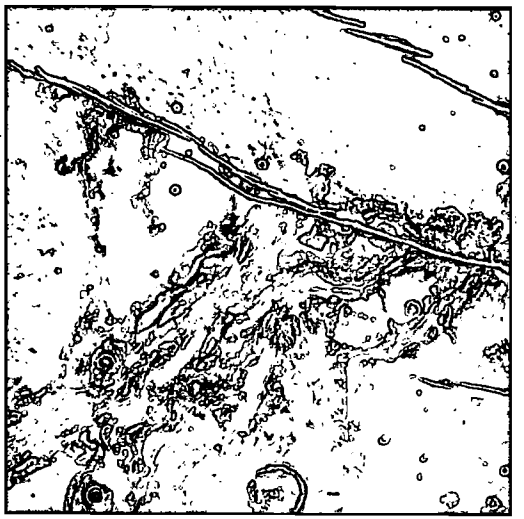
Red areas correspond to sites of enhanced boulder concentrations

2001 Mars Odyssey

MSL Landing site Support: Athabasca Vallis

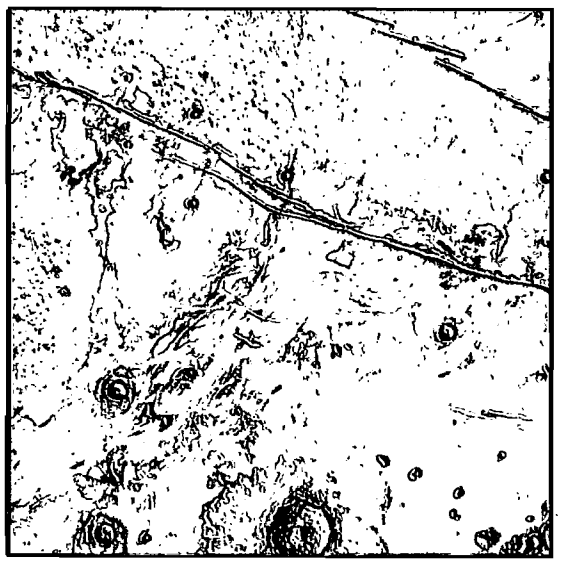


Day IR, 100 m/pixel



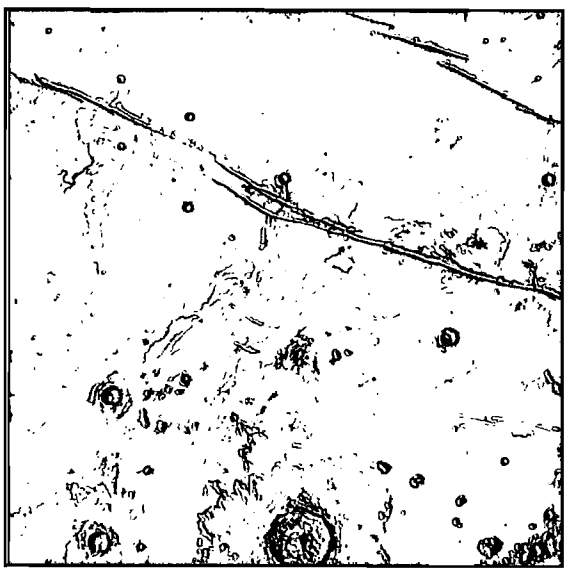
Night IR, 100 m/pixel

Visible, 18 m/pixel



Night IR on Day IR

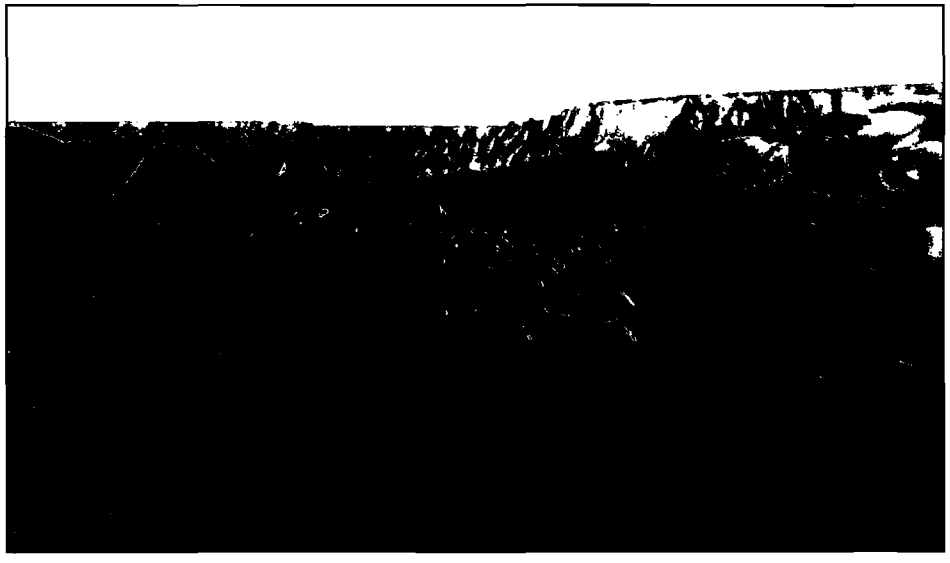
Decorrelation Stretch, Bands 8,7,5

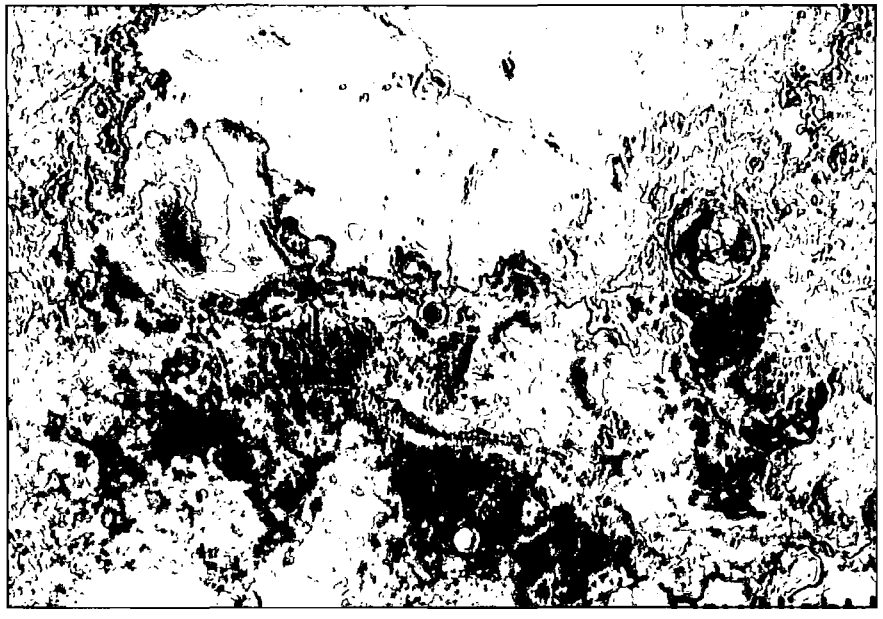


2001 Mars Odyssey

THEMIS has:

- **Discovered igneous mineral diversity that rivals Earth**
- **Discovered remarkable variation in thermal behavior of surface materials: outcrop, rocks, soils, dust**
- **Provided strong evidence against current major surface geothermal activity**
- **Created the highest resolution global maps of Mars (Day IR, Night IR)**





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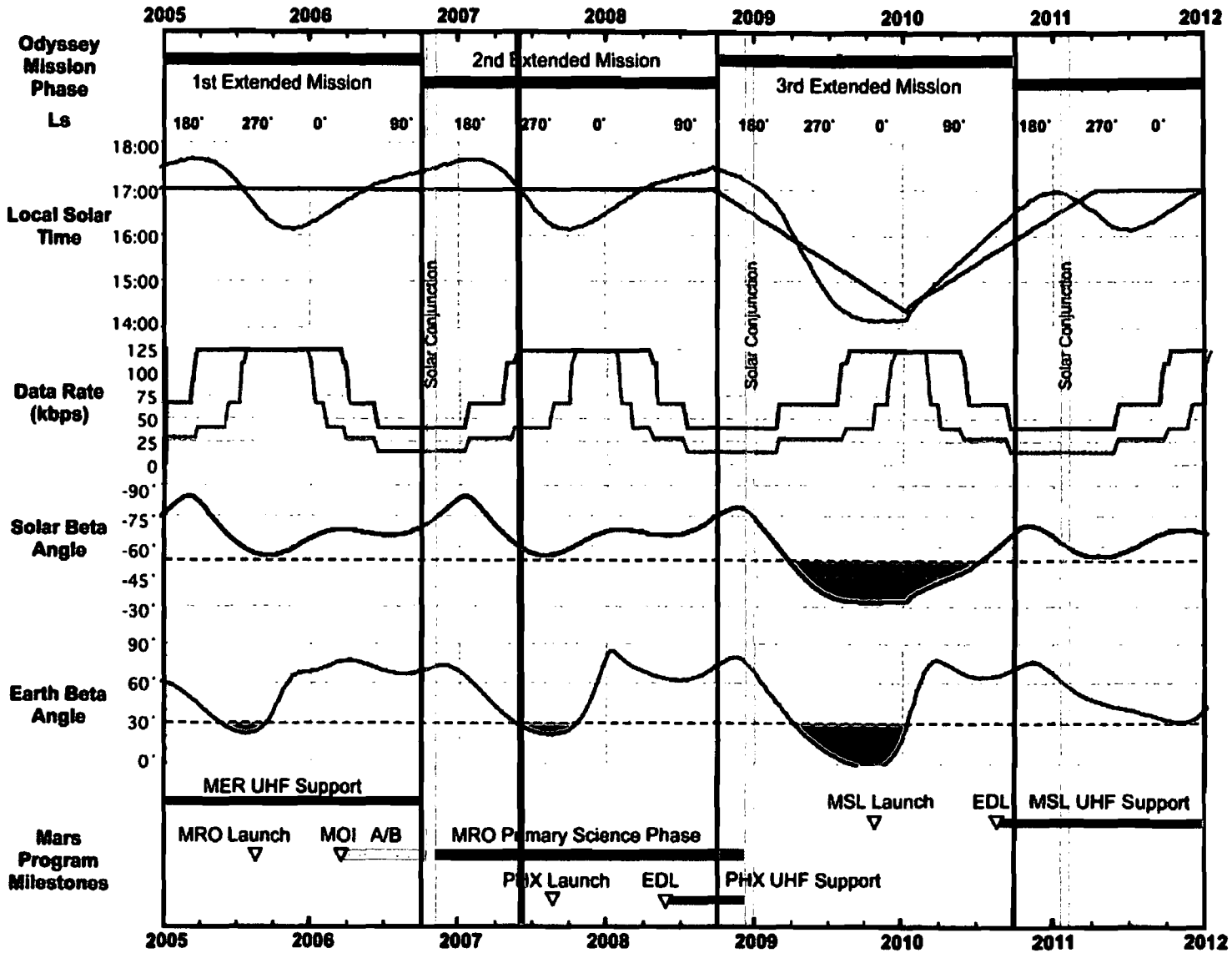
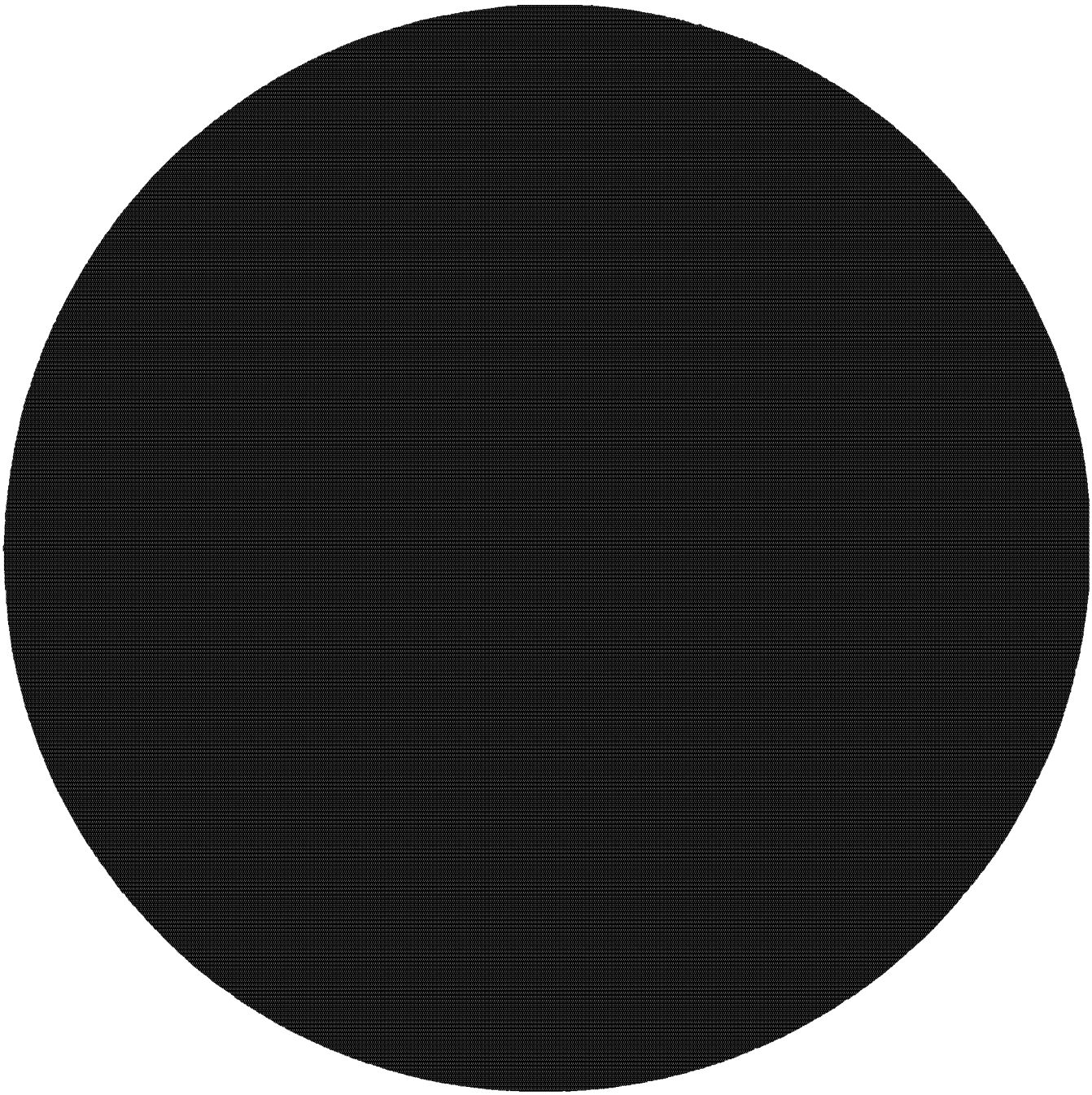


Planning for E3

- Continuing Odyssey's operation beyond the E2 mission would address NASA's Mars exploration goals by:
  - Significantly enhancing the data sets already acquired, extending their temporal and spatial coverage;
  - Enabling new types of observations by changing the local time of the orbit and operating the instruments and spacecraft in innovative ways.
  - Reinforcing Odyssey's role as a long-term asset in the scientific and operational infrastructure at Mars;
  - Providing operational support for critical phases of future missions, such as communications relay, landing site characterization, and atmospheric monitoring for aerobraking;

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