MAJOR STAGES OF MARS’ EVOLUTION

1. BEGINNING
   - MAGMA OCEAN / CONVECTIVE OVERTURN
2. CRATRED UPLANDS / VERY LARGE BASINS
3A. CORE FORMATION/GLOBAL MAGNETIC FIELD
3B. GLOBAL MAFIC VOLCANISM
3C. 4.5 - 1.3 BILLIONS OF YEARS BEFORE PRESENT
   - DENSE WATER / CO2 ATMOSPHERE
3D. LARGE BASINS
   - EROSION / LAKES / NORTHERN OCEAN
   - CATAclySM ?
4. THARSIS UPLIFT AND VOLCANISM
   - NORTHERN HEMISPHERE BASALTIC / ANDESITIC VOLCANISM
   - 1.3 - 0.2 BILLIONS OF YEARS BEFORE PRESENT
5. SUBSURFACE HYDROSPHERE / CRYOSPHERE
6. LUNAR 4.6 / PRESENT SURFACE CONDITIONS

ITALICS = SNC DATES
RED = MAJOR UNCERTAINTY
TOPOGRAPHY OF THARSIS REGION

OLYMPUS MONS

VALLES MARINERIS
THICKENING ATMOSPHERE:
- CO₂, H₂O

CRYOSPHERE / HYDROSPHERE

GARNET / NA-CPX
- NA-BIOTITE?/NA-
- HORNBLende/
- “RUTILE”
- CUMULATES

RElic MAGNETIC STRIPING

THICKENED SOUTHERN CRUST AND BASALTIC VOLCANICS

MAFIC UPPER
MANTLE WITH INCREASING SI AND FE UPWARDS

ANDESITIC INTRUSIONS?

ANDESITIC EXTRUSIONS

RELIC PROTO-
CORE?

FEₓNIᵧSₓ CORE

OLIVINE/ NA-
PYROXENE CUMULATE

OLIVINE CUMULATE

THARSIS EVENTS
<3.8 B.Y.

ELYSIUM MONS

THARSIS

THICKENED SOUTHERN CRUST AND BASALTIC VOLCANICS
THARSIS EVENTS
<3.8 - ? B.Y.

THICKENING ATMOSPHERE:
CO₂, H₂O

CRYOSPHERE / HYDROSPHERE

OLIVINE/ NA-PYroxene CUMULATE

OLIVINE CUMULATE

GARNET / NA-CHALC / NA-BIOTITE? / NA-HORNBLende / “RUTILE” CUMULATES

RElic MAGnetic STRIPING

©Harrison H. Schmitt
University of Wisconsin-Madison

— = 400 km

Mafic Upper Mantle with increasing Si and Fe upwards

Valles Marineris outflow

Andesite Rocks

Relic Proto-Core?

FExNiSz Core

Thickened Southern Crust and Basaltic Volcanics

Late Northern Ocean and Other Lakes with Outflow Sedimentation

Tharsis

Elysium Mons

APOLLO MODEL OF MARS EVOLUTION

Translated text:

THARSIS EVENTS
<3.8 - ? B.Y.

THICKENING ATMOSPHERE:
CO₂, H₂O

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Tharsis

Elysium Mons

APOLLO MODEL OF MARS EVOLUTION
GRAVITY ANOMALY IMAGE
DRAPED OVER A THREE-DIMENSIONAL (3D) VIEW OF TOPOGRAPHY

Antipodal Rise

Arabia Terra

Tharsis rise

260°E

Antipodal Rise

PHILLIPS, R.J., AND CO-WORKERS, 2001, SCIENCE, 291, 2587-2591
ARSIA MONS
(SOUTH THARSIS
MOLA DATA APPLIED TO VIKING IMAGES
MOLA PROFILES ACROSS
OLYMPUS MONS
ALBAPATERA
ARSIA MONS
MOLA SCIENCE TEAM
APOLLO MODEL OF MARS EVOLUTION

PRESENT CONDITIONS
? B.Y.

THIN ATMOSPHERE: CO₂, DUST

CRYOSPHERE / HYDROSPHERE

OLIVINE/ NA-PYROXENE CUMULATE

OLIVINE CUMULATE

GARNET / NA-CPX, NA-BIOTITE?/NA-HORNBLENDE/ “RUTILE” CUMULATES

RELIC MAGNETIC STRIPING

RELIC PROTO-CORE ?

FEₓNIₙSₓ CORE

MAFIC UPPER MANTLE WITH INCREASING SI AND FE UPWARDS

VALLES MARINERIS OUTFLOW

ANDESITE ROCKS

THICKENED SOUTHERN CRUST AND BASALTIC VOLCANICS

SOUTH POLAR ICE CAP

NORTH POLAR ICE CAP

ELYSIUM MONS

THARSIS

MAFIC UPPER MANTLE WITH INCREASING SI AND FE UPWARDS

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SOUTH POLAR ICE CAP

NORTH POLAR ICE CAP

ELYSIUM MONS

THARSIS

PRESENT CONDITIONS
? B.Y.
WESTWARD VIEW DOWN VALLES MARINERIS
(MOLA SCIENCE TEAM)
VALLES MARINERIS AND OUTFLOW CHANNEL ELEVATIONS
NASA/MOLA
OUTFLOW CHANNEL, KASEI VALLES
NASA VIKING MOSAIC
OUTFLOW CHANNEL FEATURES
GANGES CHASMA
OUTFLOW 3D

NASA/JPL/MALIN SCIENCE SYSTEMS
PROPOSED SHORELINES FOR A NORTHERN OCEAN ON MARS
HEAD, J.W.,III, AND CO-WORKERS, 1999, SCIENCE, 286,2134-2137

NOTE: OLDER, CONTACT 1, AND TO A LESSER DEGREE, CONTACT 2 ARE MOST DISPLACED UPWARD IN AREAS OF THE THARSIS, ARABIA, AND ELYSIUM RISES WHICH MUST POST-DATE A POSSIBLE "EARLY" NORTHERN OCEAN.
SEQUENTIAL FLOODING OF NORTHERN LOWLANDS
HEAD, J.W., III, AND CO-WORKERS, 1999, SCIENCE, 286, 2134-2137

STIPPLED SHOWS POLYGONAL GROUND CRATER ONSET DIAMETERS INCREASE RADIALY

CONTACT 2

500M DEPTH

1000M DEPTH

1490M DEPTH CONTACT 2

1680M DEPTH MEAN CONTACT
A. LINEAR SLOPE CHANGES ON ALBA PATERA.

B. MOLA PERSPECTIVE VIEW OF APPARENT TERRACES AT THE SOUTHERN MARGIN OF UTOPIA PLANITIA.

C. MOLA PROFILE ACROSS SOUTHERN UTOPIA PLANITIA

HEAD, J.W.,III, AND CO-WORKERS, 1999, SCIENCE, 286,2134-2137
MOLA SLOPE MAP (OVER 30 KM)

MOLA ROUGHNESS MAP (OVER 35 KM WINDOW)
THARSIS / ELYSIUM VOLCANISM UPLIFT
CONSEQUENCES - 1

- THARSIS / ELYSIUM VOLCANISM
  - PARTIAL MELTING OF MANTLE
    - CONCENTRATION OF RADIOISOTOPES IN HIGH PRESSURE MANTLE (?)
  - 3 X 10^3 KM^3 MAGMA IN SURFACE EXPRESSION OF THARSIS RISE
  - DENSE CO_2 AND H_2O ATMOSPHERE
    - ACTIVATION OF HYDROSphere, CRYOSPHERE AND CARBONATE DEPOSITS
    - PRIMARY WATER FROM HYDROUS MINERALS IN LOWER MANTLE (?)
  - ANDESITIC RESURFACING OF NORTHERN LOWLANDS
THARSIS / ELYSIUM VOLCANISM UPLIFT CONSEQUENCES -2

• THARSIS RISE BEGAT ARABIA TERRA RISE
  – EXTENTIONAL FRACTURING TO GIVE GIANT RIFT VALLEYS
    • BECAME OUTFLOW CHANNELS
  – HEAT TO ACTIVATE THE HYDROSPHERE/CRYOSPHERE
    • SOURCE FOR OUTFLOW FLOODS
  – TROUGH SURROUNDING THARSIS
    • NORTHWARD FLOW FROM MAJOR OUTFLOW CHANNELS
    • ERODED MATERIALS DEPOSITED ON NORTHERN OCEAN BED
  – UPWARD DEFORMATION OF THE EARLY NORTHERN OCEAN SHORELINE
    • LATE, LOCAL DEFORMATION OF LATE NORTHERN OCEAN SHORELINE
NORTHERN LOWLANDS/OCEANS

• LARGE, IRREGULAR BASIN
  – SEVERAL VERY LARGE IMPACTS(?)
  – INTERNAL PROCESS THAT THINNED CRUST(?)

• EVIDENCE FOR NORTHERN OCEAN(S)
  – DRAINAGE FROM VALLEY NETWORKS (EARLY VOLCANISM)
    • ABUNDANCE OF OLD LAYERED ROCKS
  – DRAINAGE FROM OUTFLOW CHANNELS (THARSIS VOLCANISM)
  – SHORELINE/STANDSTILL TERRACES(?)
  – SMOOTH TOPOGRAPHY RELATIVE TO SOUTHERN UPLANDS
  – VOLUME ENCLOSED PLAUSIBLE RELATIVE TO POTENTIAL WATER VOLUME
  – EVIDENCE FOR RECENT OR CURRENT GROUND ICE OR GROUND WATER
    • POLYGONAL GROUND
    • RAMPART CRATER EJECTA
3D VIEW OF NORTH POLAR CAP
MOLA SCIENCE TEAM/ NASA/GFSC SVS
NORTH POLAR CAP LAYERS
North Polar Layers in Same Trough

86.5°N 281.5°W
86.4°N 278.7°W
85.9°N 257.9°W

100 KM BETWEEN LEFT AND RIGHT IMAGES
SOUTH POLAR CAP LAYERING AND EROSION

PIA02391

PIA02392

1 KM

NASA/JPL/MALIN SCIENCE SYSTEMS
NEW MARTIAN LANDSLIDES
(DARK STREAKS ON INNER WALL OF CRATER

NASA/JPL/MALIN SCIENCE SYSTEMS
LANDSLIDE IN 3D

NASA/JPL/MALIN SCIENCE SYSTEMS
PATHFINDER/SOUJOURNER
“TRUE COLOR OF MARS”
PATHFINDER LANDER VIEW
NASA/JPL