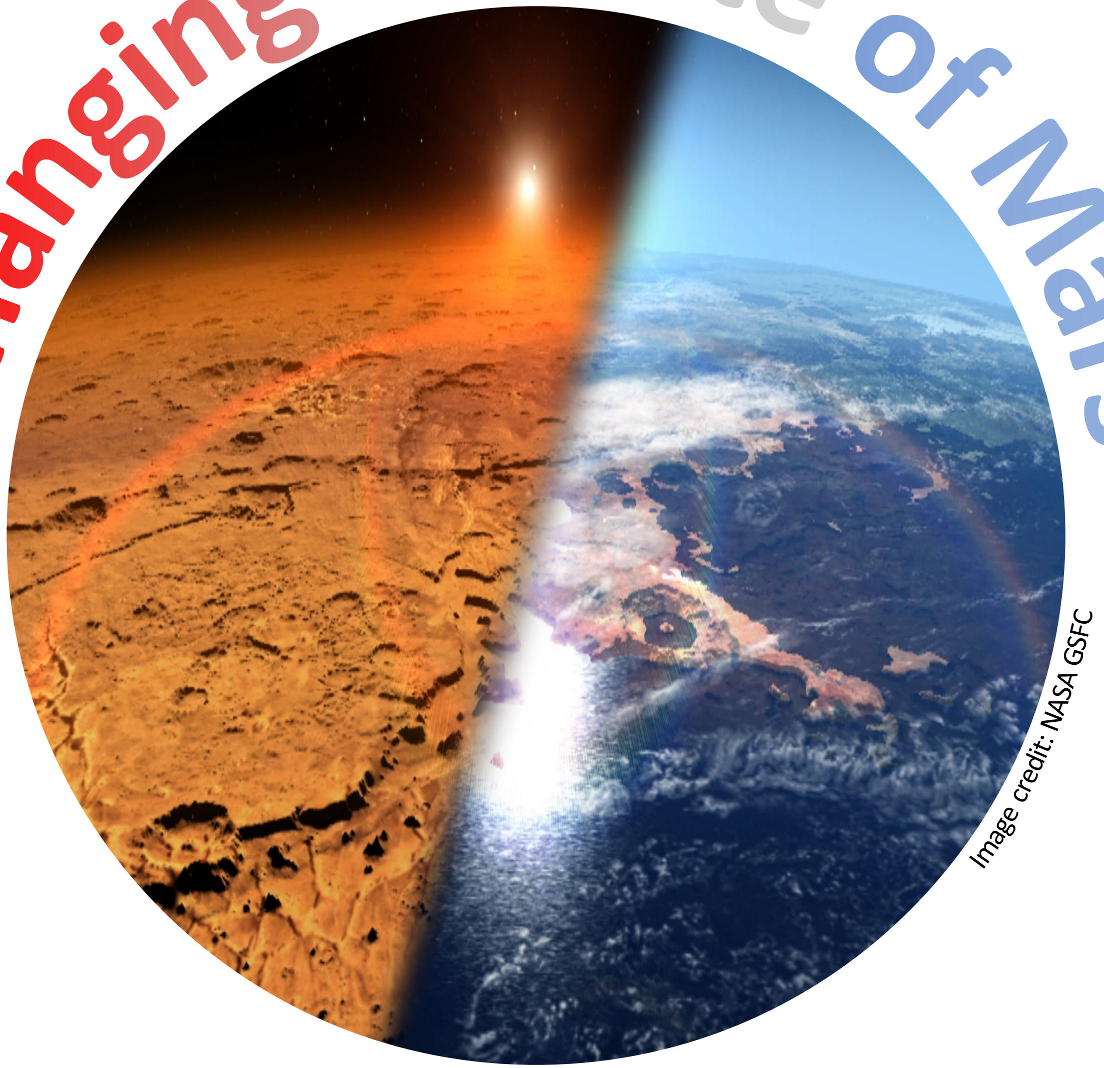
Changing Climate of Mars



CCoM

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On behalf of
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Voyage 2050

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Rationale:

- Mars missions to data have been tasked with investigating habitability, not climate change
- At least one major episode of climate change on Mars
  - Marks the Noachian-Hesperian boundary, ~ 3.5 Gyr ago
  - Exactly when and how the environment changed is still unknown
  - Disagreement between climate models and morphology
  - Occurs at approximately same time as early life starts to evolve on Earth
- Investigate the Late Noachian-Early Hesperian period through detailed study of bedrock and sediments
- Proposal is for two rovers at separate landing sites
  - Well-defined volcanic unit
  - Transition from fluvio-lacustrine to aeolian

Fit to ESA Strategy:

Historical Background:

- Cosmic Visions Programme (Science Directorate)
  - No missions to Mars selected within the programme
- Aurora/Exploration Programme (HSF Directorate)
  - Three missions to Mars: Schiaparelli lander (2016); ExoMars TGO (2017); ExoMars Lander & Rosalind Franklin Rover (2020)
  - Mars Sample Return (joint with NASA); subject to funding decision CM 2019

New programme of Mars exploration:

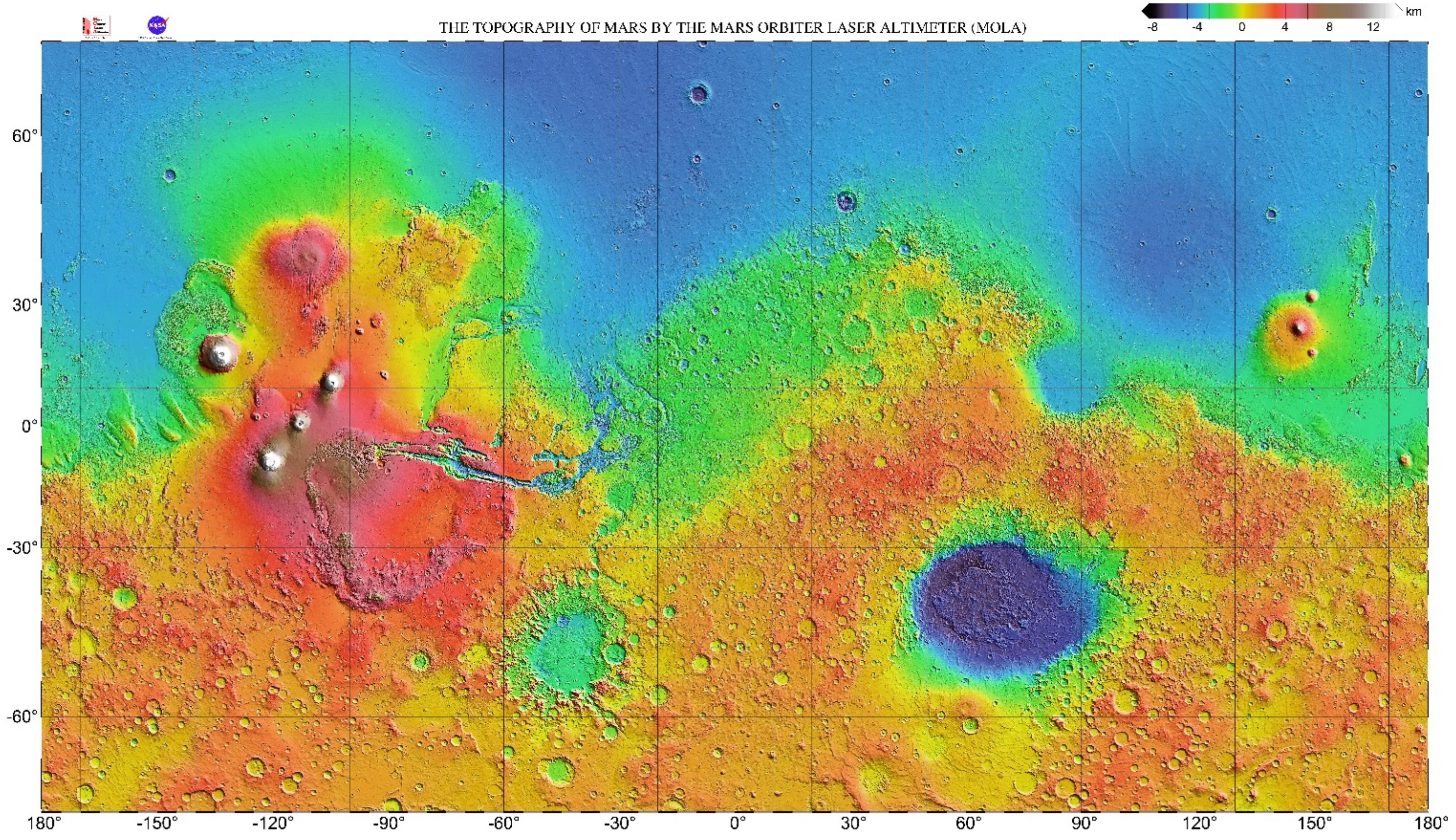
- A ‘Changing Climates’ Theme within the Voyage 2050 strategy would also encompass exploration of Venus as well as the Sun, Earth and (potentially) exoplanets
- In co-operation with other Directorates

International Context:

- NASA has just formed MASWG
  - Call for White Papers taking exploration of Mars beyond MSR
  - Input for Decadal Survey
  - Possibility for joint mission programme following success of MSR planning
- UAE: Hope Orbiter (2020): atmosphere
- JAXA: MMX: Mission to Phobos (2024): sample return
- China: Mars-1 Orbiter and Rover (2020): biosignatures
- India: Mangalyaan 2 orbiter (2024): atmosphere

- No currently planned rover missions to investigate changing climate

Science Context: 1. Age



- History divided into 3 Epochs
- Chronology based on crater size-frequency distributions
- Age ranges based on comparison with lunar cratering record (Apollo)
- Absolute age assignment of epoch boundaries depends on cratering model used
- May shift by up to 500 Myr

Science Context: 2. Fluid Flow

Abundant evidence from orbit, landers, rovers and meteorites that water was present on Mars’ surface

Morphology:

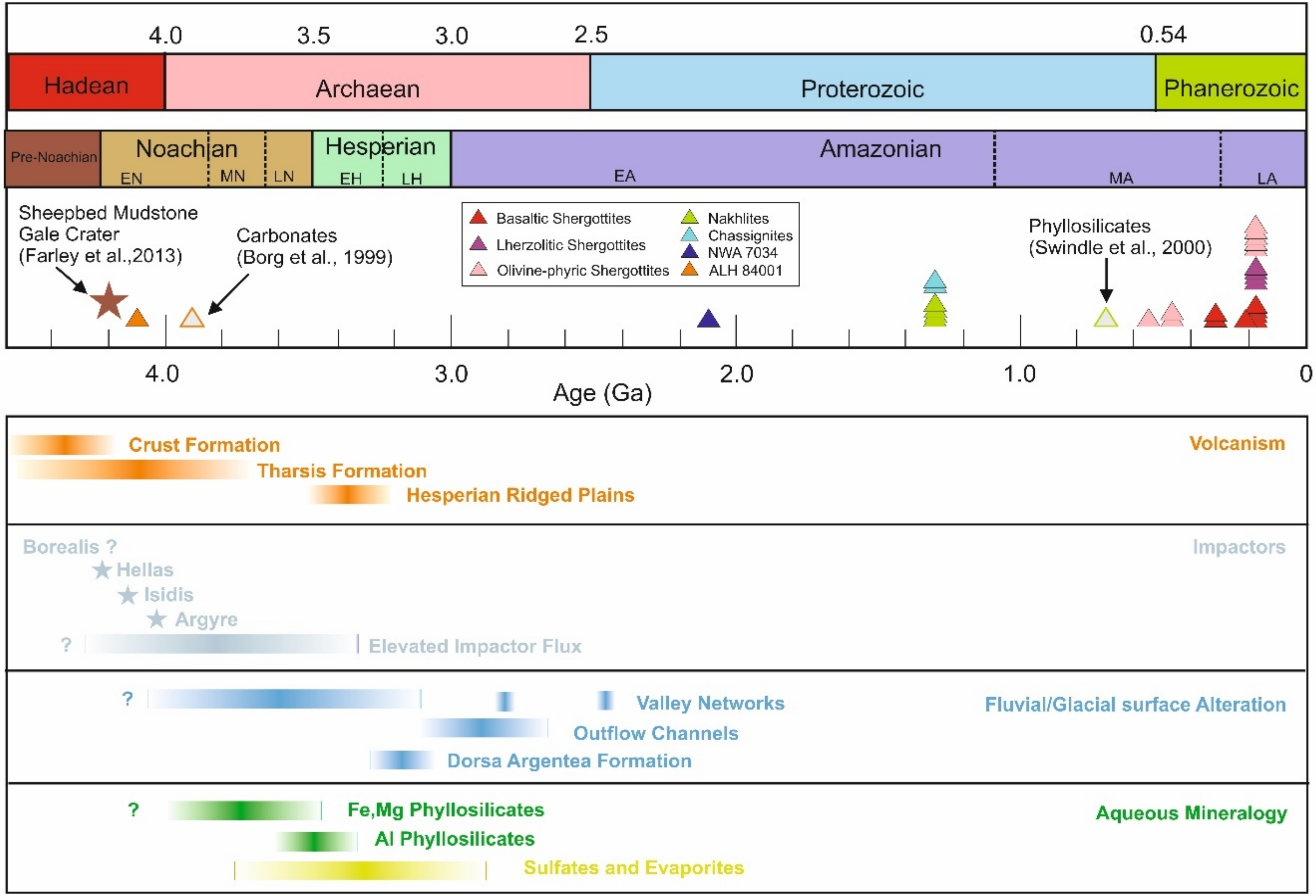
- Networks result from surface run-off from snow or rain (short-lived phenomena)
- Features show that water volume and flow-rate varied widely

Climate Modelling:

- Valley networks formed by episodic melting of ice sheets or up-welling groundwater (longer-lived phenomena)
- Faint Young Sun, obliquity, presence of clouds = Noachian cooler than previously thought

Was the change in climate gradual or sudden?

Timeline of Major Events in Mars' History



Science Goals:

- Determine the absolute age, mineralogical composition and depositional environment of Mars’ surface at the landing sites
  - Age and timing of environmental transition
  - Is the transition traceable through alteration of volcanic and/or sedimentary rocks?
  - How much fluid was involved and what was/were its source(s)?
  - Is the transition co-eval at the two sites? i.e., was the N-H transition global in terms of onset and duration?
  - Calibrate cratering age chronology
- Correlate mineral assemblages observed from orbit with surface distributions of the same mineral assemblages at specific landing sites
  - Calibrate the mineralogy and mineral chemistry of extended areas of Mars’ surface

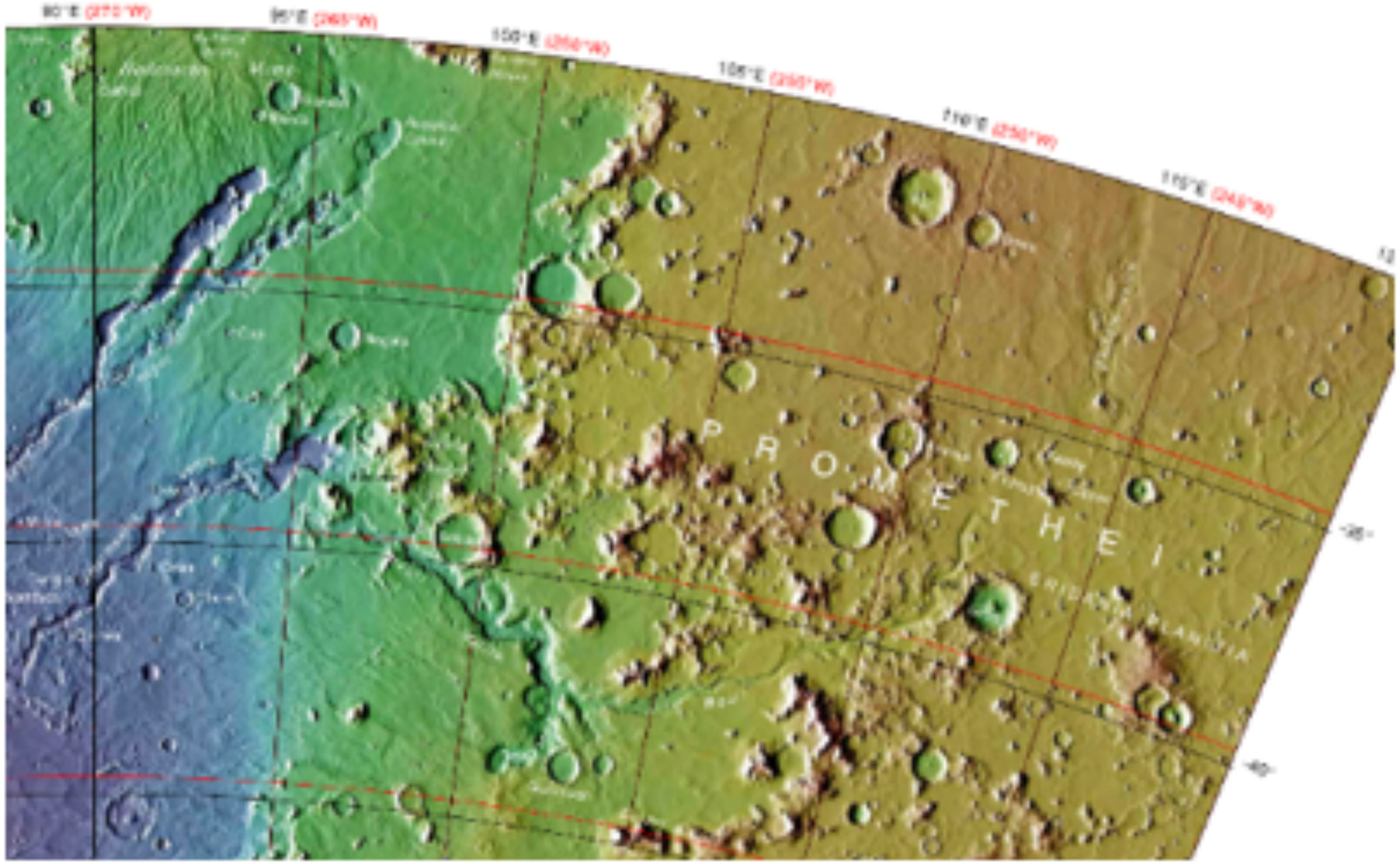
Potential Landing Sites: 1. Becquerel Crater, Arabia Terra

Taken from Tanaka et al. 2014. USGS Map

- 22.1° N, 352.0° E
- 170 km diameter;
- Early Hesperian sedimentary layers (fluvial, aeolian) lie on top of Late Noachian Highland Unit (volcanic, impact)
- Internal crater (50 km) presumably penetrates layers
- Between Oxia Planum (ExoMars) and Meridiani Planum (Opportunity)

Potential Landing Sites: 2: NE Hellas Planitia

- Early Hesperian sedimentary layers (lacustrine, aeolian) dissected by fluvial channels



Taken from Tanaka et al. 2014. USGS Map

Model Payload: 1. Orbiter

- Wide Angle Camera
  - High Resolution imagery of the surface
- UV-Vis-TES Spectrometer
  - Distribution and composition of surface minerals
- Mass & Isotope Analyser
  - Elemental and light element (H, C, N, O, noble gases) isotopic composition of atmosphere at altitude

- Orbiter will also act as Communication Relay

Model Payload: 2. Rover (the Christmas Tree version)

- Multispectral 3D imager
  - Colour images will enable compositional information
- Close up Camera
  - Detailed view of sampling area (texture, grain size, etc)
- APXS or LIBS
  - Chemistry; calibrated K abundances for K-Ar dating
- Raman or IR Spectrometer
  - Composition (organics?)
- X-Ray diffractometer
  - Mineral composition & structure
- Combined GC-MS and GC-IRMS
  - Elemental and light element (H, C, N, O) isotopic composition of rocks and atmosphere at the surface
  - Calibrated Ar abundances for K-Ar dating
- Sampling capability
  - Deliver material to GC system
- Seismic package
  - Seismometer & heat flow: combine with Insight data

Summary

- The Changing Climate of Mars mission proposal to investigate the N-H transition would be the first mission to explore the Noachian Highlands
- As well as establishing whether the N-H was globally co-eval and a sudden or gradual climate transition, the mission should:
  - calibrate Mars' cratering chronology, yielding an absolute age for the planet's surface
  - cross-calibrate mineralogy from orbit and on the surface
  - search for organics at a boundary of the same age at which life was becoming established on Earth
  - contribute to a seismic network

Thank you to the members of the CCoM consortium