Interior & Surfaces

Presentation of Science Cases

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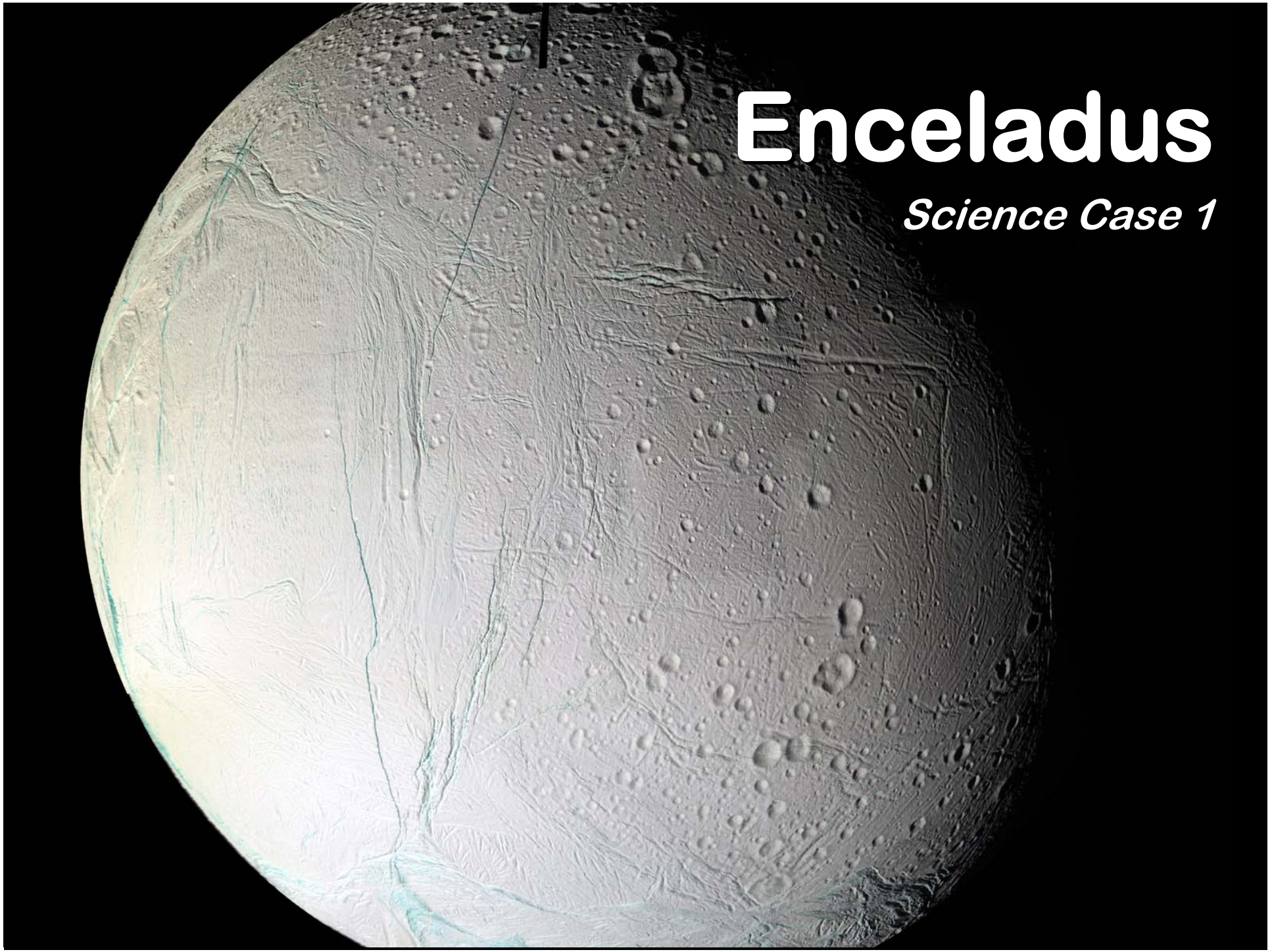
in der Helmholtz-Gemeinschaft

Overview

Enceladus – A Small Active Icy Satellite

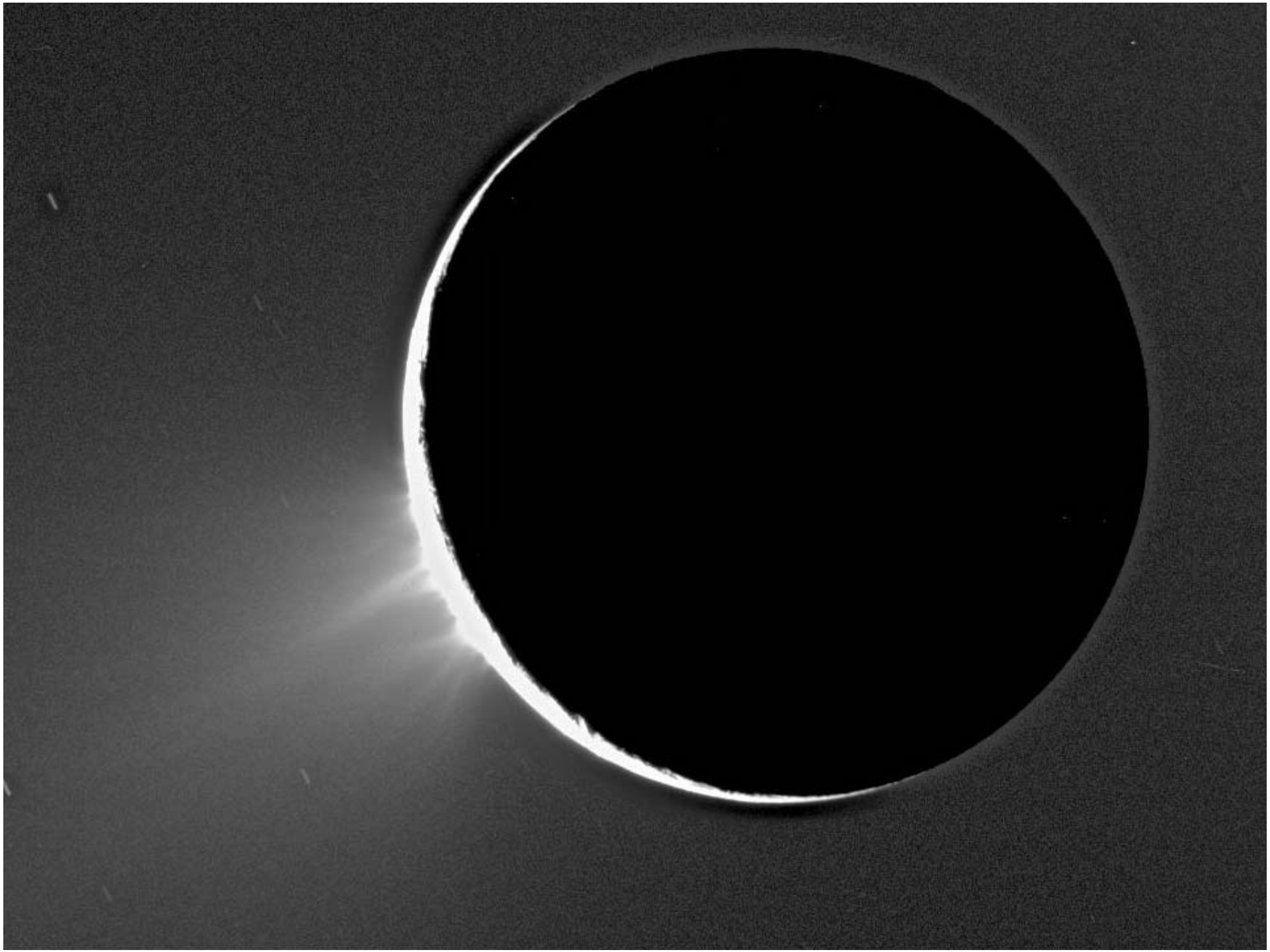
Mars Tectonics – The Link between Surface and Interior

The Use of Terrestrial Analogues in Mars Surface Science



Enceladus

Science Case 1



Science Case 1:

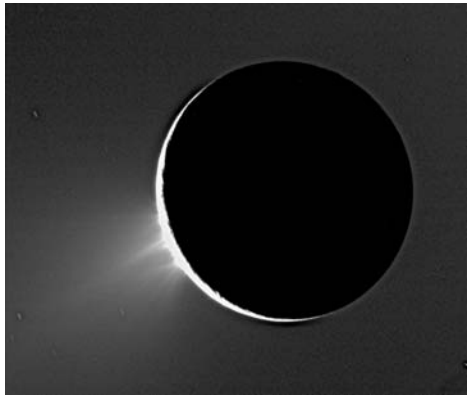
Enceladus – A Small Active Icy Satellite

Signs of activity in the south-polar region:

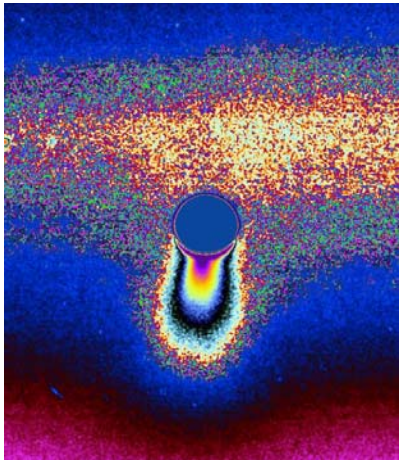
- **Plume eruptions (mainly H_2O)**
- **Thermal anomalies, correlated with geologic features ('tiger stripes')**
- **Geologically strongly modified terrain near the south pole**

Key questions:

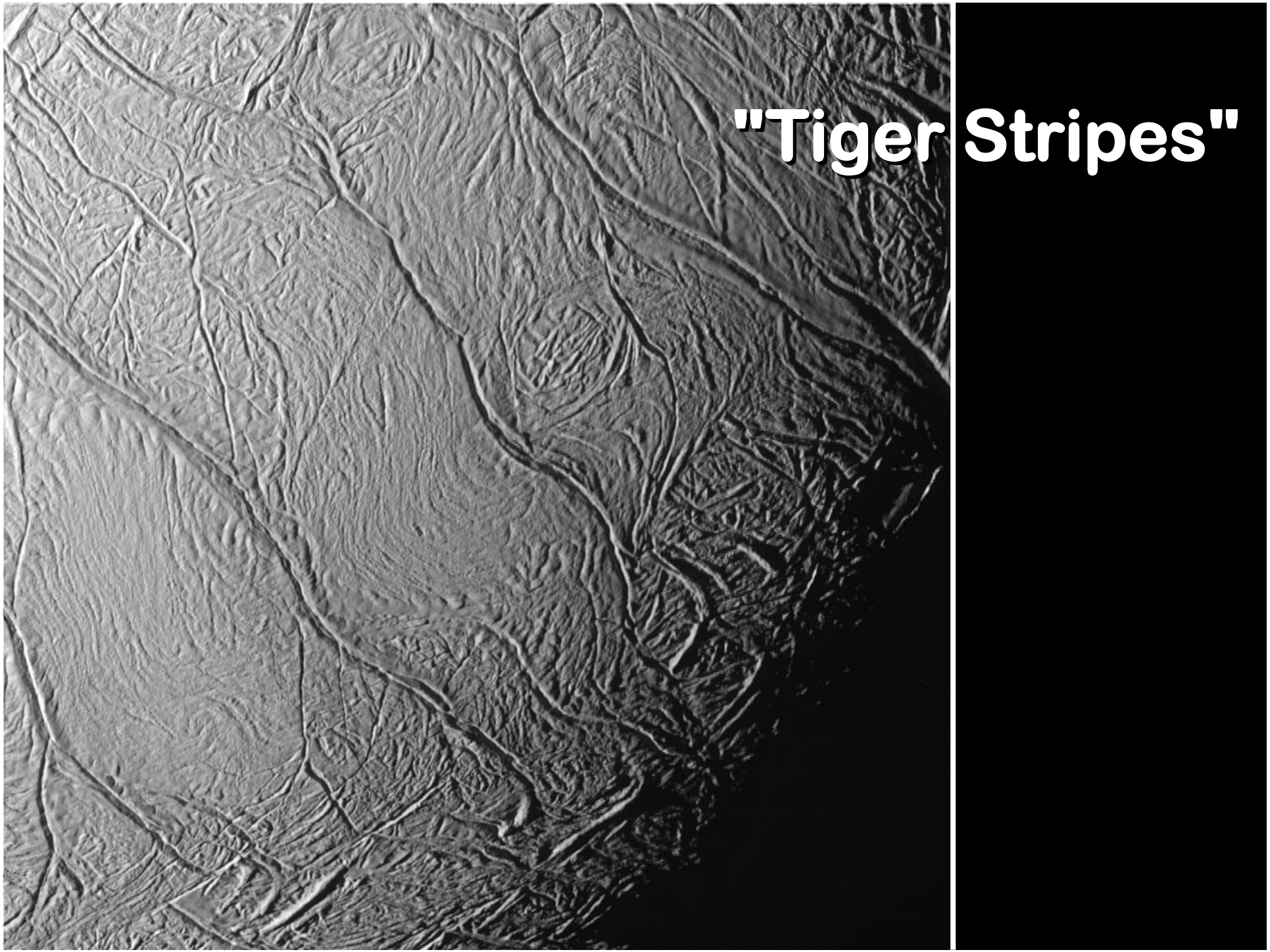
- **What is the energy source driving the thermal activity and the jets?**
- **Is the activity recent, persistent, or episodic?**
- **Is liquid water present near the surface?**
- **What are the astro-biological implications (liquid water, energy, organics …) of such an environment?**



Eruptions on Enceladus.
(NASA/JPL/Space Science Institute)



False color view of particles forming the E-Ring of Saturn.
(NASA/JPL/Space Science Institute)


"Tiger Stripes"

Surface and Interior Structure: Key questions

- **Surface:**
  - What causes the great variety of geologic features?
  - What causes the heterogeneities in surface age and geologic activity?

- **Interior:**
  - Is Enceladus fully or partly differentiated?
  - What are the internal heat sources?
  - What is the amount and distribution of tidal heating?
  - Is there liquid water near the surface?

→ **Study the connection of internal and surface processes!**

Surface Activity, a Key to the Interior and Evolution

- **Plume composition**
  - H_2O particles and vapor (90%)
  - Other constituents (CO_2, CH_4, …)
  - Physical characteristics (particle size …)
  - What is the isotopic ratio of chemical compounds?

- **Plume dynamics**
  - What internal (near surface) mechanism drives the plumes?
  - Link to Saturn's E-ring

High temperatures are correlated with the 'tiger stripes' at the South Pole.
(NASA/JPL/GSFC/Space Science Institute)

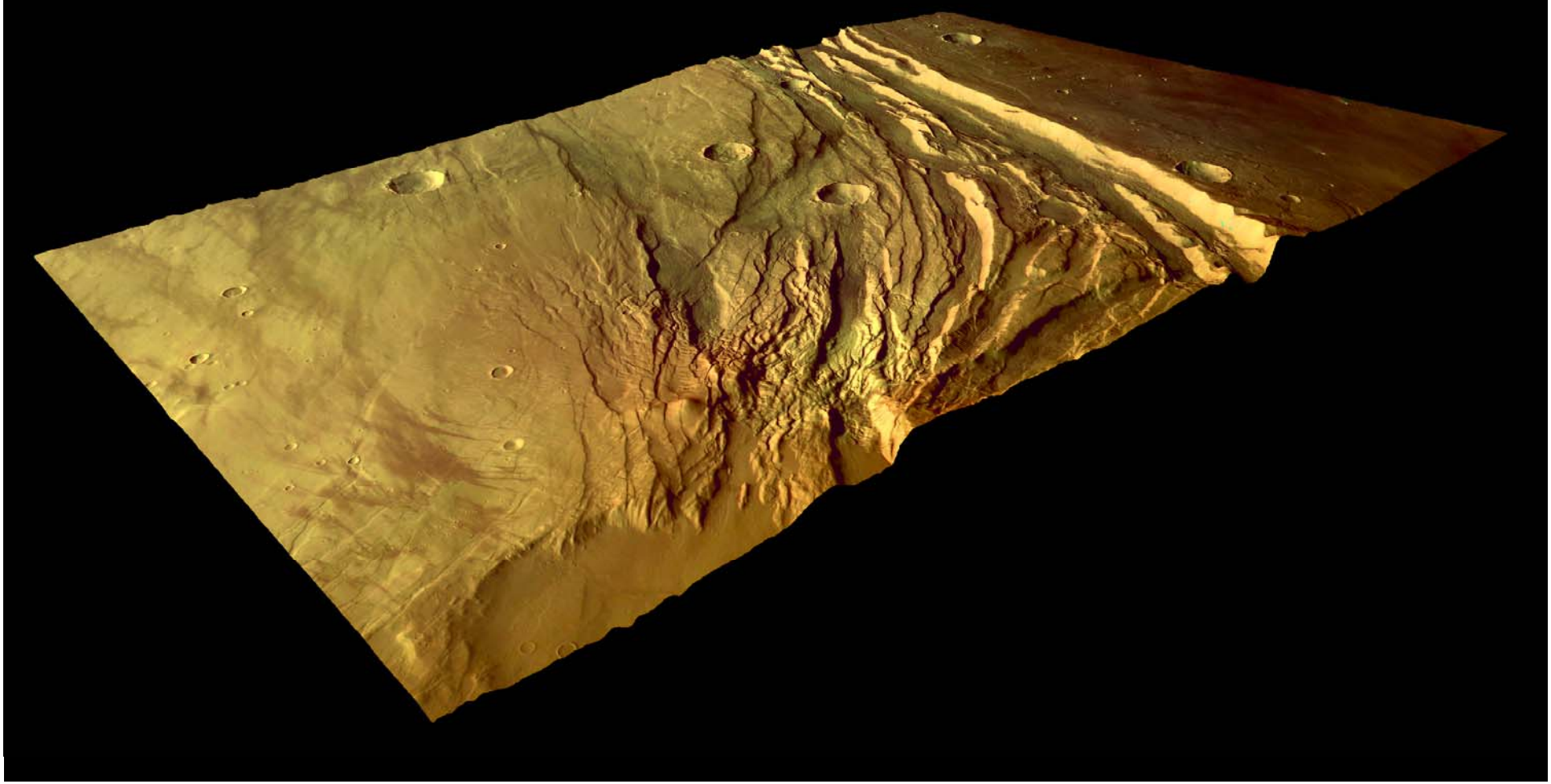
- **Implications for Evolution**
  - Isotopic abundances ↔ origin
  - Thermal activity ↔ nature and distribution of heat sources
  - Dynamical state (rotation and orbit) ↔ satellite's history

Online Resources

- **Missions**
  - Cassini
  - Voyager (and Pioneer)
- **Data**
  - Global properties (JPL-SSD Satellites page …)
  - Surface maps (DLR, USGS …
  - Material Sciences (ice and rock)
- **Bibliography**
  - ADS Abstract Service, ISI (Science Cit. Index), ELIB, …
  - Special issues (Science 311, 10 March 2006, …)
  - Books, Proceedings, Special Sections …
- **Exchange of information**
  - Enceladus Focus Group
  - Icy Satellites Focus Group
  - OPAG

Tectonics on Mars

Science Case 2



Science Case 3

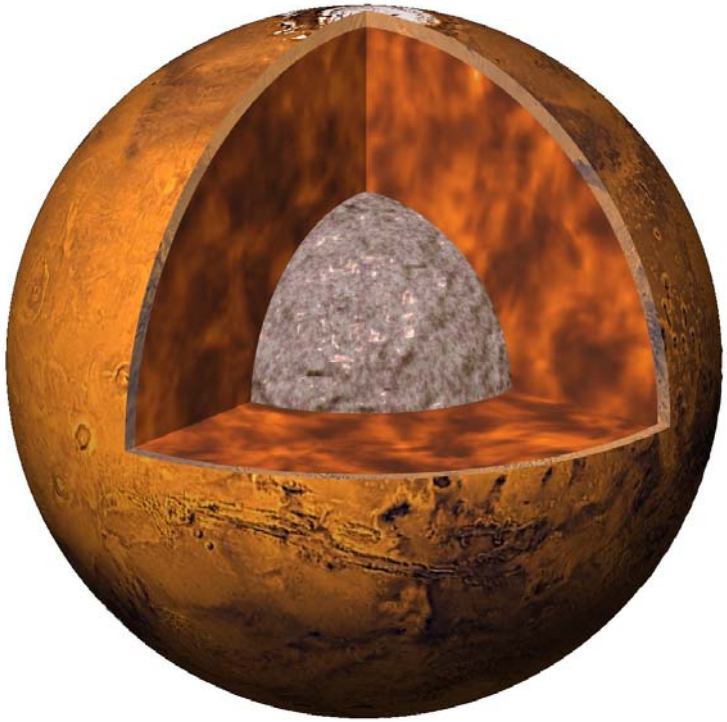
MARS TECTONICS – THE LINK BETWEEN SURFACE AND INTERIOR

- The tectonic record of Mars is well preserved
- Tectonic activity is the surface expression of interior processes

Key questions:

- What was the sequence, intensity and spatial distribution of tectonic events?
- How is this related to the interior structure, the style of mantle convection and the thermal evolution of the planet?
- What are the similarities and dissimilarities in terms of sources and style between Martian and terrestrial tectonics?

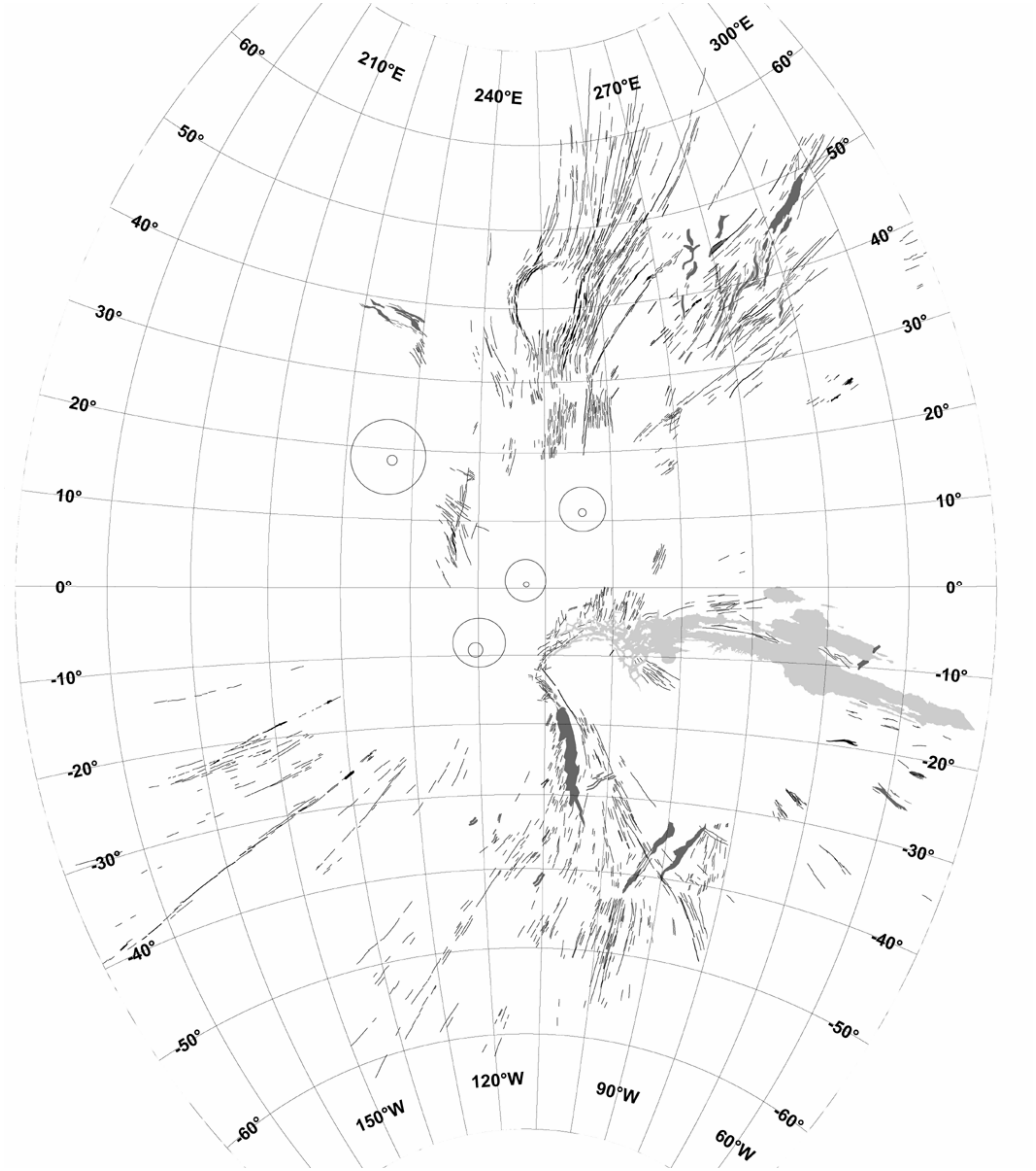
Interior Structure and Evolution: Key features and questions



- **Size and state of the core**
  - Solid, liquid
  - Magnetic field generation
- **Style of heat transport**
  - Early plate tectonics
  - Stably layered mantle
  - Stagnant lid convection
- **Global / Hemispheric Scale Activity**
  - Dichotomy
  - Tharsis
- **Local Activity**
  - Crustal structure
  - Diapirism

Surface Expressions and Tectonics

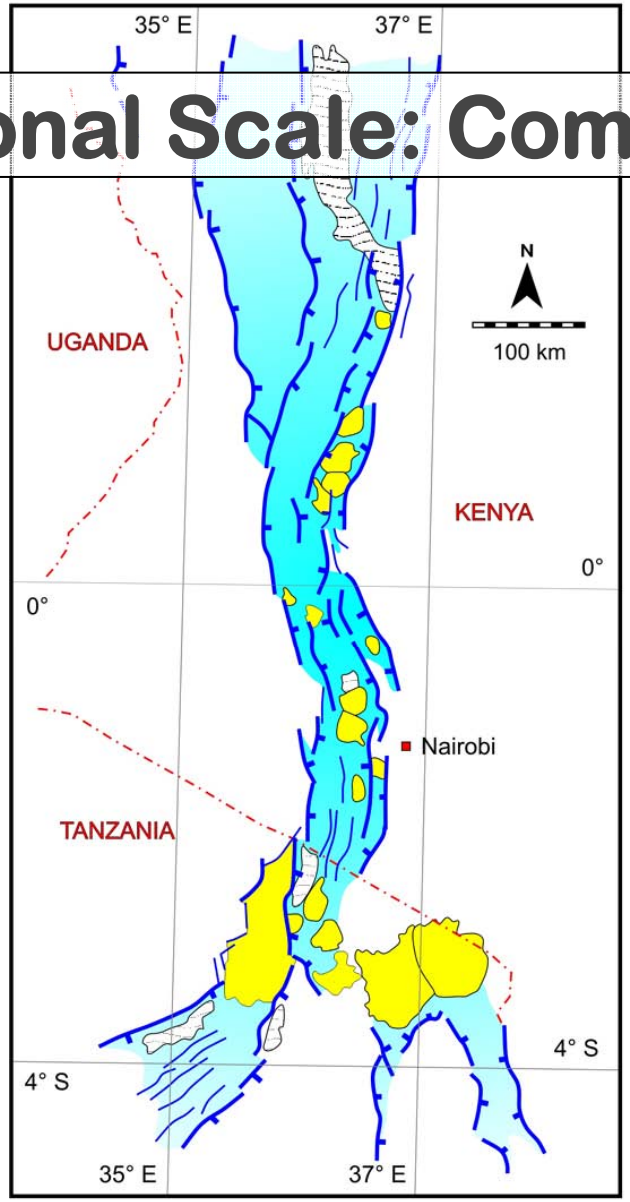
- **Large scale activity**
  - Lithospheric shrinking, global activation of faults
  - Emplacement of the dichotomy, formation of graben and thrust features
  - Emplacement of Tharsis, formation of concentric wrinkle ridges and radial graben
- **Local activity**
  - Doming, volcanism and rift formation
  - Extension, formation of narrow graben sets
- **Fault characteristics**
  - Displacement-Length Relations
  - Spacing



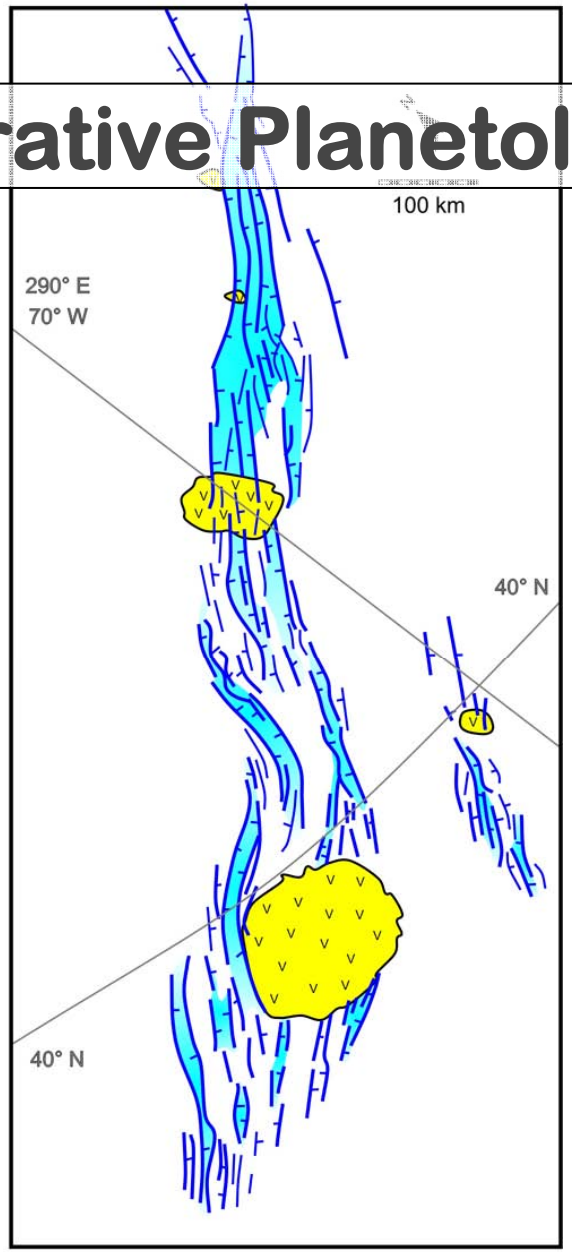
Global scale: Tharsis

- Concentric wrinkle ridges
- Radial grabens
- Complex rifts

Regional Scale: Comparative Planetology

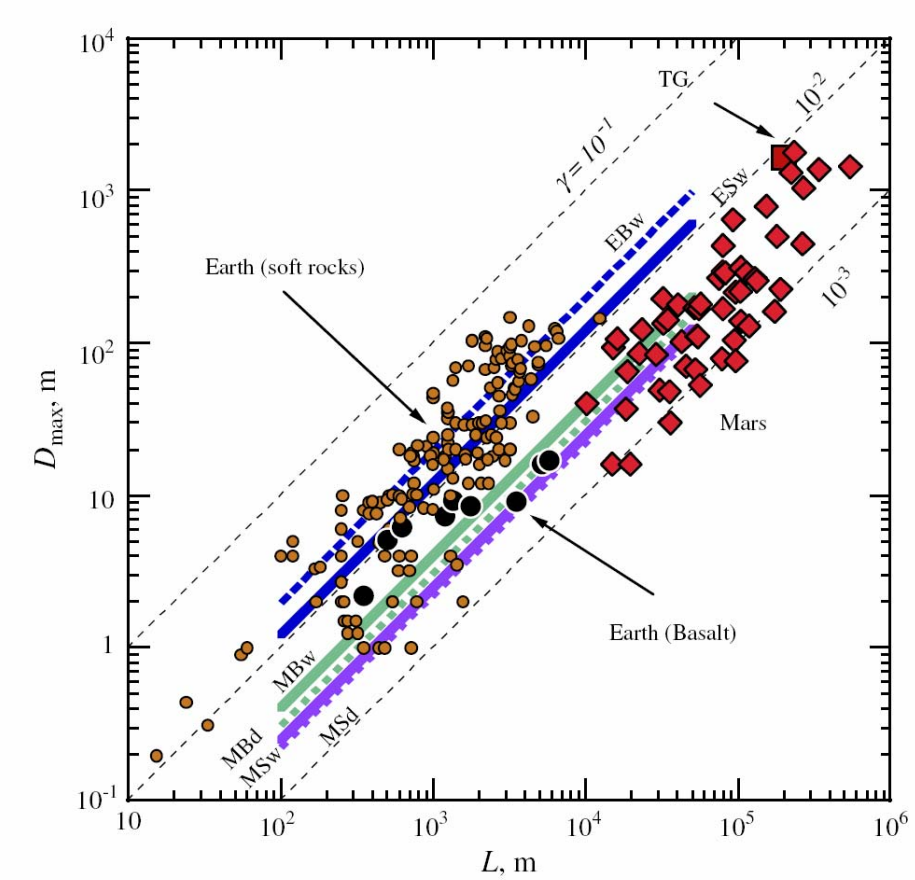


Kenya Rift

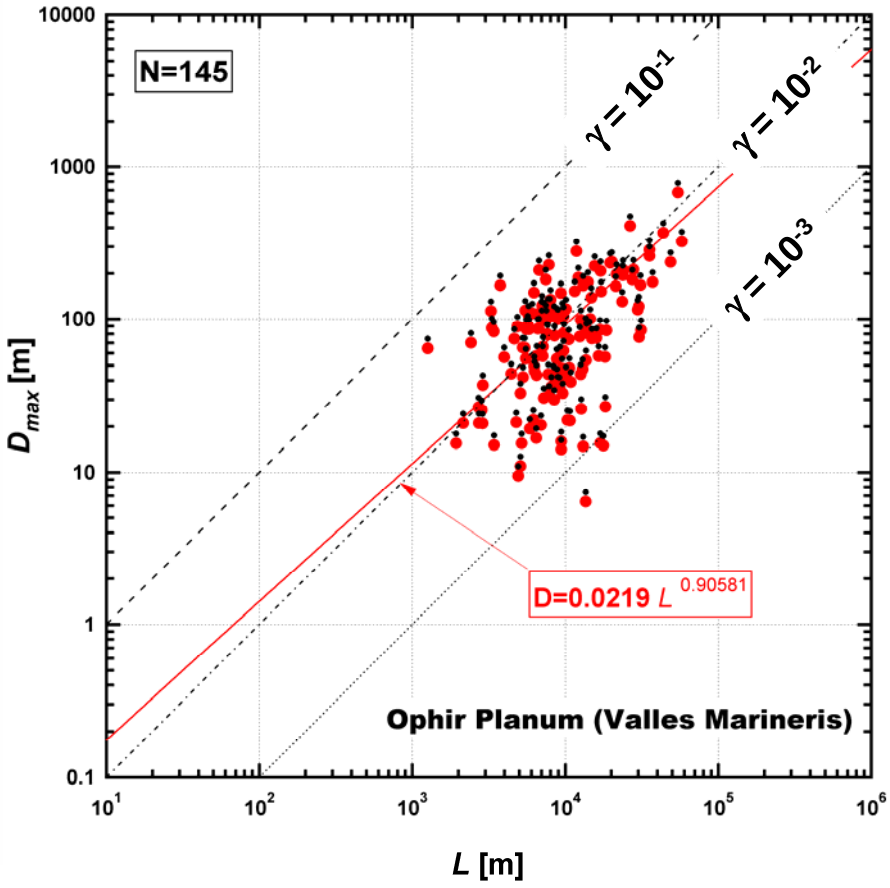


Tempe Rift

Local Scale: Displacement-Length Relationship



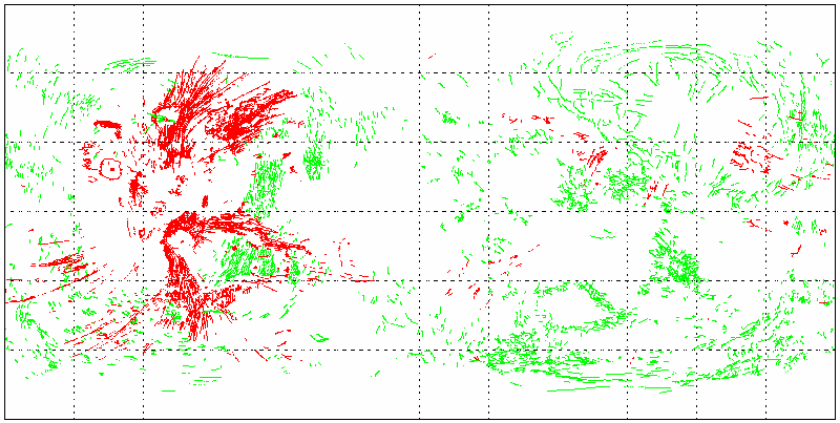
Schultz et al. (2006)



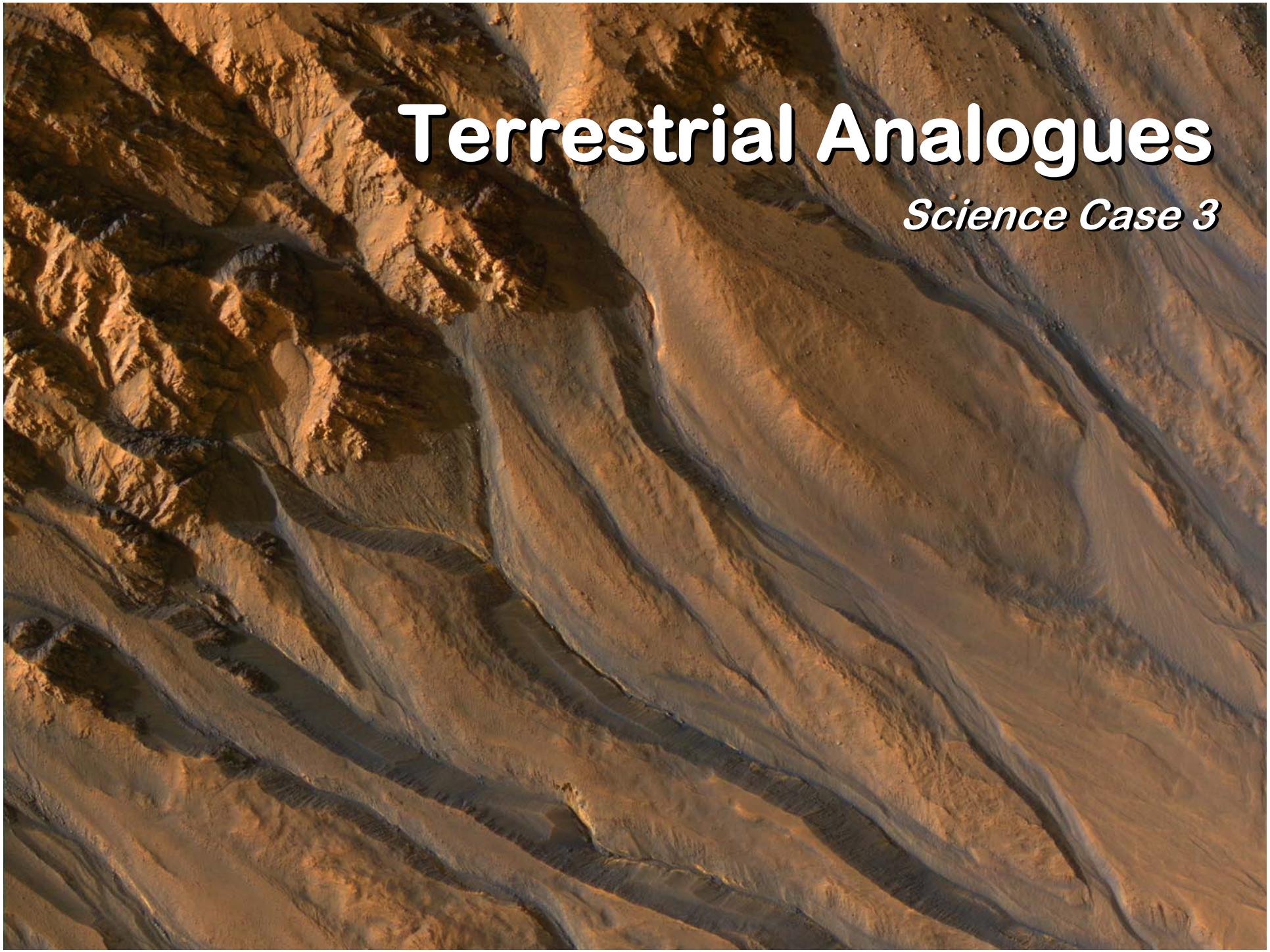
Hauber et al. (2007)

Online Resources

- General Information
  - Earth tectonic analogues
  - Structural geology sites
  - Mantle convection sites
- Data
  - Fault map (DLR)
  - Mars Information Sites
  - Lab data (rock rheology, melting curves, the Fe-FeS system)
  - Available software (mantle convection codes, …)
- Bibliography
  - ADS, ISI (Science Citation Index), Online Books, Special Journal Issues, Monographies



(Global Fault Map, DLR)



Terrestrial Analogues

Science Case 3

Science Case 3

The Use of Terrestrial Analogues in Studies of the Martian Surface

- **Terrestrial analogues are widely used in planetary research**
- **Main fields: Geological Process Studies, Technology Development, Laboratory Measurements and Modeling**

Key questions:

- ***How do terrestrial analog studies tie into prime Mars science objectives?***
- ***How can future instrumentation be used to address these questions?***

Further questions:

- ***What kind of analogues are useful for what studies?***
- ***What are the limits of analogue studies?***

Frequently used Analogues

Morphological analogs

- Fluvial features (e.g., drainage patterns, gullies)
- Glacial features (e.g., rock glaciers)
- Volcanic features (e.g., Hawaii)

Mineralogical and geochemical analogues

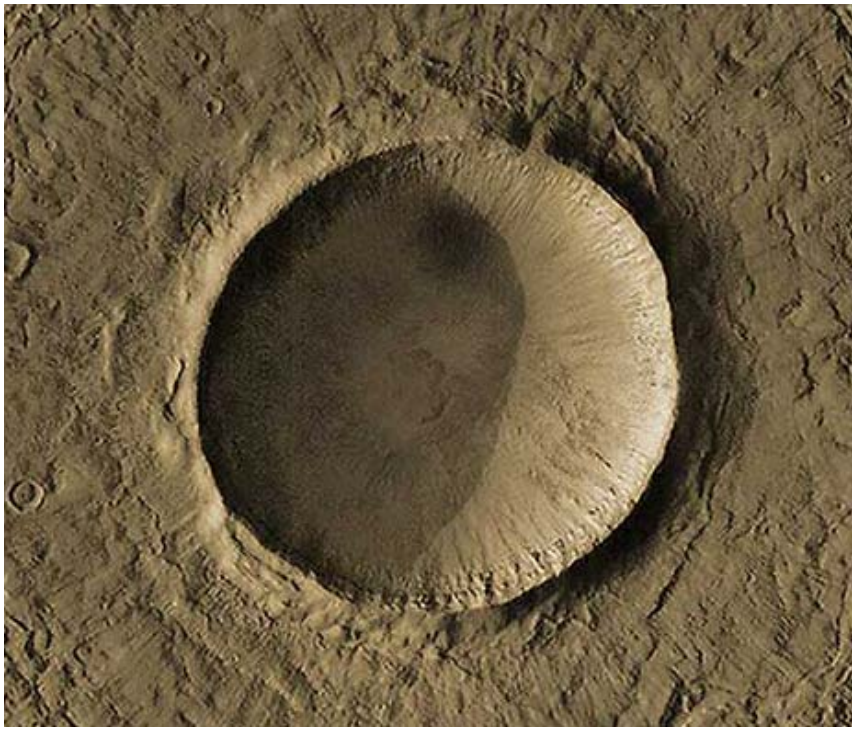
- Natural materials (e.g., basalt, palagonite)
- Material assemblages (e.g., Rio Tinto)
- Simulants (e.g., JSC Mars-1 soil simulant)

Climatic analogs

- Arid regions (e.g., Atacama Desert)
- Cold regions (e.g., Antarctic Dry Valleys)

Impact Craters

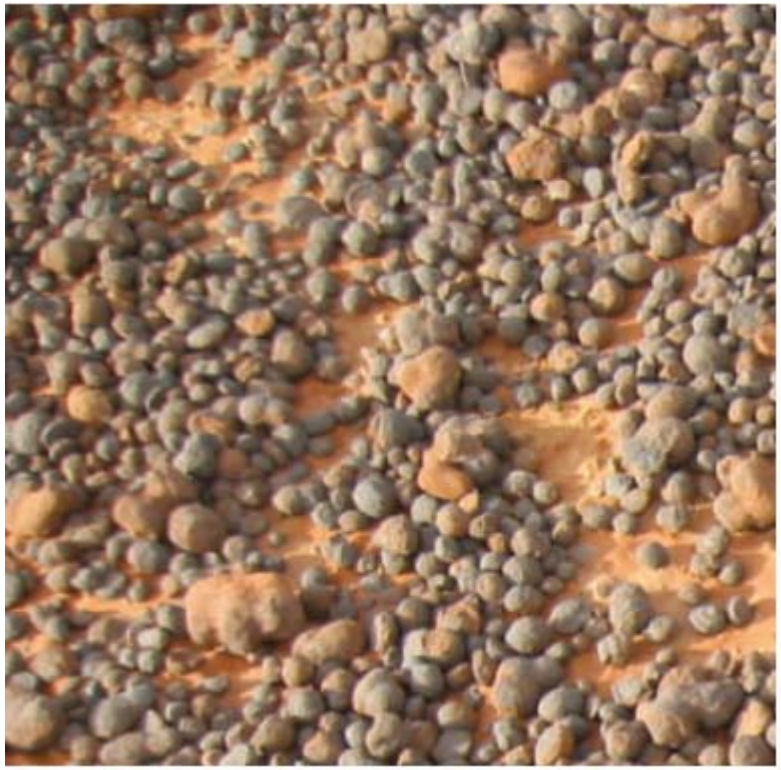
Barringer Meteor Crater (Arizona)



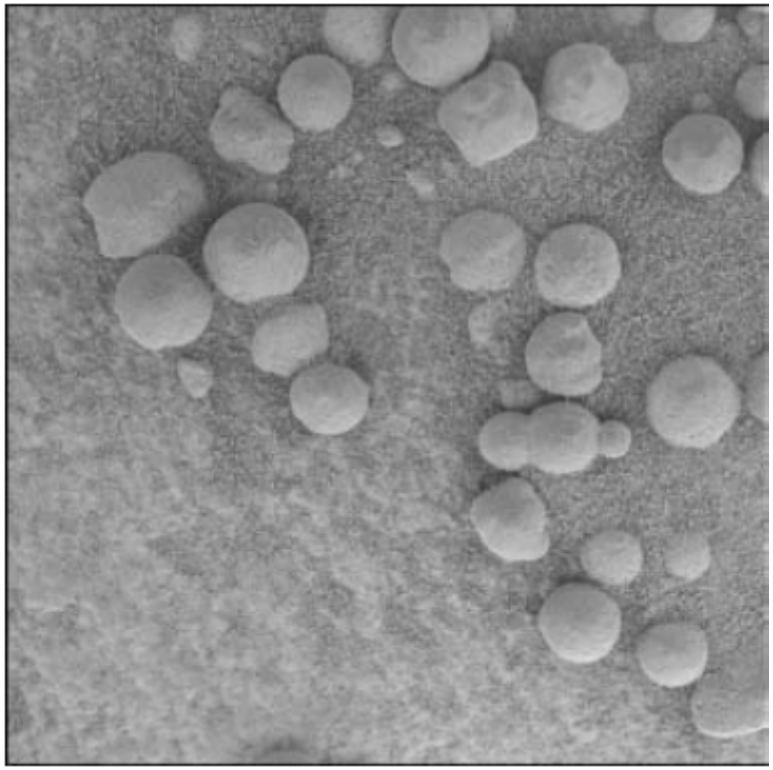
Crater in Utopia Planitia, Mars

Advance of our understanding of impact processes by observations of nuclear explosions

Hematite marbles



Hematite ‘marbles’ found in Utah

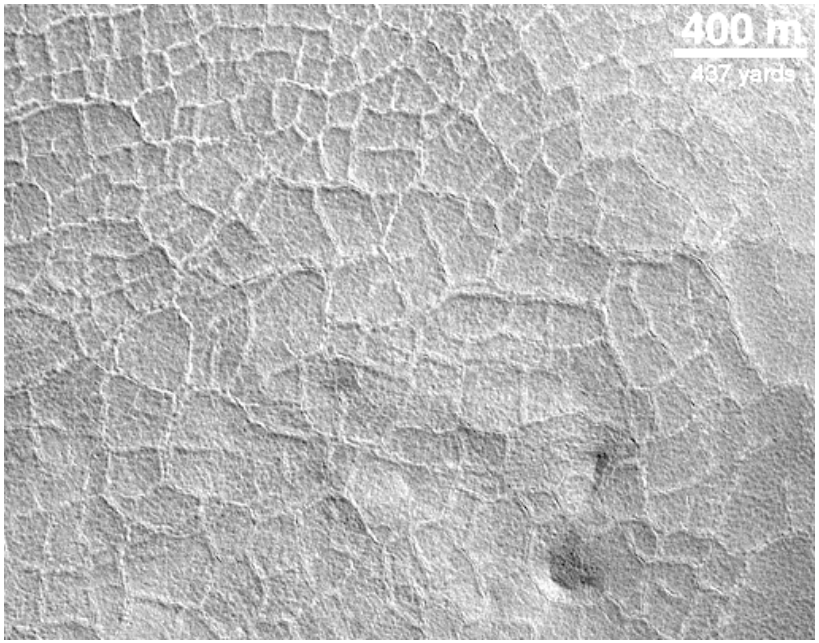


"Blueberries“: hematite concretions on the Martian surface found in Meridiani Planum

from Catling (2004)

Polygonal patterns – similar genesis

Polygonal pattern on Earth



Polygonal pattern on Mars

Mineralogical analogues

- Phyllosilicates


Nontronite


Chamosite


Montmorillonite

- Sulfates

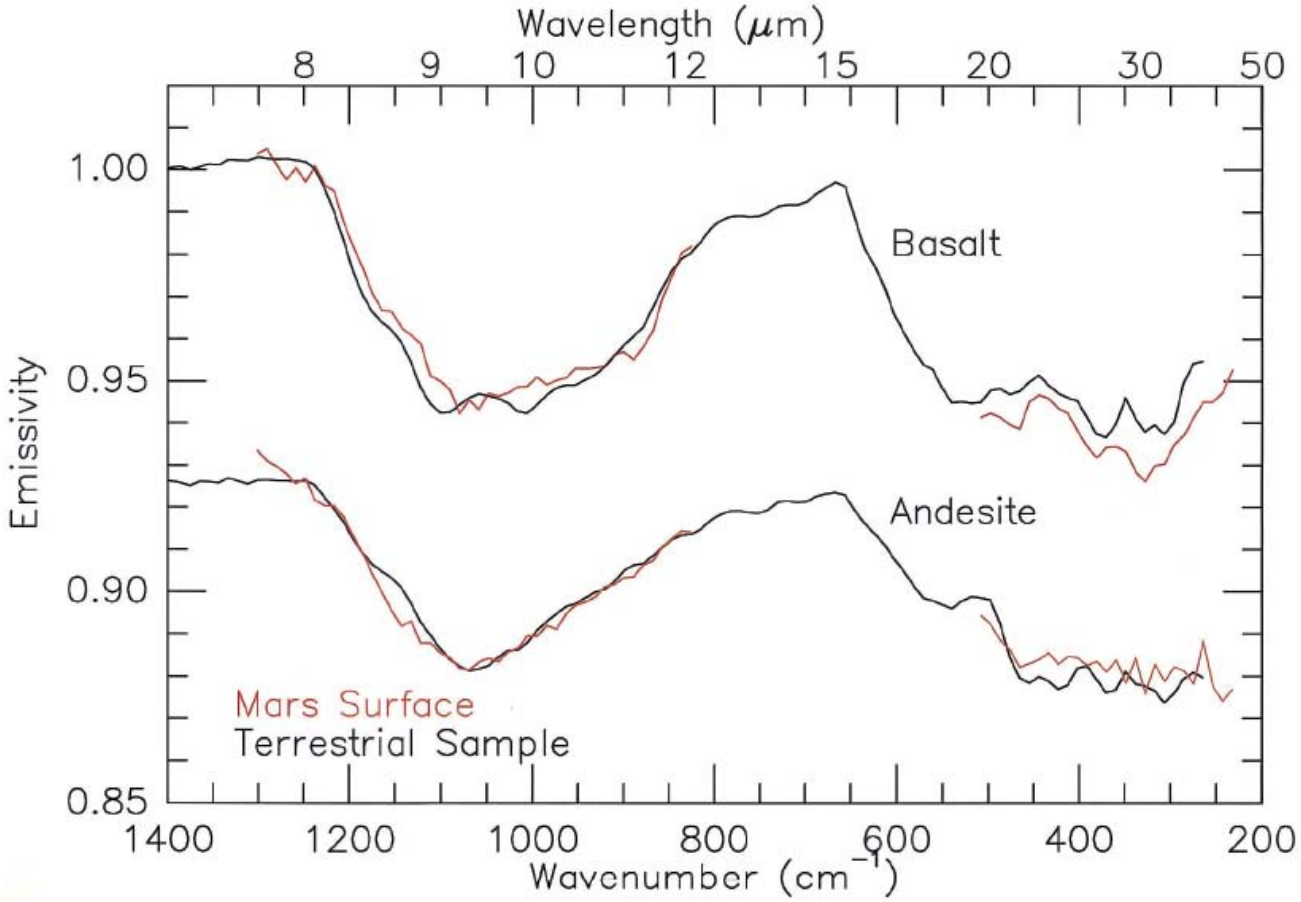

Kieserite


Gypsum


Epsomite

- Hematite
- Mafic rocks (Basalt, Andesite)

Mafic rocks



Average basalt and andesite spectrum of **Earth samples**

and the **Martian surface**

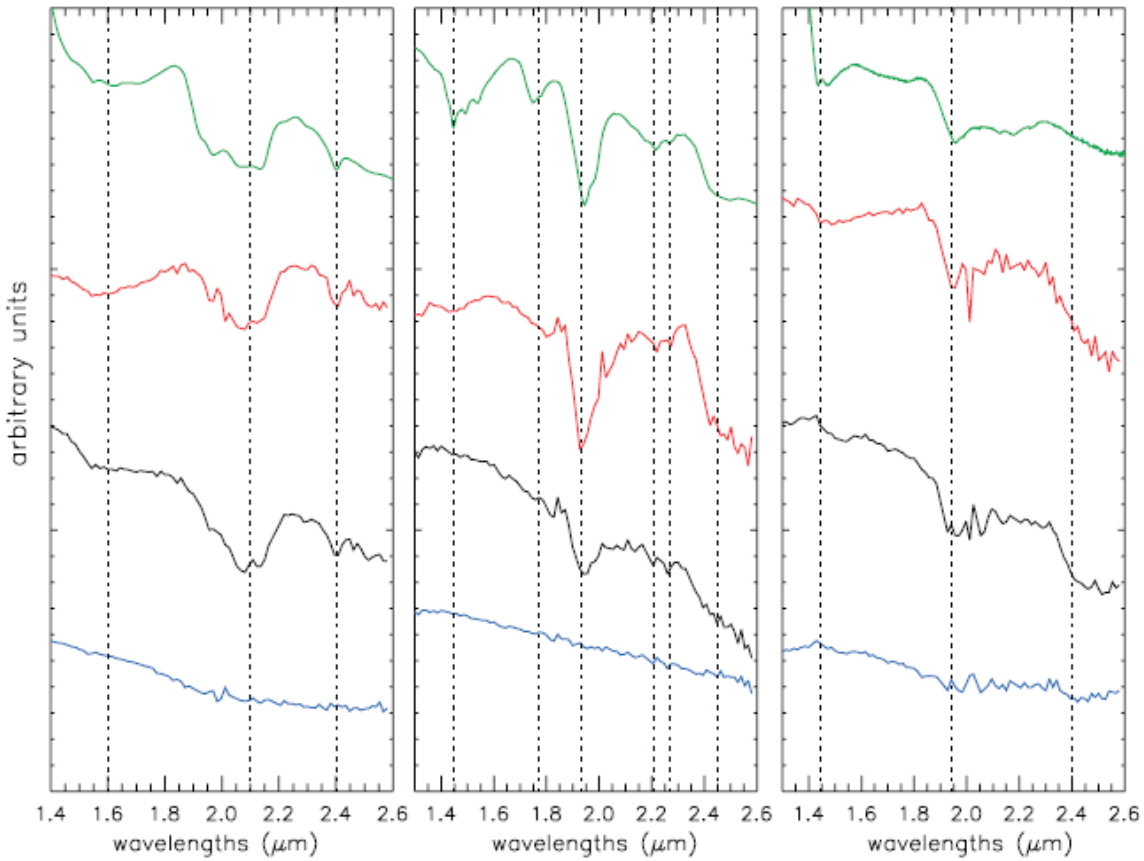
(Christensen et al. 2001)

Sulfates

Kieserite [$MgSO_4*H_2O$]

Gypsum [$CaSO_4*2H_2O$]

Polyhydrated sulfates Epsomite [$MgSO_4*7H_2O$]



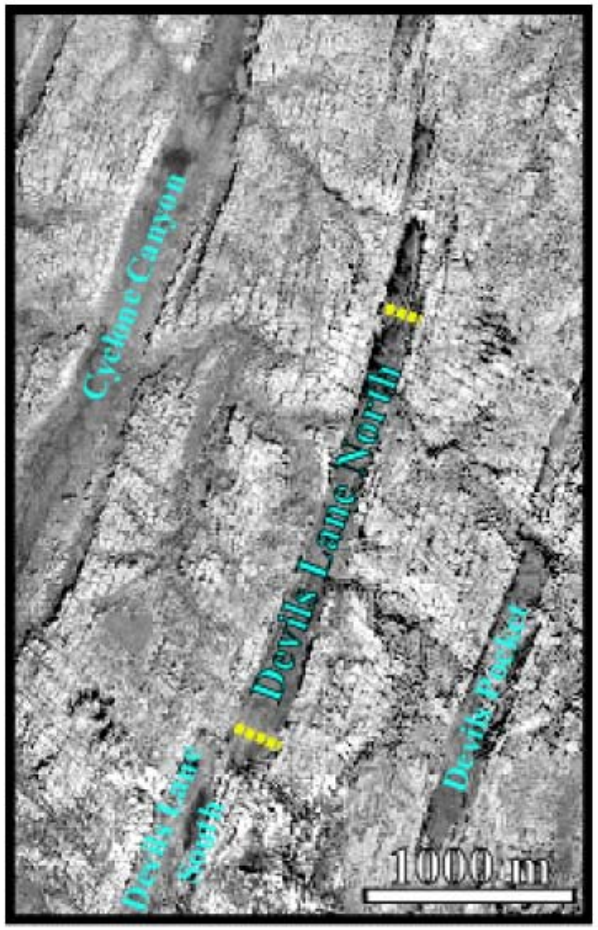
Library spectrum

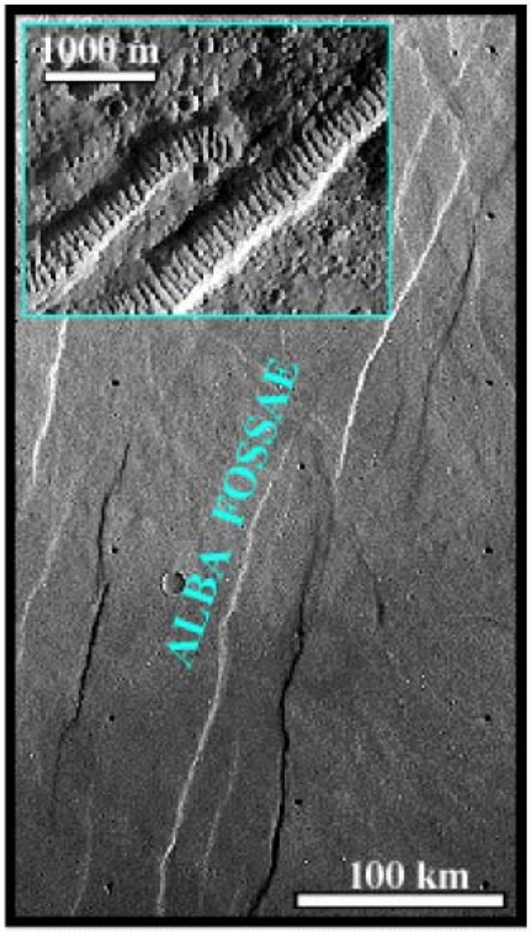
Spectral ratio

Mars OMEGA spectrum

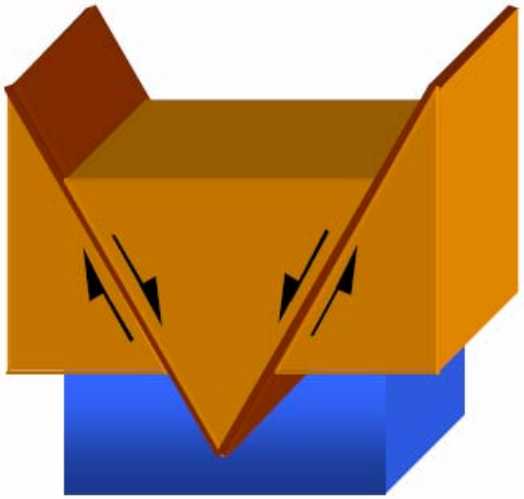
Reference spectrum

(Gendrin et al. 2005)





An example: "Simple" Tectonic Grabens

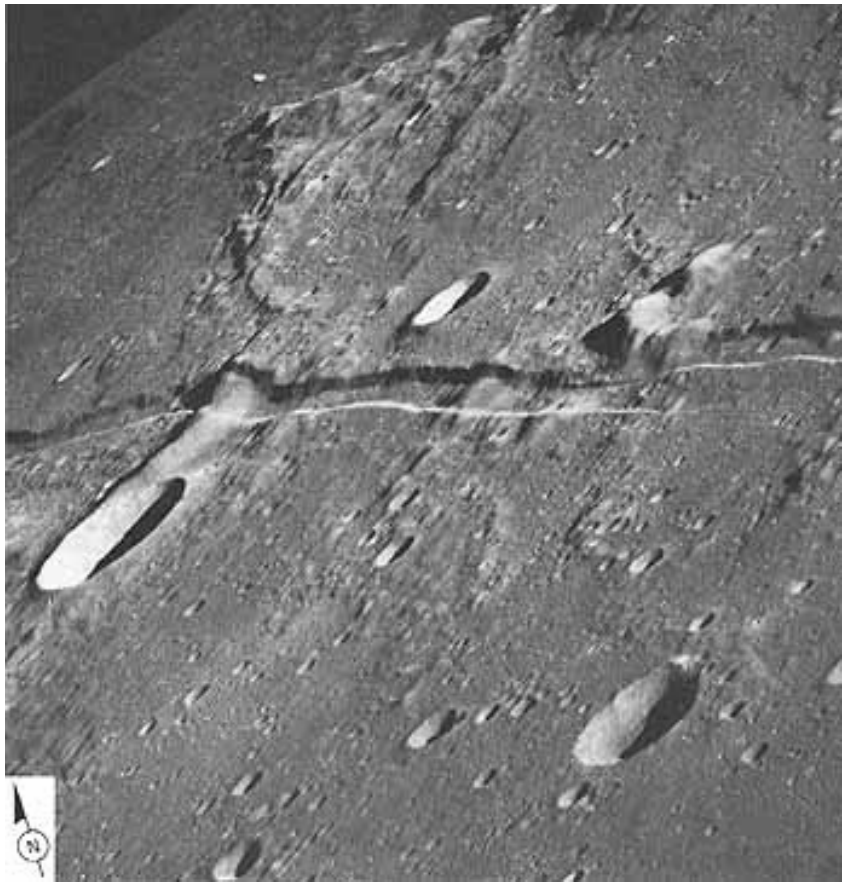


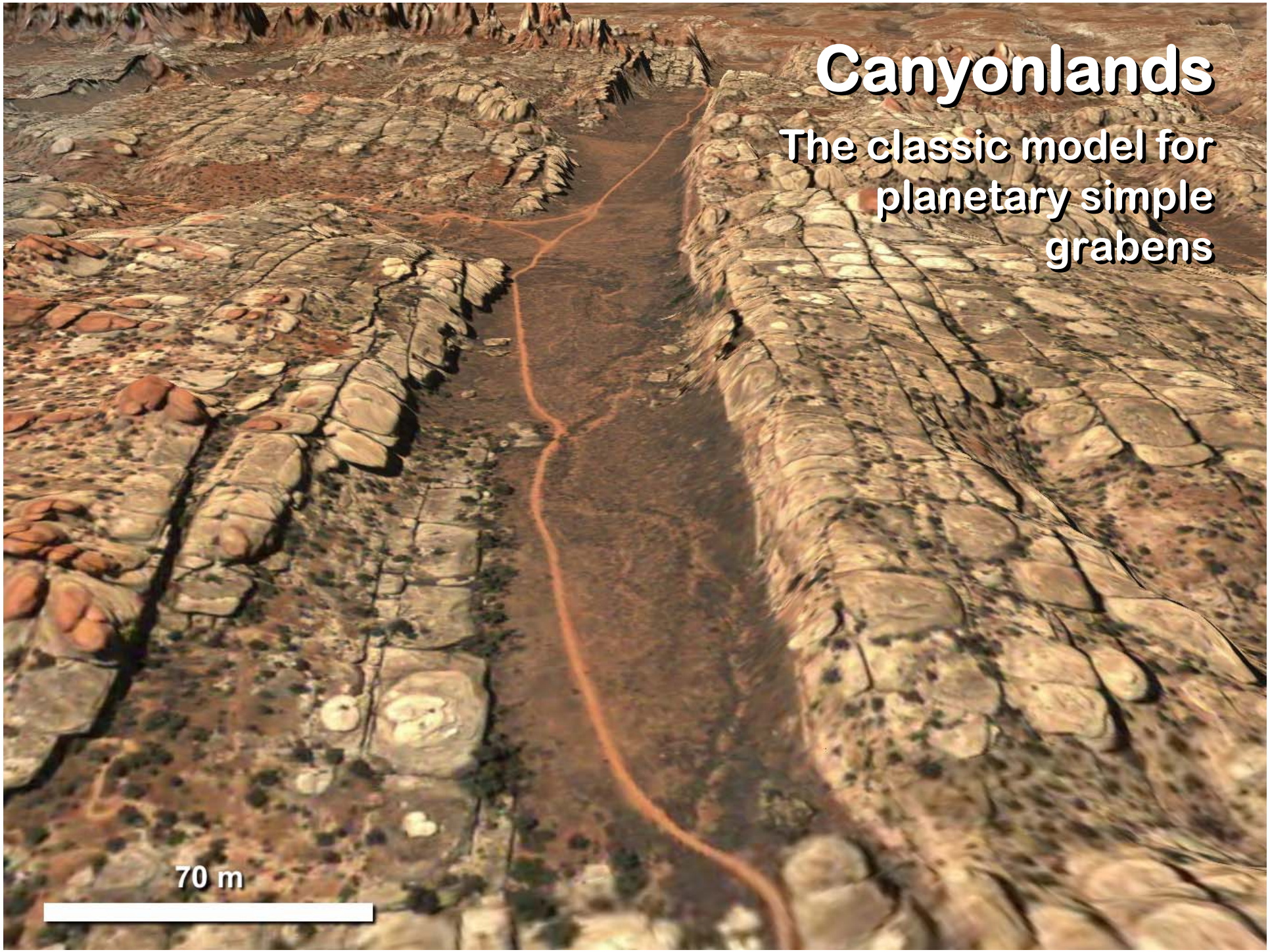
Earth

Mars

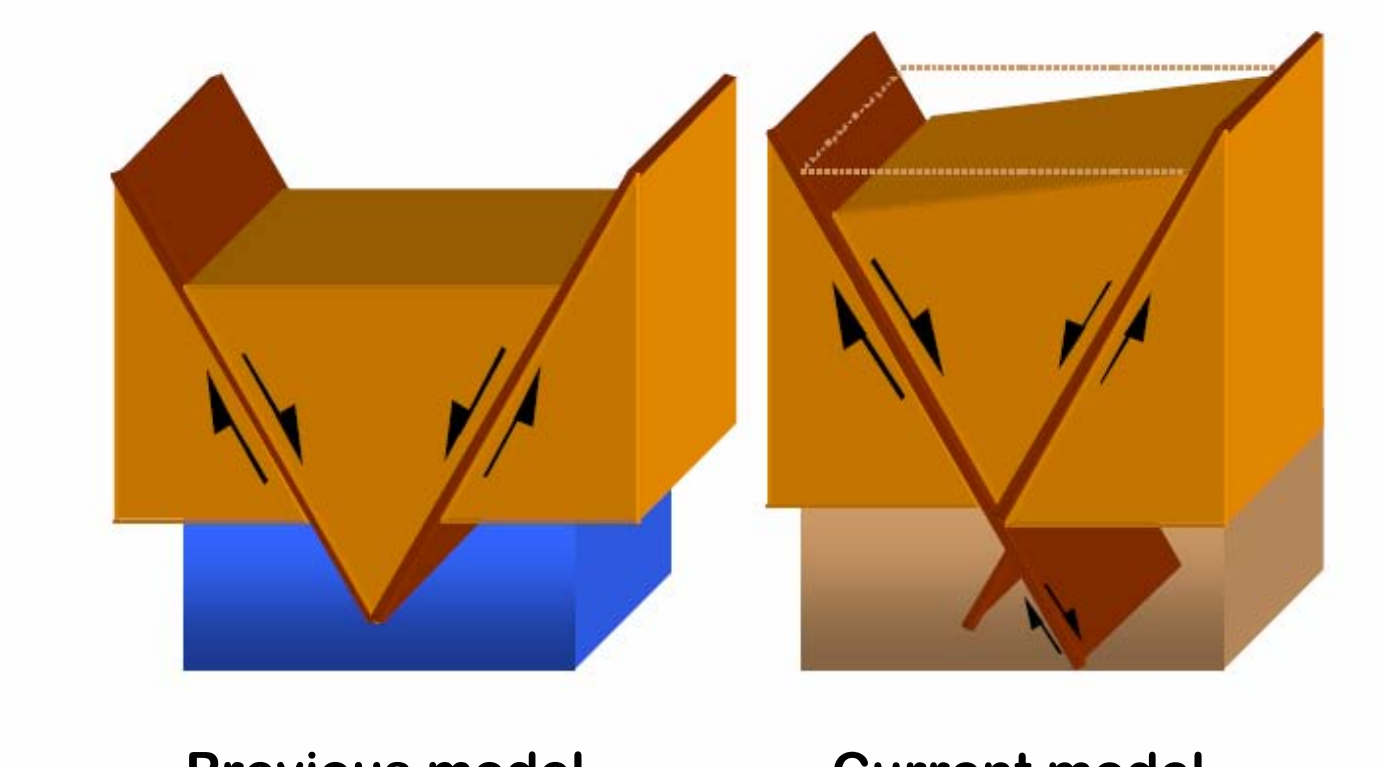
Previous model

"Simple" Grabens on the Moon



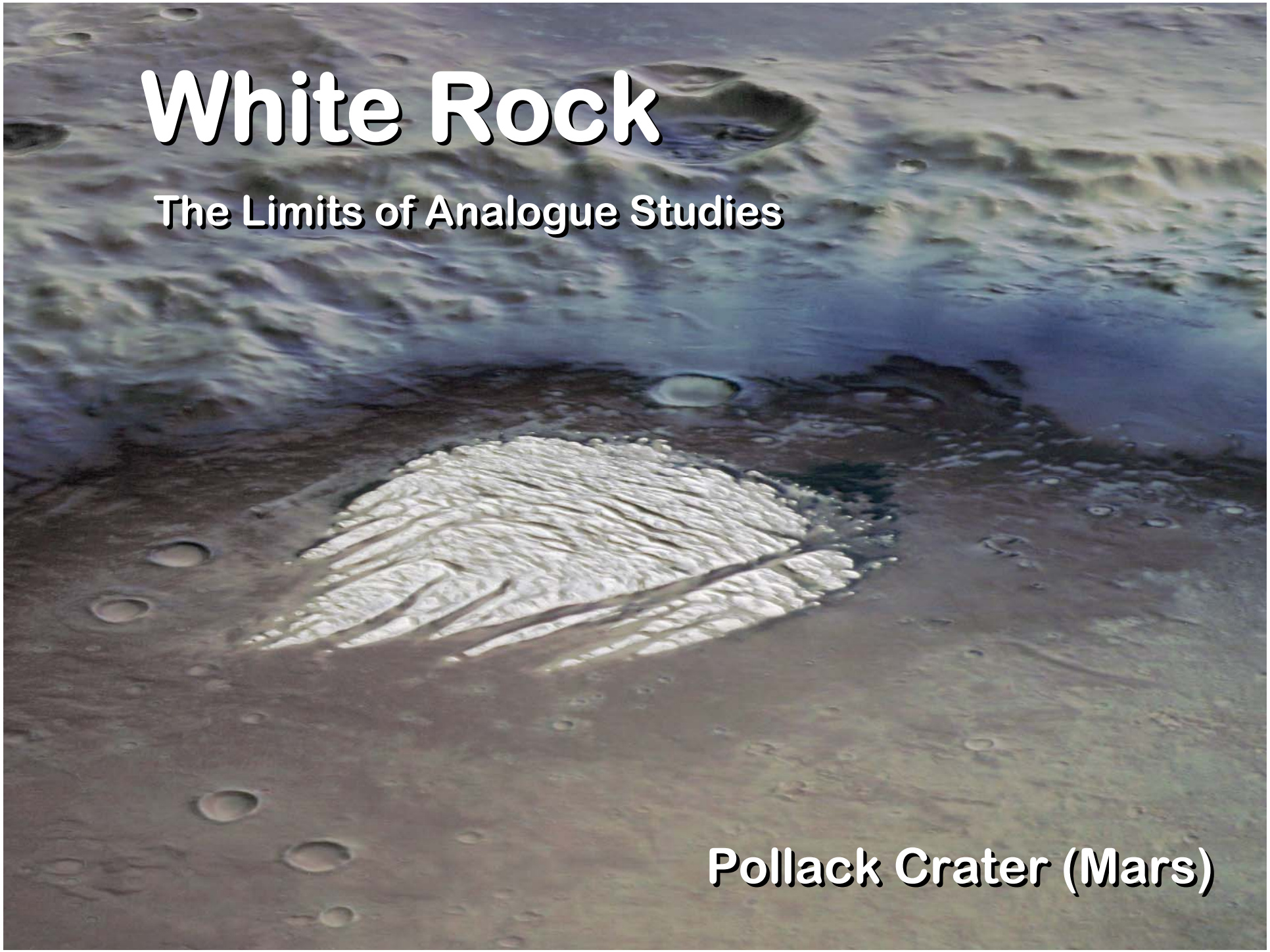

Canyonlands
The classic model for planetary simple grabens
70 m

"Simple" Grabens



Previous model **Current model**

An example how a better understanding of terrestrial analogues lead to a different interpretation of planetary features

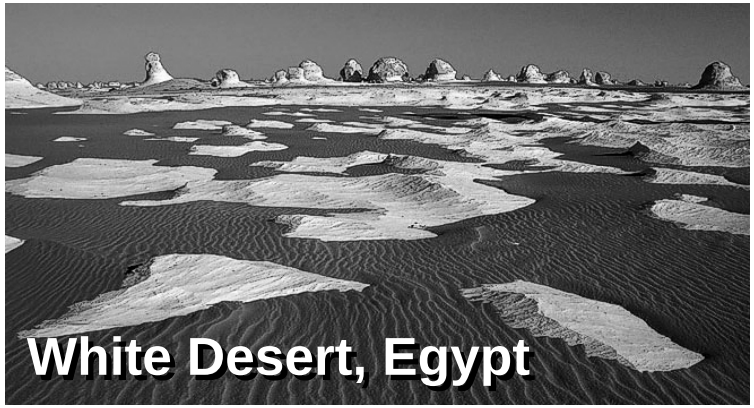

White Rock
The Limits of Analogue Studies
Pollack Crater (Mars)

White Desert

Limestones (Sahara)

On Mars as it is on Earth?

— The limits of analogue studies —



- **Analogues don`t prove anything**
- **Earth analogs are never perfect**
  - they are only partially valid
  - scaling issues
- **Example: White Rock**
  - morphologically very similar
  - but composition is different (*White Rock* is NOT a carbonate deposit – as far as available spectra tell us)

Online Resources

- **General Information**
  - Mars Information (data pages, mission pages, fact sheets, GoogleMars)
  - Earth information (e.g., Volcano observatory sites, GoogleEarth)
  - Documents (e.g., NRC community decadal report)
- **Data**
  - Spectral libraries
  - Remote sensing data
  - Image collections
- **Projects**
  - Field sites (Haughton Mars Project; AMASE)
- **Bibliography**
  - ADS, ISI (Science Citation Index), Online books, Special Issues, Monographies