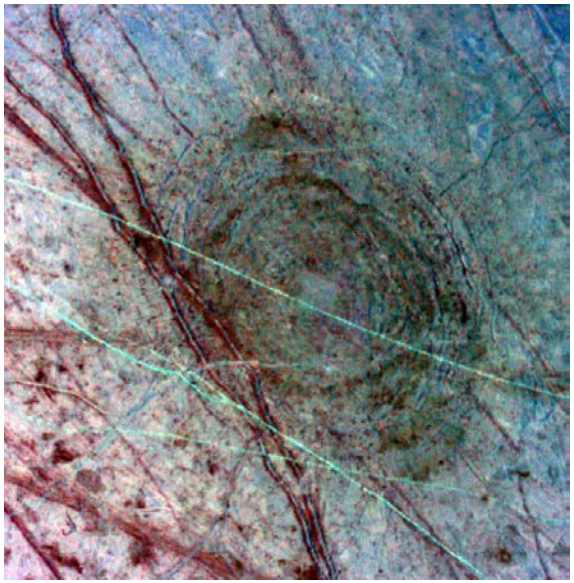
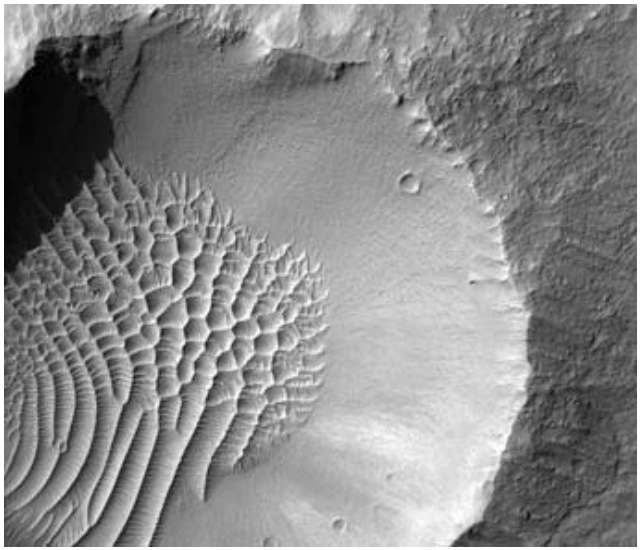
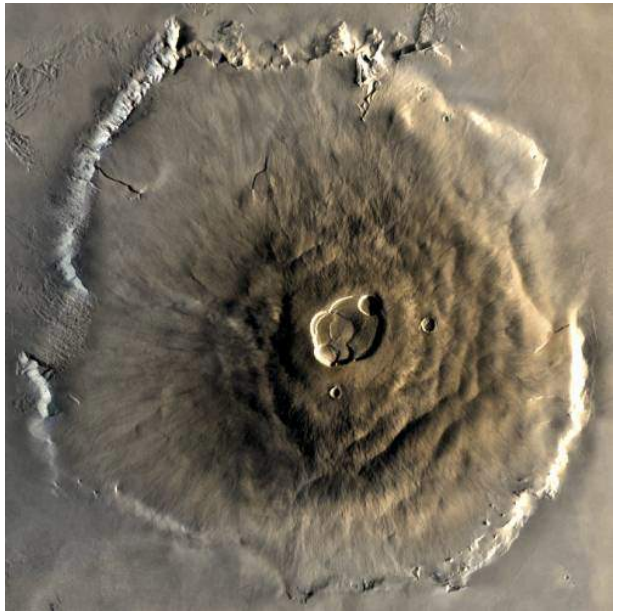
Planetary Surface Processes

Cratering
Gravity
Tectonics
Volcanism
Winds
Fluvial
Glacial
Chemical weathering



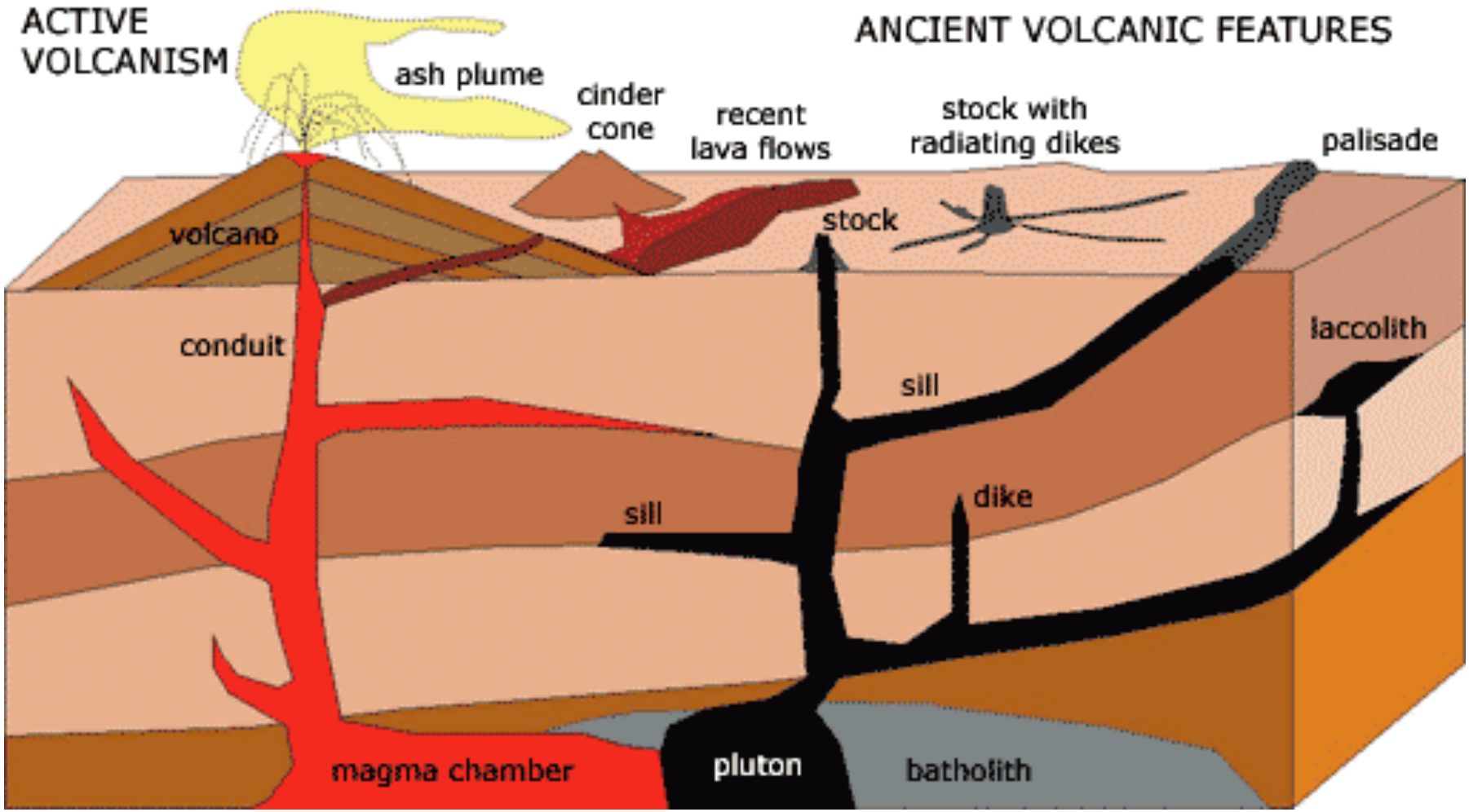




Volcanism


Melting of material (silicate, water, sulfur) inside a planet and its subsequent eruption onto the surface

Intrusive vs. extrusive features



Volcanic Activity Recipe

- Heat source(s) for melting:
  1. Generated from accretion during planet formation and continuing differentiation
  2. Radioactive nuclides (radioactive decay in terrestrial planets/bodies)
  3. Tidal interactions between bodies (moons orbiting around planets, planets elliptically orbiting close to their stars, etc.)

- Buoyant material below the crust/surface of a planet
  - *Buoyancy problem for H_2O cryovolcanism?*

Volcanic Activity Types

Two **types** are due to plate tectonics, from either:

1. Subduction zone eruptions
2. Eruptions along mid-ocean ridges

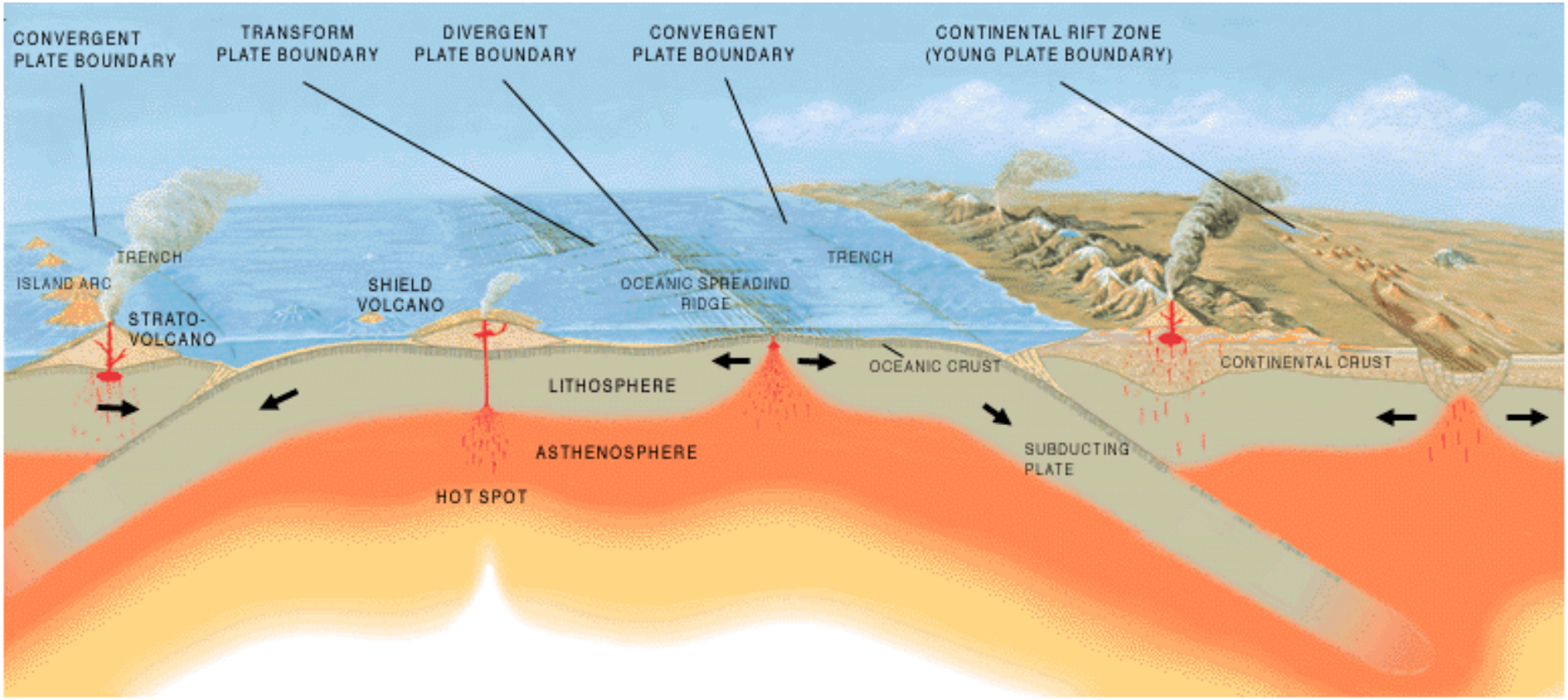
Third type:

3. Hot spots or mantle ‘plumes’

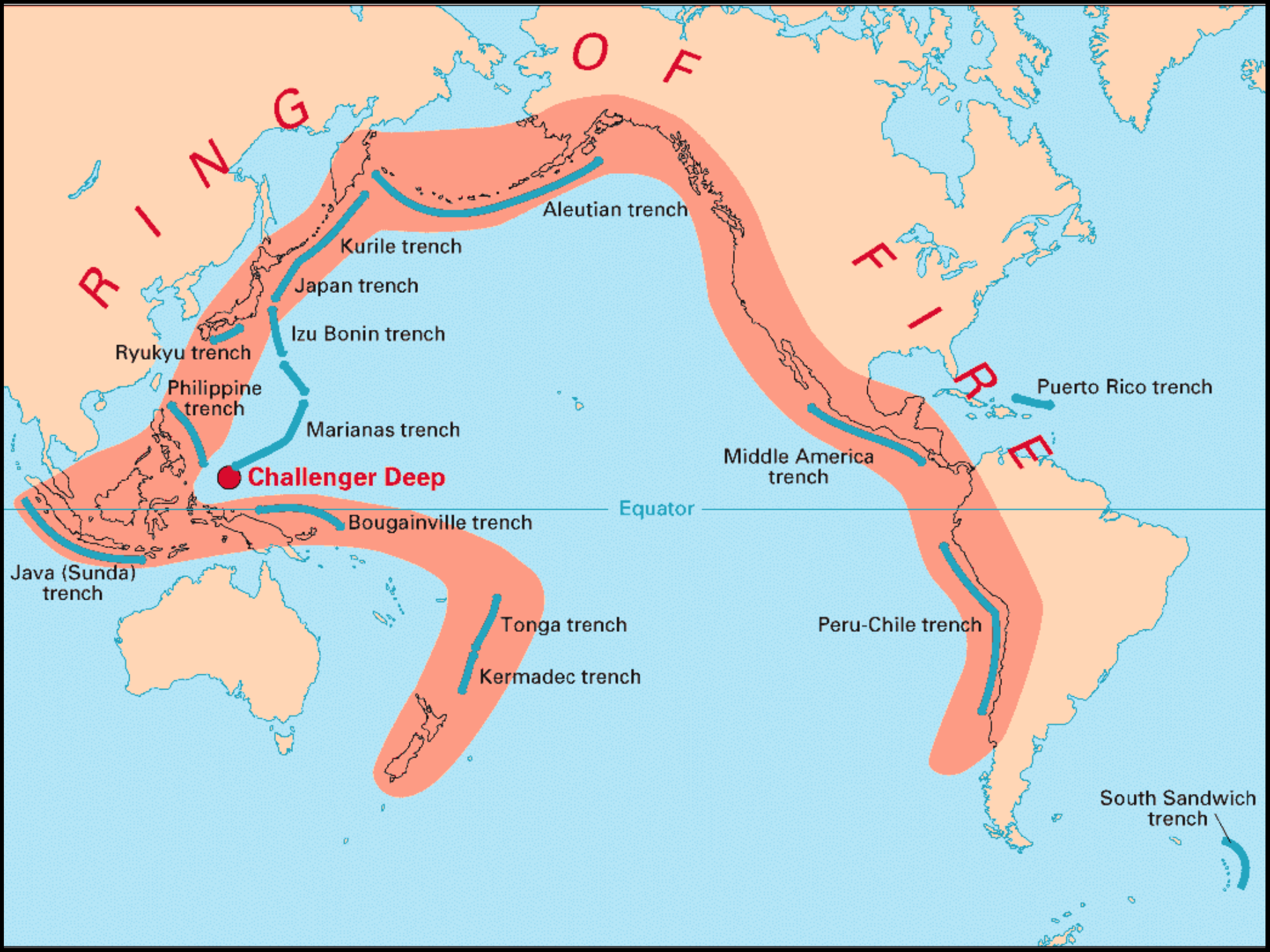
Styles of eruptions:

1. Explosive - Magmas rich in volatiles and with high viscosity (silica rich). Gas cannot escape or bubble out of the highly viscous magma (Mt. St. Helens style)
2. Effusive - Basaltic magmas are low viscosity and allow volatiles to bubble off (Hawai’i style eruptions)

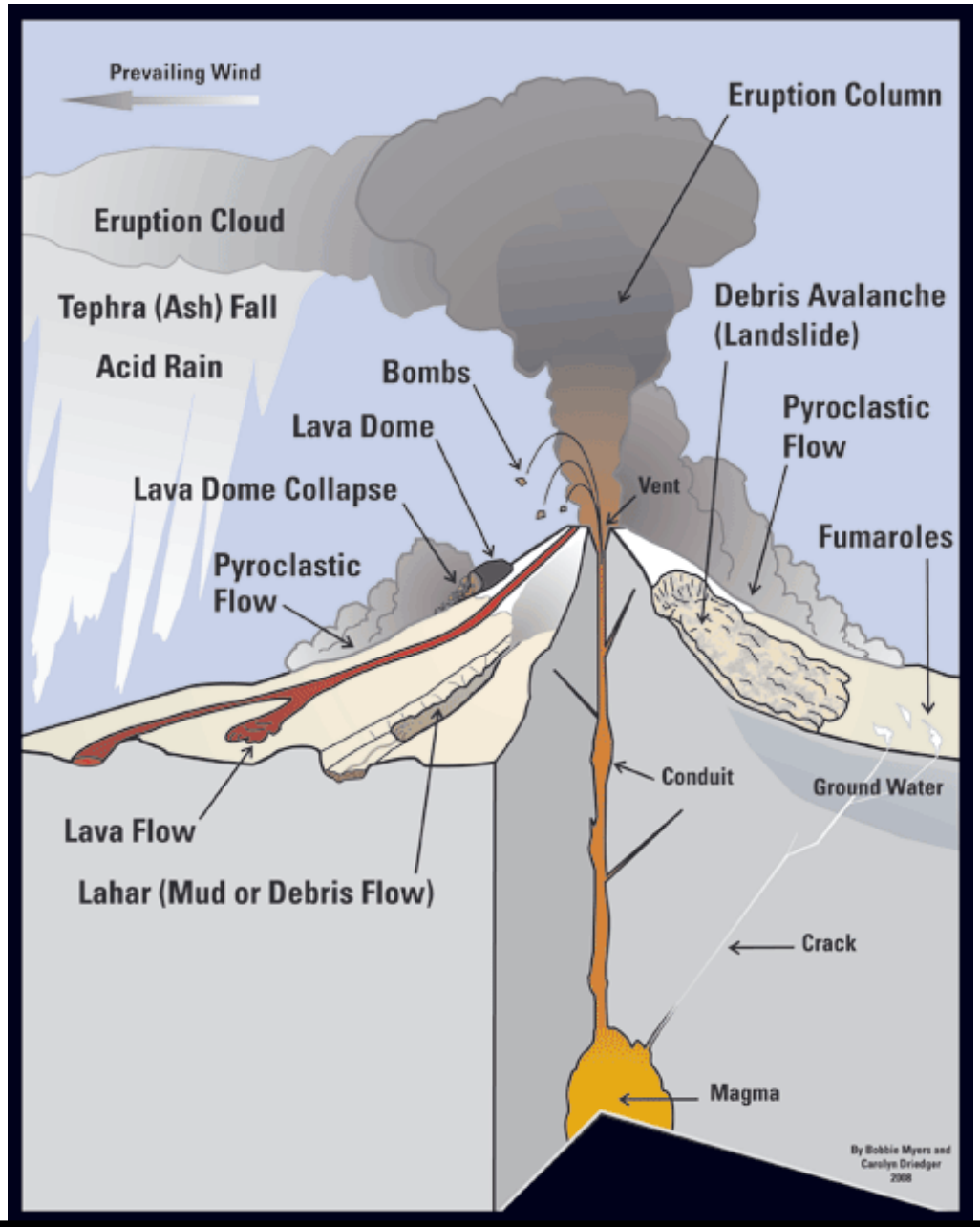
Volcanism: three different settings



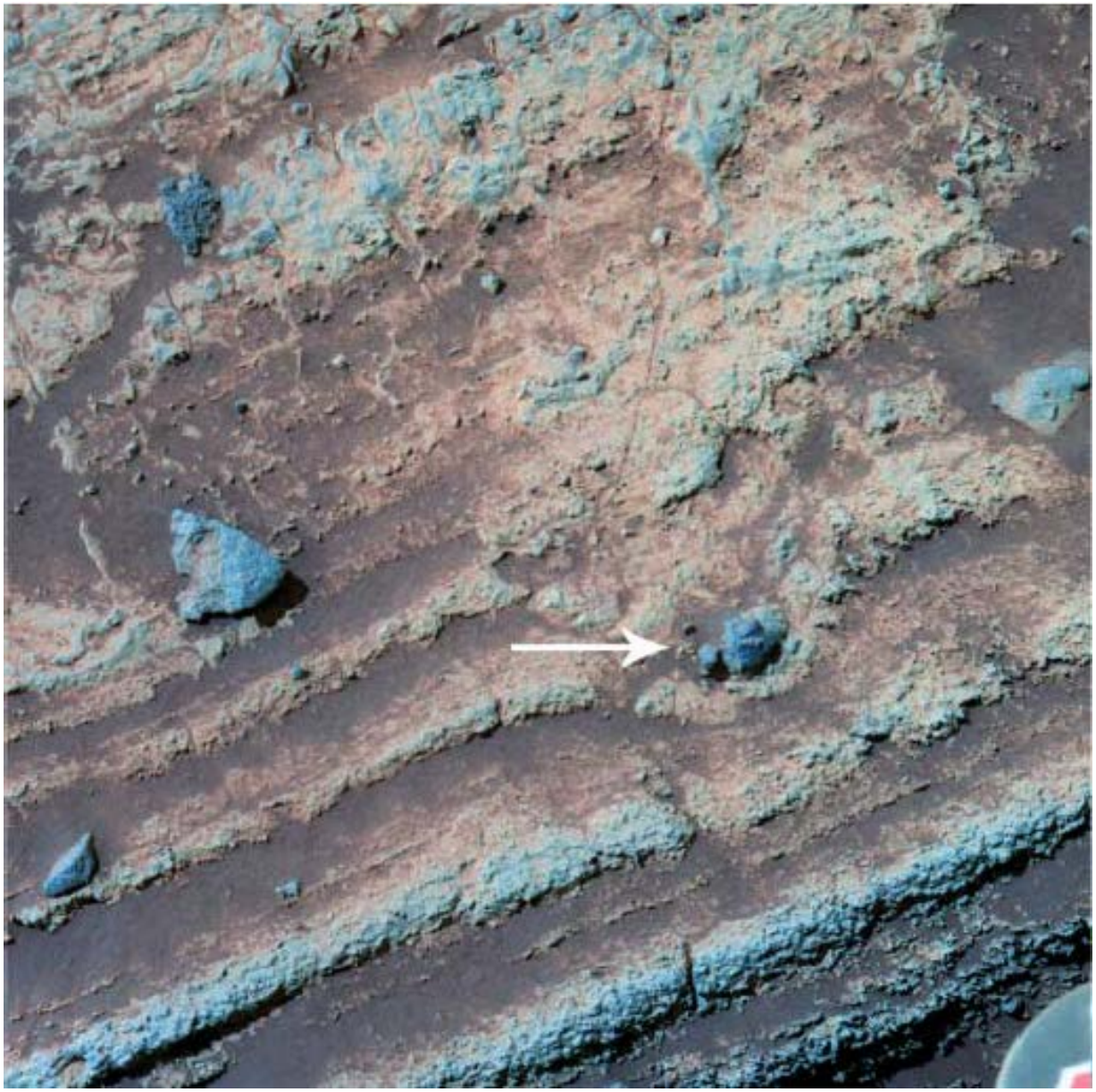
Explosive volcanism most common at subduction zones


RING OF FIRE
Aleutian trench
Kurile trench
Japan trench
Izu Bonin trench
Ryukyu trench
Philippine trench
Marianas trench
Challenger Deep
Bougainville trench
Java (Sunda) trench
Tonga trench
Kermadec trench
Middle America trench
Puerto Rico trench
Peru-Chile trench
Equator
South Sandwich trench

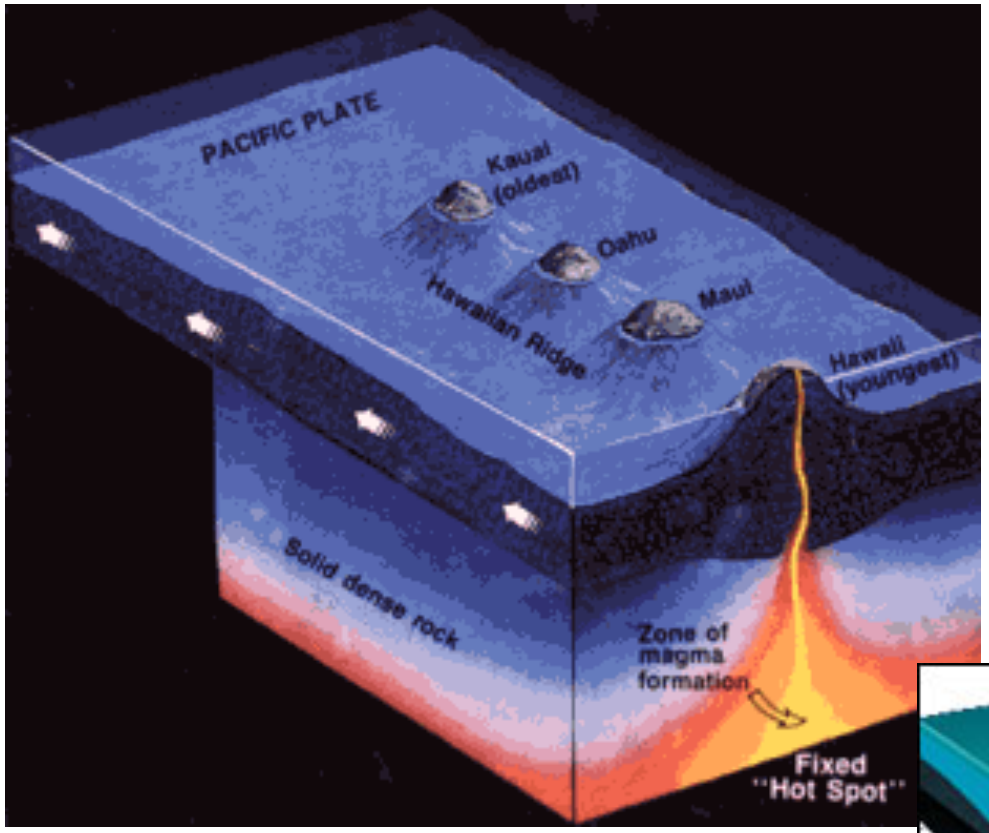
Stratovolcano



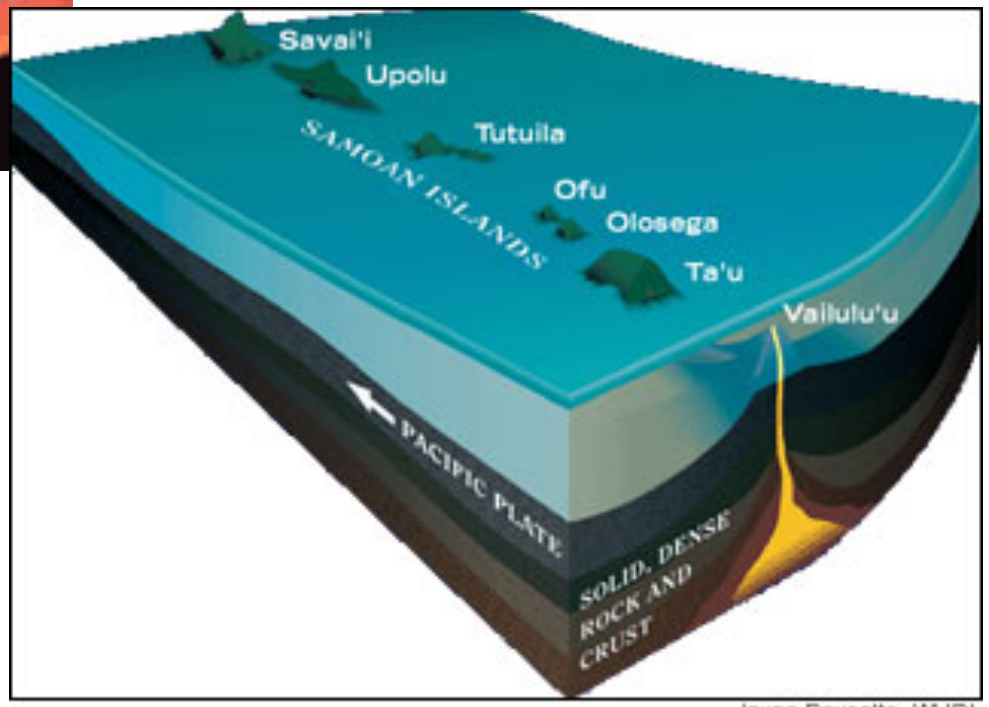
Martian bomb in reworked ash deposits?



Squyres et al. (2007)

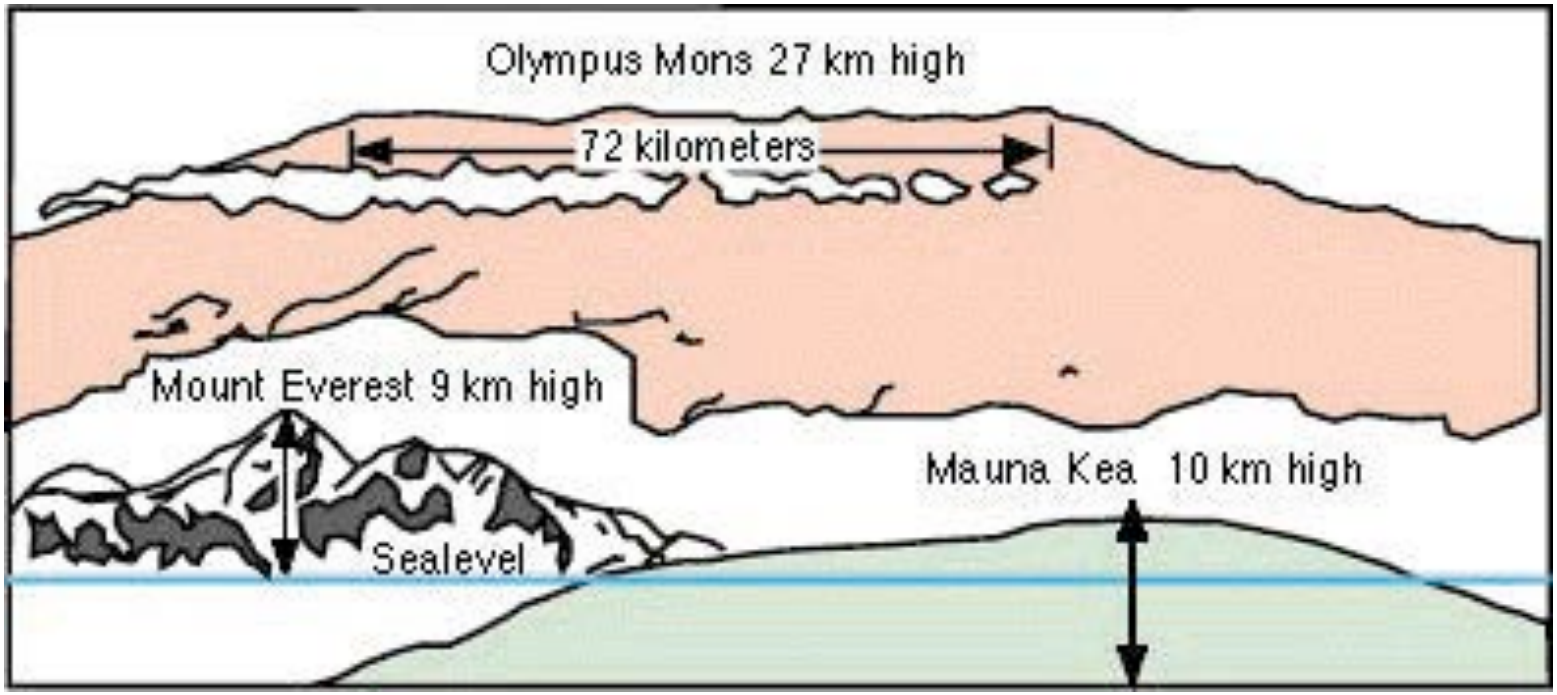


Hawaiian & Samoan Island Chains are due to mantle 'plumes'



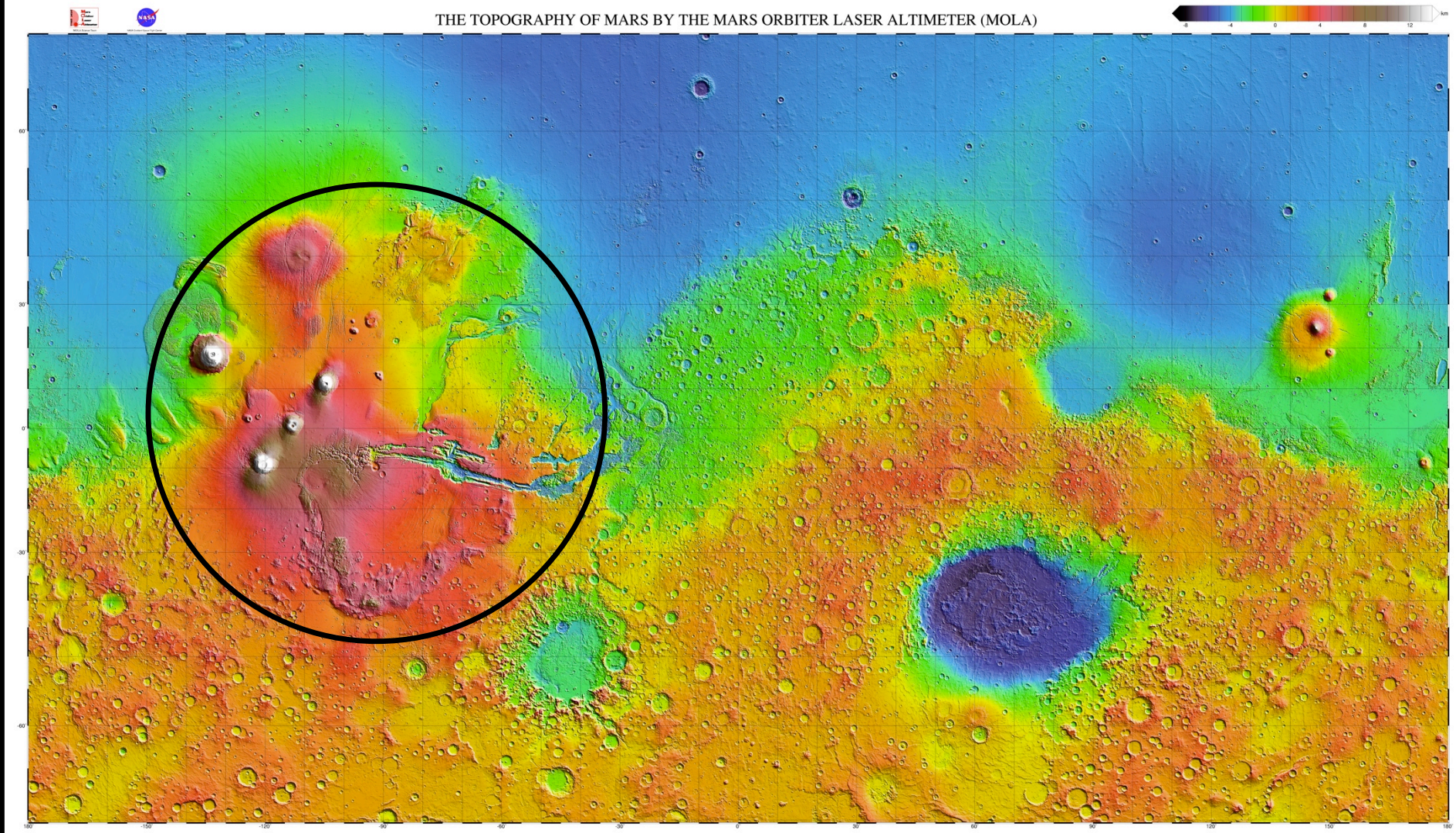
Jayne Doucette, WHOI

Hot spot volcanism: Earth's tallest mountain



Mauna Kea, Mauna Loa are low-slope, rounded *shield volcanoes*

Hot spot volcanism without plate motion

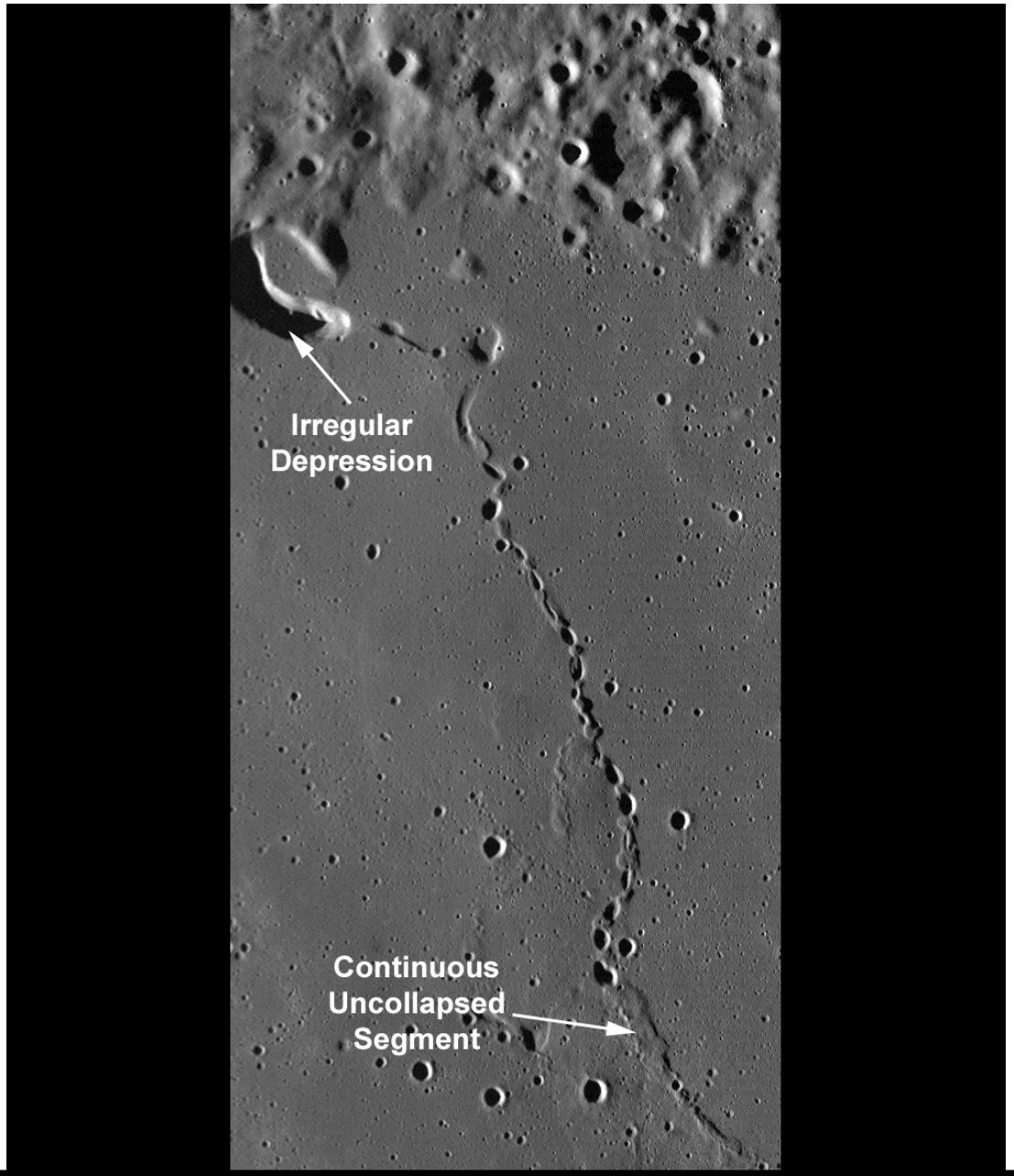


Hawaiian Volcanism

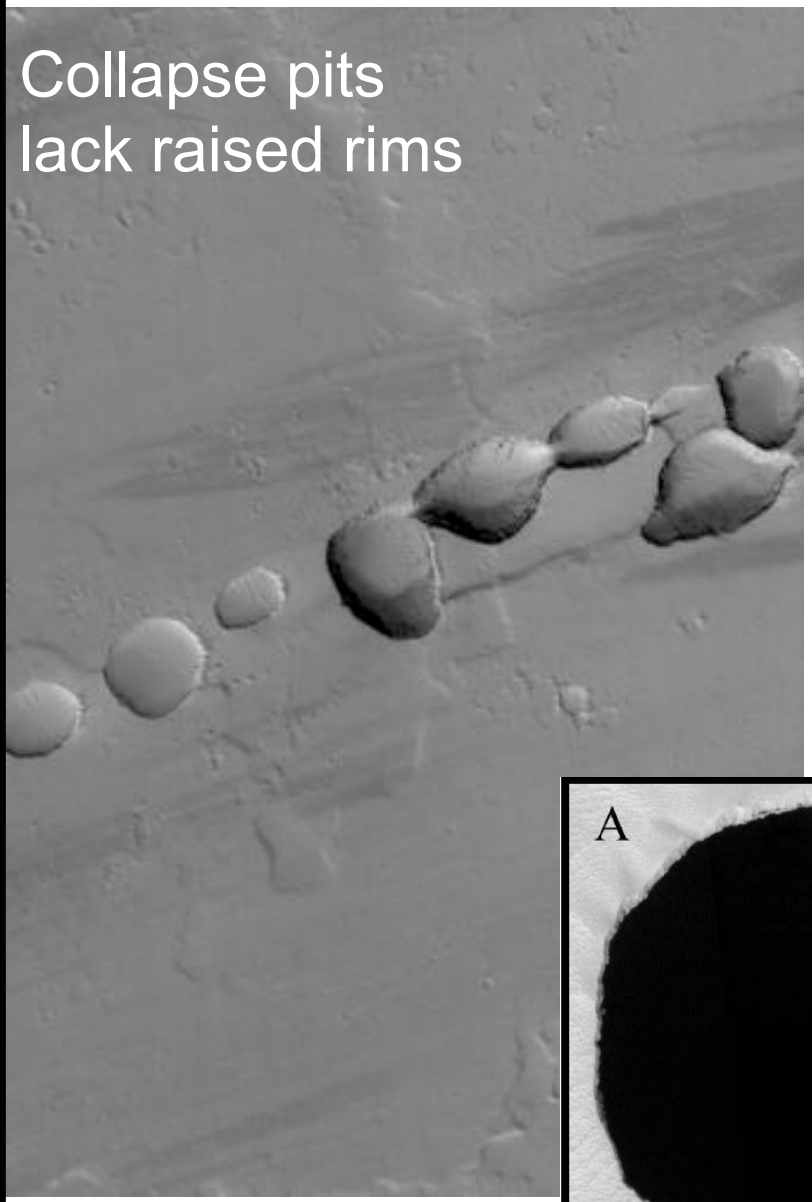
Hawaiian Volcanism

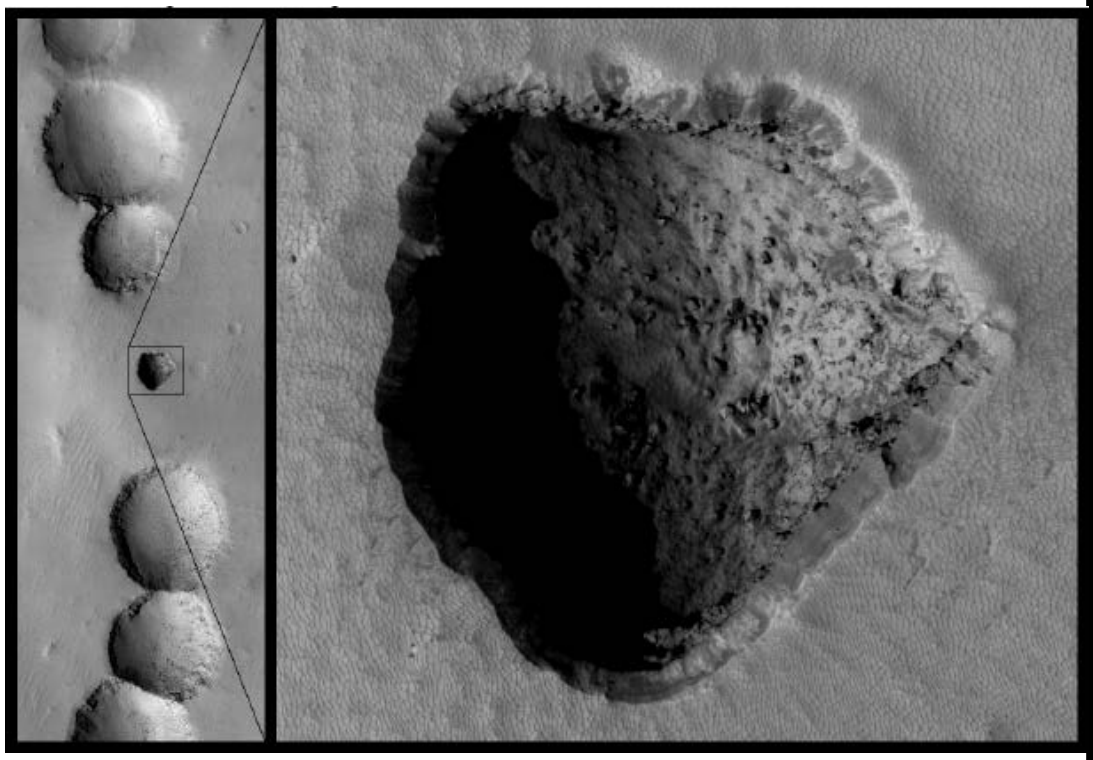
Hawaiian Volcanism: active lava tube!

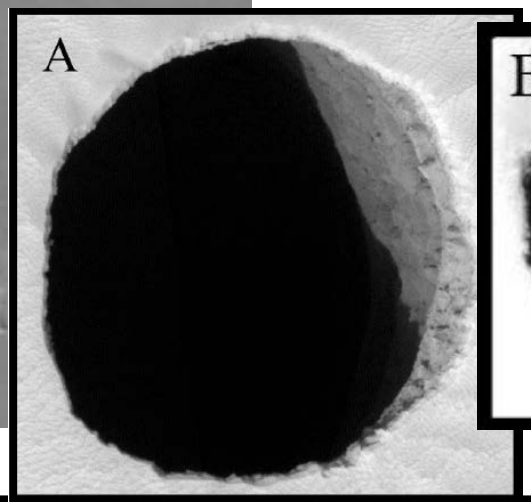
Lunar lava tubes

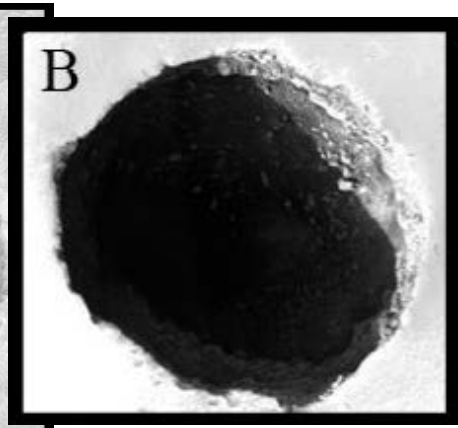


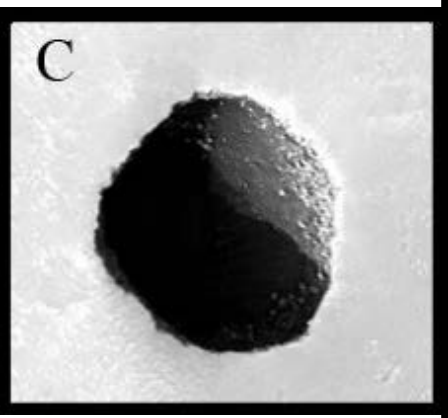
Martian pit craters and chains





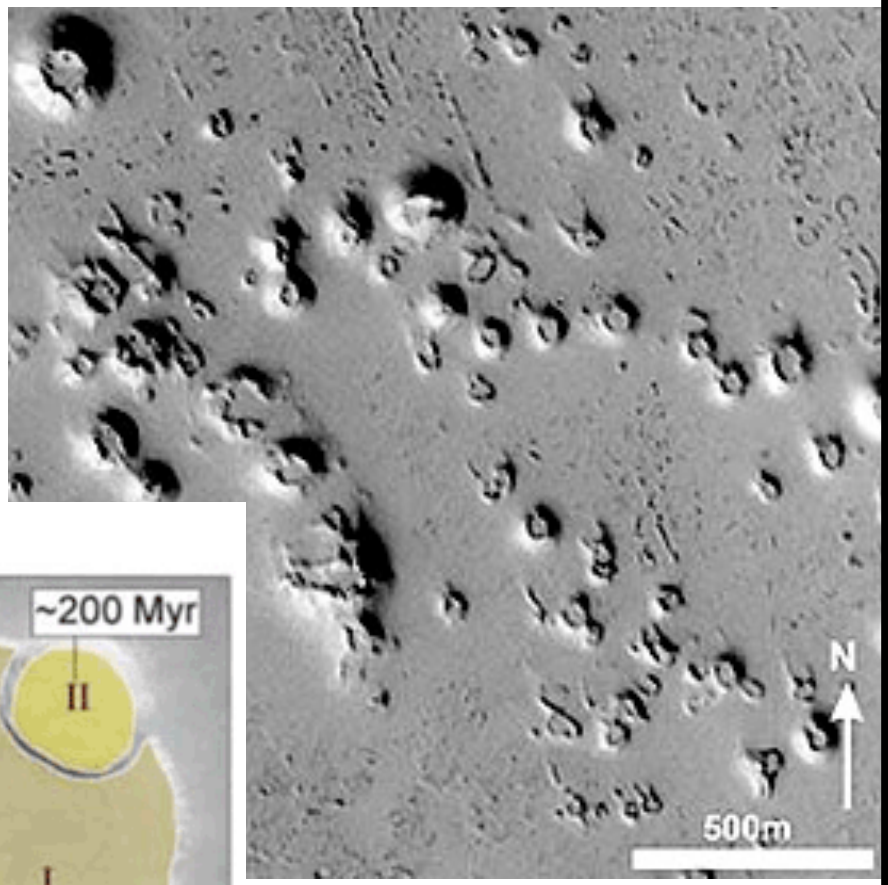




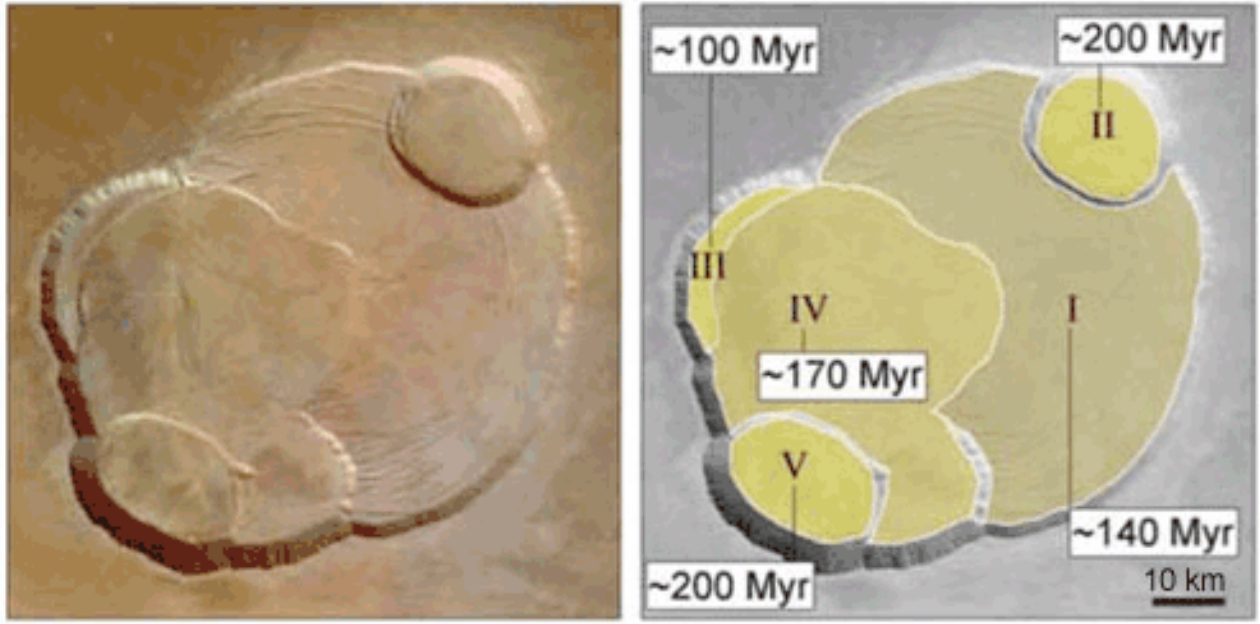


Cushing et al. (2008)

Calderas, cratered cones

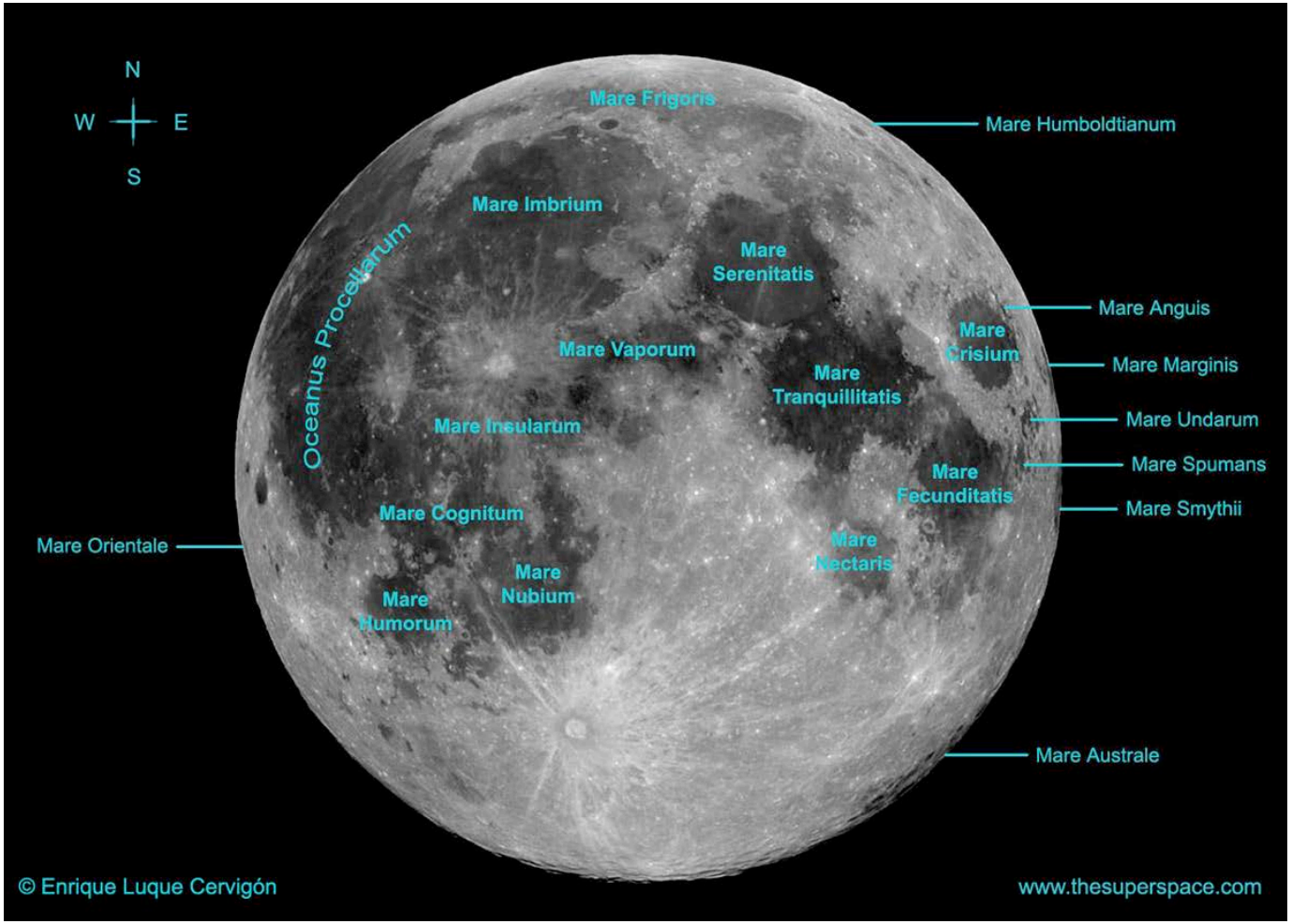


Olympus Mons



(From Neukum *et al.*, 2004, *Nature*, v. 432, p. 972.)

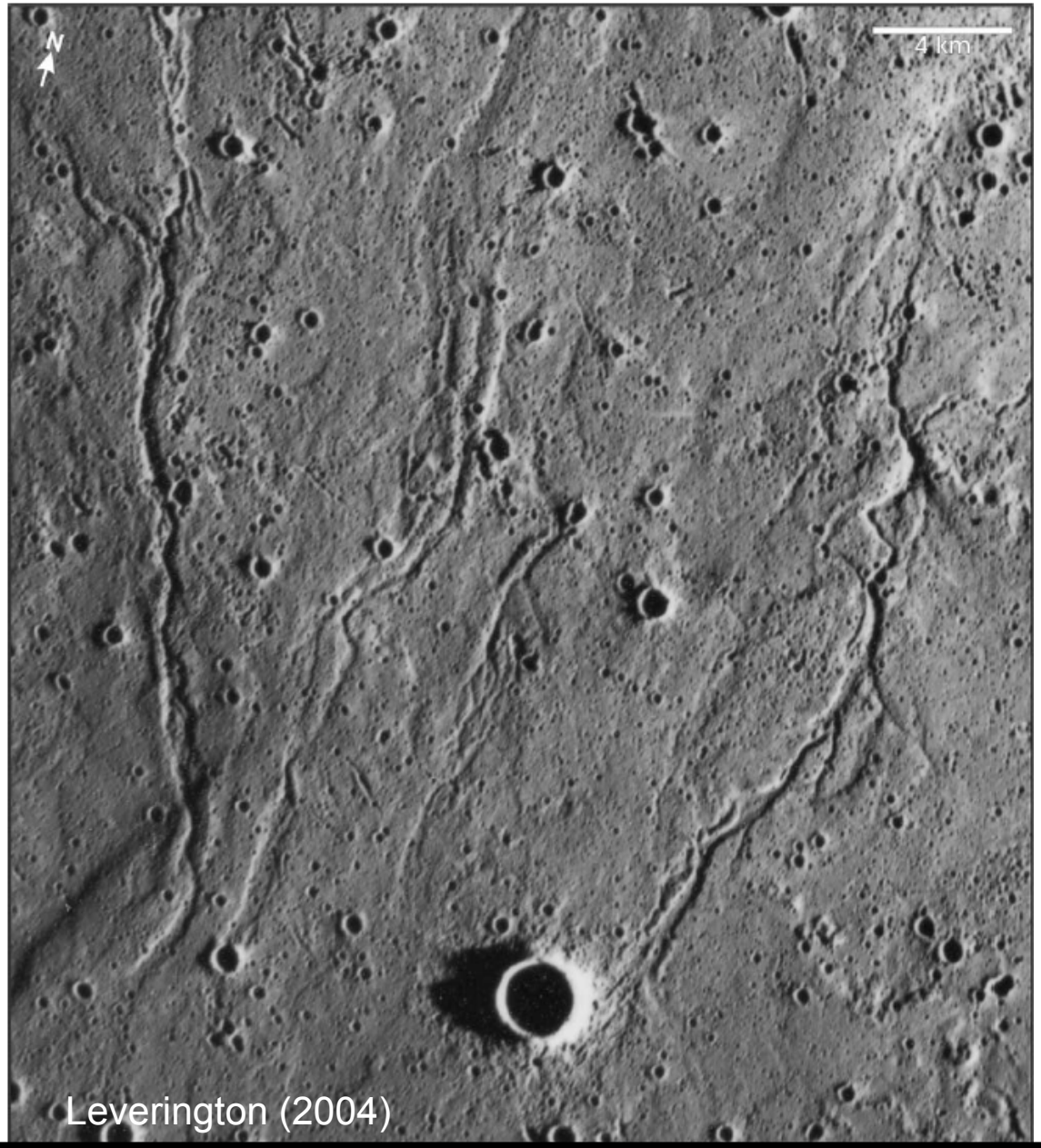
Lunar maria: former *seas* of lava



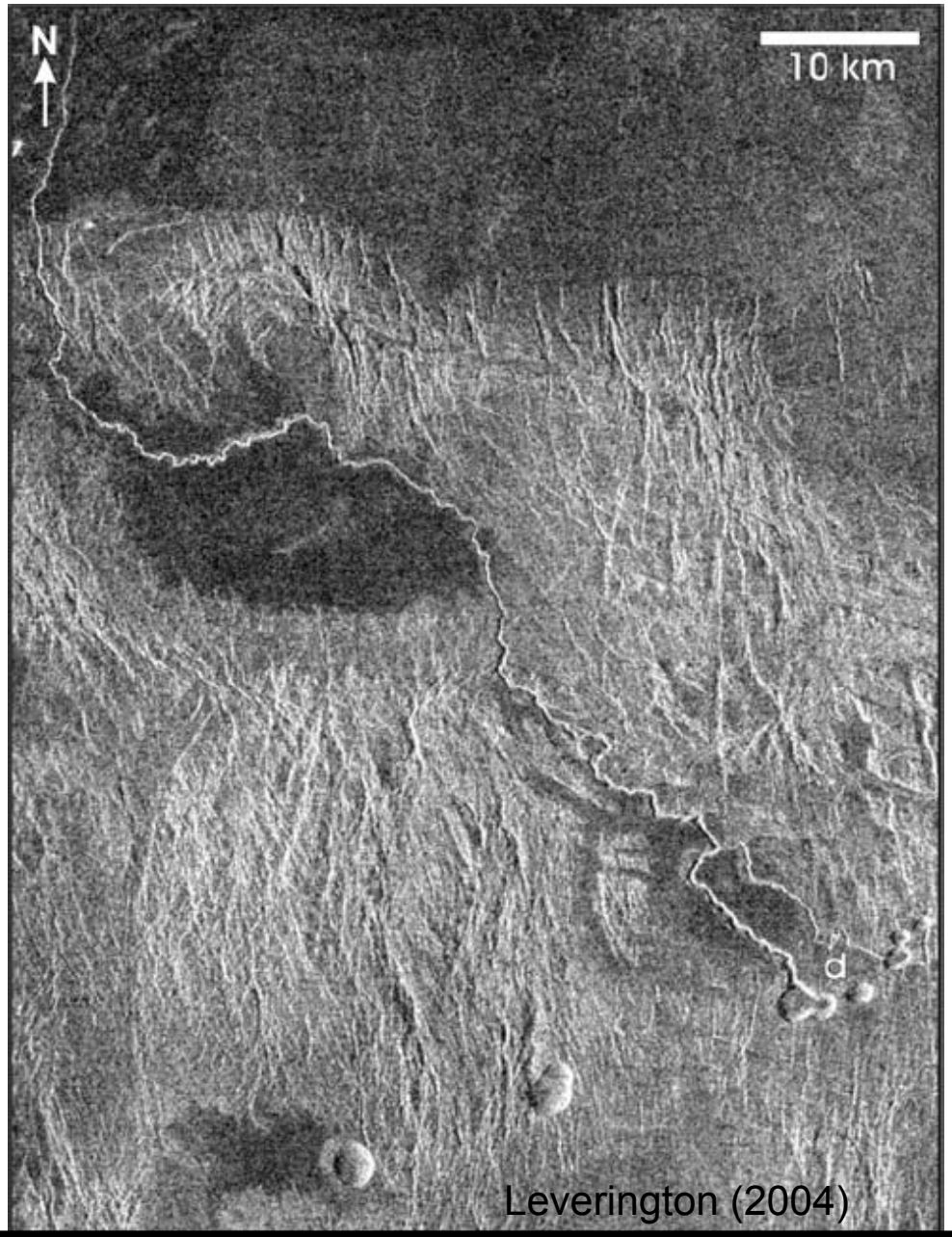
- Effusive volcanism, but most vents/fissures now buried
- Possible lunar pyroclastics are an area of ongoing research

Lunar sinuous rilles

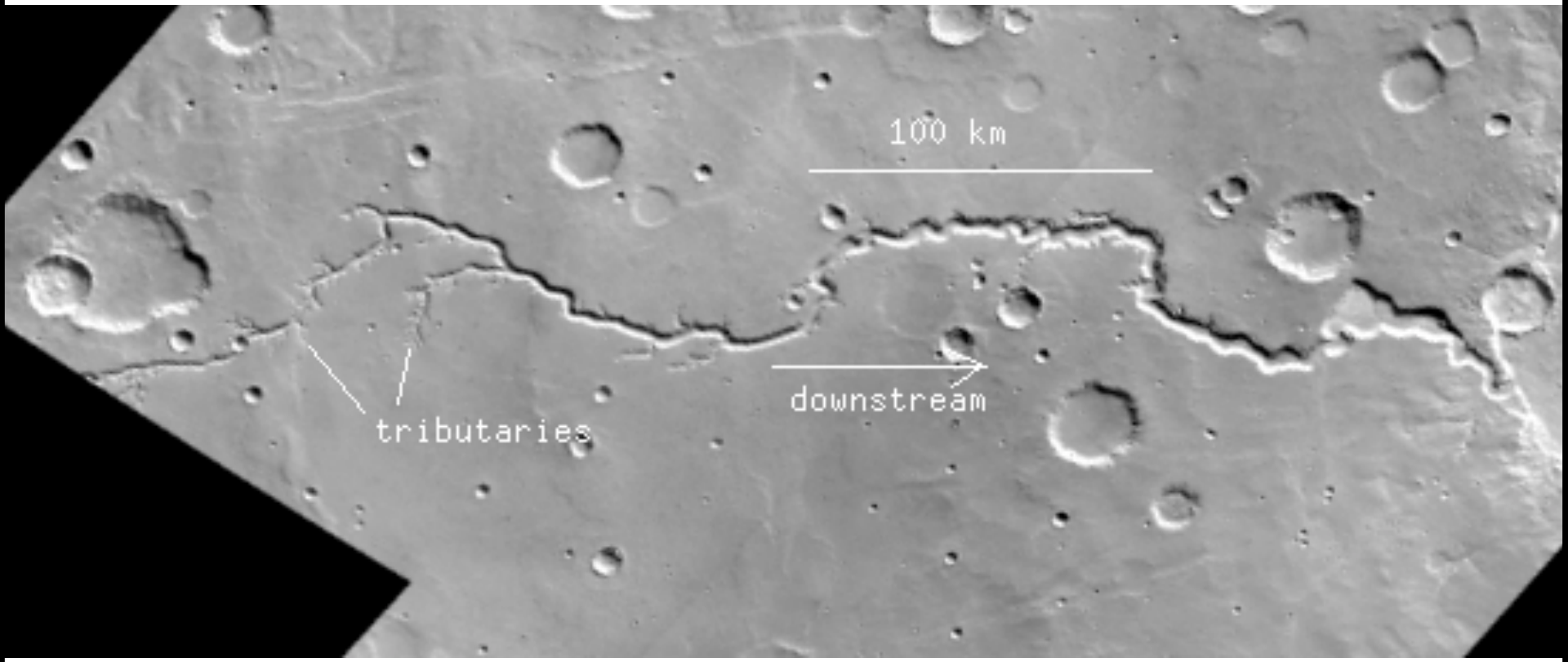
Lunar sinuous rilles

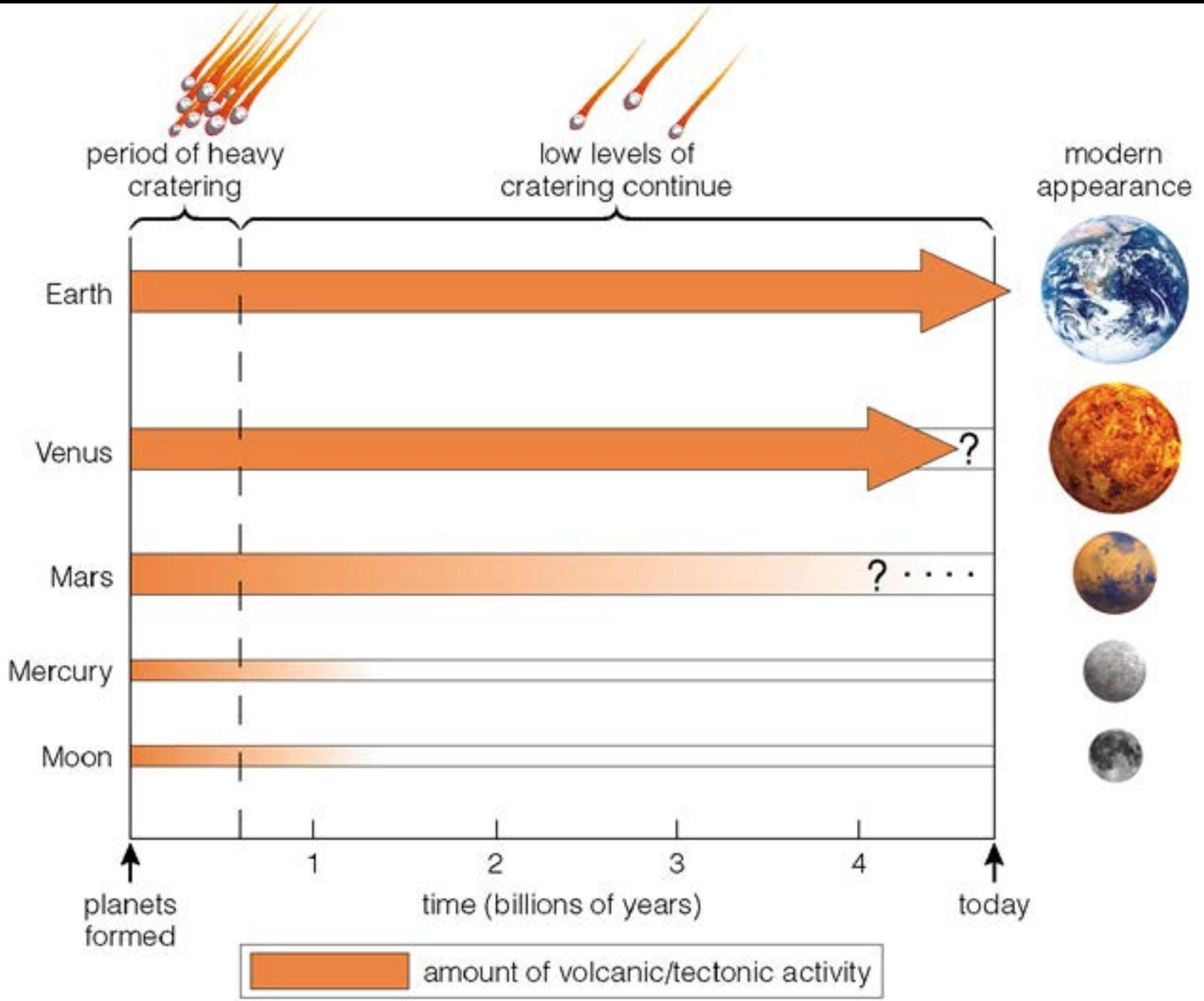


Venusian sinuous rilles



Comparison to Martian valleys



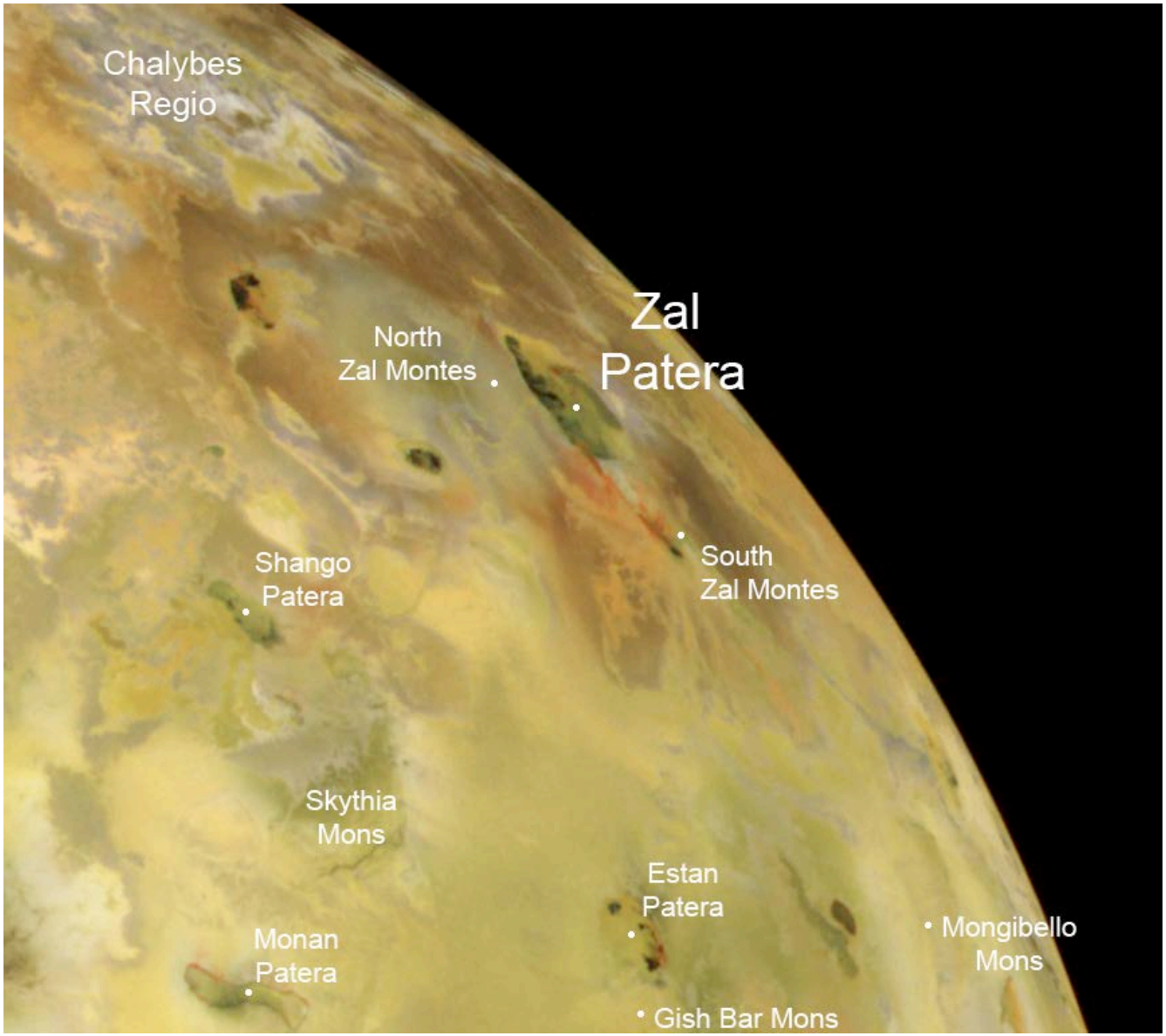

period of heavy cratering
low levels of cratering continue
modern appearance
Earth
Venus
?
Mars
? . . . .
Mercury
Moon
1
2
3
4
planets formed
time (billions of years)
today
amount of volcanic/tectonic activity

Volcanism on Io

Visible band (left + top right) and infrared views of the volcanoes of Io with the New Horizons spacecraft. Note the infrared glow from at least ten fainter volcanoes.

Courtesy of NASA/John Hopkins Univ Applied Physics Laboratory/Southwest Research Institute

Volcanism on Io



Planetary Surface Processes

Cratering
Gravity
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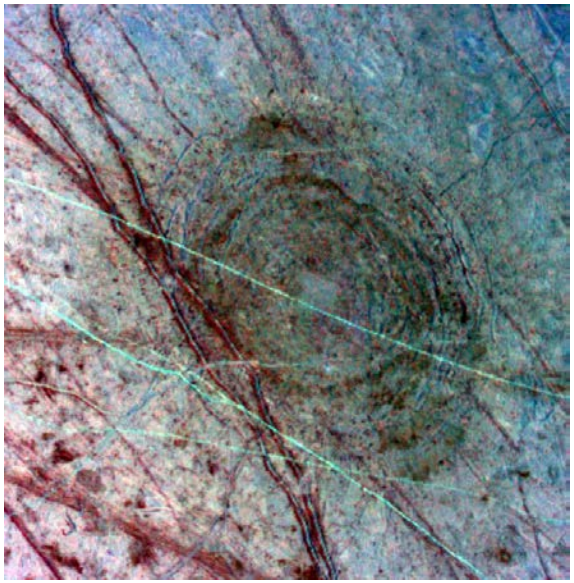
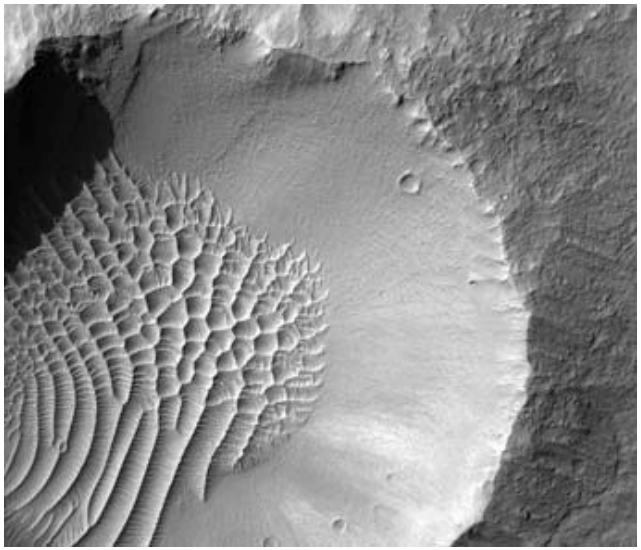
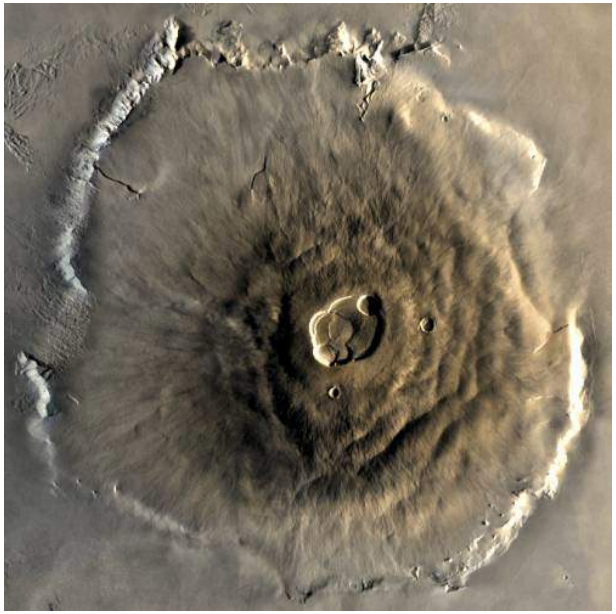
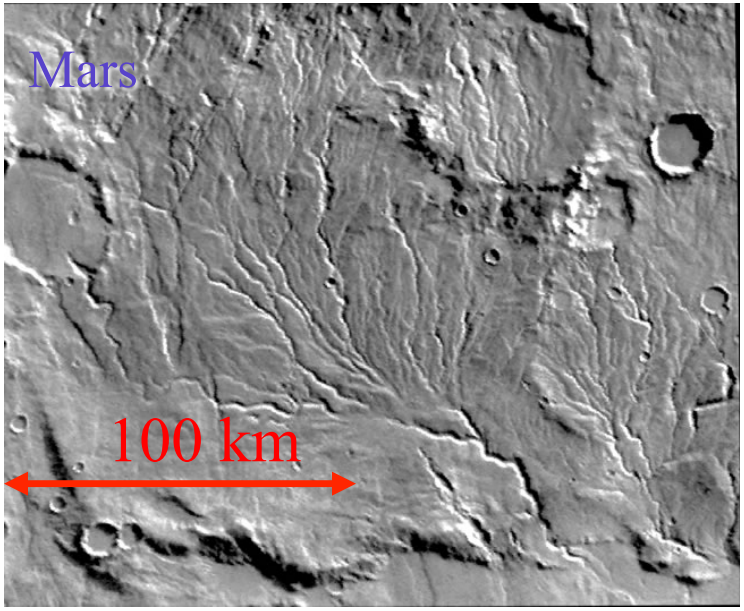
Chemical weathering



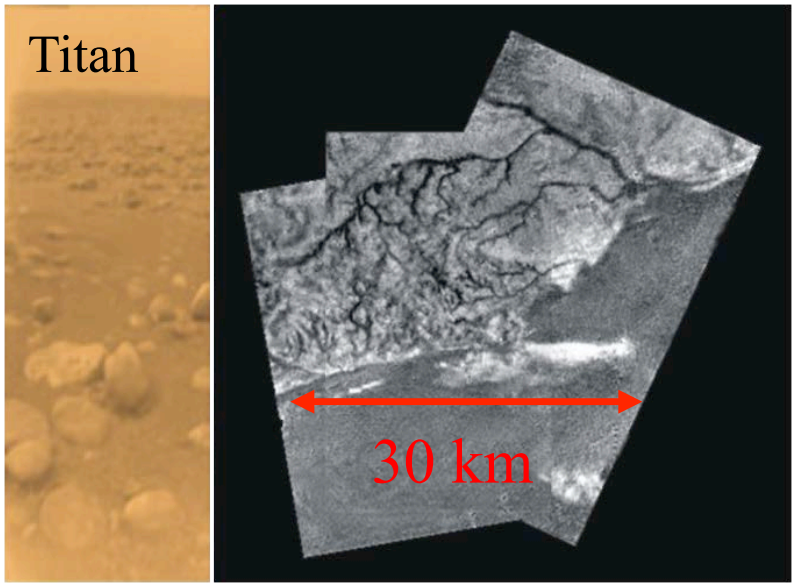


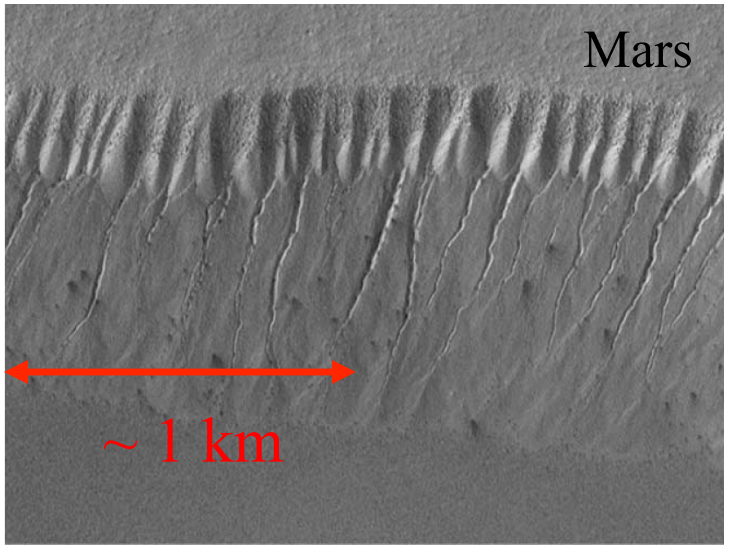


Fluvial Processes

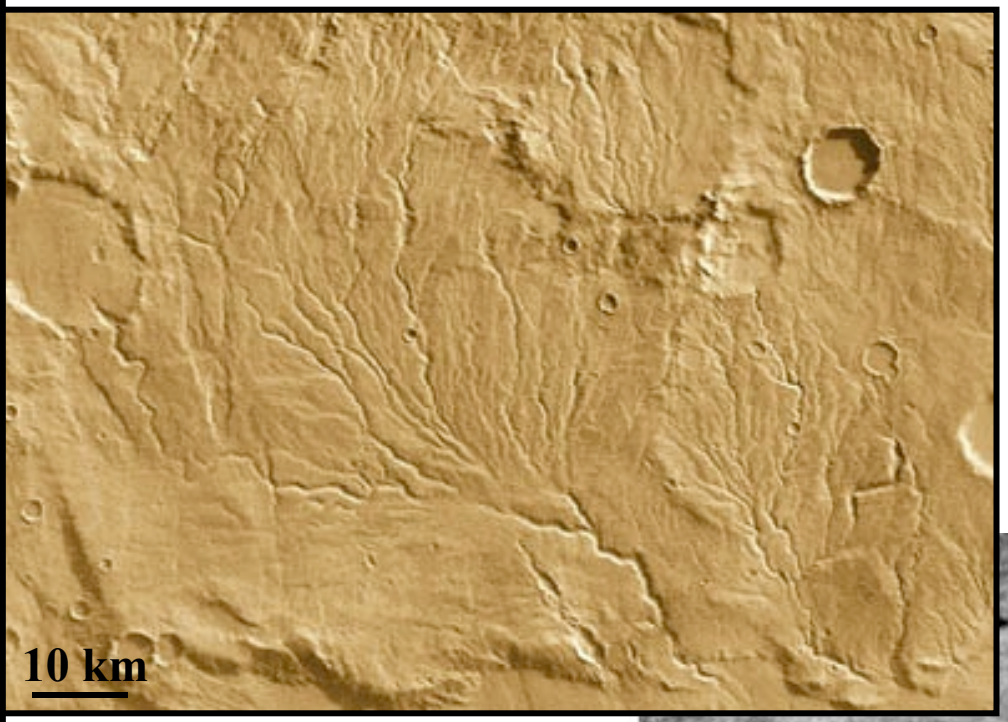


- Erosion, transport, and deposition of material by liquid flowing across a planetary surface

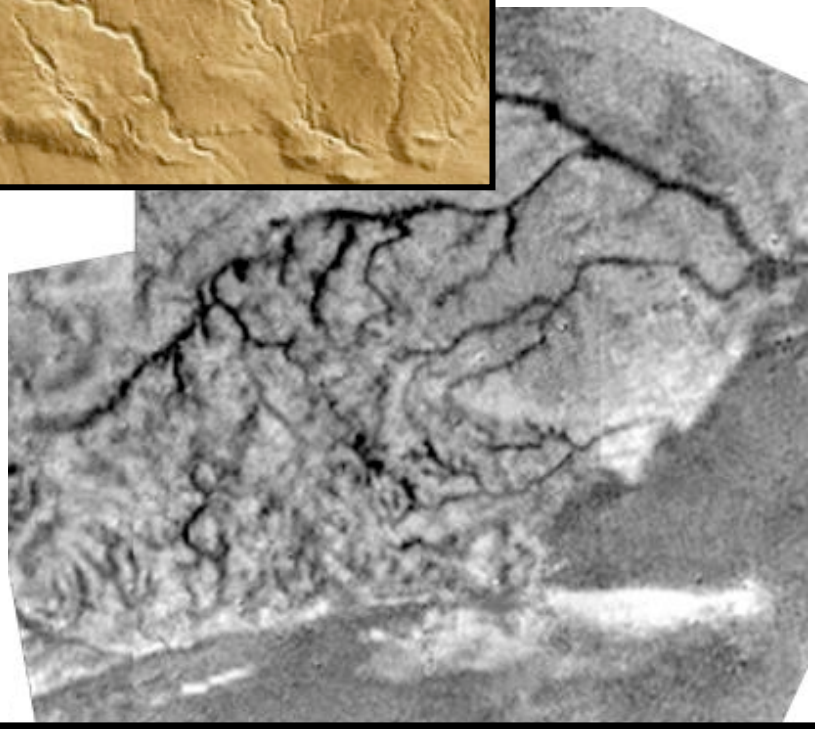




Dendritic Valley Networks



Mars

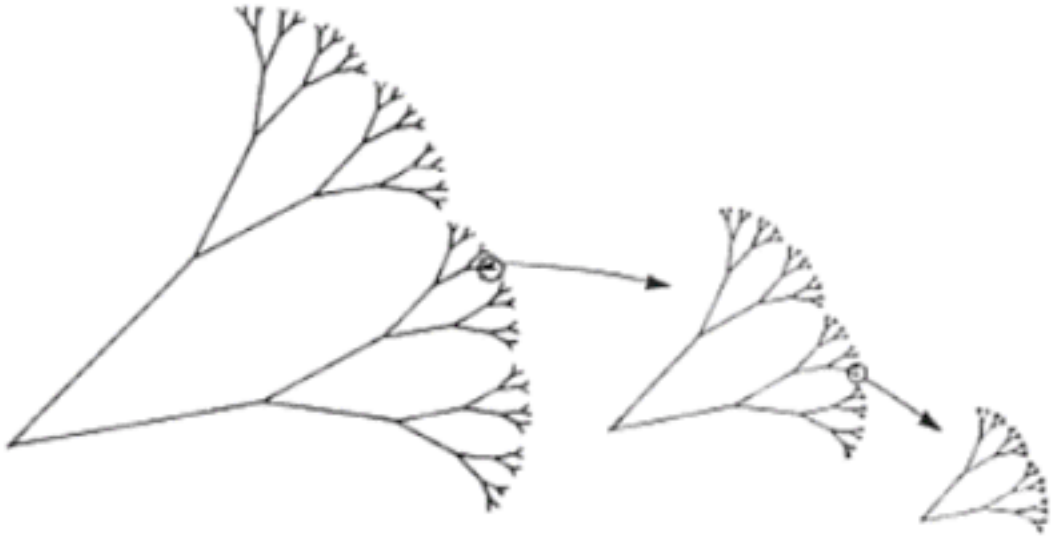


Titan

Yemen

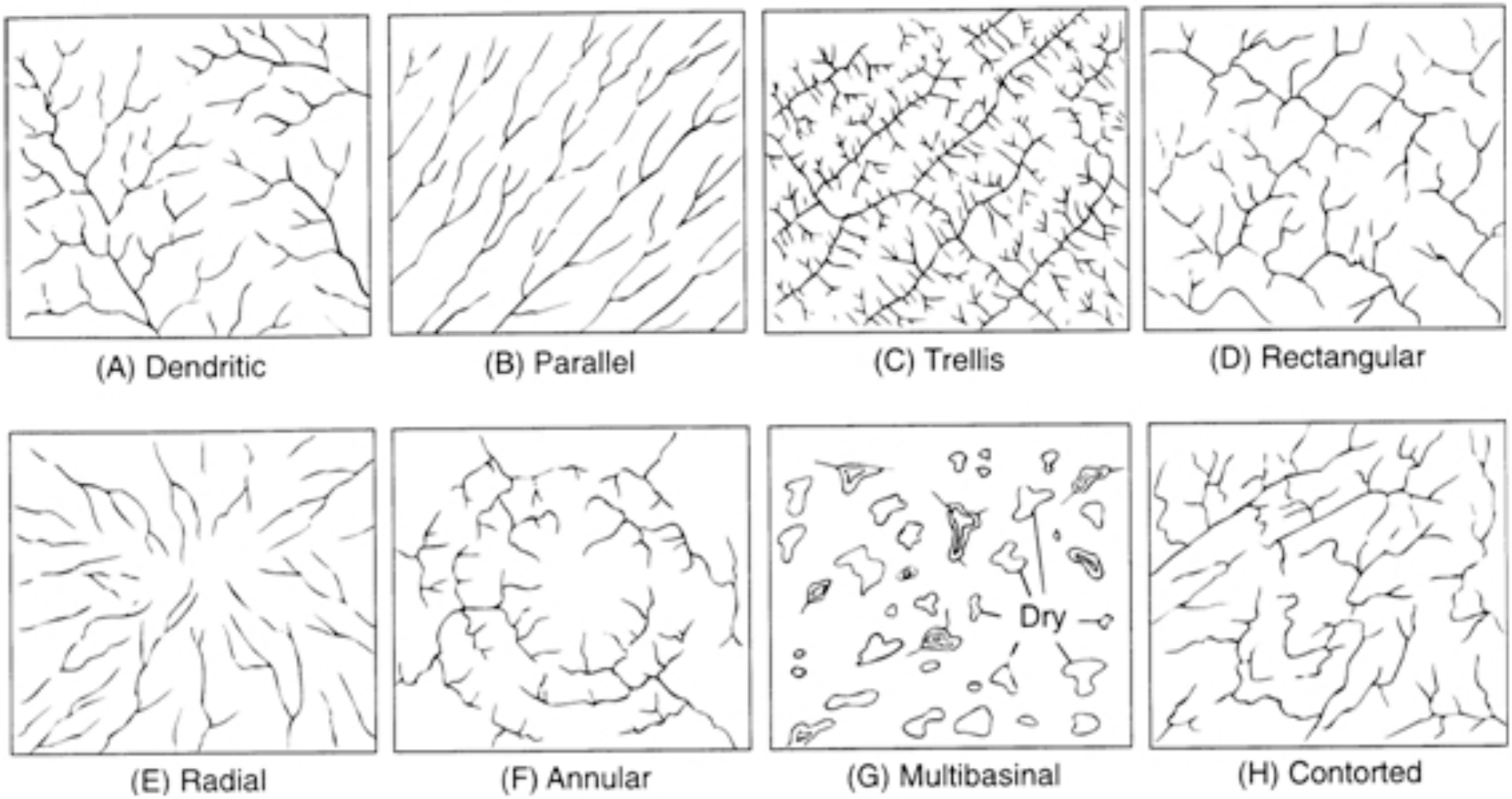
Dendritic Valley Networks

from Greek “dendron” (tree)



Self-similar (“fractal”) geometry

Topography influences valley forms

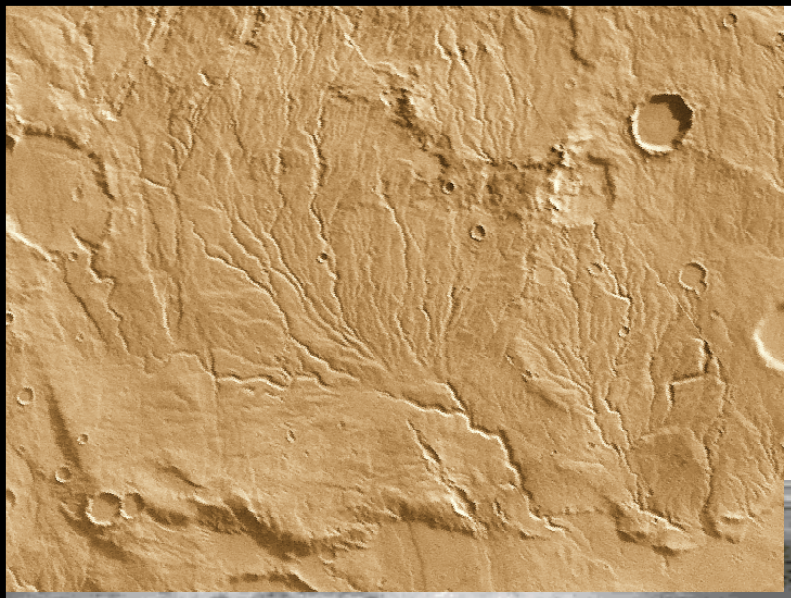


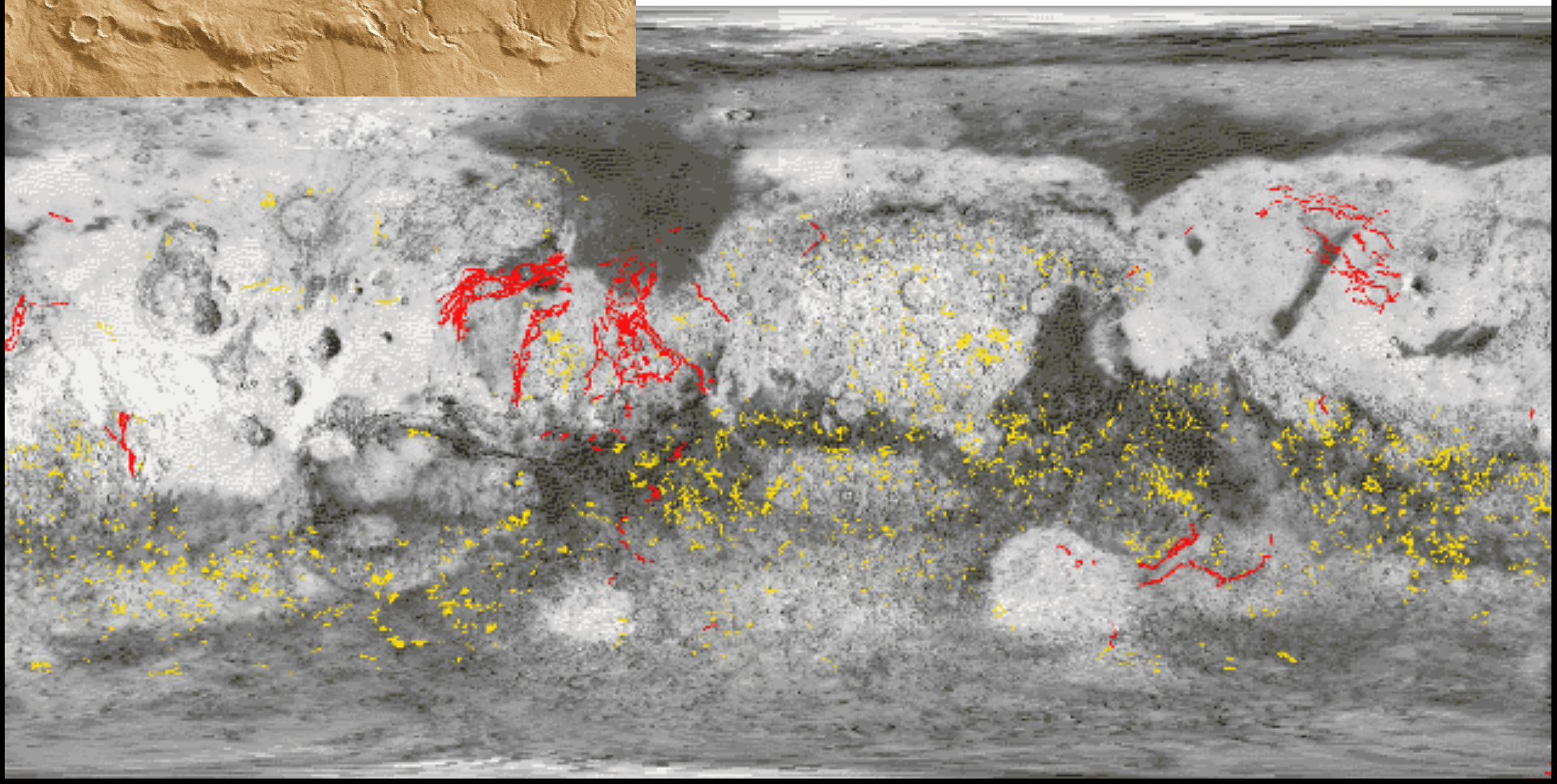
Howard (1967)

Valley networks

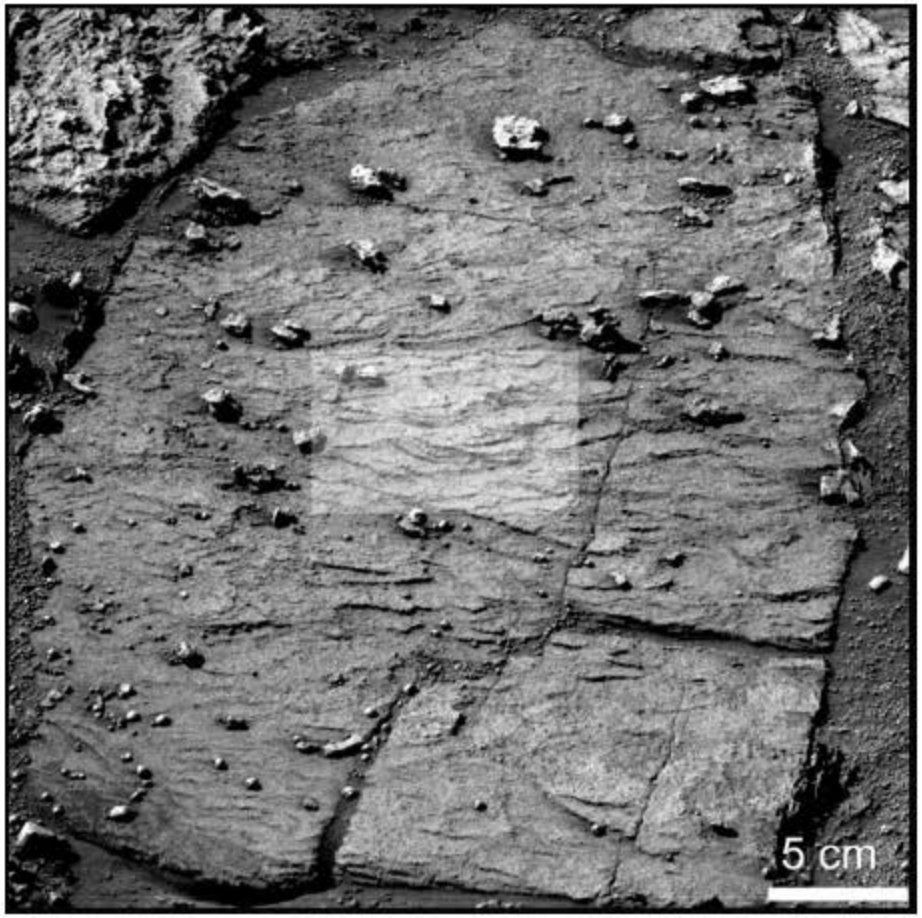
(yellow)

Evidence for ancient precipitation belt?
Some flow into/out of paleolake basins

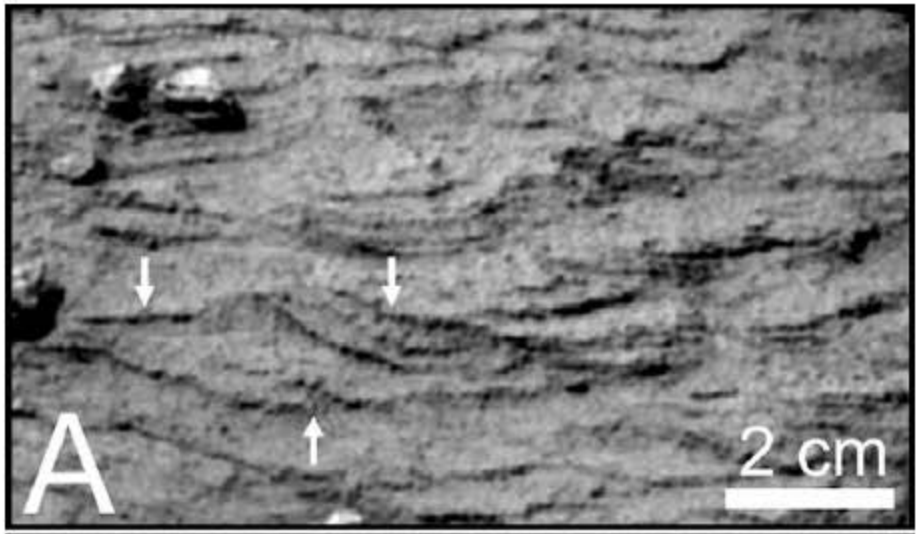


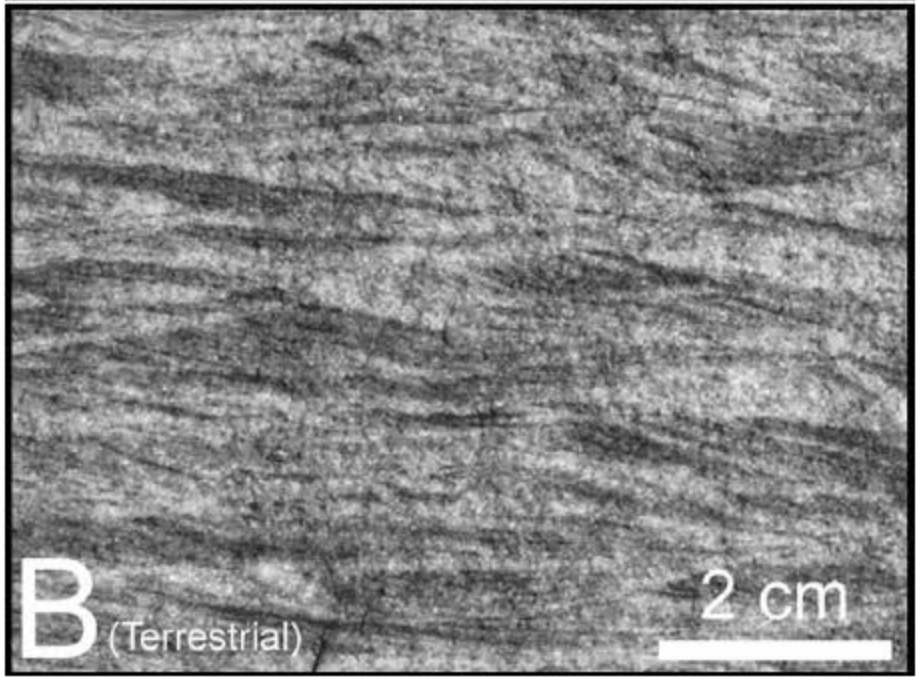


Shallow ponds at Meridiani Planum

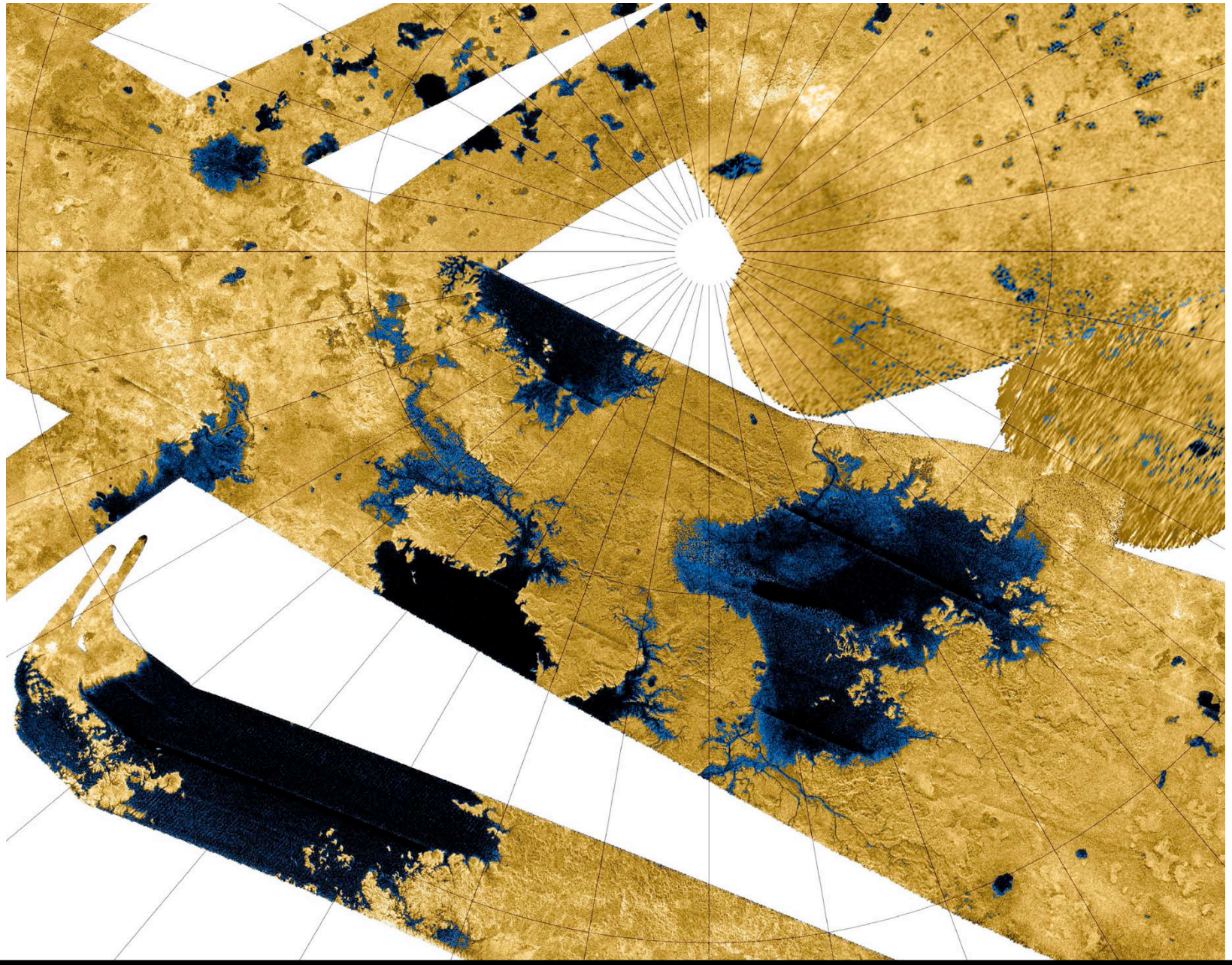


Grotzinger et al. (2006)

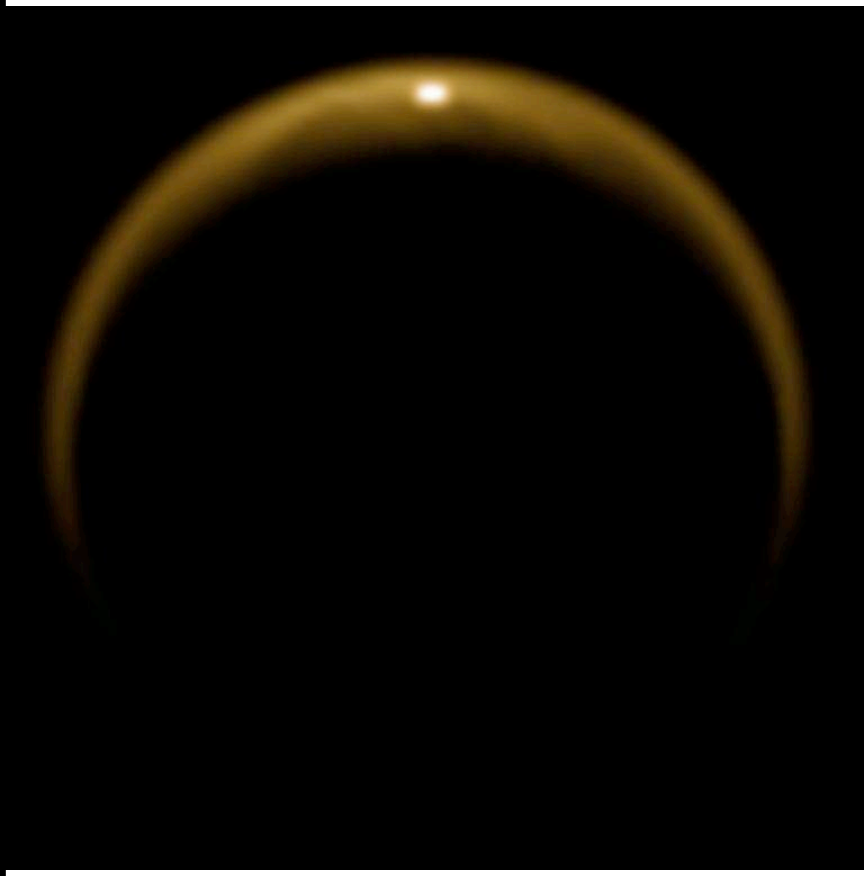




CH_4 Lakes on Titan



Lakes on Titan

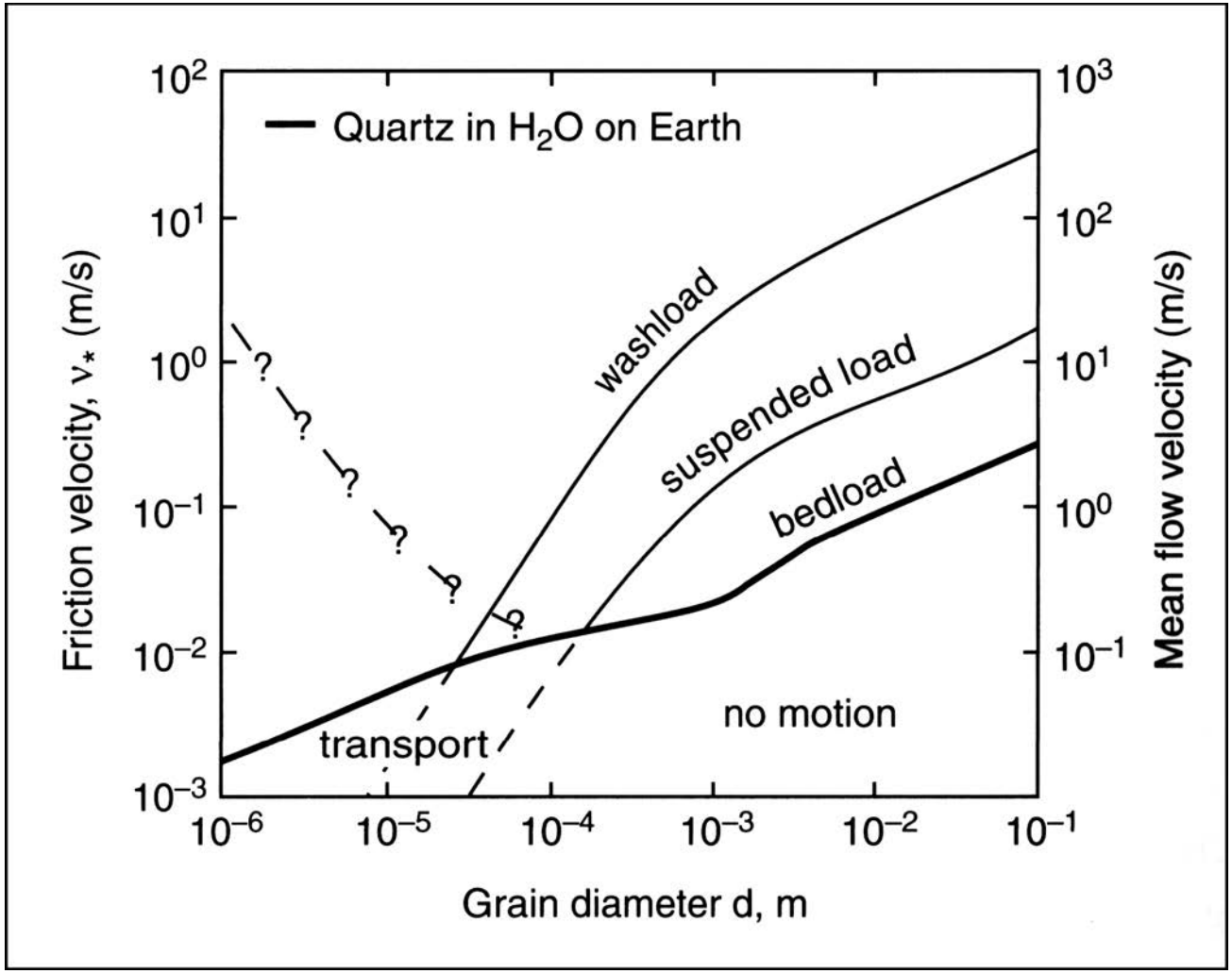


- Specular reflection confirms liquid
  - minimal waves
- Some lakes evaporating over time?
- Cobbles rounded by fluvial transport?

Curiosity landing site

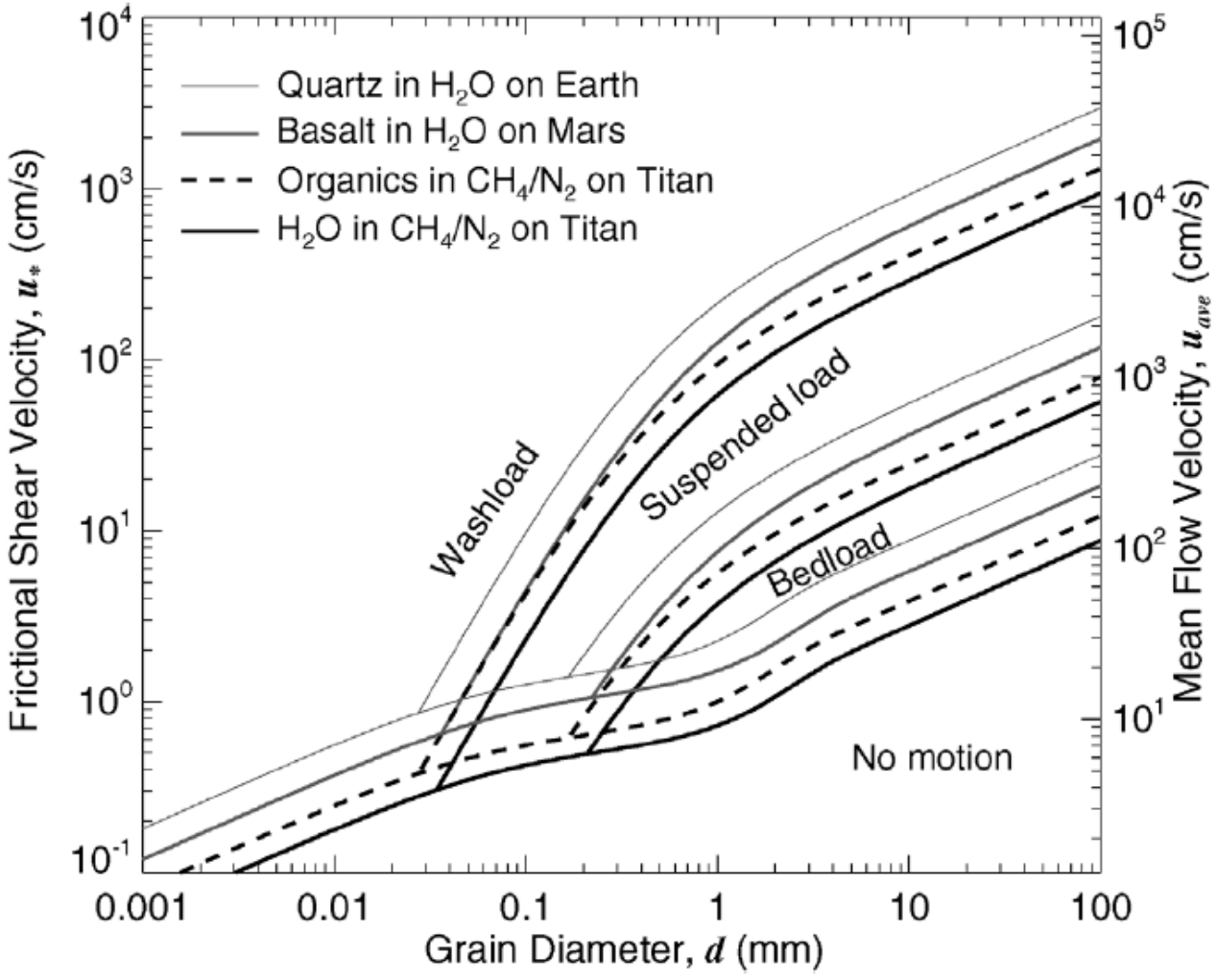
- Rounded stones emerging from matrix (more rounded than Atacama stream pebbles)
- Grain size/density, slope, Martian gravity, and estimated Shields parameter → *dm depths*

Fluvial sediment transport



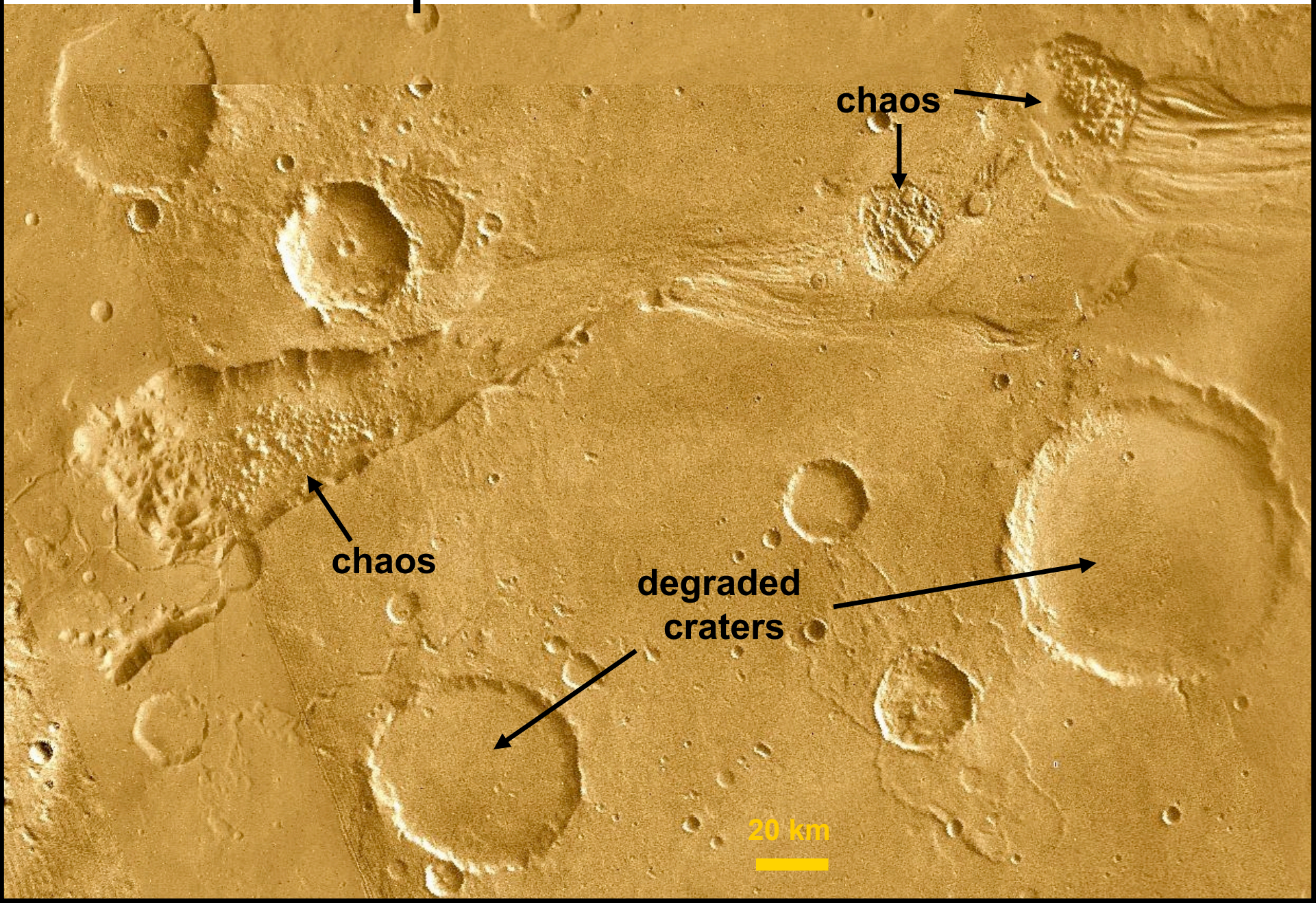
Melosh (2011)

Fluvial sediment transport



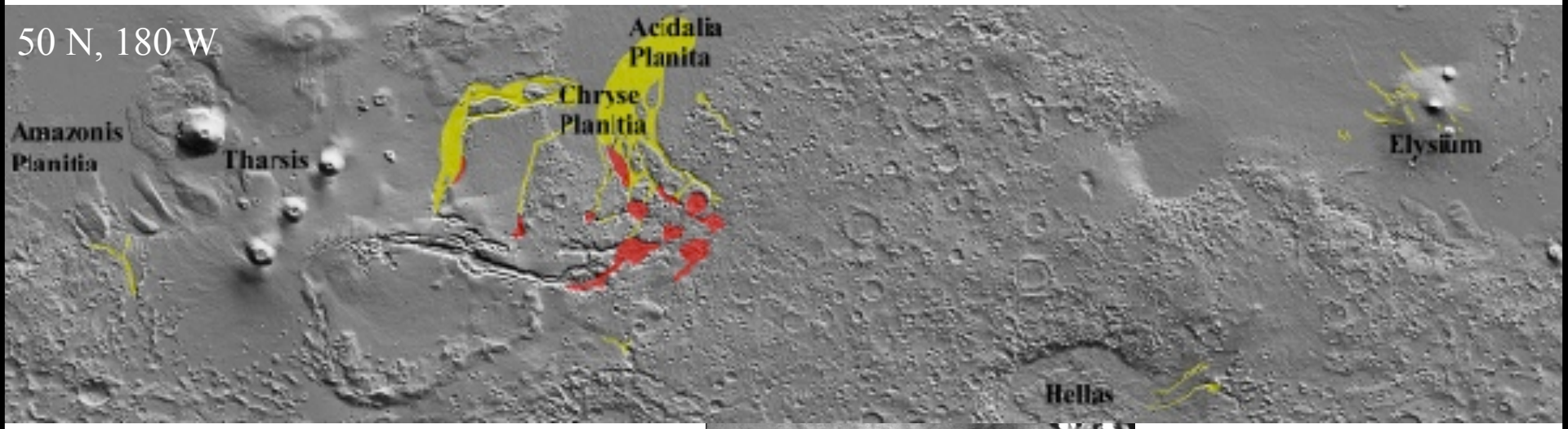
Burr et al. (2006)

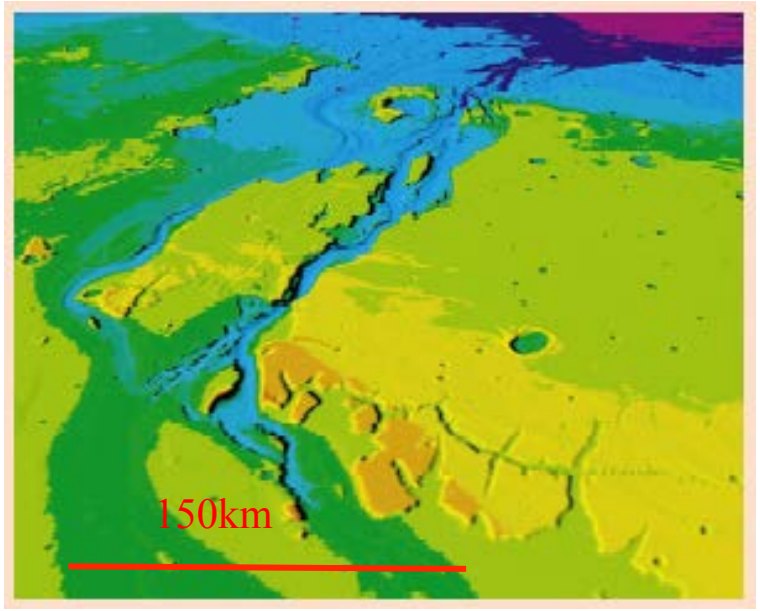
Catastrophic Outflow Channels

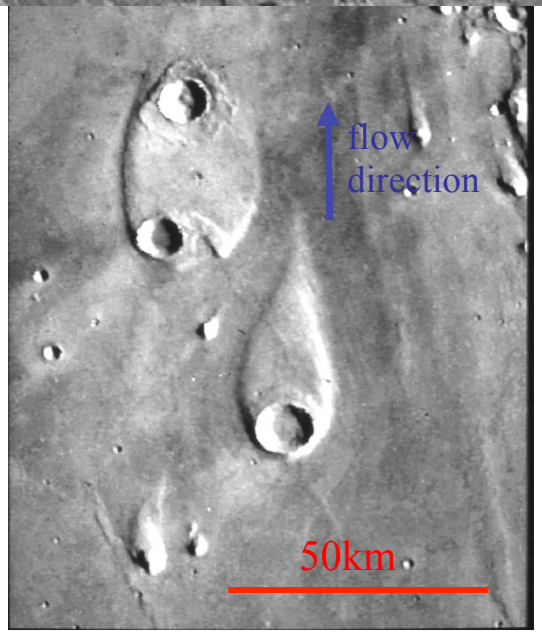


Map of Mars Outflow Channels

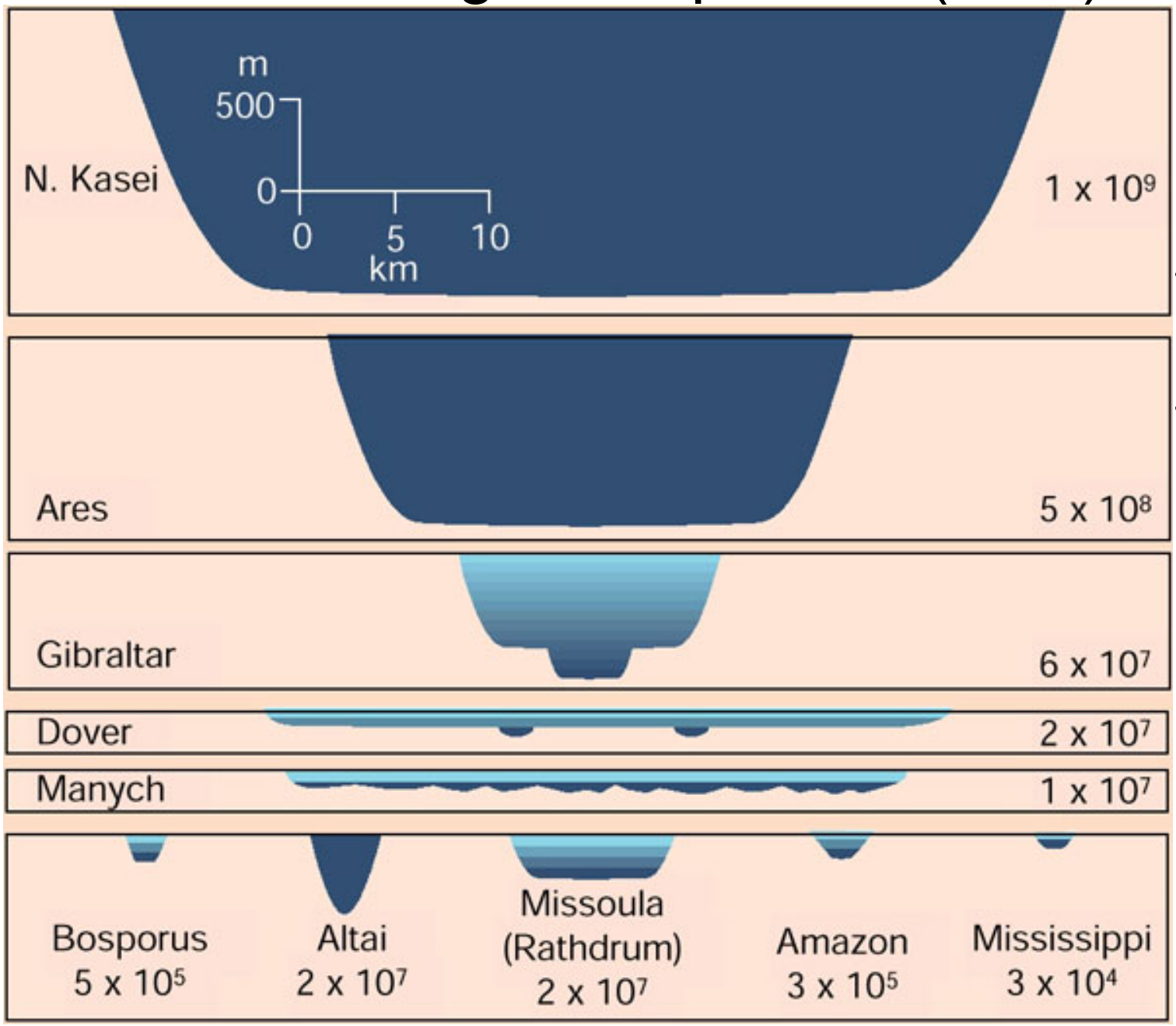
Concentrated east of Tharsis in topographic trough



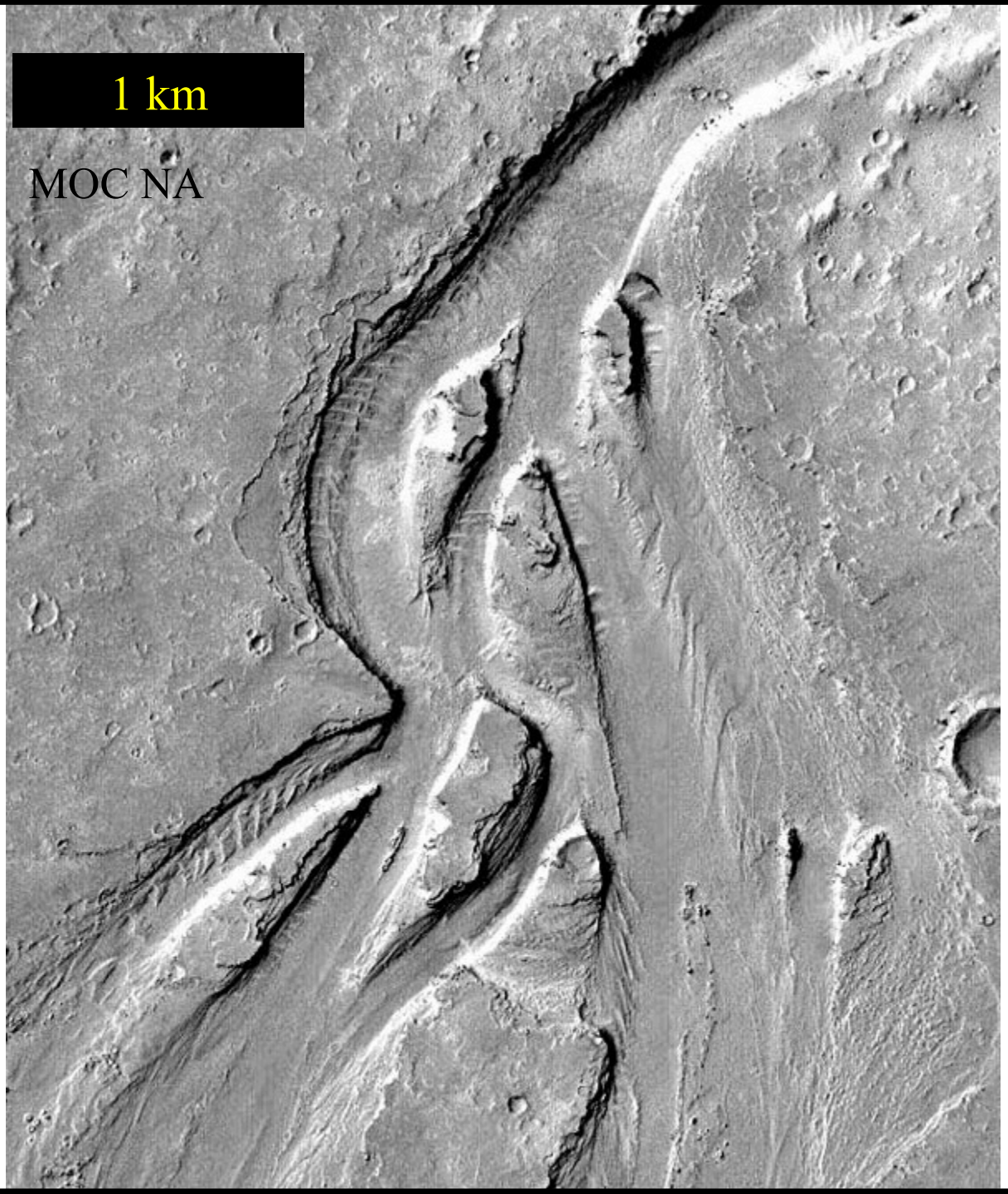




Flood Discharge Comparison (m^3/s)



Baker, 2001


1 km
MOC NA

Martian Gullies

- Found predominantly at high latitudes (>30º), on pole-facing slopes
- Inferred to be young, < 10 MA – cover young features like dunes and polygons
- Snowmelt? Melting of ground ice? ***Groundwater aquifers?!?*** Or not related to water at all?

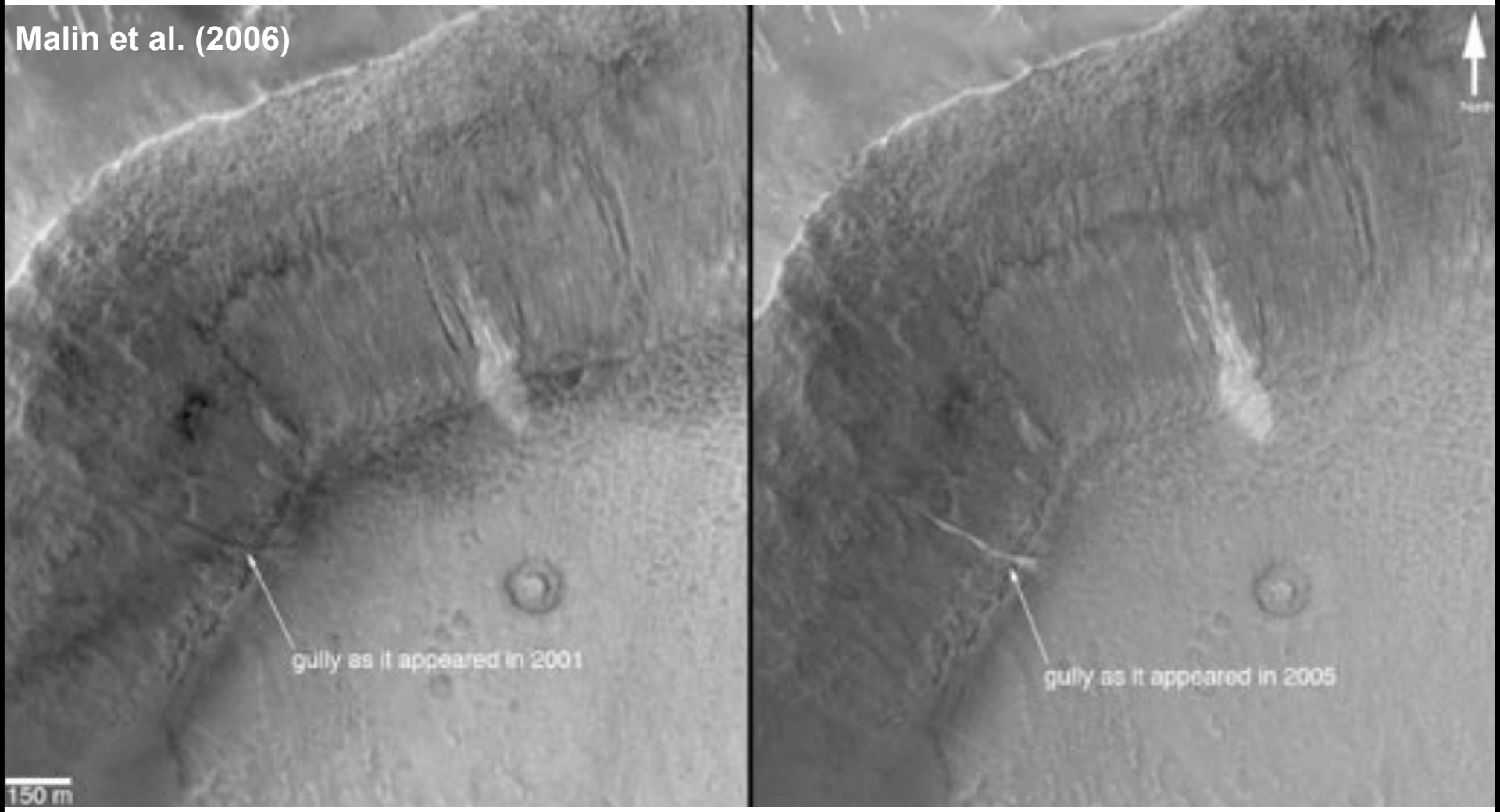
Gullies in the northern wall of a crater at 39.1 °S, 166.1 °W
Subframe of MOC image E11-04033

NASA/JPL/Malin Space Science Systems

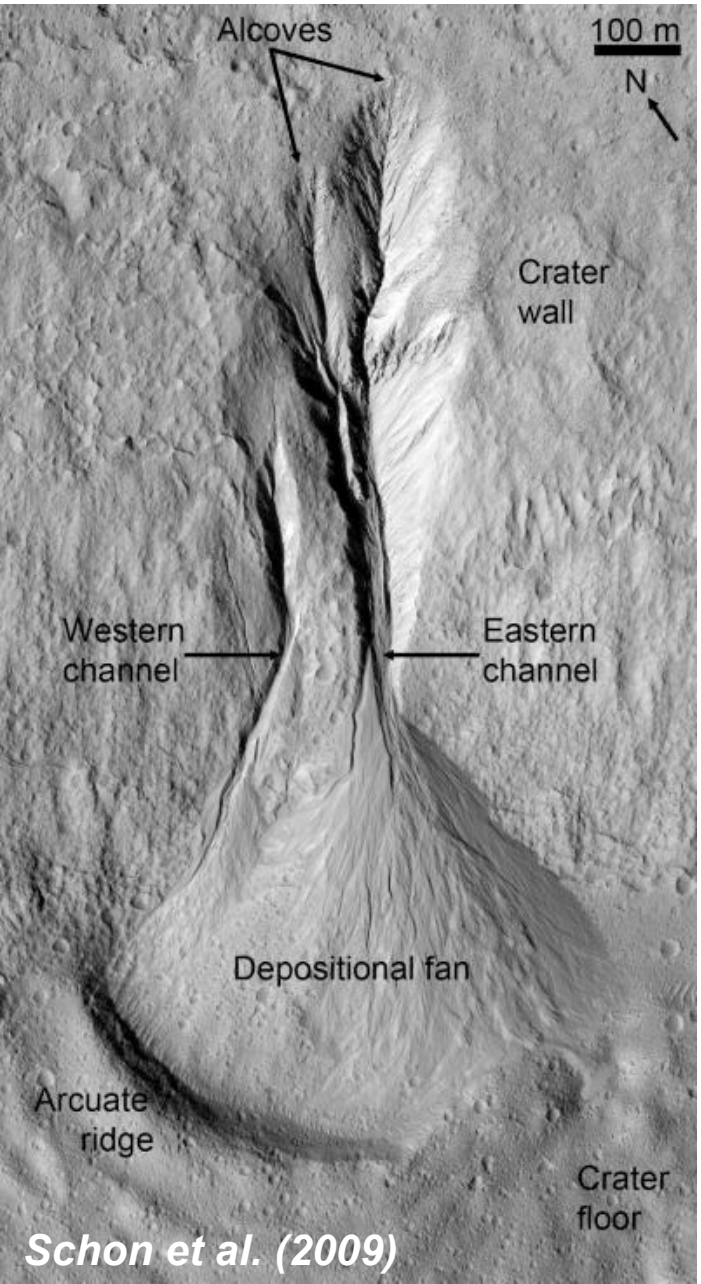
Gullies in crater near 39°S, 200°W

MOC2-388/PIA04570 NASA/JPL/MSSS

Gullies are active today!



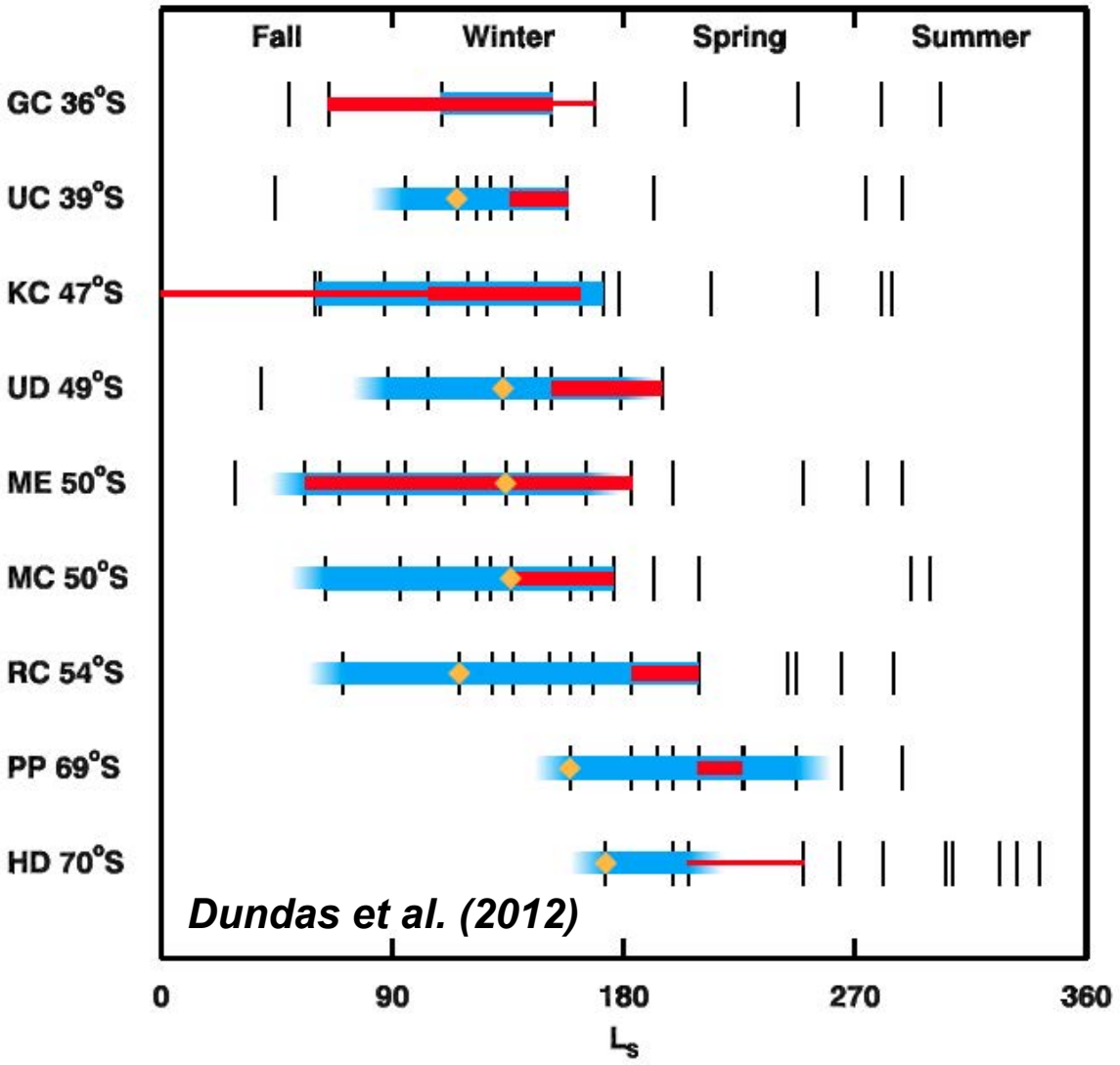
Gullies look like water-carved features…



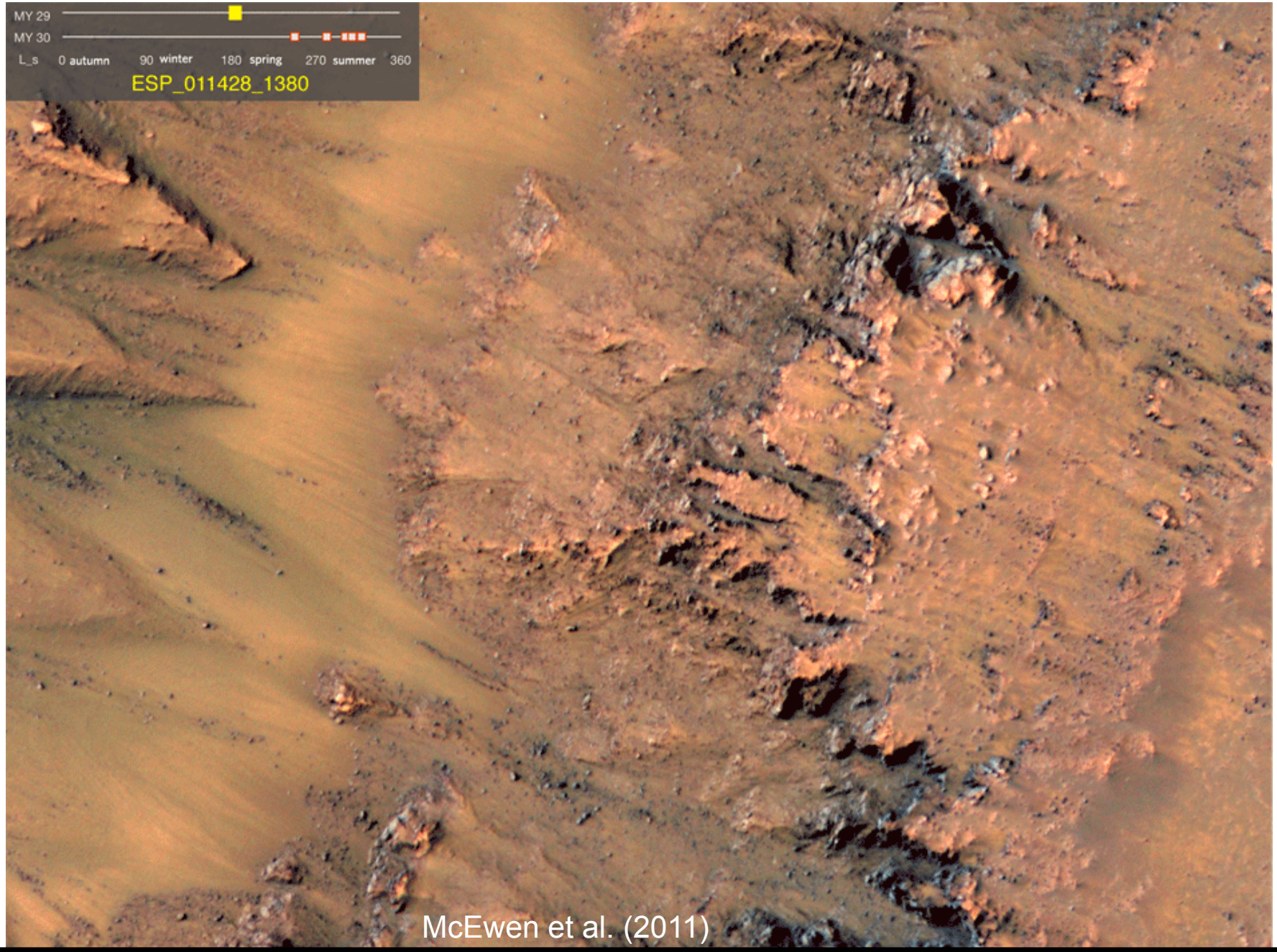
Schon et al. (2009)

…but they're active in the winter time!

➔ related to CO_2 frost?



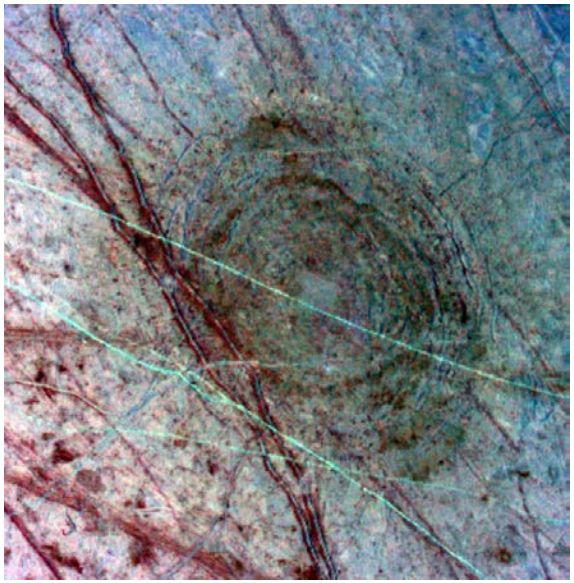
Recurring slope lineae: active in summer

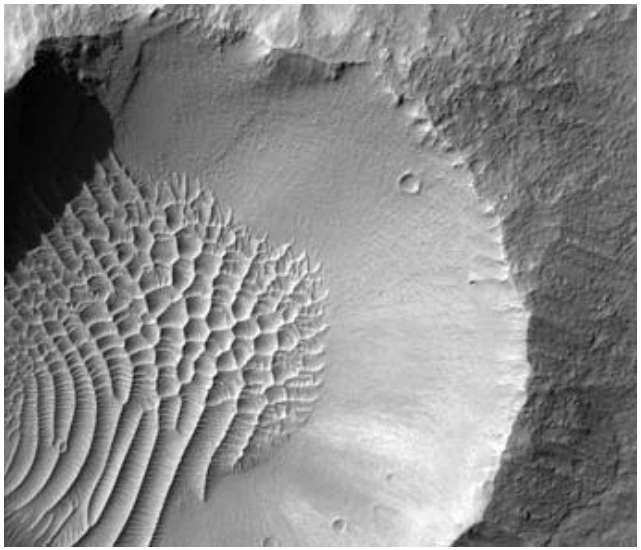


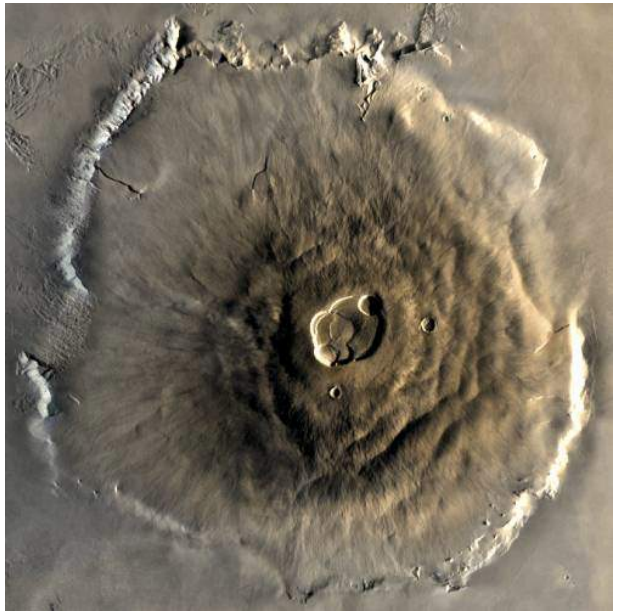
McEwen et al. (2011)

Planetary Surface Processes

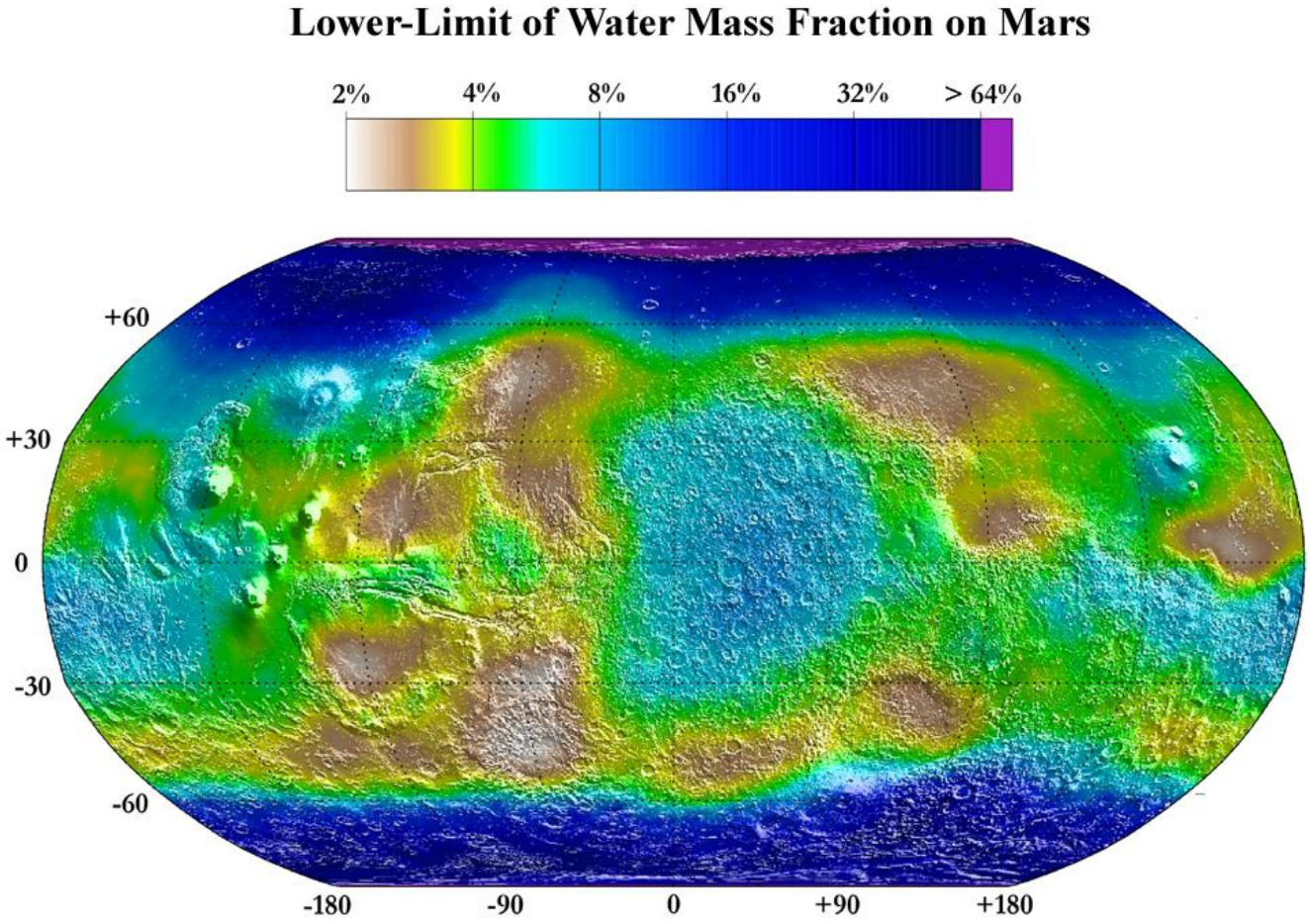
Cratering
Gravity
Tectonics
Volcanism
Winds
Fluvial
Glacial
Chemical weathering







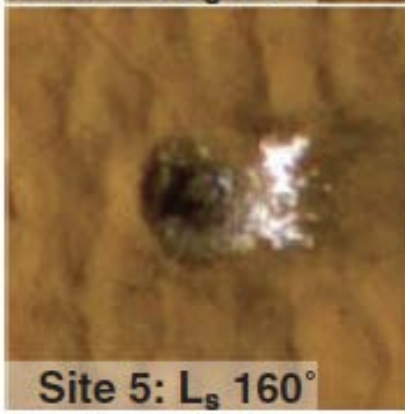
Ground Ice (and hydrated minerals): Evidence from Neutron Spectroscopy

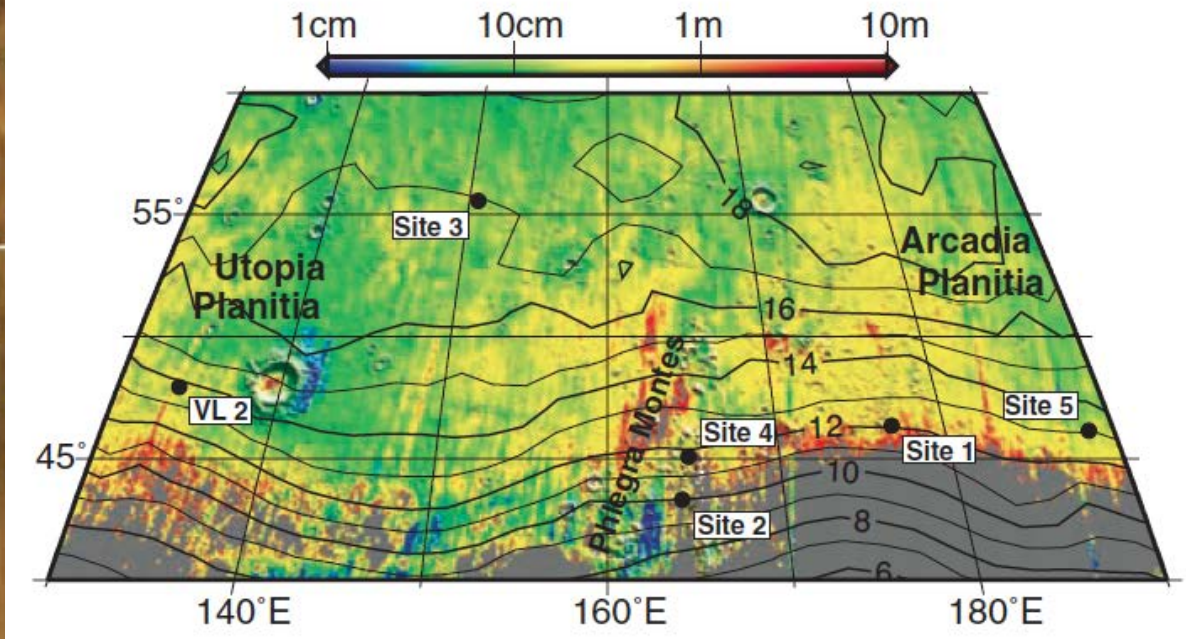


Data from Mars Odyssey Gamma Ray Spectrometer, see for example Feldman et al. 2002

Ice revealed by impacts

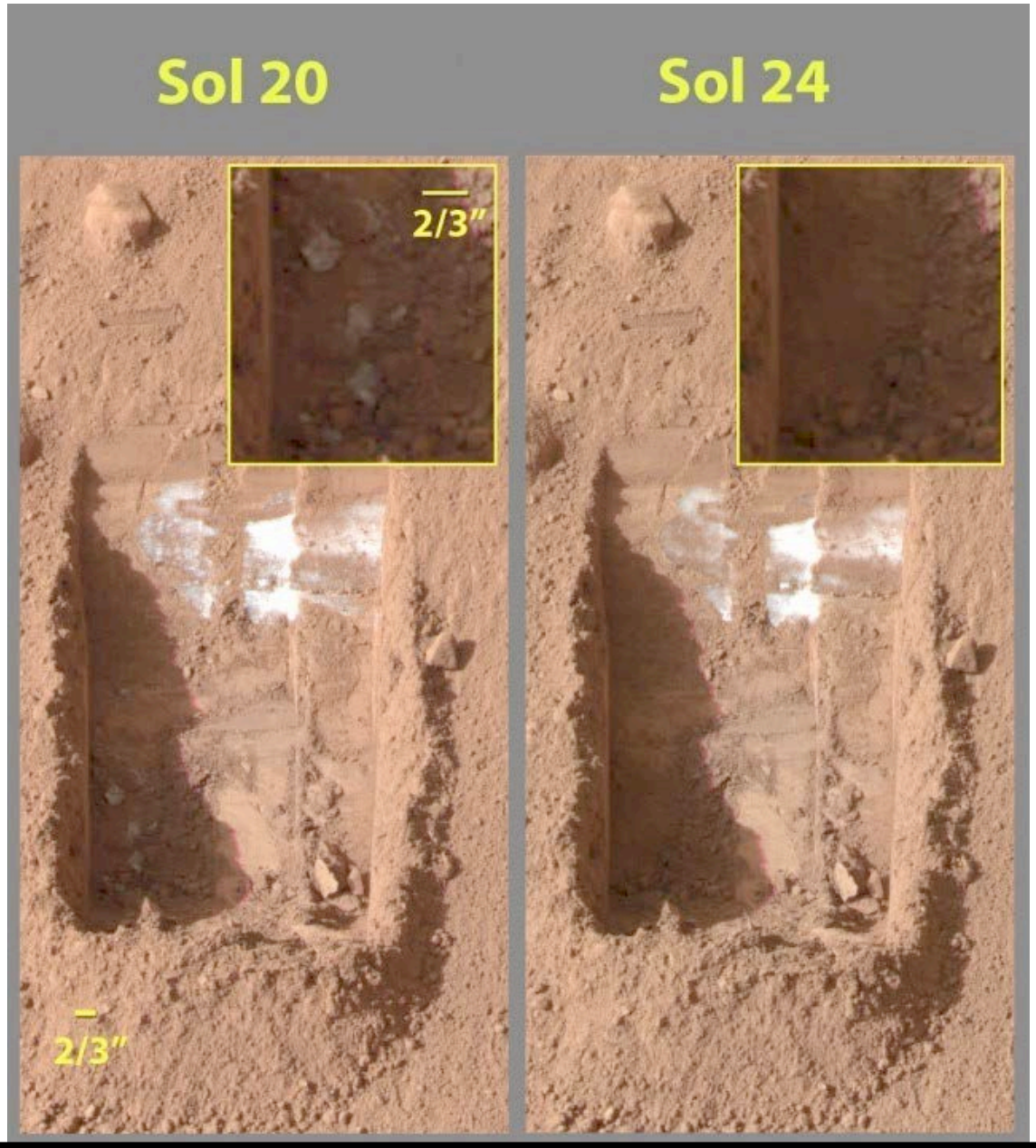
Observed to fade over time



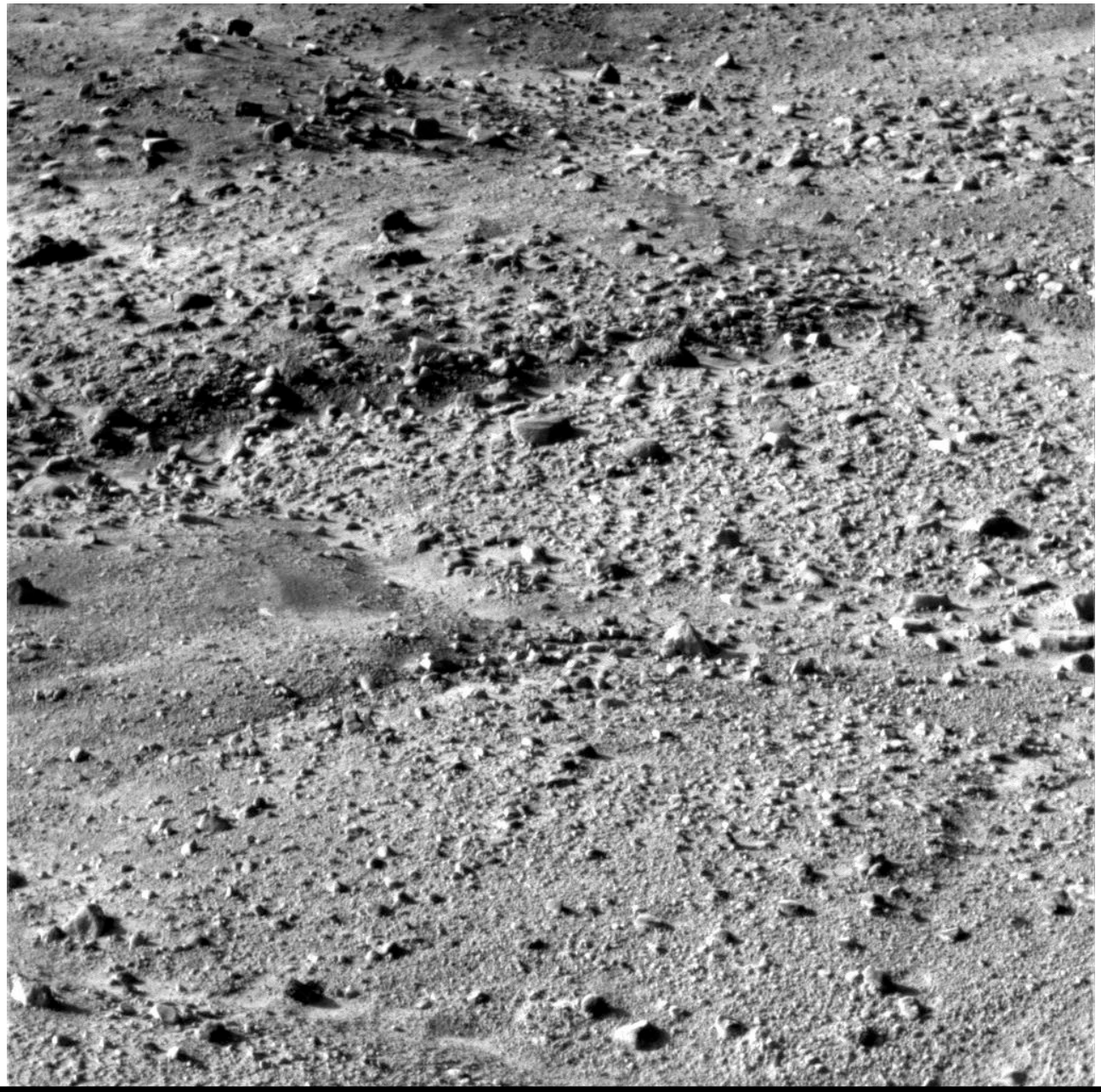


Byrne et al. (2009)

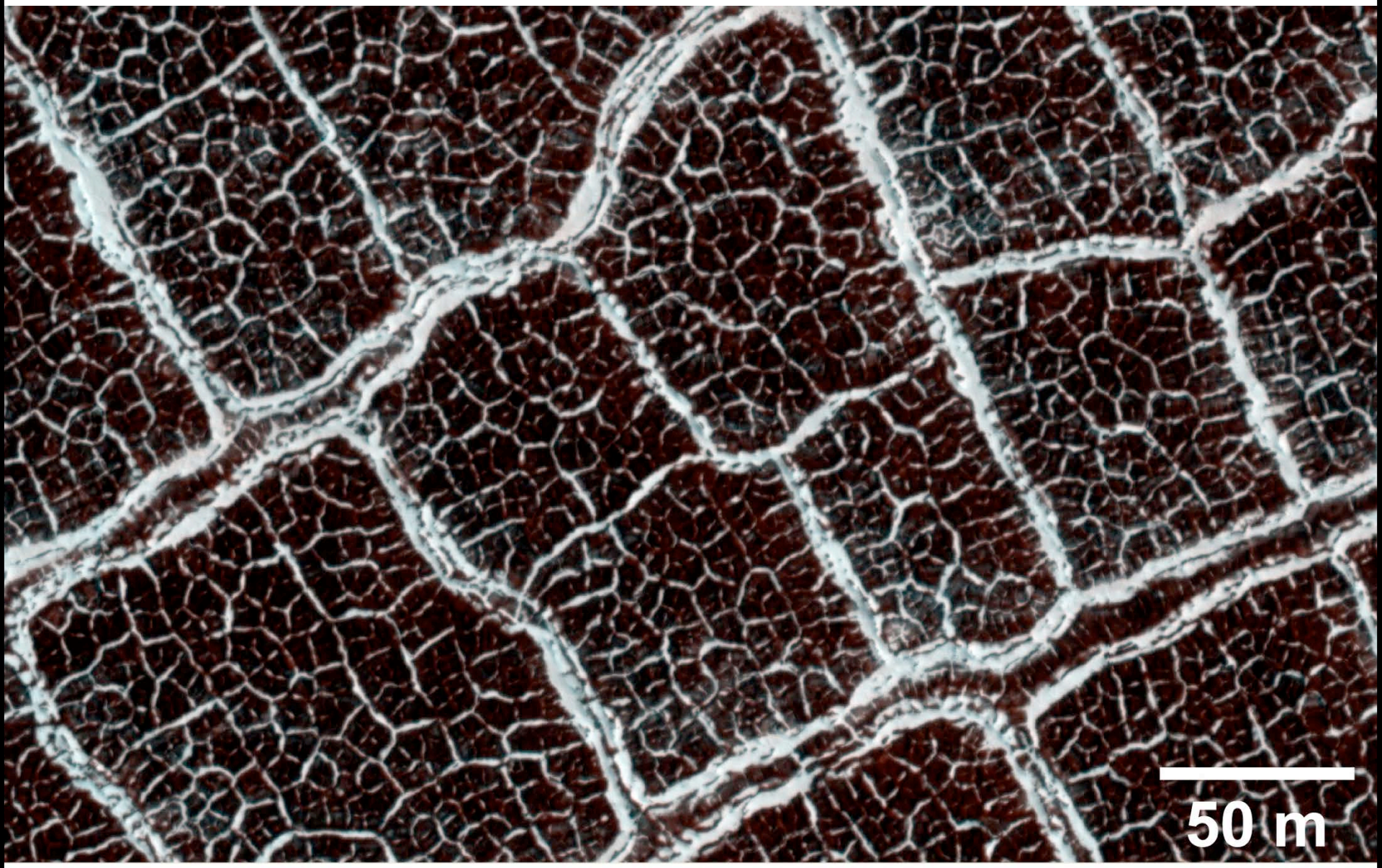
Phoenix observed ice directly



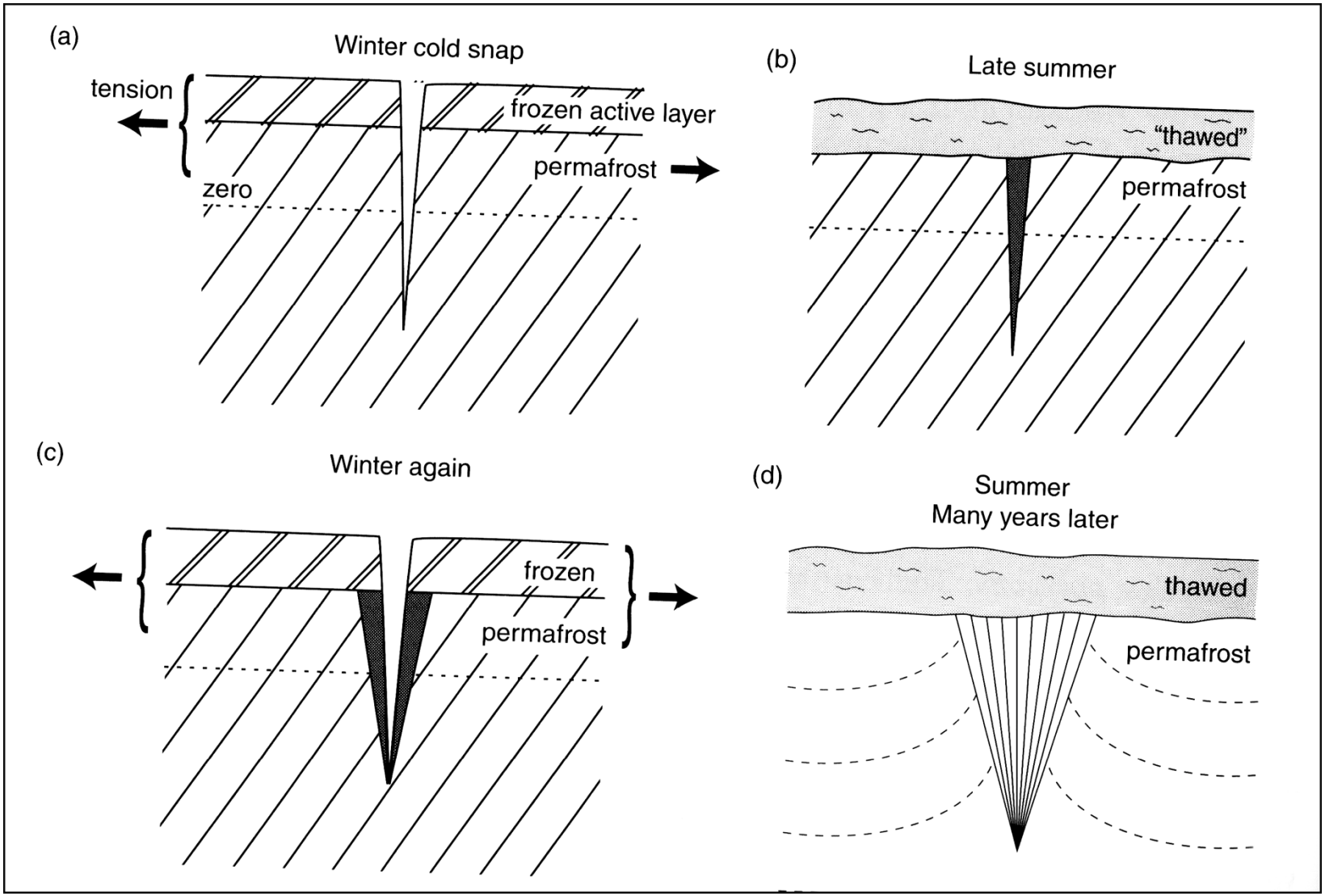
Polygonal patterned ground - Phoenix



Polygonal patterned ground - HiRISE

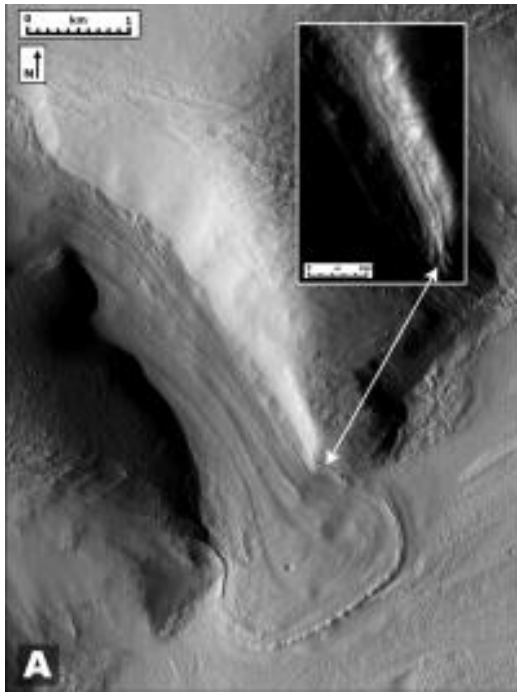


Contraction crack formation

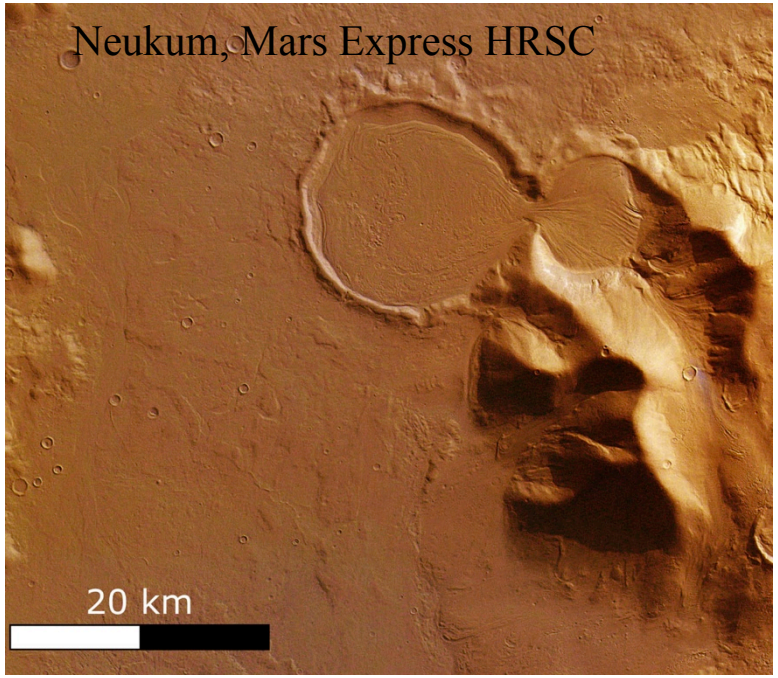


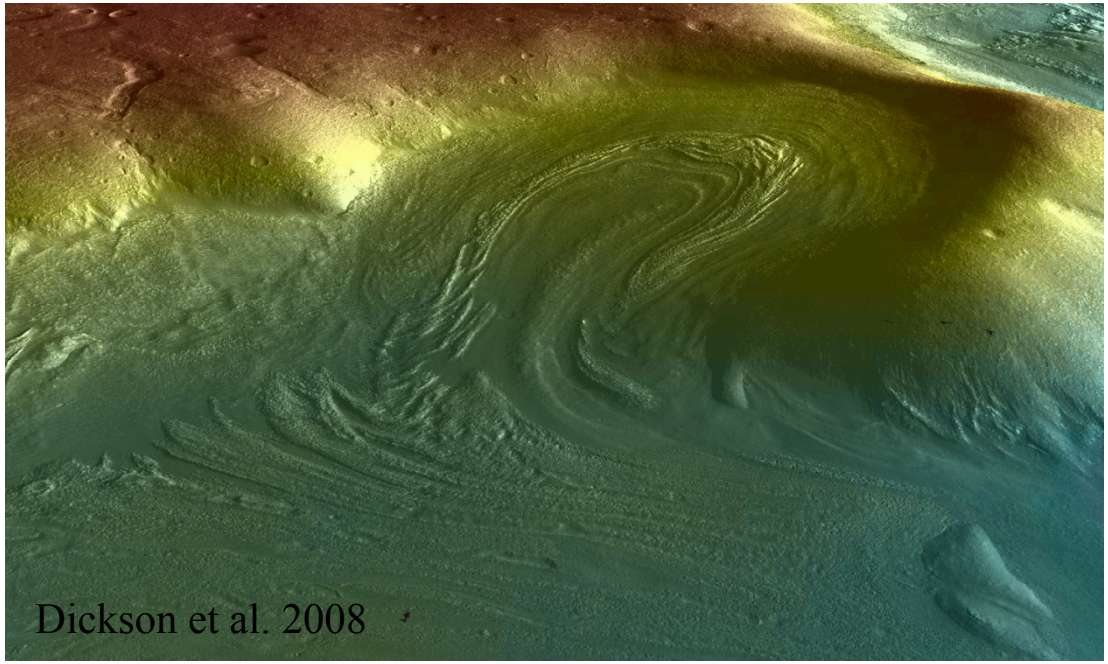
Melosh (2011)

Glaciers on Mars

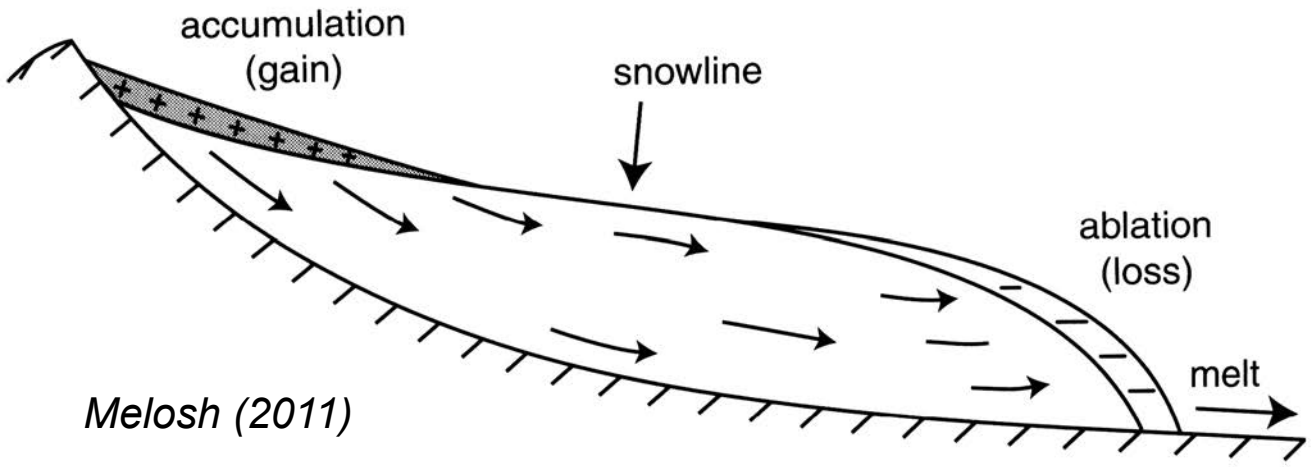


Fastook et al. 2008





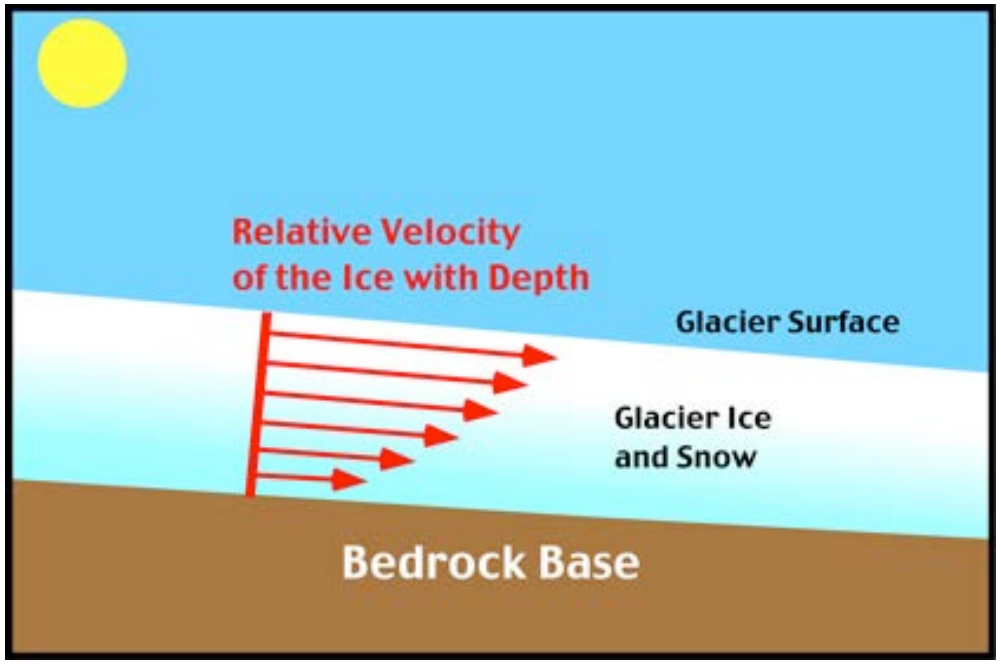
A glacier at equilibrium



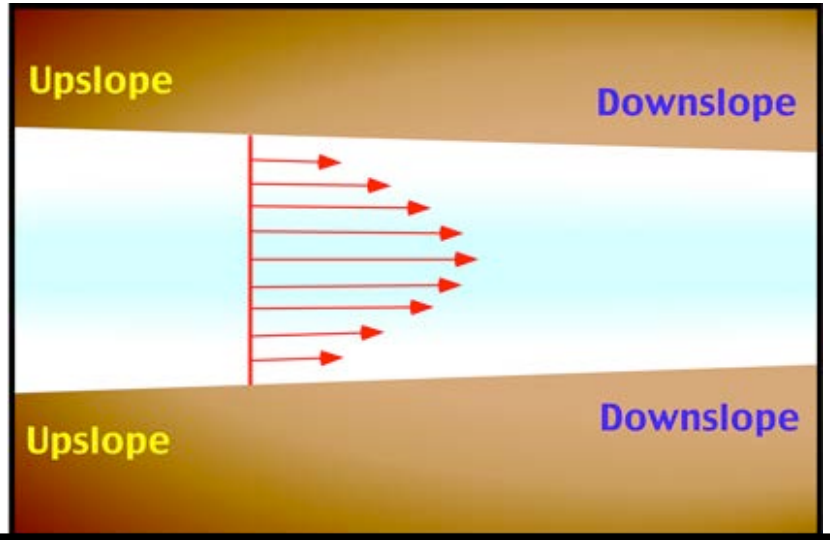
Melosh (2011)

Flow velocity is not uniform

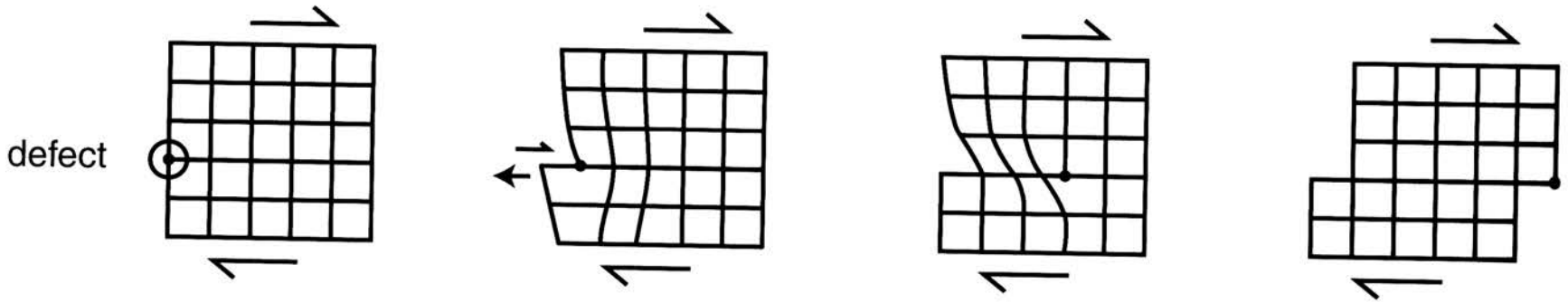
Side view:



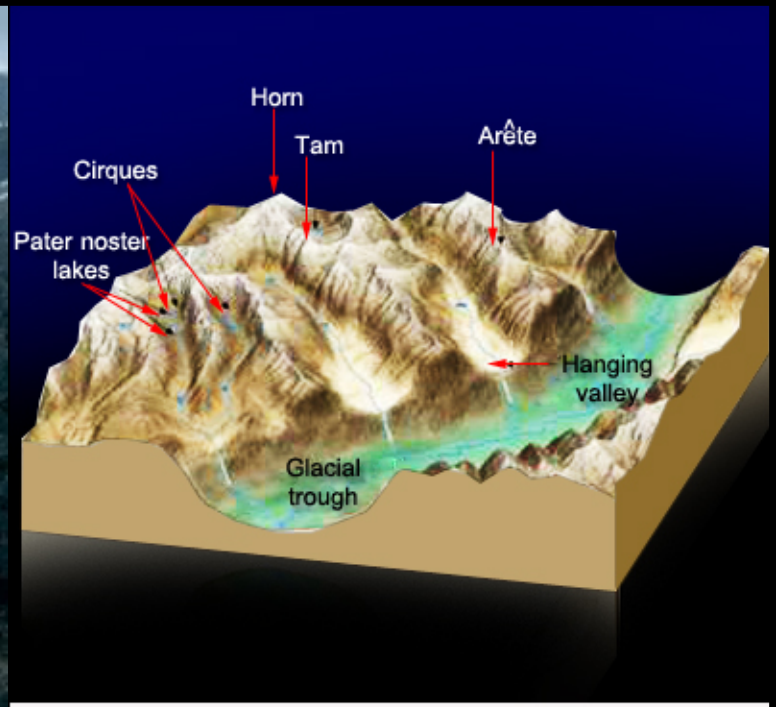
Overhead view:



Glacial creep



Melosh (2011)



Glacial Valley