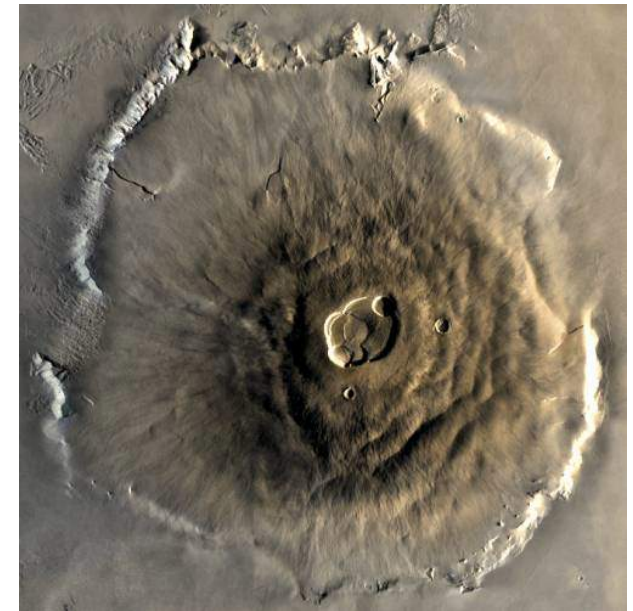
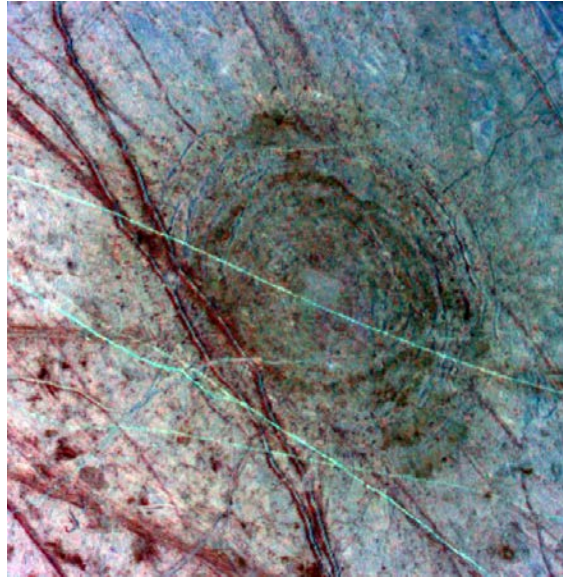


# Planetary Surface Processes

Cratering  
Gravity  
Tectonics  
Volcanism  
**Winds**  
Fluvial  
Glacial  
Chemical  
weathering

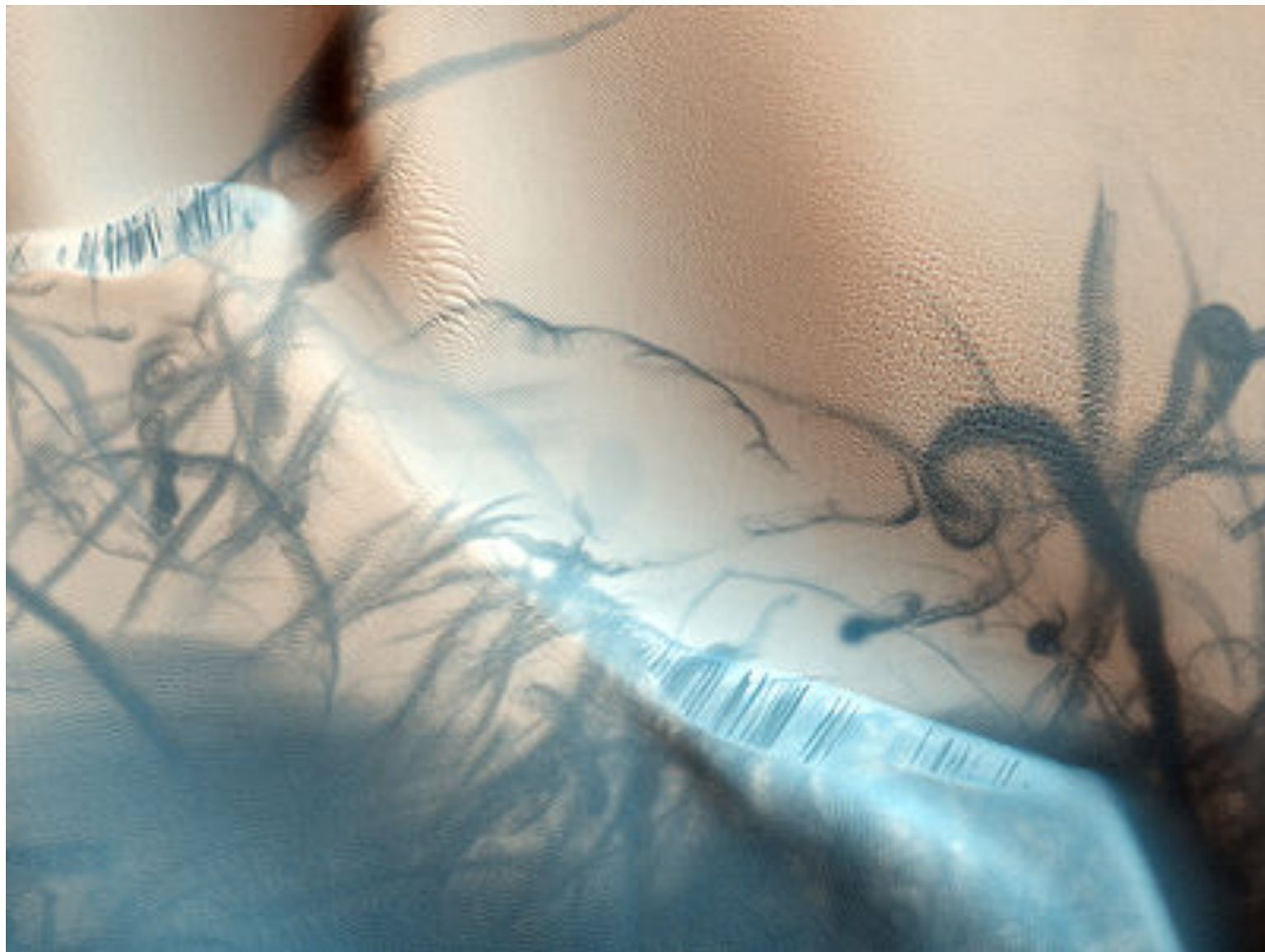


# Dust Devils

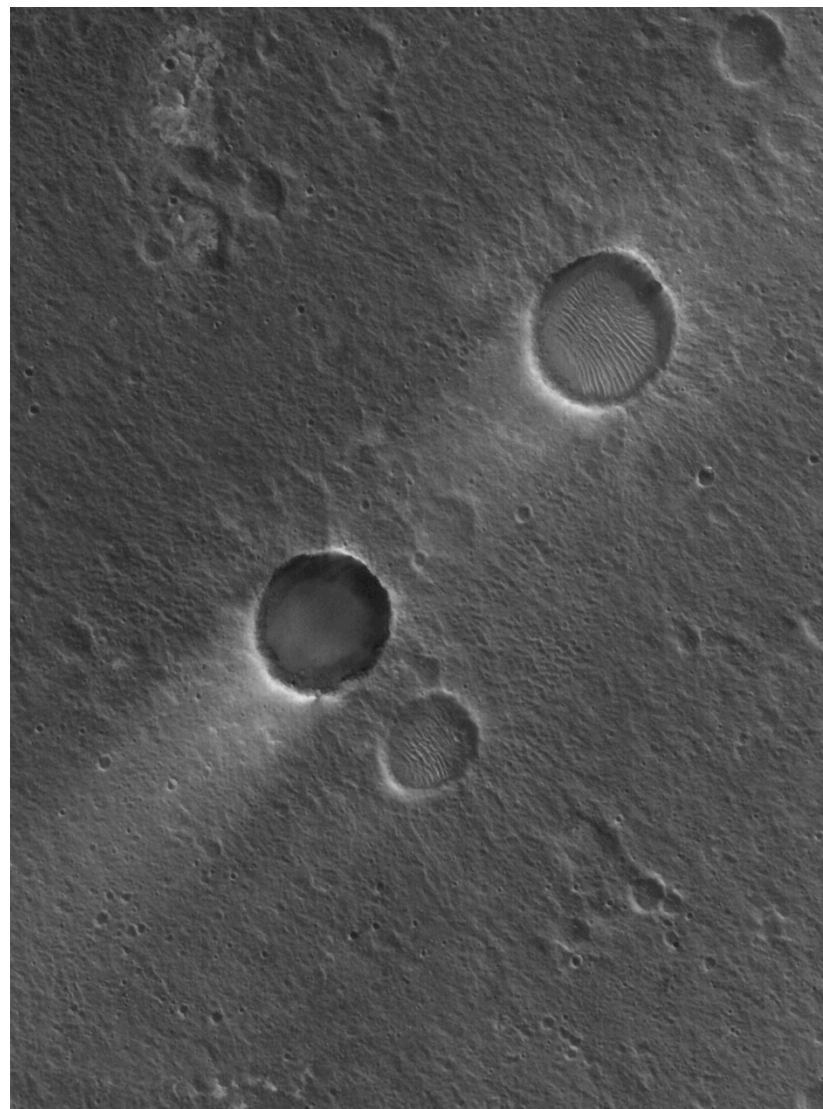
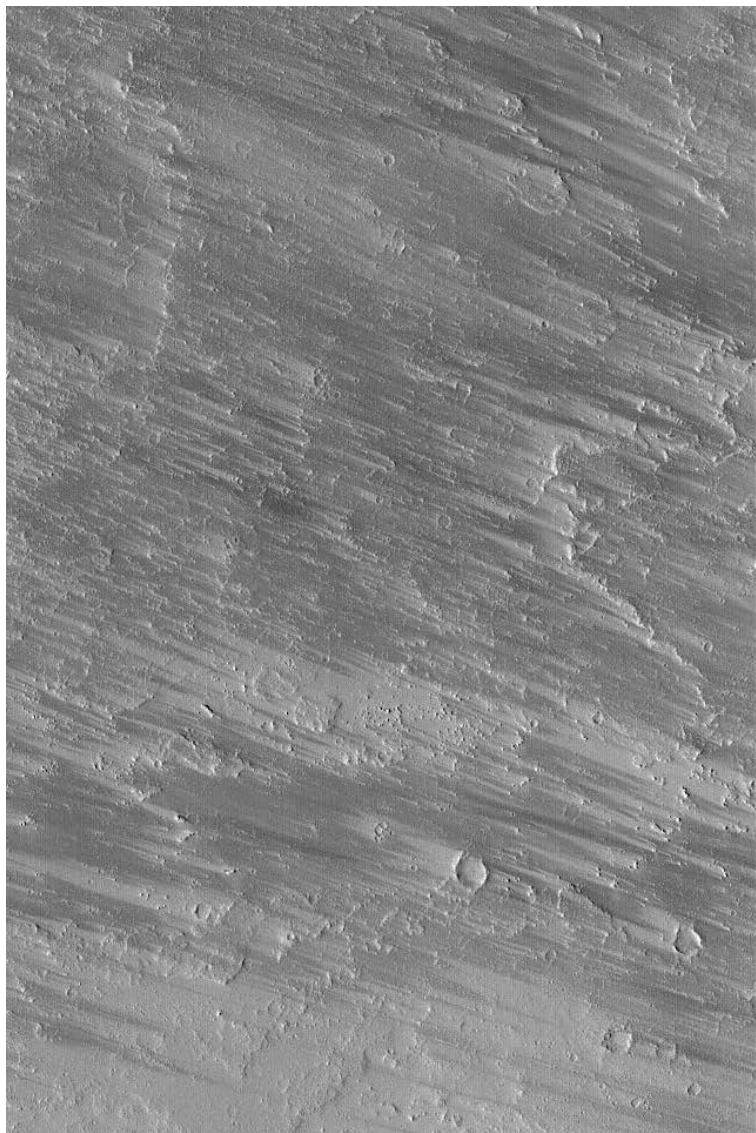


Phoenix Public Release Image

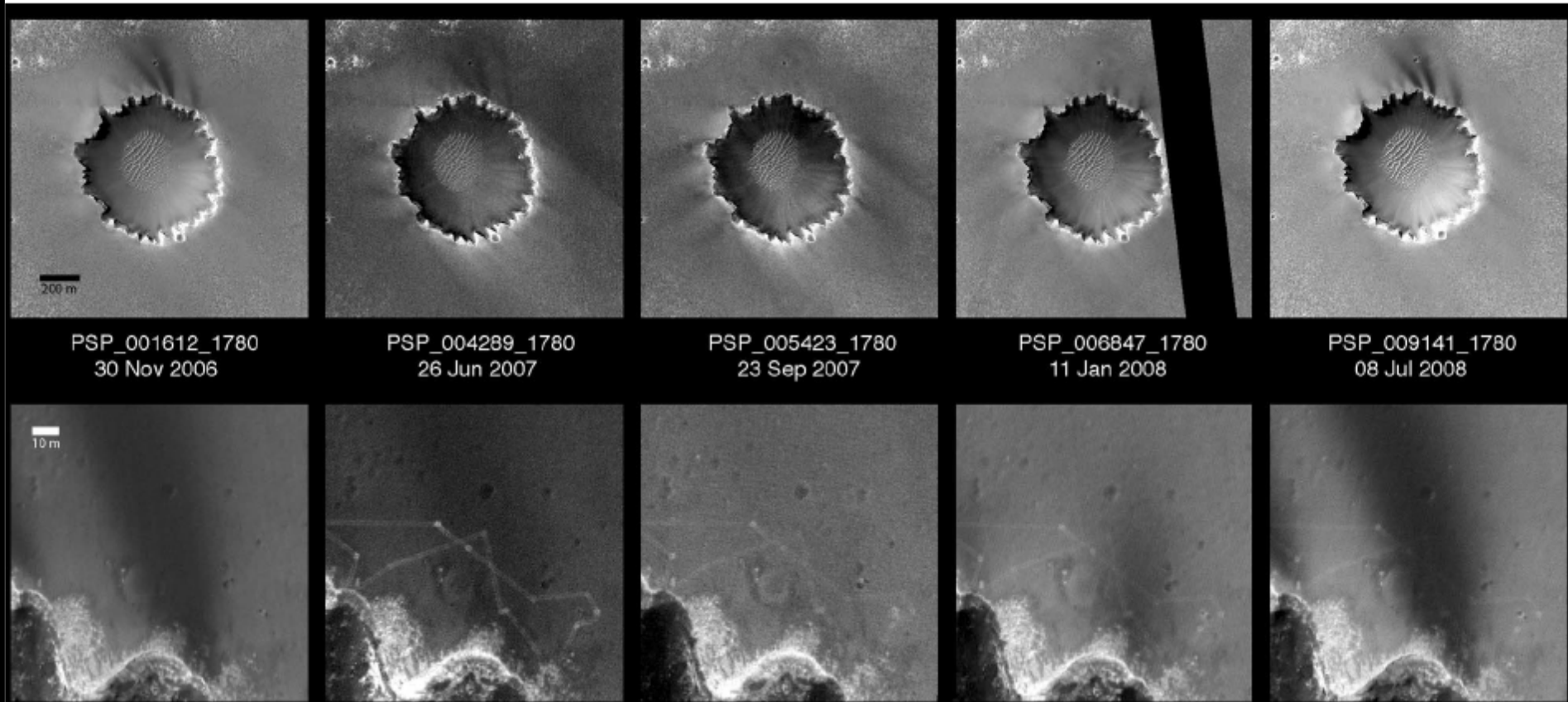
# Mars dust devil tracks



# Wind streaks

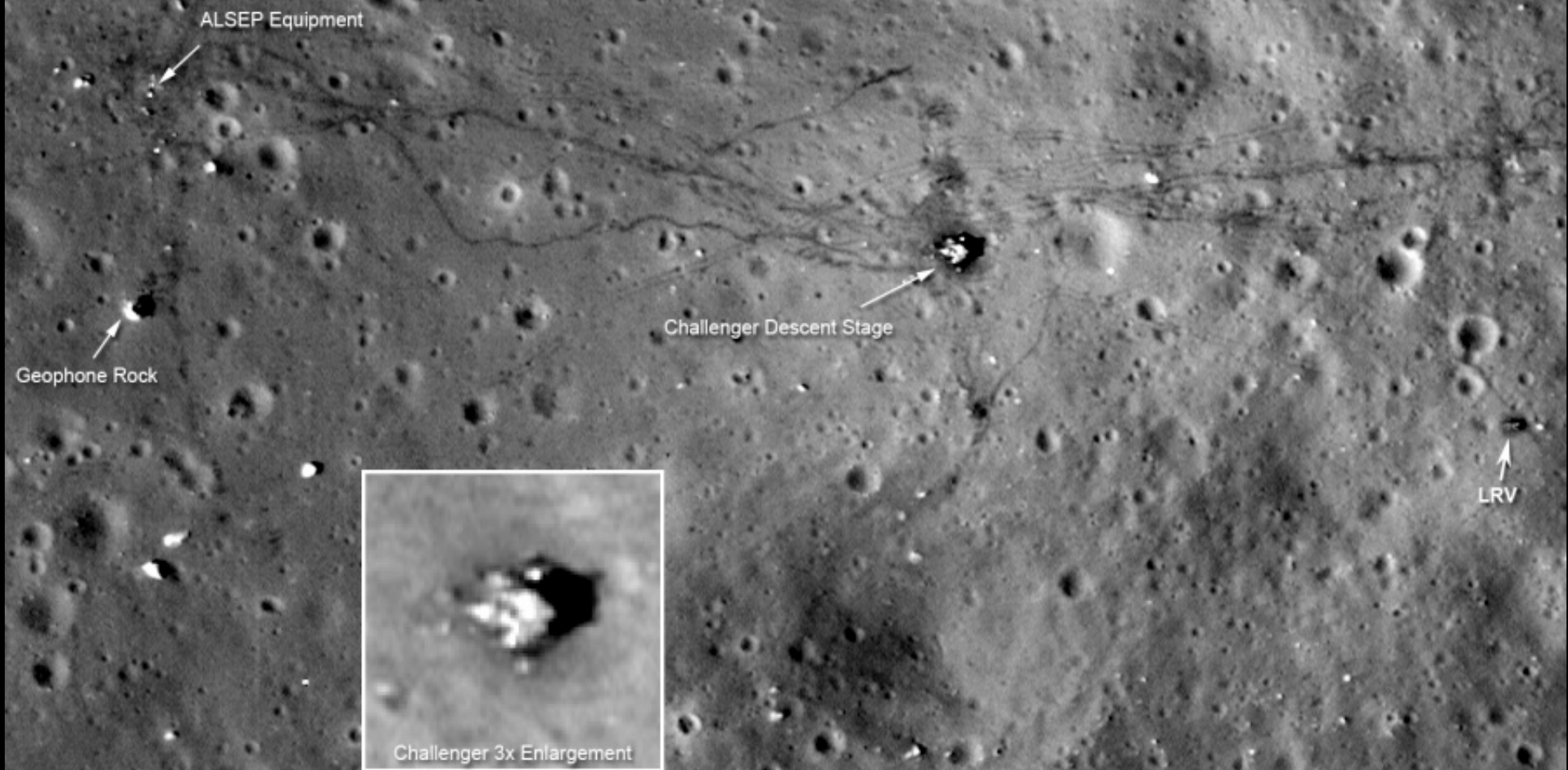


# Mars: rover track erasure

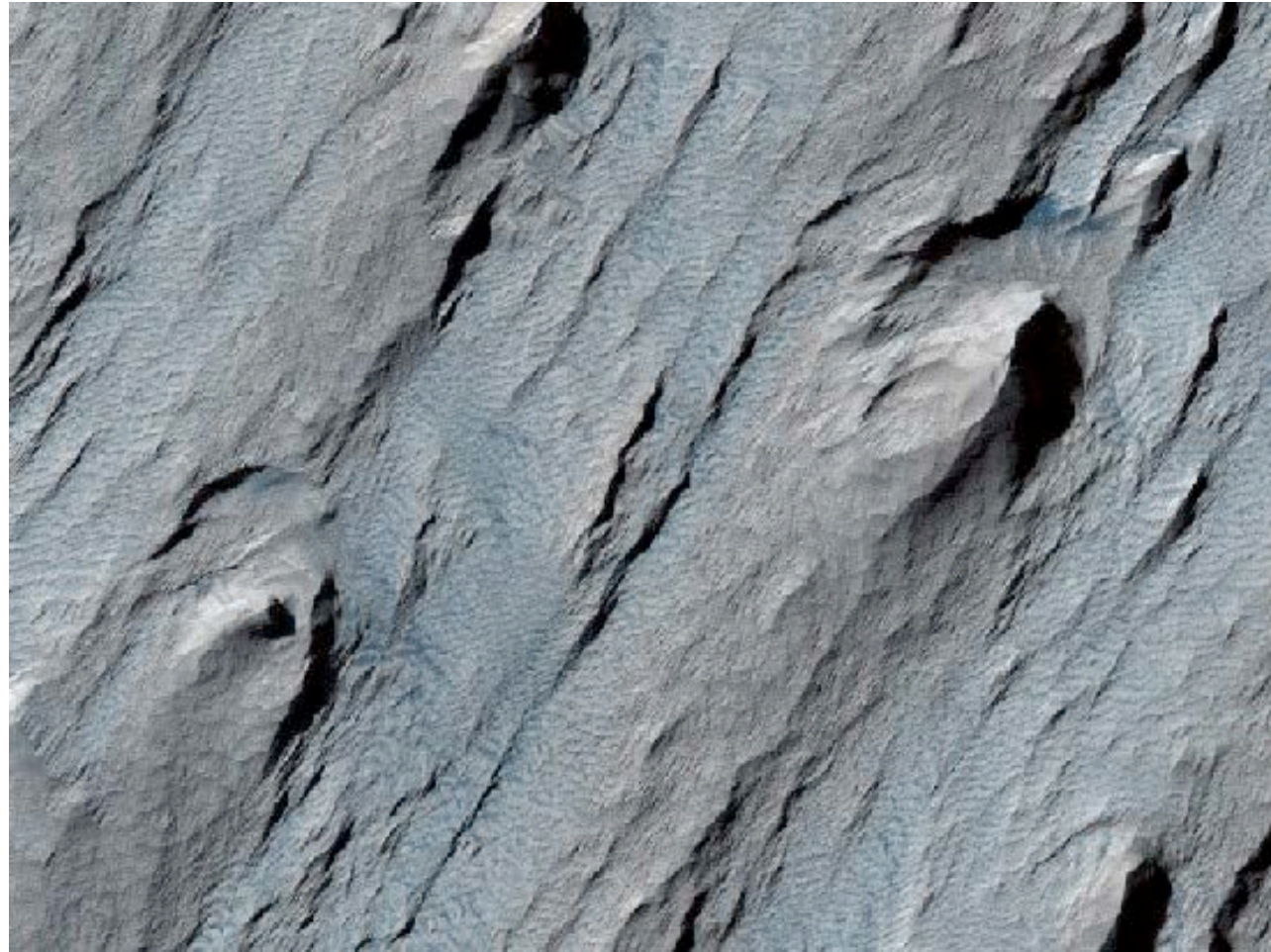


Geissler et al. (2010)

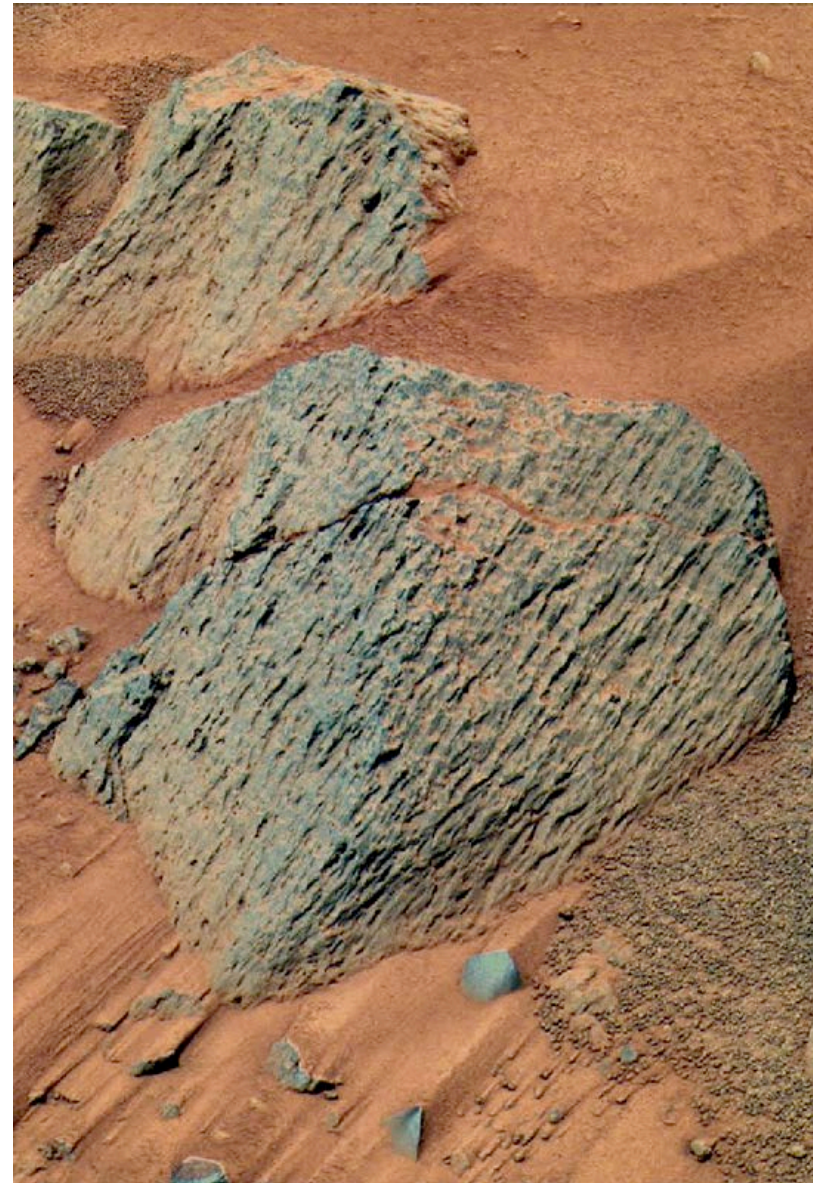
# Moon: rover track erasure (not)



# Wind also erodes: Martian yardangs



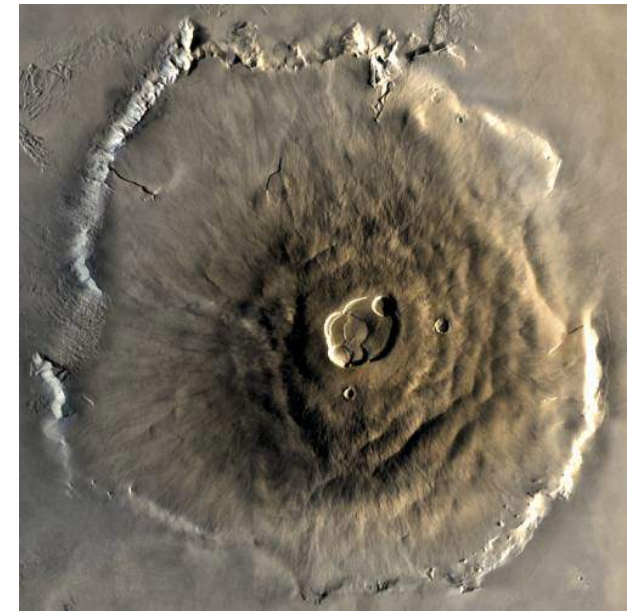
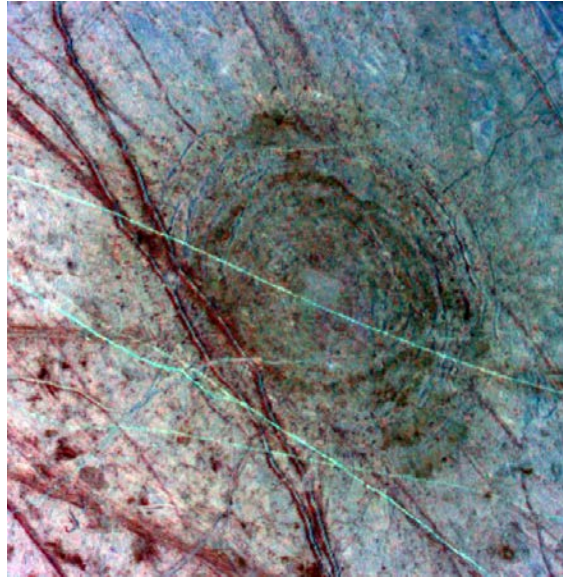
# Wind also erodes: ventifacts





# Planetary Surface Processes

Cratering  
Gravity  
Tectonics  
Volcanism  
Winds  
Fluvial  
**Glacial**  
Chemical  
weathering

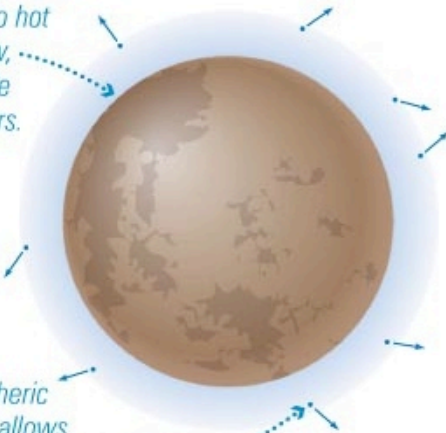


# Mars is the outermost terrestrial planet.

## The Role of Distance from the Sun

### Planets Close to the Sun

*Surface is too hot for rain, snow, or ice, so little erosion occurs.*



*High atmospheric temperature allows gas to escape more easily.*

### Planets at Intermediate Distances from the Sun

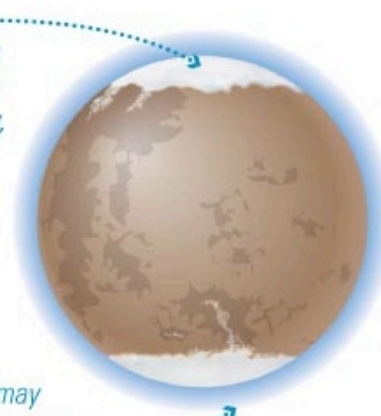
*Moderate surface temperatures can allow for oceans, rain, snow, and ice, leading to substantial erosion.*



*Gravity can more easily hold atmospheric gases.*

### Planets Far from the Sun

*Low surface temperatures can allow for ice and snow, but no rain or oceans, limiting erosion.*



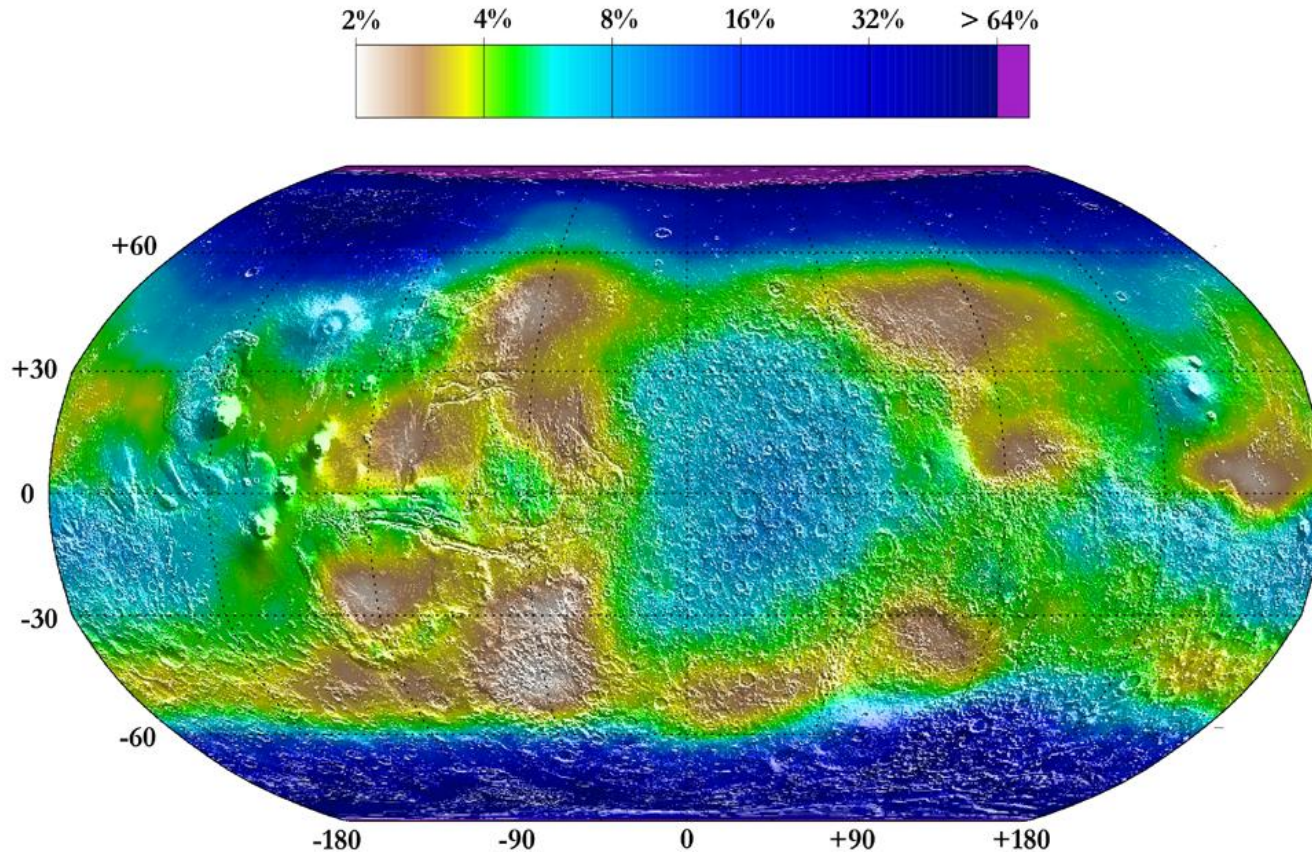
*Atmosphere may exist, but gases can more easily condense to make surface ice.*

# Where is Mars's water now?

- Lost to space
- In atmosphere
- Trapped in
  - Polar caps (at surface)
  - Ground ice
  - Mineral structures in rocks

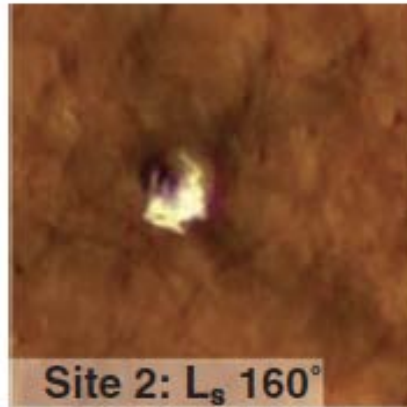
# Ground Ice (and hydrated minerals): Evidence from Neutron Spectroscopy

Lower-Limit of Water Mass Fraction on Mars

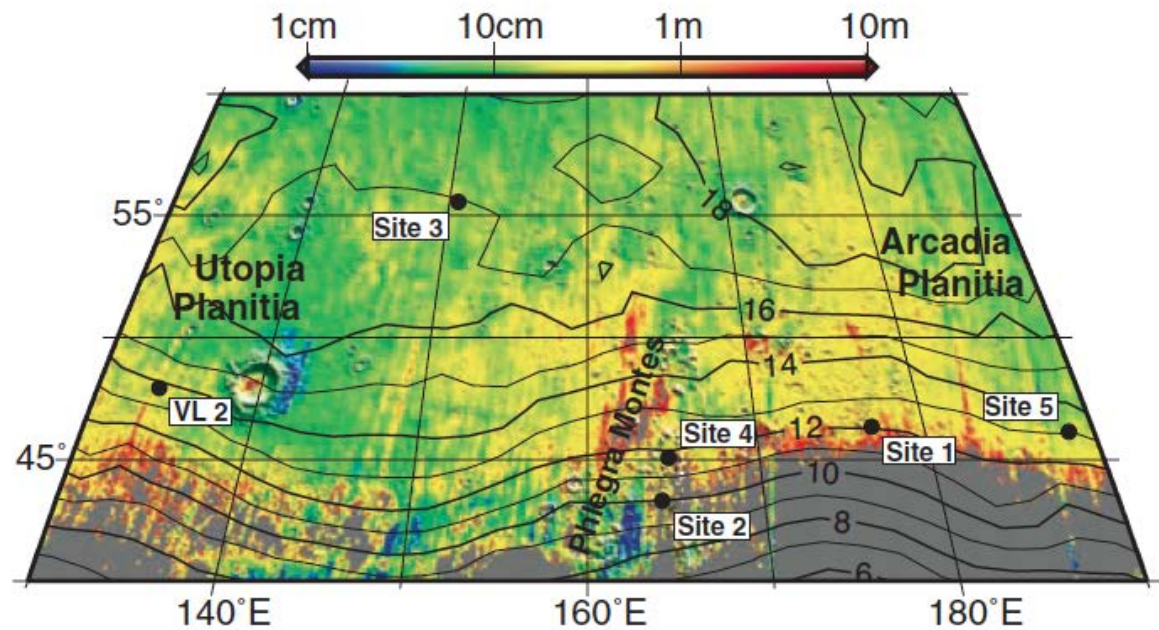
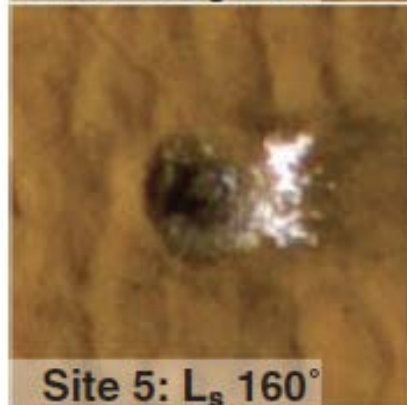


*Data from Mars Odyssey Gamma Ray Spectrometer, see for example Feldman et al. 2002*

# Ice revealed by impacts

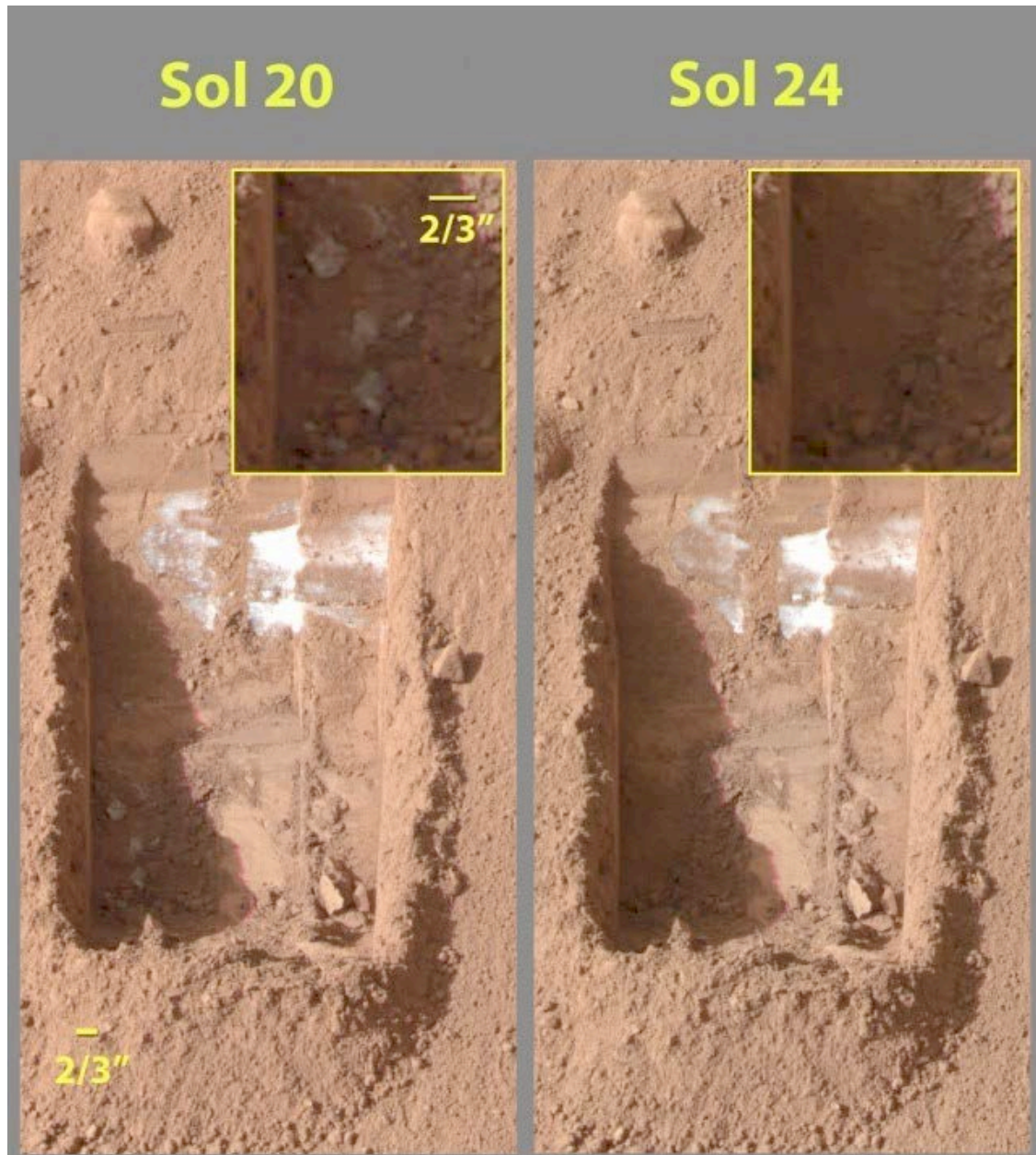


Observed to fade over time

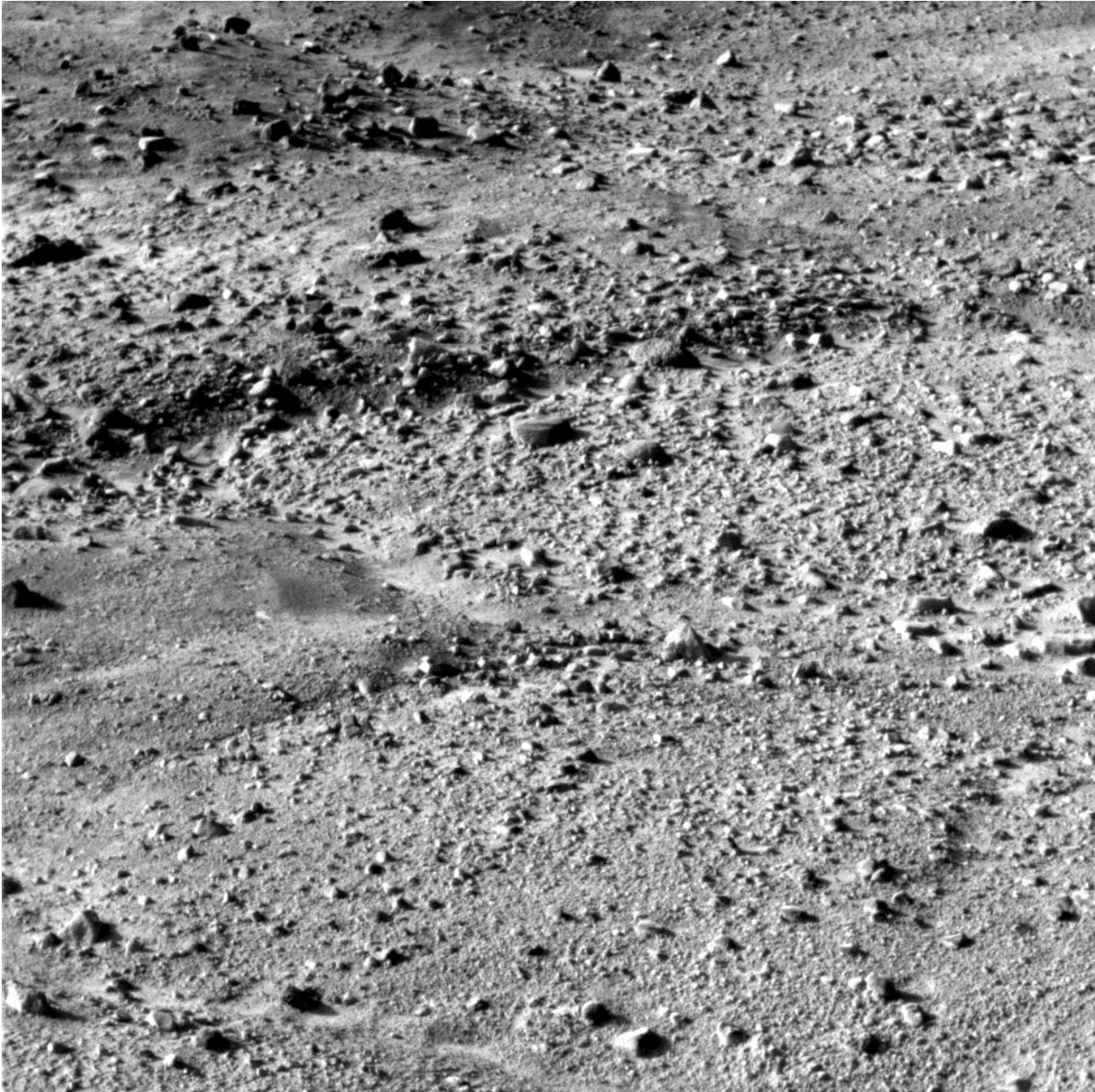


*Byrne et al. (2009)*

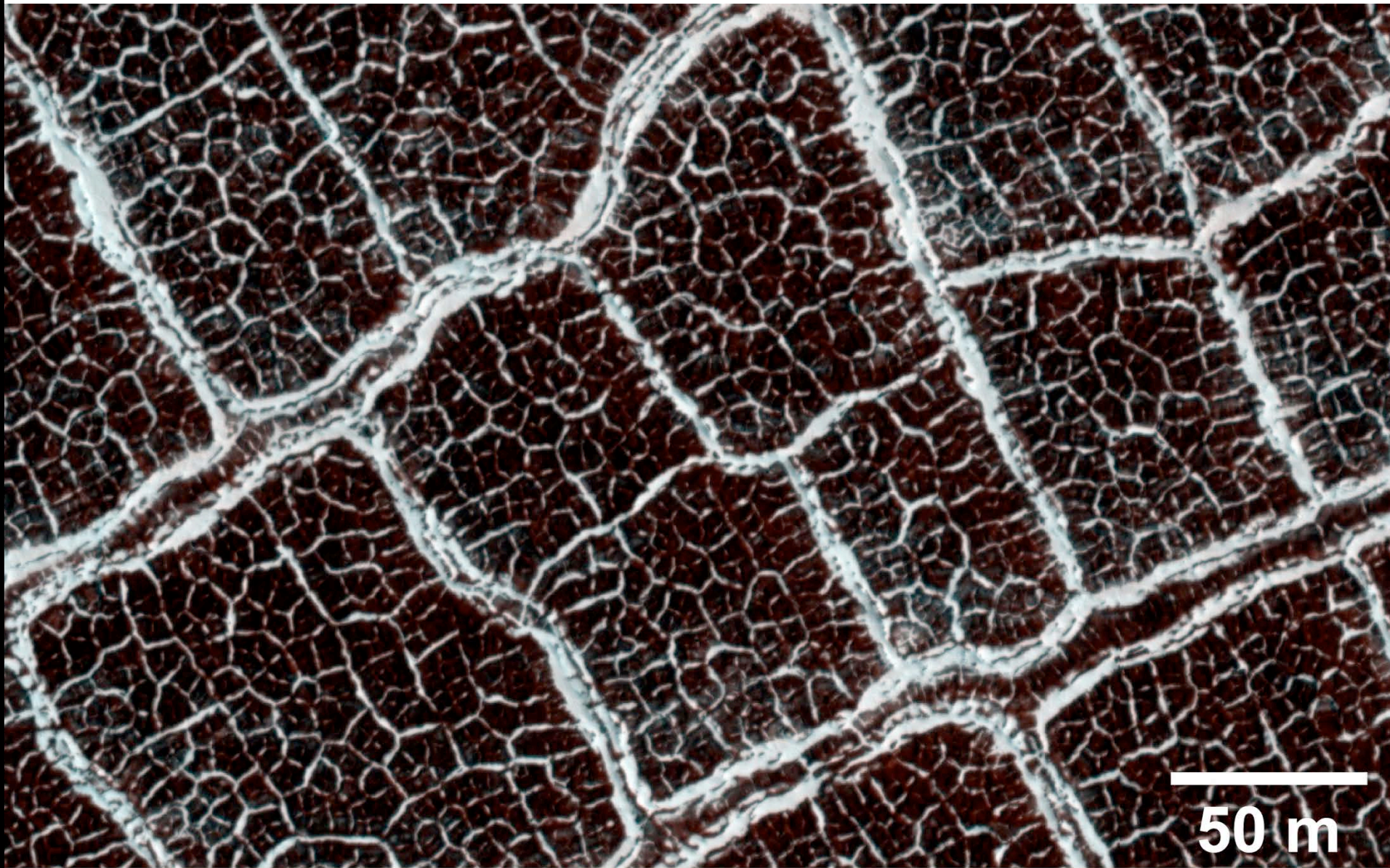
# Phoenix observed ice directly



# Polygonal patterned ground - Phoenix

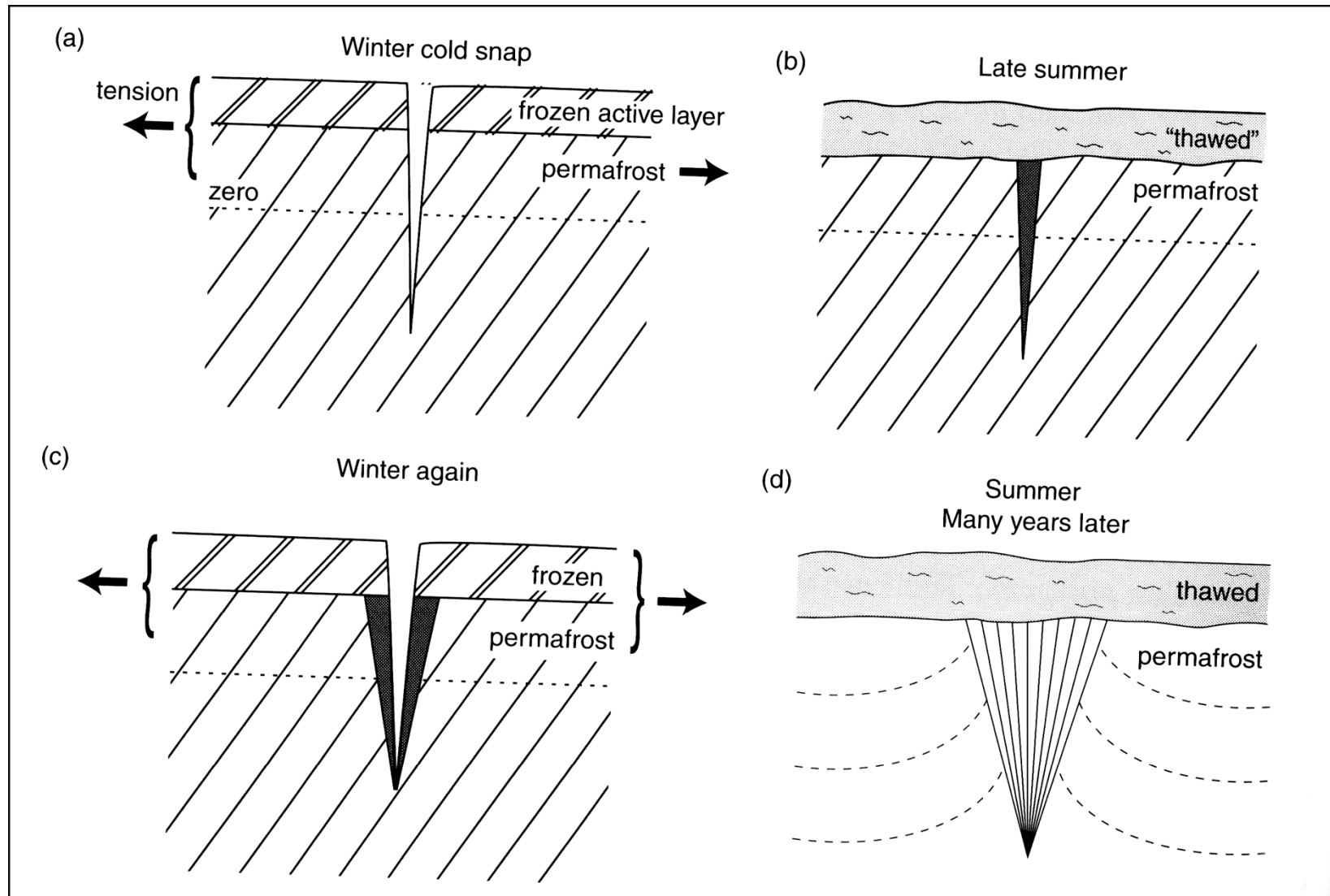


# Polygonal patterned ground - HiRISE



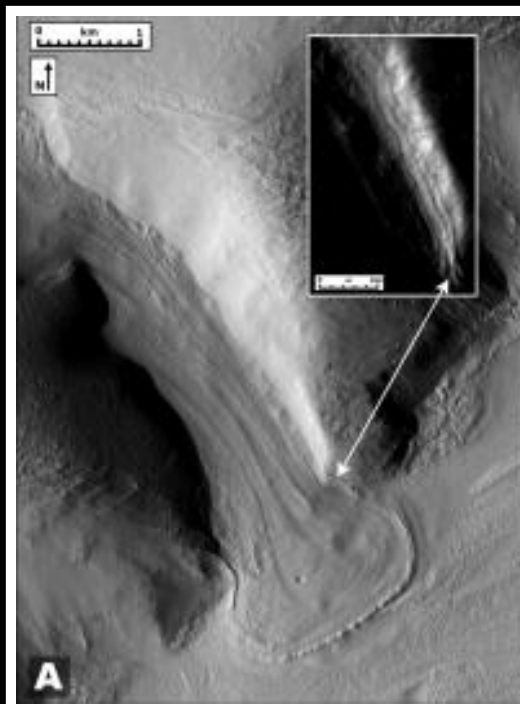


# Contraction crack formation

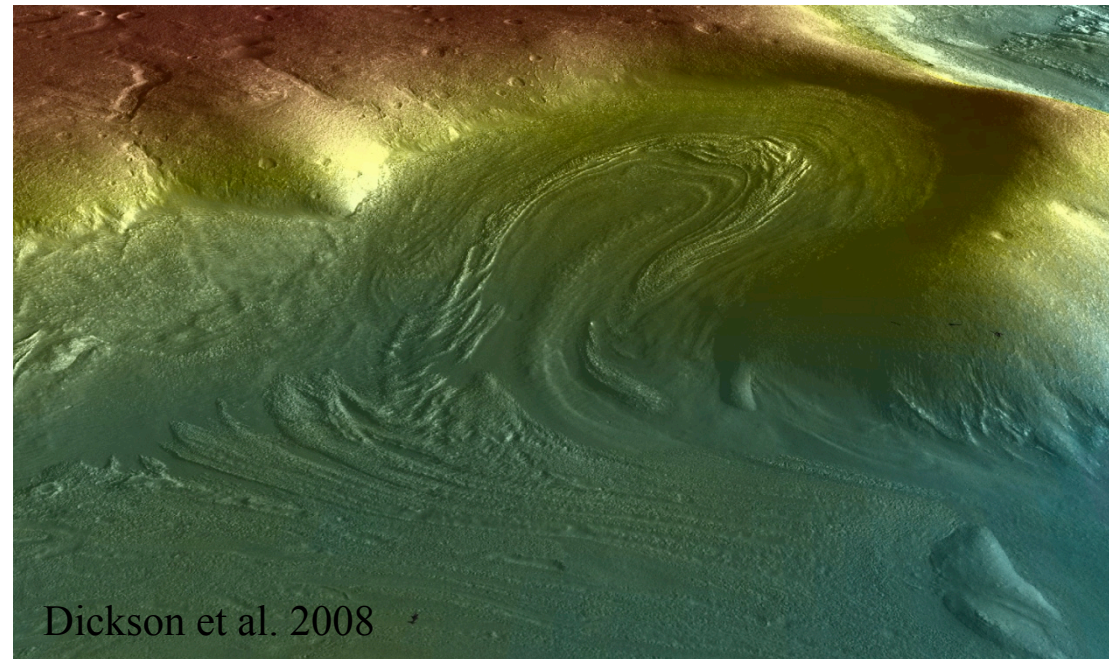
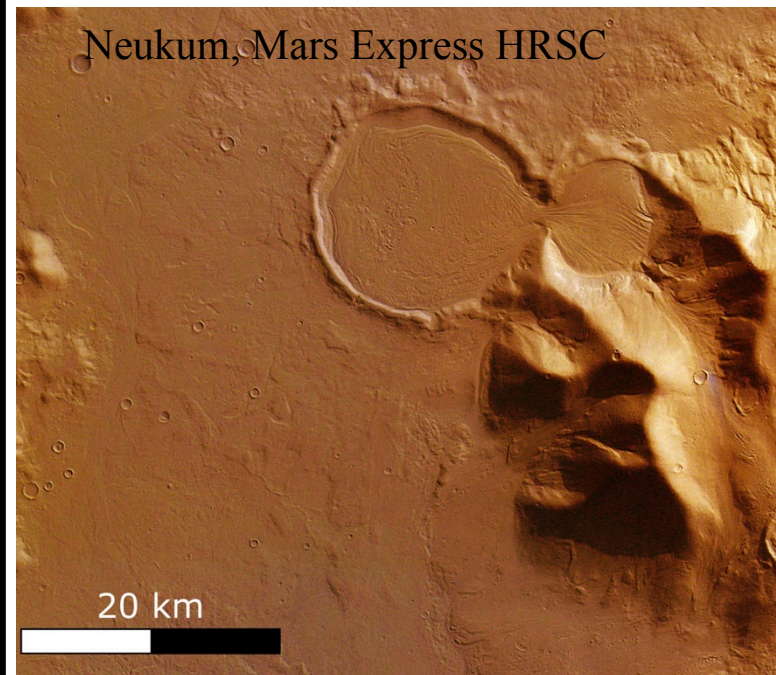


Melosh (2011)

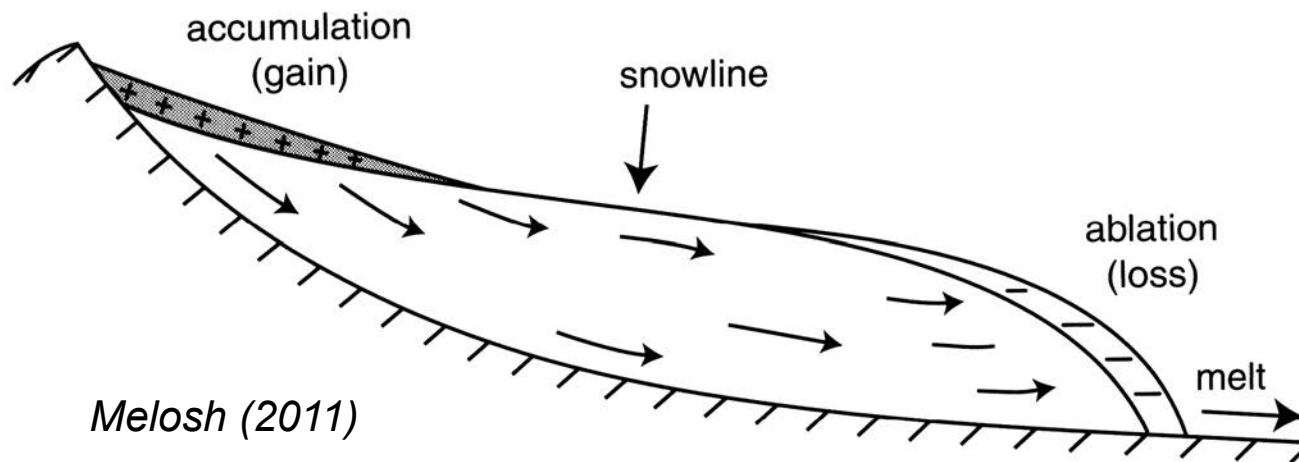
# Glaciers on Mars



Fastook et al. 2008



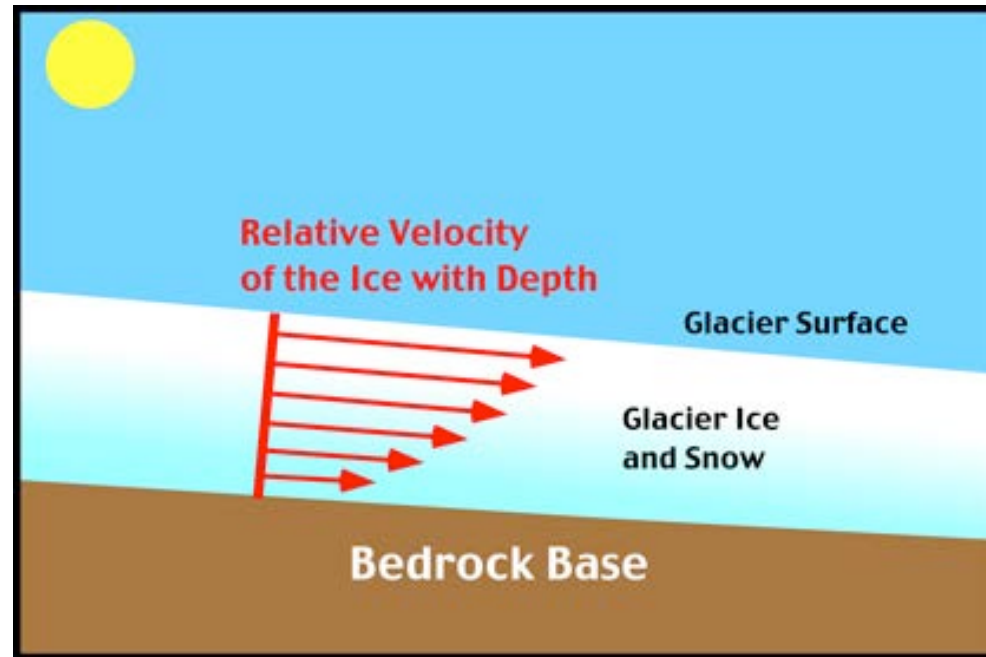
# A glacier at equilibrium



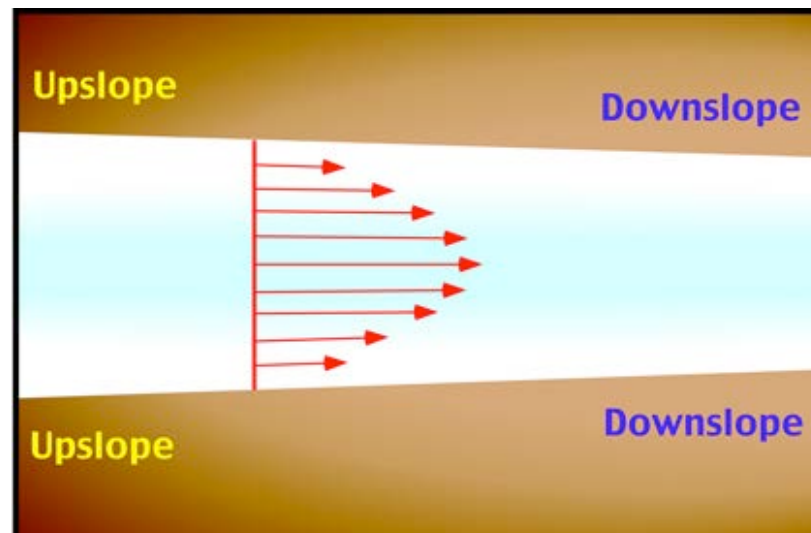
Melosh (2011)

# Flow velocity is not uniform

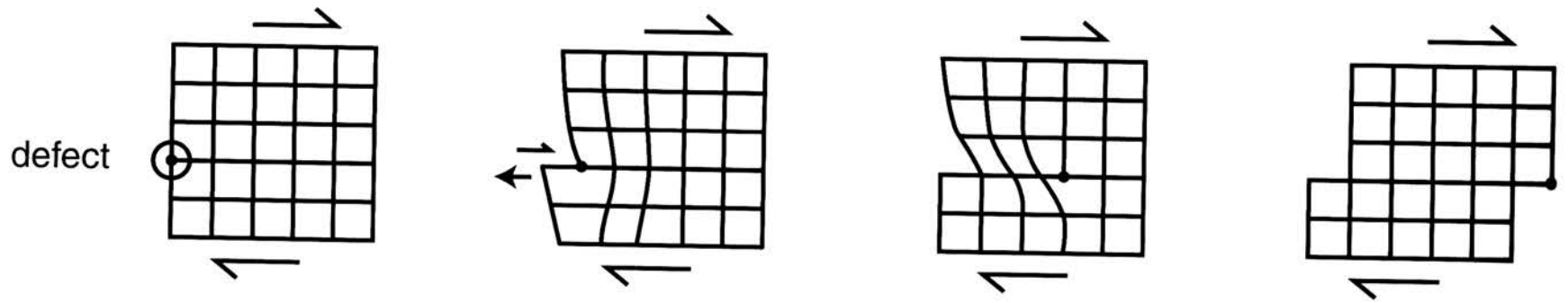
Side view:



Overhead view:

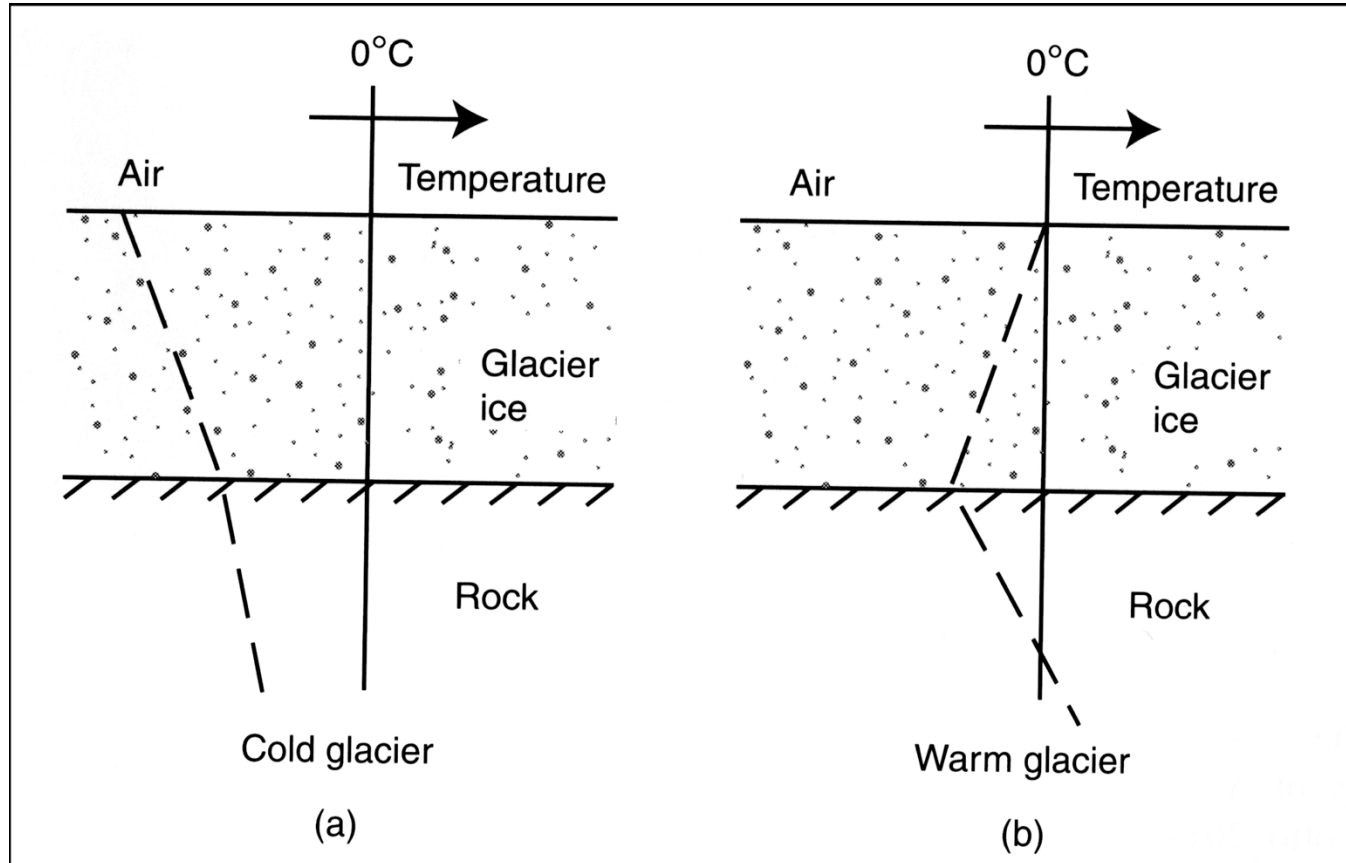


# Glacial creep

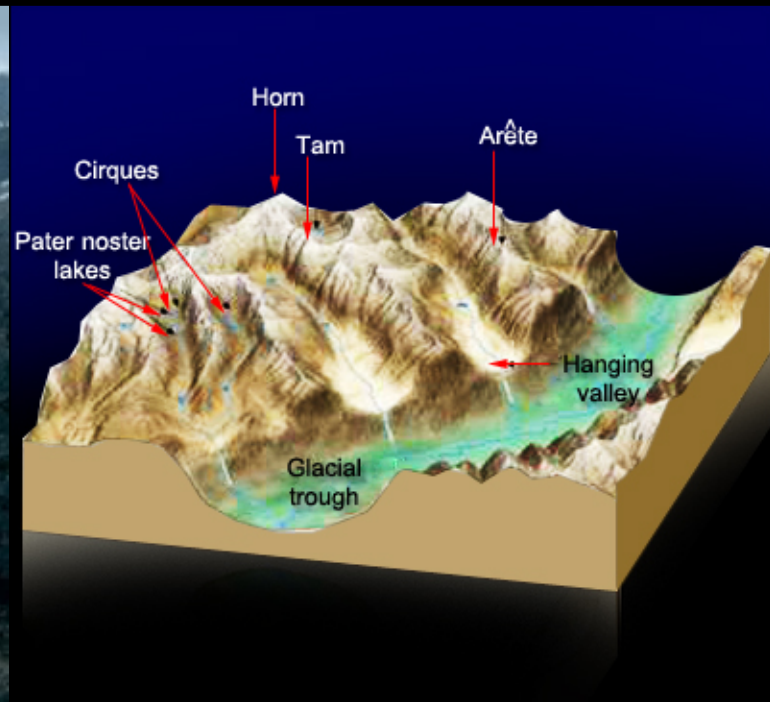


*Melosh (2011)*

# Cold vs. warm-based glaciers



*Melosh (2011)*



Glacial Valley

