

# Impact Crater Lakes and the Astrobiological Exploration of Mars

*NASA Astrobiology Institute Mars Focus Group  
Videocon (01/08/01)*

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# Criteria for Astrobiology Sites

- Evidence of water
- Presence of mechanisms to concentrate life
- Presence of thermal energy source
- Evidence of rapid burial (water or sediment, lava, ice...)
- Excavation or exposure in outcrops

# Science Priorities and Martian Environments

- Geologic History
- Climate History
- Chemical Evolution
- Fossil Life
- Extant Life
- Channels, Valleys, **Paleolakes**
- Channels, Valleys, Polar deposits, **Paleolakes**
- Deep Hydrothermal Systems, **Paleolakes**
- Thermal Springs, **Lakebeds**
- Frozen in ice, Current Hydrothermal sites, **Caves, Evaporites, Endoliths, etc...**

*Table adapted from Farmer and DesMarais, in Landing Site Catalog*

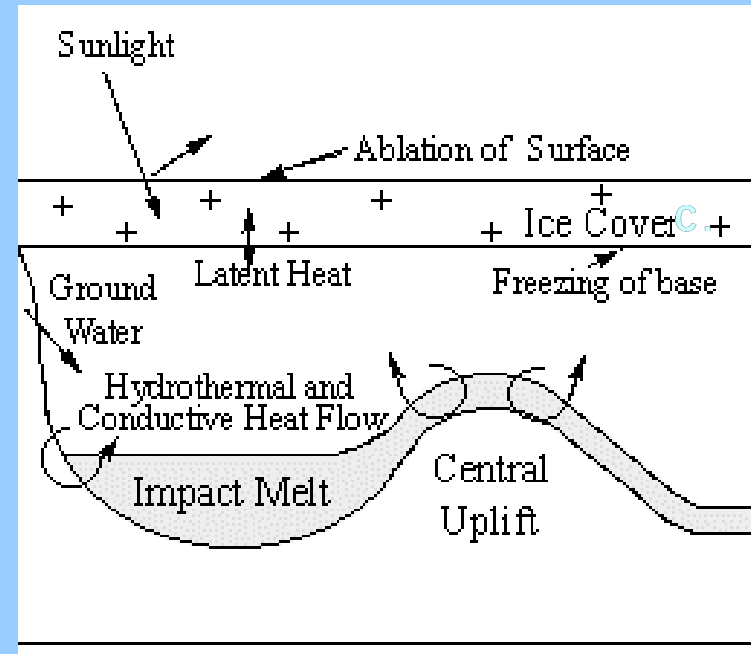
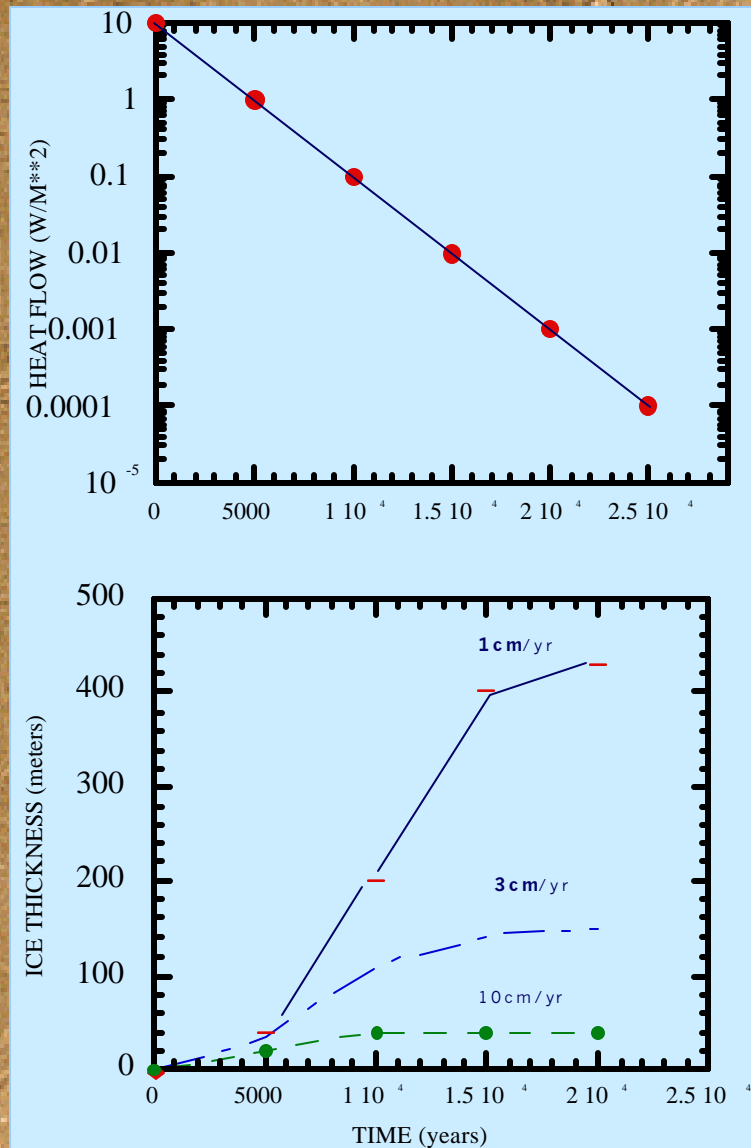
# Why Lakes in Impact Craters?

- Well-delimited topography
- Protected Environments (“Local” Climate);
- Unlike most other lakes, they were at some point in their history associated with a heat source.

⇒ Combining Water and Energy Source



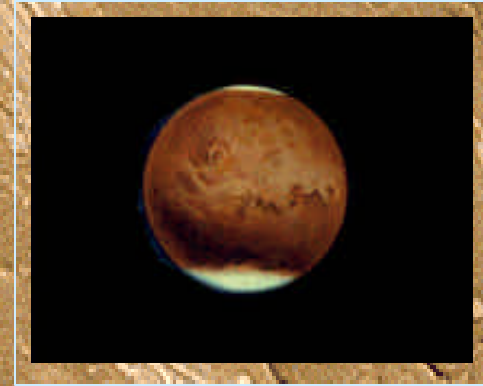
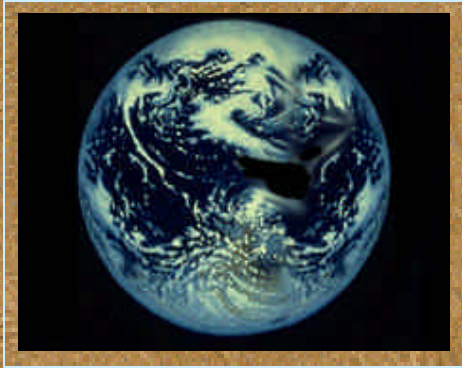
# Melt Material, Central Peak and Ice-cover



A. Declining heat from impact melt sheet;  
B. Ablation rate of an ice-cover (cm/yr) in a 65-km Ø crater with a 200-m thick melt sheet.

C. Energy Sources for an impact crater lake. Convective currents related to water temperature variations are associated with rotary currents related to channel flow. (Grin and Cabrol 1997)

# A Lake is Defined by:



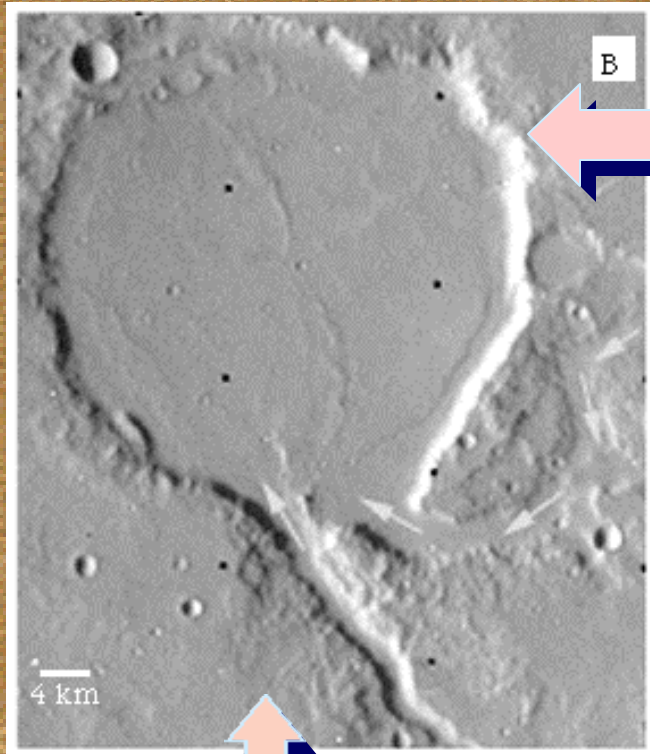
- Physical Processes;
- Hydrological Processes;
- Chemical Processes;
- Biological Processes

- Observed and/or can be modeled;
- Reconstructed from data;
- Poorly known

. ???

classification based on fluvio-lacustrine systems for Mars.

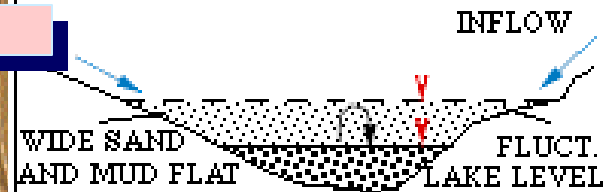
# Closed Lake System: Concentration with Lifetime (ancient)



Closed and deep crater basin without an outflow. Terraces in the channel suggest either there was several episodes of flow (several lakes) or one major episodes with fluctuating levels

After Cabrol and Grin, 1999 Icarus.

## **b** "CLOSED" LAKE SYSTEMS



SHIFTING FACIES BELT, REPEATED REWORKING AND DISSOLUTION OF SALTS

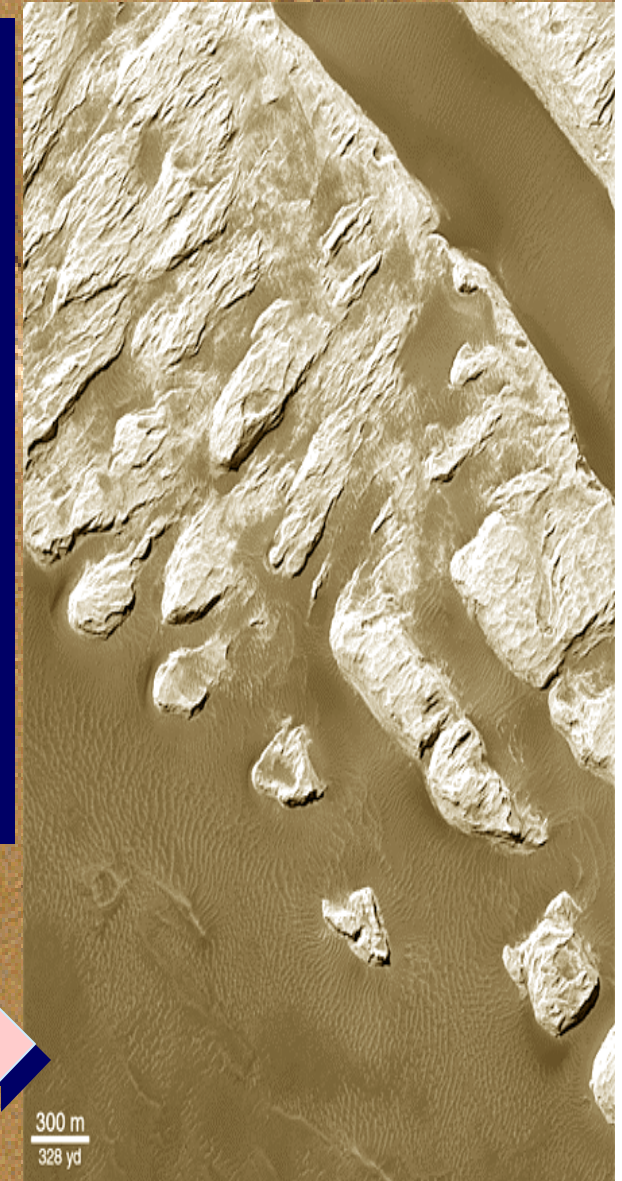
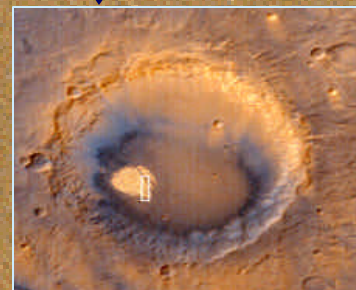
## **b3** EPHEMERAL LAKES (Playa, Inland Sabkha)

MUD CRACKS, CRUST OF MG-CALCITE, DOL. GYPS. OR HALITE

Freshwater  
Carbonate  
Spring

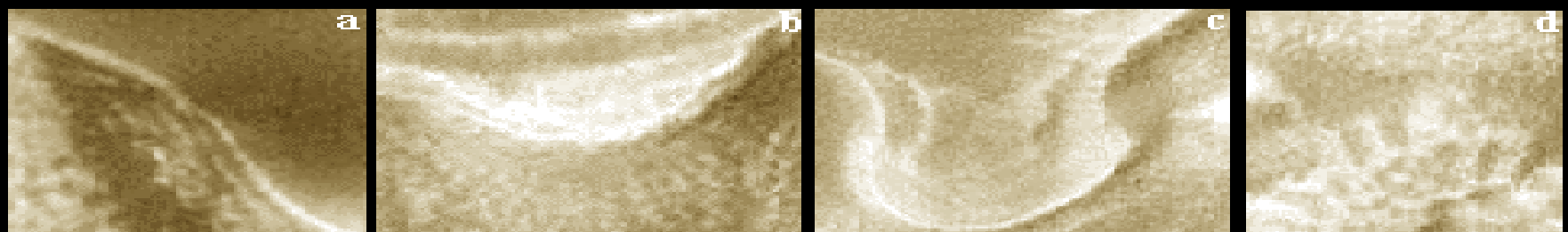
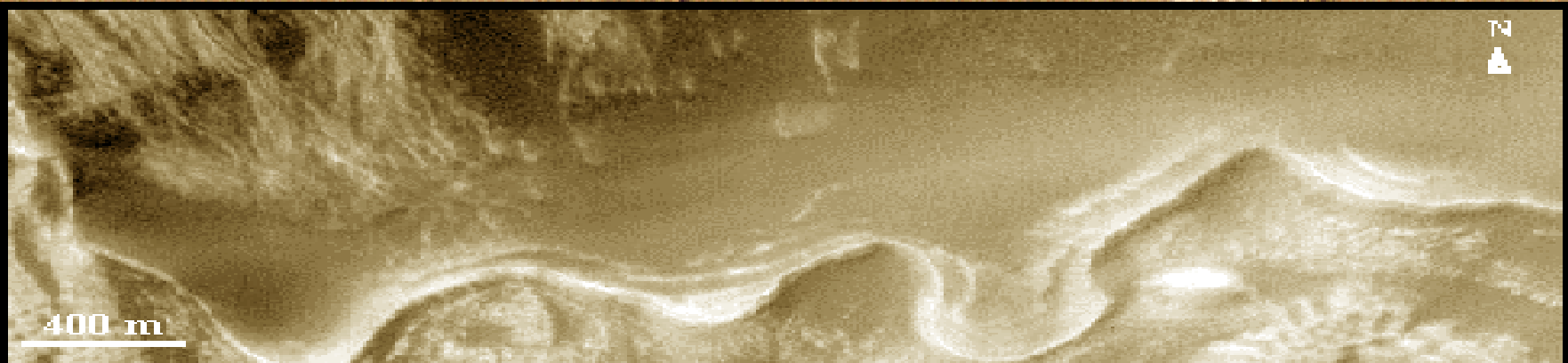
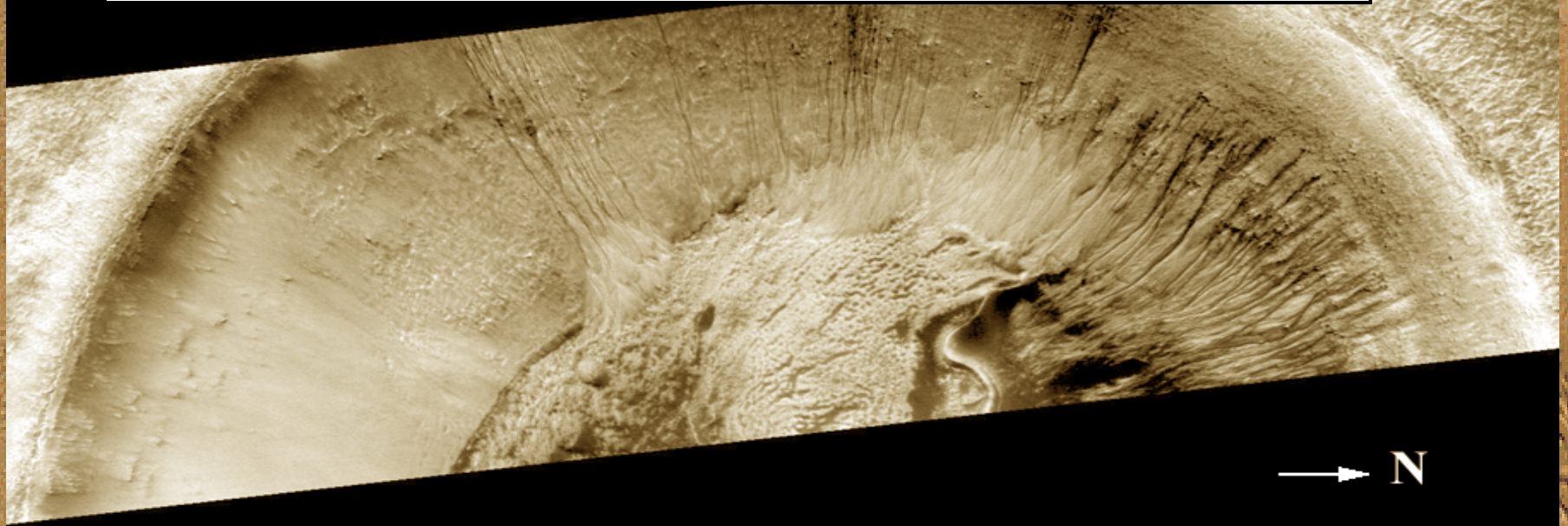
Evaporite pumping through high water table

CENTRAL THIN SALT DEP.  
ALTERN. WITH CLASTICS



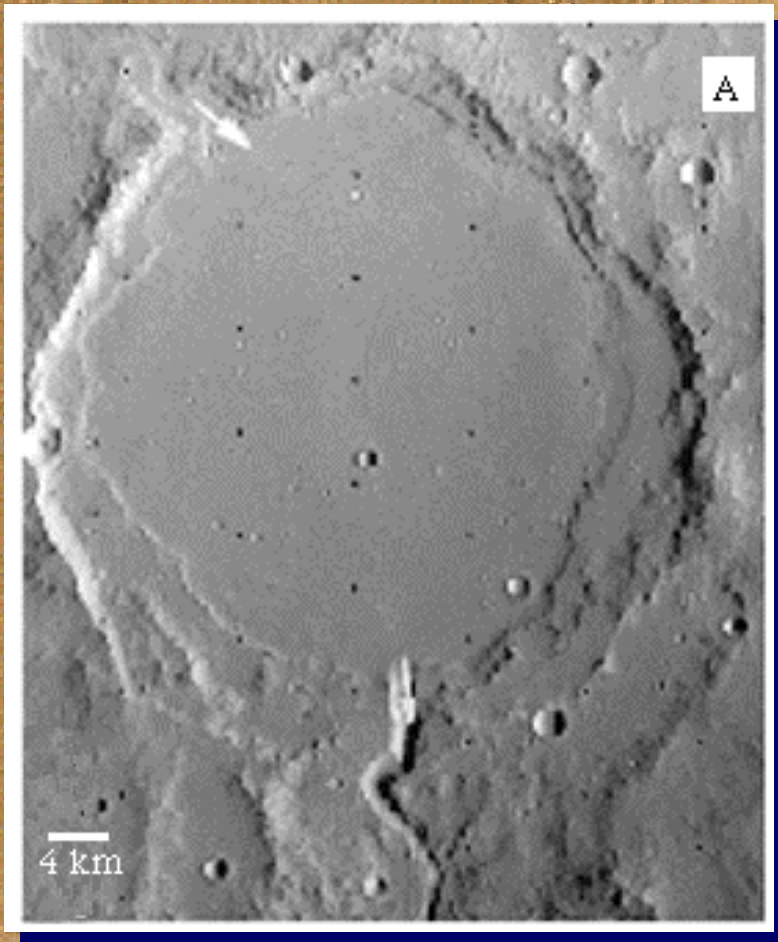


# Closed Lake/Pond System: Recent?



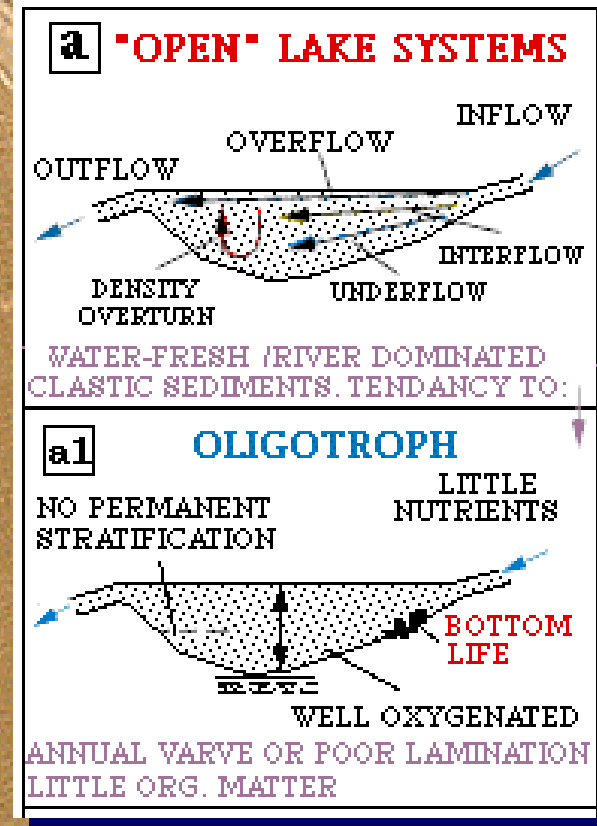


# Open Lake System: River-Dominated



Example of open crater lake system in the Memnonia NW region of Mars. Open crater systems may have experienced a “closed” phase before channels cut through the rim and outflow from the basin. This episode might be found in deep sedimentary record.

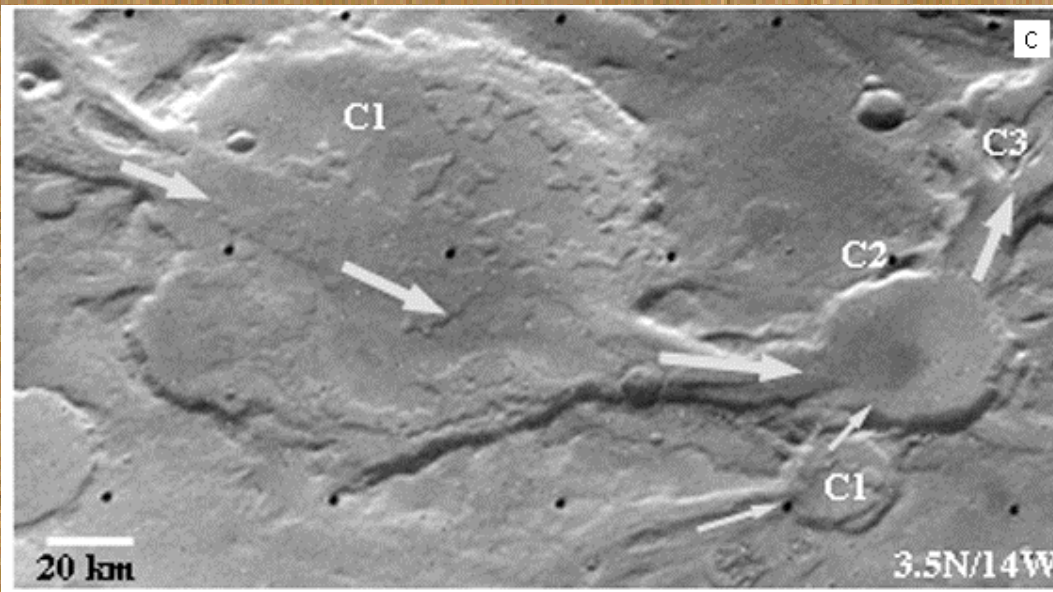
*After Cabrol and Grin, 1999 Icarus.*



(a) River dominated clastic sediment. The lake water chemistry is river-dominated. Search for parent-rock;

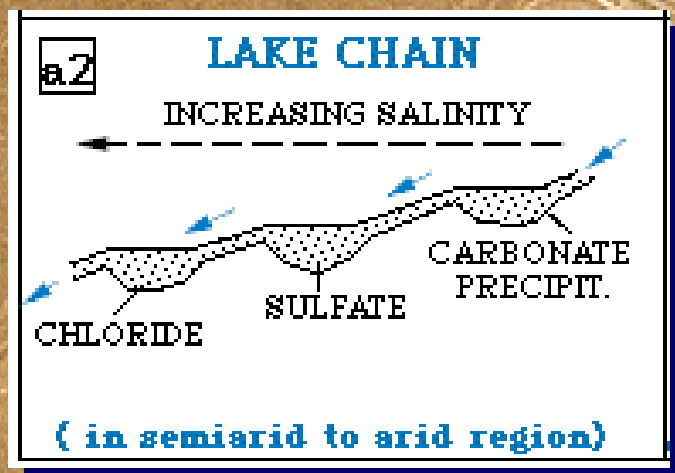
(a1) Episodes of flow recorded in varves; layers. Importance of near-inlet shoreline to search for life.

# Lake Chain System: Fractioning of Evaporites



Chain of impact craters connected by a channel, with 3 open components. Fractioning of evaporites, and clasts, from C1 to C3.

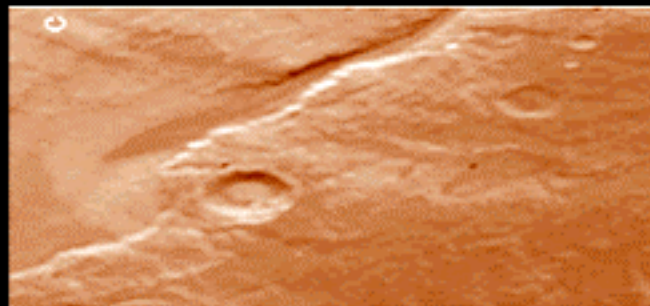
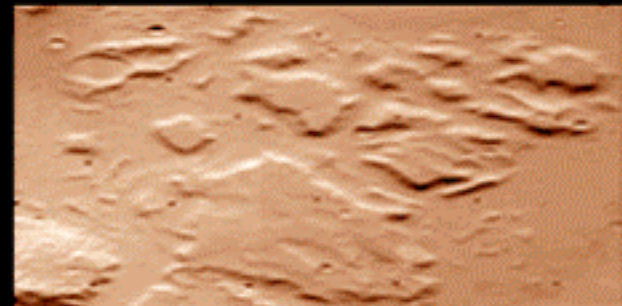
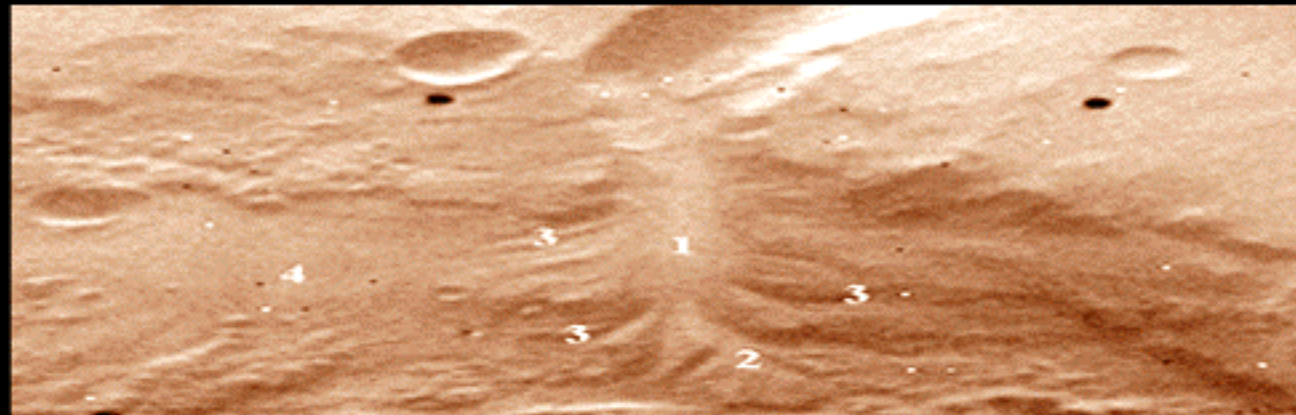
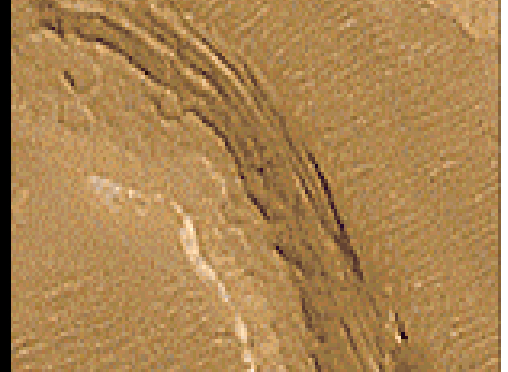
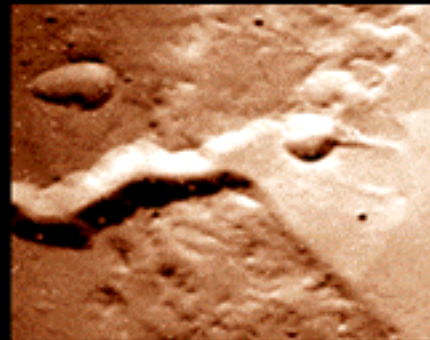
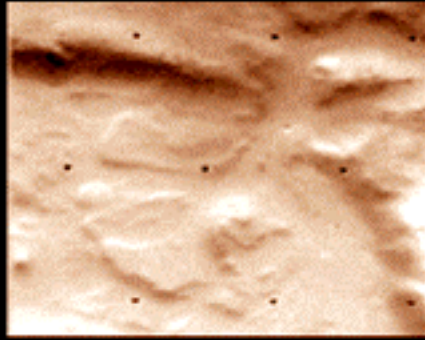
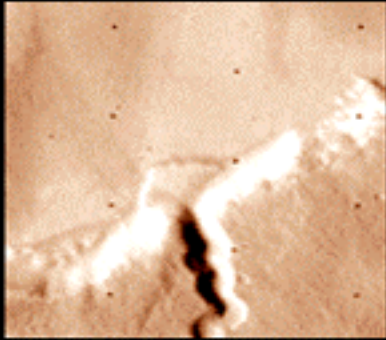
The degree of concentration is predicted to be higher for crater lake chain supported by long-lived runoffs than for short outburst of outflows.



*The degree of salinity and evaporite fractioning will vary depending if the system ends by a closed or an open basin.*



# Lacustrine Deltas in Impact Craters



**Deltas provide vertical facies succession, with indication of climate and atmosphere (composition, thickness, and grain-size of sediment; hydrological regime; geologic history in sequence. Sites to search for fossils.**

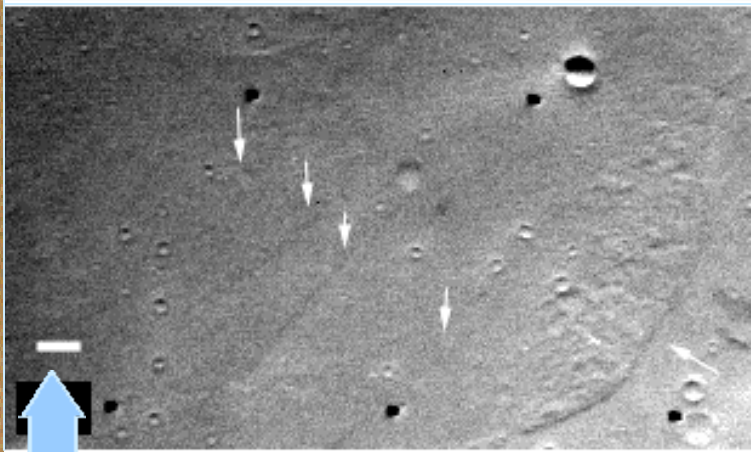
# Terraces and Layered Sedimentary Deposits

## Lacustrine Terraces

*Open window on hydrogeological variations during the lake lifetime.* Lacustrine Terraces, and Structural Terraces provide access to ancient crust material and subsequent sedimentary and geologic history. Climate accessible by morphologic analysis and sediment mineralogical composition. Sites to search for fossils.



# • Shorelines, Mounds, Evaporites



Margin of deposits and traces of waning



## Mounds associated with shoreline

They could be either relics of ancient sedimentary deposits or tufas towers as suggested in recent works.

**Tufas Tower:** sites for diversified communities of bacterias. They are observed near shore.



## Evaporites

- Climate, regional envir.
- Chemistry of the basin
- Lifetime of crater lake
- Can host microorganisms

# What Environments for Life in Martian Impact Crater Lakes

- Water: *prerequisite for Life*
- Evaporites (carbonates, sulfates...): *Halophiles...*
- Caves (dissolution, thermokarst, cracks): *Troglodytes*
- Sediments: *Endoliths, chasmoendoliths, Chemolithoautotrophic organisms, etc...*
- Hydrothermal Systems: *Thermophilic Bacterias*
- Ice: *algae...*

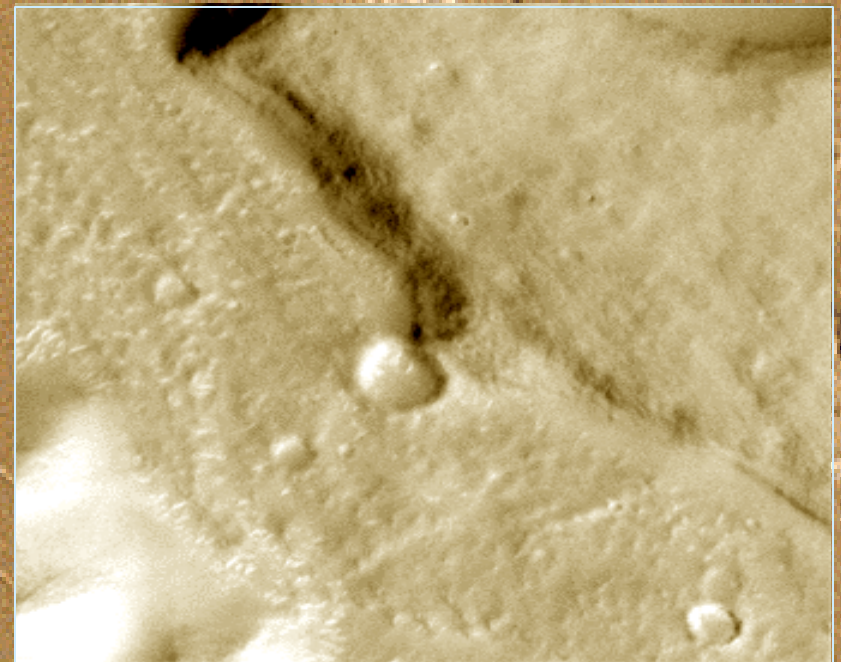
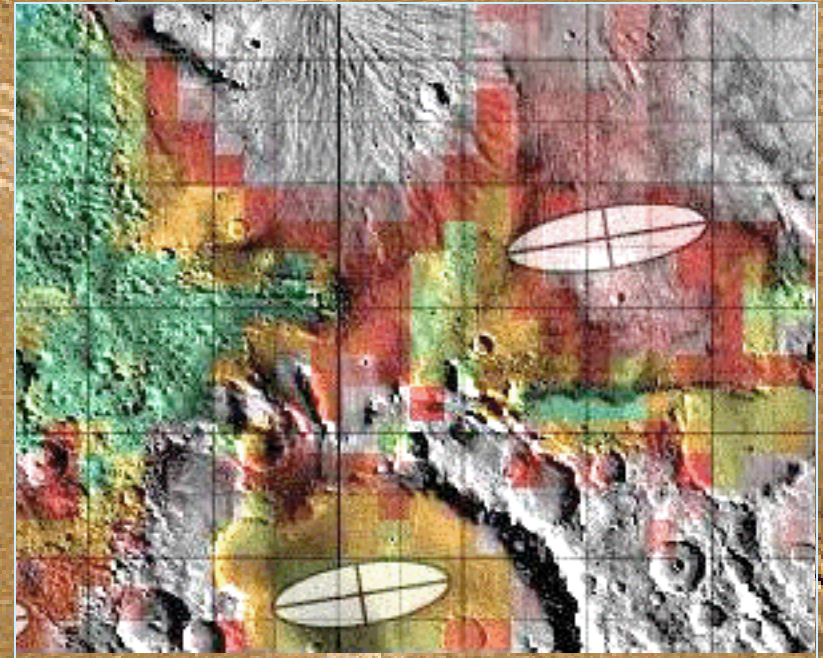
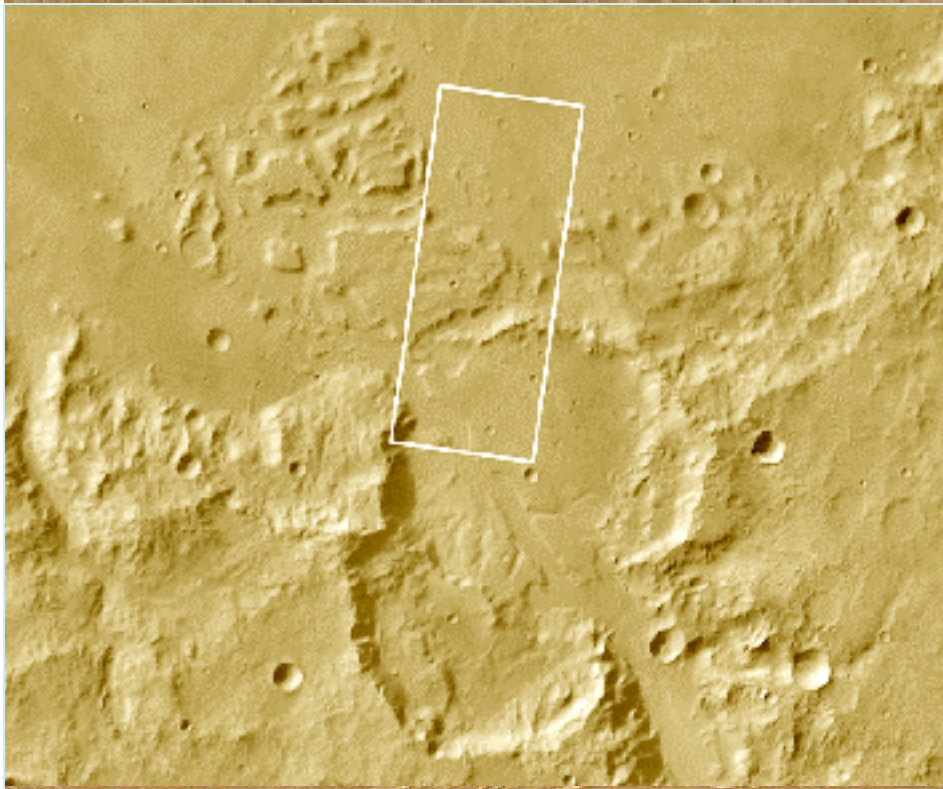
Fossils *in Layers, Terraces. Possibly at surface if excavated by young impacts*

# Some Favorites: 2003 and Beyond

- ~ 180 Impact Crater Lakes at Viking Resolution
- Probably thousands will be discovered at MOC and M-Ex Res.
- Latitudes should not be a constraint for studies as it varies with mission windows of opportunities and landing precision will be improved with future technologies.
  - Gusev (2003?)
  - Gale (2003?)
  - Schiaparelli (2003)
  - 7-km crater in Newton
  - Many others (Holden, Galle, Pollack, etc...)

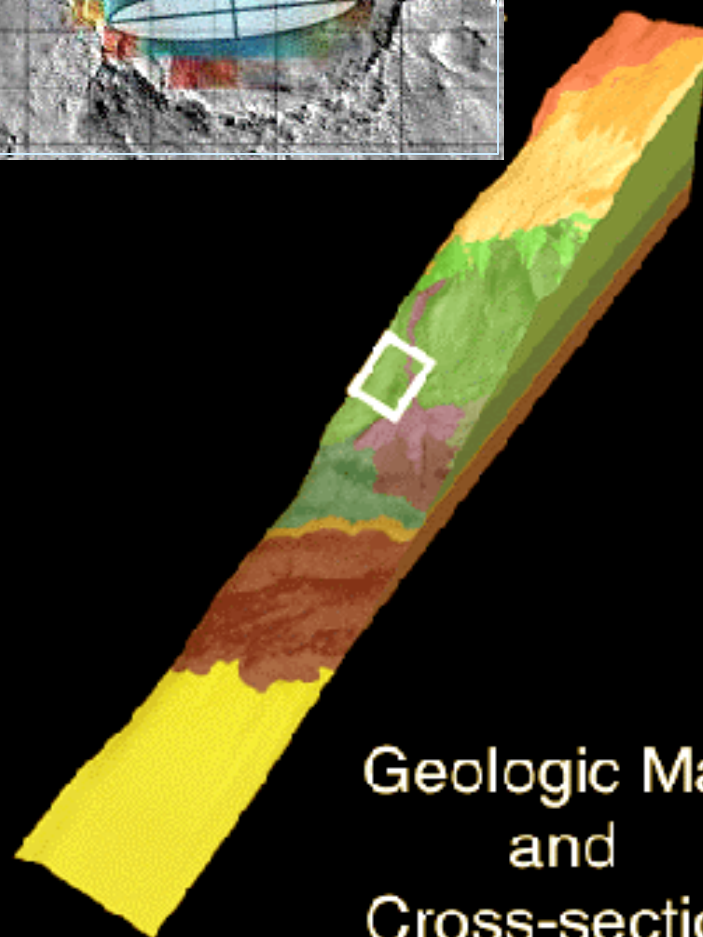
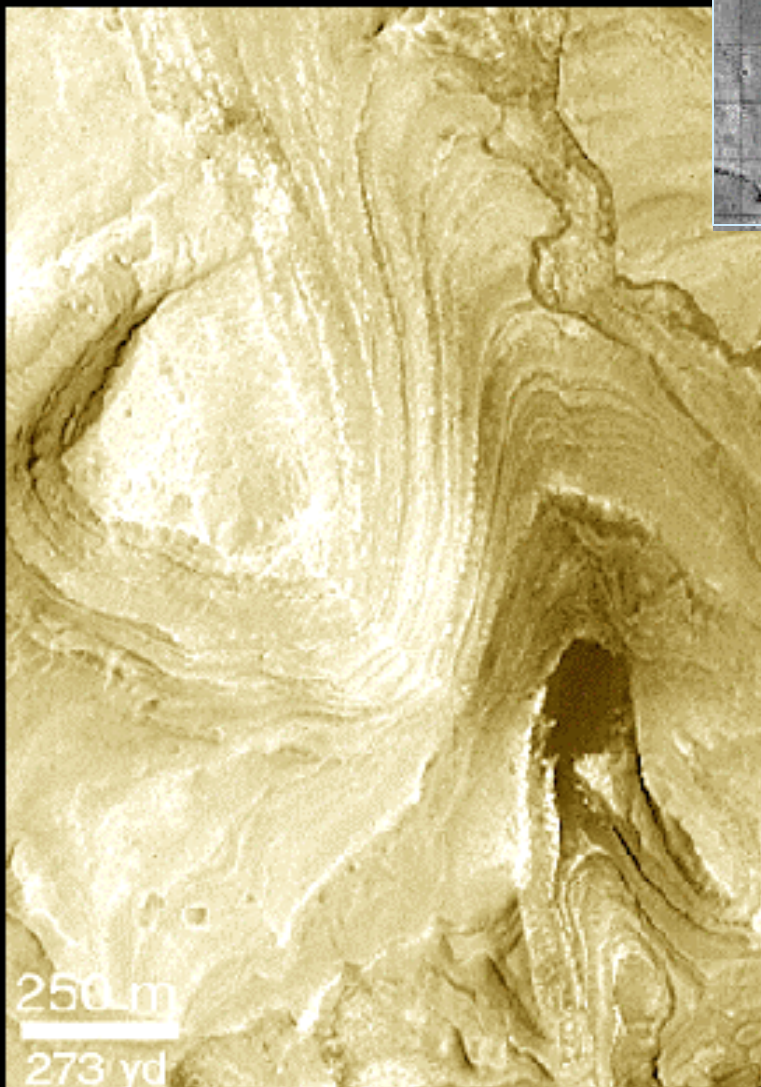
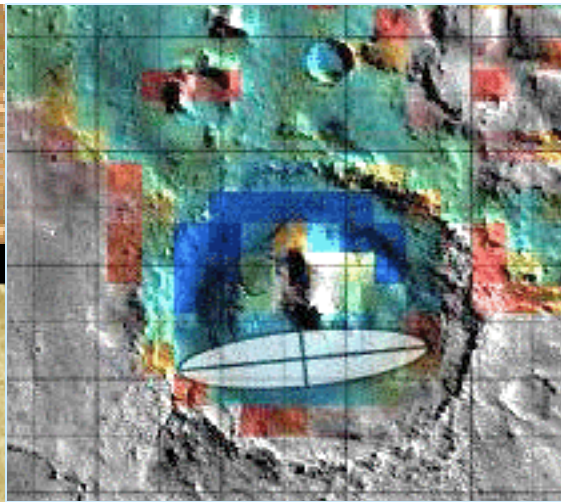


# Gusev





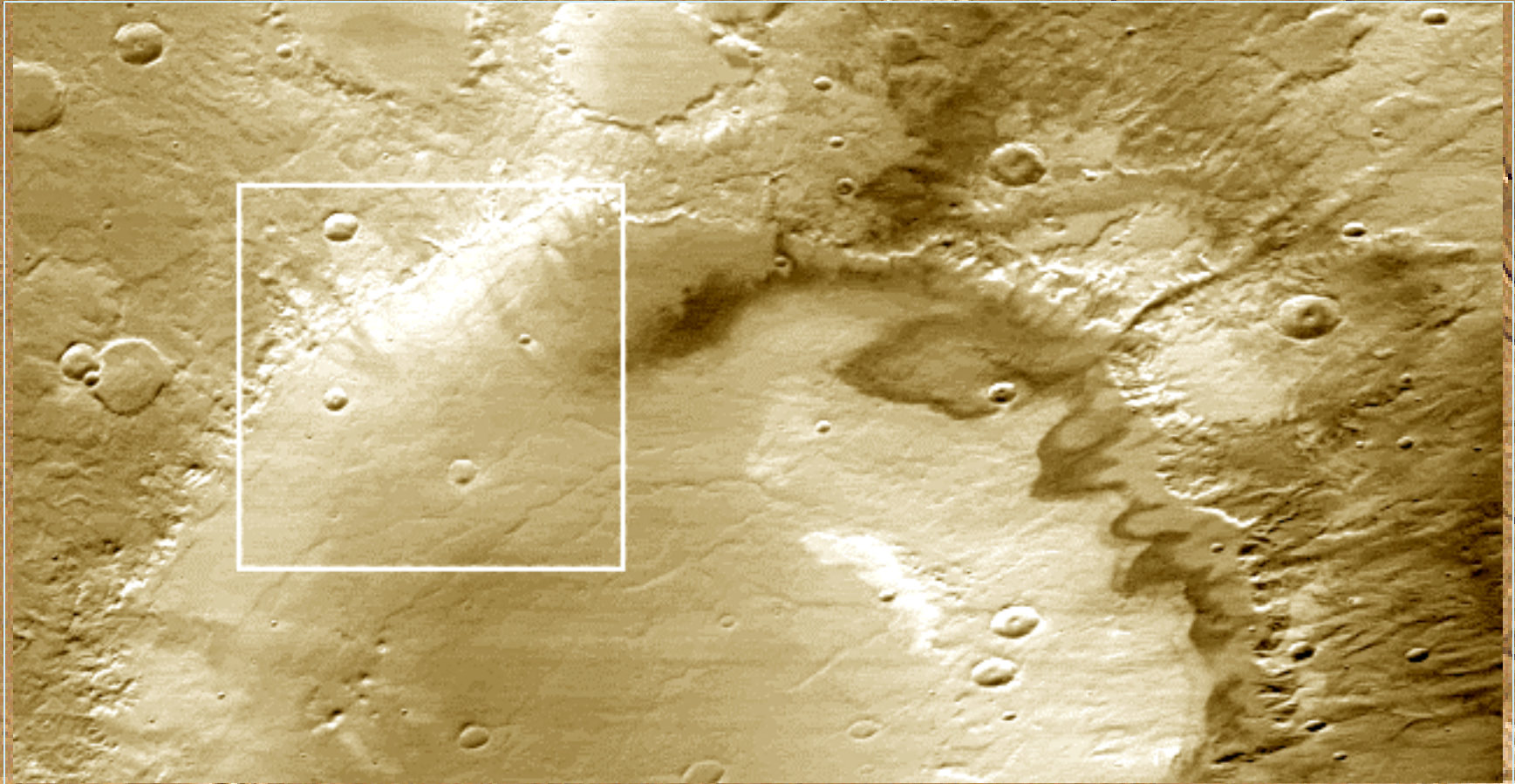
# Gale



Geologic Map  
and  
Cross-section



# Schiaparelli



# C-Newton

