

# **<sup>AV</sup>River Deltas in Crater Lakes on Early Mars**

By

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## **Abstract**

There remains significant debate as to whether there were persistent water flows, significant precipitation and standing water bodies during the early Noachian history of Mars. Recent Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) images of meandering channels associated with a Noachian-age, lacustrine delta within Holden NE Crater show evidence for persistent water flows.

The topmost layer shows clear evidence of meandering streams associated with four depositional lobes. The channels record a complex history of migration, avulsion and bifurcation, forming a distributive pattern with up to 5 orders of branching. Several channels show a distinct transition from initially straight, to highly sinuous followed by classic chute cutoffs.

Relatively smooth, and more brightly reflective layers deeper in the crater fill may represent more-flat lying lacustrine bottom sets, and could speculatively be evaporitic. The transition from smooth lower layers that lack channel belts, to straight channels to meandering channels suggest a progressive evolution of the sedimentary fill.

Our analysis of the surface features, as well as estimates of accumulation rates of the underlying 150 meters of strata within the crater fill, suggests that Holden NE Crater may have contained a lake that persisted for a few thousand to possibly as long as a few million years. This supports the hypothesis that early Mars was both warmer and wetter during the Noachian. In addition, these sediments represent a probable watery habitat that should be investigated for evidence of possible extinct Martian life.



# River Deltas in Crater Lakes on Early Mars

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# Environments on Early Mars

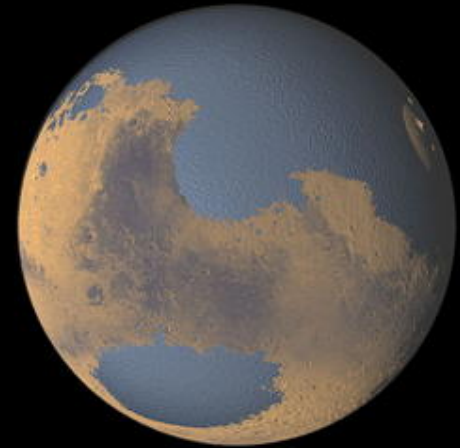
- Mars may have been hotter and wetter in early history.
- Escape velocity of Mars much lower than earth, so atmosphere has long since escaped.
- Could life have evolved on early Mars?
- Evidence for water compelling.
- Present Nasa Mission's have found evidence for water that could indicate potential habitats for life.

# Martian History

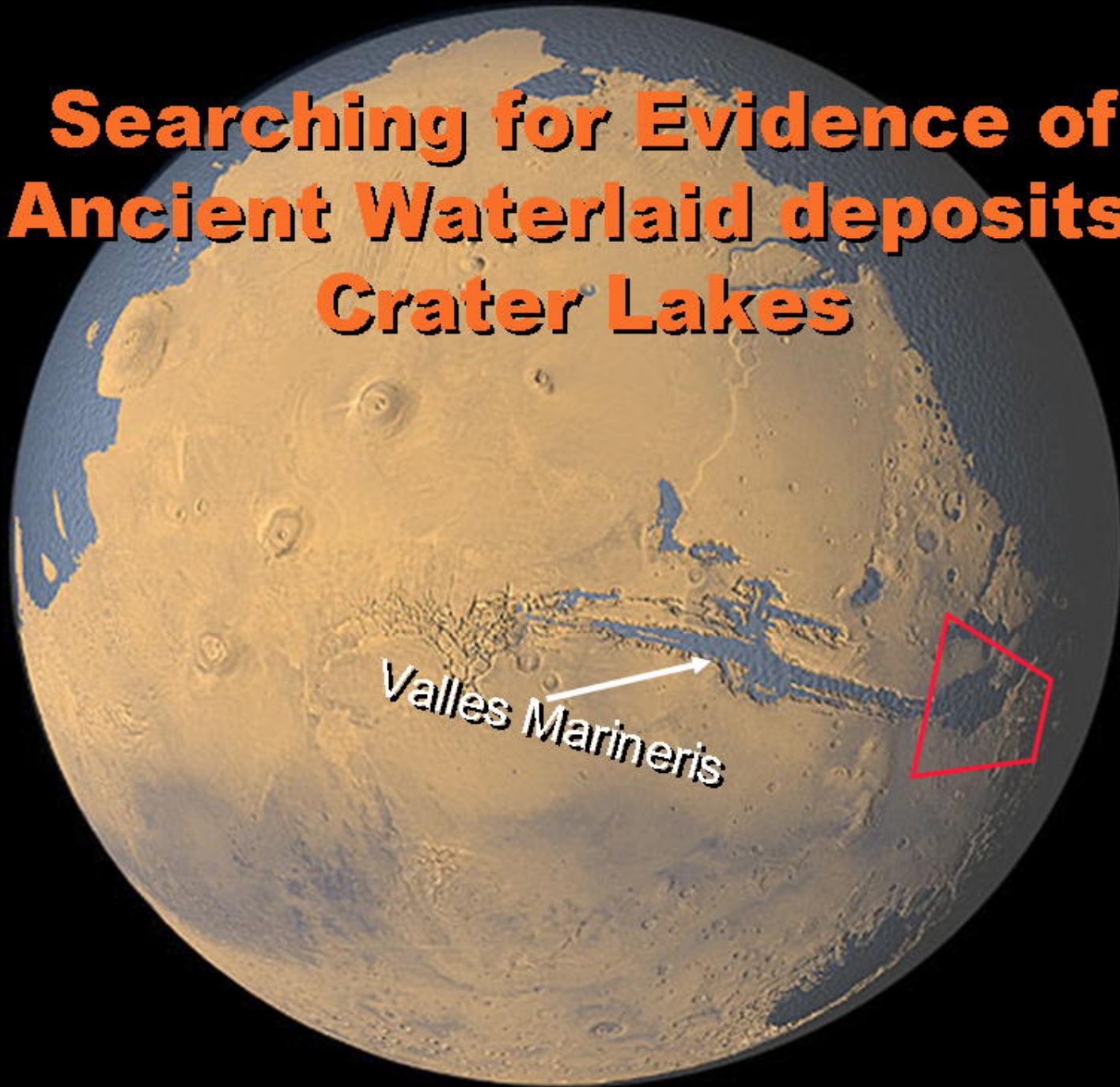
- Noachian: 4.5Ba - 3.5Ba
  - Heavy bombardment
- Hesperian: 3.5 - 2.0Ba
  - Moderate bombardment
- Amazonian: 2.0Ba - present
  - Light bombardment
- Mars is tectonically inactive and has been that way for most of its history.
- Near complete record of Archean.



**Views of  
hypothesized  
watery Mars**  
Goddard Space  
Flight Center,  
2001



# Searching for Evidence of Ancient Waterlaid deposits: Crater Lakes



# Themis Image Map of Mars

Smooth Amazonian Plains (young surface covered with aeolian dust)

Mons  
Olympus

Opportunity Rover Site

Valles Marineris

Holden Crater

Noachioan-Hesperian Heavily cratered uplands (better  
chanced to find "Archean" sediments)

[http://themis.asu.edu/mars-bin/mars\\_cgi\\_map.pl](http://themis.asu.edu/mars-bin/mars_cgi_map.pl)

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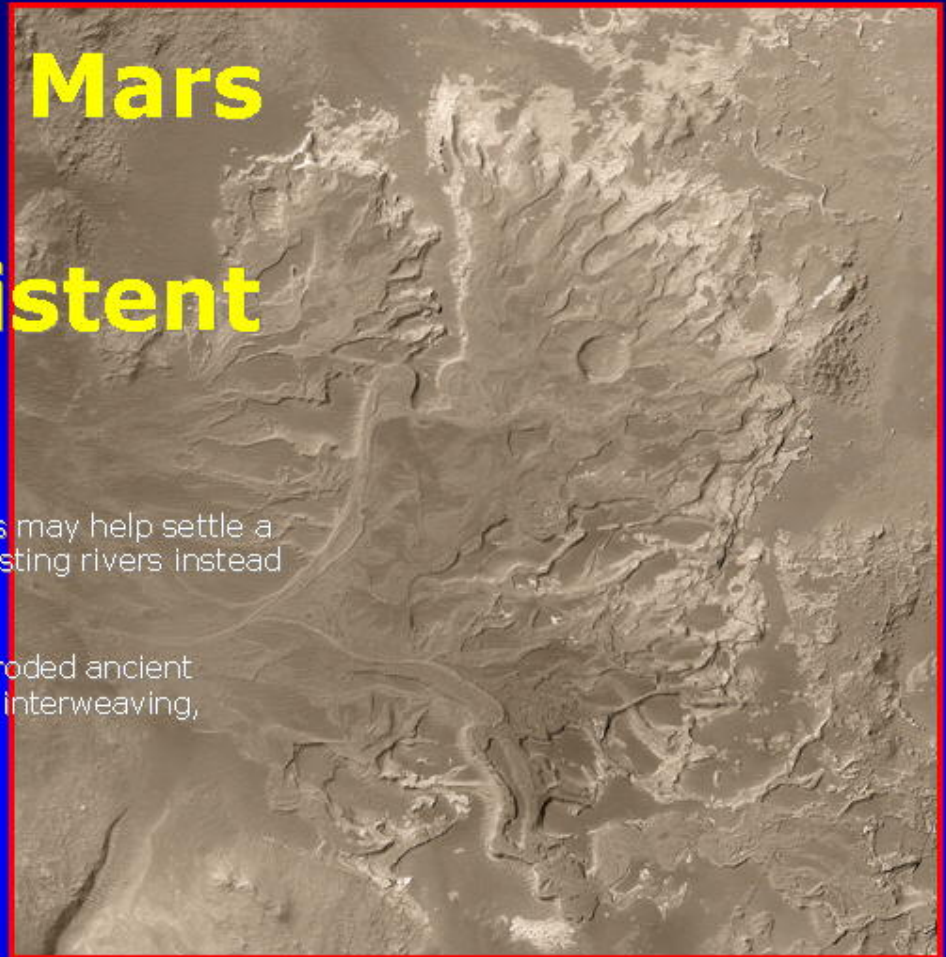
[http://themis.asu.edu/mars-bin/mars\\_cgi\\_map.pl](http://themis.asu.edu/mars-bin/mars_cgi_map.pl)

# Delta-Like Fan on Mars Suggests Ancient Rivers Were Persistent

## NASA Asks, 'Did Rivers Once Run on Mars?'

Newly seen details in a fan-shaped apron of debris on Mars may help settle a decades-long debate about whether the planet had long-lasting rivers instead of just brief, intense floods.

Pictures from NASA's Mars Global Surveyor orbiter show eroded ancient deposits of transported sediment long since hardened into interweaving, curved ridges of layered rock.



## Recent Papers:

Malin, M.C., and Edgett, K.S., 2003

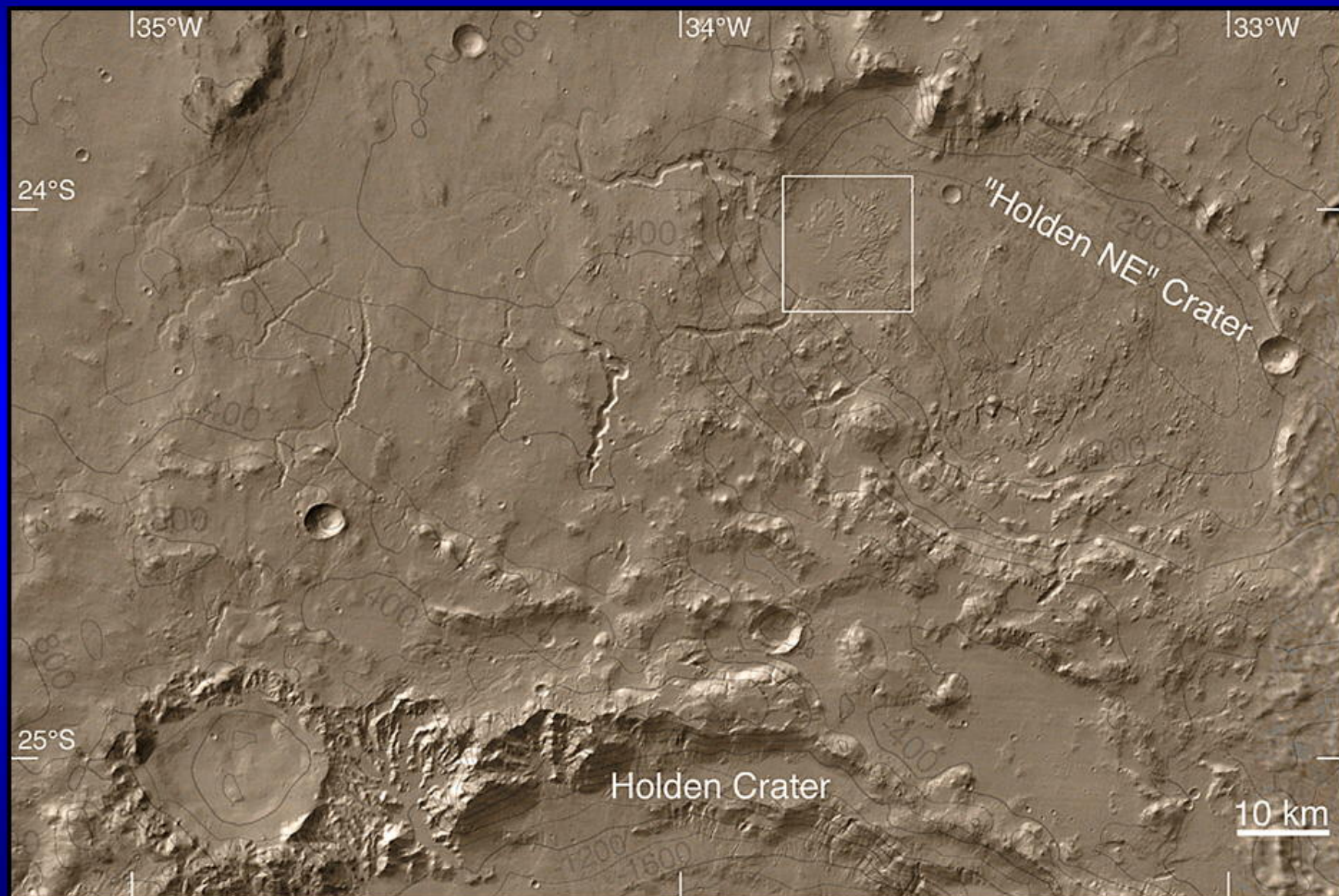
Moore, J.M., Howard, A.D., Dietrich, W.E., and Schenk, P.M., 2004

Lewis, K. and O. Aharonson, 2004

Jerolmack, D.J., D.M. Mohrig, M.T. Zuber and S. Byrne, 2004

Bhattacharya, J.P., Payenberg, T., Lang, S., and Bourke, M., 2005

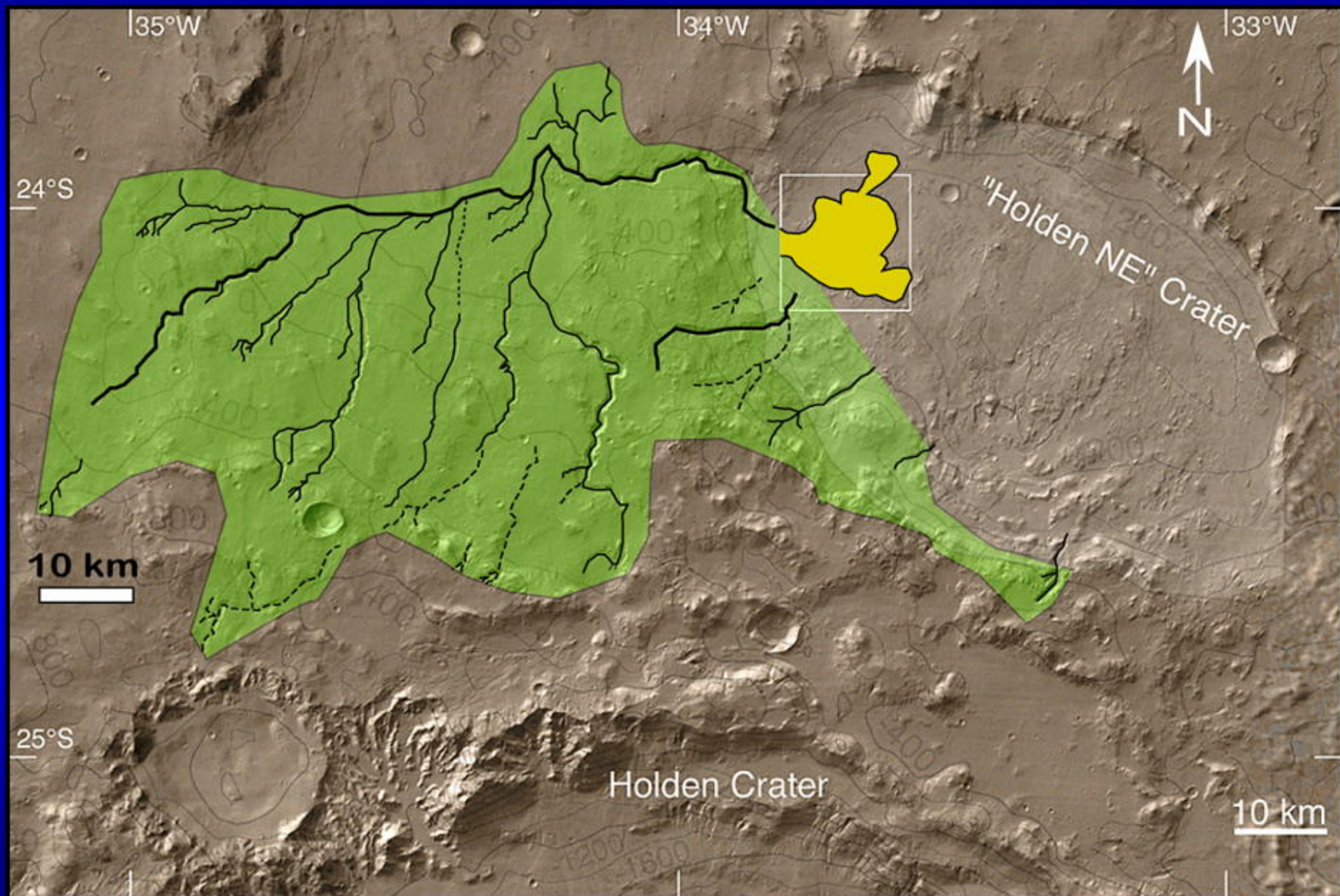
# Area NE Holden Crater



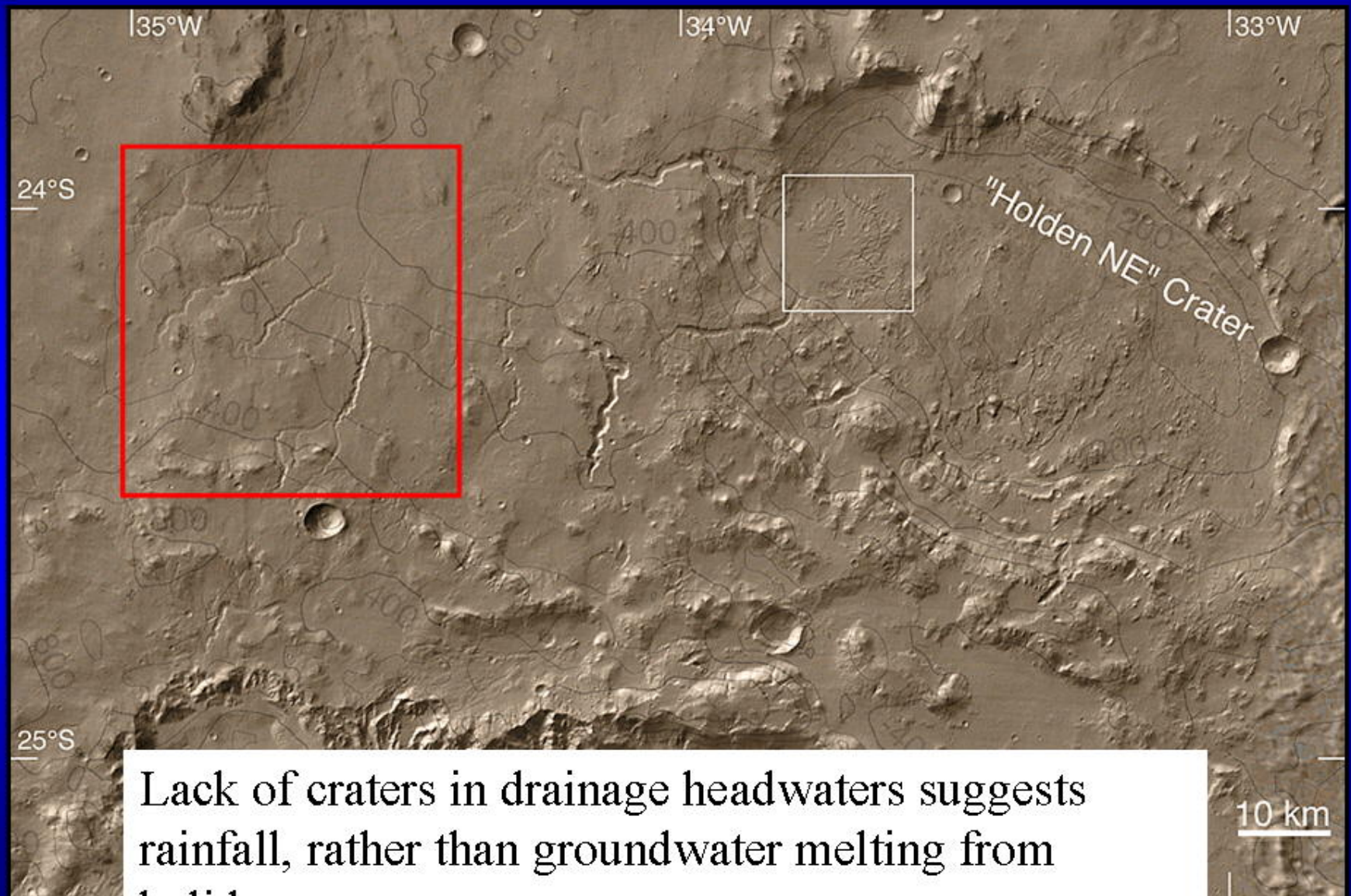
# **Martian Drainage**

- How long-lived was drainage basin?
- How was drainage basin carved?
  - Rainfall?
  - Groundwater sapping?
    - Caused by bolide impacts that melt groundwater

# Map of Drainage basin

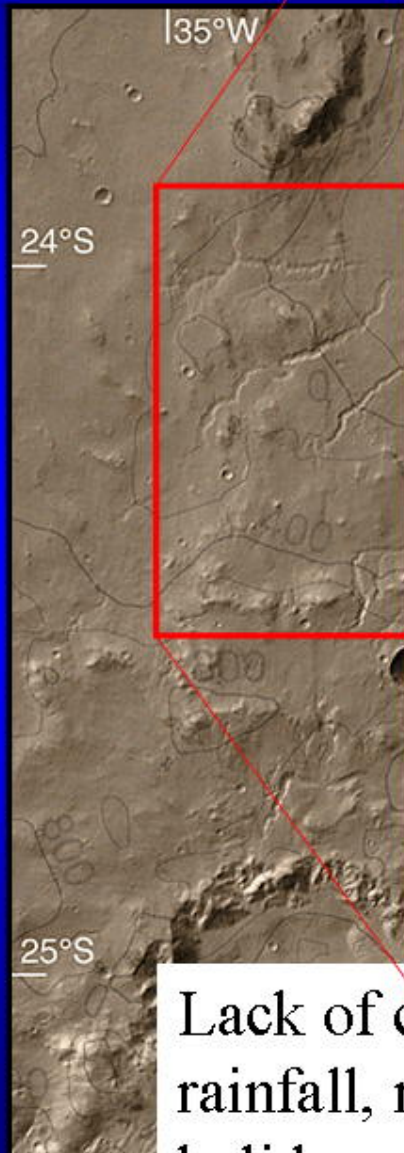


# Close-up



Lack of craters in drainage headwaters suggests rainfall, rather than groundwater melting from bolides.

# Close-up

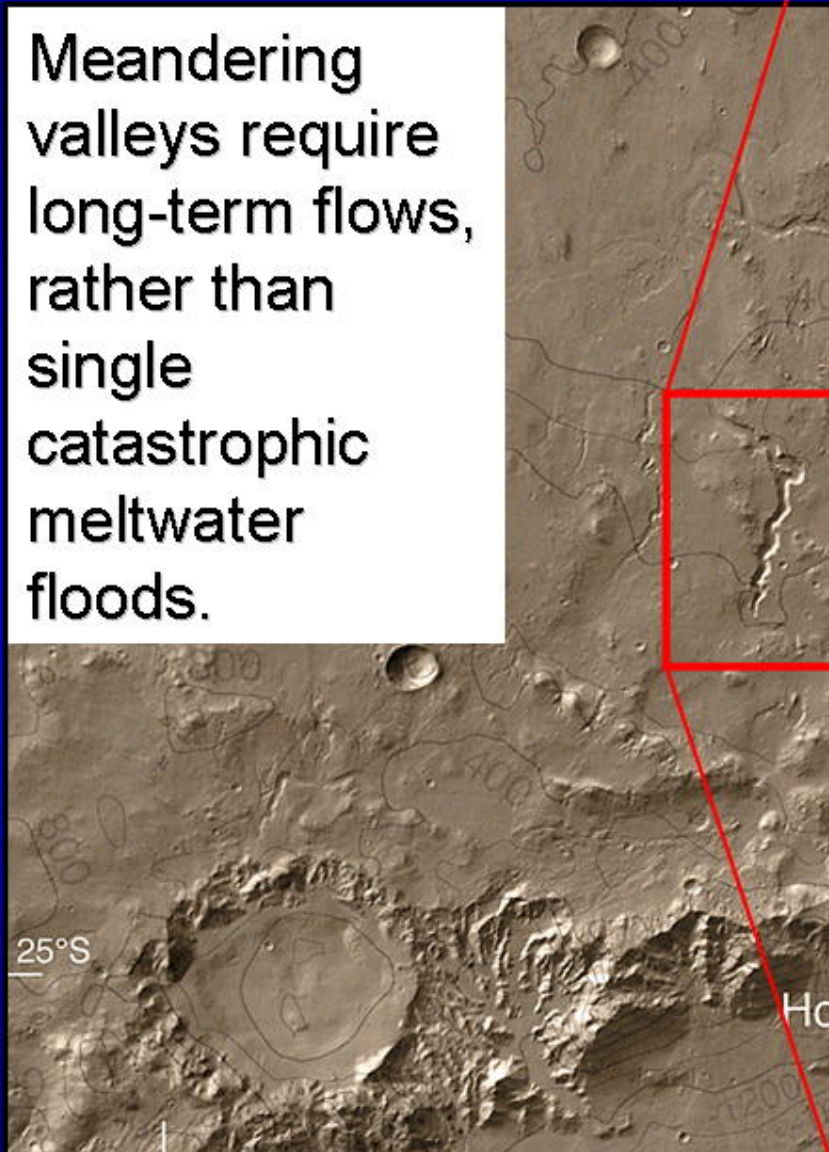


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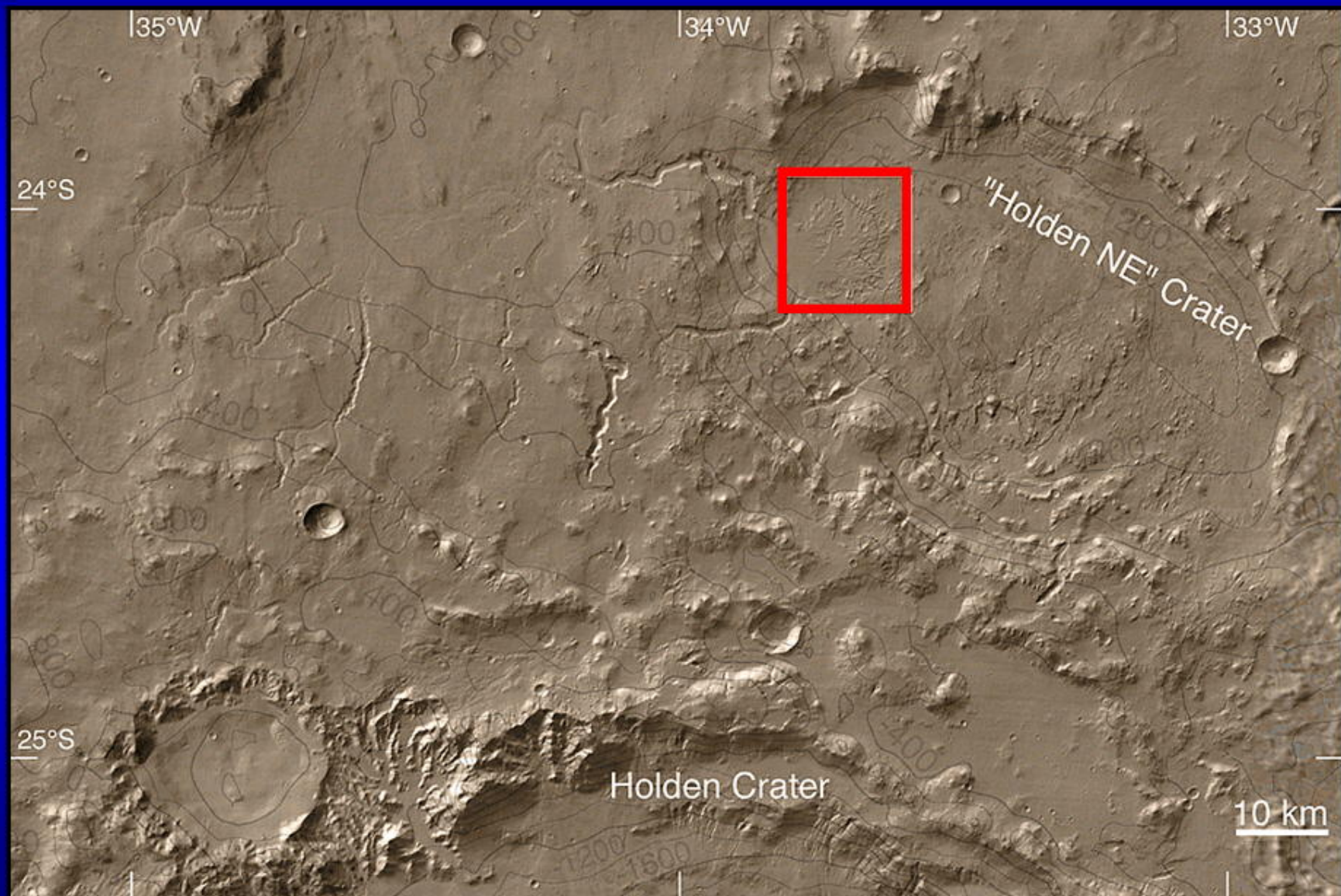
10 km

# A Meander Valley

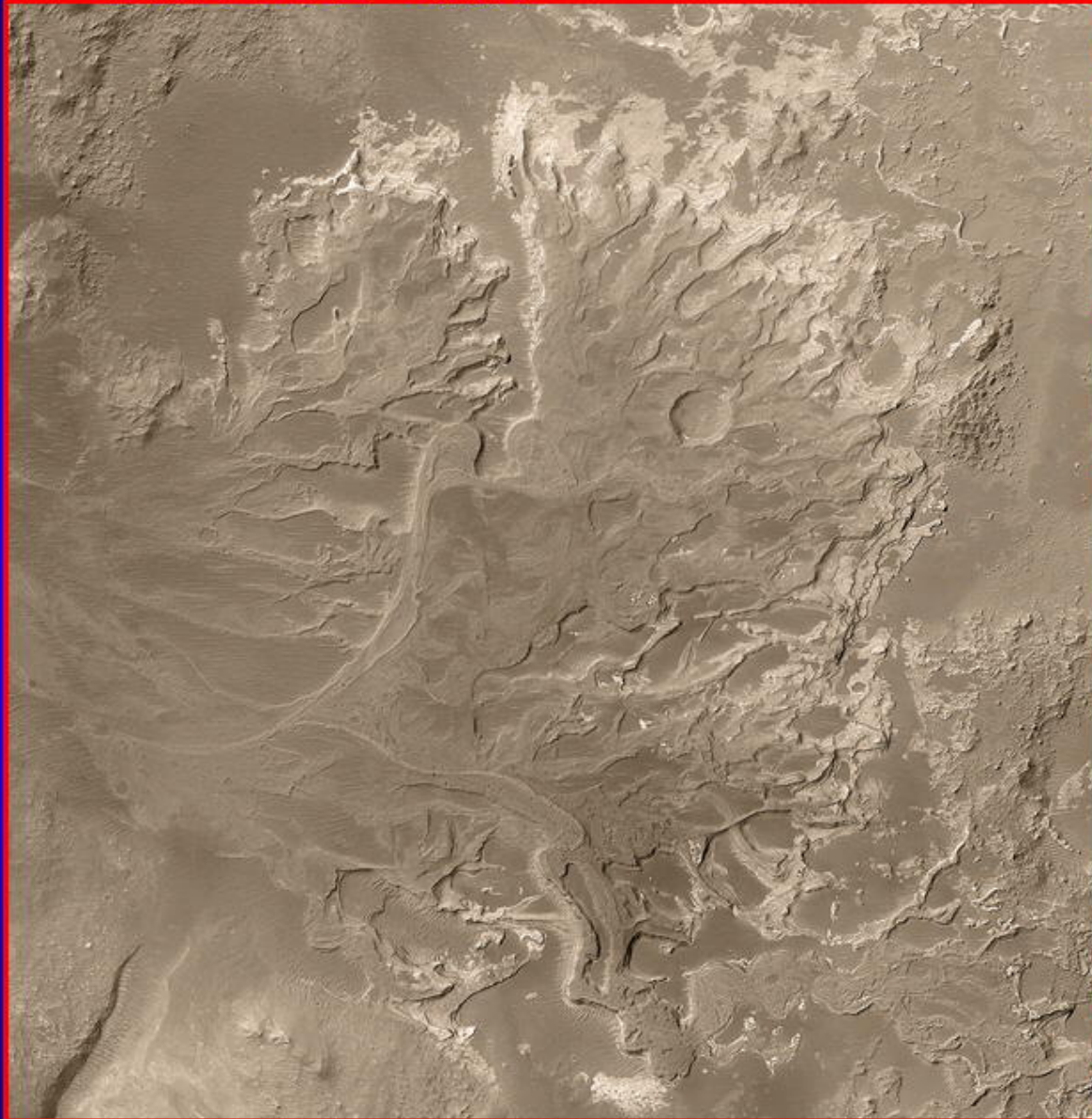
Meandering valleys require long-term flows, rather than single catastrophic meltwater floods.



# Lets look at the crater fill!



# Channel

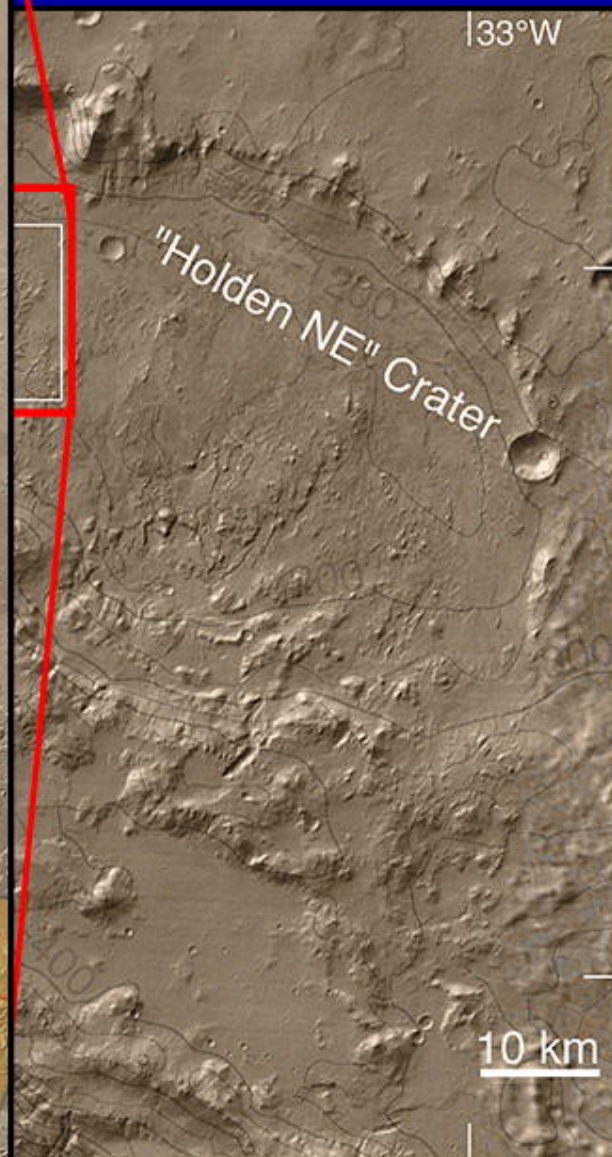
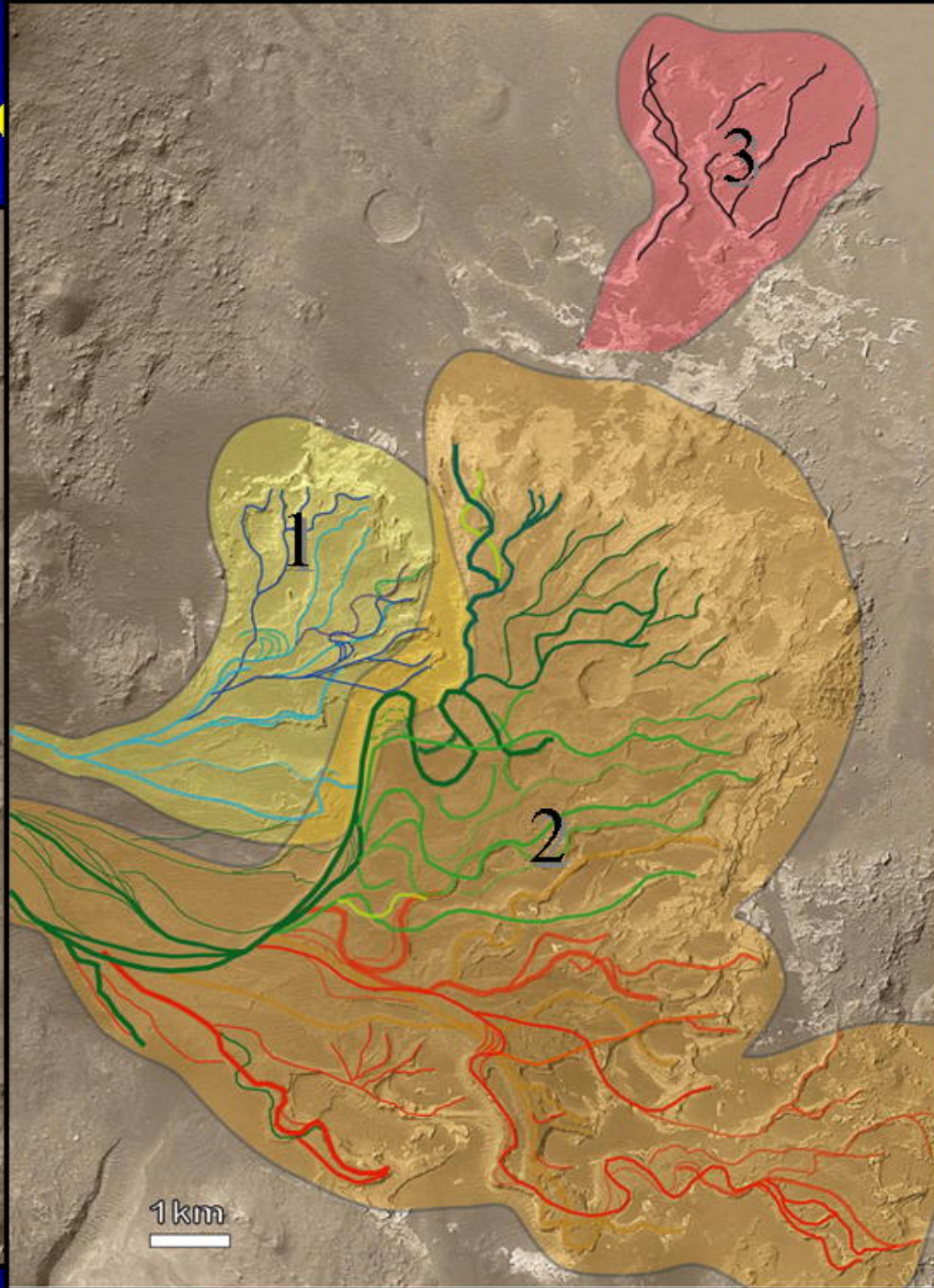


- Multiple channels.
- Downstream decrease in channel width.
- Distributive channel pattern
- Straight to meandering, single thread channels.

133°W

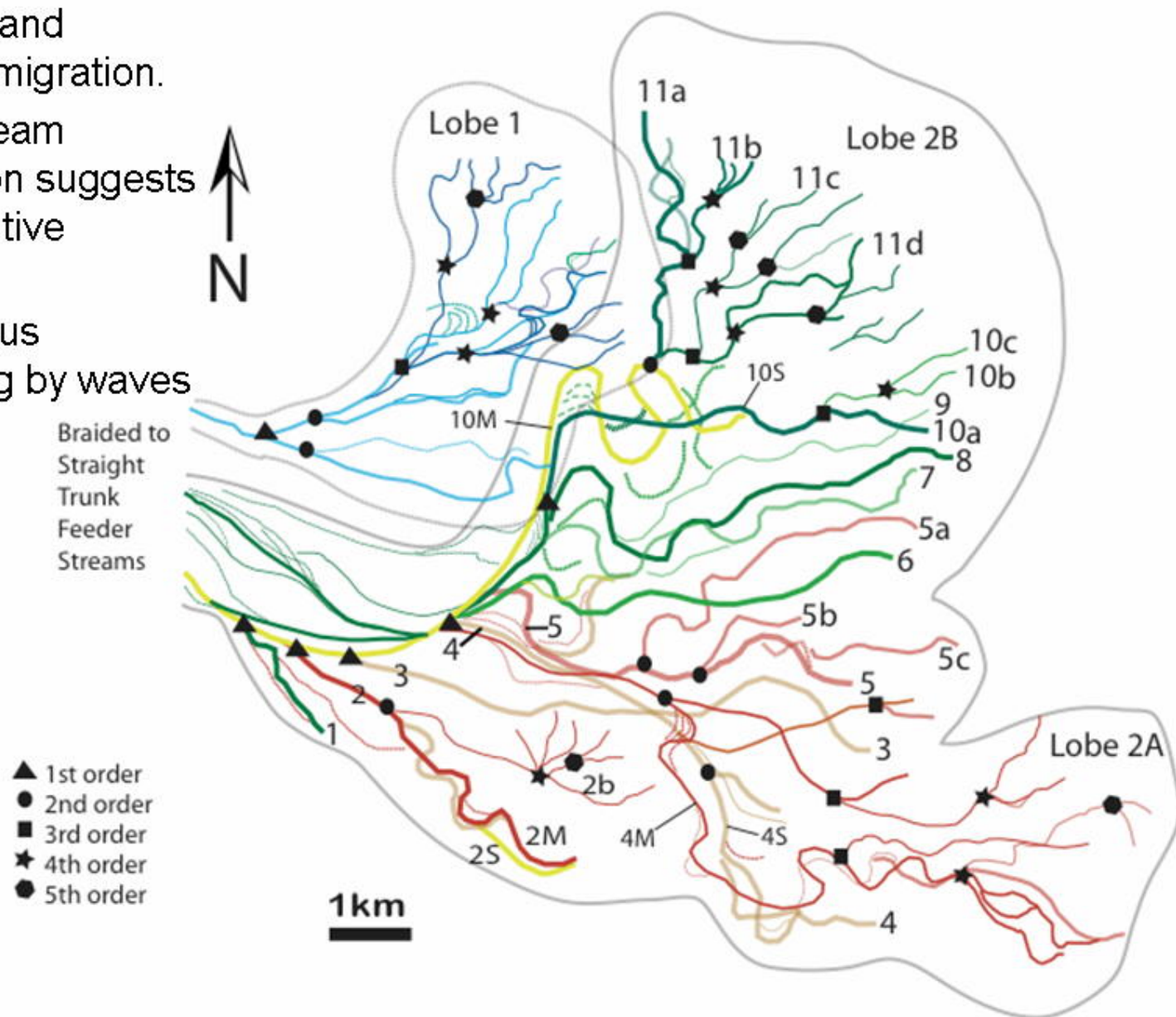
10 km

CI

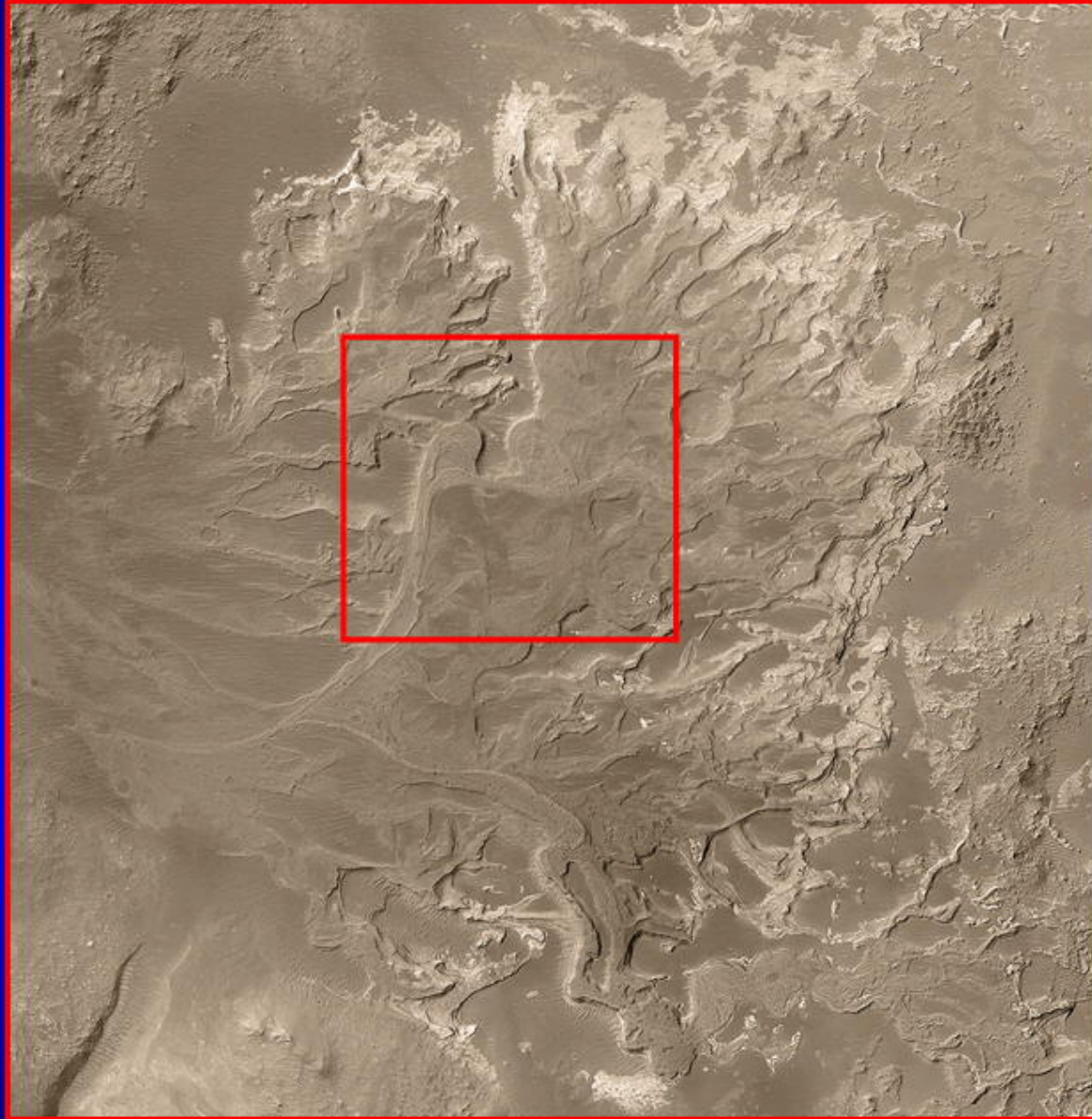


- Records complex history of fluvial avulsion and channel migration.
- Downstream bifurcation suggests a distributive system.
- No obvious reworking by waves or tides.

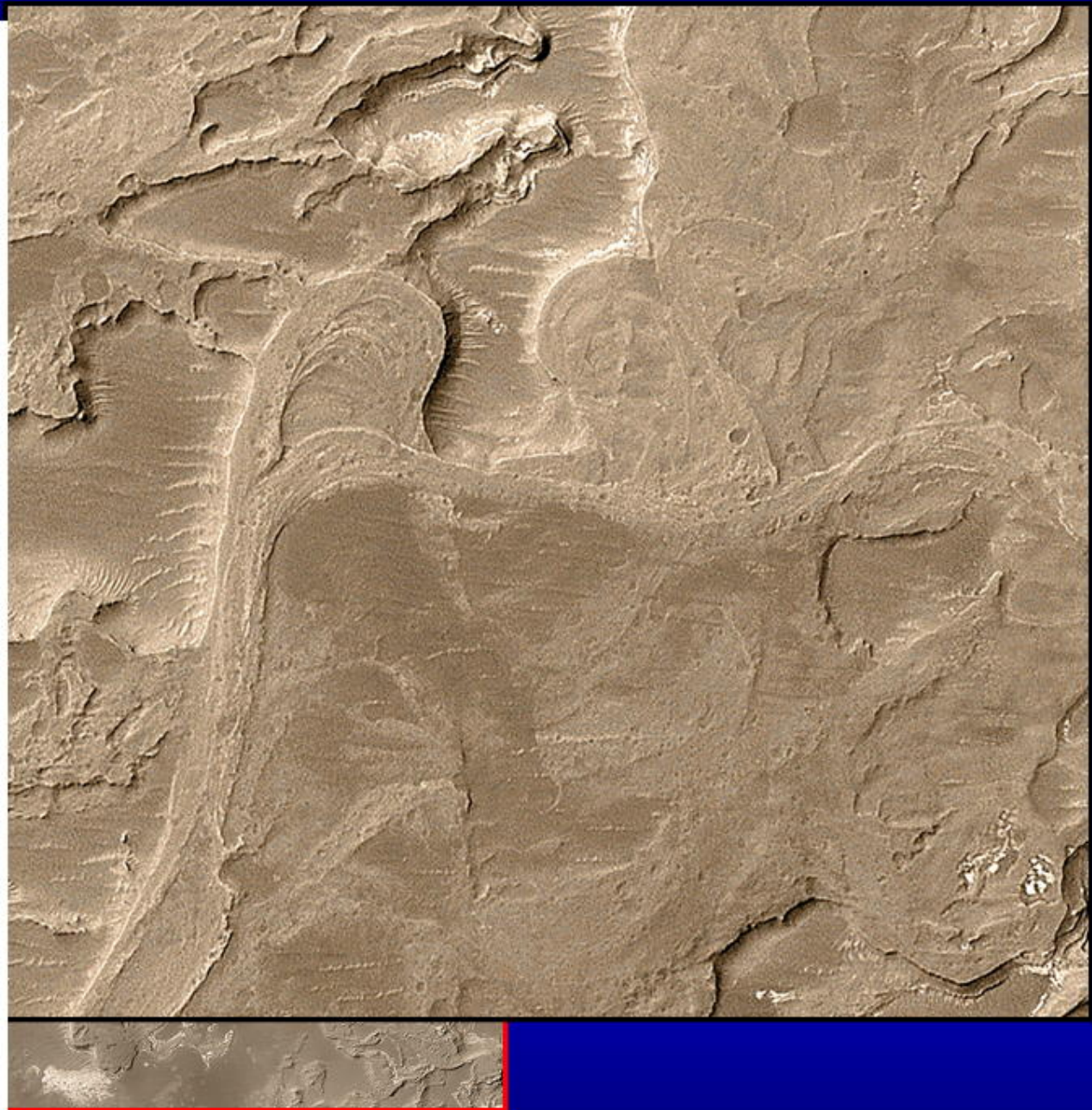
# Martian Delta Lobes



# Close-up View of Meanders



- Coarse-grained channel belt deposits are held high.
  - Finer-interchannel (floodplain) sediment is eroded by wind.
  - Inverted geomorphology.
- Channel belt surface is severely pock-marked, suggesting an extremely old (Noachian) age.
  - Over 3 Ga.

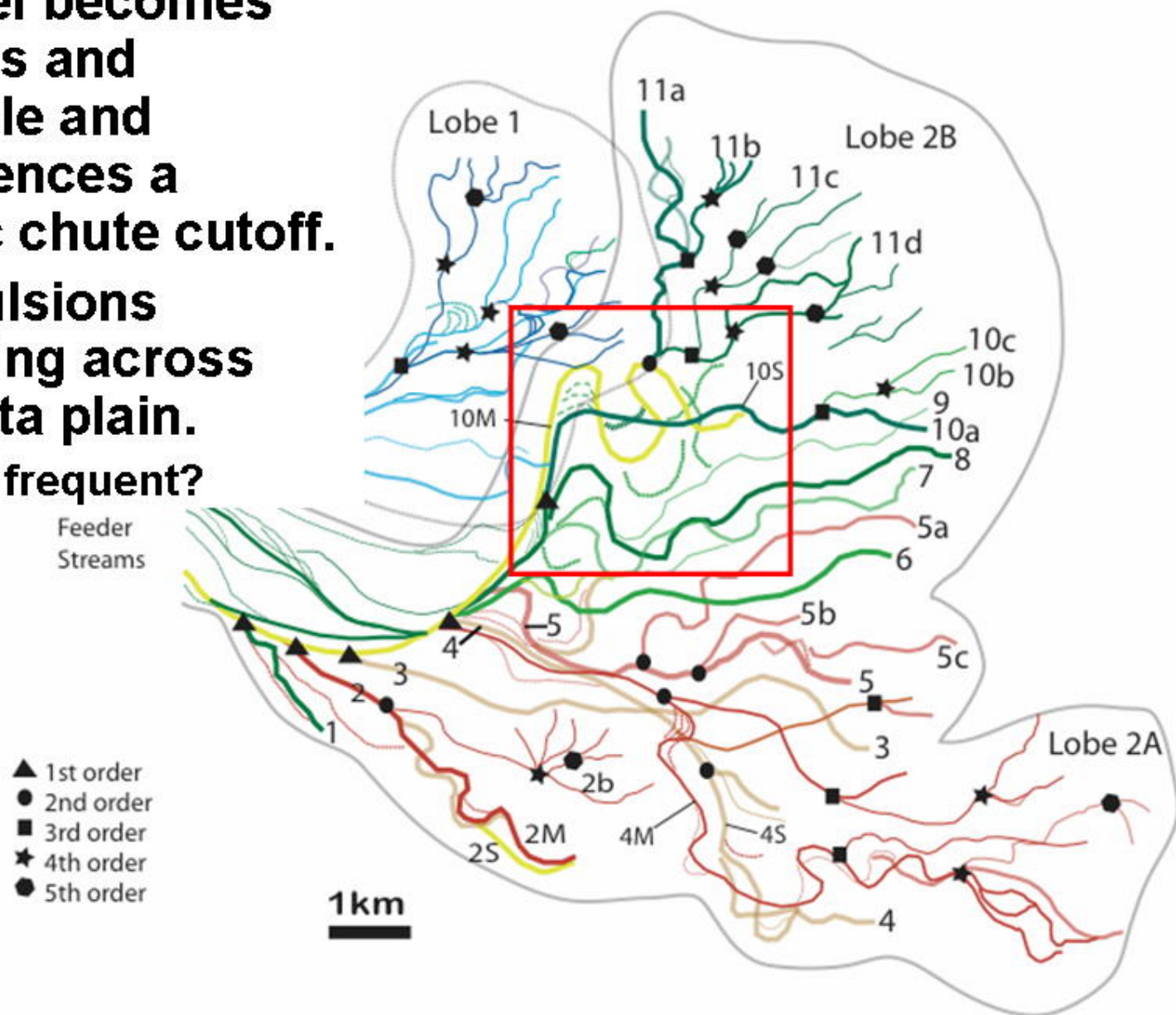


- Channels about 100m wide.
- Cross-cutting relationships.
- Channels wander, meander, and avulse.
  - Scroll bars represent “frequent” floods.
  - Avulsions represent “infrequent” major-floods.
  - How frequent???



- Original straight channel becomes sinuous and unstable and experiences a classic chute cutoff.
- 11 avulsions sweeping across the delta plain.
  - How frequent?

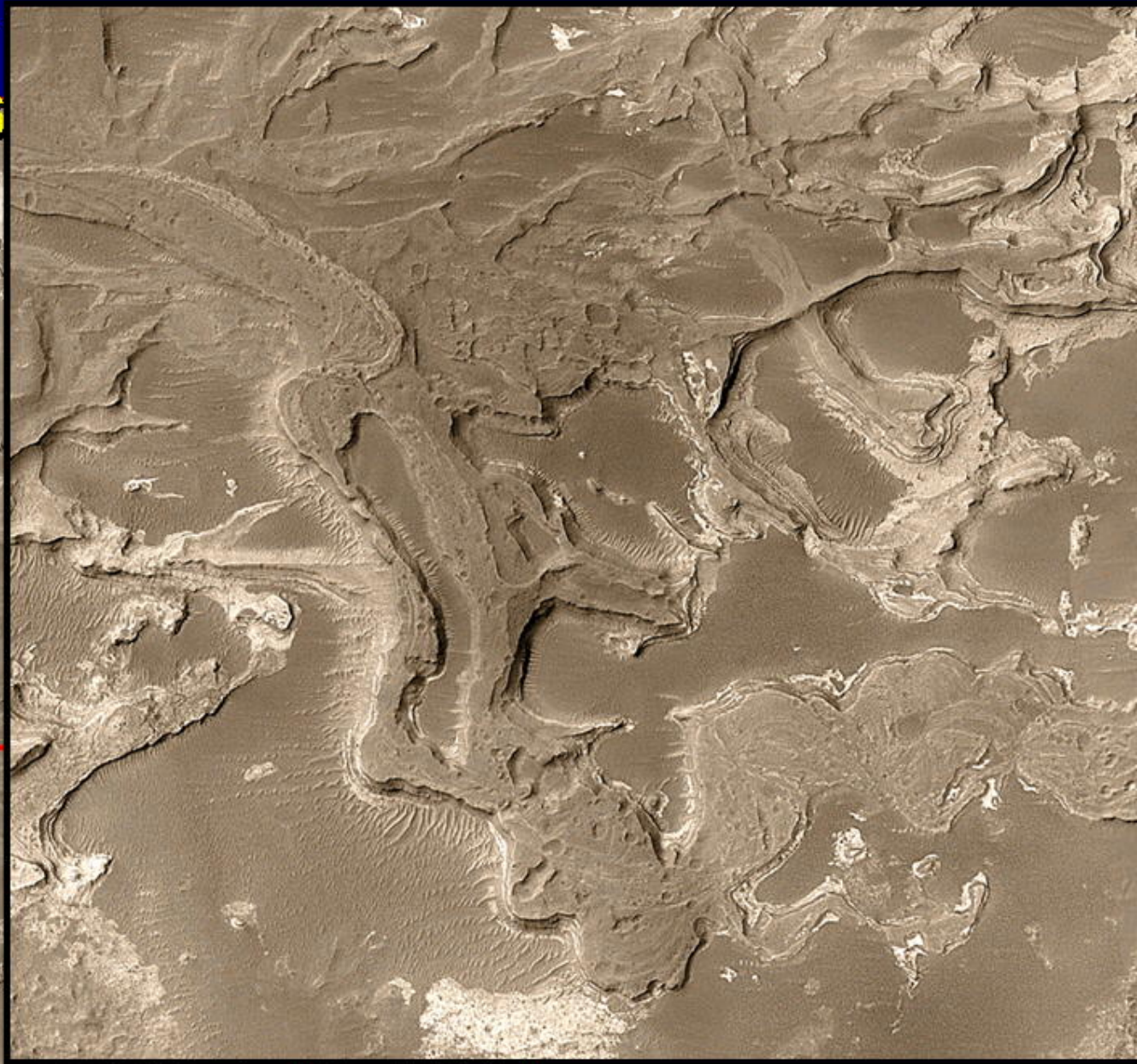
# Martian Delta Lobes



# More close-ups

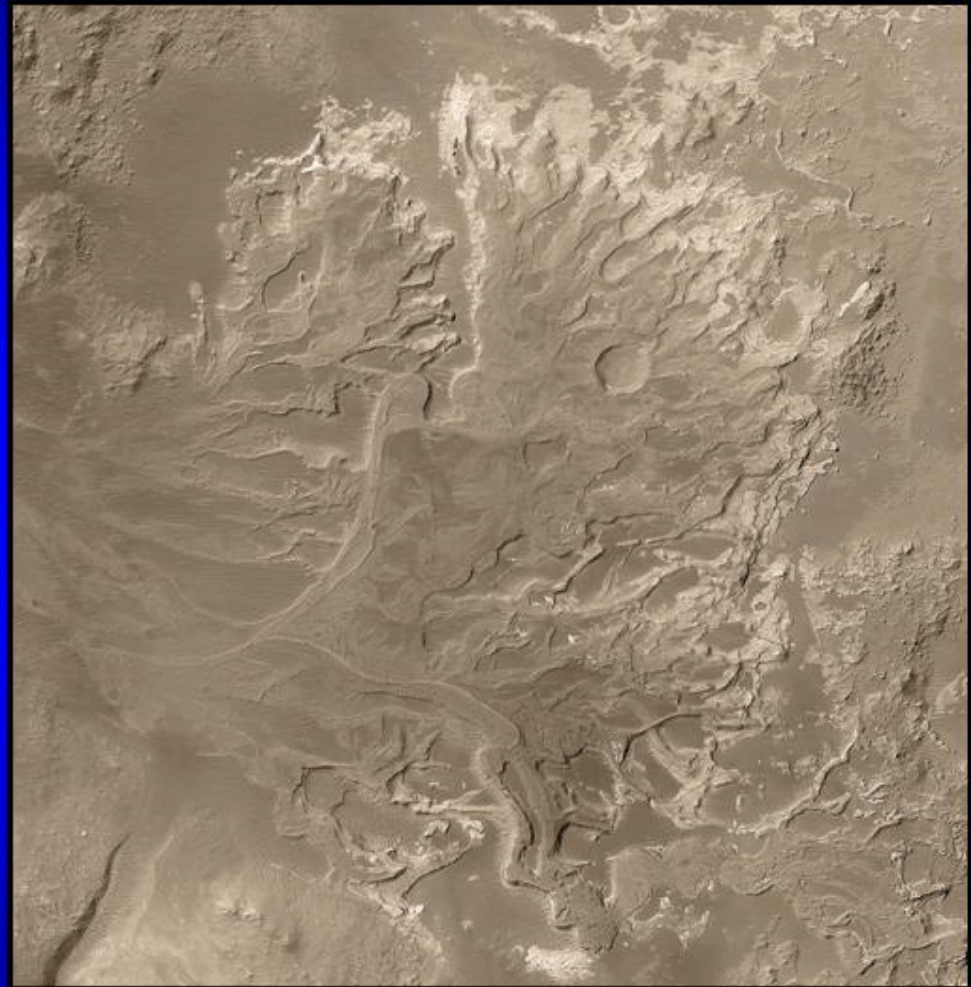


- Older channels are straight and then become more sinuous.
- Younger channels overlie older channels.
- Clear bifurcation downstream, suggesting distributary channels.



# Delta versus Fan

- Lack of debris flows or sheetflood deposits.
- Highly organized single-thread, straight to meandering channels.
- Lack of braided channels
  - indicate lower slopes or lower discharge than might be expected on an alluvial fan.



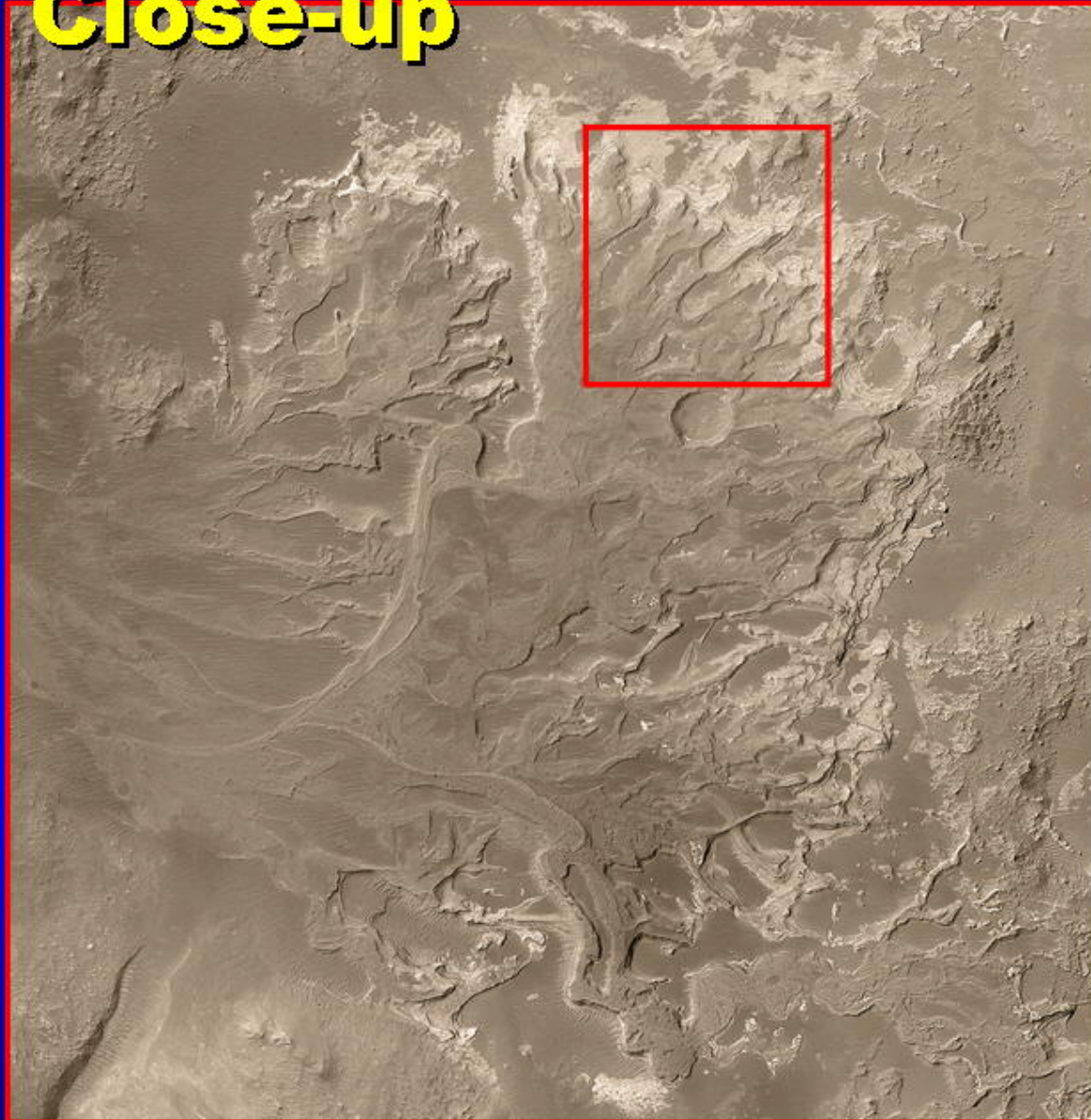
## Estimating the duration of the delta

<i>River</i>	<i>Mean Avulsion Period (years)</i>
Mississippi	1400
Rhine-Meuse	945
Saskatchewan	670
Yellow	600
Po	490
Kosi (Mega-Fan)	28

Data compiled by Bridge, 2003

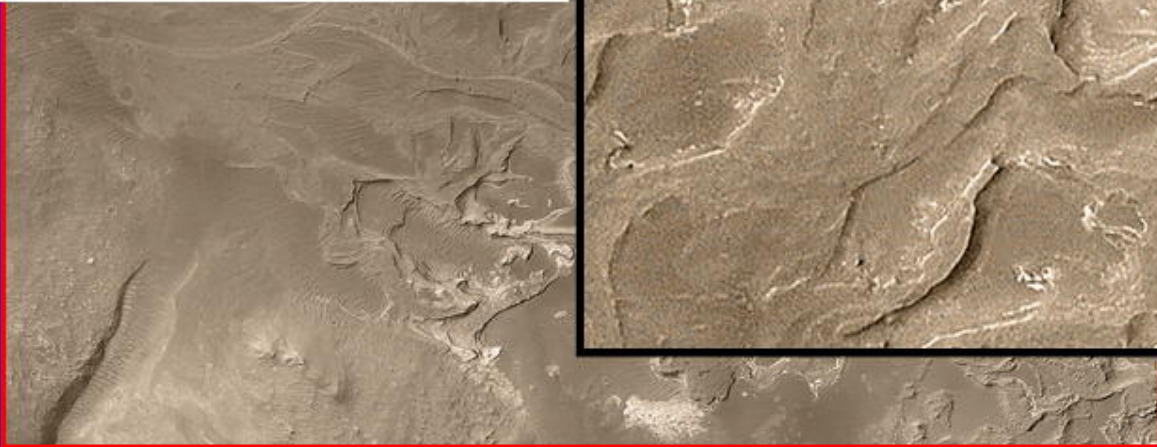
- **Deltaic versus fan numbers considered more likely**
  - No vegetation on Mars, but floodplain may have been frozen much of the year: stable floodplain?
  - *Assume avulsion period of 100-500 years?*
- **11 avulsions = 1100 to 5500 years for topmost layer.**

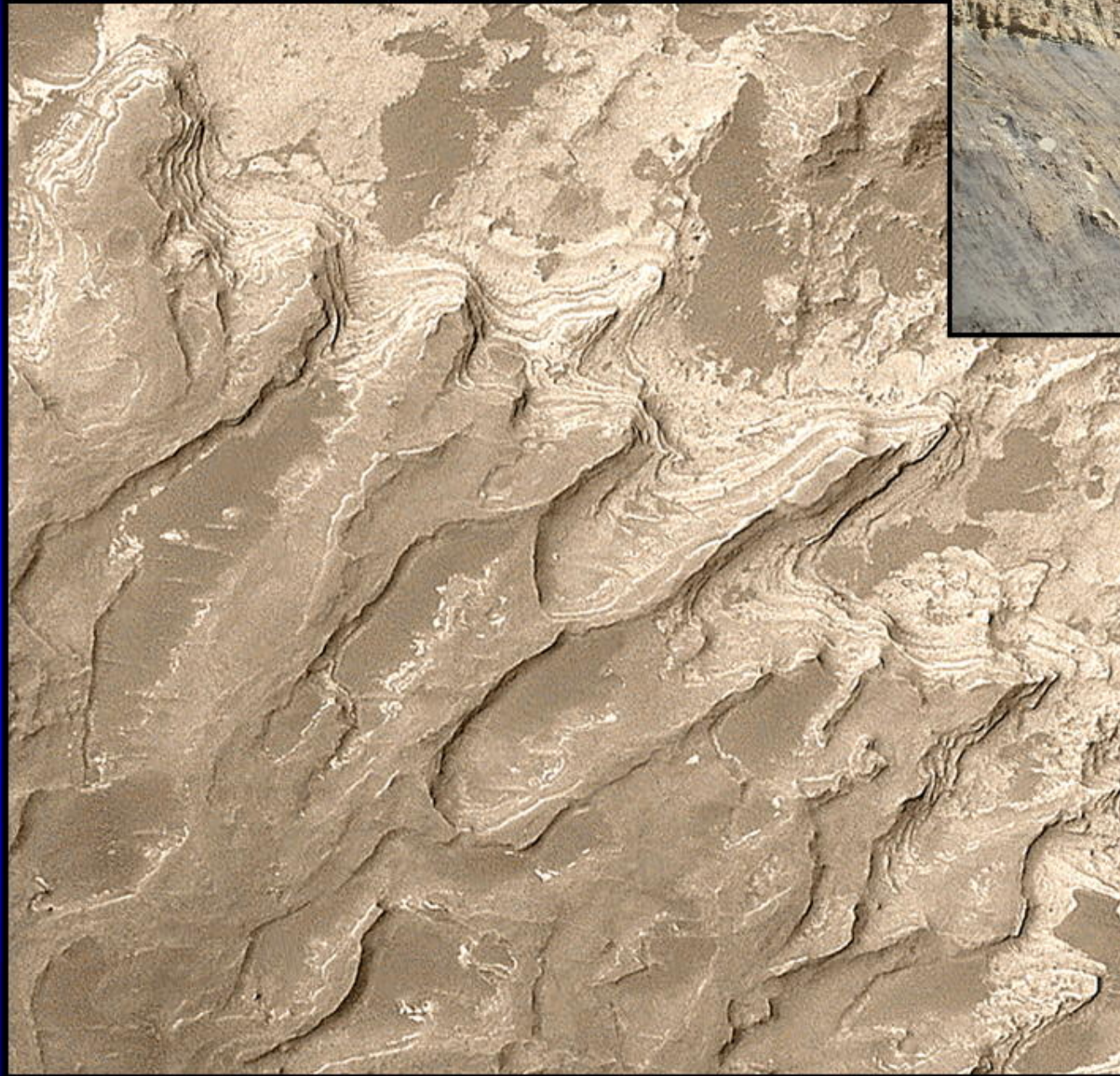
# Close-up



- Let's look at the distal end to get thickness.

- Examine edge of outcrop to get thickness.
  - 150 m thick
- Note lighter deeper layers
  - Prodelta bottomsets?
  - Evaporites?

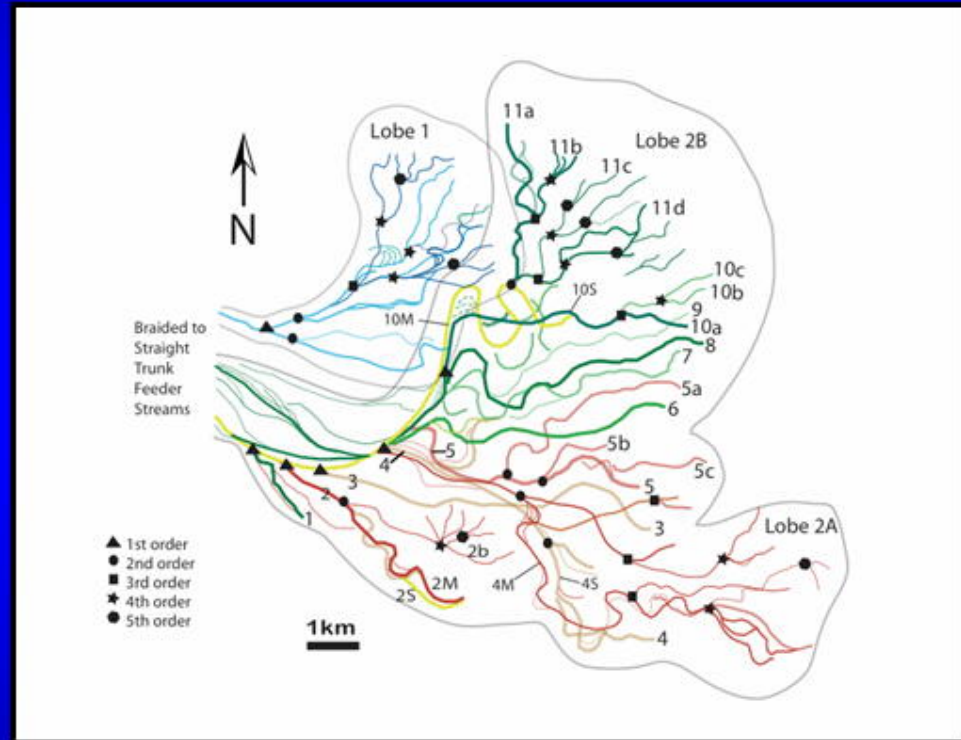




- Outcrops about 150m high.
- 1100 - 5500 years for upper layer.
- $150\text{m} \times 1\text{mm/year} = 150,000$  years for entire feature.

# Conclusion

- Long-lived delta.
- Complex, dynamic history
  - Countless scroll-bar flood events
  - 11 avulsions in top layer
  - Feature may have formed over 10,000 to 100,000 years.
- Clearly not due to 1 major bolide-induced catastrophic groundwater melt episode.
- It was probably raining on Mars during the Archean.

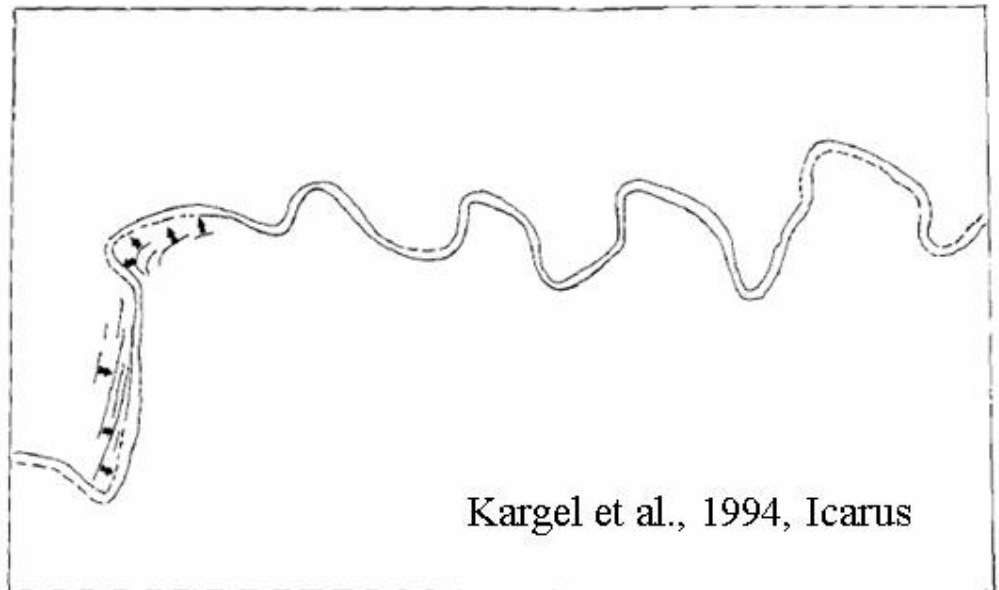
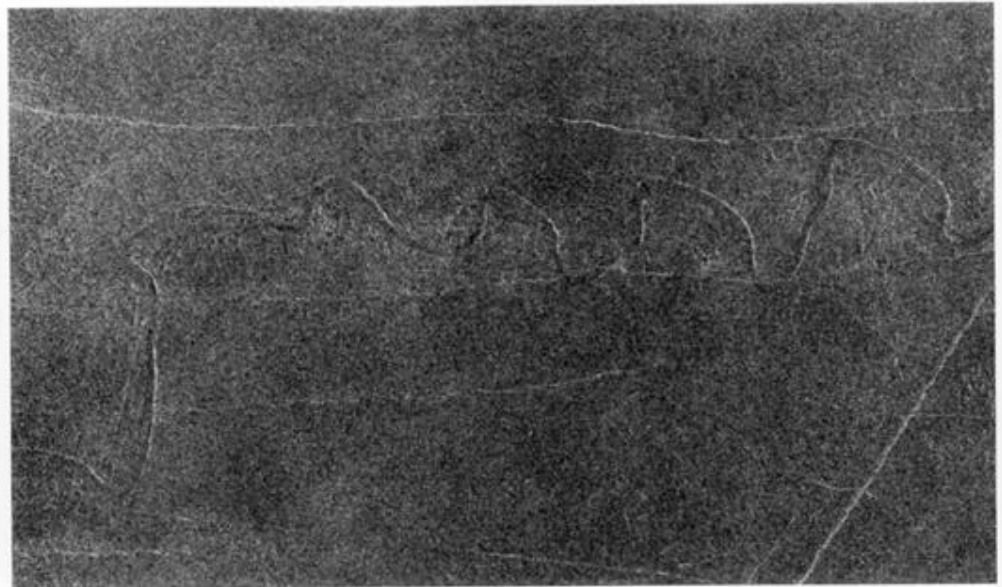


# Could life have occupied this potential habitat?



# Meandering Channel on Venus

Feature interpreted to  
be formed by  
Carbonate-Sulfate  
Lavas, that have fluid  
properties similar to  
water on earth



Kargel et al., 1994, Icarus

# Lava Deltas on Venus

- “The universe is not only as queer as you suppose, but it is queerer than you can suppose.”  
(*J.B.S. Haldane*)

Kargel et al., 1994, *Icarus*

