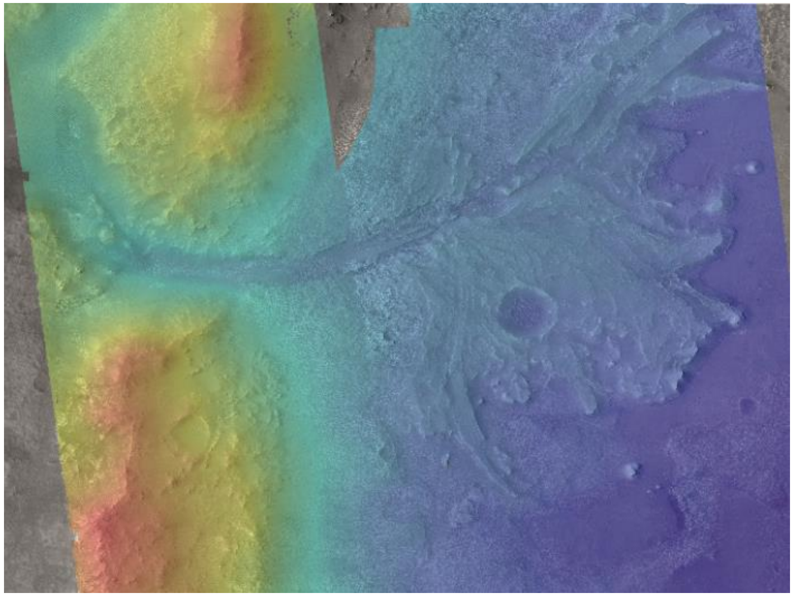
Constraints on the duration of the fluvial and lacustrine activity at Jezero crater

N. Mangold (1), G. Dromart (2), F. Salese (3), V. Ansan (1), M. Massé (1), M. Kleinhans (3)

(1) LPG, Nantes, France, (2) LGL, Lyon, France, (3) Geosciences, Utrecht, Netherlands

Goal

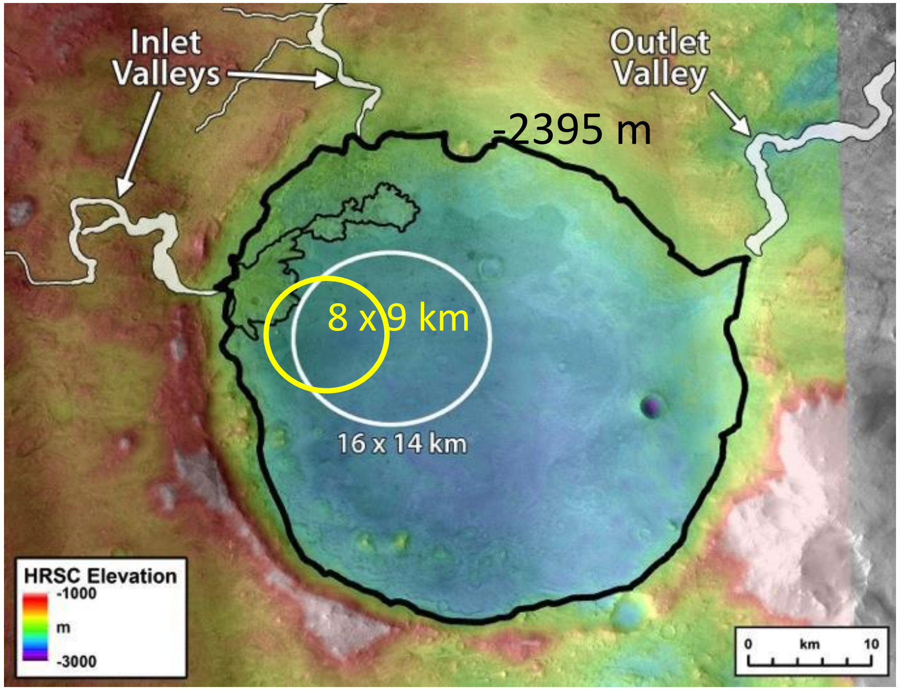
To refine the context of sedimentary deposition by analyzing the fluvial morphology upstream of Jezero



Jezero Crater: A paleolake with diverse mineralogy

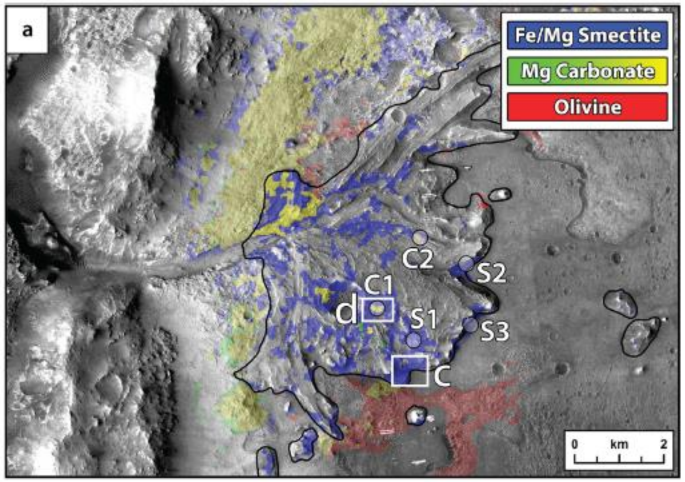
Jezero crater is a paleolake from the observation of two delta fans and the presence of an outlet => Open-lake basin *(Fassett and Head, 2005)*

Elevation at -2395 m consistent with delta fan plain and a breach of the outlet valley.



Goudge et al., 2015

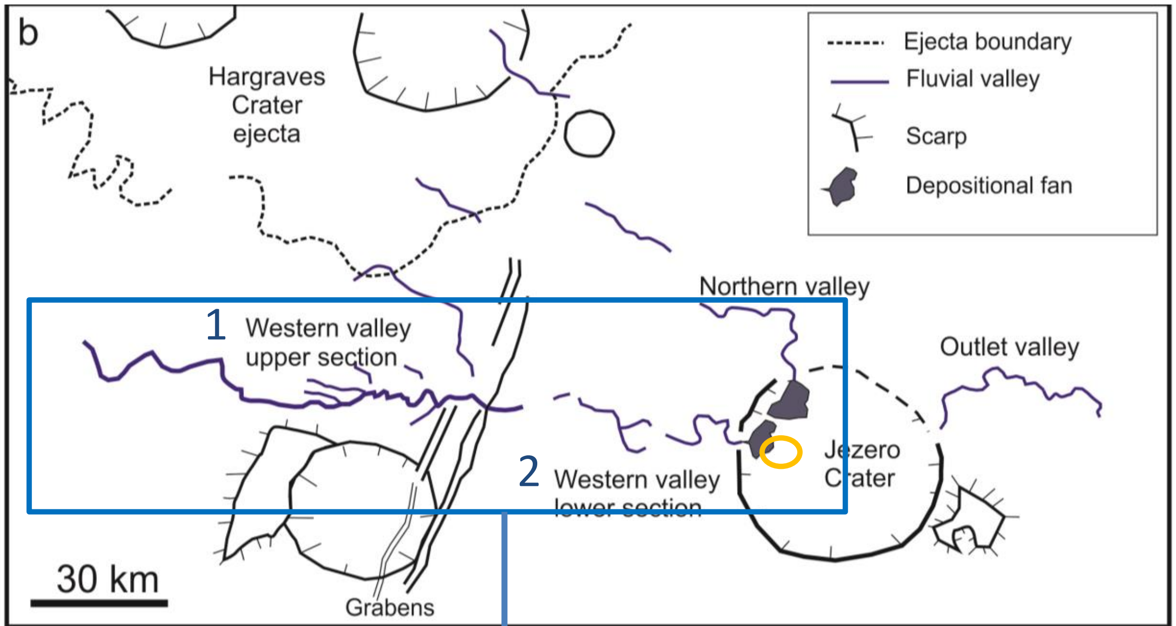
Mineralogical diversity incl. carbonates, smectites and unaltered mafics



Ehlmann et al., 2008, Goudge et al., 2017

Jezero crater contains key minerals (carbonates, smect.) for exobio./climate objectives and unaltered rocks for geochronology/igneous evolution objectives in the context of a paleolake.

Fluvial morphology

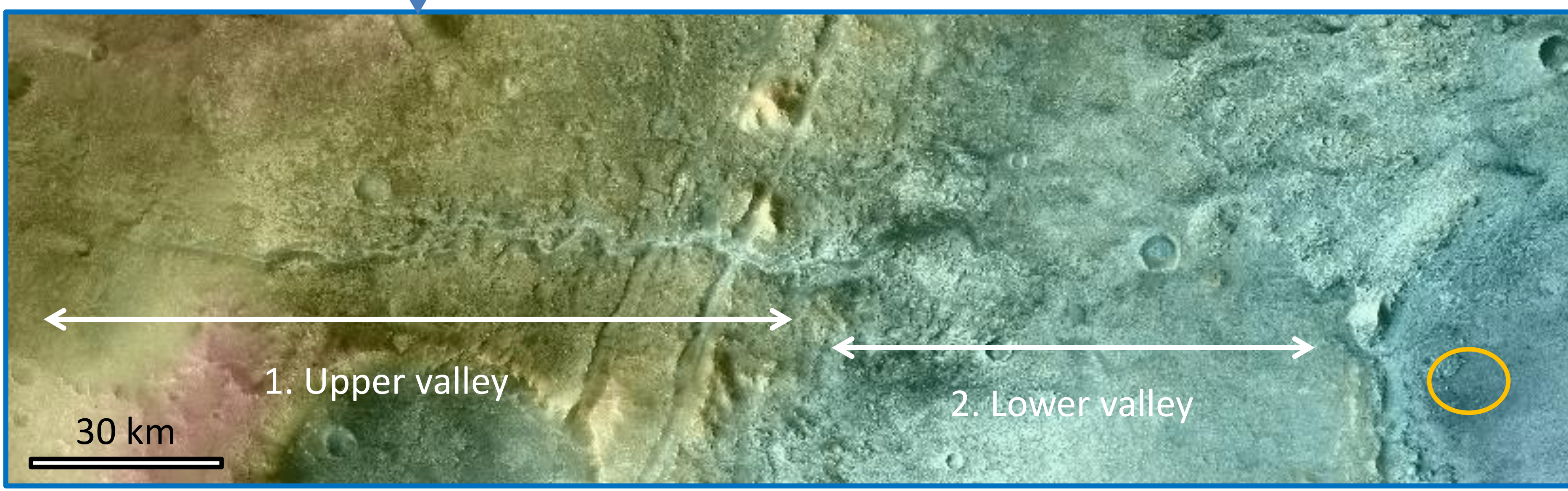


Focus on valley upstream Jezero fan

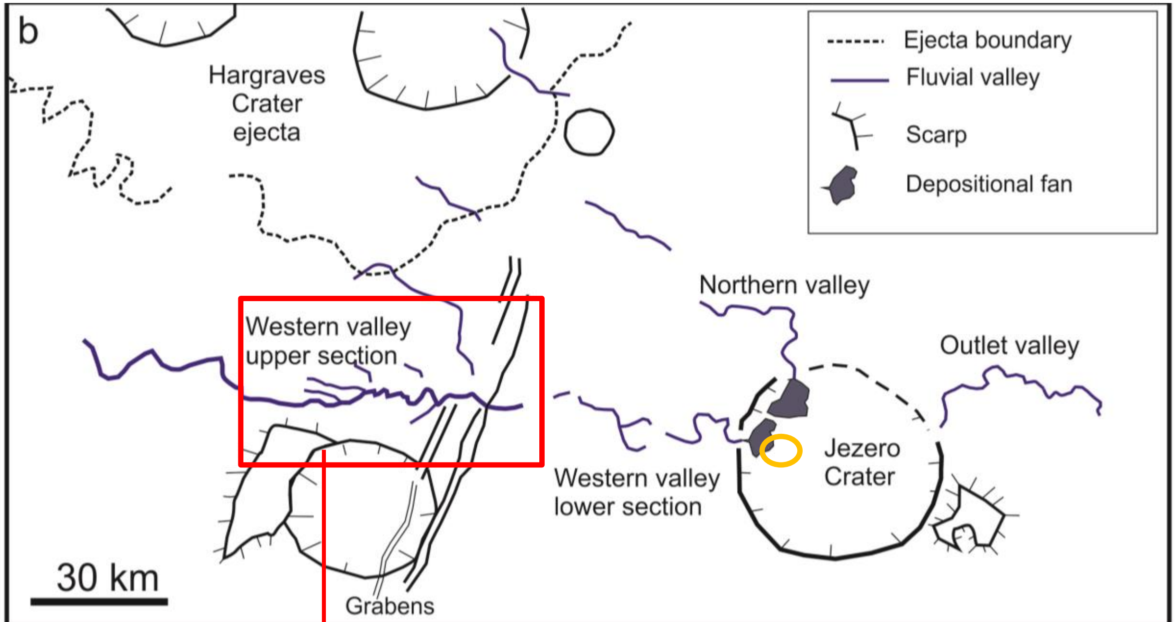
200 km long fluvial valley

Valley divided in 2 sections:

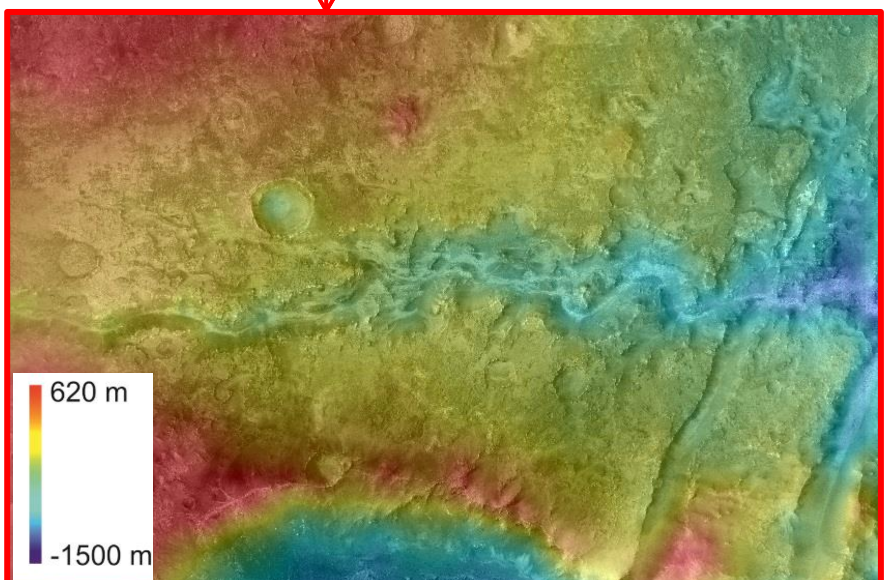
1. Upper Valley
2. Lower Valley

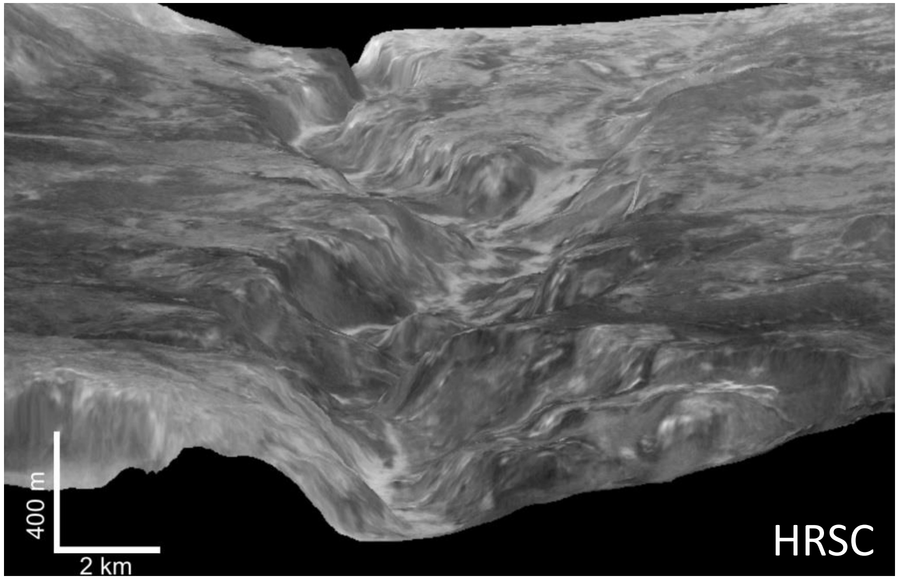


Fluvial morphology: 1. Upper valley



* 100 to 400 m deep incision into bedrock
* Locally sinuous
* 53 km^3 eroded volume (strict minimum, strong etching of basement)





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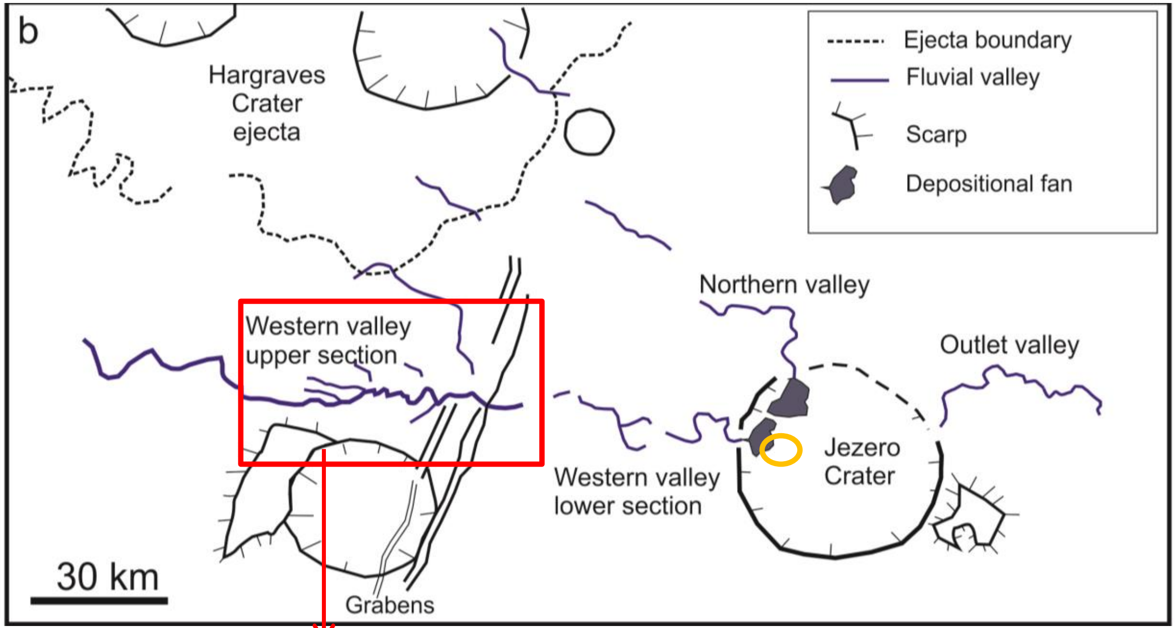
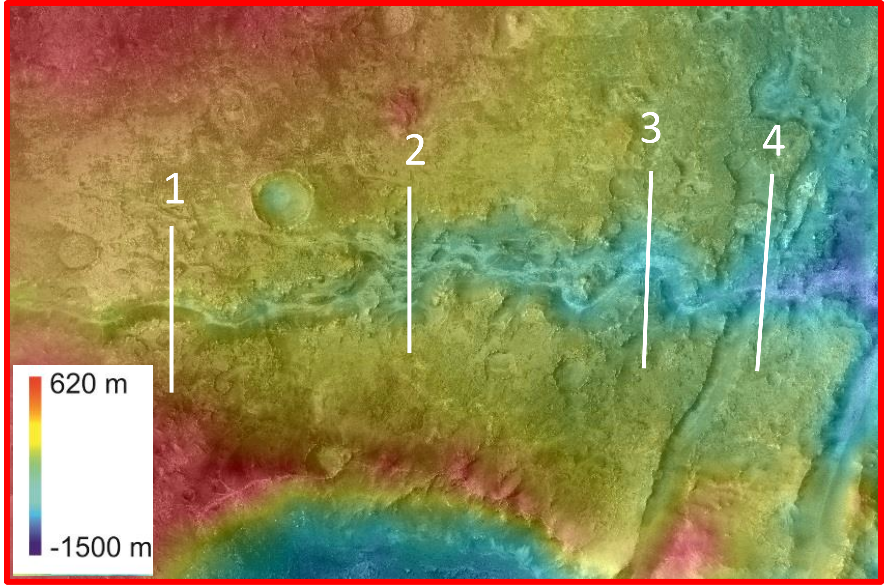
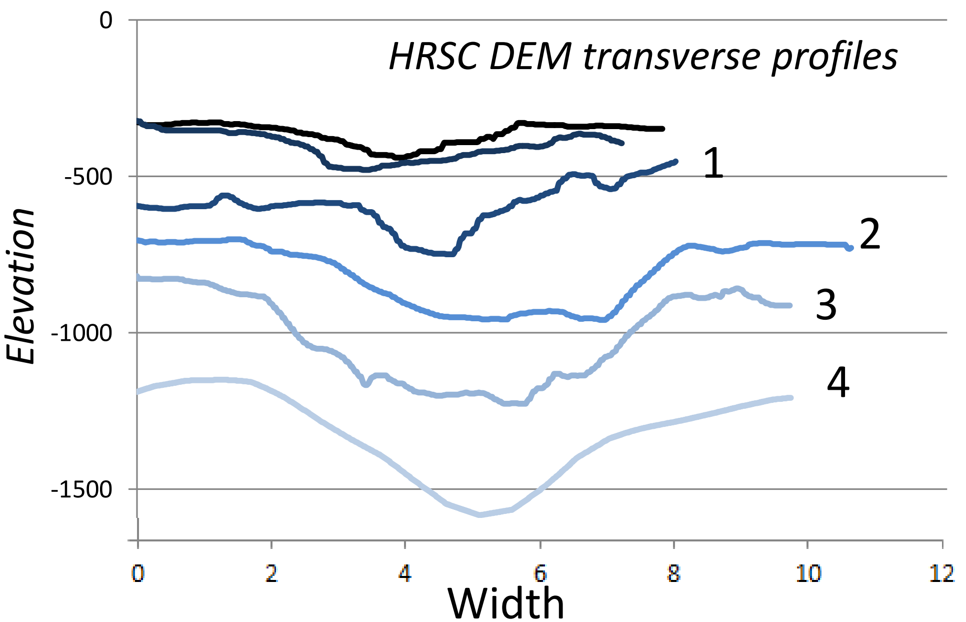


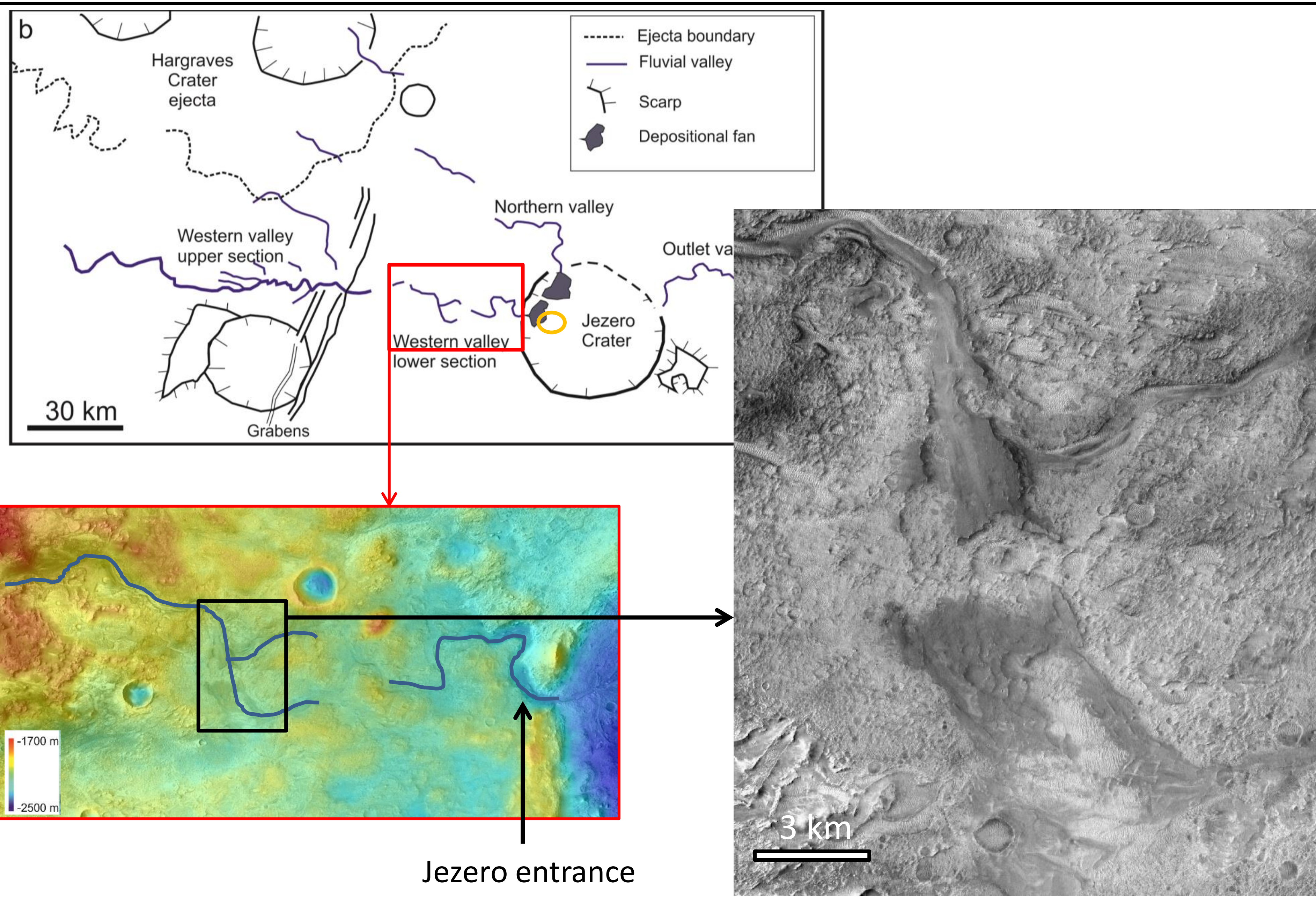
* 100 to 400 m deep incision into bedrock
* Locally sinuous
* 53 km^3 eroded volume (strict minimum, strong etching of basement)

Increasing depth and width downward => **Substantial erosion - Long-lived system**
Classical Noachian activity



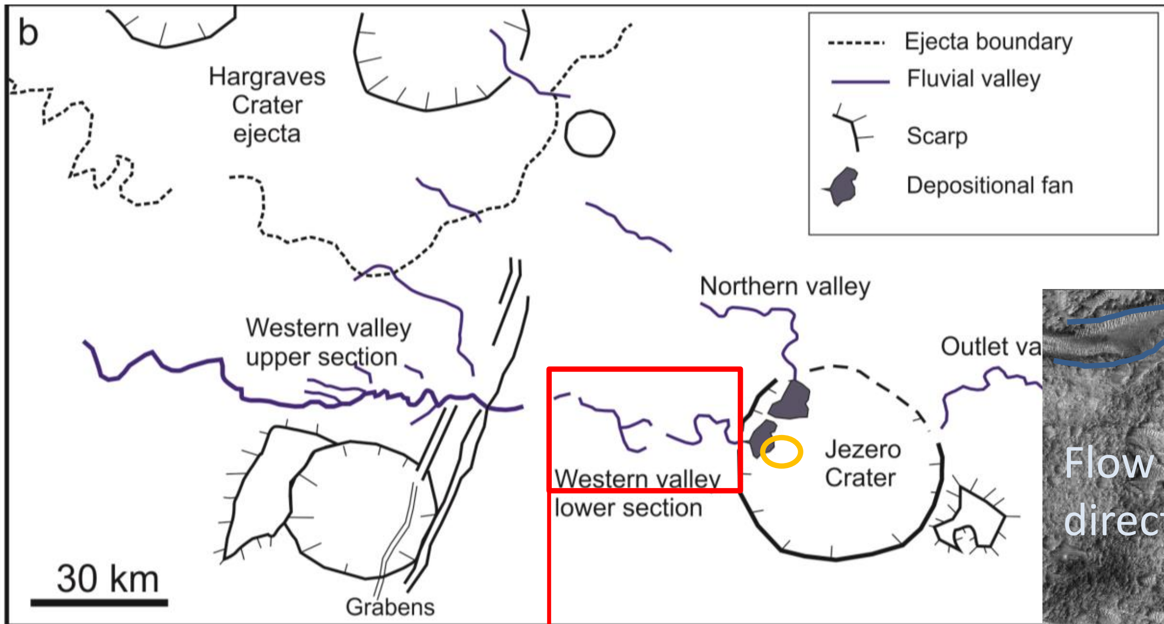


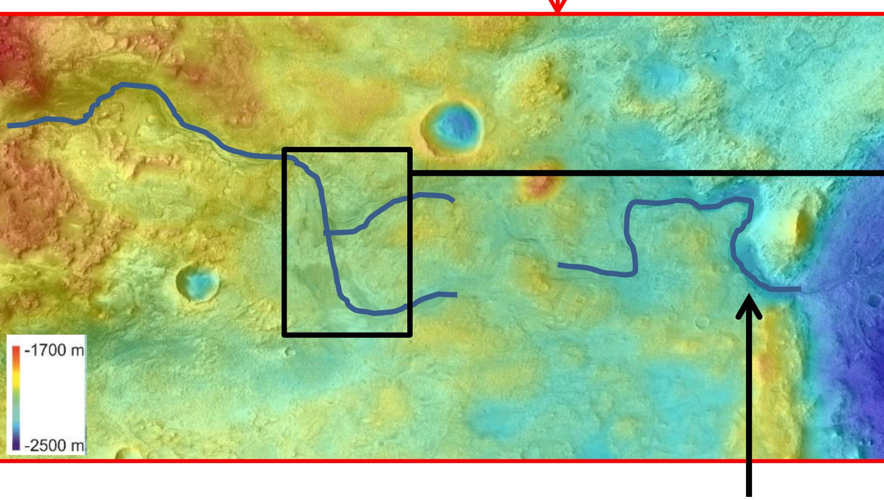
Fluvial morphology: 2. Lower valley

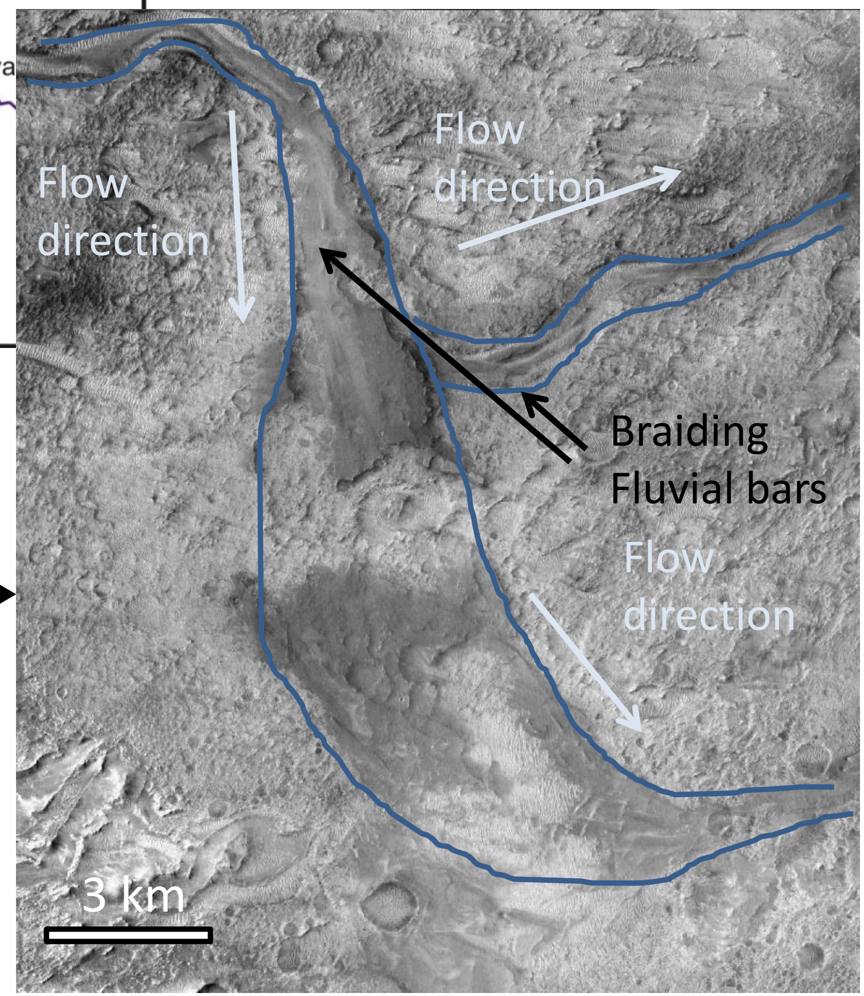


Fluvial morphology: 2. Lower valley

Morphology typical of channels
Braiding, fluvial bars, deposits.



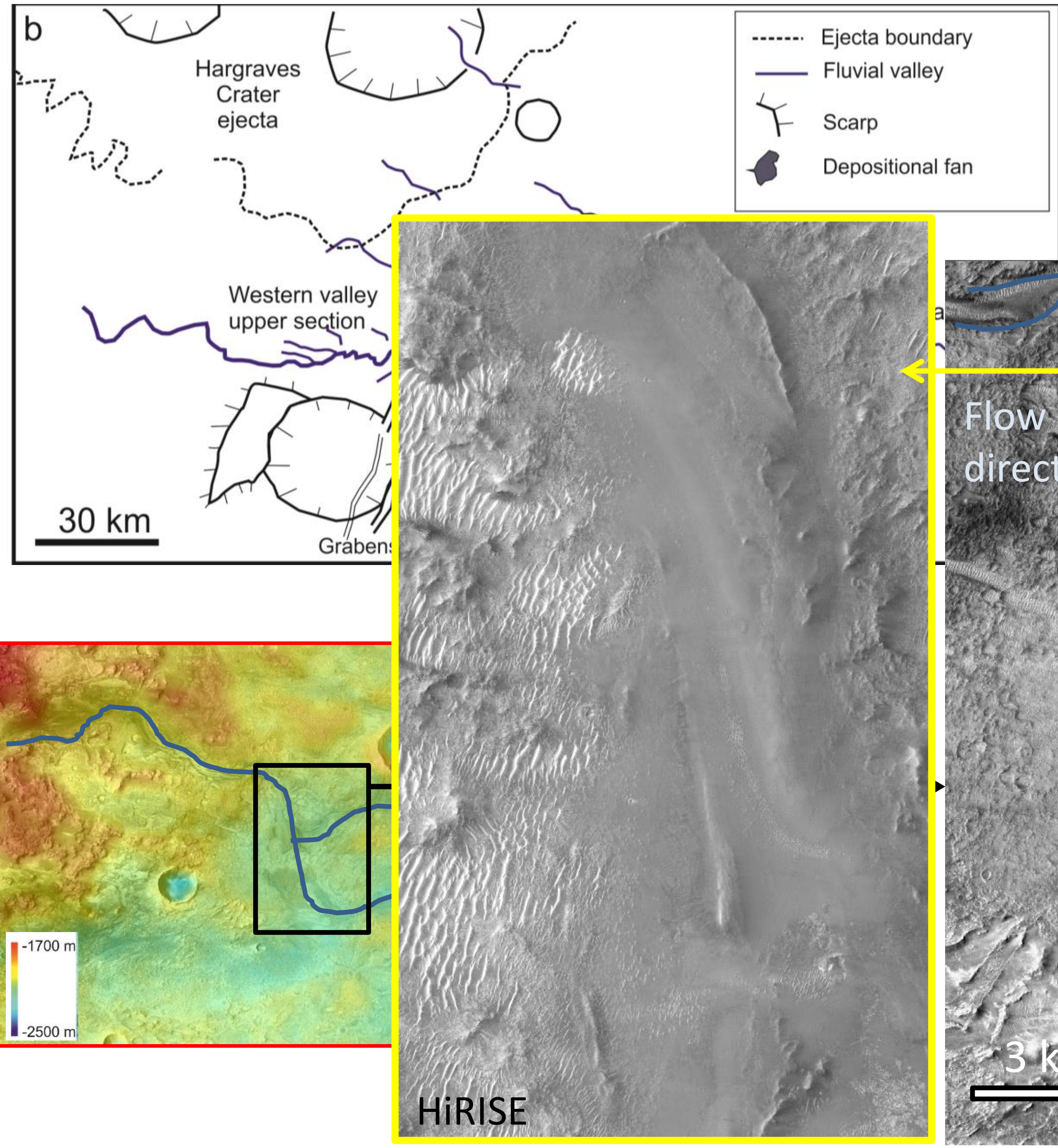


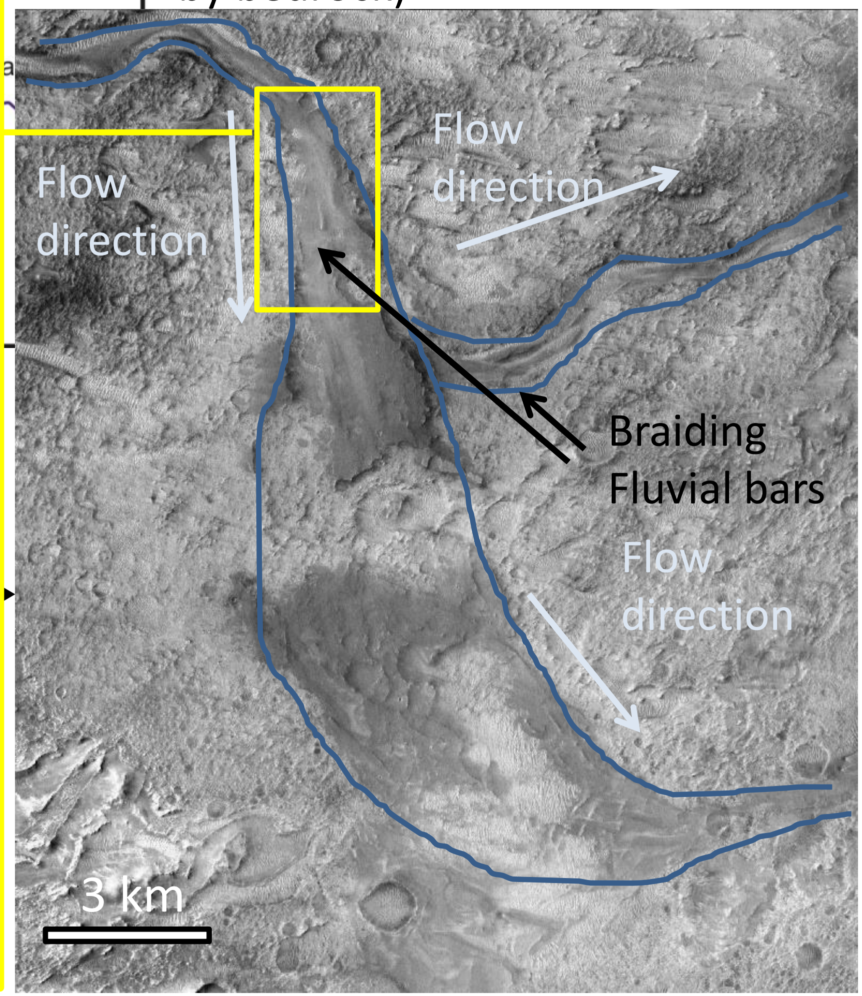


Fluvial morphology: 2. Lower valley

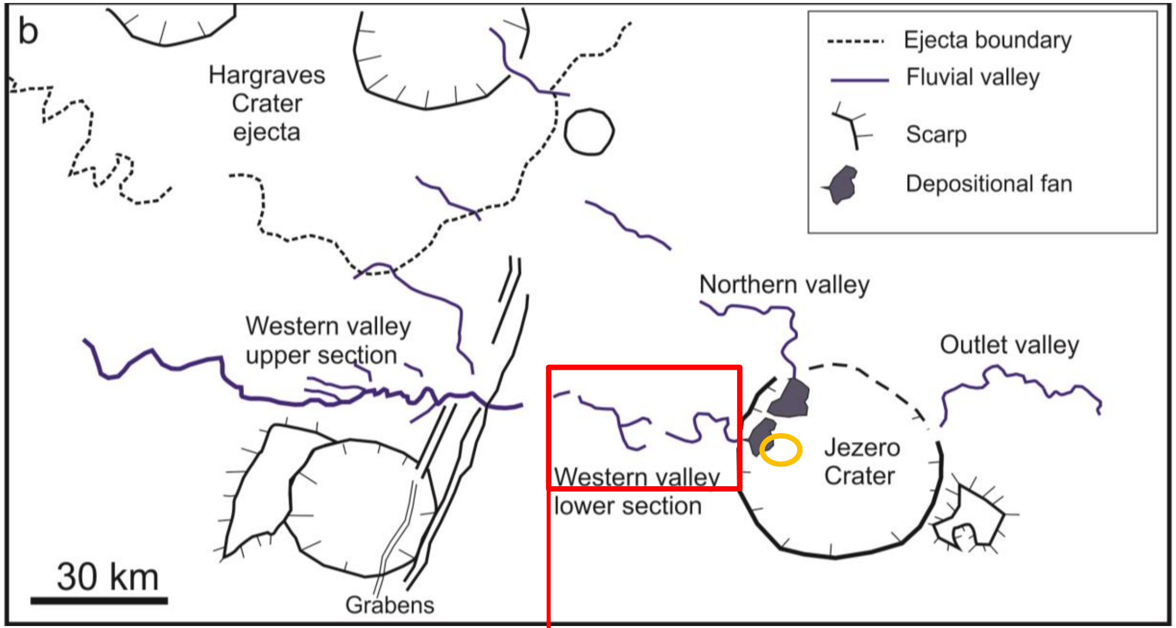
Morphology typical of channels
Braiding, fluvial bars, deposits.

Not alluvial plains (surrounded by bedrock)





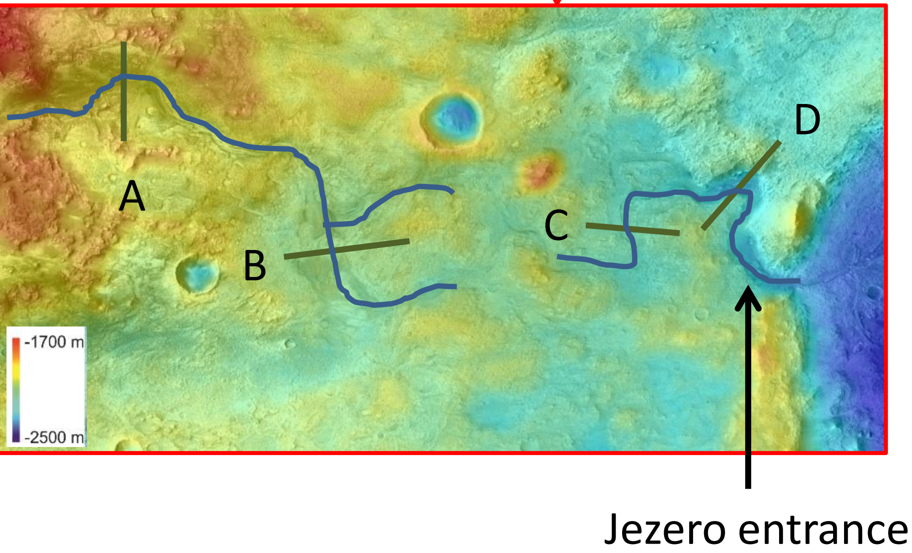
Fluvial morphology: 2. Lower valley

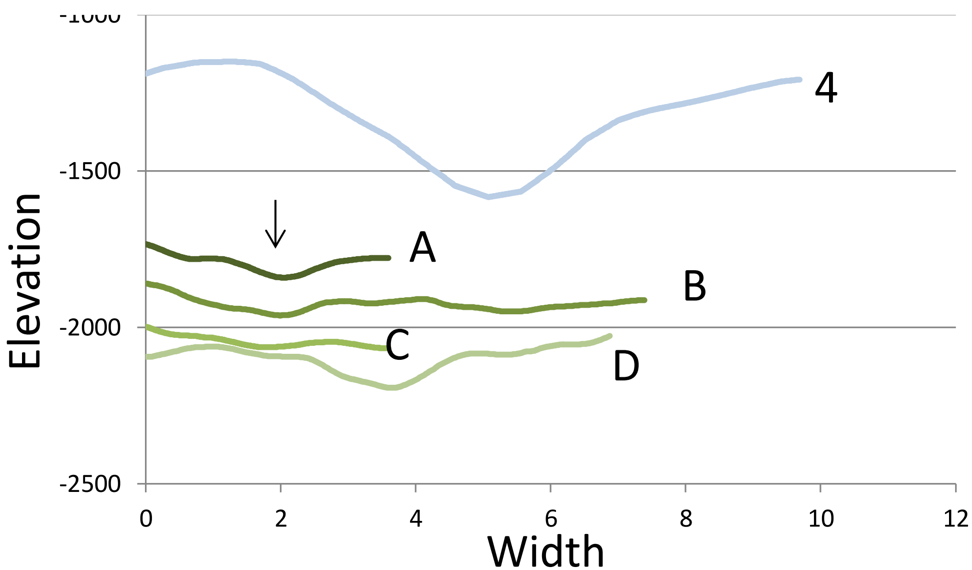


Morphology typical of channels
Braiding, fluvial bars, deposits.

< 50 m incision
(except Jezero entrance)
<3 km^3 eroded volume
(20 times less than upper section)

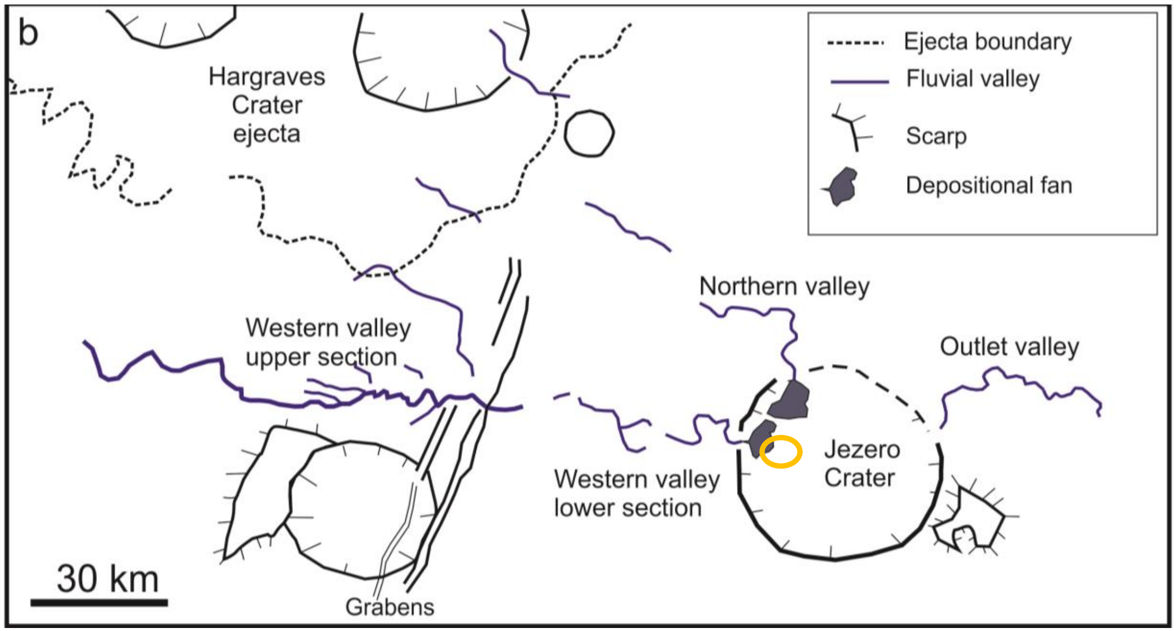
No significant fluvial incision
Not classical of Noachian valleys





HRSC DEM transverse profiles

Fluvial morphology: 2. Lower valley



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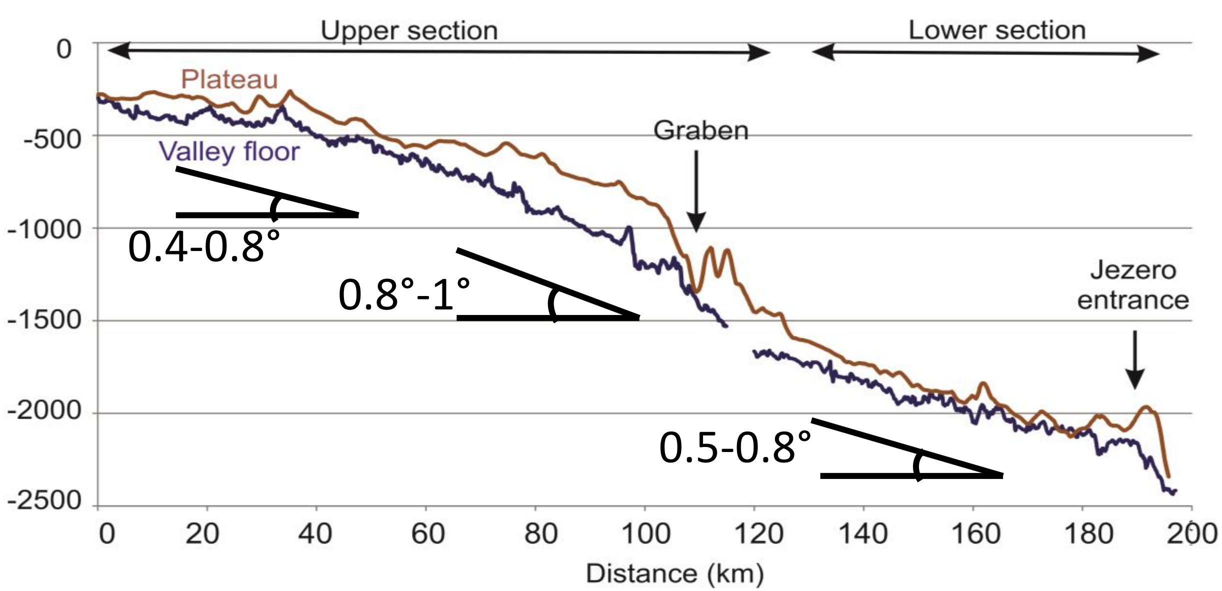
Braiding, fluvial bars, deposits.

↓

Alluvial deposits at lower slope?
Could the difference in style be related to gentler slopes only, i.e., alluvial plains?

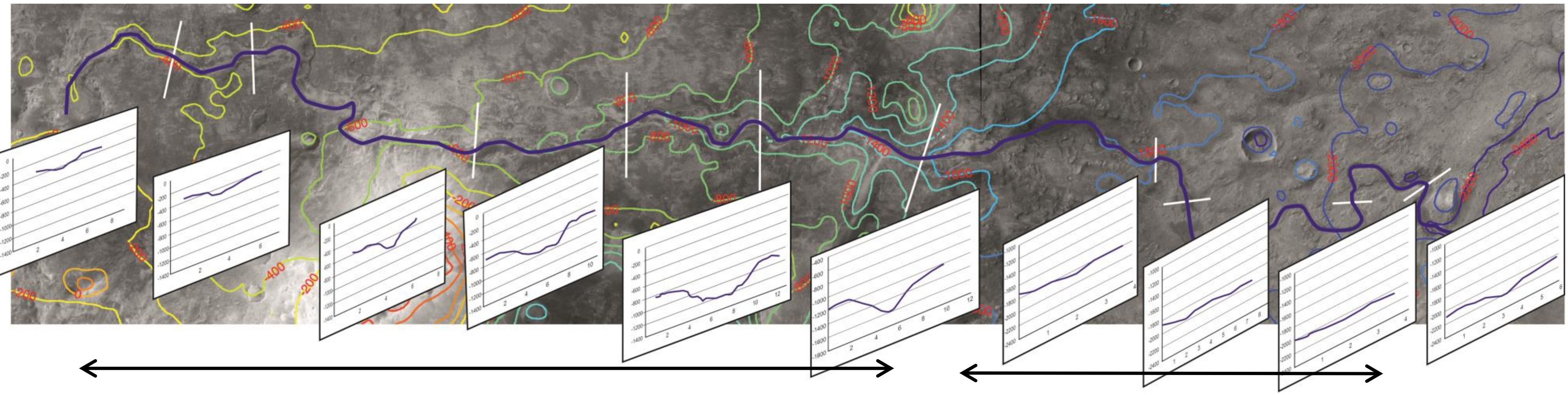


Longitudinal profile:

- Slope is not much shallower than on the basement
- No alluvial plains
- Topographic drop at Jezero entrance

Fluvial morphology: Summary

Upper Valley: 53 km^3 **Lower valley: 3 km^3** **Fan: 4-5 km^3**



Deep bedrock incision *Poor incision*

1. Upper Valley:

Strong incision
Classic Noachian valley

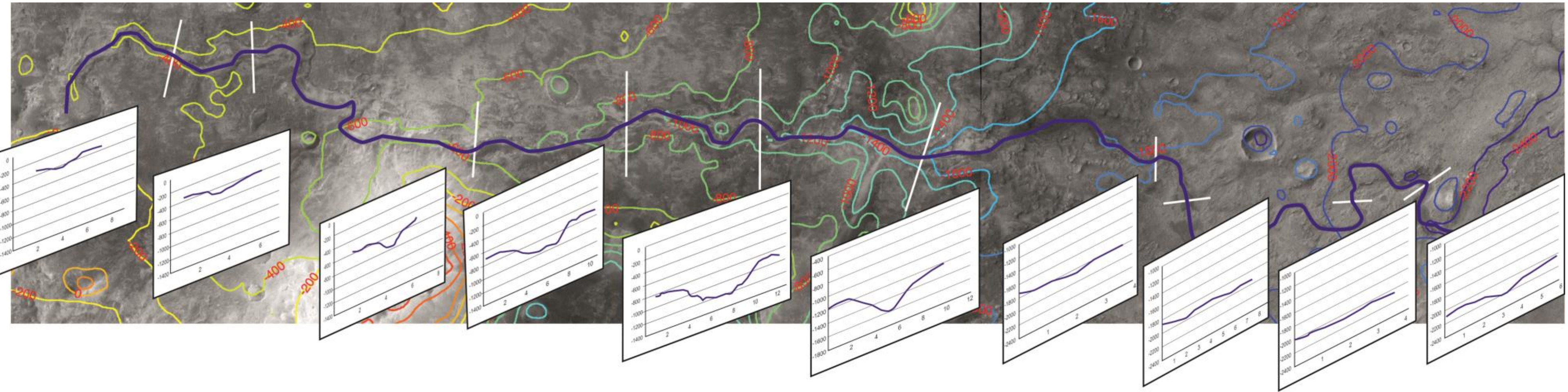
2. Lower Valley:

Poor incision
Braided channels
Not typical of Noachian valleys

How to explain these apparent discrepancies?

Fluvial morphology: Summary

Upper Valley: 53 km³ **Lower valley: 3 km³** **Fan: 4-5 km³**

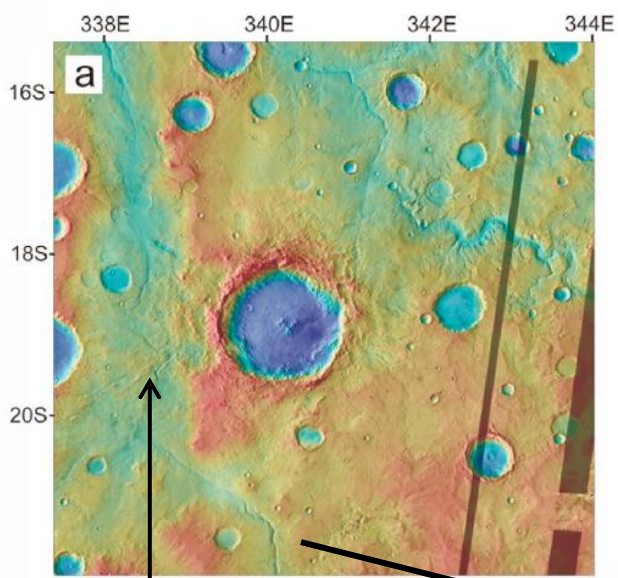


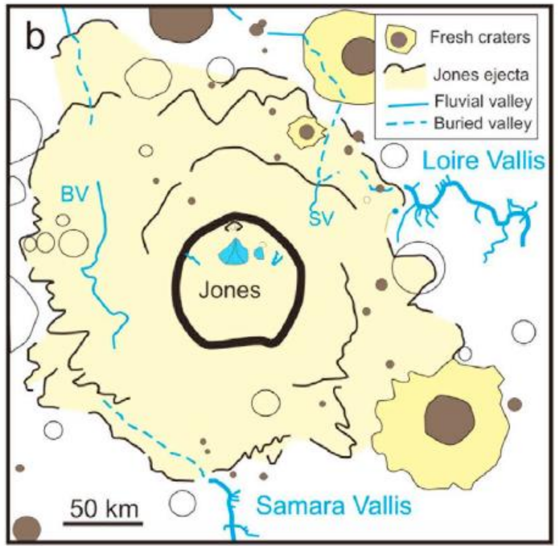
Map from Goudge et al, 2015 Noachian basement] [Mottled Olivine Carbonate unit

Working hypothesis:
The fluvial activity started before the olivine unit formation
A reactivation of the fluvial network occurred after the olivine unit formation
=> This would explain the difference in morphology, and in eroded volume,
+ the low volume of the fan compared to the total volume eroded upstream

Example of reactivation of fluvial valleys: Samara Vallis

Mangold et al, JGR, 2012





Samara Vallis is a deep valley typical of Noachian activity.

It has been blanketed by Jones impact crater in the Hesperian

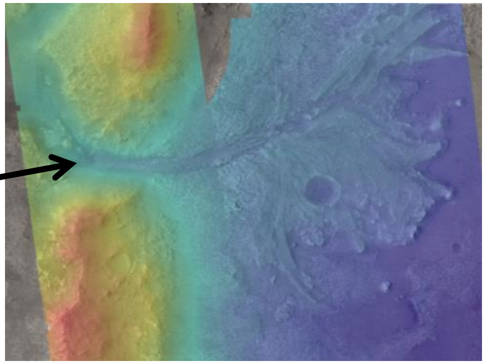
And reactivated as shorter episodic fluvial activity shown by braided channels

Reactivation has been observed in several places on Mars (first observed by Brakenridge, 1986)

Hydrology: Lake duration

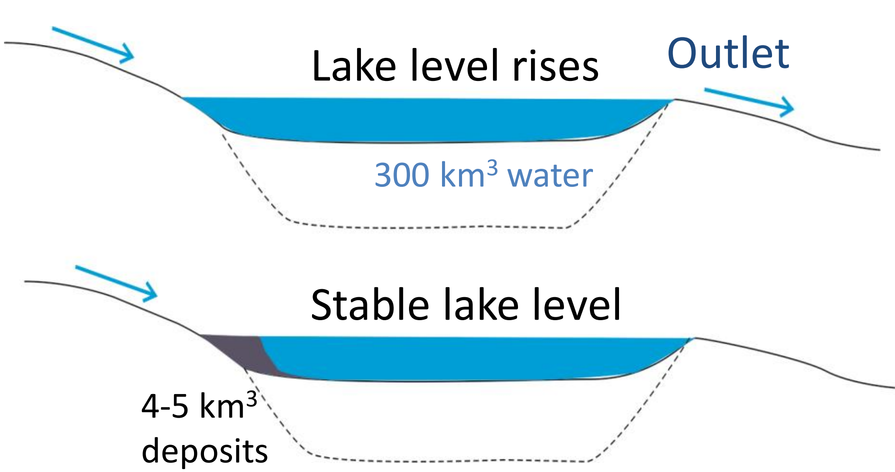
Assumptions:
- Estimations made only for the fan formation of ~5 km^3 *
- Model from Kleinhans et al. (2010), Salese et al, in prep.

Fixed parameters from DEMs : Channel width (50-190 m), slope, etc.
Deduced parameters: Discharge rates (440-2800 m^3/s), W:R ratio (2,000-3,000)
Variable parameters : Grain size (D50 from 4 mm to 10 cm)



1. Filling of the lake - Breach of the outlet

2. Formation of the fan by continuous flow



*NB: With possible delta remnants the volume would be of 8 km^3 maximum

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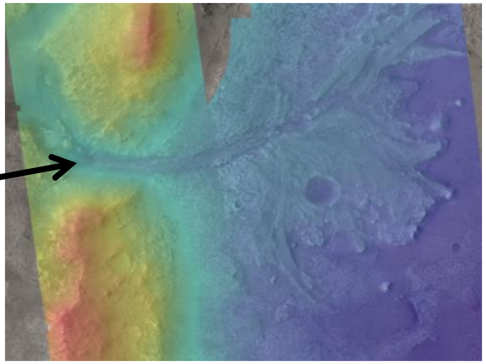
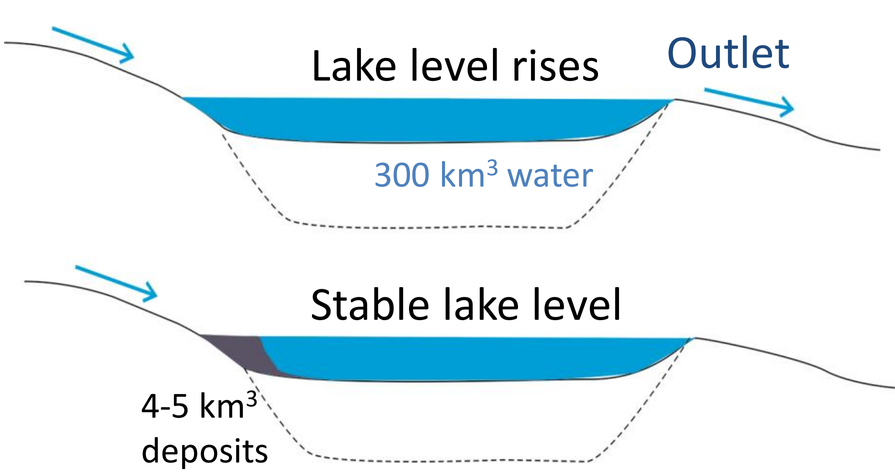


1. *Filling of the lake - Breach of the outlet*

~4-20 y (consistent with Fassett and Head, 2005)

Strict minimum – Not dependent on fan formation

2. *Formation of the fan by continuous flow*



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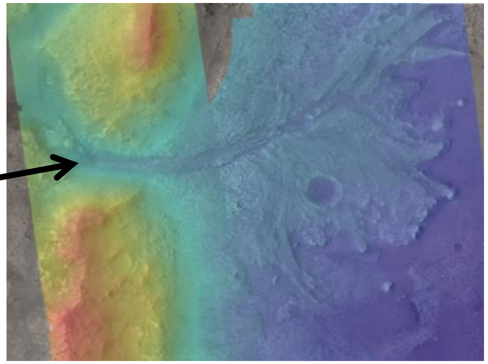

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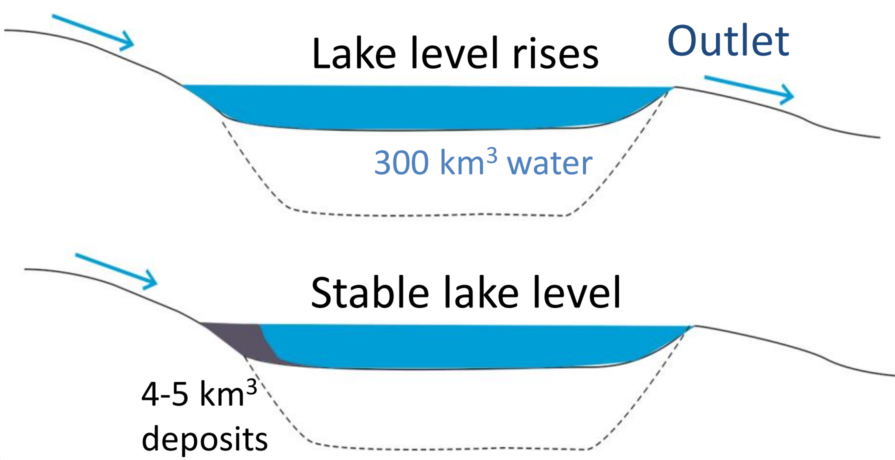


~**4-20 y** (consistent with Fassett and Head, 2005)
Strict minimum – Not dependent on fan formation

2. *Formation of the fan by continuous flow*

~50-3,000 years (D50 of respectively, 4 mm and 10 cm)
(Channel width of respectively, 190 and 50 m)

Up to 10-30,000 years may be possible with discontinuous flows (a factor of 10 in intermittency is a maximum, because the lake must remain stable for the formation of the delta fan).

*NB: With possible delta remnants the volume would be of 8 km^3 maximum

Scenario proposed for the fluvial evolution

1. Strong fluvial erosion of basement (pre-Olivine unit, Noachian)

>50 km^3 of sediments deposited downstream
Duration of activity cannot be estimated from deposits
Compared to Earth the basement erosion suggests extended periods (>>10,000 ys)

2. Formation of the olivine-rich unit (Mid- to Late Noachian)

3. Reactivation of the fluvial activity after olivine unit (Late Noachian or Hesperian)

The well-preserved delta fan is linked to this late-stage of activity
The duration is estimated from 50 y to 3,000 ys of continuous flow
(up to 10,000s years with intermittency taken into account)
There are Hesperian regional activities (e.g., Hargraves crater) to which this episode may be linked, but no regional Amazonian episodes.

Implication: The well preserved fan may be the « tip of the iceberg »

Implications for Jezero as a landing site: Testable hypotheses

IGNEOUS EVOLUTION:

\+ Upper fan as a grab bag of fresh clasts from the basement (but - not in place)

AQUEOUS EVOLUTION:

\+ Paleohydrology of late-stage episode from fluvial deposits in upper fan deposits (size and rounding of pebbles, etc.)

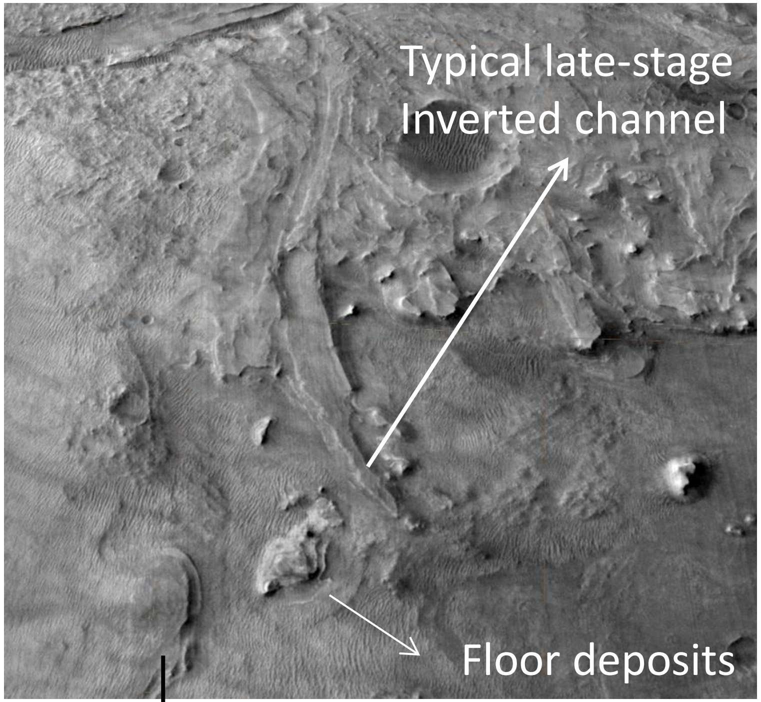
? Unclear if hydrology of early stages is accessible

EXOBIOLOGY:

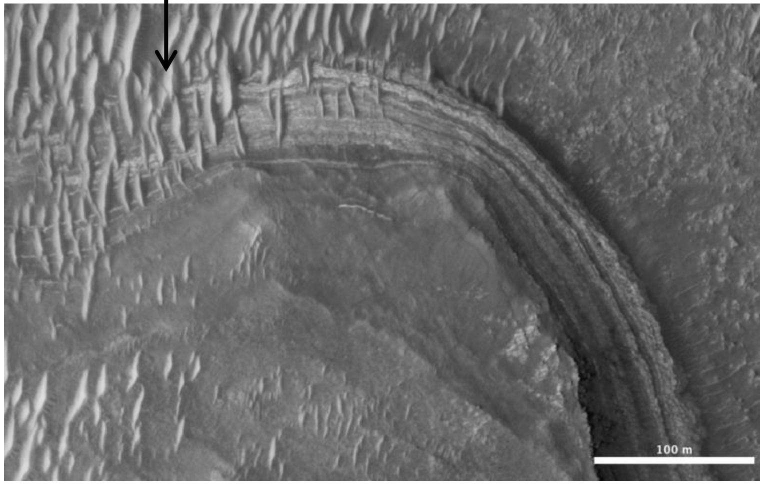
\- Upper fan not that relevant for exobiology (potentially coarse clastic deposits)

\+ Bottomsets of the late stage delta will concentrate fines and organics, whatever duration of the system.

\+ Sediments of the floor and margins may be linked to early stages and so could be of stronger exobiological interest (for ex. carbonates at the margin)



Jezero margin deposits



See B. Horgan presentation

Jezero crater contains key minerals (carbonates, smect.) for exobio./climate objectives and unaltered rocks for geochronology/igneous evolution objectives in the context of a depositional basin with multiple stages of fluvial activity at distinct periods of Early Mars.