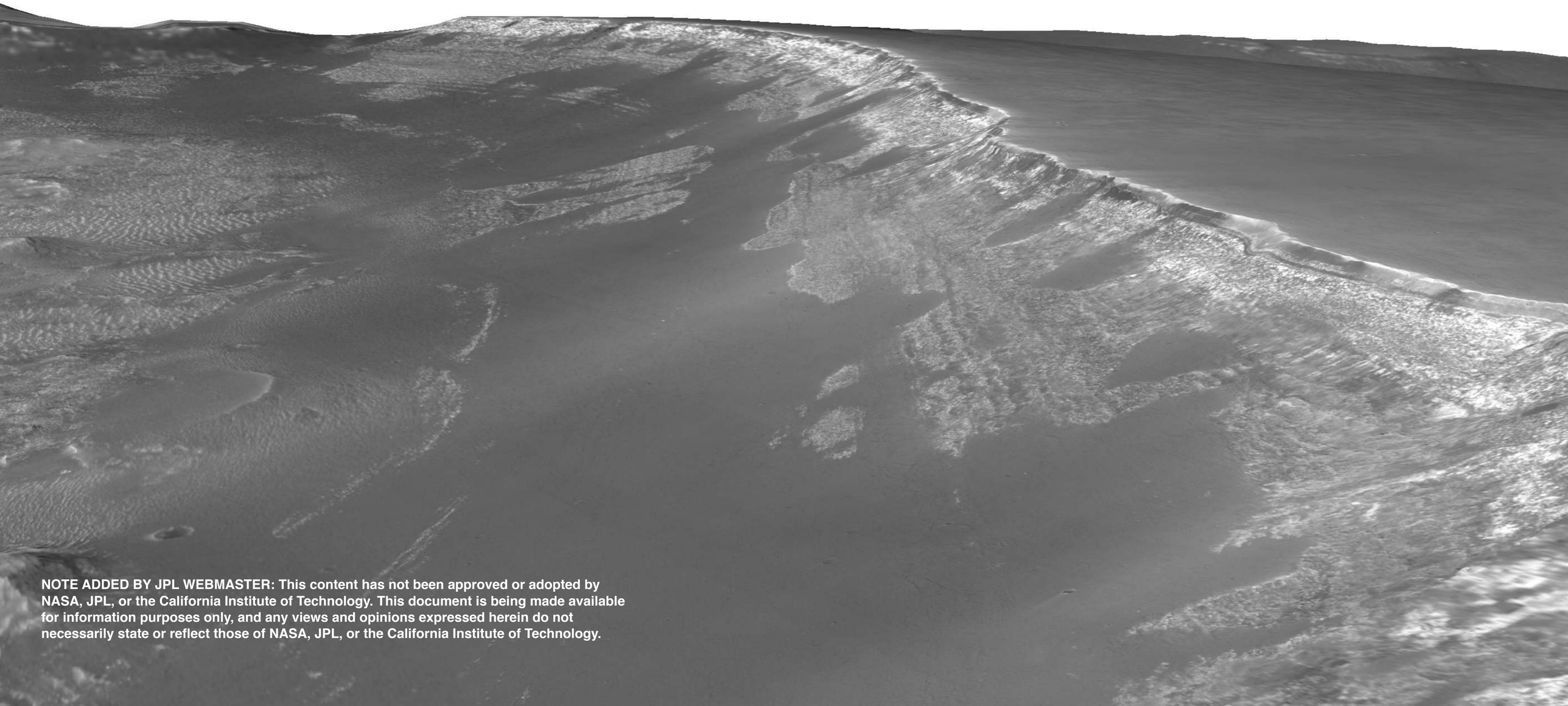
Sedimentary units accessible in the NE Syrtis extended mission area and recent findings on the history of surface water in the broader region

Daven P. Quinn and B.L. Ehlmann



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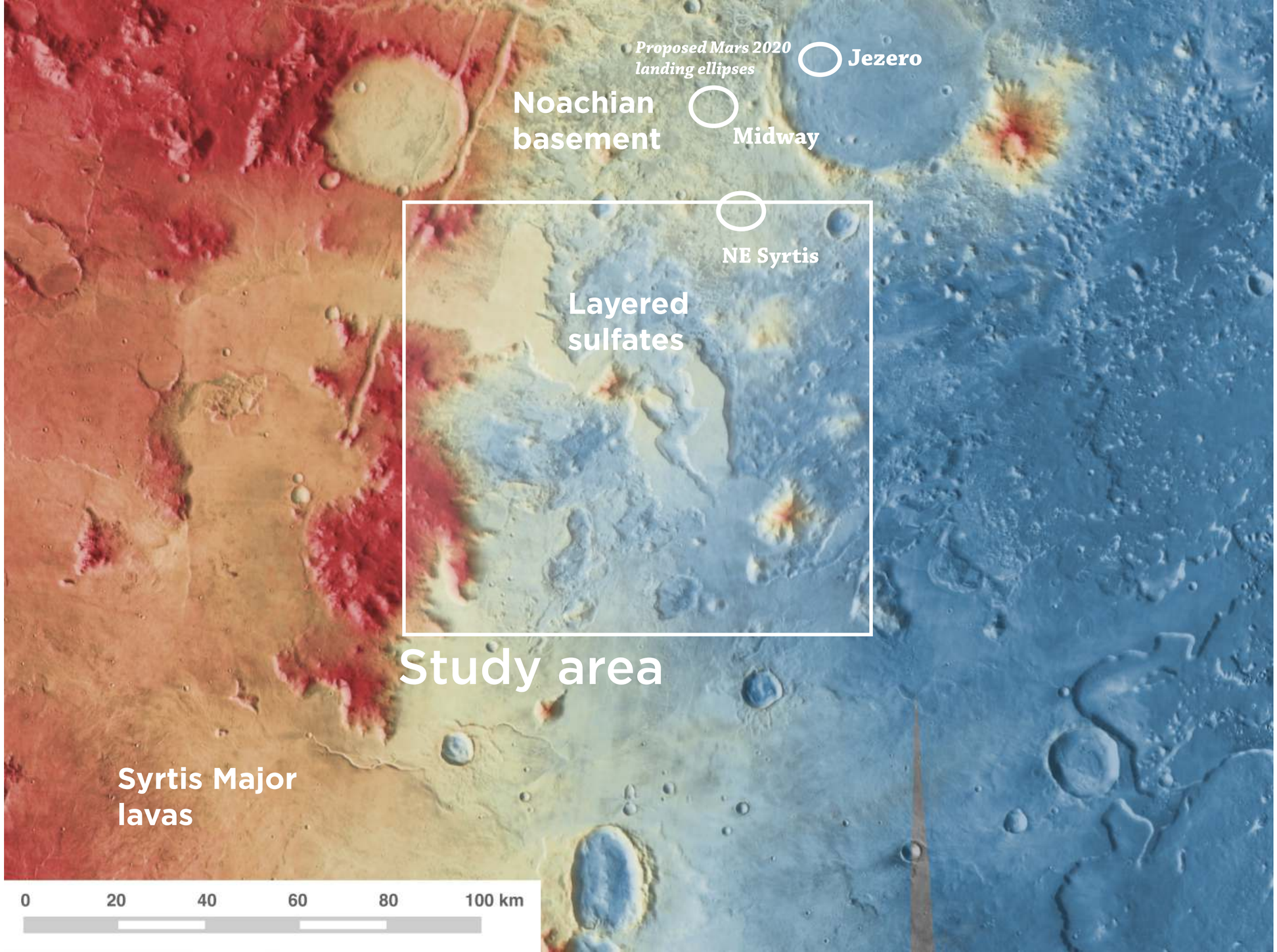
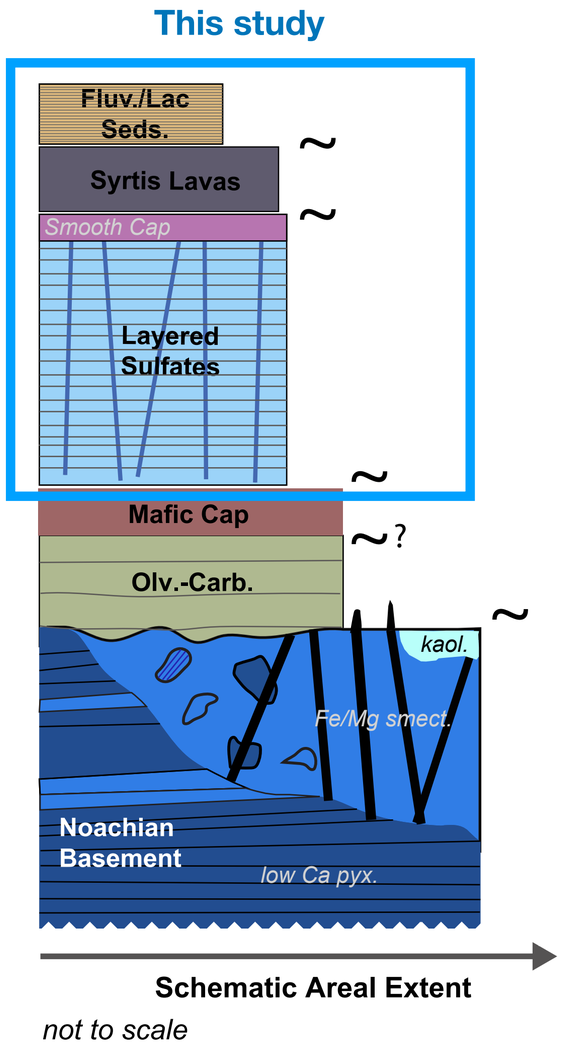
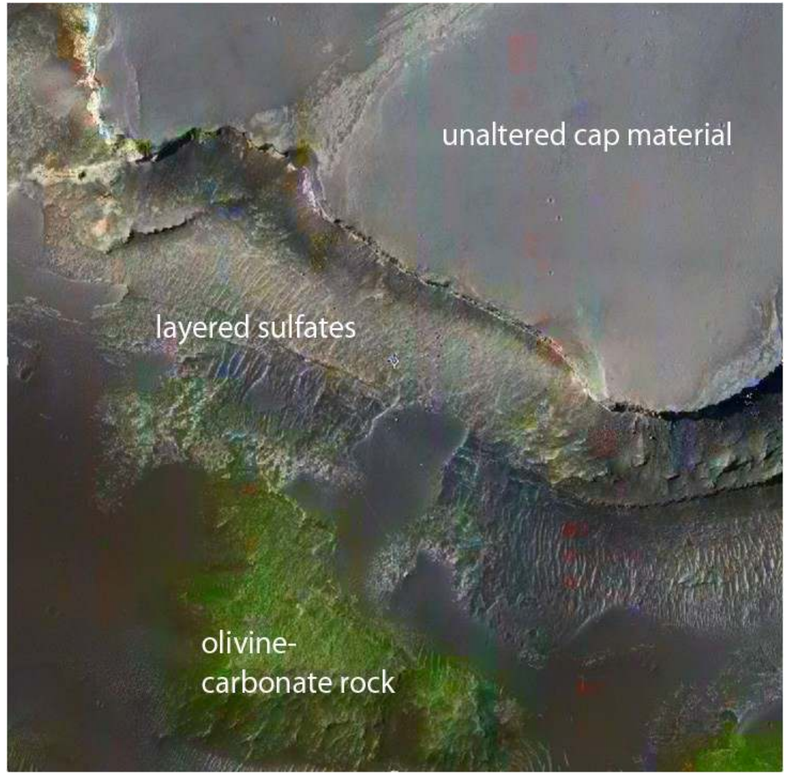

Proposed Mars 2020 landing ellipses
Jezero
Noachian basement
Midway
NE Syrtis
Layered sulfates
Study area
Syrtis Major lavas
0
20
40
60
80
100 km


This study
Fluv./Lac Seds.
Syrtis Lavas
Smooth Cap
Layered Sulfates
Mafic Cap
Olv.-Carb.
kaol.
Fe/Mg smect.
Noachian Basement
low Ca pyx.
Schematic Areal Extent
not to scale

NE SYRTIS UPPER STRATIGRAPHY: BASIC ARCHITECTURE

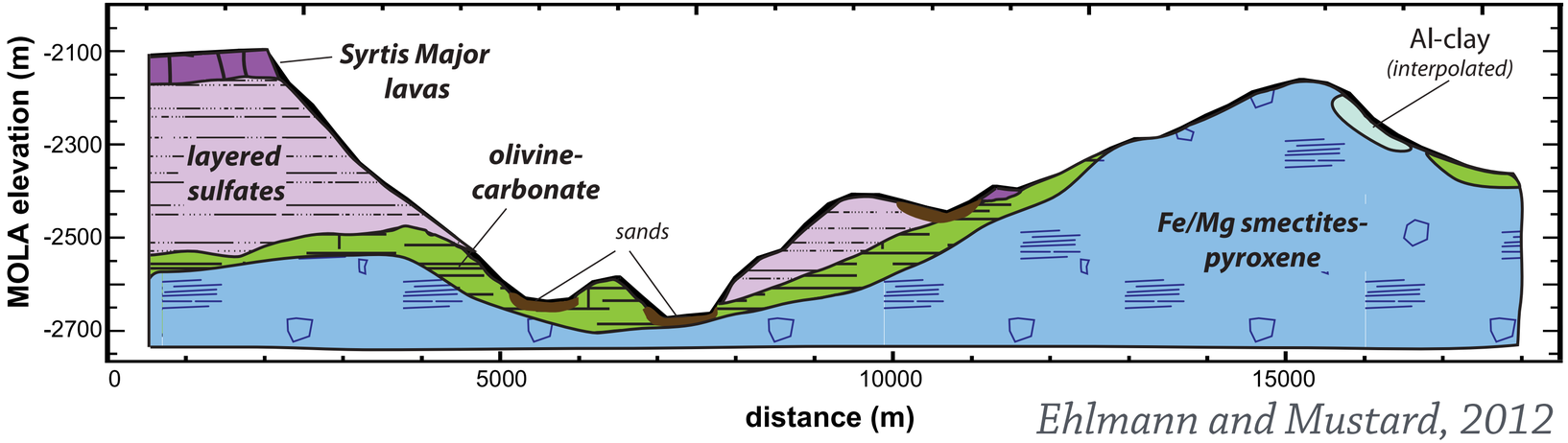


Layered sulfates

- Thick sedimentary unit
- Acidic style of aqueous alteration (distinct from Noachian basement units)
- Depositional timing bracketed by units of known Noachian and Hesperian age

Syrtis Major lavas

- No signatures of aqueous alteration
- Known early Hesperian age (crater counting)



Ehlmann and Mustard, 2012

Preprint manuscript: https://eartharxiv.org/fzhk7

NE SYRTIS UPPER STRATIGRAPHY: NEW FRAMEWORK

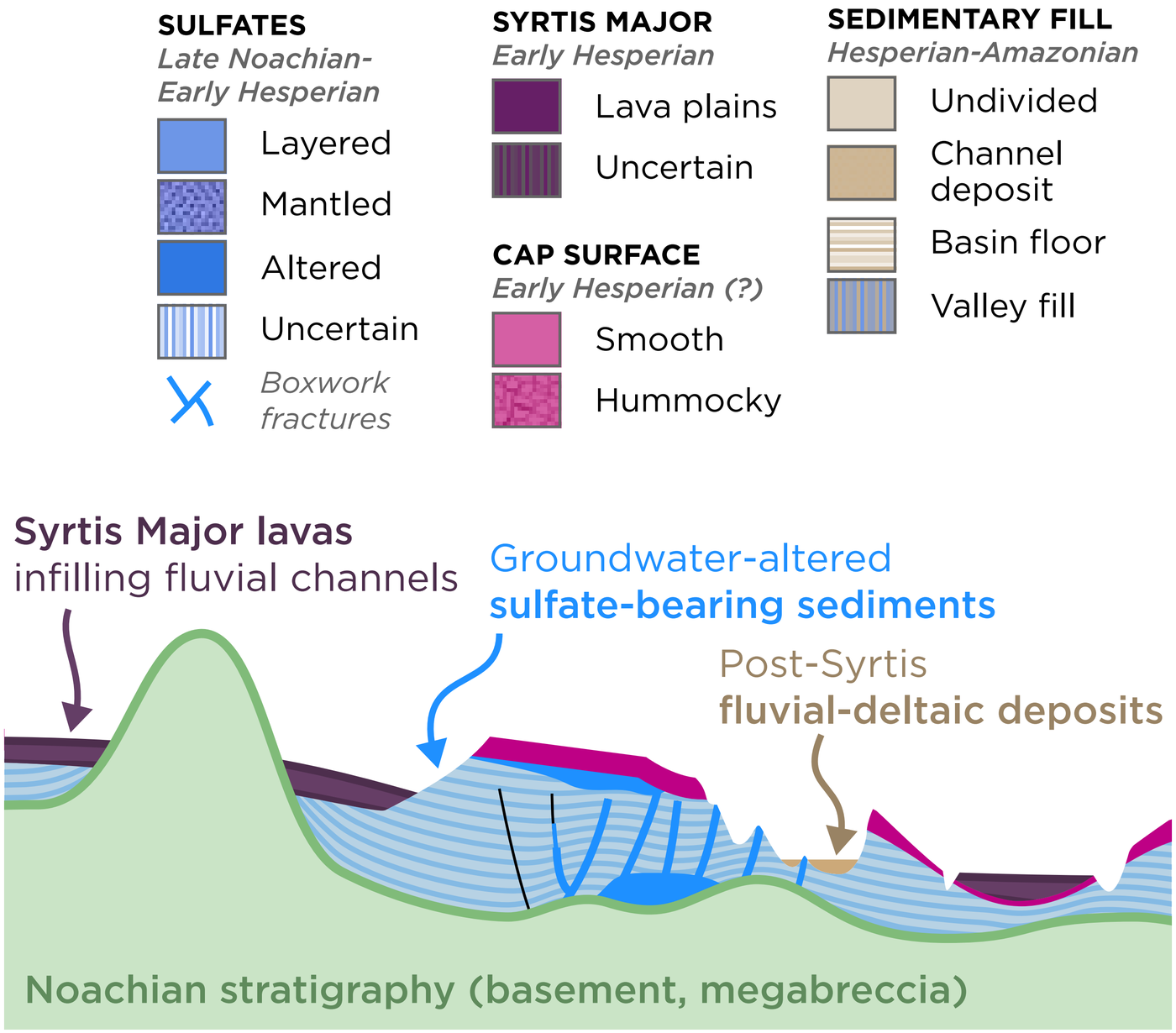
Methods

- 3D structural analysis
- Geologic mapping

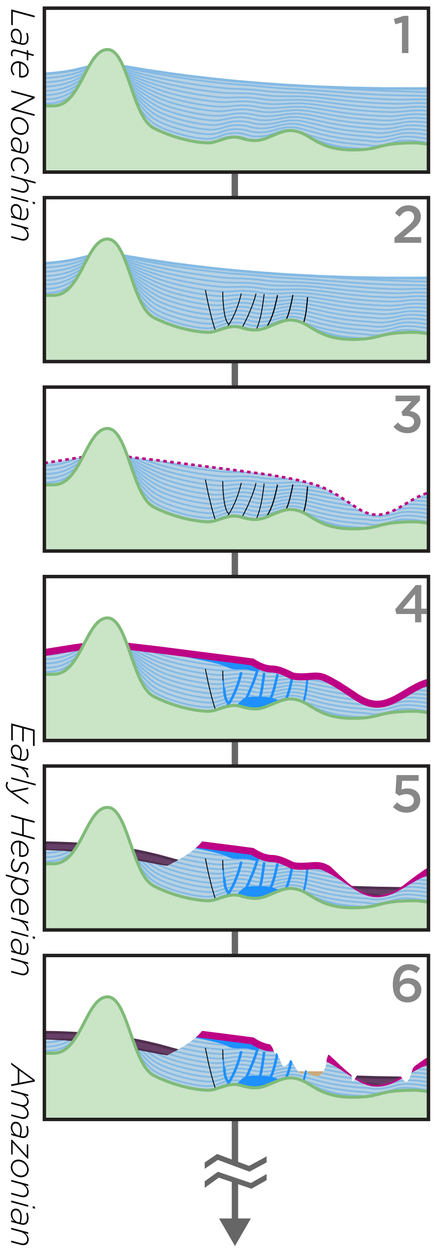
Results

- Three sets of units postdating the Noachian basement stratigraphy
- Multiple episodes of surface- and groundwater activity postdating Noachian basement alteration

Manuscript in 2nd-round review at JGR-Planets: D.P. Quinn and B.L Ehlmann, *The Deposition and Alteration History of the Northeast Syrtis Layered Sulfates*. Preprint available at https://eartharxiv.org/fzhk7



NE SYRTIS UPPER STRATIGRAPHY: NEW FRAMEWORK



Layered sulfates

Diagenesis

Erosion (1)

Smooth cap surface

Syrtis Major lavas

Erosion (2)

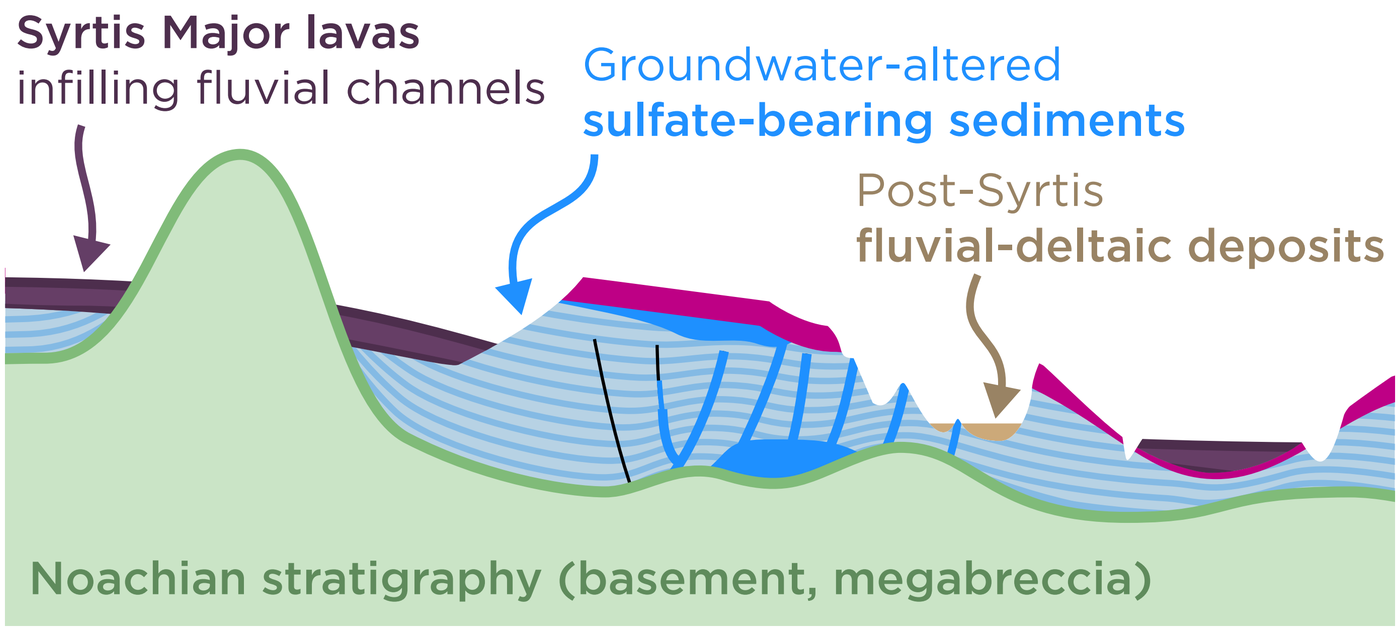
Fluvial-deltaic deposits

SULFATES
Late Noachian-Early Hesperian
- Layered
- Mantled
- Altered
- Uncertain
- *Boxwork fractures*

SYRTIS MAJOR
Early Hesperian
- Lava plains
- Uncertain

CAP SURFACE
Early Hesperian (?)
- Smooth
- Hummocky

SEDIMENTARY FILL
Hesperian-Amazonian
- Undivided
- Channel deposit
- Basin floor
- Valley fill



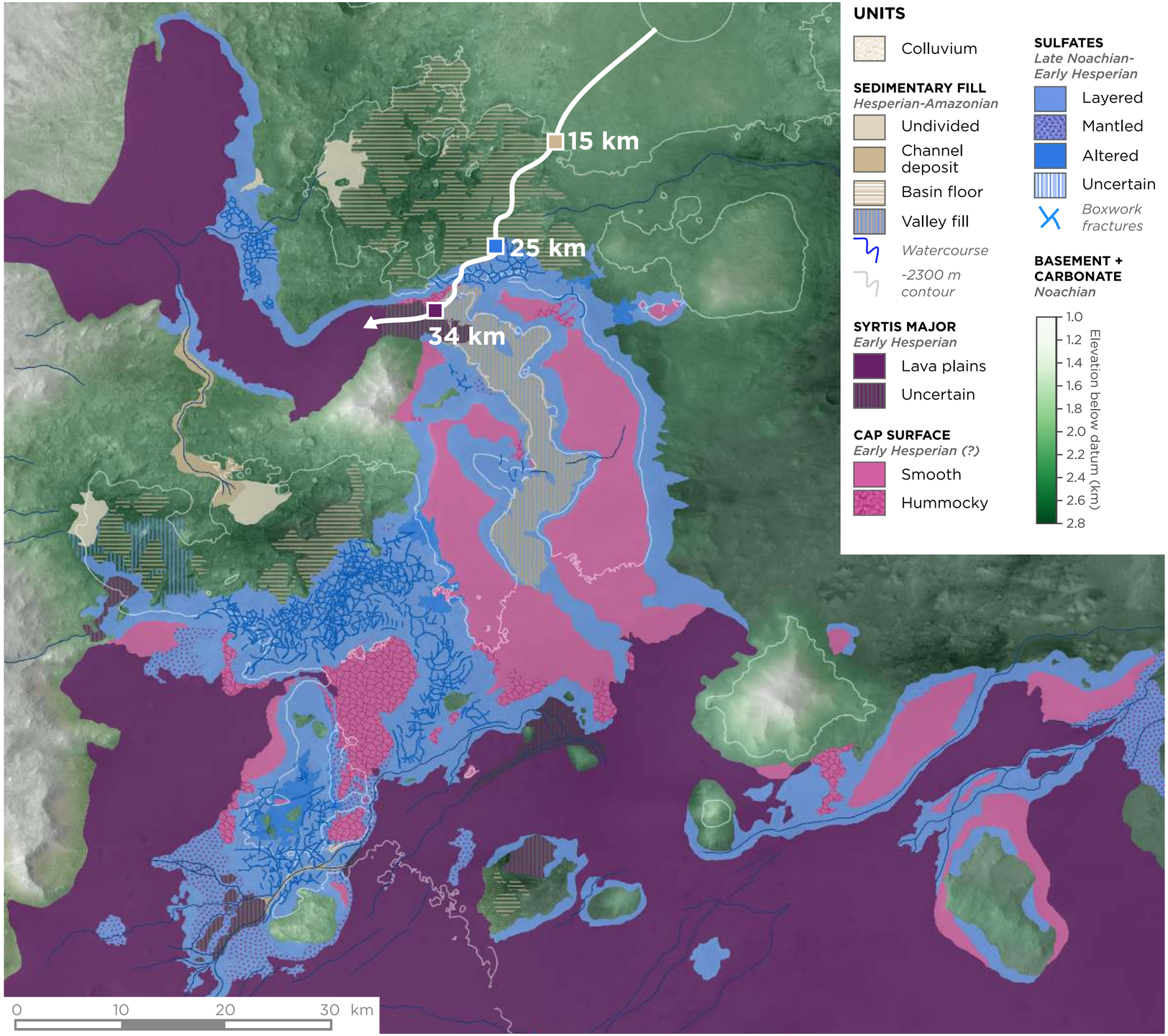
Preprint manuscript: https://eartharxiv.org/fzhk7

GEOLOGIC MAP of NE Syrtis focusing on the upper sedimentary stratigraphy

- Define and characterize units
- Evaluate potential depositional processes

All units accessible from NE Syrtis ellipse in extended mission traverse:

1. Late sedimentary deposits
2. Layered sulfates
3. Syrtis Major lavas



Preprint manuscript: *The Deposition and Alteration History of the NE Syrtis Layered sulfates* (https://eartharxiv.org/fzhk7)

LAYERED SULFATES

Thick stratigraphy

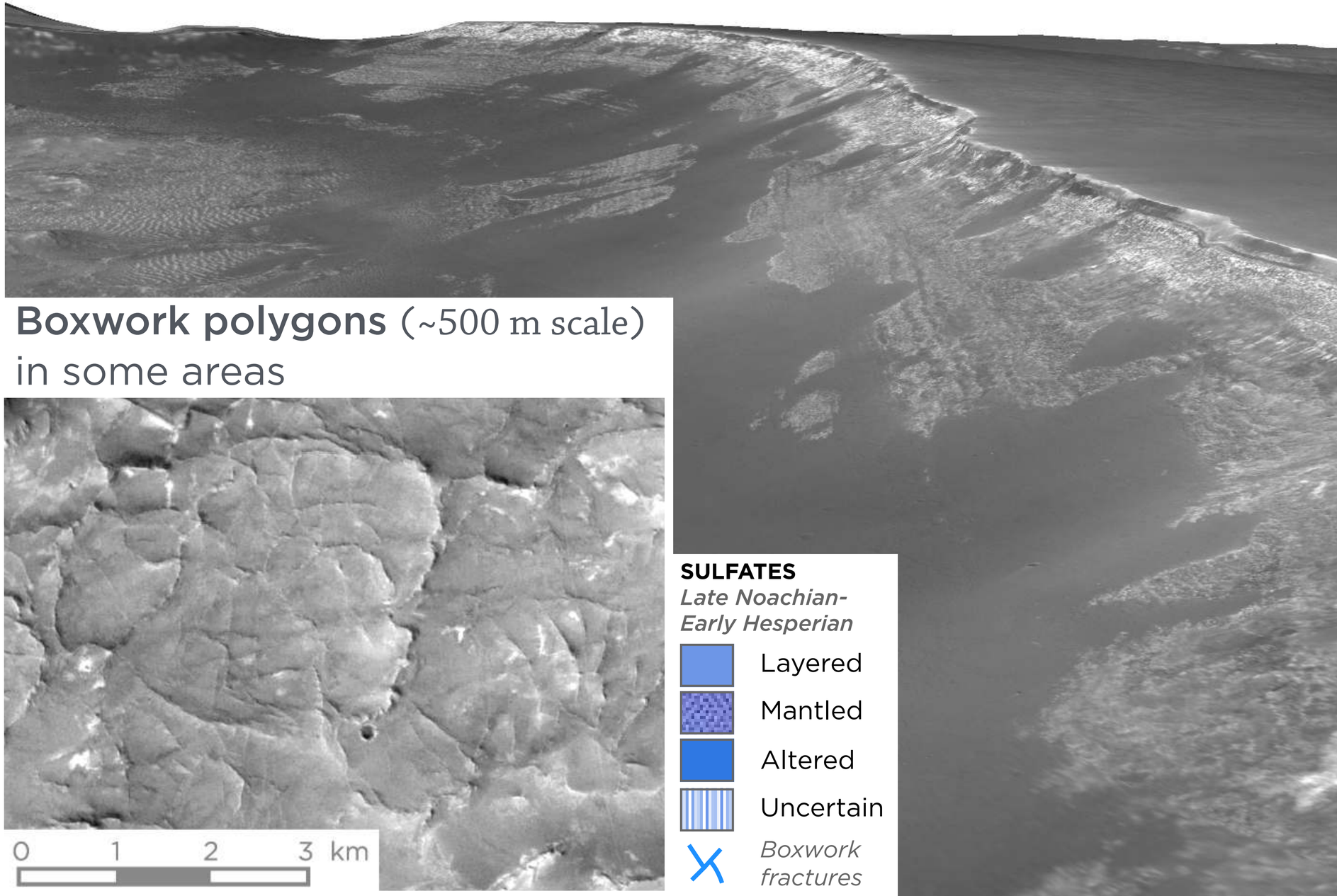
~400 m relief in this scene (NF6)

Layered at meter-scale

μ = 1.4 m, s = 0.4 m (NF1, NF6, and NF7)

Easily eroded

Preserved where capped or buttressed by resistant ridges



Boxwork polygons (~500 m scale) in some areas

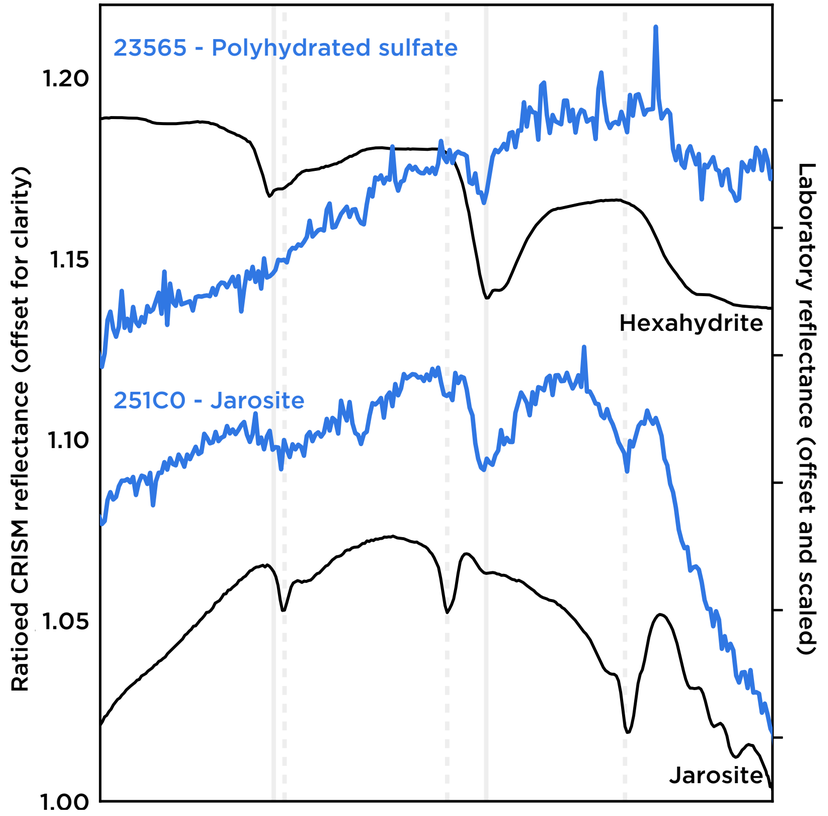
Preprint manuscript:
https://eartharxiv.org/fzhk7

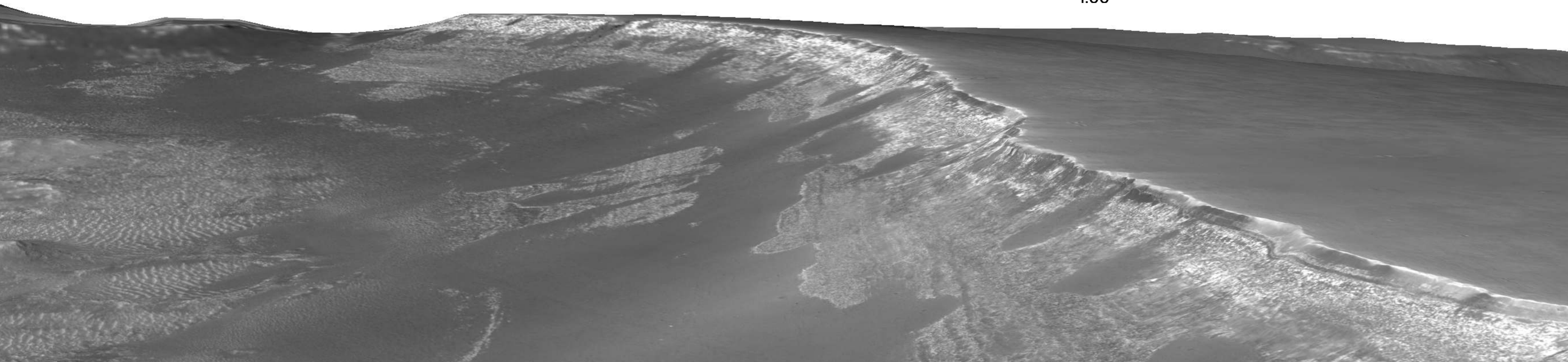
LAYERED SULFATES

- Basaltic composition detrital sedimentary rock
- Deposited above Noachian basement units
- Polyhydrated sulfate mineral signatures
- Jarosite-bearing boxwork ridges

Sulfates represent an environmental transition to:

- Clearly sedimentary deposition
- More acidic style of aqueous alteration





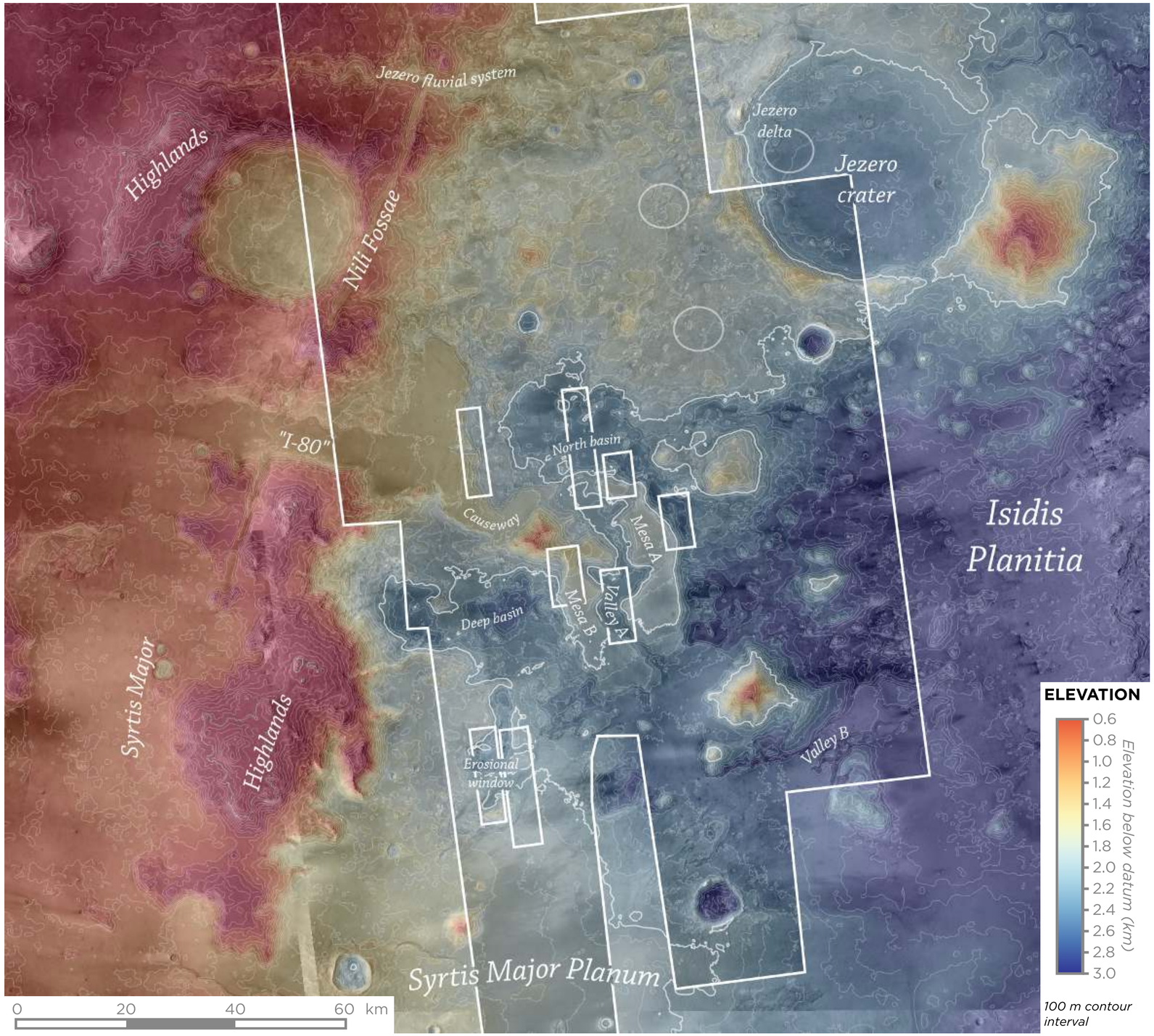
STUDY METHODS

Build elevation models providing detailed topographic data

CTX and HiRISE elevation models, 1-10 m per pixel

Detailed geologic mapping

Structural characteristics to distinguish depositional mechanisms



Preprint manuscript: https://eartharxiv.org/fzhk7

LAYERED SULFATES: DEPOSITIONAL MECHANISMS

Structural characteristics can help distinguish depositional mechanism between possible options.

VOLCANIC

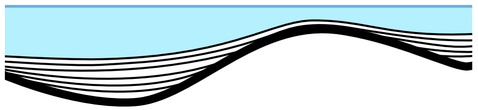
Lava flow
Effusive material blanketing large area

Ash fall
Airborne ash from explosive eruptions

Ash flow
Pyroclastic flow deposits

SEDIMENTARY

Deep lake
Lake covering the entire region



Shallow lake
Lakes in localized craters or valleys

Evaporite
Playas and ephemeral lakes

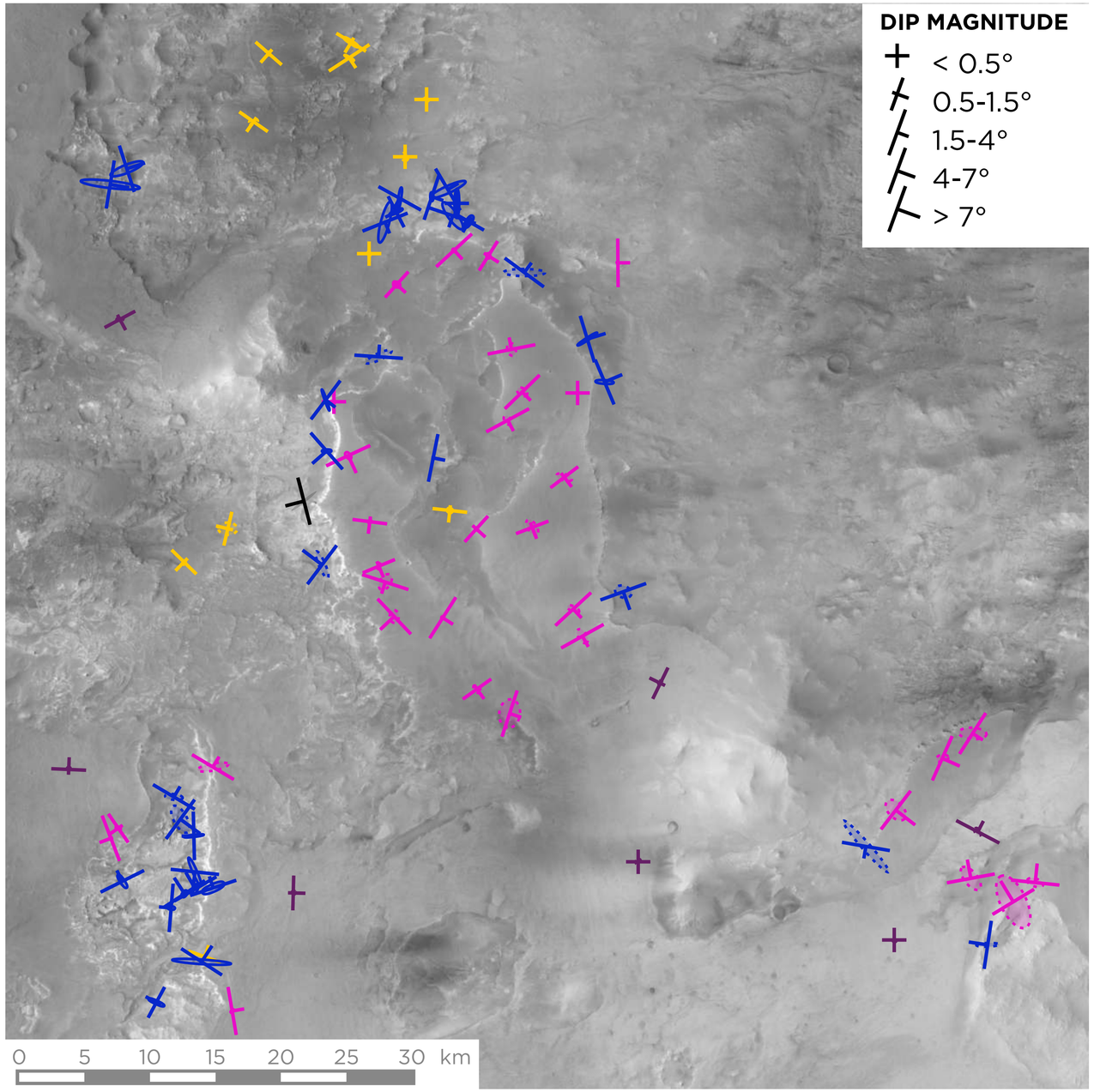
Alluvial/fluvial
River or upstream sedimentary system

Aeolian
Wind-blown dust and sand

Glacial/snow
Dust residue from precipitation and sublimation

Preprint manuscript: https://eartharxiv.org/fzhk7

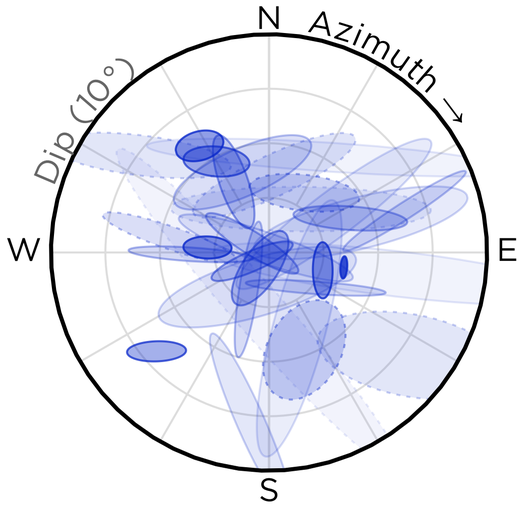
REGIONAL ORIENTATIONS



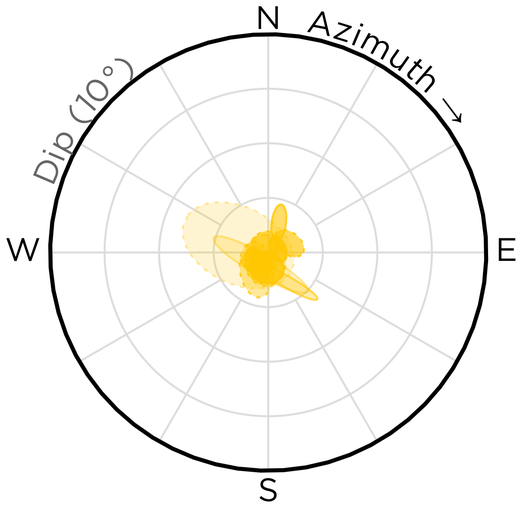
Orientation errors

LAYERED DEPOSITS

Layered sulfates

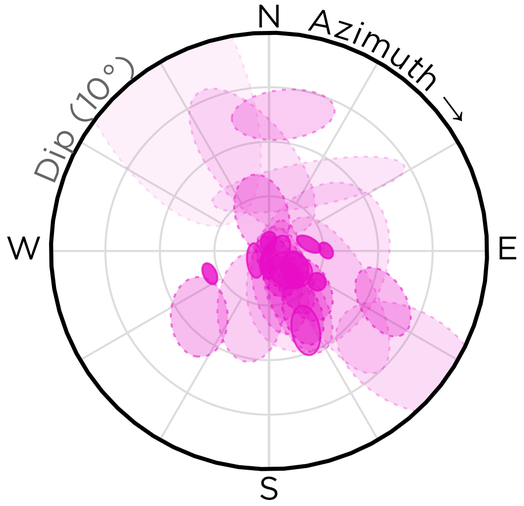


Sedimentary fill

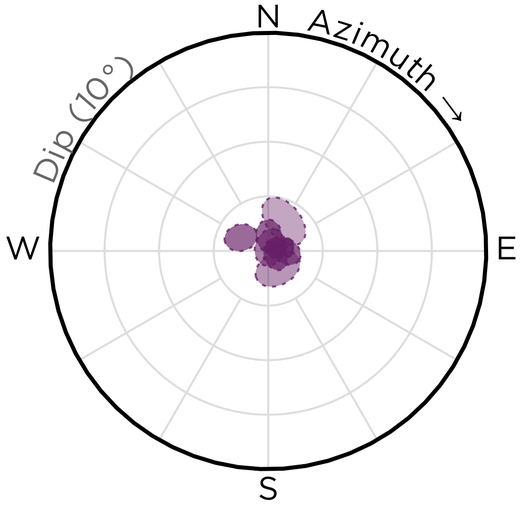


CAPPING SURFACES

Smooth capping surface



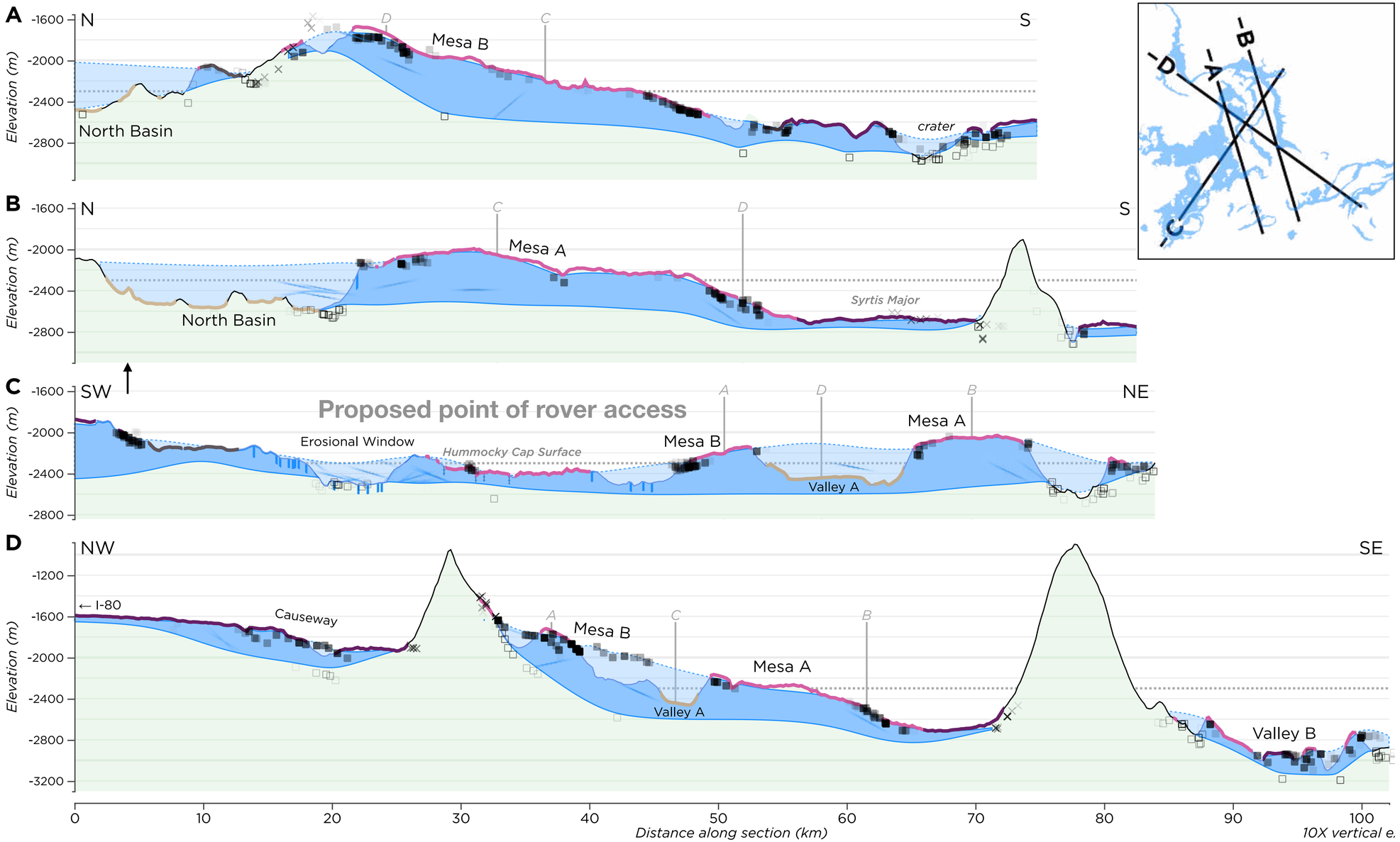
Syrtis Major lavas



Preprint manuscript: https://eartharxiv.org/fzhk7

LAYERED SULFATES: CROSS SECTIONS

- Thick (up to 600 m) layered deposits
- Layers drape and onlap basement topography



■ □ X = *model constraint based on observed contact*

10x vertical exaggeration

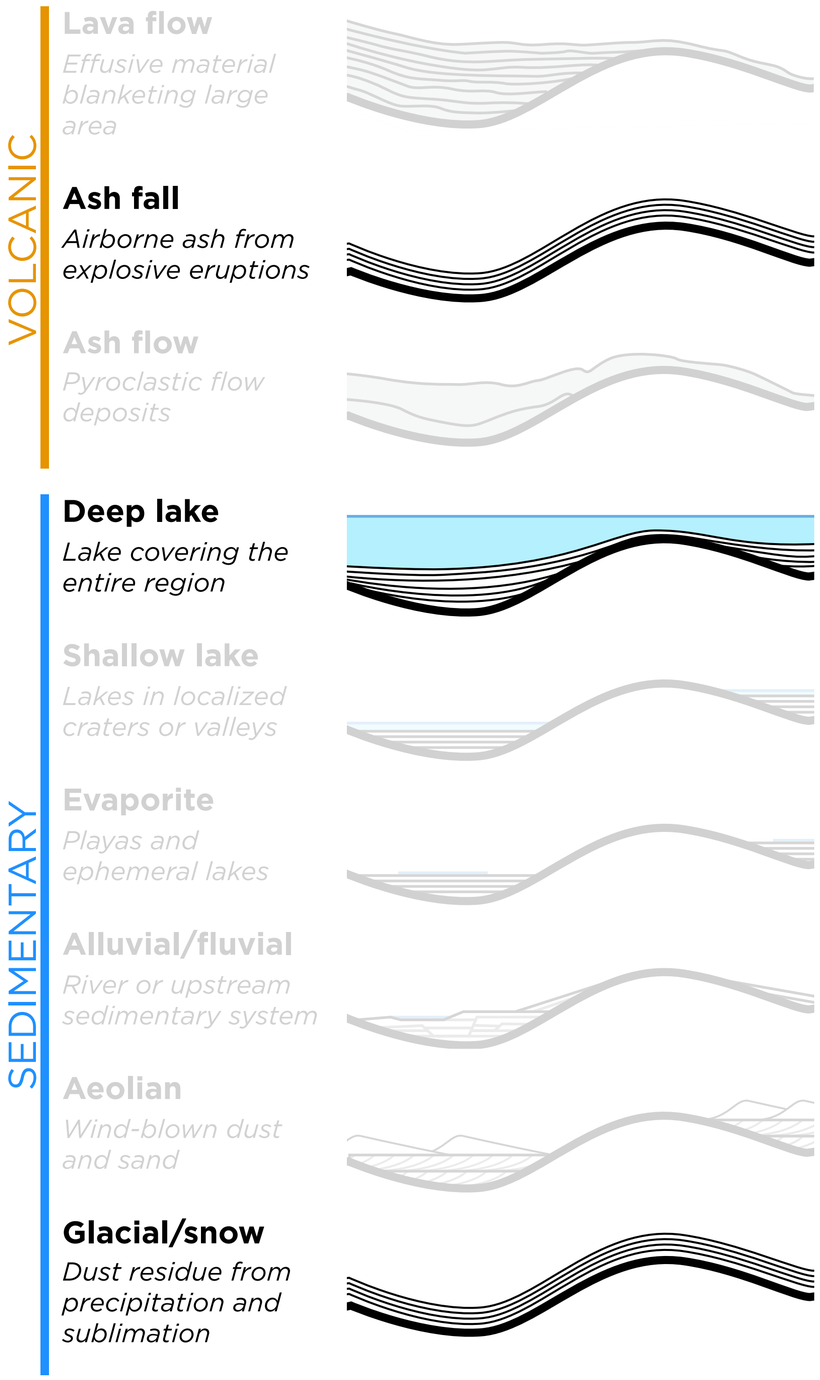
Preprint manuscript:
https://eartharxiv.org/fzhk7

LAYERED SULFATES: DEPOSITIONAL MECHANISMS

Thick (up to 600 m) layered deposits

Deposition by settling from suspension

- Consistent, meter-scale bedding
- Low-angle (<10°) but nonzero dips
- Layers drape and onlap basement topography

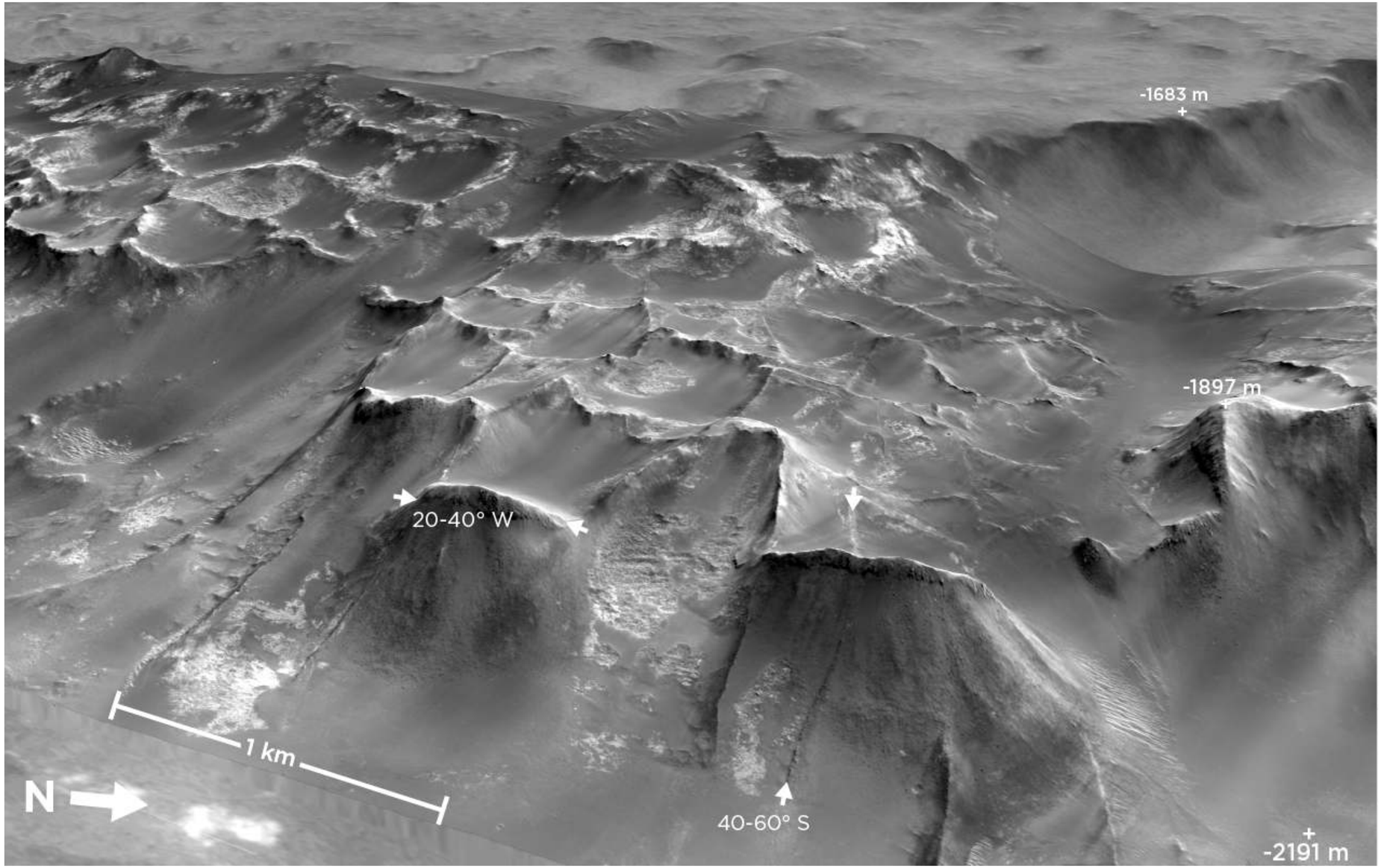


Preprint manuscript: https://eartharxiv.org/fzhk7

LAYERED SULFATES: POST-DEPOSITIONAL ALTERATION

Boxwork fractures

- ~500 m scale
- polygonal geometry
- penetrate entire thickness of unit (>200 m)
- filled with jarosite-bearing material to form resistant ridges



Scene ~3 km wide with 400 m of relief

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LAYERED SULFATES: BOXWORK FRACTURES

Filled-fracture morphology

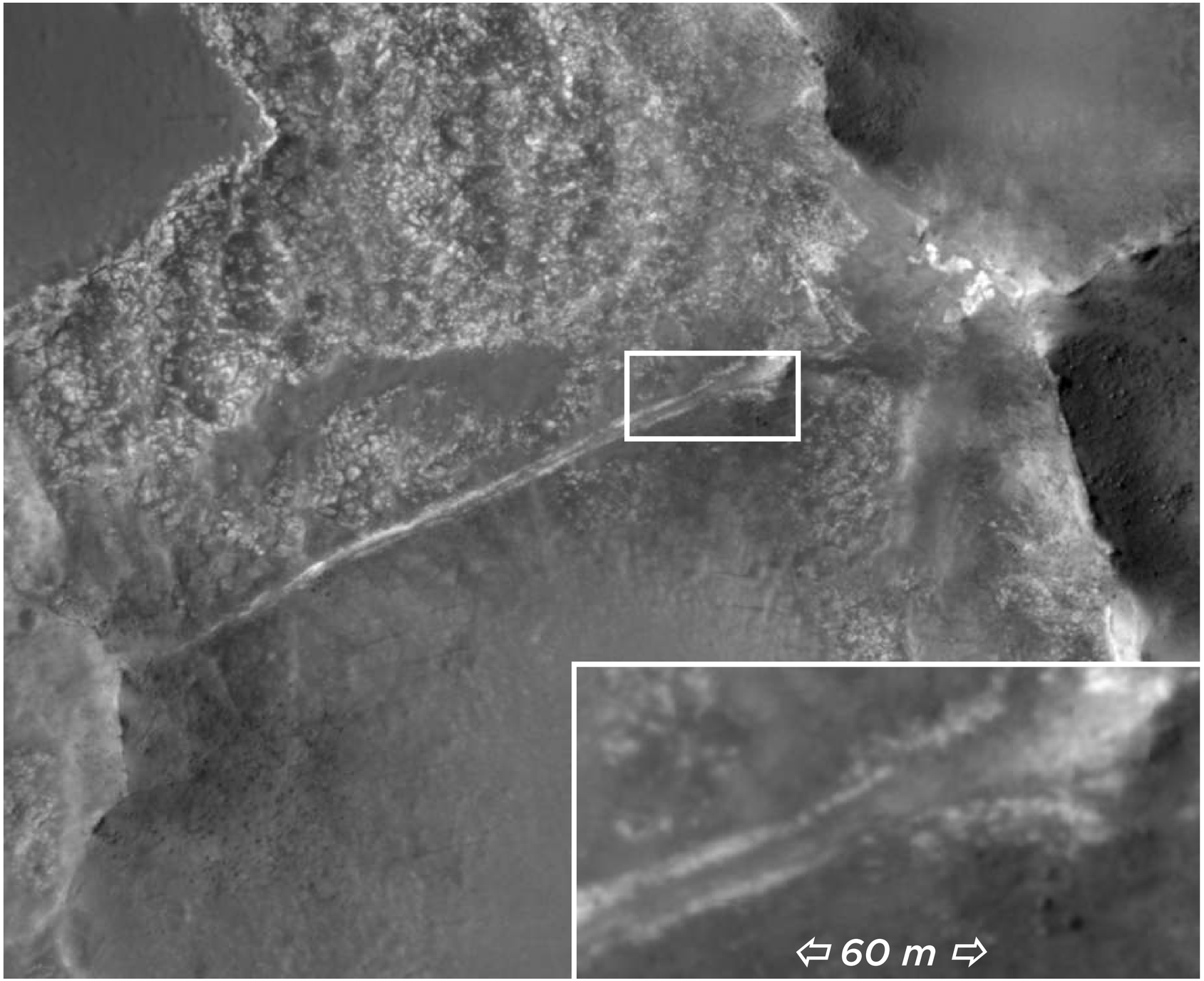
Isopachous fill

Progressive mineralization by continuous fluid flow

Fractures were **mineralized** ***after formation.***

Jarosite (Fe-sulfate) mineral signature *in fracture fills*

Aqueous alteration with an acidic character



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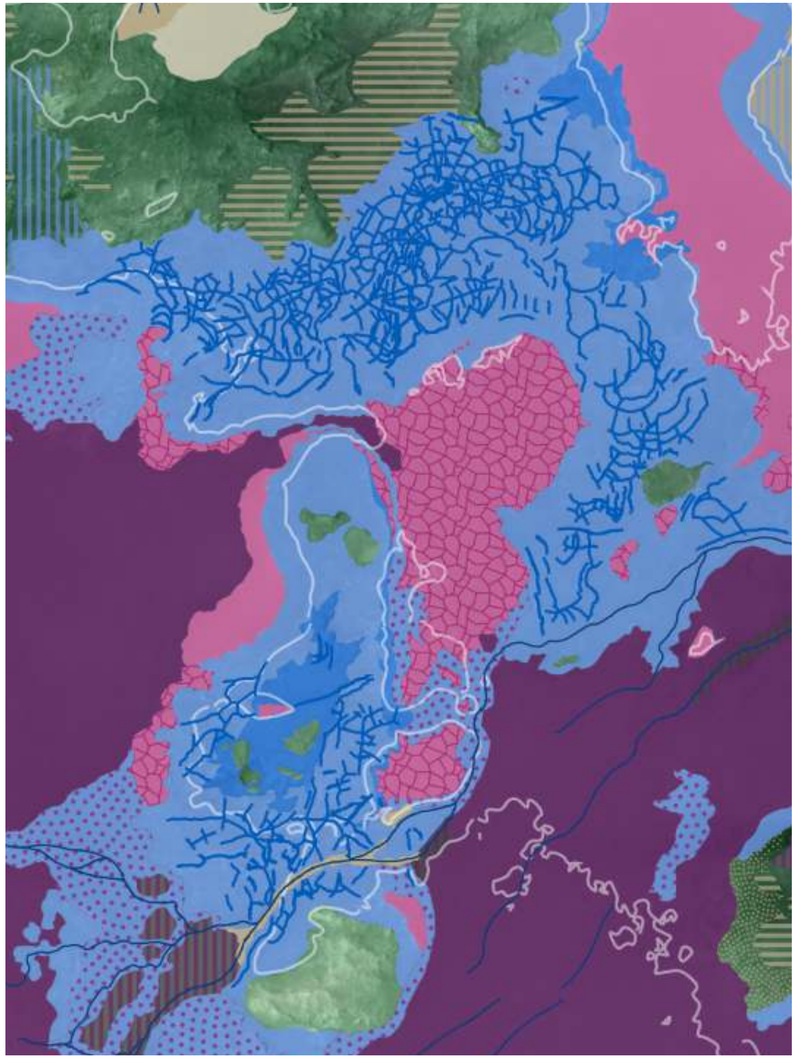
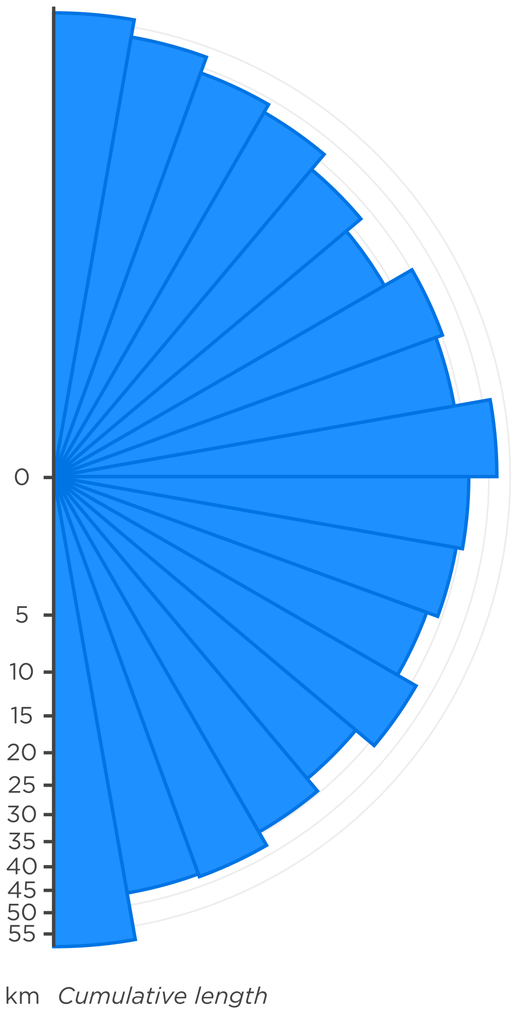
LAYERED SULFATES: BOXWORK FRACTURES

No favored orientation → Not tectonically controlled

Mechanism: internal volume loss



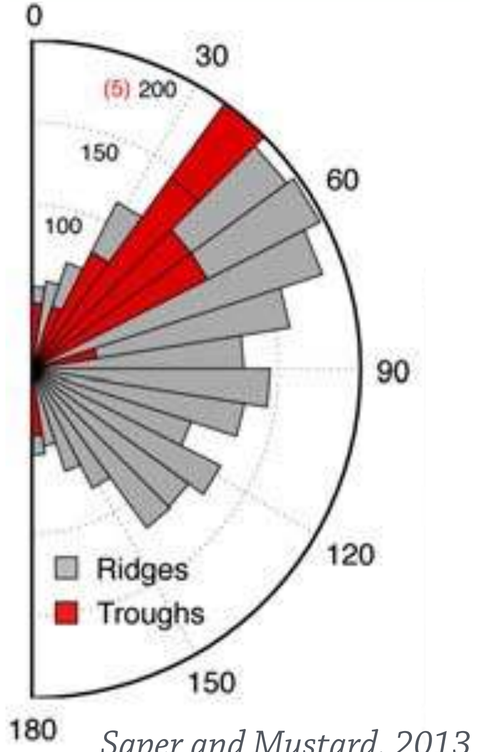
Segment azimuth



Comparison

Ridges in Noachian basement

Tectonically controlled by Isidis Basin formation

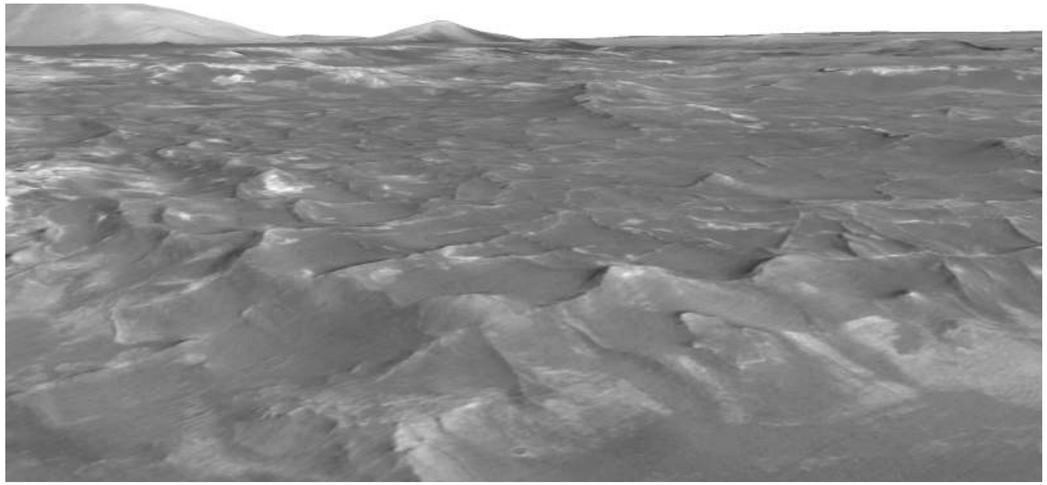


Saper and Mustard, 2013

Preprint manuscript: https://eartharxiv.org/fzhk7

LAYERED SULFATES: BOXWORK FRACTURES

Polygonal faulting – an Earth analog



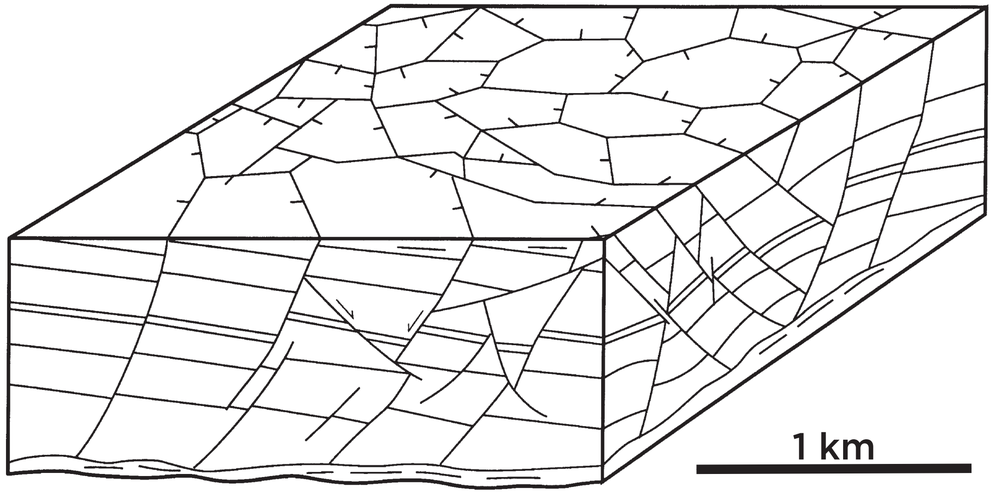
Key characteristics

- polygonal fracture geometry
- hundred-meter to kilometer scale

Mechanism

Compaction of **clay-rich sediments** forms **layer-bound faults** during **diagenesis and shallow burial**

On Earth, typically associated with thick, subaqueous basin sediments.



Cartwright and Lonergan, Basin Research, 1996

Preprint manuscript: https://eartharxiv.org/fzhk7

LAYERED SULFATES: DEPOSITIONAL MECHANISMS

Thick (up to 600 m) layered deposits

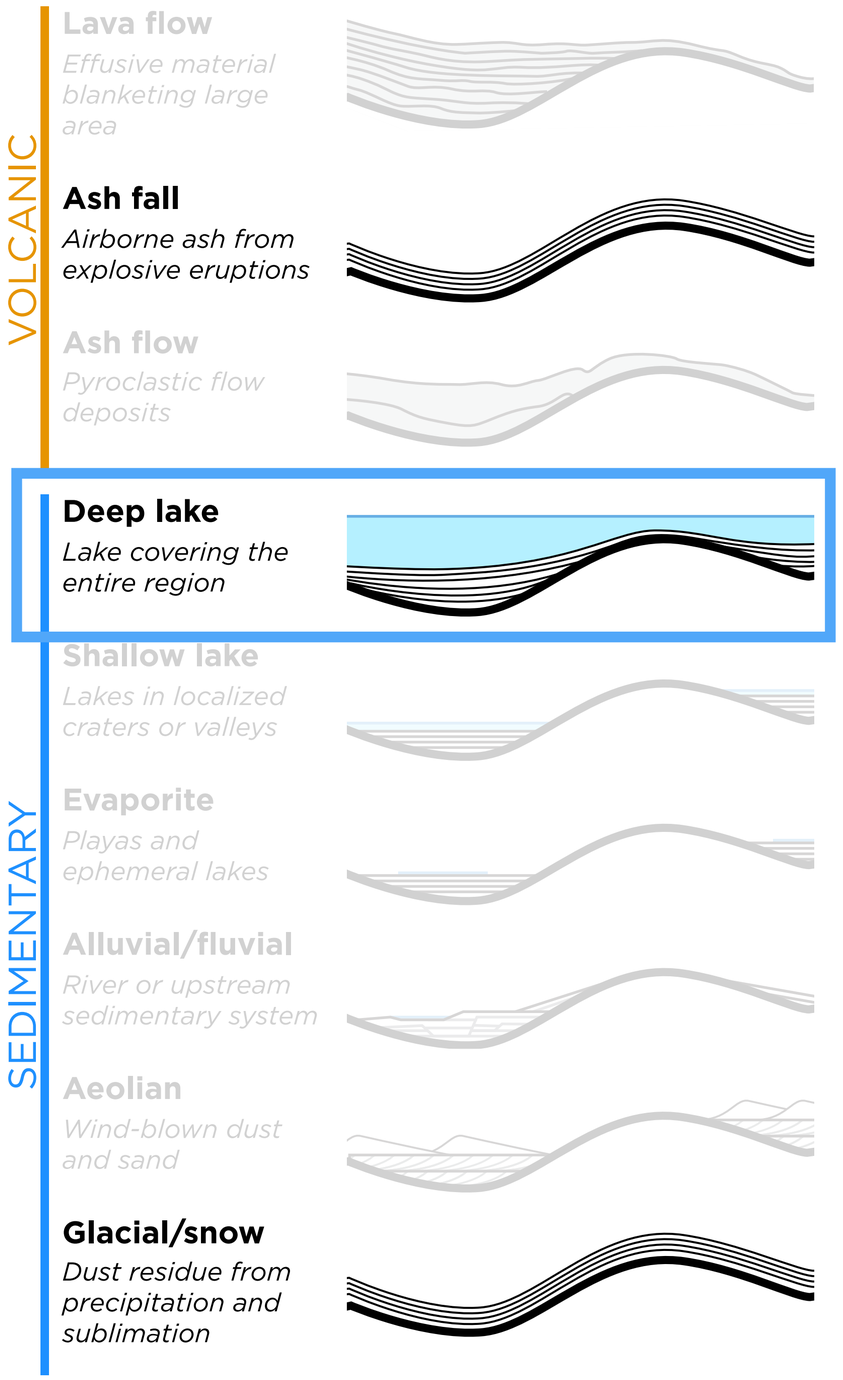
Deposition by settling from suspension

- Consistent, meter-scale bedding
- Low-angle (<10°) but nonzero dips
- Layers drape and onlap basement topography

Single-stage diagenetic volume loss

Boxwork polygonal fractures

- Penetrate entire thickness of unit
- No external tectonic control



Preprint manuscript: https://eartharxiv.org/fzhk7

POST-SULFATE HISTORY

- Capping surfaces
- Several erosional phases
- Late fluvial/lacustrine deposits

SYRTIS MAJOR
Early Hesperian

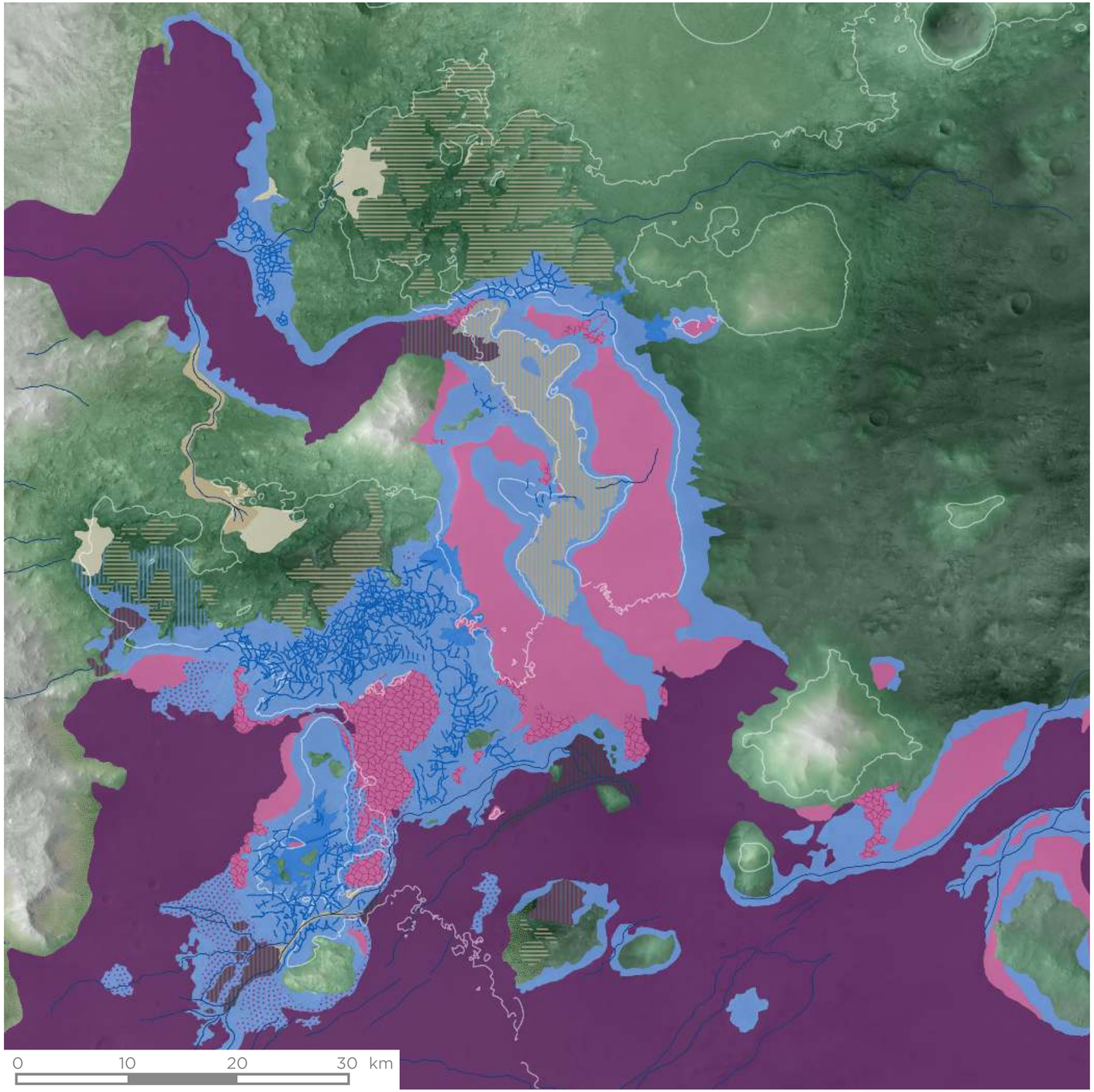
- Lava plains
- Uncertain

CAP SURFACE
Early Hesperian (?)

- Smooth
- Hummocky

SEDIMENTARY FILL
Hesperian-Amazonian

- Undivided
- Channel deposit
- Basin floor
- Valley fill



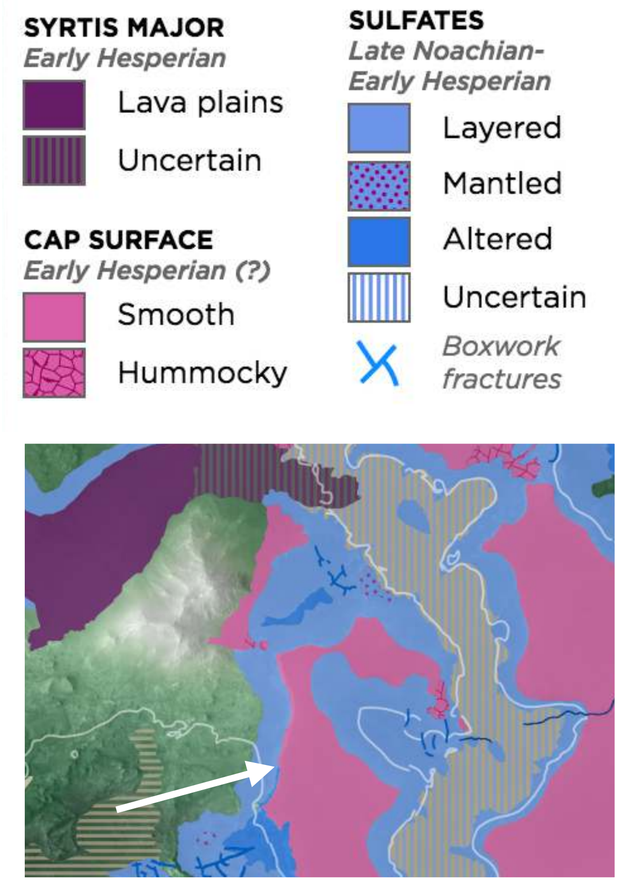
Preprint manuscript:
https://eartharxiv.org/fzhk7

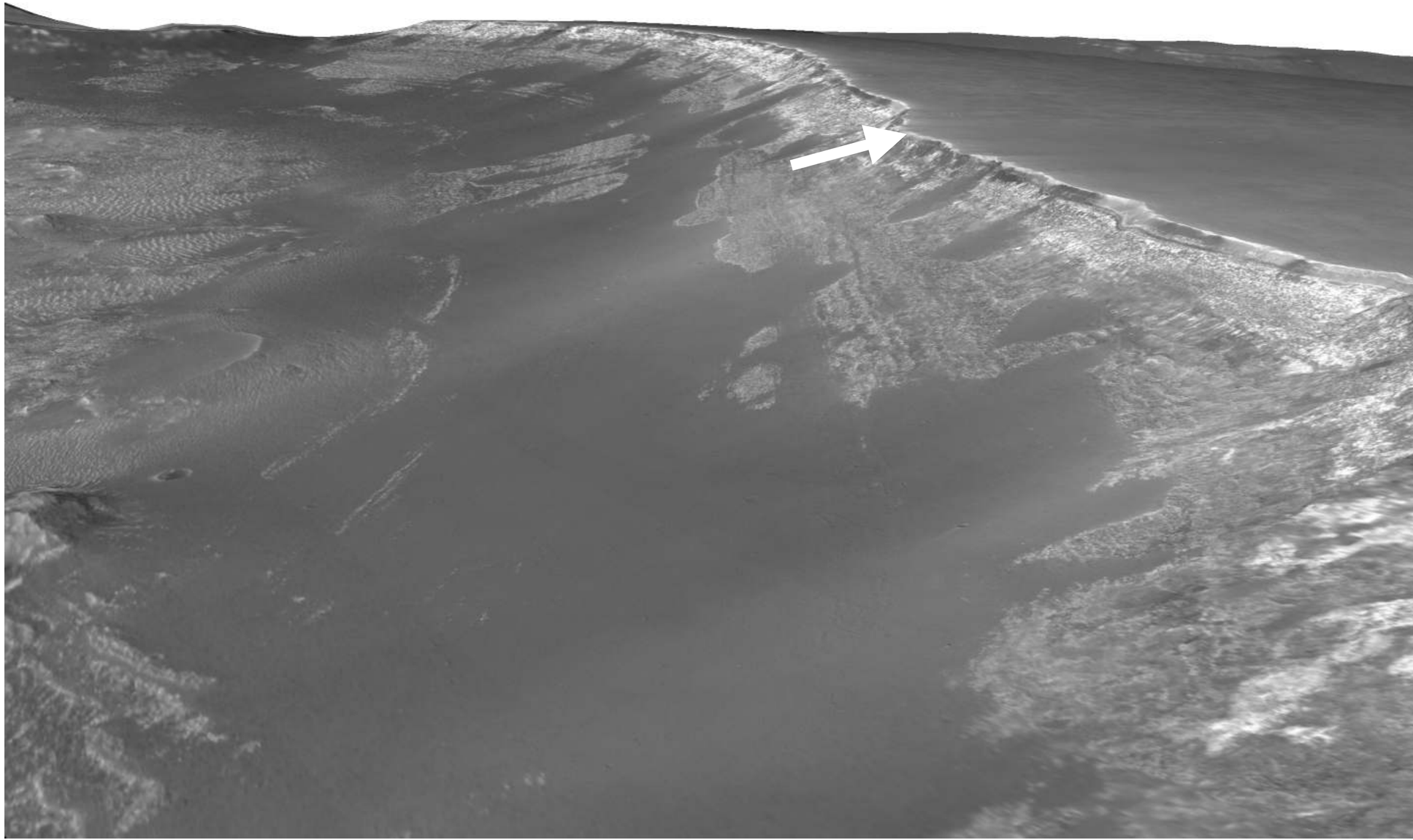
SMOOTH CAPPING SURFACE: NEWLY DEFINED UNIT

Distinct from and formed prior to Syrtis Major lavas

Also caps layered sulfates

- ~10-20 m thick
- Low thermal inertia
- Low crater density

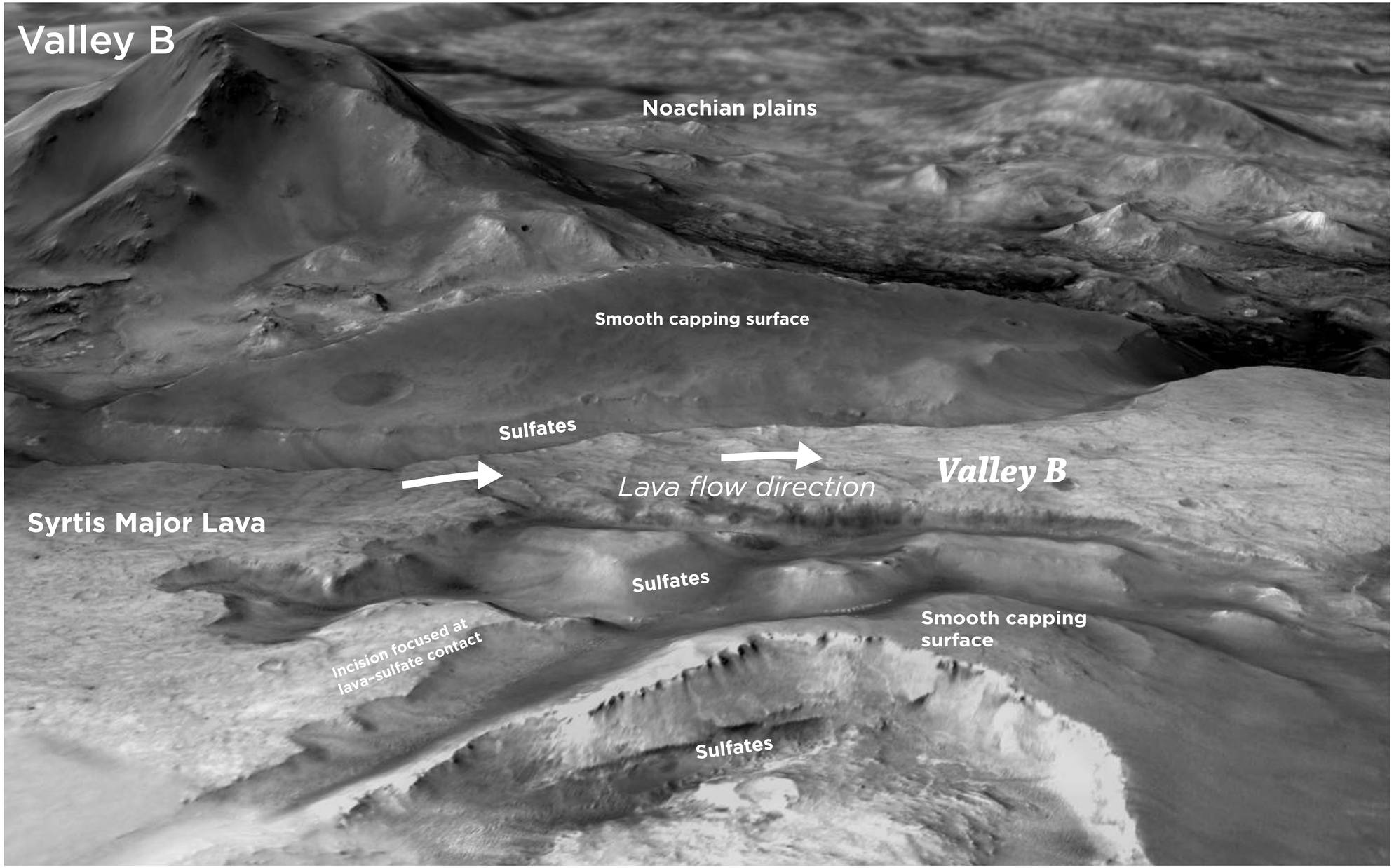




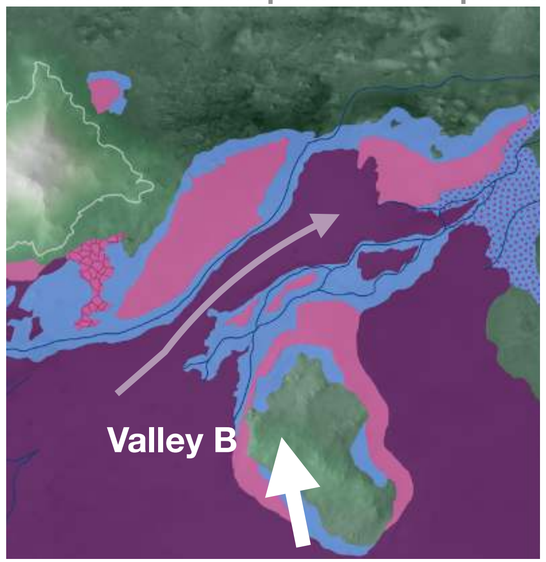
Preprint manuscript:
https://eartharxiv.org/fzhk7

PALEOVALLEYS CHANNELIZING SYRTIS MAJOR LAVAS

- Partially eroded sulfate stratigraphy
- Syrtis Major lavas cap remaining sulfates, forming inverted topography



Arrow shows viewpoint of main panel



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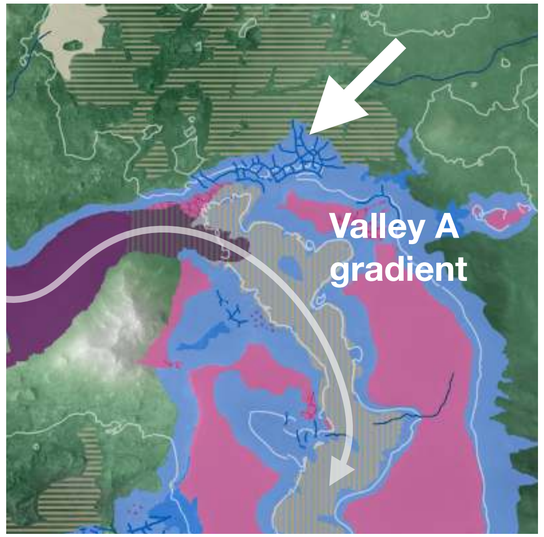
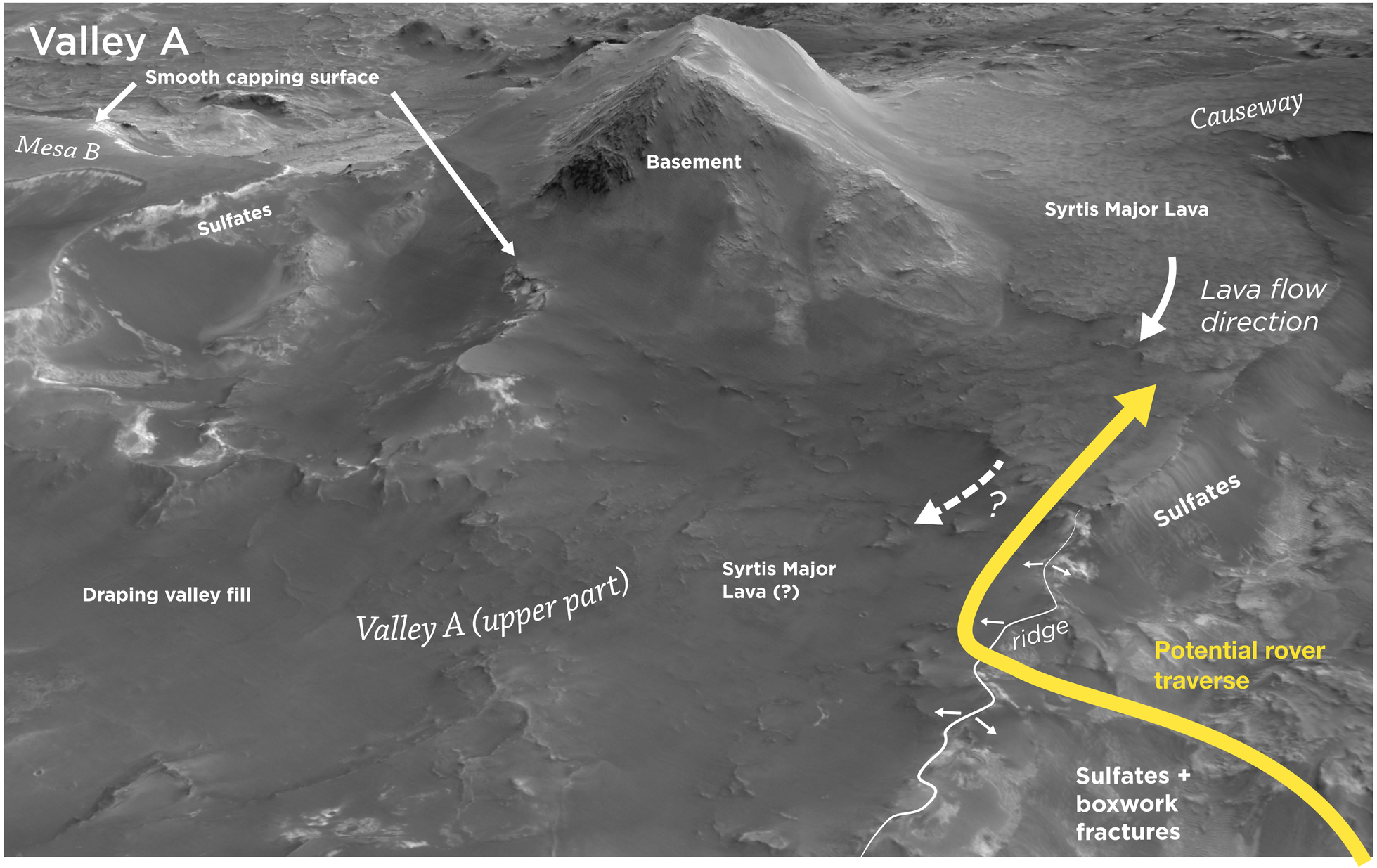
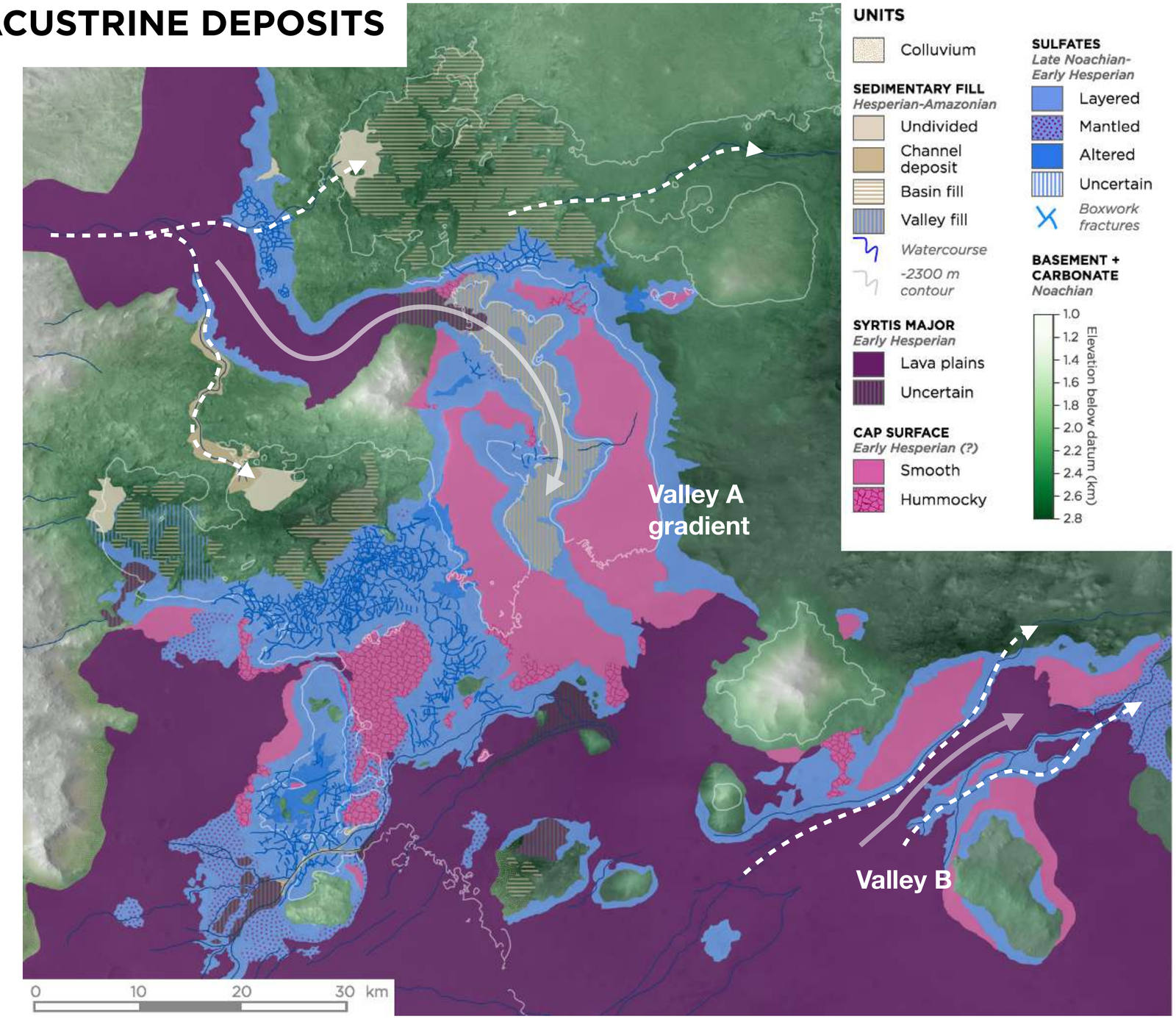




Preprint manuscript: https://eartharxiv.org/fzhk7

LATE FLUVIAL AND LACUSTRINE DEPOSITS

Paleovalleys bypassed or re-incised by flow postdating Syrtis Major lavas



Preprint manuscript:
https://eartharxiv.org/fzhk7

LATE FLUVIAL AND LACUSTRINE DEPOSITS

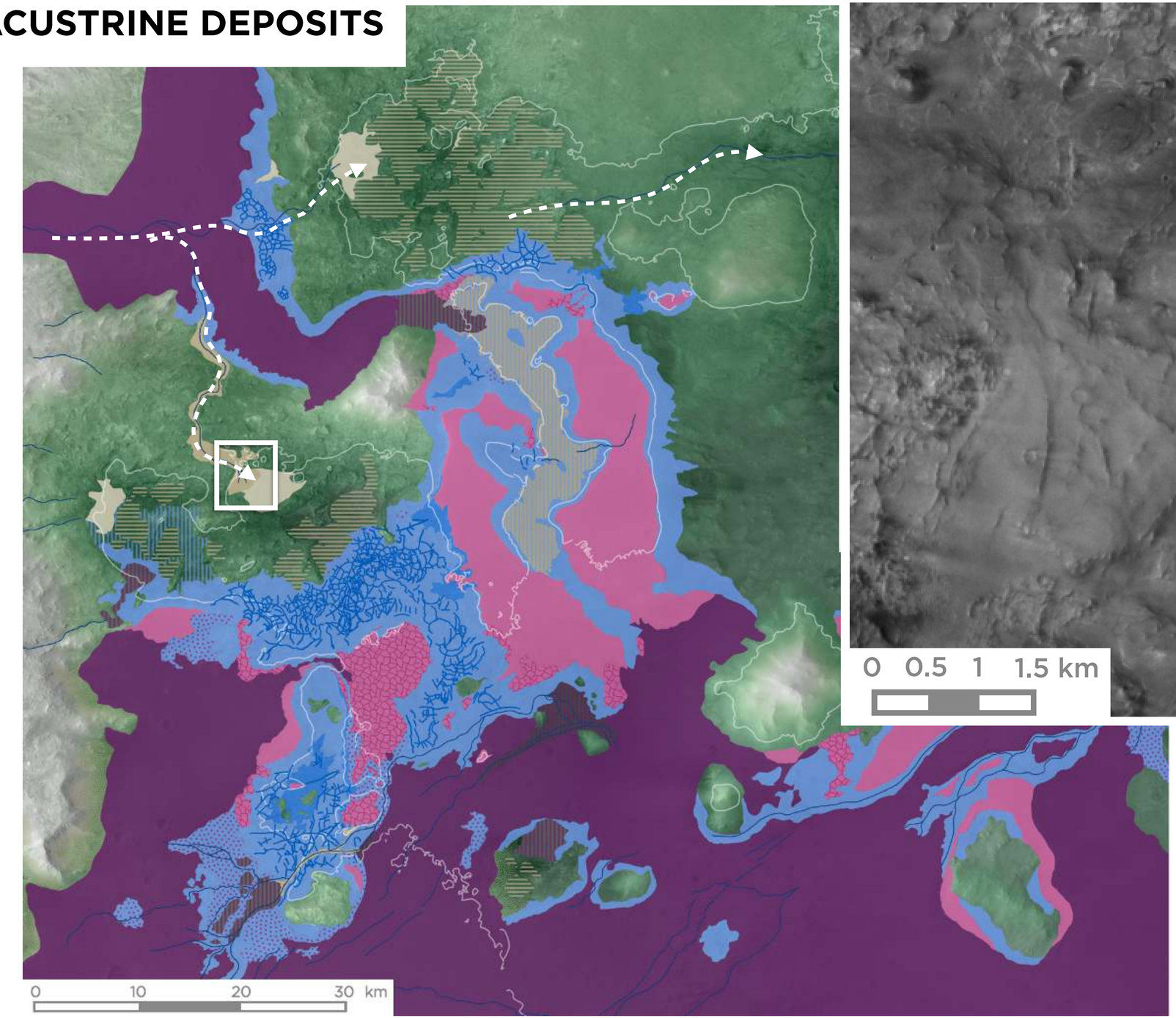
Fluvial and deltaic systems postdating Syrtis Major lavas

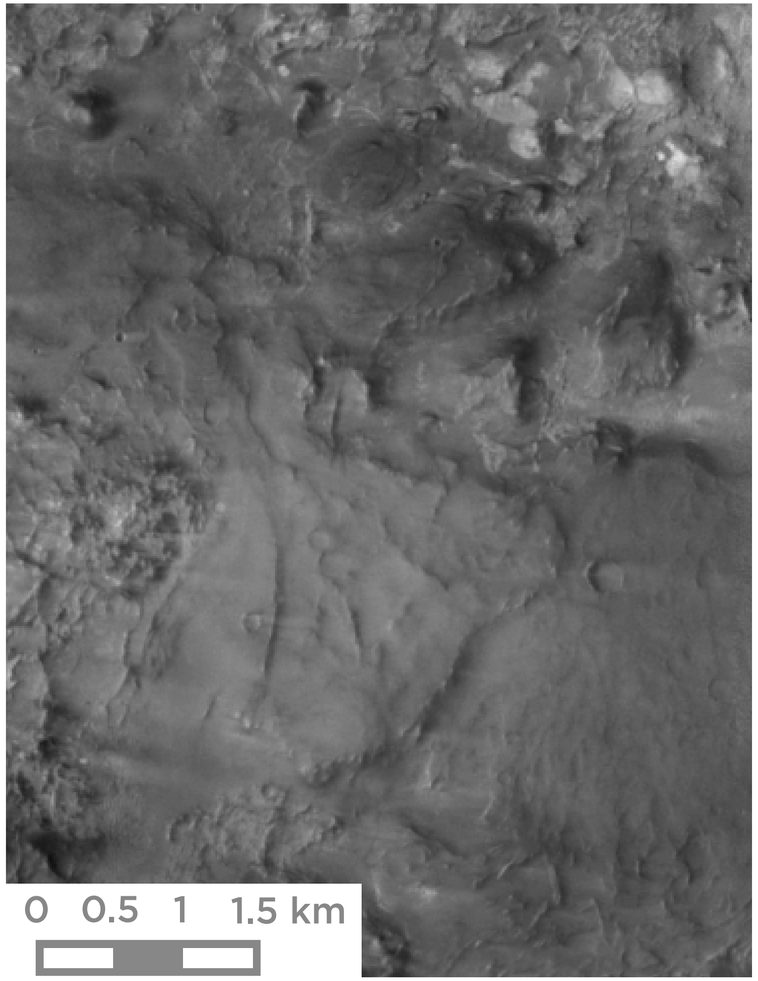
UNITS

- Colluvium

SEDIMENTARY FILL
Hesperian-Amazonian

- Undivided
- Channel deposit
- Basin fill
- Valley fill
- *Watercourse*
- *-2300 m contour*



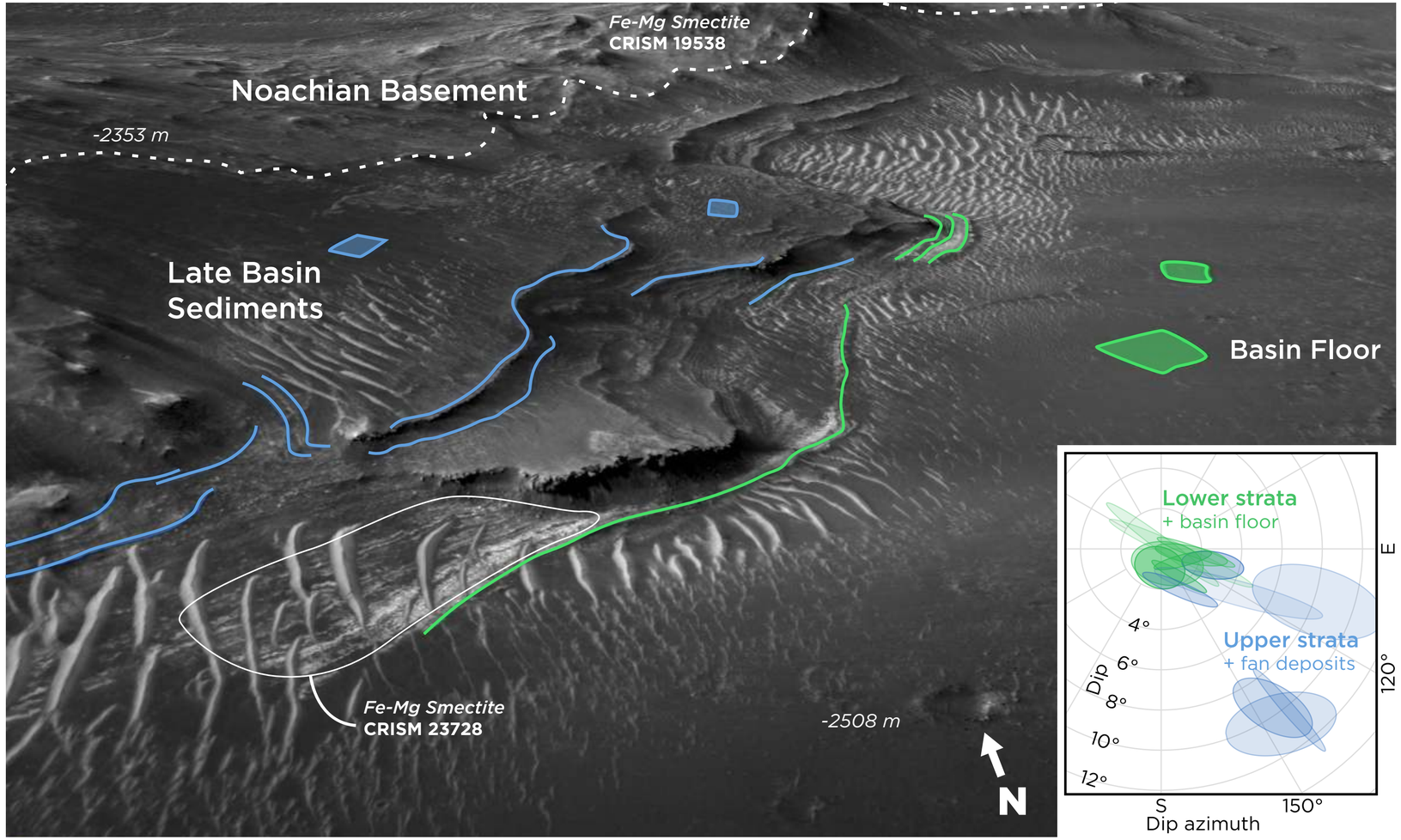


Preprint manuscript:
https://eartharxiv.org/fzhk7

LATE FLUVIAL AND LACUSTRINE DEPOSITS

Basin-filling and fan deposits: likely lacustrine origin

- The rover will traverse these deposits to access the sulfates
- 1.29 Ga (Amazonian) crater-counting age *(Skok and Mustard, 2014)*



Preprint manuscript:
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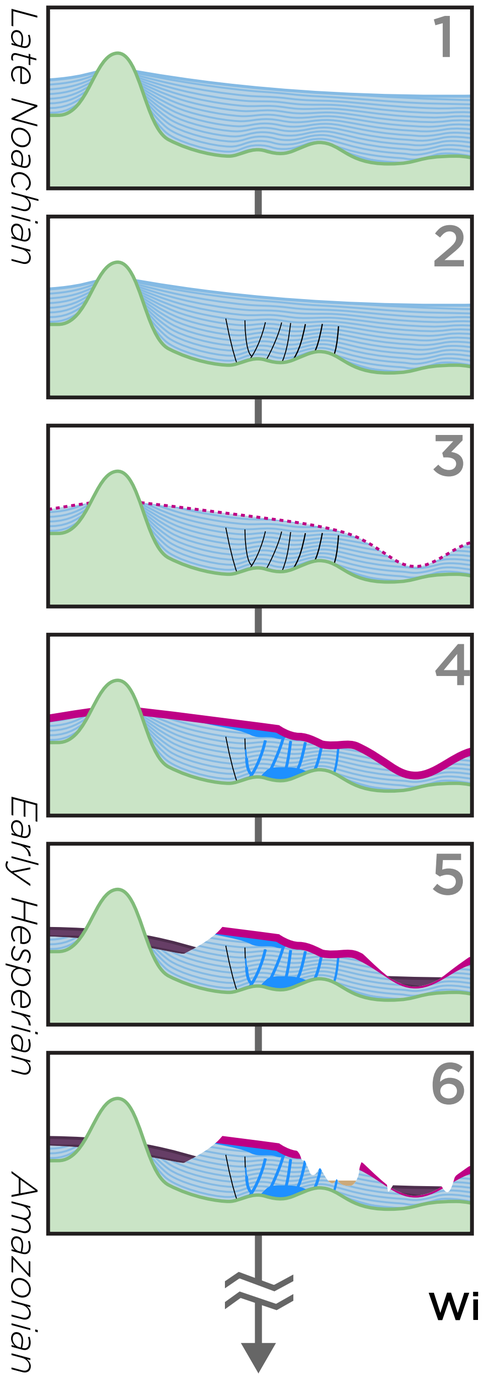
MULTIPLE EPISODES OF AQUEOUS ACTIVITY FROM NOACHIAN—EARLY AMAZONIAN



Deposition *of sediments gently draping basement*

Diagenesis *and volume-loss fracturing*

Erosion *to unconformity and paleovalley formation*

Fracture mineralization *and* **formation of smooth*** **capping surface**

Erosion *to mesas and* **embayment** *and capping by Syrtis Major lavas*

Differential erosion *and deposition of fluvial sediments*

Wind erosion *to present*

AQUEOUS EPISODE

regionally extensive subaqueous sedimentation

single-stage dewatering

fluvial erosion

subsurface fluid flow
*relative timing uncertain

fluvial erosion

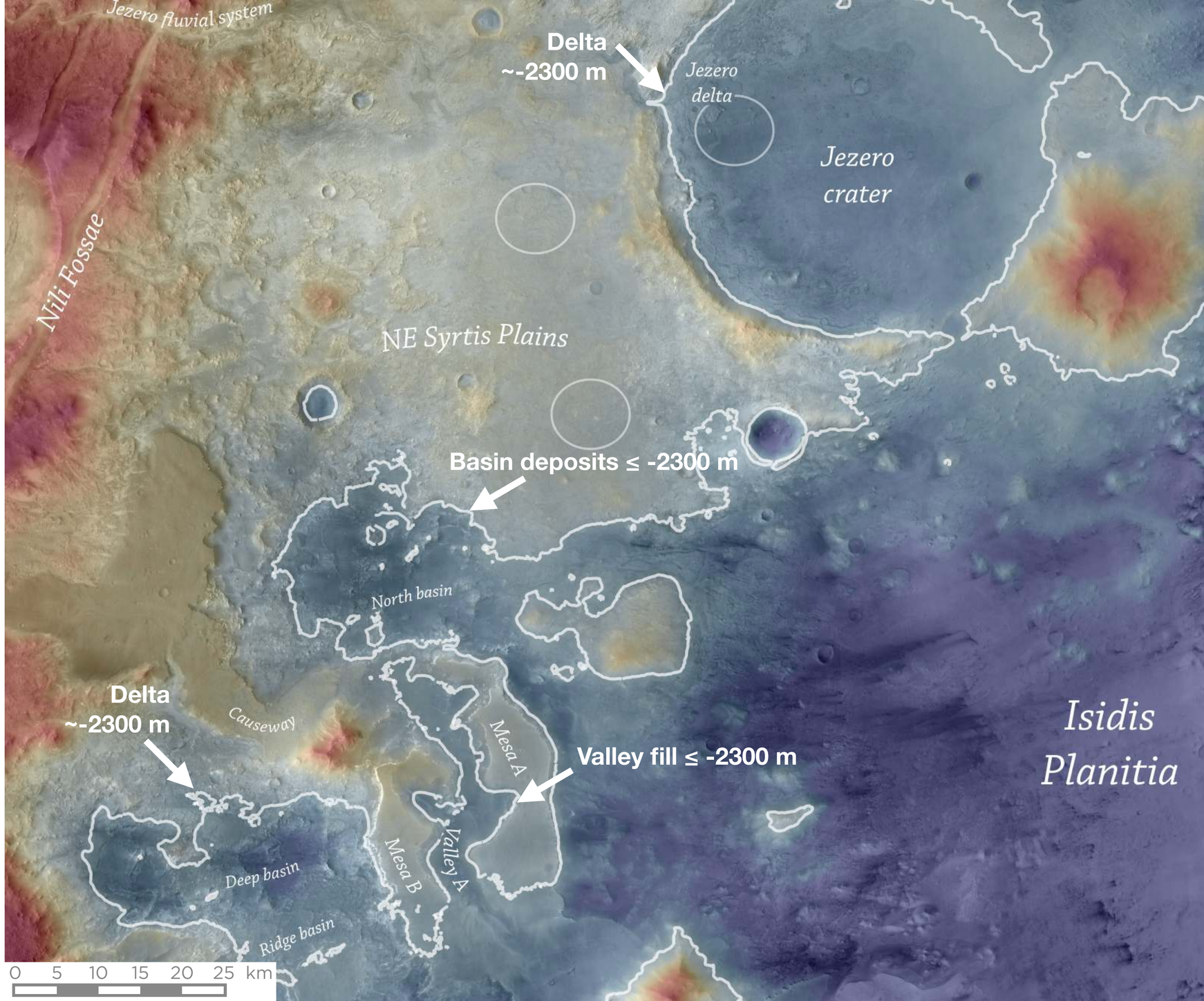
fluvial and lacustrine sedimentation

Preprint manuscript:
https://eartharxiv.org/fzhk7

IMPLICATIONS FOR NE SYRTIS/JEZERO REGIONAL SEDIMENTARY SYSTEM

- Aggradation of a thick stratigraphy adjacent to the NE Syrtis Plains
- Multiple episodes of fluvial incision and erosion
- Deltas and lacustrine deposits at **nearly the same elevation** (~2300 m) as the Jezero crater delta

-2300 m contour highlighted



Preprint manuscript:
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Key rover deliverables

at N margin of sulfates

1. **Layering style** of sulfate units can determine depositional environment
2. **Chemistry of fracture-filling cements** can illuminate alteration history
3. **Dateable volcanic surface** of the Syrtis Major lava plains
4. **Composition of smooth capping surface** will suggest formation mechanism

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