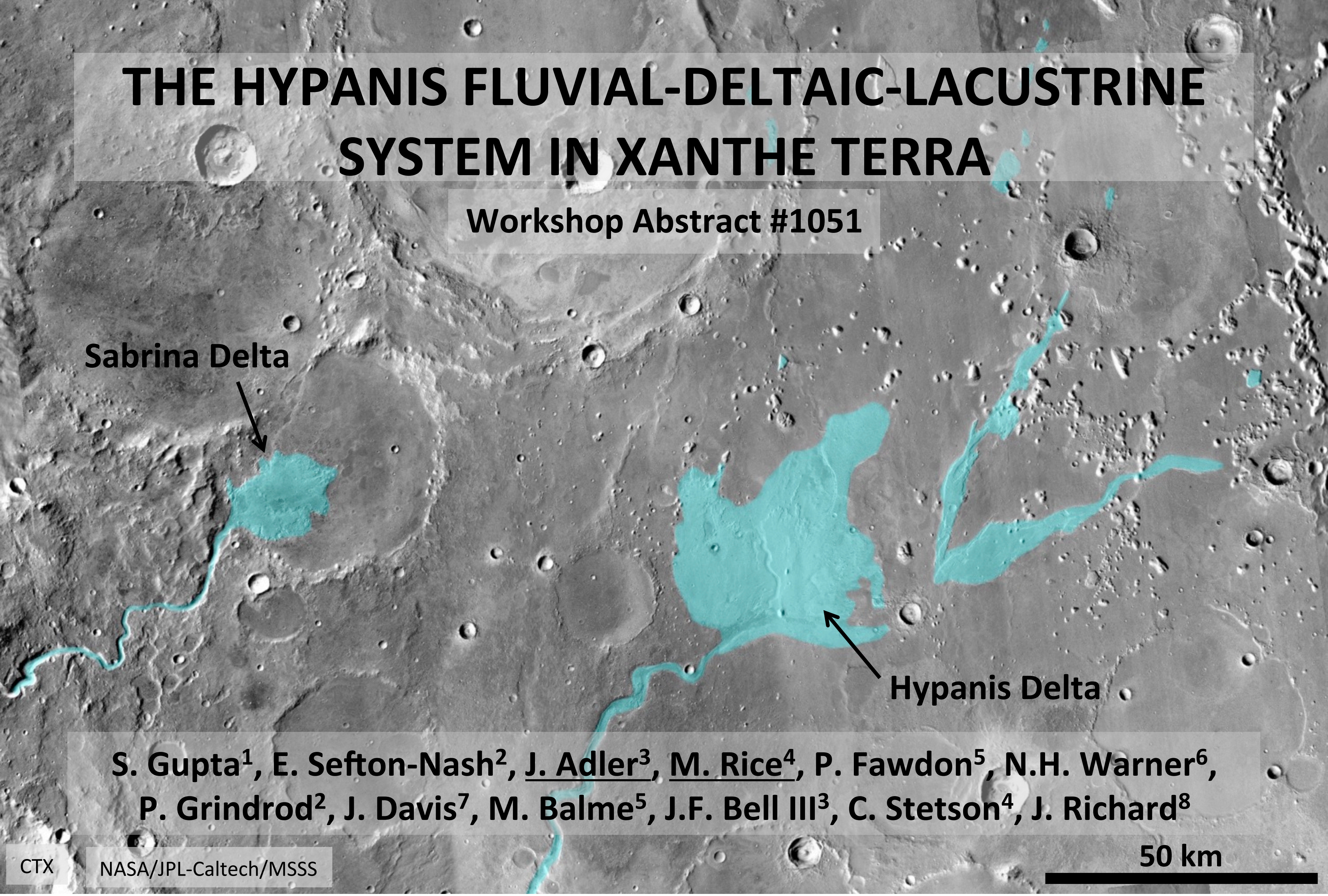
# THE HYPANIS FLUVIAL-DELTAIC-LACUSTRINE SYSTEM IN XANTHE TERRA

## Workshop Abstract #1051

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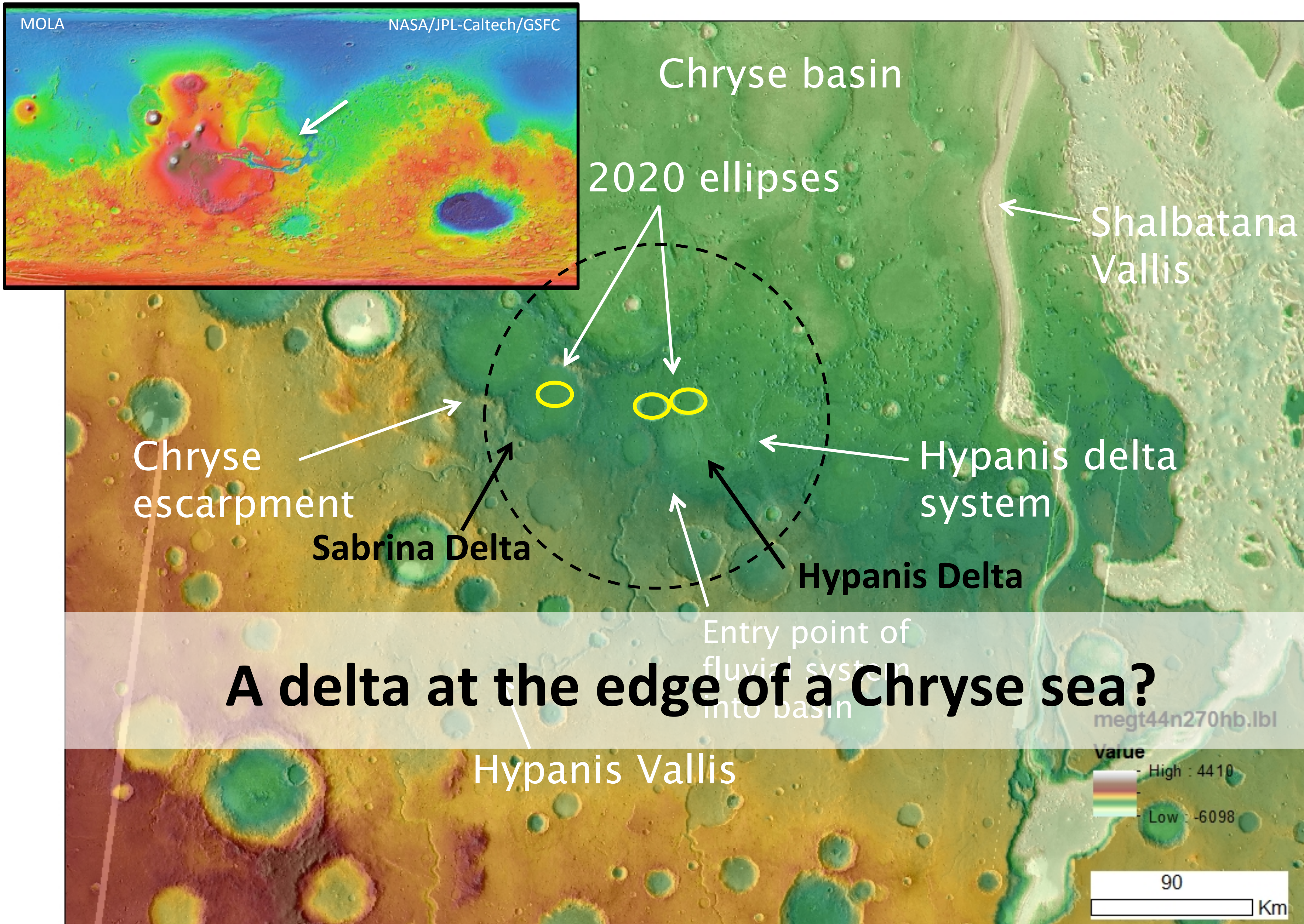
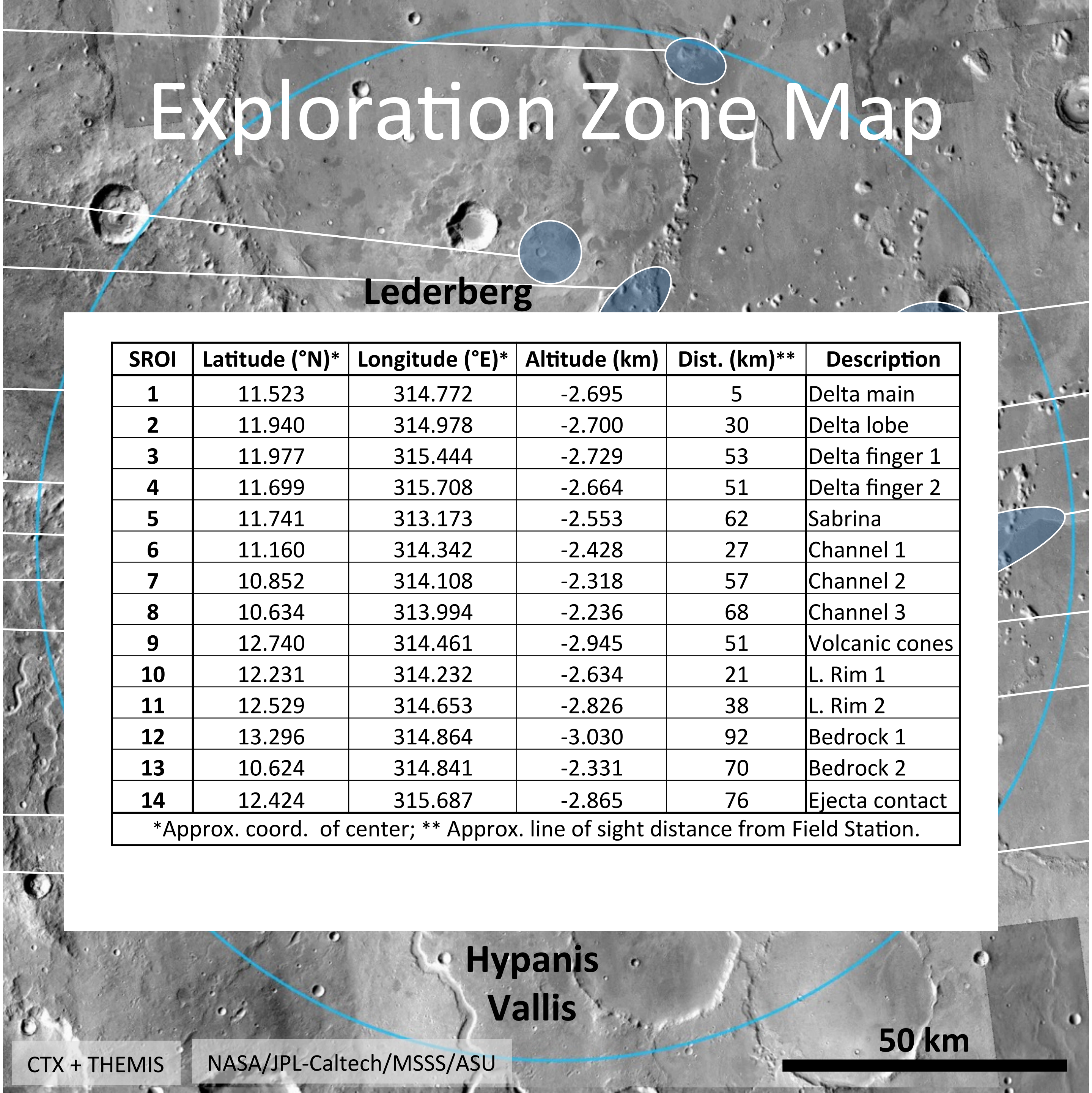
# MOLA Topography: Overview location of Hypanis system in Xanthe Terra




MOLA + THEMIS

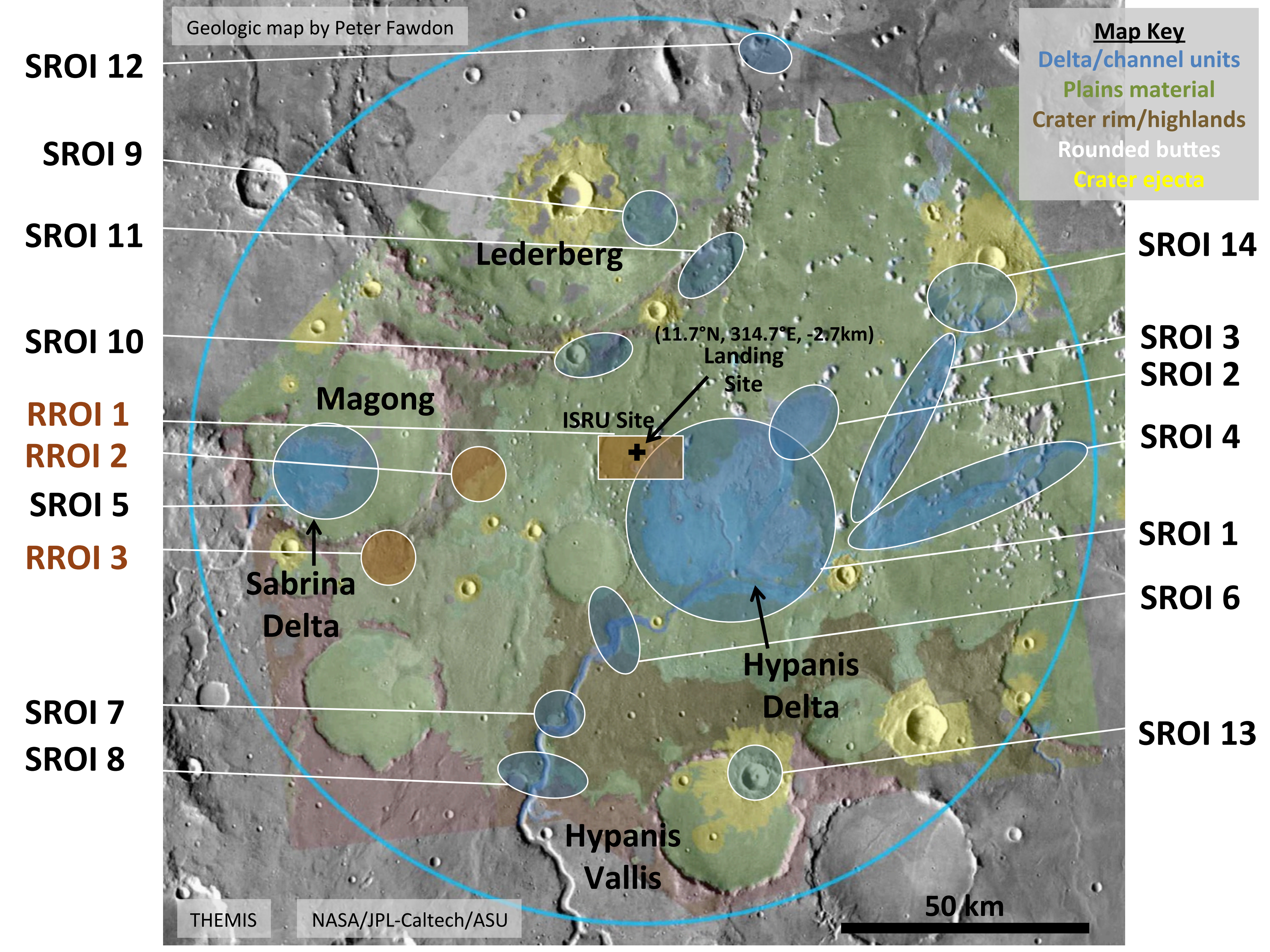
NASA/JPL-Caltech/GSFC/ASU

# Exploration Zone Map




| SROI | Latitude (°N)* | Longitude (°E)* | Altitude (km) | Dist. (km)** | Description |
|---|---|---|---|---|---|
| 1 | 11.523 | 314.772 | -2.695 | 5 | Delta main |
| 2 | 11.940 | 314.978 | -2.700 | 30 | Delta lobe |
| 3 | 11.977 | 315.444 | -2.729 | 53 | Delta finger 1 |
| 4 | 11.699 | 315.708 | -2.664 | 51 | Delta finger 2 |
| 5 | 11.741 | 313.173 | -2.553 | 62 | Sabrina |
| 6 | 11.160 | 314.342 | -2.428 | 27 | Channel 1 |
| 7 | 10.852 | 314.108 | -2.318 | 57 | Channel 2 |
| 8 | 10.634 | 313.994 | -2.236 | 68 | Channel 3 |
| 9 | 12.740 | 314.461 | -2.945 | 51 | Volcanic cones |
| 10 | 12.231 | 314.232 | -2.634 | 21 | L. Rim 1 |
| 11 | 12.529 | 314.653 | -2.826 | 38 | L. Rim 2 |
| 12 | 13.296 | 314.864 | -3.030 | 92 | Bedrock 1 |
| 13 | 10.624 | 314.841 | -2.331 | 70 | Bedrock 2 |
| 14 | 12.424 | 315.687 | -2.865 | 76 | Ejecta contact |

*Approx. coord. of center; ** Approx. line of sight distance from Field Station.


Geologic map by Peter Fawdon
Map Key
Delta/channel units
Plains material
Crater rim/highlands
Rounded buttes
Crater ejecta
SROI 12
SROI 9
SROI 11
SROI 10
RROI 1
RROI 2
SROI 5
RROI 3
SROI 7
SROI 8
SROI 14
SROI 3
SROI 2
SROI 4
SROI 1
SROI 6
SROI 13
Lederberg
Magong
Sabrina Delta
(11.7°N, 314.7°E, -2.7km)
Landing Site
ISRU Site
Hypanis Delta
Hypanis Vallis
50 km
THEMIS
NASA/JPL-Caltech/ASU

# Science ROIs Rubric



| Site Factors | | | | SROI1 | SROI2 | SROI3 | SROI4 | SROI5 | SROI6 | SROI7 | SROI8 | SROI9 | SROI10 | SROI11 | SROI12 | SROI13 | SROI14 | EZ SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Science Site Criteria | Astrobio | Threshold (AND/OR) | Potential for past habitability | ● | ● | ● | ● | ● | | | | | | | | | ? | 8,1 |
| | | | Potential for present habitability/refugia | | | | | | | | | | | | | | | 0,0 |
| | | Qualifying | Potential for organic matter, w/ surface exposure | ● | | | | | | | | | | | | | | 9,1 |
| | Atmospheric Science | Threshold | Noachian/Hesperian rocks w/ trapped atmospheric gases | | | | | | | | | | | | | | | 2,1 |
| | | Qualifying | Meteorological diversity in space and time | ● | | | | | | | | | | | | | | 6,2 |
| | | | High likelihood of surface-atmosphere exchange | ● | | | | | | | | | | | | | | 14,0 |
| | | | Amazonian subsurface or high-latitude ice or sediment | | | | | | | | | | | | | | | 0,0 |
| | | | High likelihood of active trace gas sources | ? | | | | | | | | | | | | | | 0,0 |
| | Geoscience | Threshold | Range of martian geologic time; datable surfaces | | | | | | | | | | | | | | | 14,0 |
| | | | Evidence of aqueous processes | ● | | | | | | | | | | | | | | 10,3 |
| | | | Potential for interpreting relative ages | ● | | | | | | | | | | | | | | 13,1 |
| | | Qualifying | Igneous Rocks ... different times | ○ | | | | | | | | | | | | | | |
| | | | Near-surface ice, glacial or permafrost | | | | | | | | | | | | | | | |
| | | | Noachian or pre-Noachian bedrock units | | | | | | | | | | | | | | | |
| | | | Outcrops with remnant magnetization | | | | | | | | | | | | | | | |
| | | | Primary, secondary, and basin-forming impact deposits | ● | | | | | | | | | | | | | | |
| | | | Structural features with regional or global context | | | | | | | | | | | | | | | |
| | | | Diversity of aeolian sediments and/or landforms | ● | | | | | | | | | | | | | | |

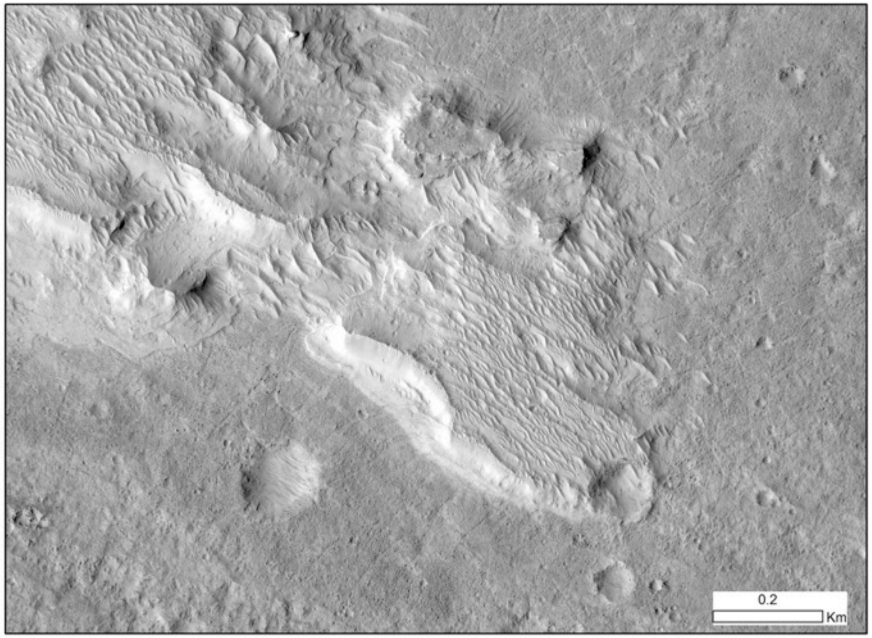
## Key Points

- **GREAT** environment [Summons et al., 2011] for organic formation, concentration, and preservation
- Both Noachian bedrock and Hesperian units
- Clear evidence of aqueous activity
- Addresses major global question: **Was there a Chryse Sea?!**

# Science ROIs 1-4,6-7



## Image of SROI 1



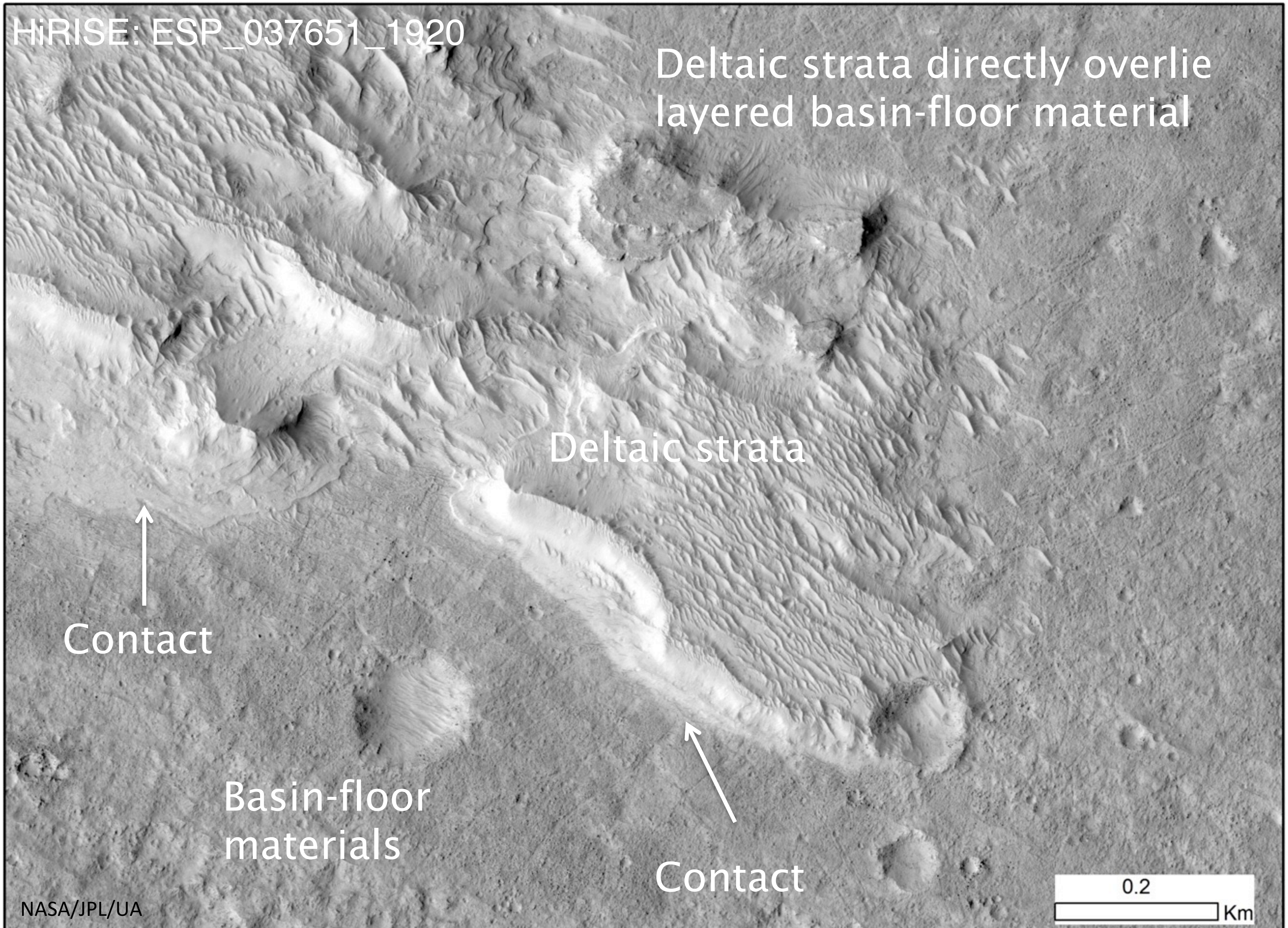

HiRISE: ESP_037651_1920

NASA/JPL/UA

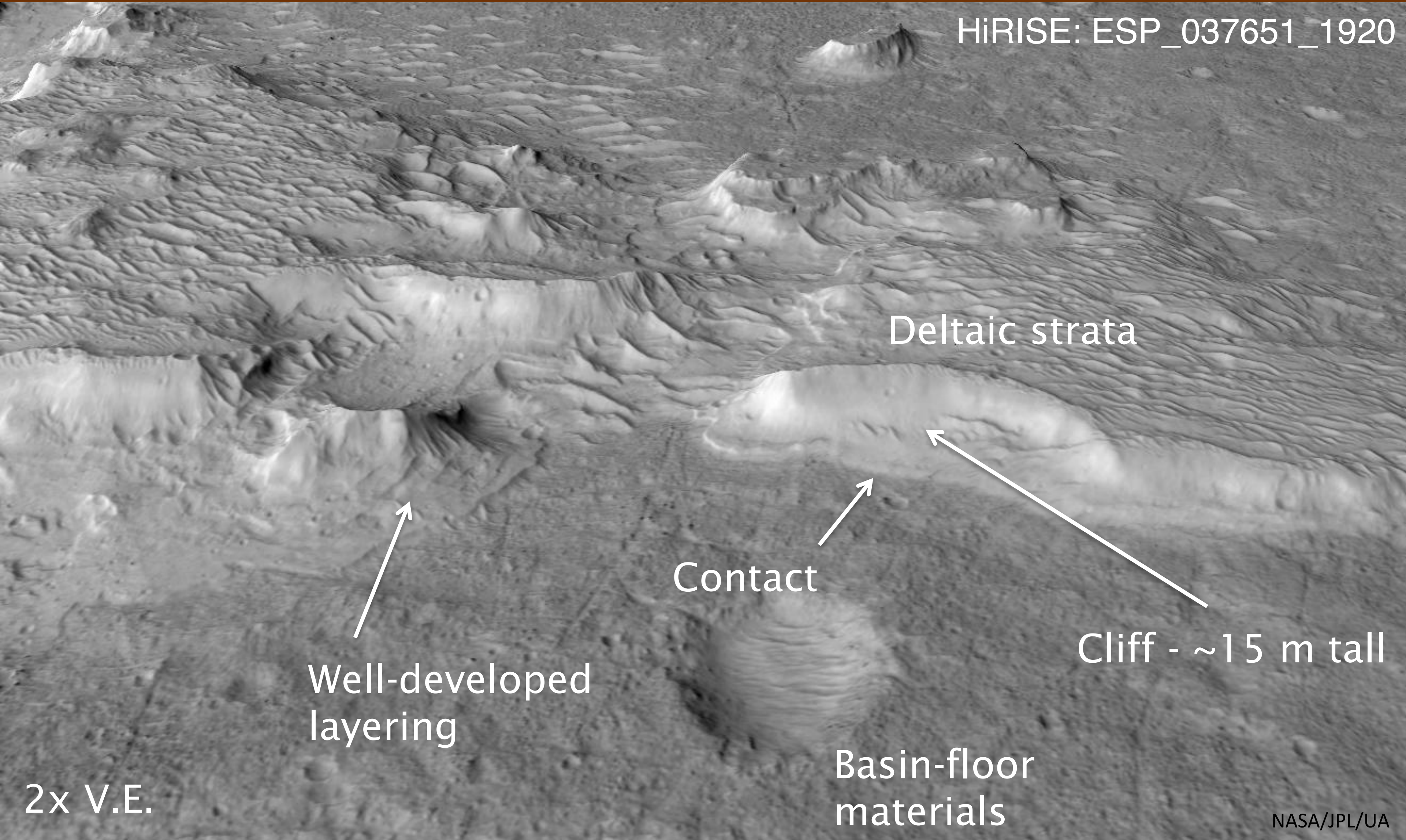
## Hypanis Delta and Inverted Fluvial Channels

- Delta main: 11.5°N, 314.8°E, -2.7 km
- Layered sedimentary strata in lobes of Hypanis delta and in inverted channel complexes
- Threshold:
  - Potential for past habitability
  - Clear evidence for aqueous processes
  - Identifiable stratigraphic contacts
  - Outcrop units with a range of ages
- Qualifying:
  - Access to deposits with potential for containing organic matter

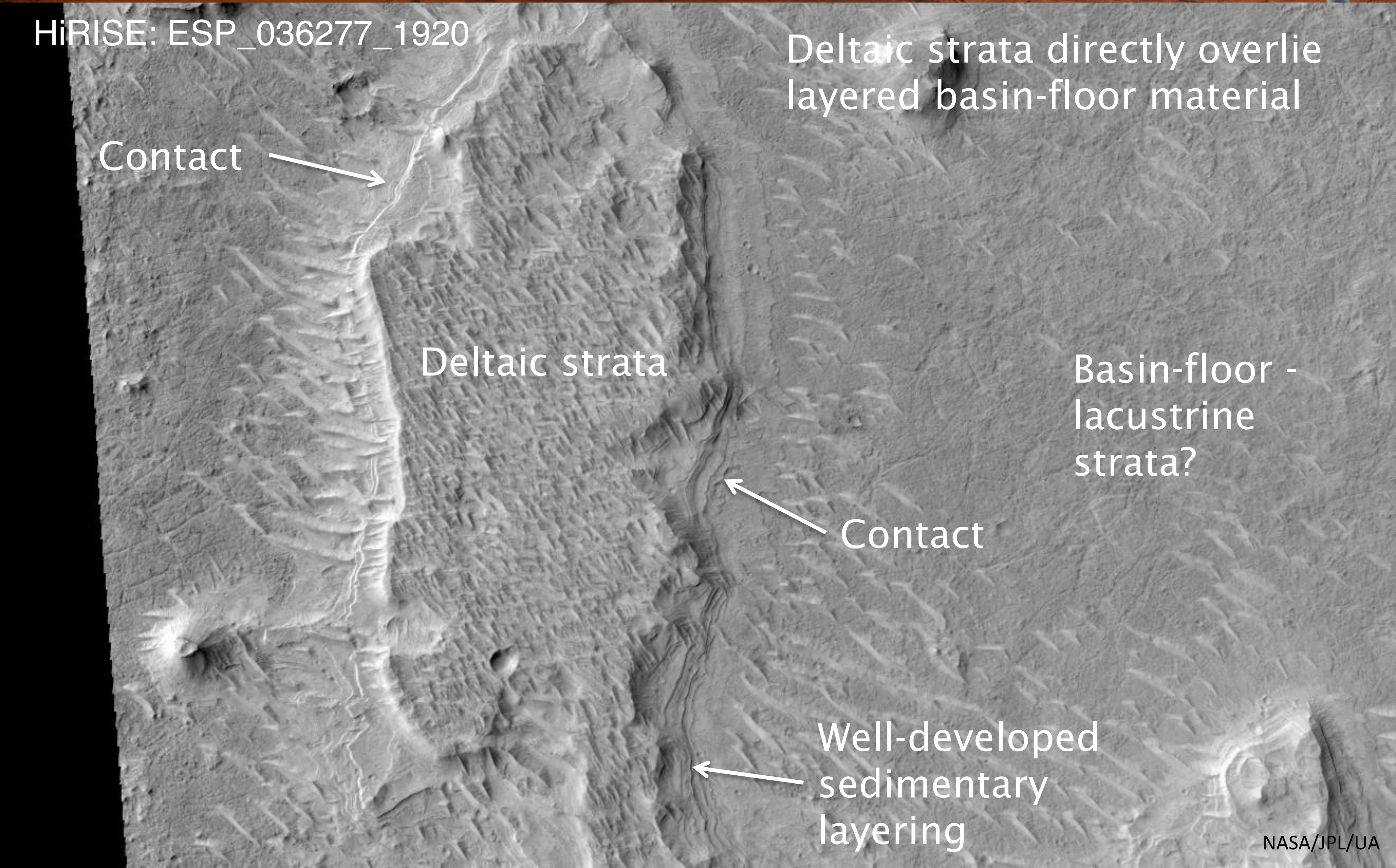
# SROI 1 Hypanis Deltaic strata



# Perspective view of SROI 1

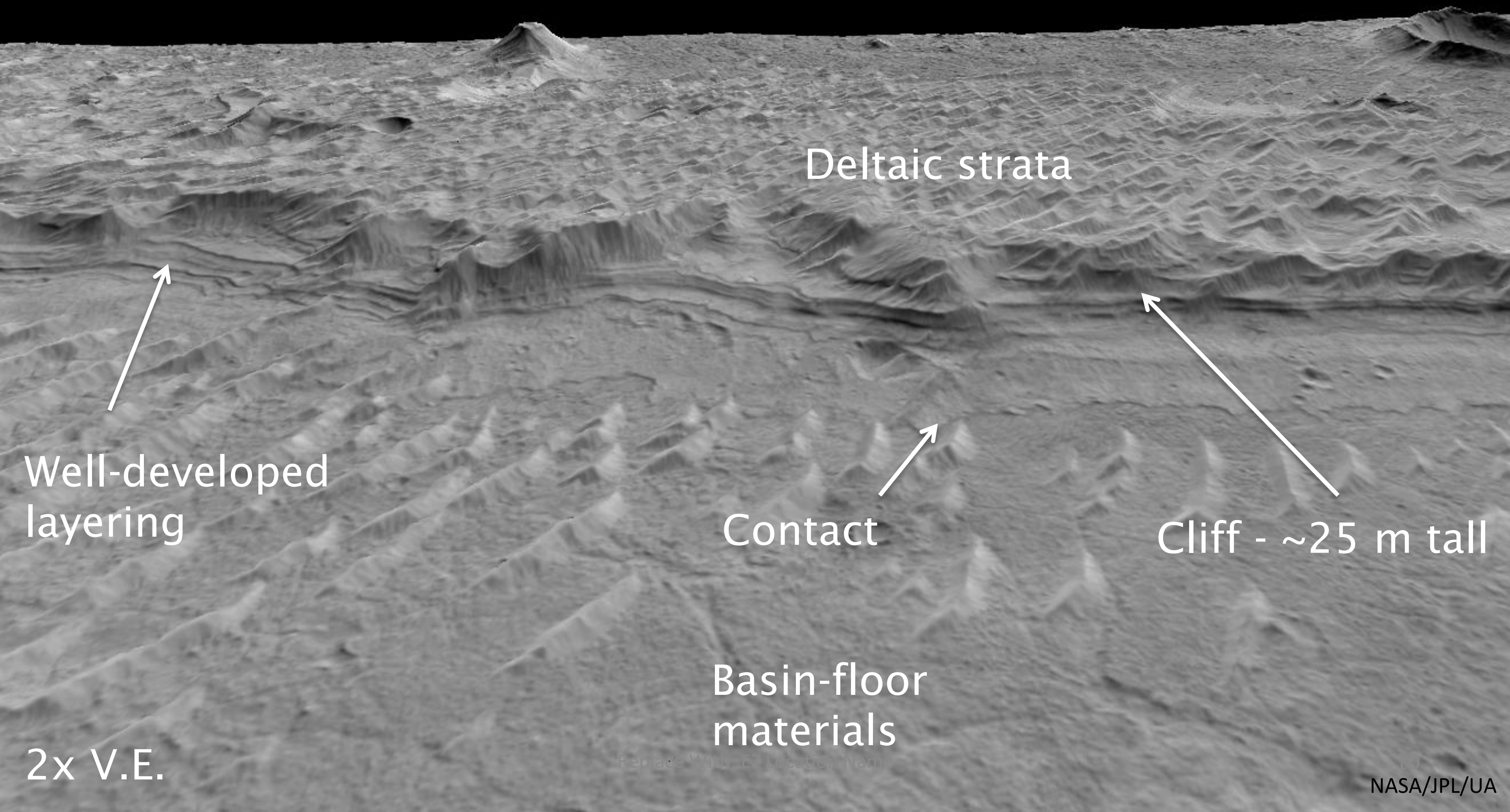


# SROI 1 Hypanis Deltaic strata



# Perspective view of SROI 1

HiRISE: ESP_036277_1920






NASA/JPL/UA

# Science ROIs 1-4,6-7




## Image of SROI 2

Delta lobe

Prominent feeder channel

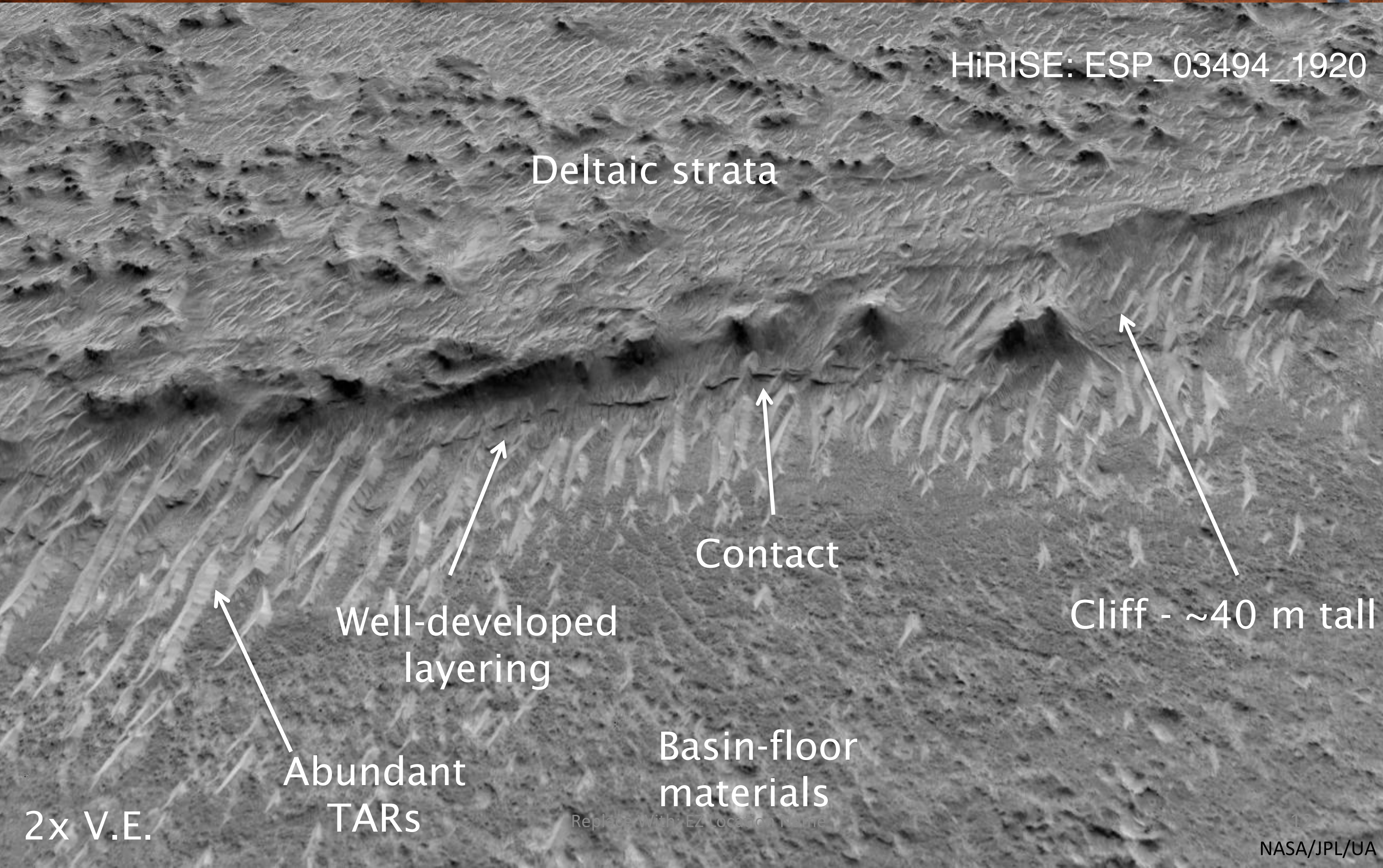
<u>Hypanis Delta</u>

- Prominent lobe: 11.9°N, 314.9°E, -2.7 km
- Layered sedimentary strata in lobes of Hypanis delta and in inverted channel complexes
- Threshold:
  - Potential for past habitability
  - Clear evidence for aqueous processes
  - Identifiable stratigraphic contacts
  - Outcrop units with a range of ages
- Qualifying:
  - Access to deposits with potential for containing organic matter

HiRISE: ESP_03494_1920

NASA/JPL/UA

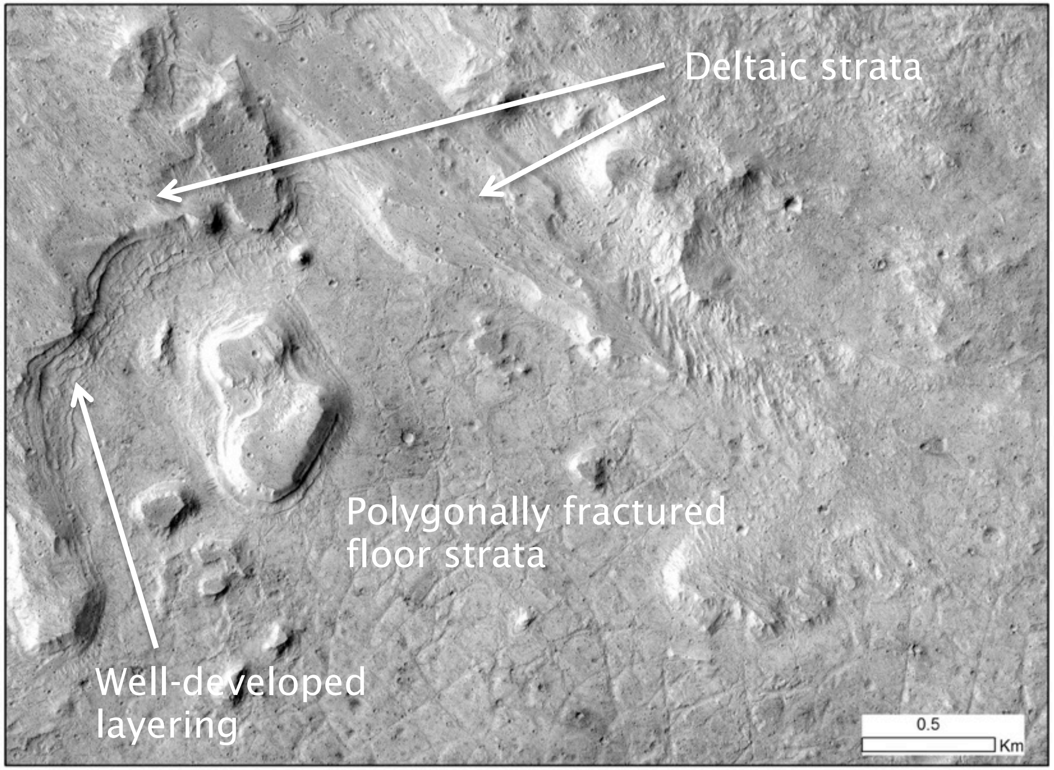
# Perspective view of SROI 2



# Science ROI 5



## Image of SROI 5



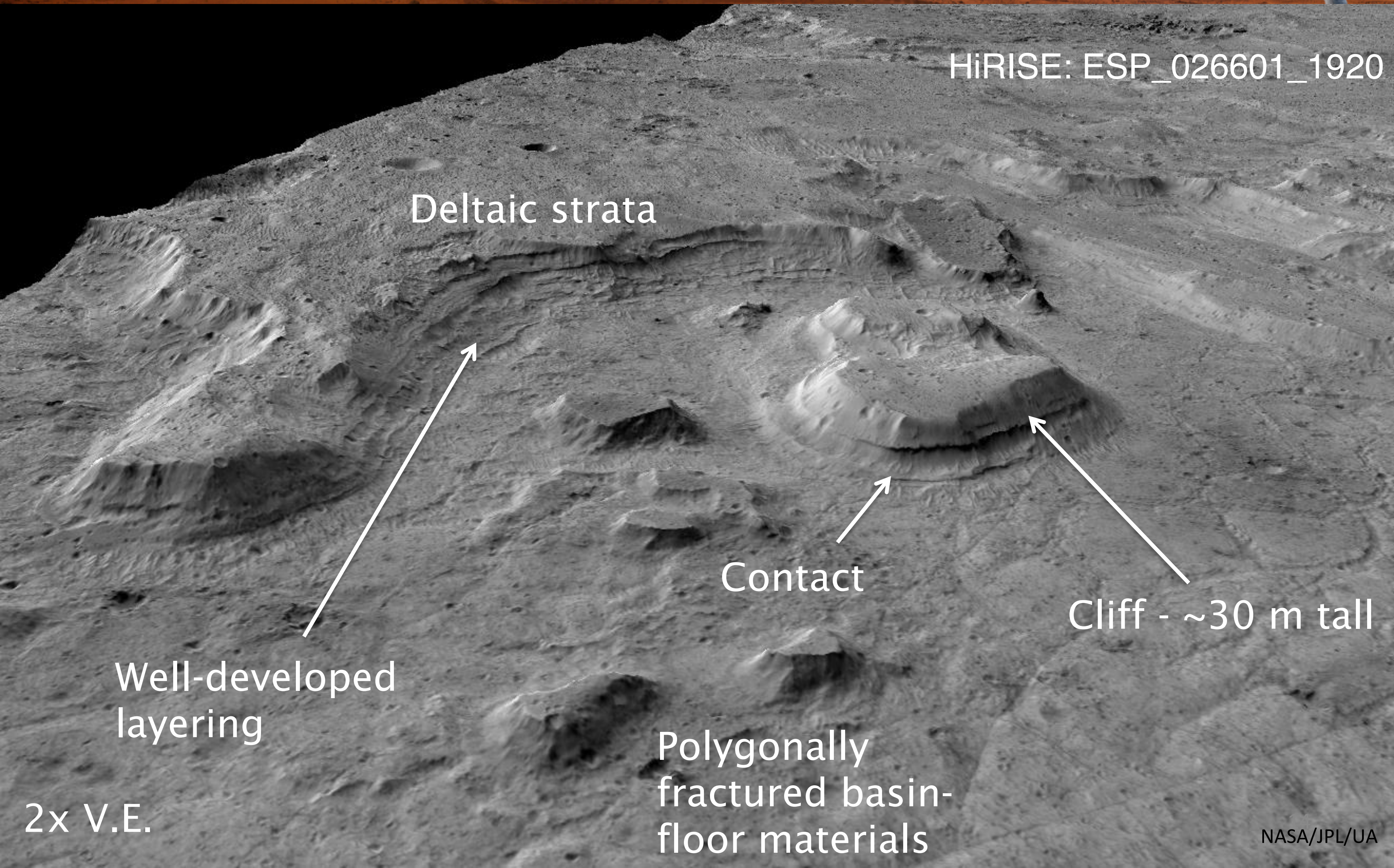

HiRISE: ESP_026601_1920

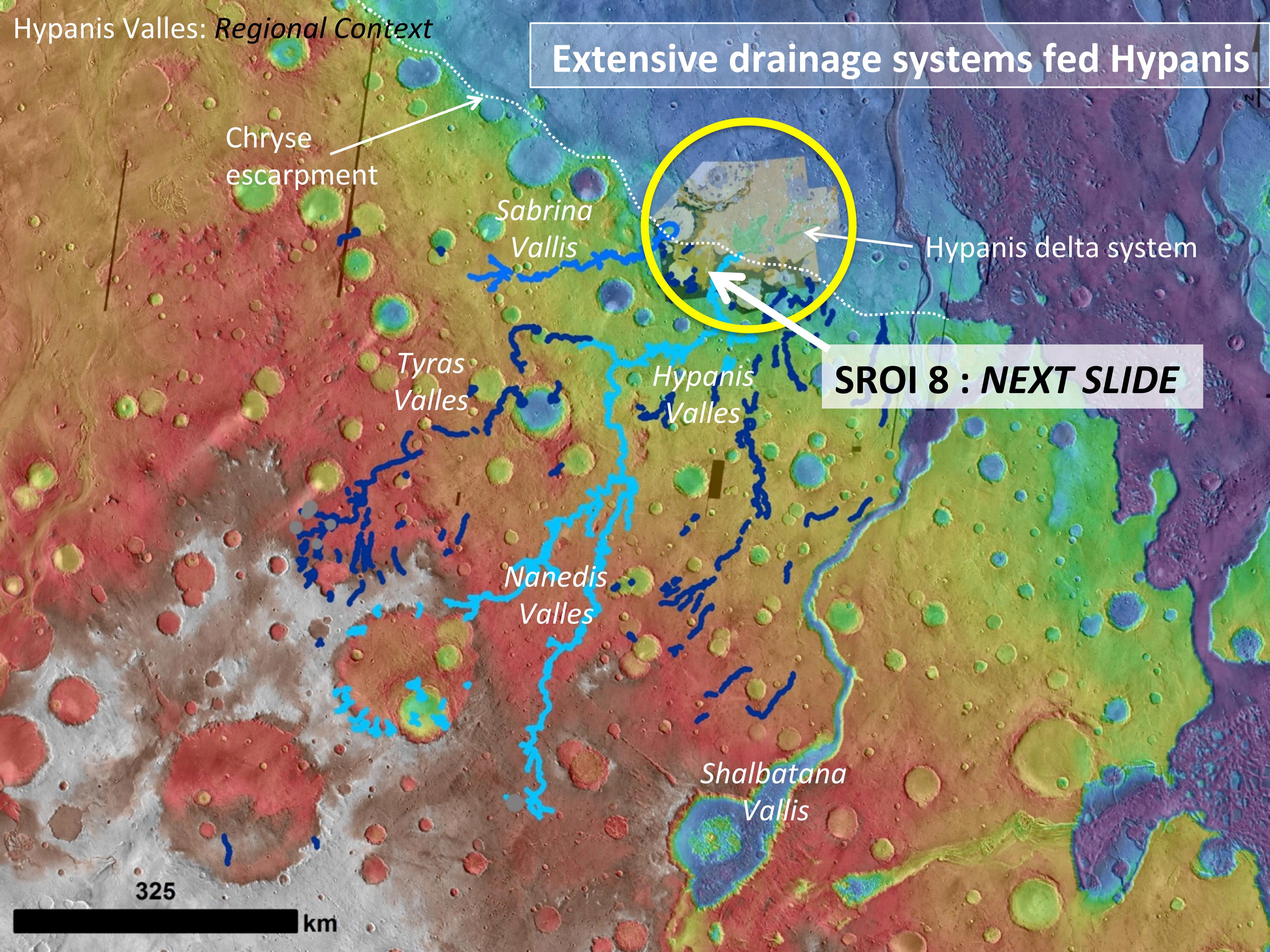
NASA/JPL/UA

## Sabrina Delta

- 11.7°N, 313.1°E, -2.5 km
- Layered sedimentary strata in lobes of Hypanis delta and in inverted channel complexes
- Threshold:
  - Potential for past habitability
  - Clear evidence for aqueous processes
  - Identifiable stratigraphic contacts
  - Outcrop units with a range of ages
- Qualifying:
  - Access to deposits with potential for containing organic matter

# Perspective view of SROI 5

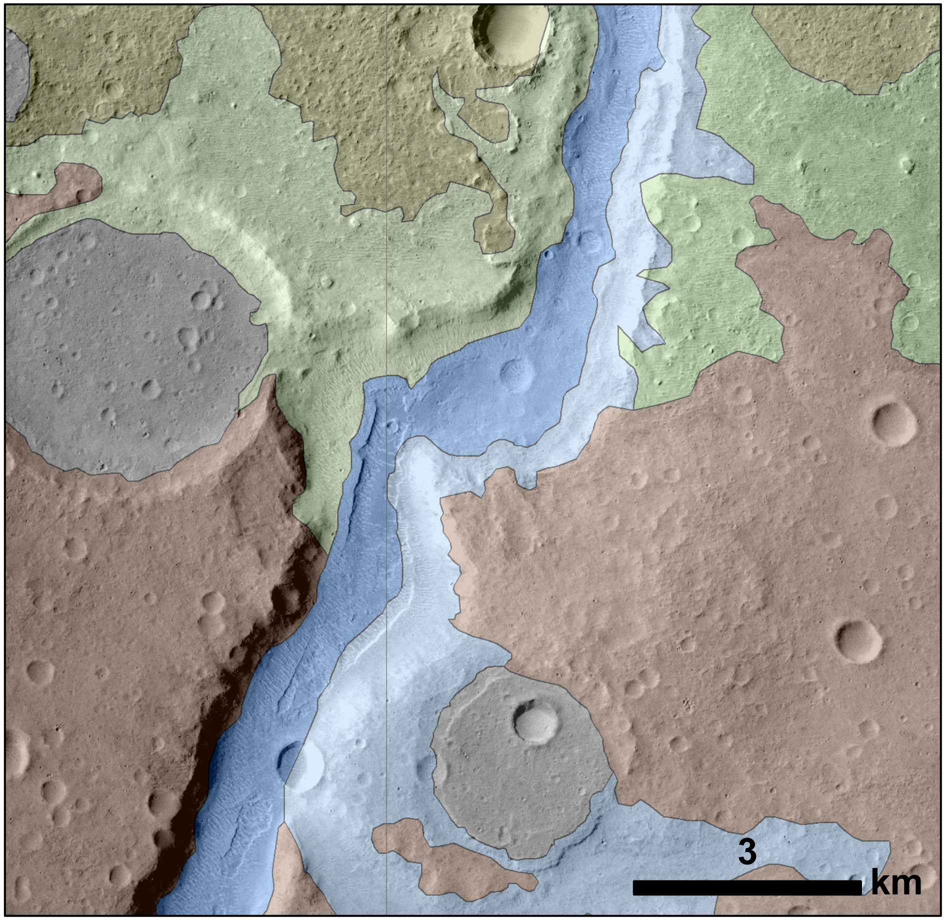




Hypanis Valles: *Regional Context*
Extensive drainage systems fed Hypanis
Chryse escarpment
Sabrina Vallis
Hypanis delta system
Tyras Valles
Hypanis Valles
SROI 8 : *NEXT SLIDE*
Nanedis Valles
Shalbatana Vallis
325
km

# Science ROI 8



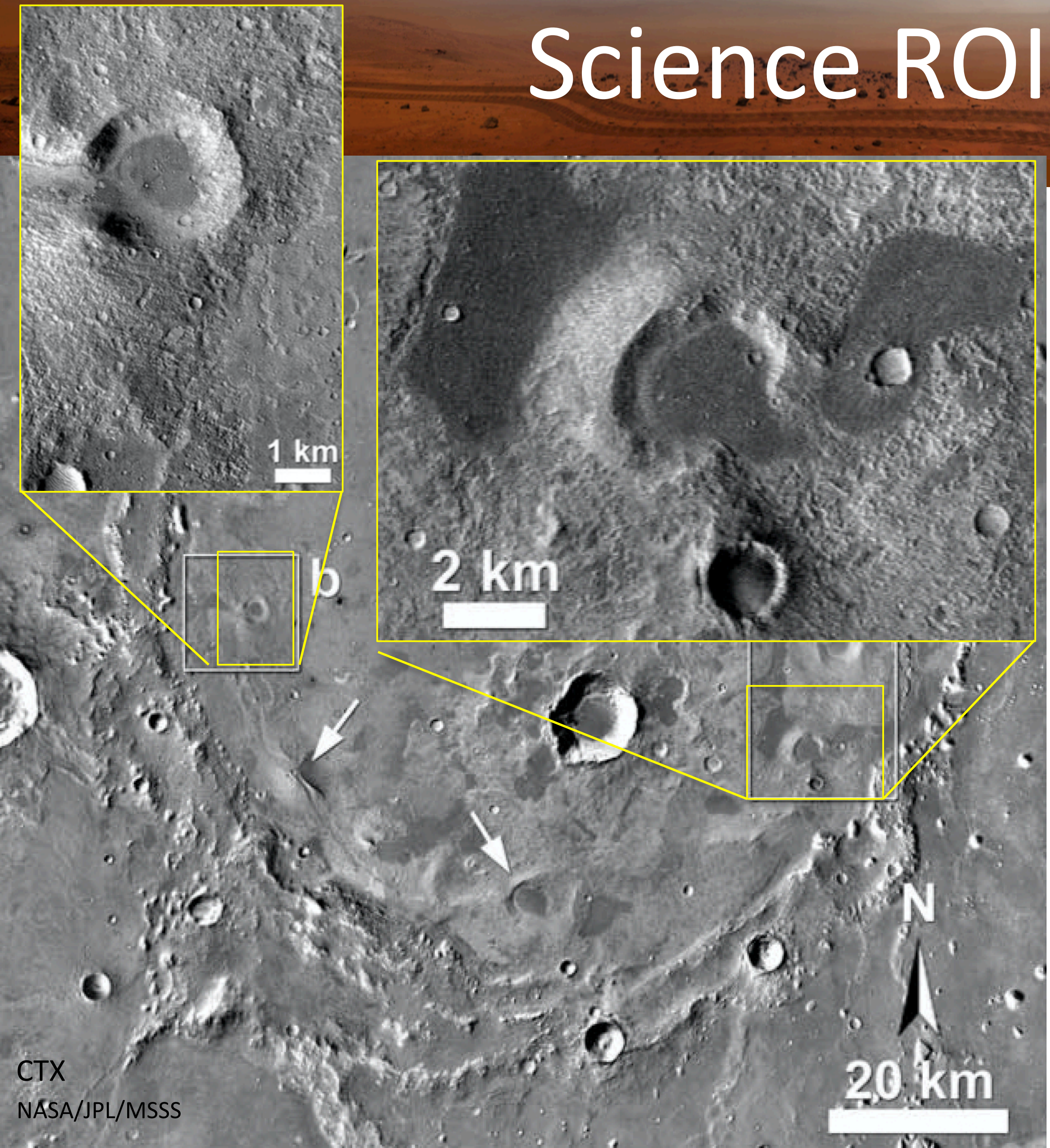



## Channel Contact on Dichotomy Boundary

- 10.6°N, 313.9°E, -2.2 km
- Hypanis Valles channel exposes stratigraphy along the Martian Dichotomy Boundary
- Threshold:
  - Identifiable stratigraphic contacts
  - Range of datable surfaces (Noachian and Hesperian plains units)
- Qualifying:
  - Evidence of aqueous activity
  - Exposed Noachian bedrock

# Science ROI 9






## Possible Hydrovolcanic Features

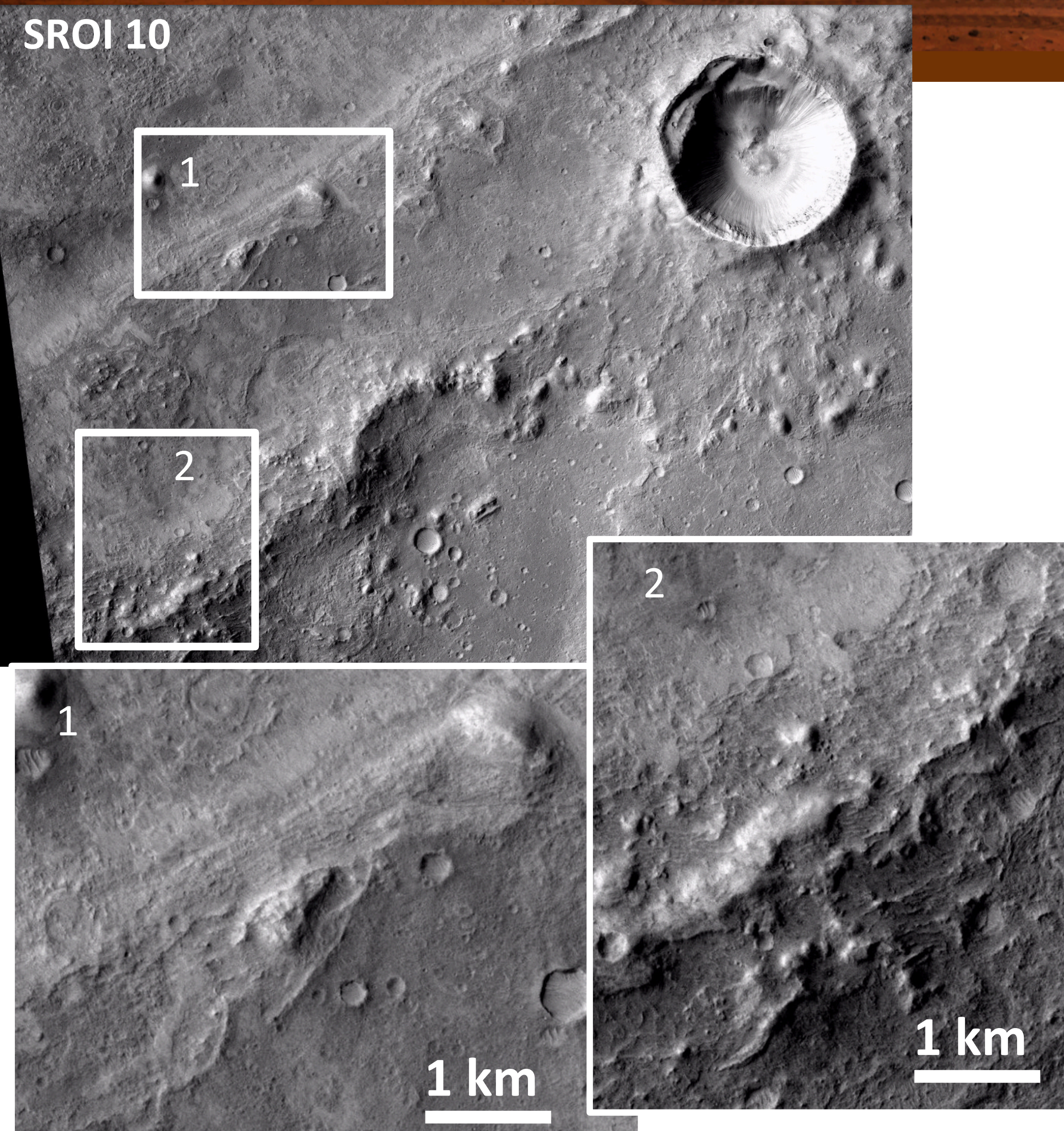
- 11.7°N, 314.4°E, -2.5 km
- Conical landforms in Ledeberg Crater hypothesized to be tuff cones by Brož & Hauber (2013)
- Threshold:
  - Evidence of aqueous activity
  - Stratigraphic context Ledeberg and other units
- Qualifying:
  - Potential Hesperian igneous materials

CTX: F01_036161_1909_XN_10N045W

NASA/JPL/MSSS

# Science ROIs 10-12






## Lederberg Rim Outcrops

- SROI 10: 12.2°N, 314.2°E, -2.6 km
- SROI 11: 12.6°N, 314.6°E, -2.8 km
- SROI 12: 13.3°N, 314.8°E, -3.0 km

- Noachian bedrock exposed in crater rim
- Multiple units with some indication of layering
- Threshold:
  - Identifiable stratigraphic contacts
  - Potential for trapped gases in impact melts
- Qualifying:
  - Fresh impact structures
  - Exposed Noachian bedrock

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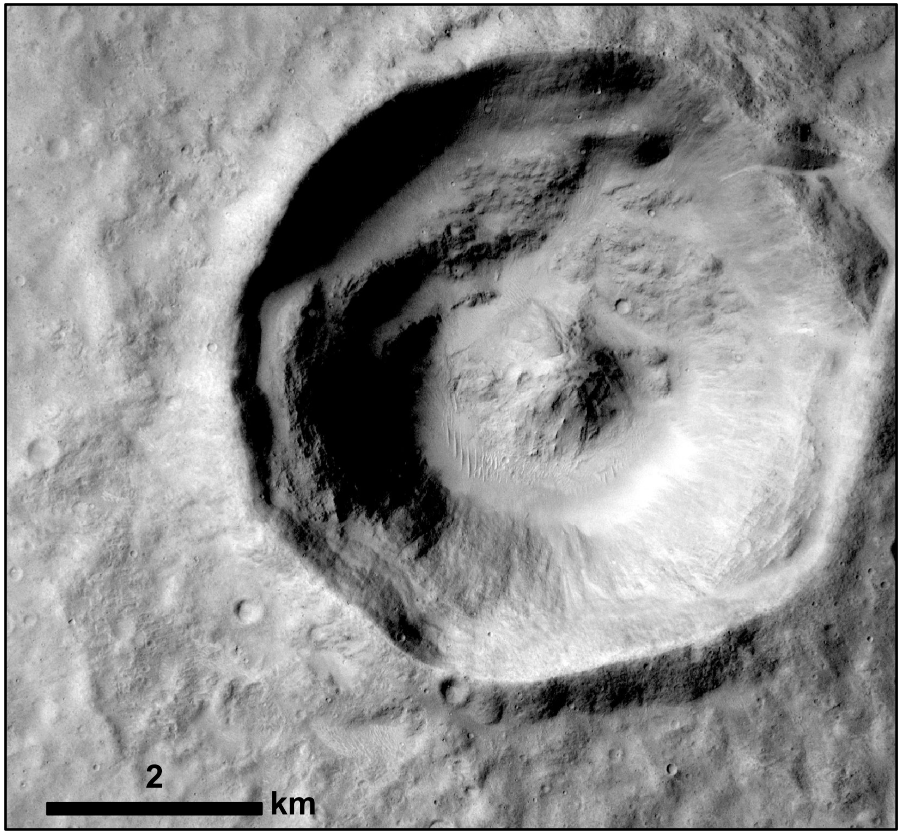
# Science ROIs 13-14



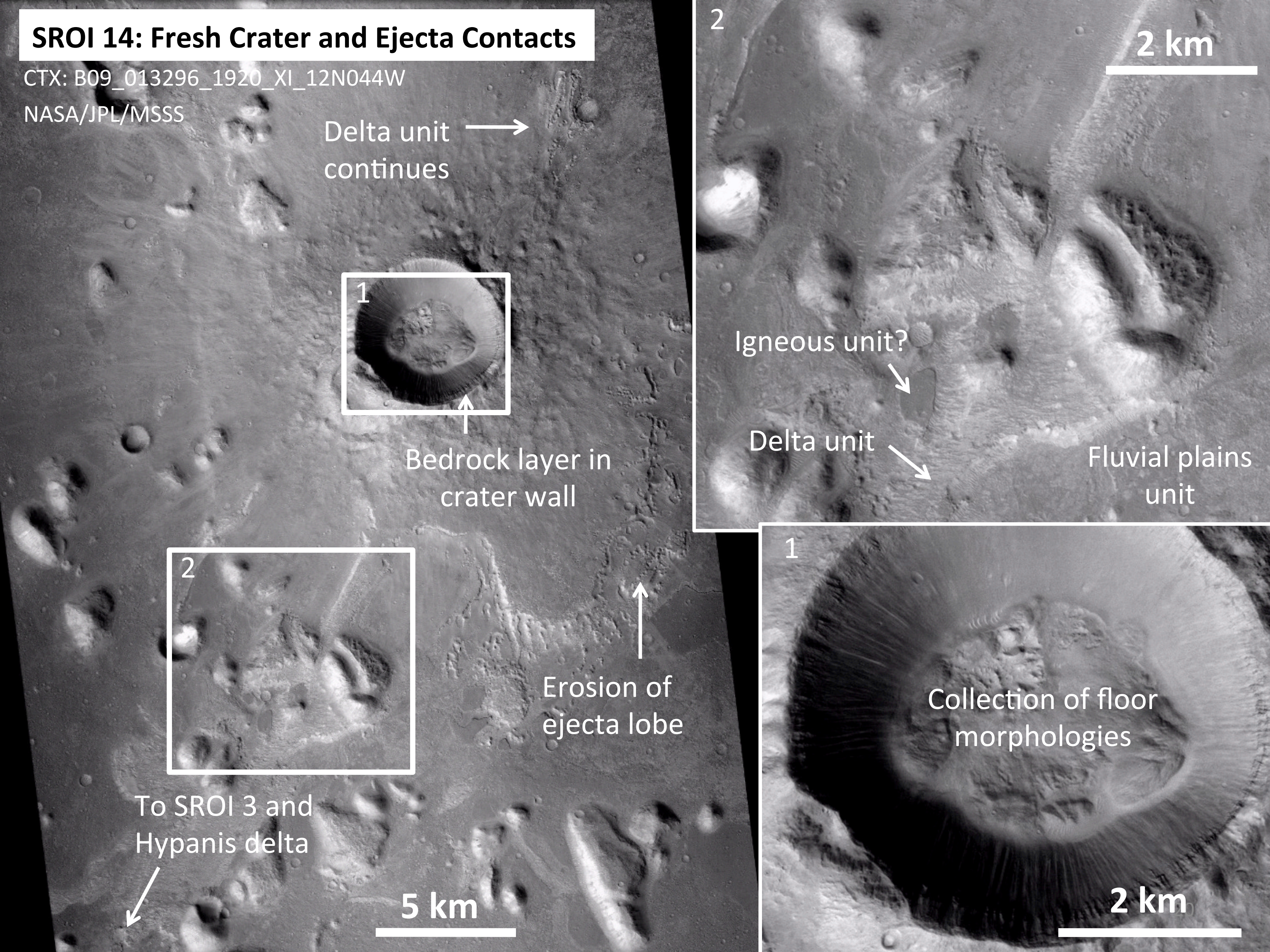
**SROI 13: Fresh Crater**




## Craters and Ejecta

- SROI 13: 10.6°N, 314.8°E, -2.3km
- SROI 14: 12.4°N, 315.7°E, -2.8km

- Threshold:
  - Identifiable stratigraphic contacts between multiple EZ units
  - Potential for trapped gases in impact melts
- Qualifying:
  - Fresh impact structure
  - Exposed Noachian bedrock

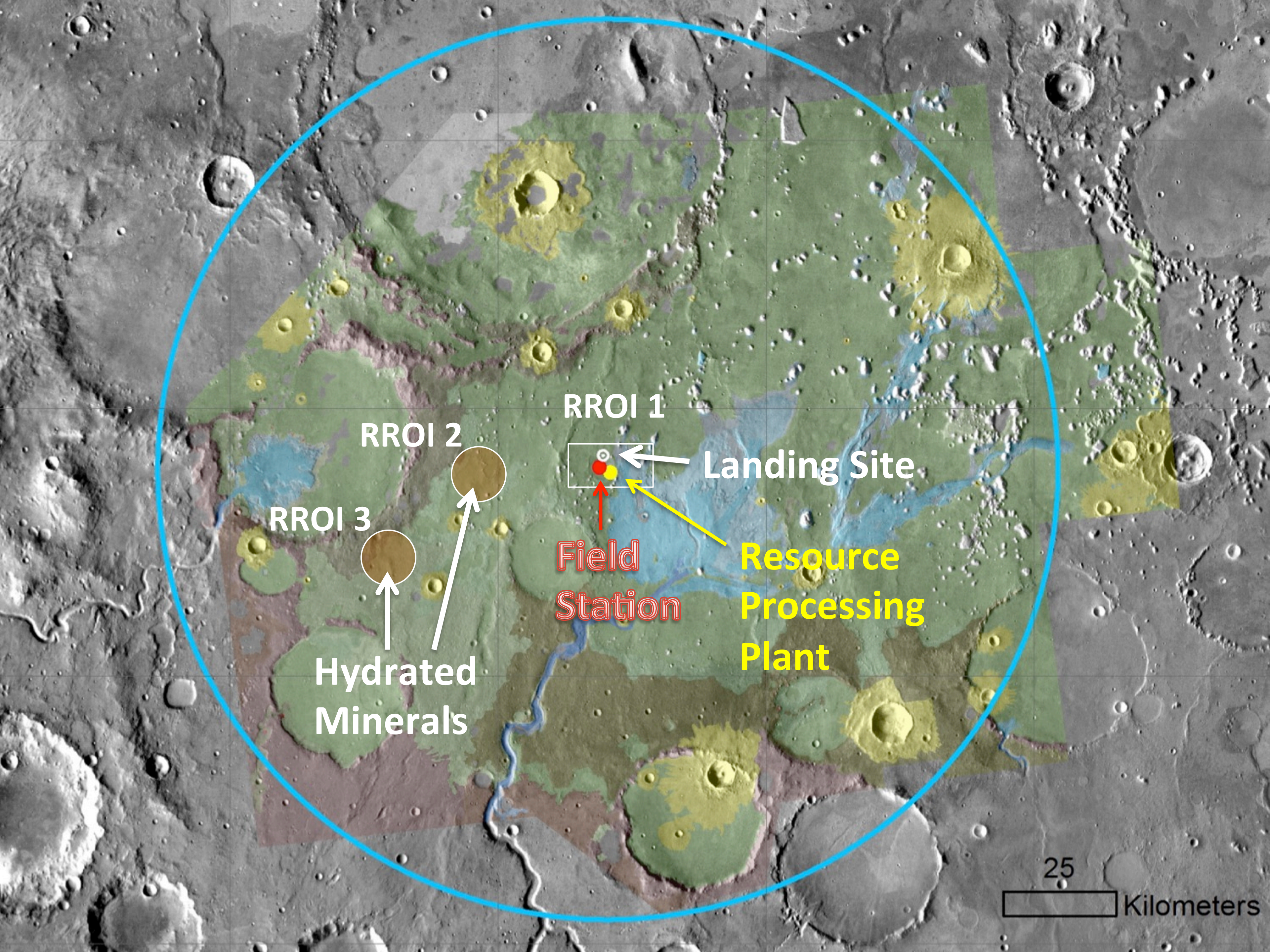

SROI 14: Fresh Crater and Ejecta Contacts
CTX: B09_013296_1920_XI_12N044W
NASA/JPL/MSSS
Delta unit continues
1
Bedrock layer in crater wall
2
Erosion of ejecta lobe
To SROI 3 and Hypanis delta
5 km
2
2 km
Igneous unit?
Delta unit
Fluvial plains unit
1
Collection of floor morphologies
2 km

# Resource ROIs Rubric



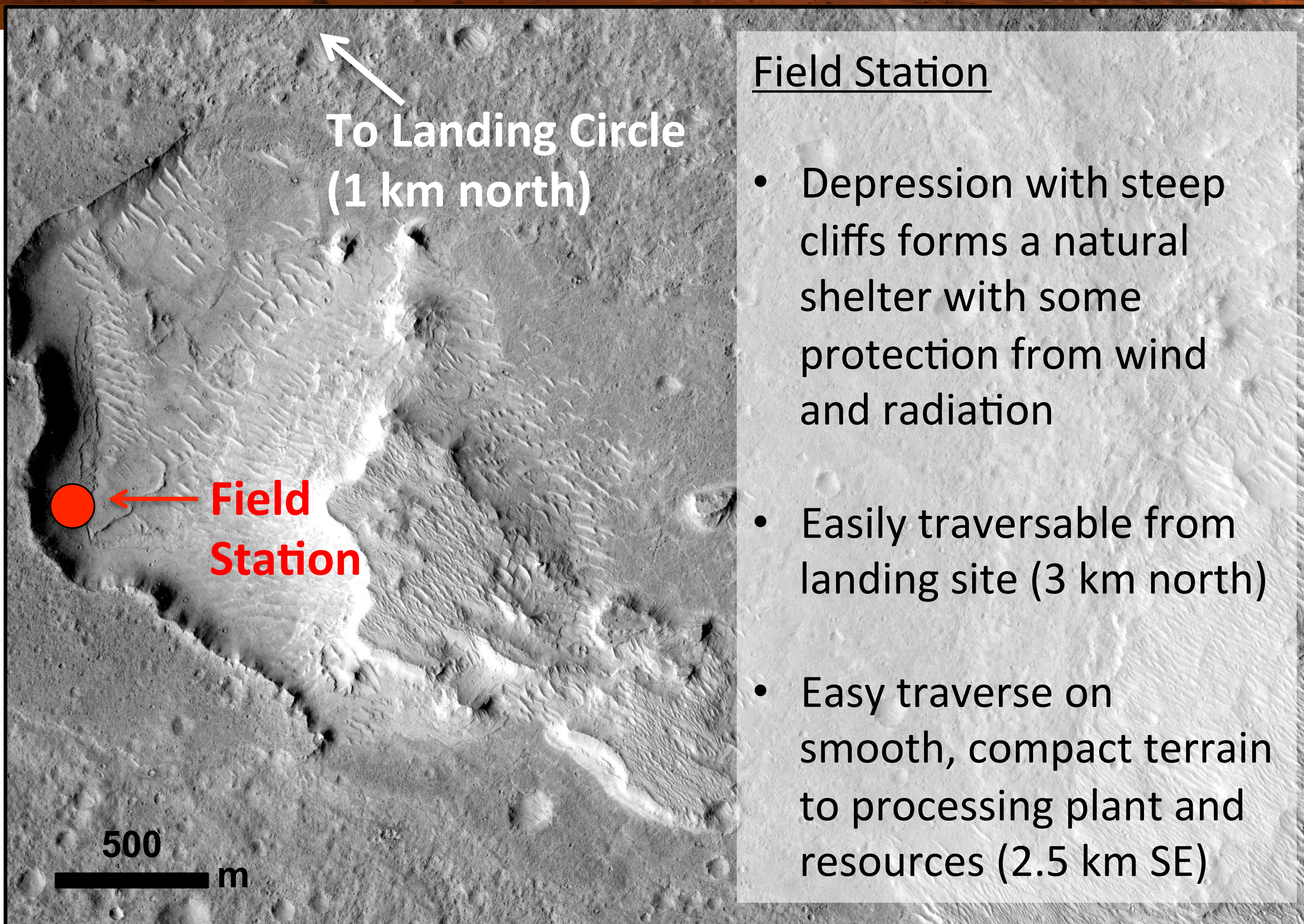
| Criteria | Resource | Type | | Site Factors | RROI1 | RROI2 | RROI3 | EZ SUM |
|---|---|---|---|---|---|---|---|---|
| ISRU and Civil Engineering Criteria | Engineering | | | Meets First Order Criteria (Latitude, Elevation, Thermal Inertia) | ● | ● | ● | 3,3 |
| | Water Resource | Threshold | AND/ OR | **Potential for ice or ice/regolith mix** | | | | 0,0 |
| | | | | **Potential for hydrated minerals** | ● | ● | ● | 3,3 |
| | | | | **Quantity for substantial production** | ● | ● | ● | 3,3 |
| | | | | **Potential to be minable by highly automated systems** | ● | ● | ● | 3,3 |
| | | | | **Located less than 3 km from processing equipment site** | ● | ● | ● | 3,3 |
| | | | | **Located no more than 3 meters below the surface** | ● | ● | ● | 3,3 |
| | | | | **Accessible by automated systems** | ● | ● | ● | 3,3 |
| | | Qualifying | | Potential for multiple sources of ice, ice/regolith mix **and** hydrated minerals | | | | 0,0 |
| | | | | Distance to resource location can be >5 km | ● | ● | ● | 3,3 |
| | | | | Route to resource location must be (plausibly) traversable | ● | ● | ● | 3,3 |
| | Civil Engineering | Threshold | | **~50 sq km region of flat and stable terrain with sparse rock distribution** | ● | ● | ● | 3,3 |
| | | | | **1–10 km length scale: <10°** | ● | ● | ● | 3,3 |
| | | | | **Located within 5 km of landing site location** | ● | | | 1,0 |
| | | Qualifying | | Located in the northern hemisphere | ● | ● | ● | 3,3 |
| | | | | Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith | ● | | | 1,0 |
| | | | | Utilitarian terrain features | ● | | | 1,0 |
| | Food Production | Qualifying | | Low latitude | ● | ● | ● | 3,3 |
| | | | | No local terrain feature(s) that could shadow light collection facilities | ● | ● | ● | 3,3 |
| | | | | Access to water | ● | ● | ● | 3,3 |
| | | | | Access to dark, minimally altered basaltic sands | ● | | | 1,0 |
| | Metal/Silicon Resource | Threshold | | **Potential for metal/silicon** | ● | ● | ● | 3,3 |
| | | | | **Potential to be minable by highly automated systems** | ● | ● | ● | 3,3 |
| | | | | **Located less than 3 km from processing equipment site** | ● | ● | ● | 3,3 |
| | | | | **Located no more than 3 meters below the surface** | ● | ● | ● | 3,3 |
| | | | | **Accessible by automated systems** | ● | ● | ● | 3,3 |
| | | Qualifying | | Potential for multiple sources of metals/silicon | ● | | | 1,0 |
| | | | | Distance to resource location can be >5 km | | | | 0,0 |
| | | | | Route to resource location must be (plausibly) traversable | ● | ● | ● | 3,3 |

| Key | |
|---|---|
| ● | **Yes** |
| ○ | **Partial Support or Debated** |
| | **No** |
| **?** | **Indeterminate** |


RROI 1
RROI 2
RROI 3
Landing Site
Field Station
Resource Processing Plant
Hydrated Minerals
25
Kilometers

# Resource ROI 1



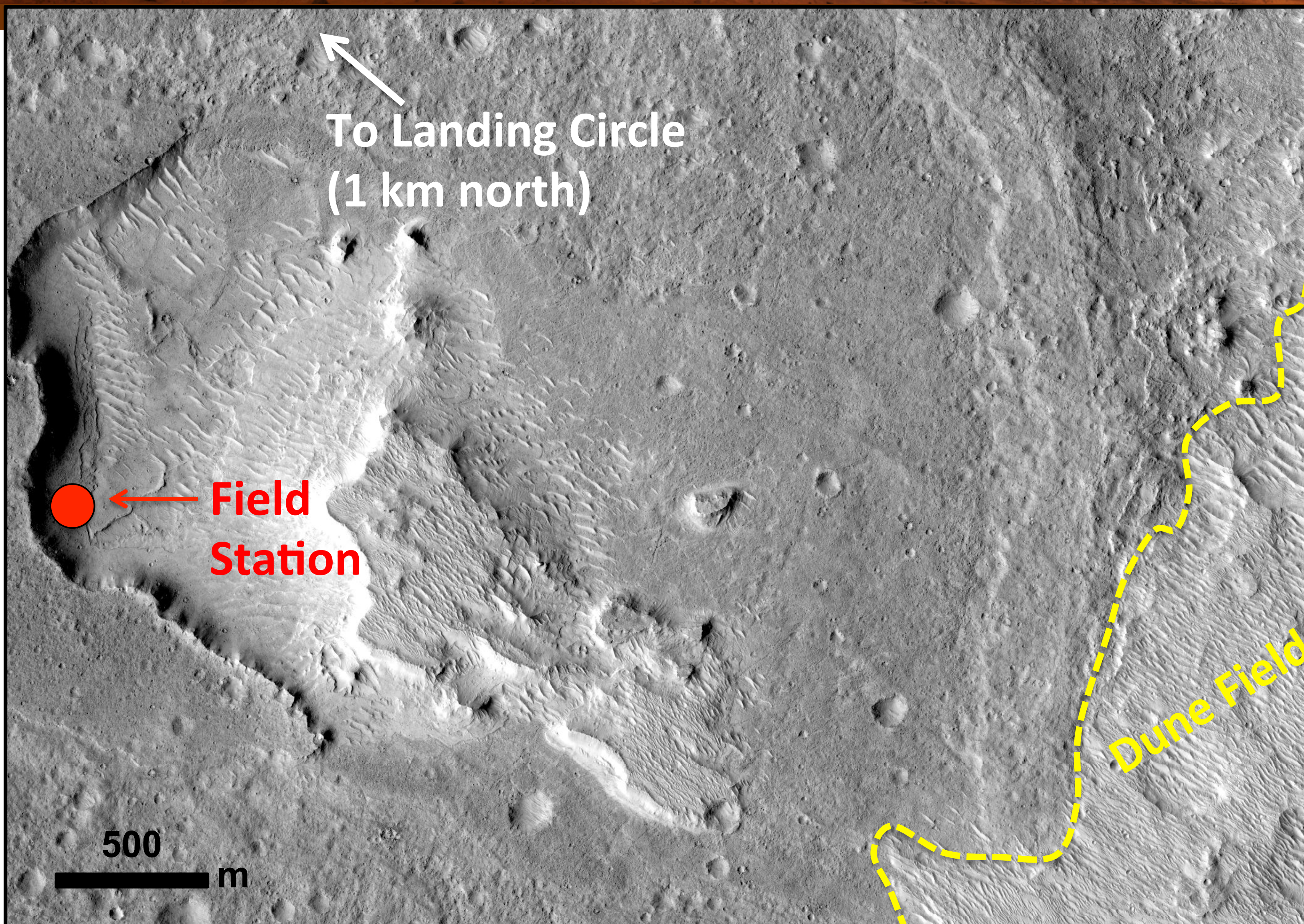



Field Station

- Depression with steep cliffs forms a natural shelter with some protection from wind and radiation
- Easily traversable from landing site (3 km north)
- Easy traverse on smooth, compact terrain to processing plant and resources (2.5 km SE)

# Resource ROI 1





# Resource ROI 1

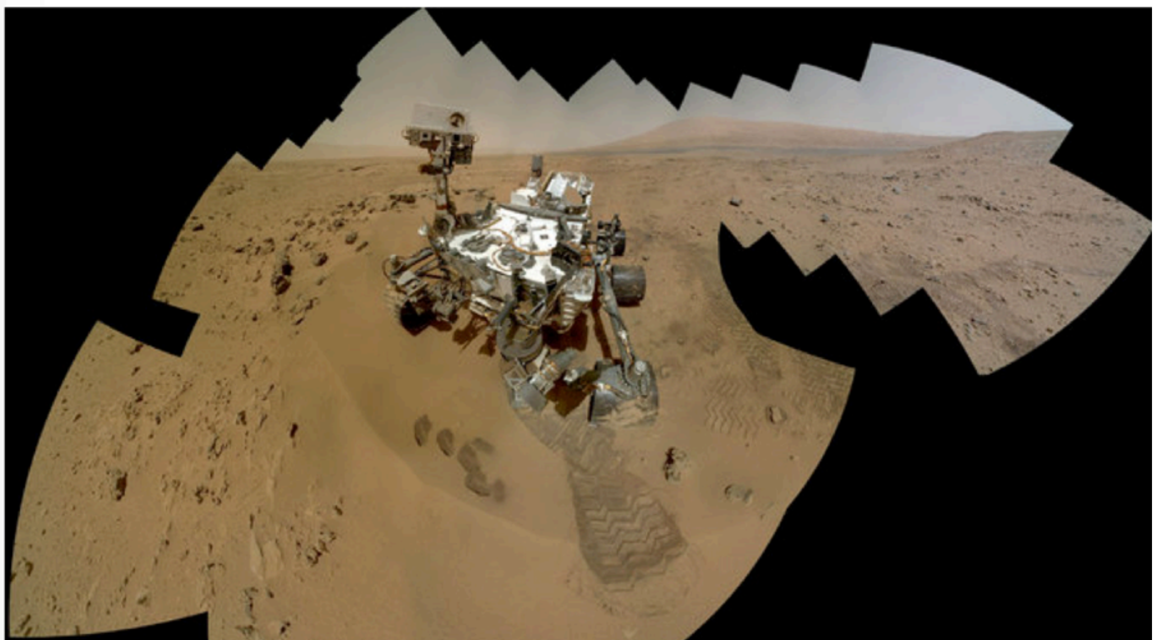


SECTIONS HOME SEARCH The New York Times

SPACE & COSMOS

## *Hitting Pay Dirt on Mars*

By KENNETH CHANG SEPT. 30, 2013

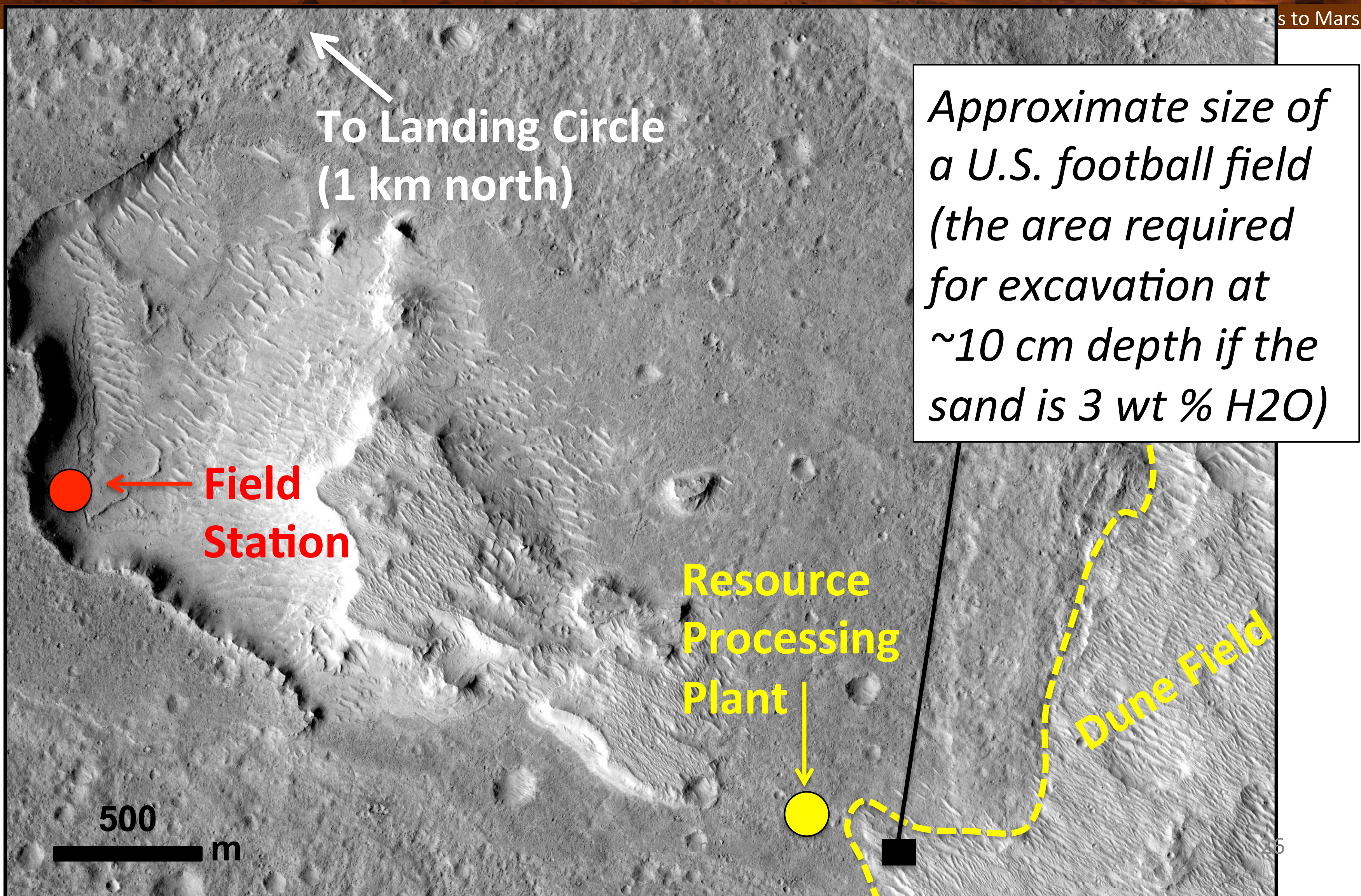


### Water and Metal Resource: Dunes

- In-situ water resources are potentially provided by the extensive aeolian dune sands
- Observations by MSL of atmospheric water adsorbed in dune sands (Meslin et al., 2013) and 3-6 wt. % $H_2O$ in sands at Rocknest (Leshin et al., 2013)
- Absence of crater retention indicates that the TARs are weakly indurated and could be easily mobilized to a processing facility constructed on adjacent, level bedrock
- Could provide metal and silicon resources and building material

# Resource ROI 1

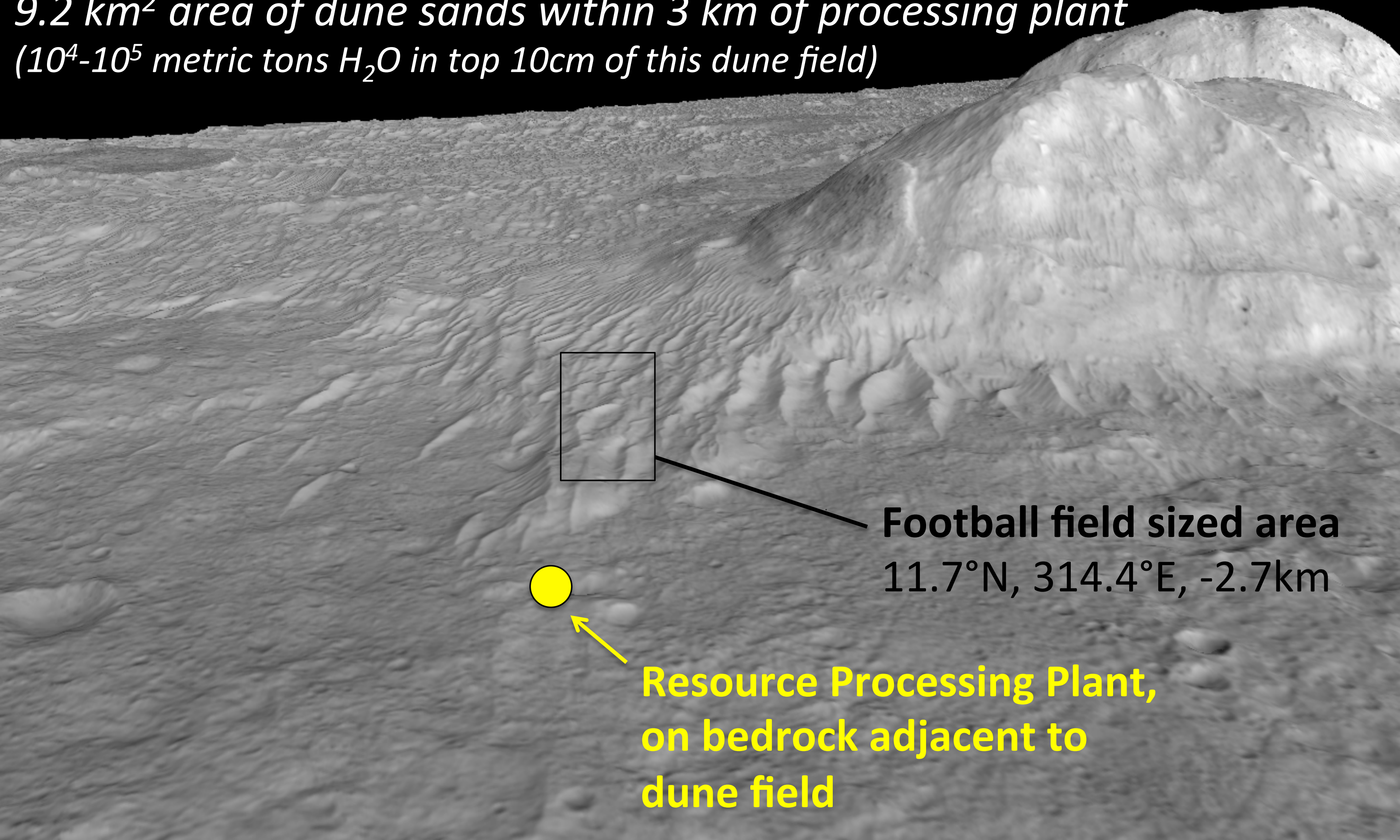




# Dune Sands as Resources

*9.2 $km^2$ area of dune sands within 3 km of processing plant*

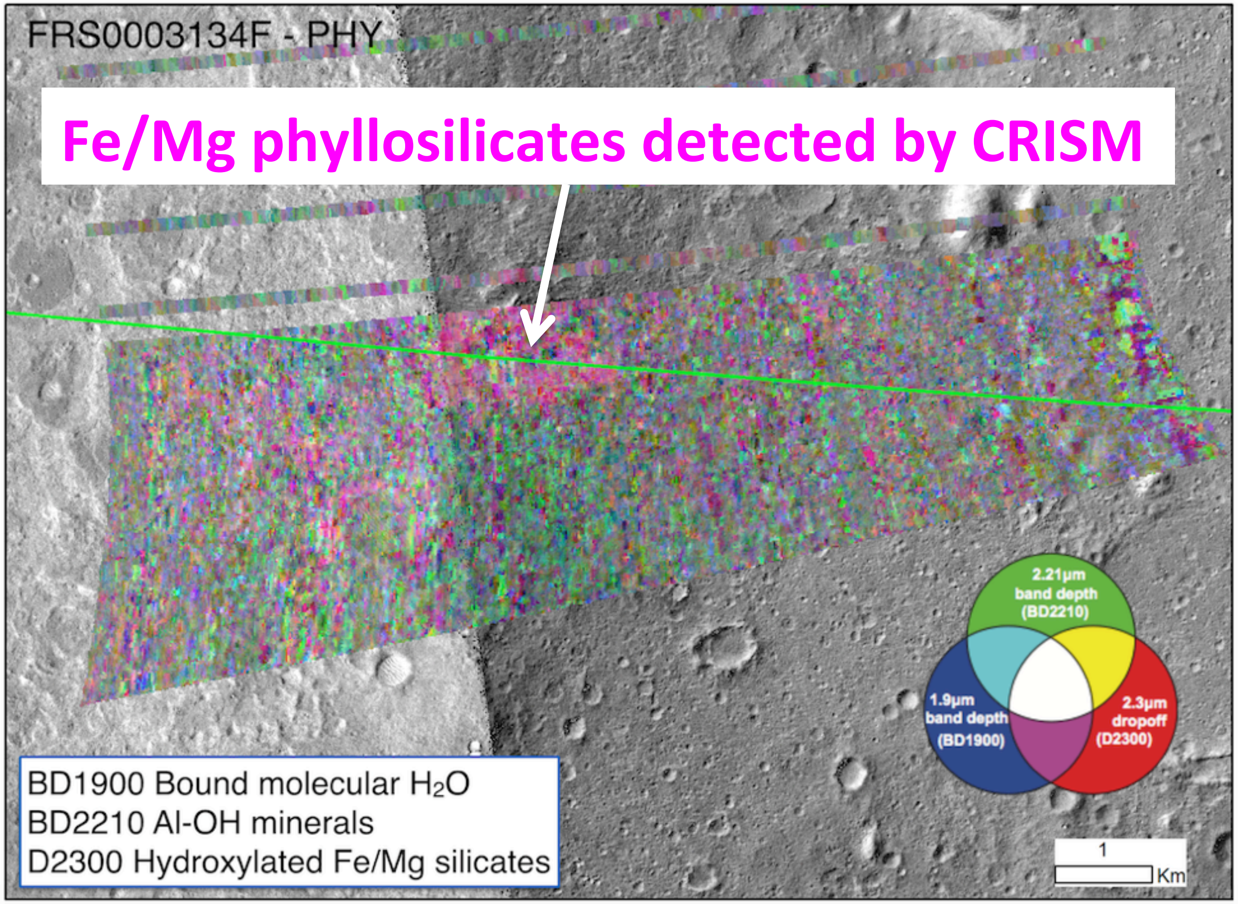
*($10^4$-$10^5$ metric tons $H_2O$ in top 10cm of this dune field)*



# Resource ROIs 2-3



**Water Resource: Hydrated minerals in multiple EZ locations**




<u>Clays and Hydrated Units</u>

- RROI 2: 11.8°N, 313.8°E, -2.5 km
- RROI 3: 11.5°N, 313.4°E, -2.3 km

- Fe/Mg phyllosilicates identified in CRISM FRT and MSP observations at multiple locations on the plains units

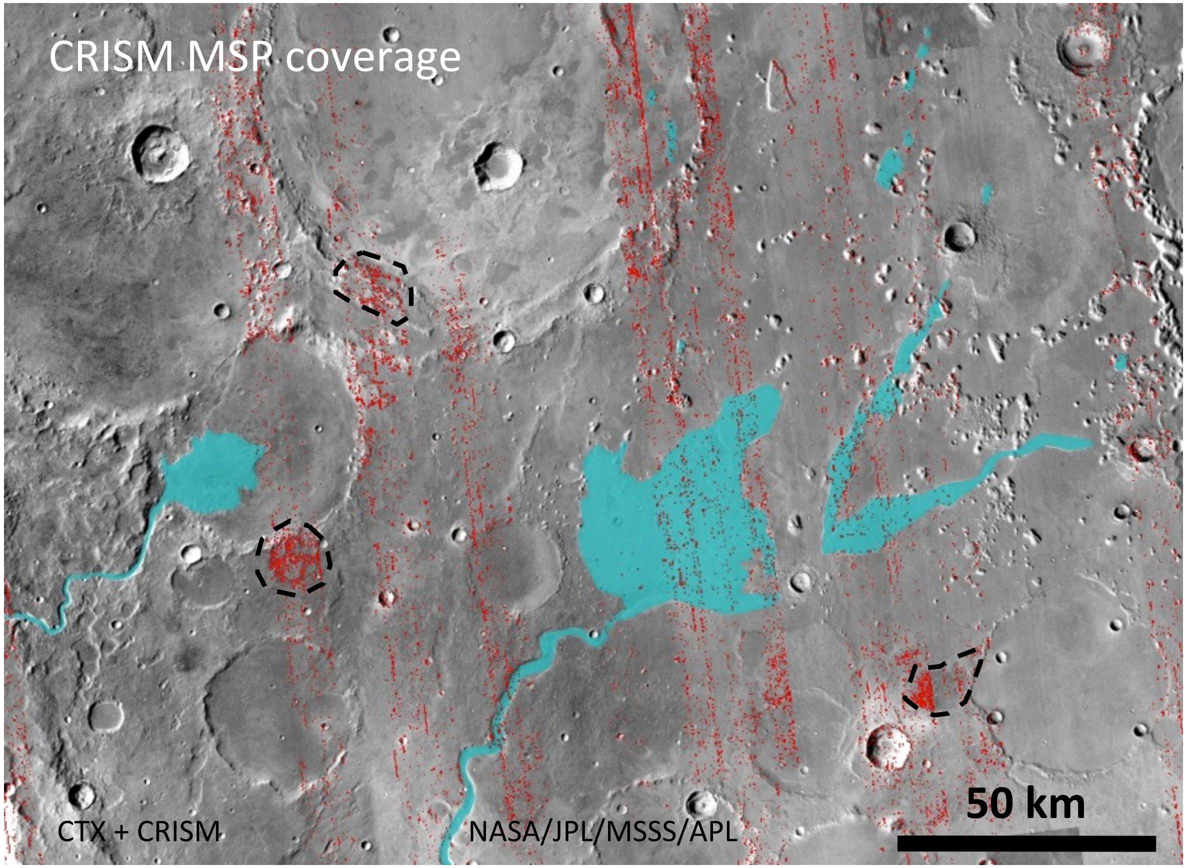
- Threshold:
  - Hydrated minerals
  - Multiple large exposures
  - Accessible and potentially easily-minable
- Qualifying:
  - Routes to all exposures are easily traversable from landing site

# Highest Priority EZ Data Needs



Most important to assess science: **CRISM FRTs**

Most important to assess resources: **CRISM FRTs**




Band depth at 2.3µm

0.5% < D2300 < 3%

# Summary



- Hypanis delta is a great environment for potential habitability and astrobiological preservation
- Key stratigraphic contacts and ROIs are ideal for a human mission since can actually access these distant sites
- Resources are relatively easy to mine – processing and accessing is right next to landing site
- Science is fascinating and has GLOBAL implications: a delta along the dichotomy boundary, **Chryse sea**?

# BACKUP SLIDES

# Prioritization List of EZ Data Needs



## 1 – CRISM FRT images

- CRISM signatures in D2300 parameter low, but correlate with morphology
- The best potentially phyllosilicate bearing deposits have not been targeted in higher resolution

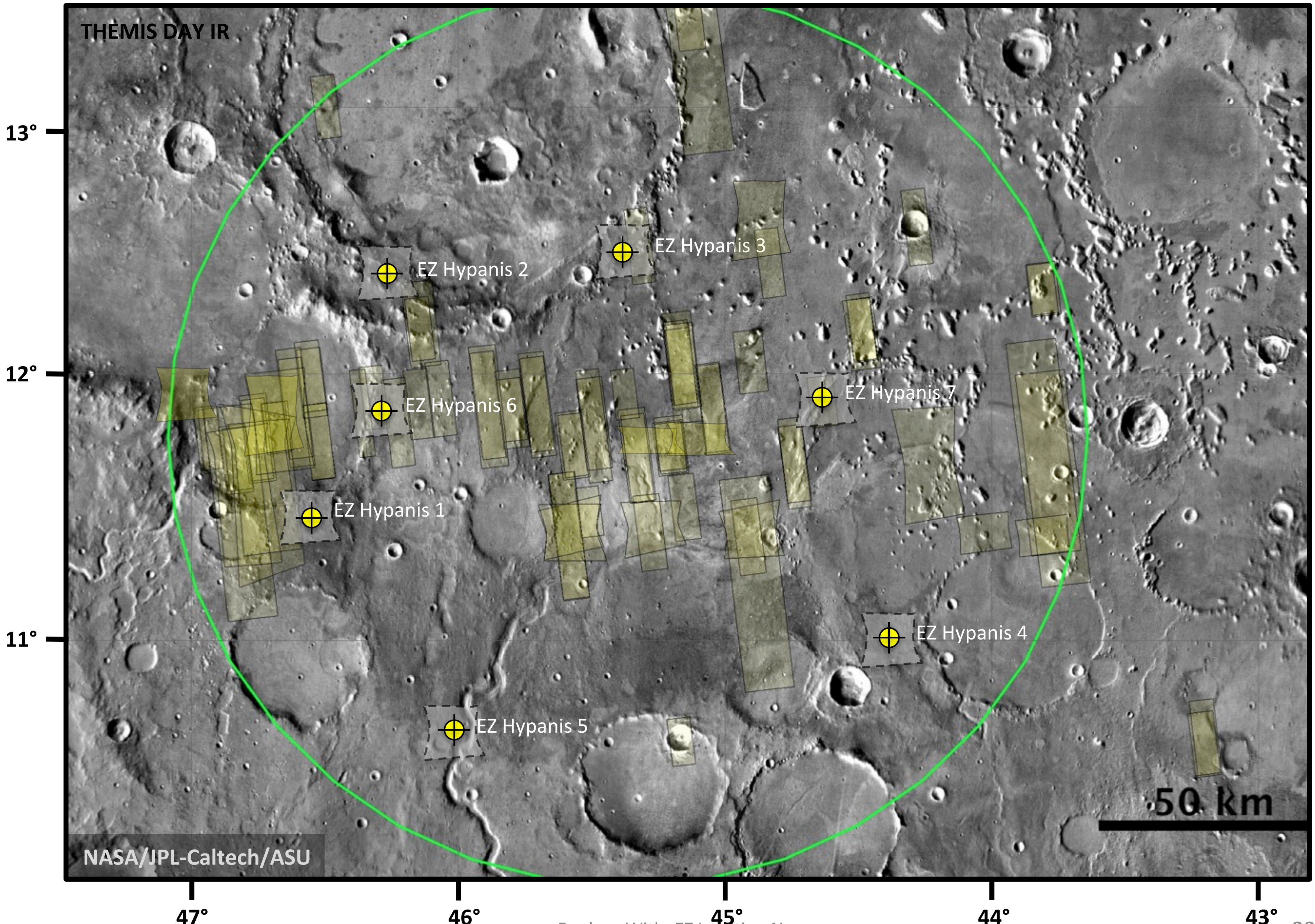
## 2 – HiRISE images

- Delta stratigraphy
- To couple with CRISM FRT spectral analysis of phyllosilicates

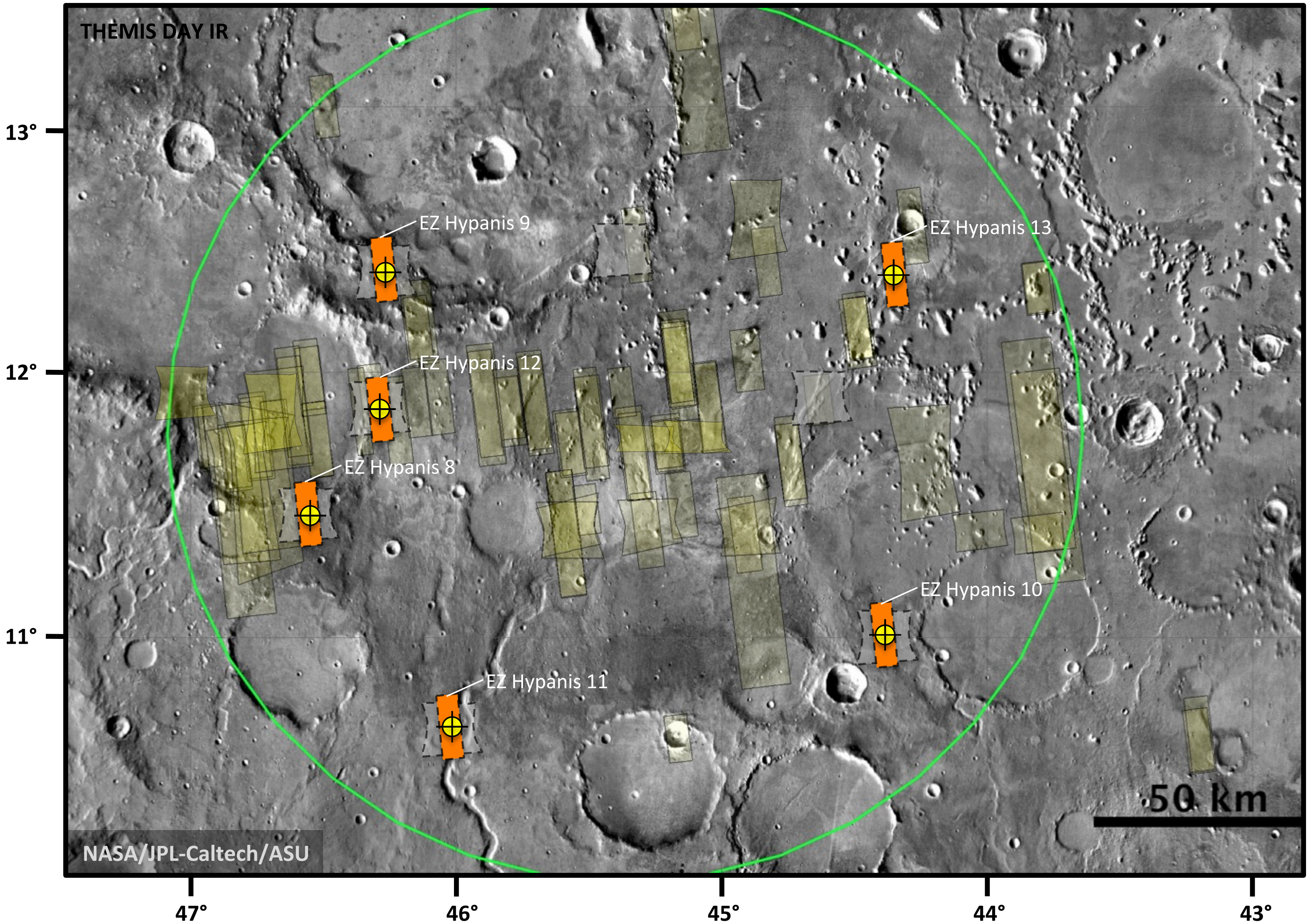
## 3 – CTX stereo pairs

- Delta slope analysis along proximal and distal lobes using CTX DTM

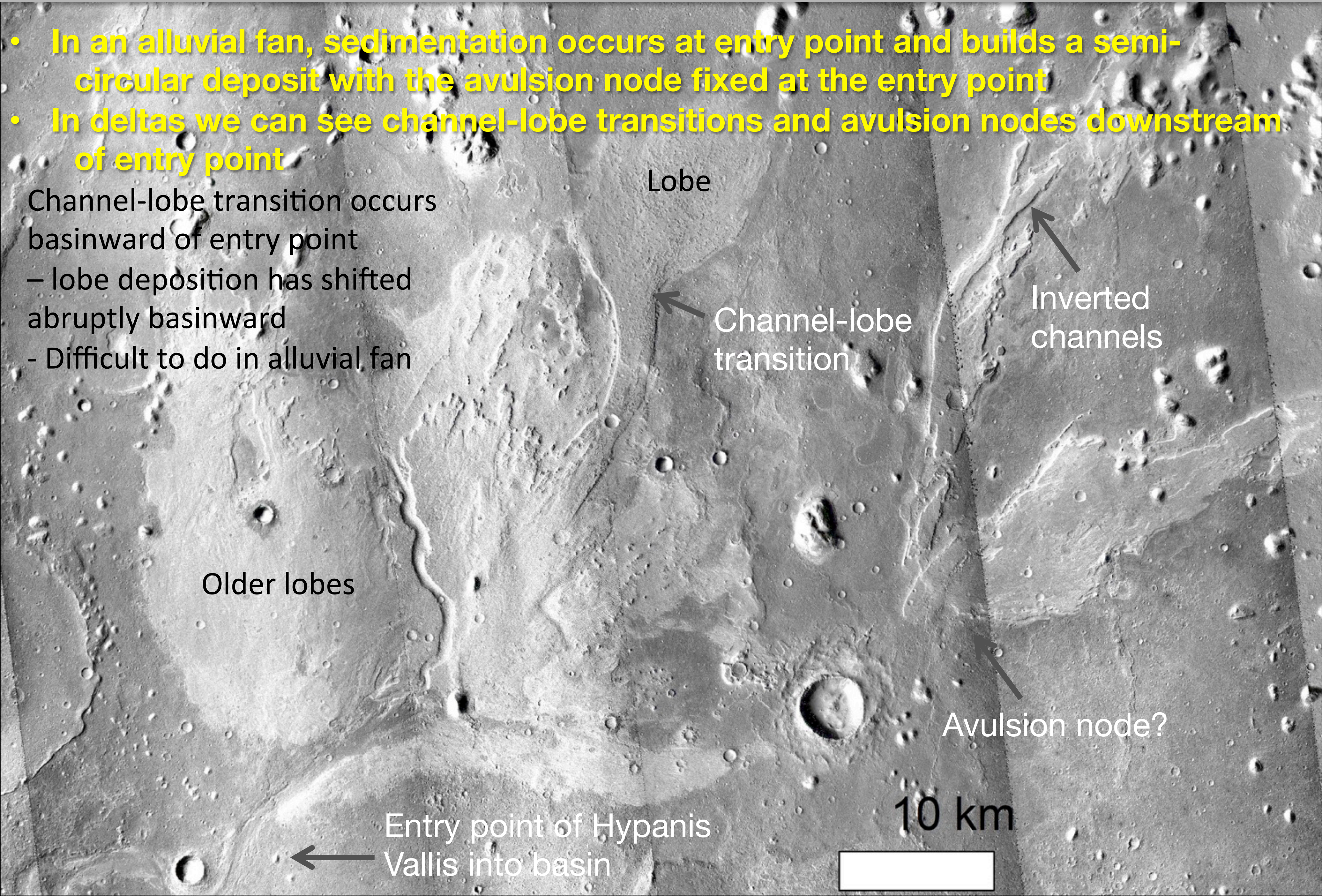
# Hypanis Human Exploration Zone CRISM Requests



# Hypanis Human Exploration Zone HiRISE Requests

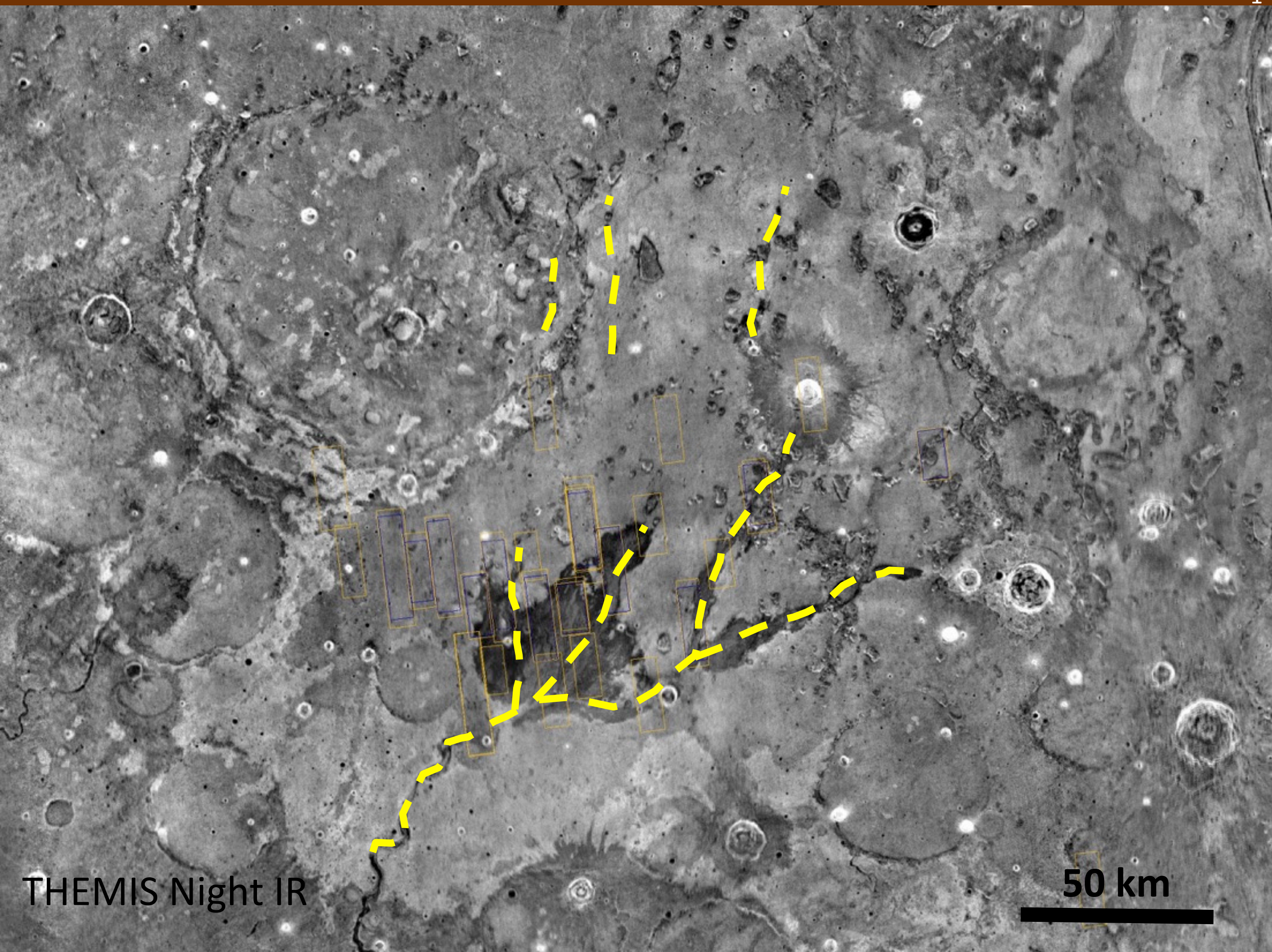


# Hypanis – why is it a delta and not an alluvial fan?



# Delta vs. Fan





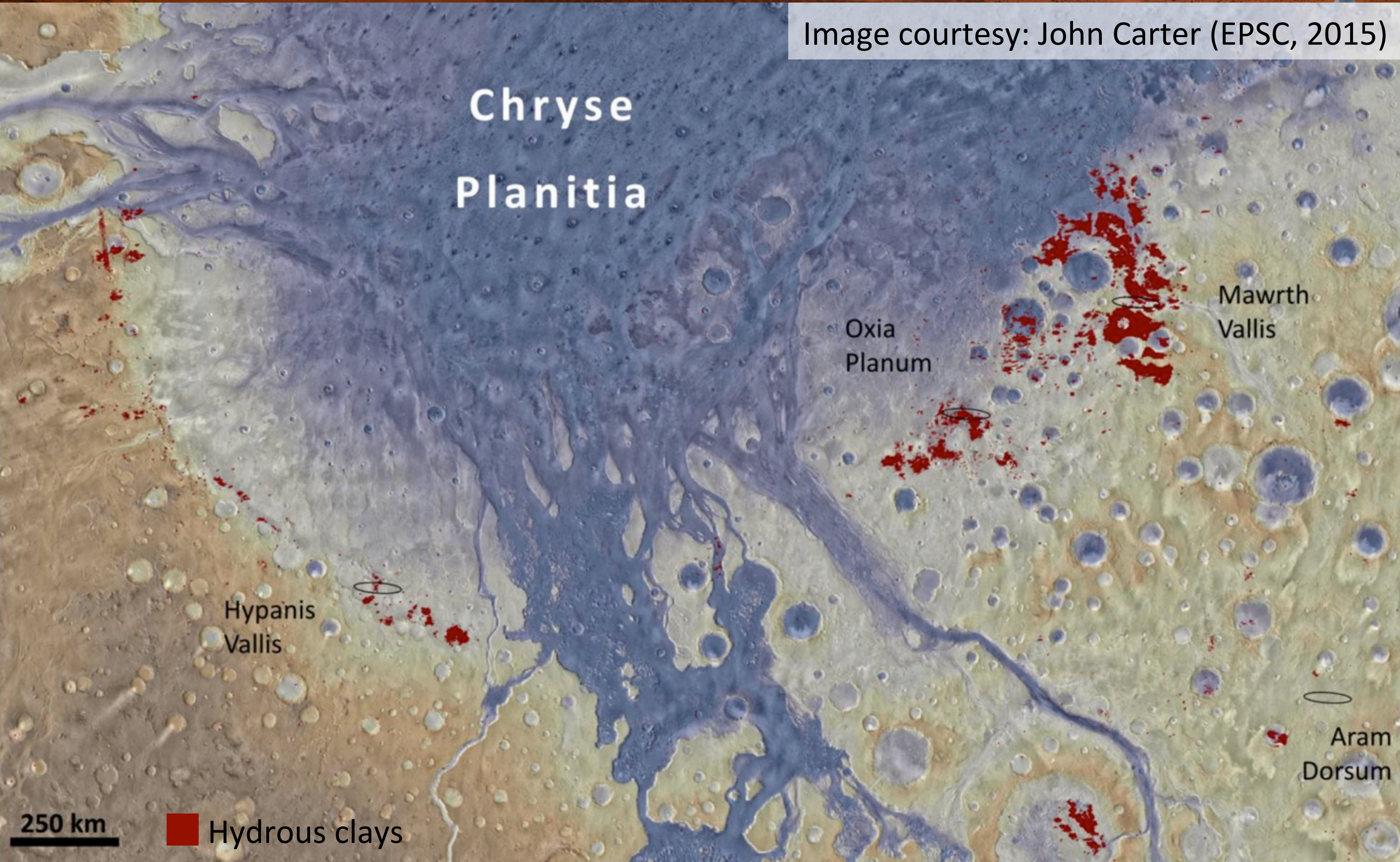

- Need DTMs spanning downstream profiles
- Examine:
  - channel lobe transitions
  - avulsion node migration
  - slopes connecting farthest deposits
- Some HiRISE, CTX DTMs made
- HRSC will work, but CTX DTM of entire delta extent is better



# MINERALOGY

# Hypanis Valles: *Mineralogy - OMEGA*

- Hydrated signatures (hydrous clays) at Hypanis form part of the wider, circum-Chryse basin, 'bathtub' ring of deposits → *related to large water body in Chryse/beyond?*



# What is the bath-tub that ponded water?



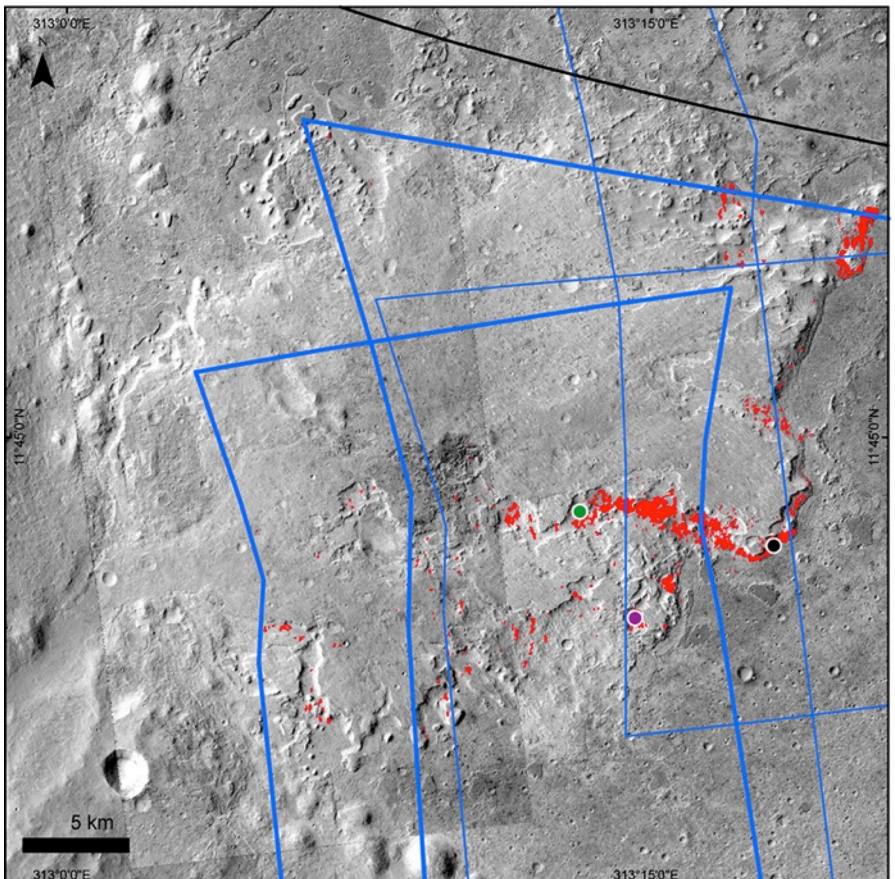
Was the Chryse basin the bathtub?

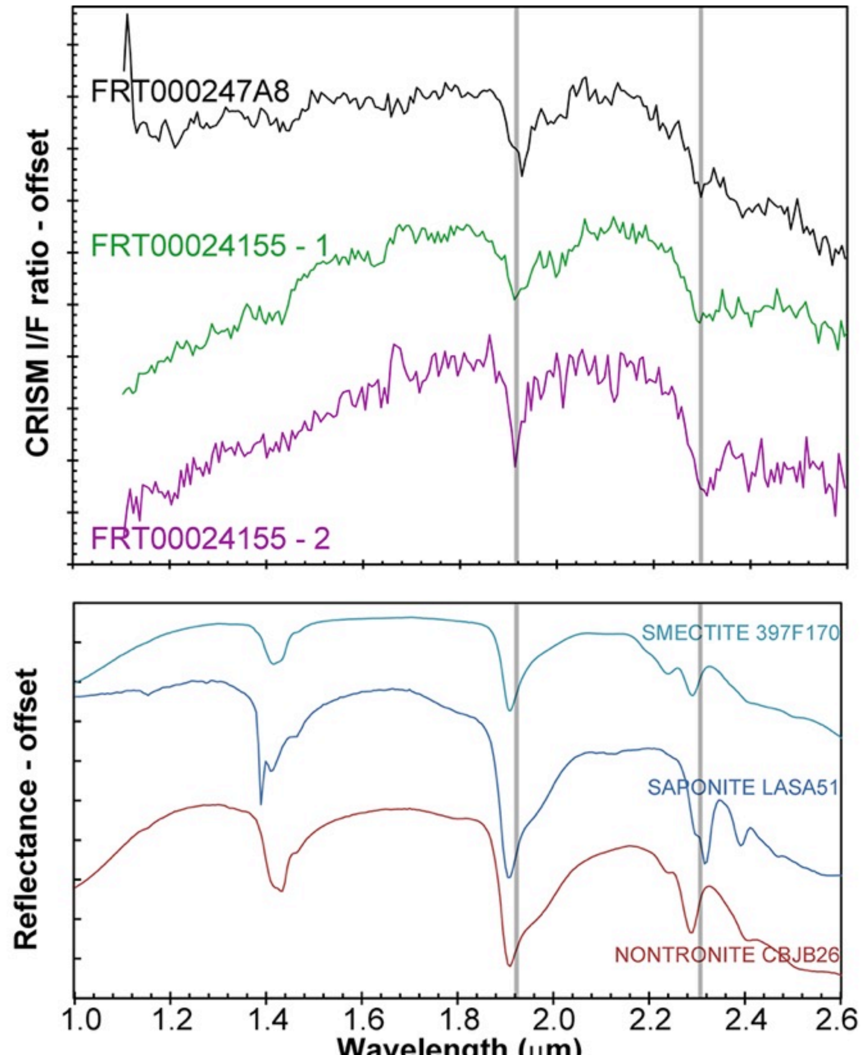
# Hypanis Valles: *Mineralogy - CRISM*

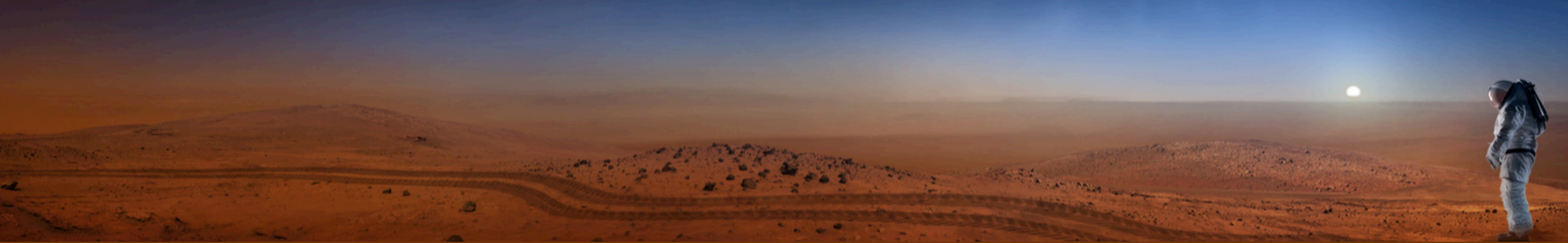


## Detrital Phyllosilicates

- Fe/Mg phyllosilicates (nontronite?) at low stratigraphic level in fan deposits
- Outside the ellipse to SW
- Across multiple (high SNR) CRISM observations



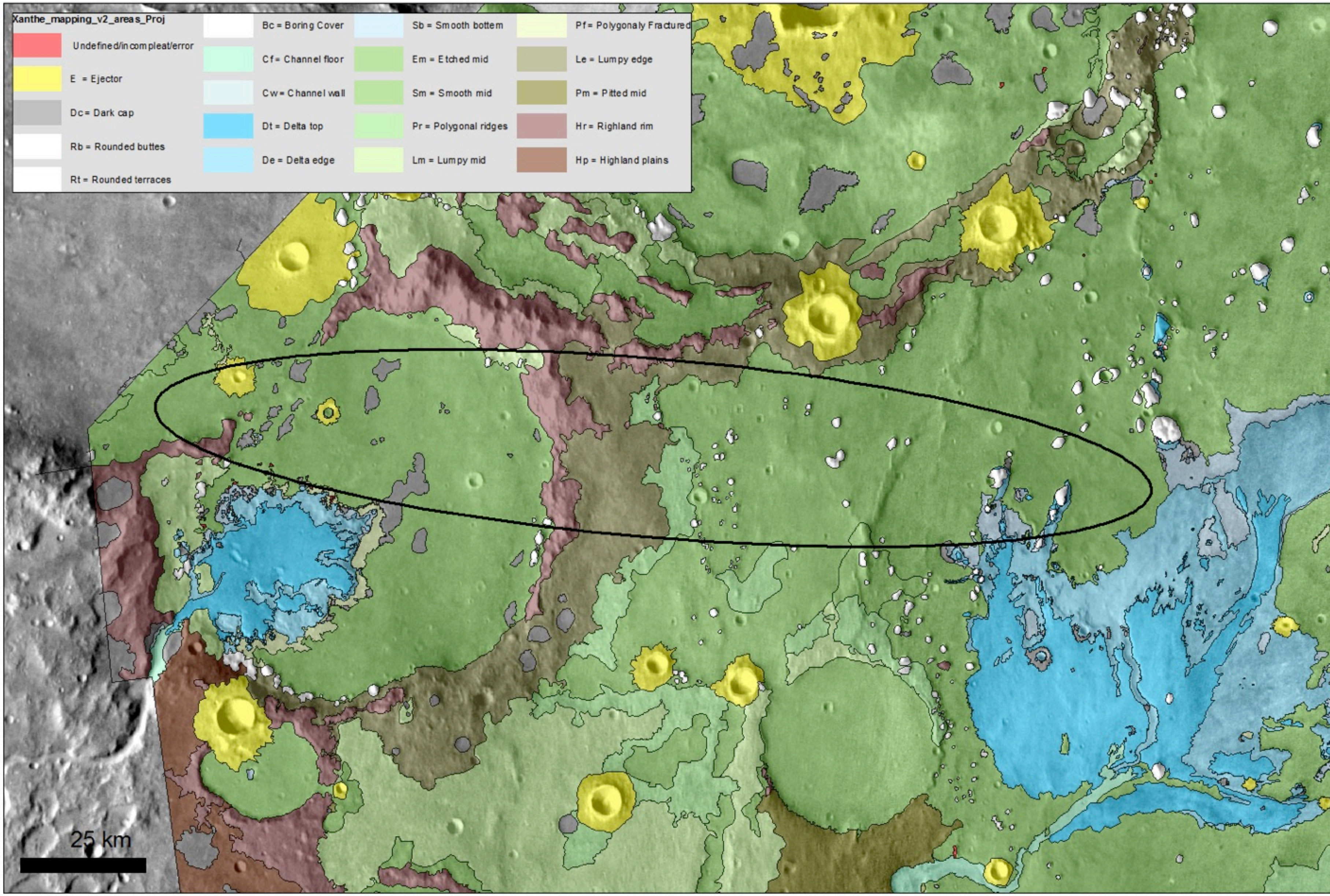





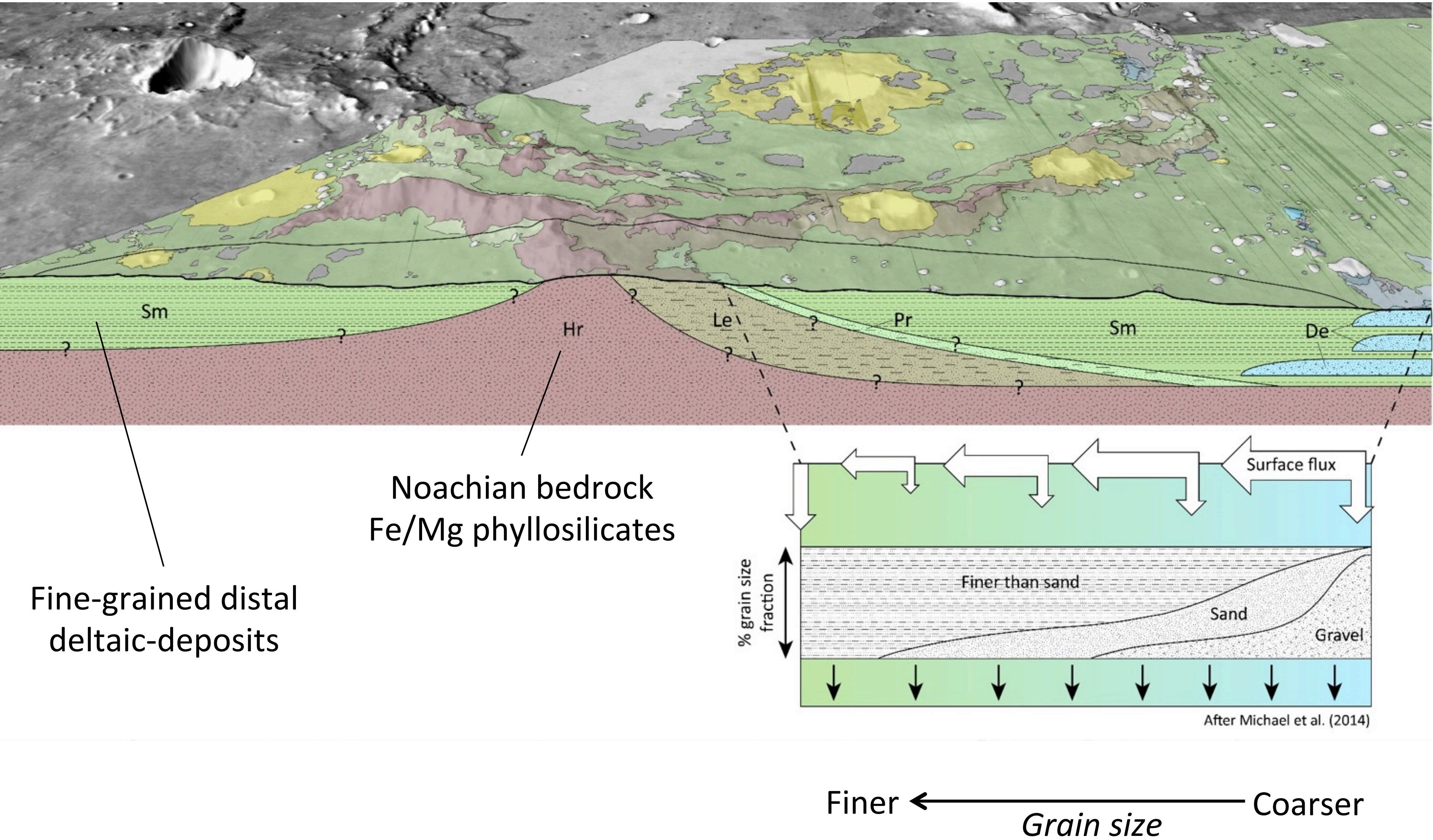


# GEOLOGIC MAP

# Hypanis Valles: *Geological mapping – CTX basemap*



# Hypanis Valles: *Geological mapping – CTX basemap*





# Biosignature Preservation Potential

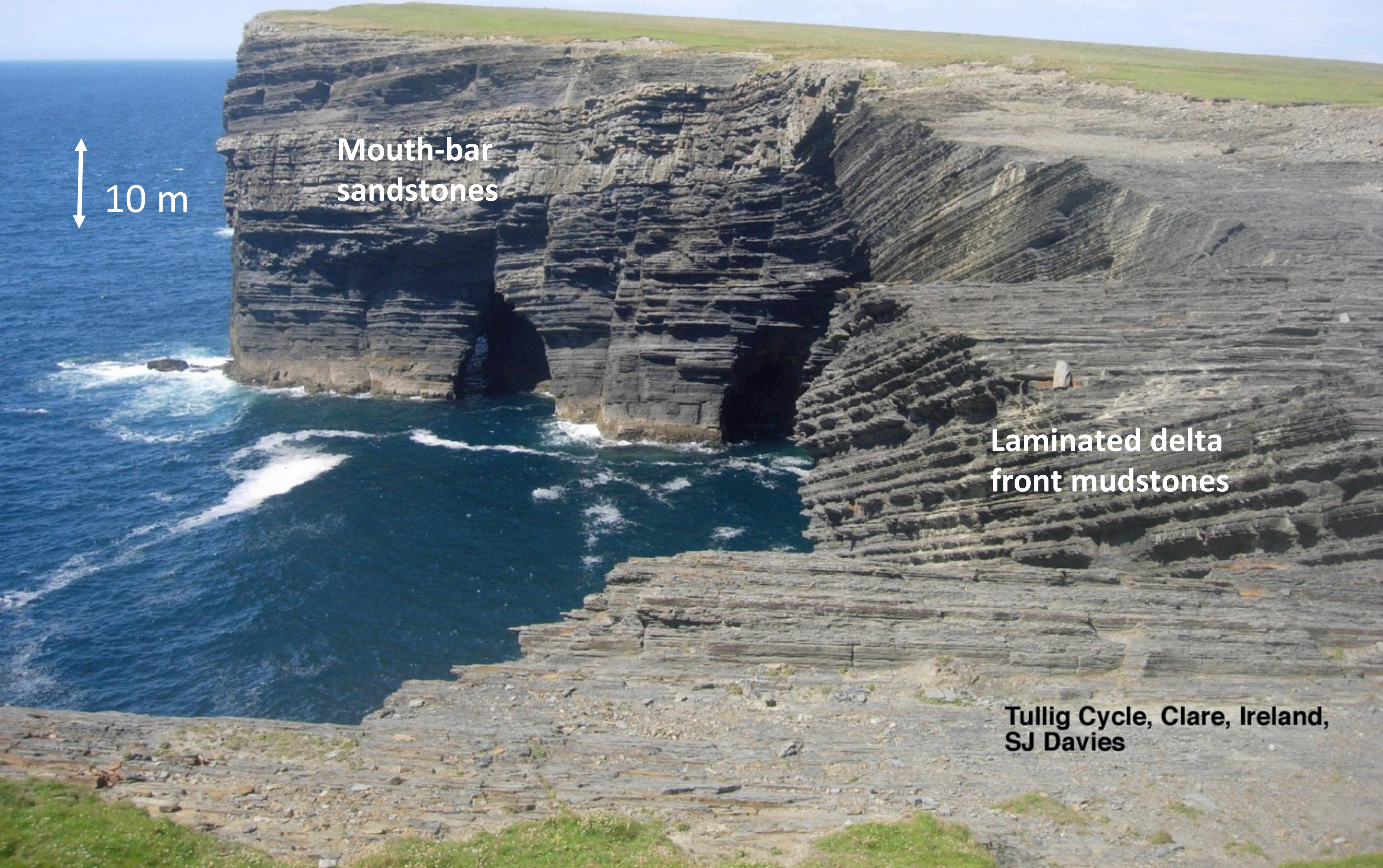
# What makes deltaic-lacustrine systems good for biosignature formation and



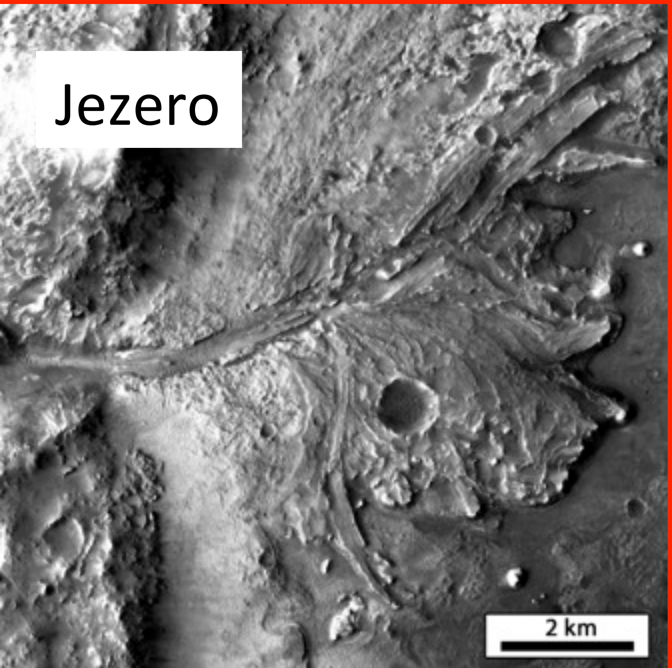
- Rapid deposition due to abrupt change in sediment transport efficiency => rapid burial => enhanced preservation of organics
- Enhanced settling of fines (silts & clays) from suspension – include clay minerals
- Input of mineral ‘resources’ – nutrients
- Low energy environments – reduced destruction by high energy fluid flows

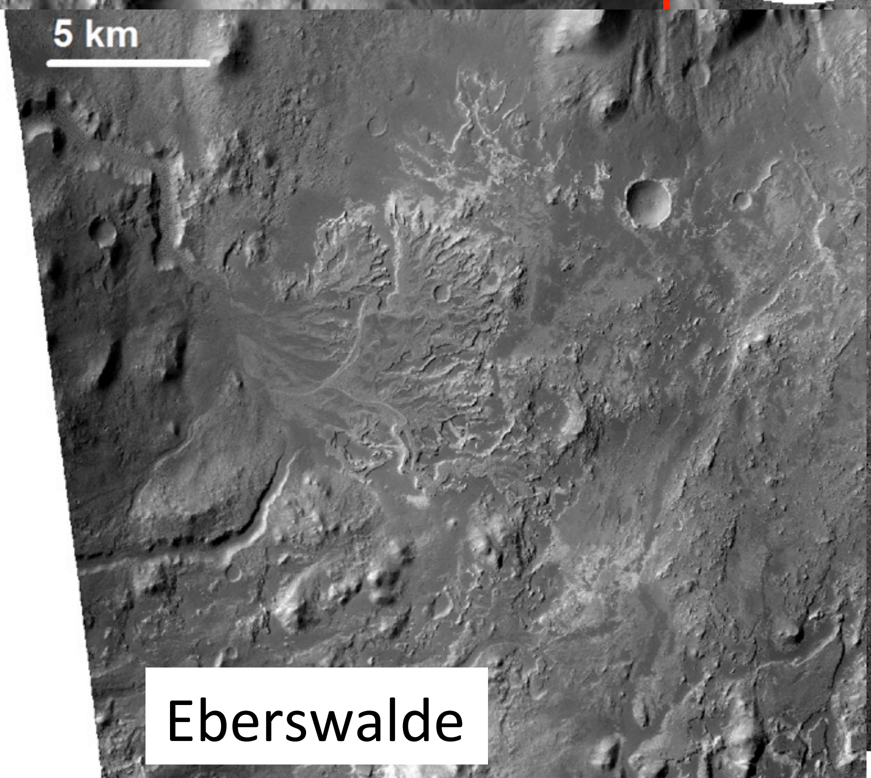
# Delta toe deposits interfingering with basinal mudstones

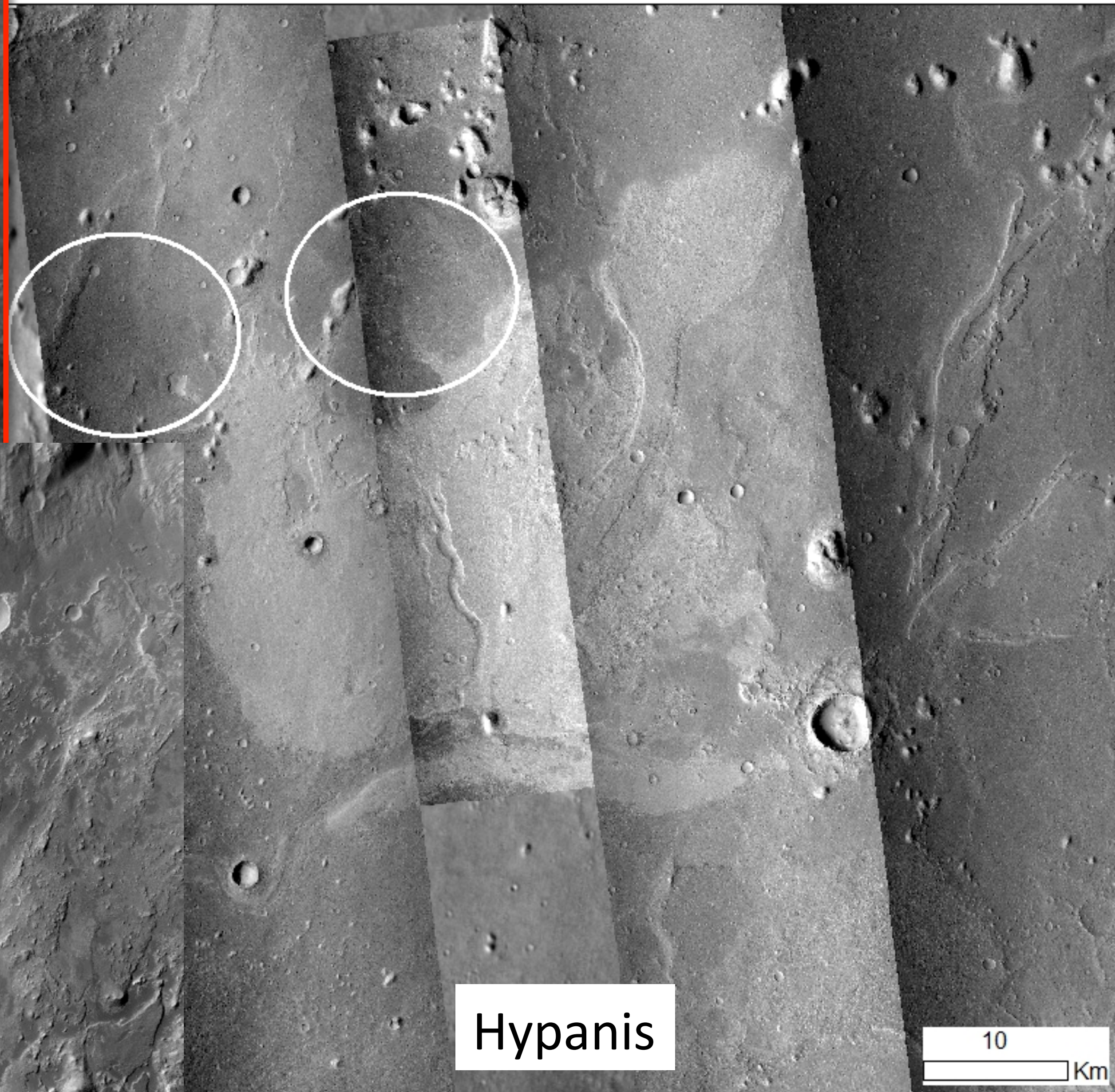
# Preservation of deltaic deposits in the stratigraphic record



# Scales of deltas



## Hypanis Valles: *Regional Context*

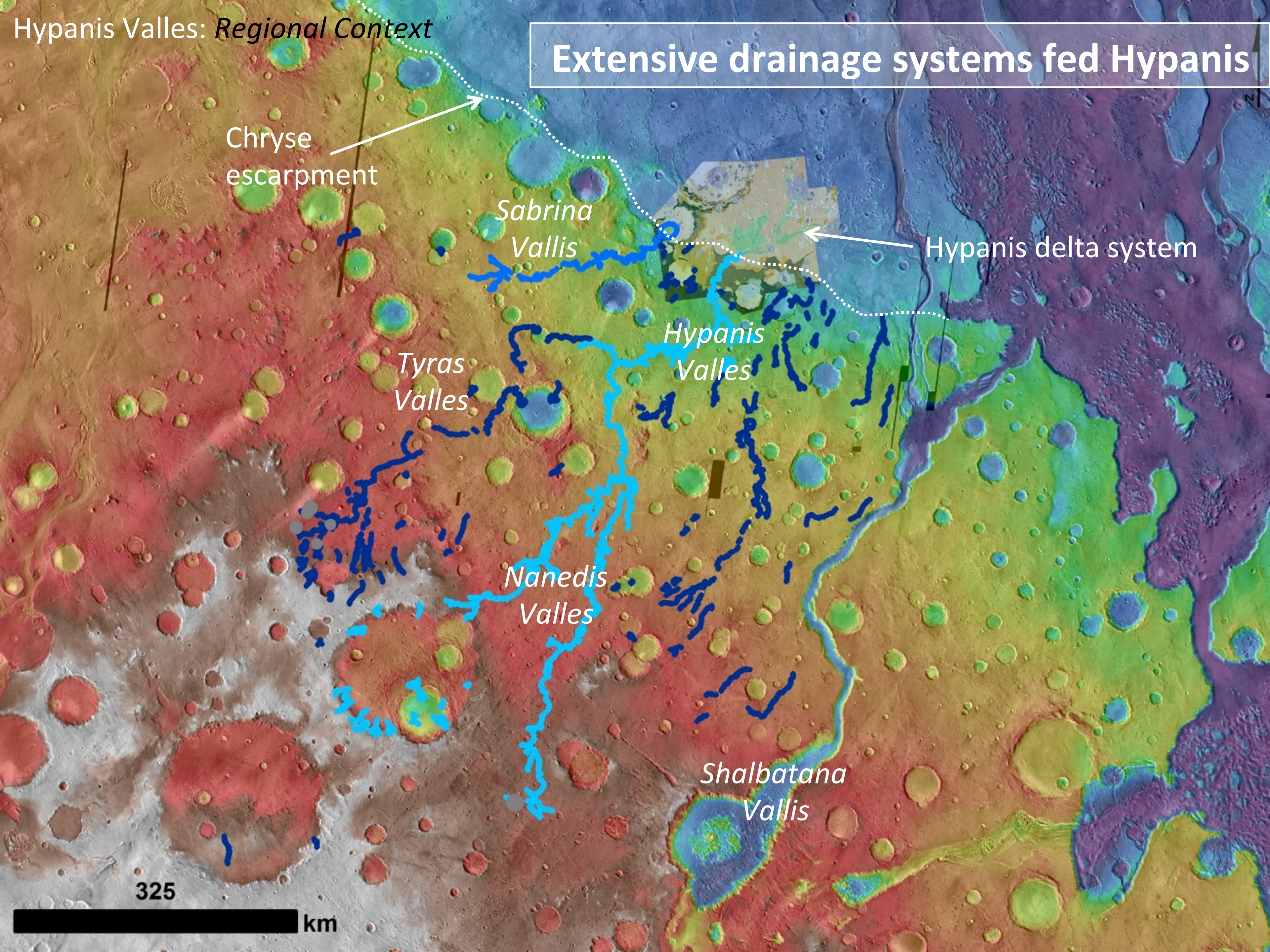
- Hypanis fan system is fed by a very extensive bedrock valley – Hypanis Valles – several hundred kilometres long (?), ~75 m deep
  - Hypanis Valles connected to Nanedi Vallis? NO

- Large volume of rock has been removed by fluvial erosion

- Valley network is very different to drainages sourced from crater rims (c.f. Gale crater fan and other crater-rim fed fans)
  - Hypanis is a much bigger system

- Hypanis and Sabrina deltas are located at margin of Chryse escarpment – abrupt transition from erosional to depositional realm

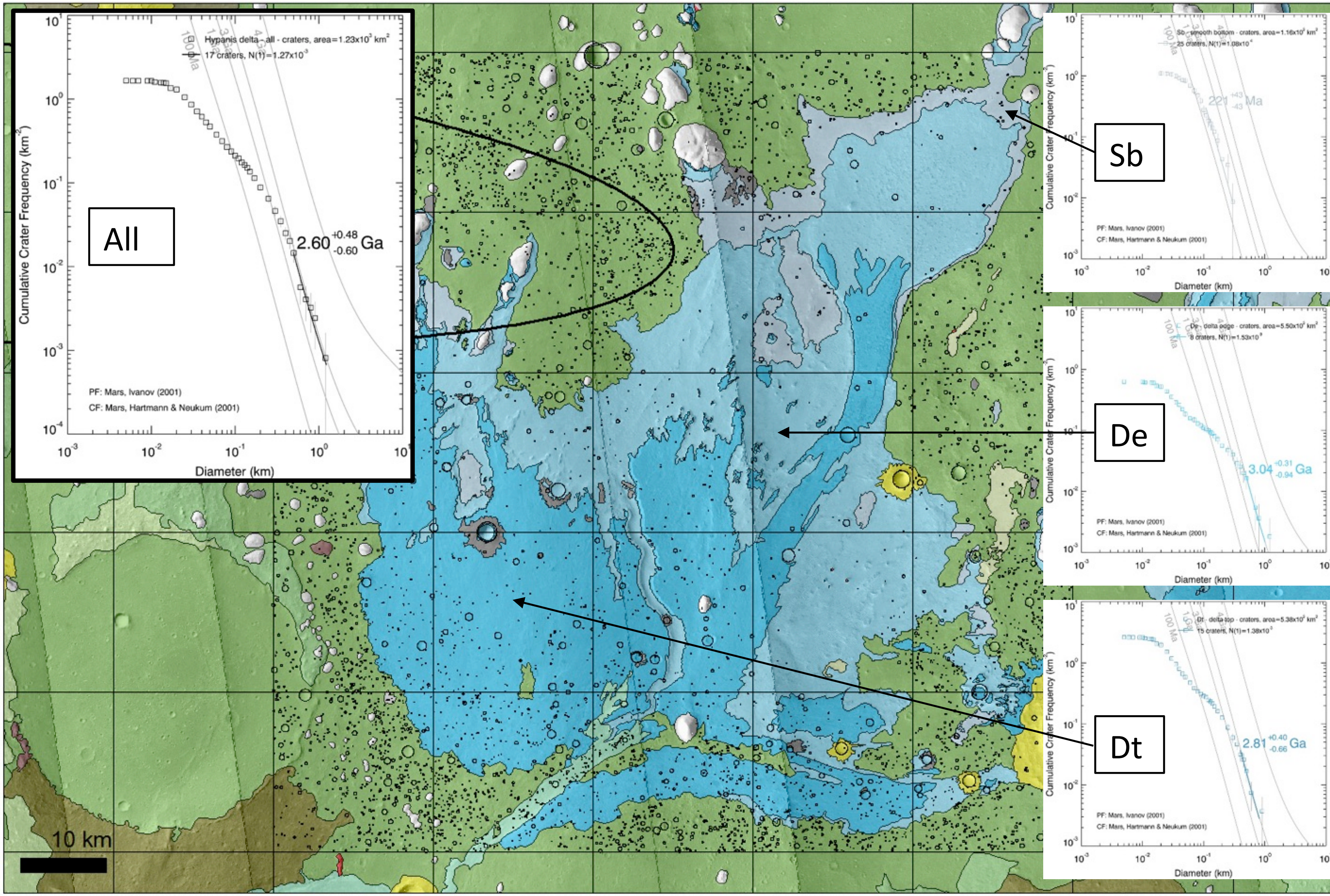
- Timescale of fluvial erosion
  - Difficult to estimate precisely
  - Valley form is different to outflow channels
  - Narrow width, sinuous valley form
  - Suggests long-lived erosion – not instantaneous or short-lived erosion


Hypanis Valles: *Regional Context*
Extensive drainage systems fed Hypanis
Chryse escarpment
Sabrina Vallis
Hypanis delta system
Hypanis Valles
Tyras Valles
Nanedis Valles
Shalbatana Vallis
325
km



# CRATER COUNT AGE DATING

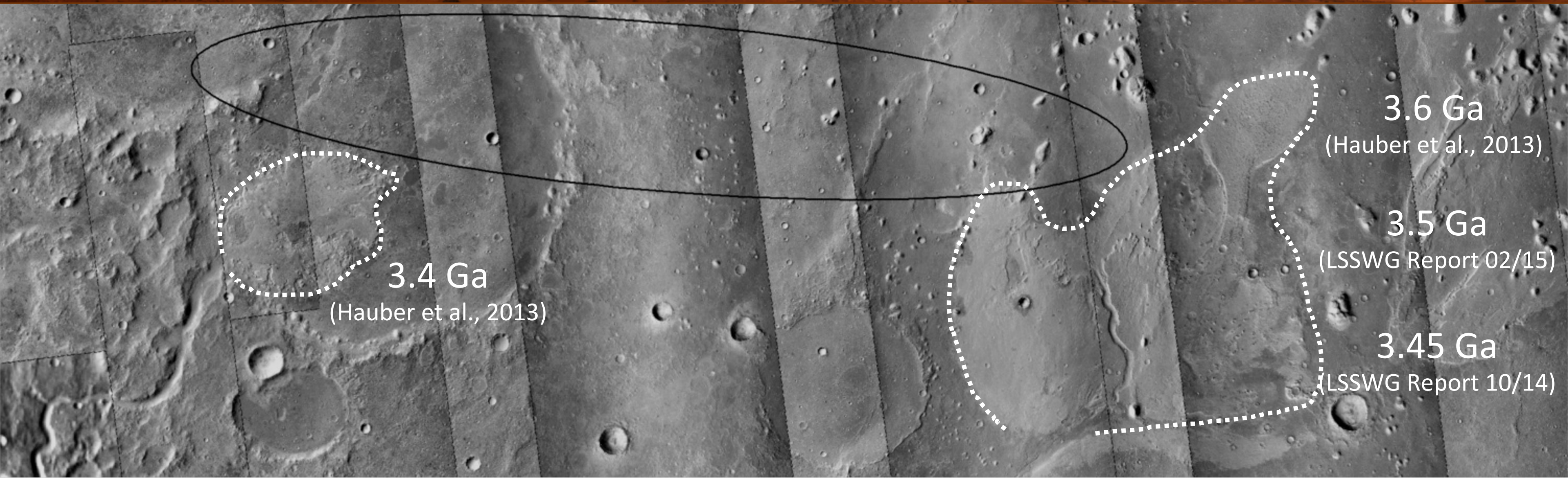
# Hypanis Valles: *Age - local*



## Hypanis Valles: *Age - regional*

**Crater Counts on Deltas? Can we trust them?**

- Crater counting directly on deltas in Xanthe Terra (e.g. Hypanis Delta) has limitations.
    - Are Hypanis targets "*more recent than those at other sites*"? (LSSWG Report, 02/15)



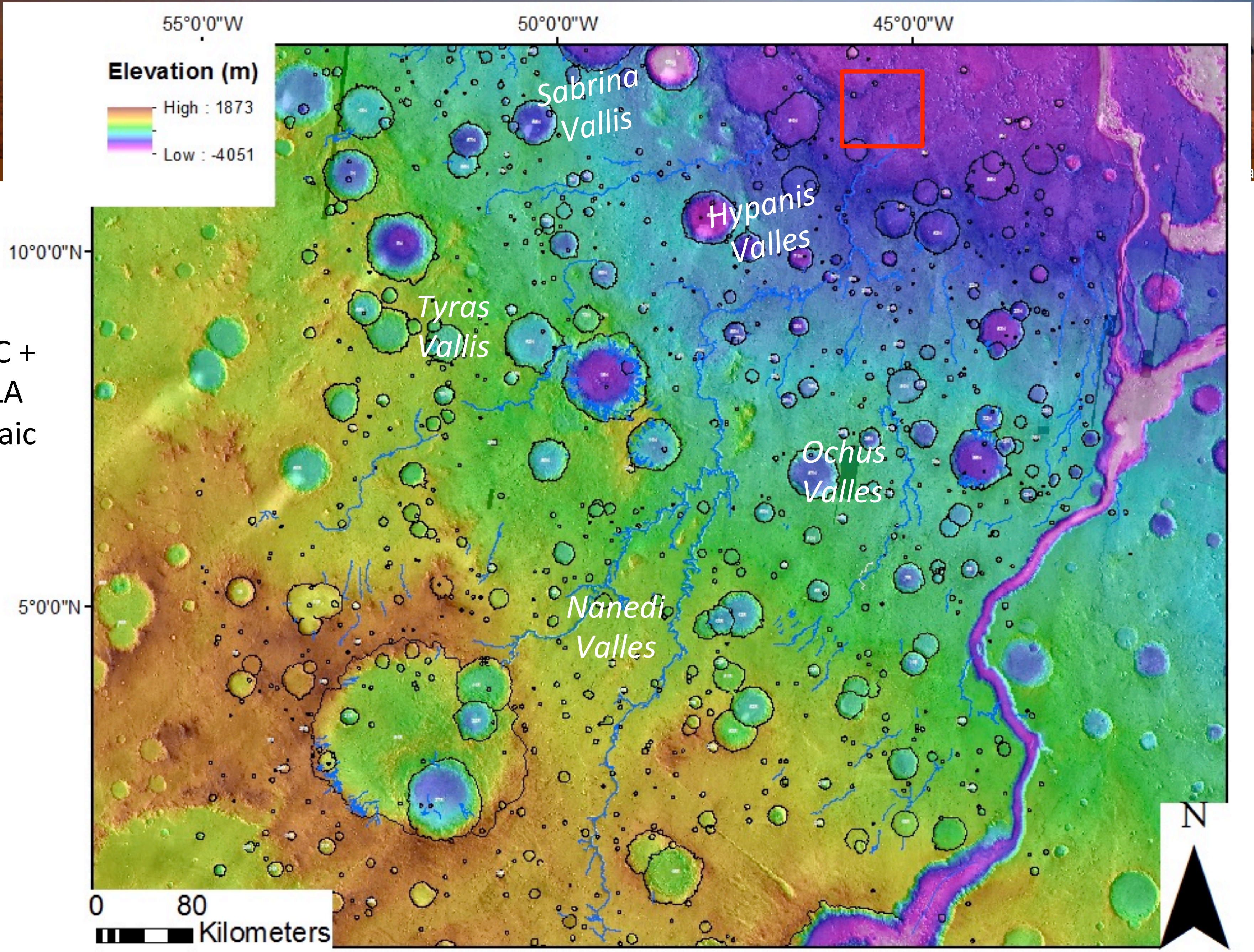

- Area of typical deltas = $10^1 - 10^2$ km$^2$, possibly too small for accurate crater counting given
  (1) crater resurfacing
  (2) the spatial variability of cratering as a random process.

- Deltas in this region show evidence for significant resurfacing (inverted landforms, isolated layered mesas and buttes, degraded craters) and do not preserve craters well.

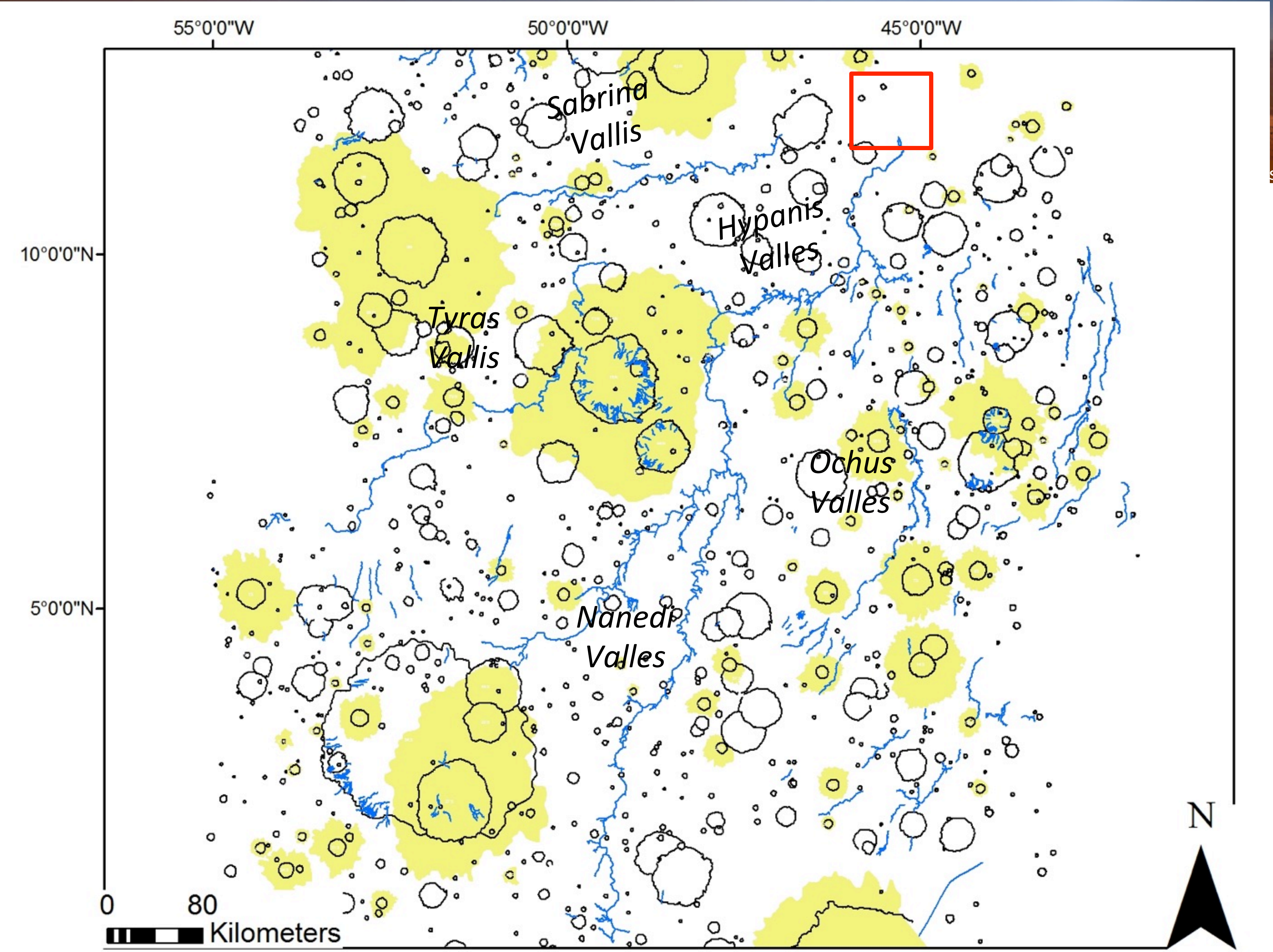
- **Another more regional method of dating has also been applied**.

Hypanis Valles: *Age - regional*

HRSC + MOLA Mosaic



# Hypanis Valles: *Age - regional*



# Hypanis Valles: *Age - regional*

**Objective**: How old is Hypanis Valles and its delta?



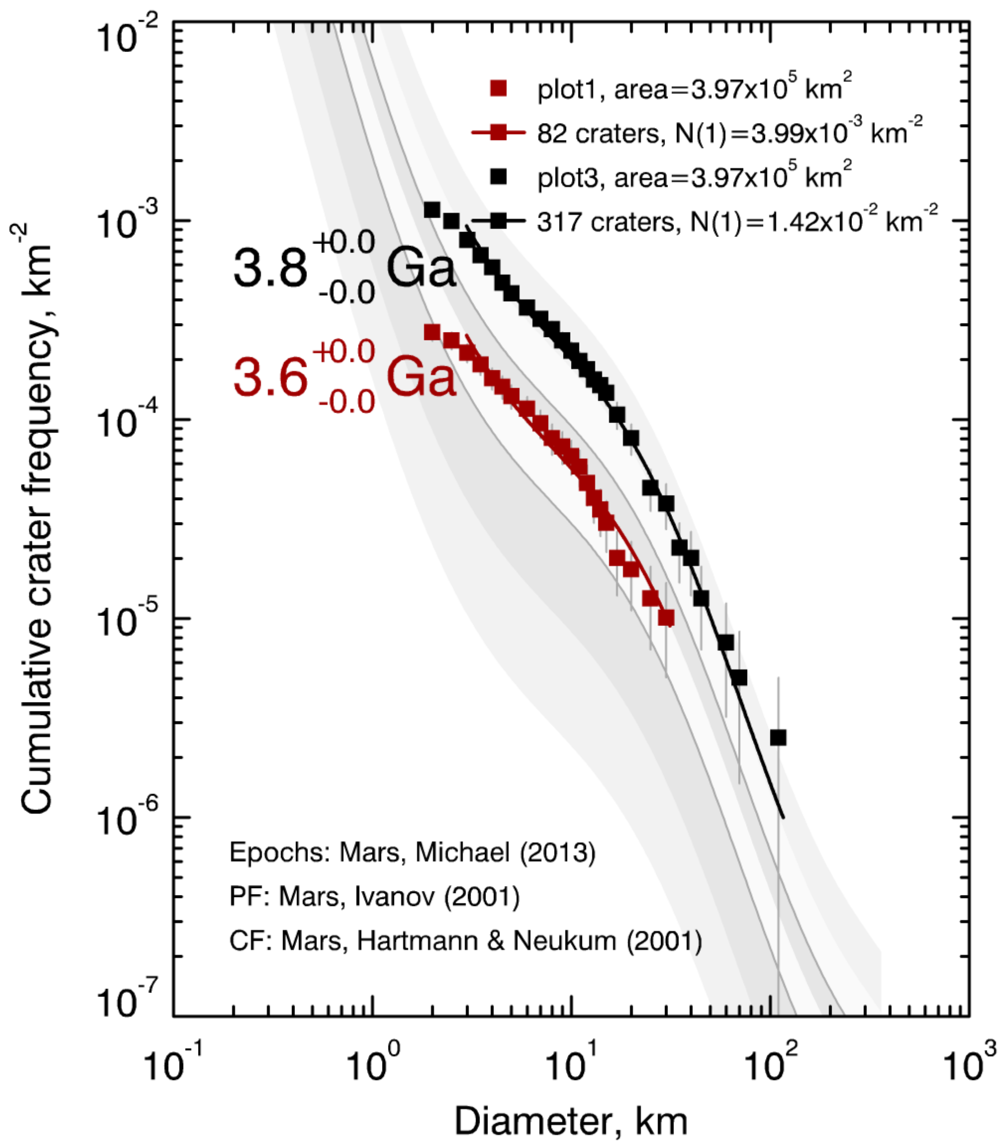
**Method**:

- Constructed a near complete CTX mosaic of Xanthe Terra upstream of Hypanis Delta.
- Mapped major river networks and > 2 km diameter craters at 1:40,000 using CTX.
- Our focus: relative age of impact craters compared to river networks.
- Timing methods
    1. Crater counts on ejecta that pre and post-date valley networks.
    2. Size frequency distribution of > 2 km craters at relative morphologic states (timescales of degradation of Xanthe craters).

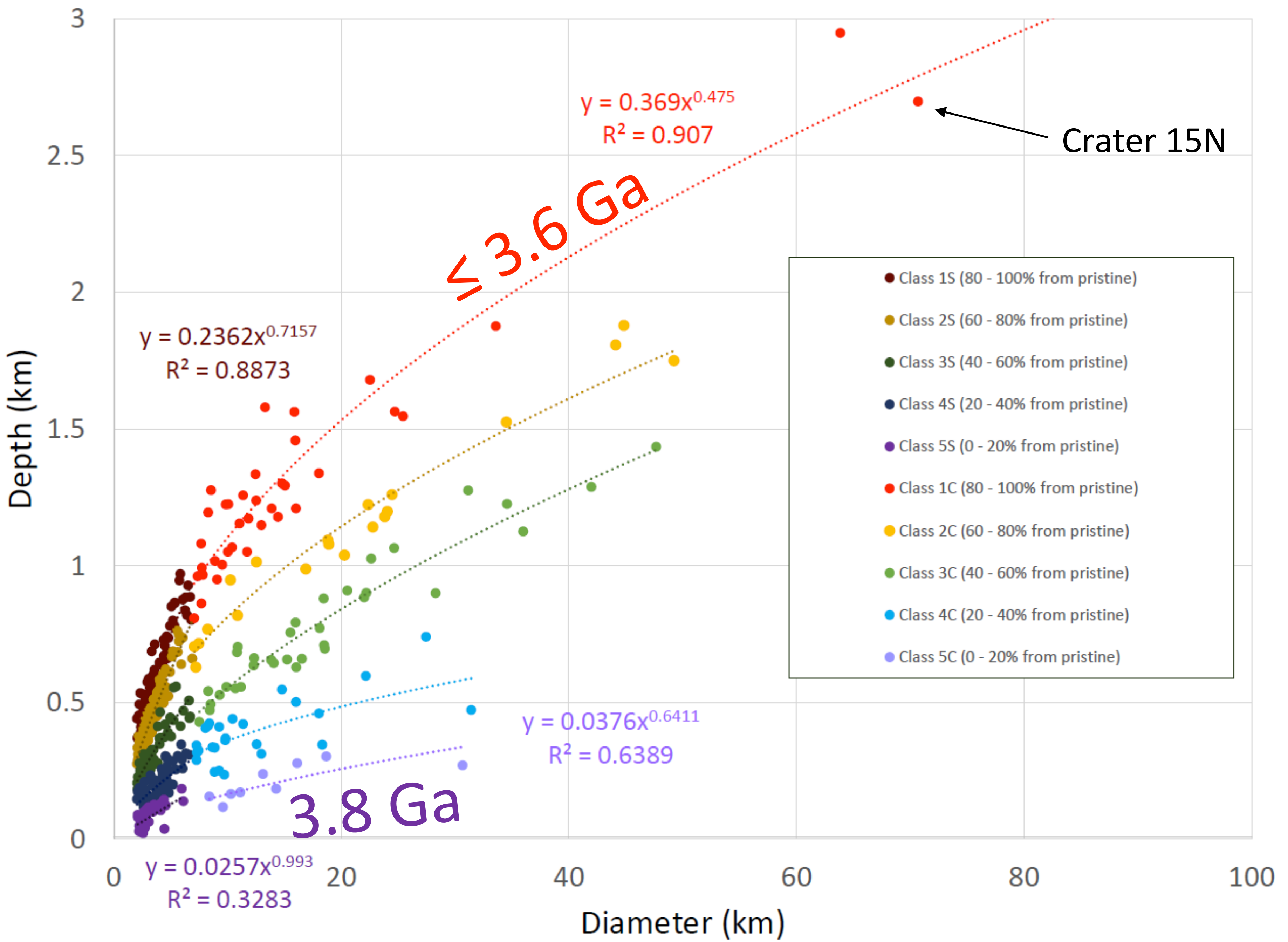
Hypanis Valles: *Age - regional*

**Size Frequency Distributions (SFD)**

- SFD of all 317 craters = age of Xanthe Terra.
  - 3.8 Ga (Late Noachian)
- SFD of only the most pristine craters (<80% from pristine model depth)
  - 3.6 Ga (Early Hesperian)
- Consistent with rapid decrease in surface erosion rates in Hesperian.
- Most degradational work done over short interval from 3.8 – 3.6 Ga.



# Hypanis Valles: *Age - regional*



# Hypanis Valles: *Age - regional*



**Hypanis Valles Relative Age**

1. **Older than Nanedi Valles**
    - Suggests multiple fluvial events in this region.
    - Consistent with fluvial channel superposition relationships elsewhere in Xanthe Terra.
    - Nanedi Valles likely does not connect to Hypanis delta.

2. **Hypanis Valles older than crater 15N**
    - Ejecta crater count = 3.7 Ga
    - Crater degradation data: 15N is 80% from pristine d/D (≤ 3.6 Ga)
    - Hypanis Valles is likely Early Hesperian or older.

3. **Nanedi Valles is younger than 15 N**
    - Nanedi Valles is ≤ 3.6 Ga
    - Suggests multiple fluvial events spanning relatively long period of time (separated by large impact events).