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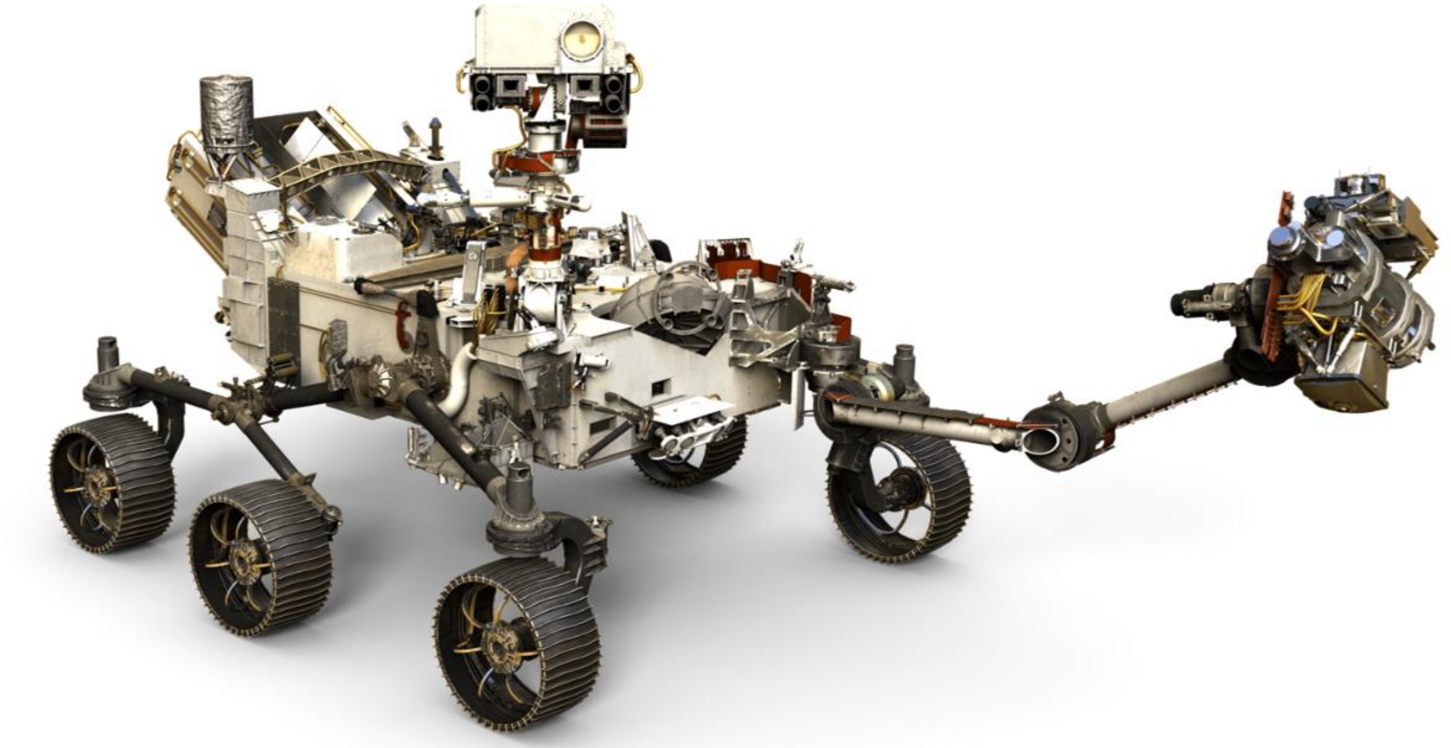
Mars 2020 Mission:

Geology of Jezero crater and Outside Jezero and Sampling on a notional Mission Traverse



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on behalf of Mars 2020 team

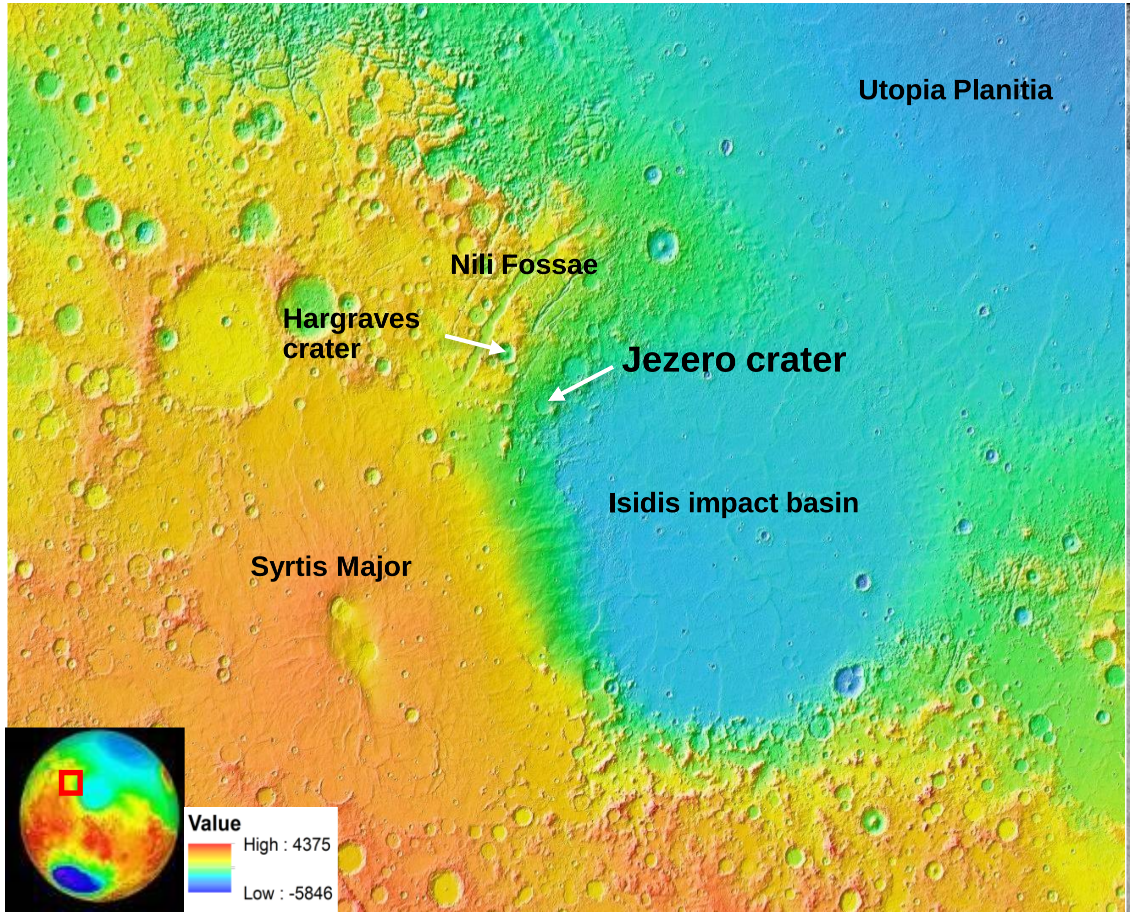
January 21, 2021

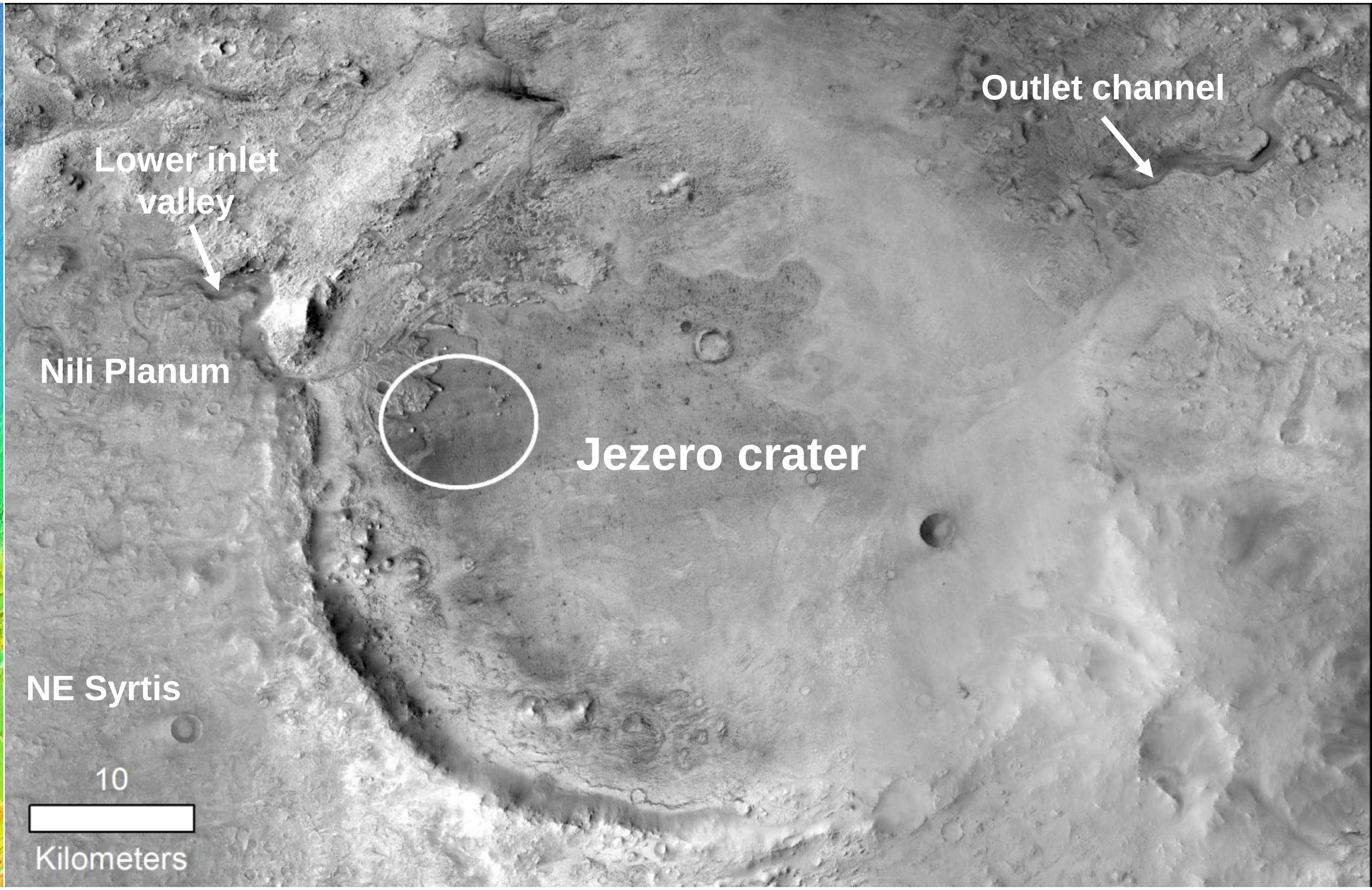
MARS 2020 PERSEVERANCE

Mars 2020 Mission Objectives

1. the mission should develop a scientific understanding of the geology of its landing site;
2. based on that geologic understanding, the mission should identify ancient habitable environments, locate rocks with a high probability of preserving biosignatures, and in those rocks, the rover’s instruments should be used to look for potential biosignatures;
3. the mission should collect and document a suite of scientifically compelling samples for possible Earth return by a future mission;
4. the mission should enable future Mars exploration especially by humans, by making progress in filling strategic knowledge gaps and by demonstrating new technologies.

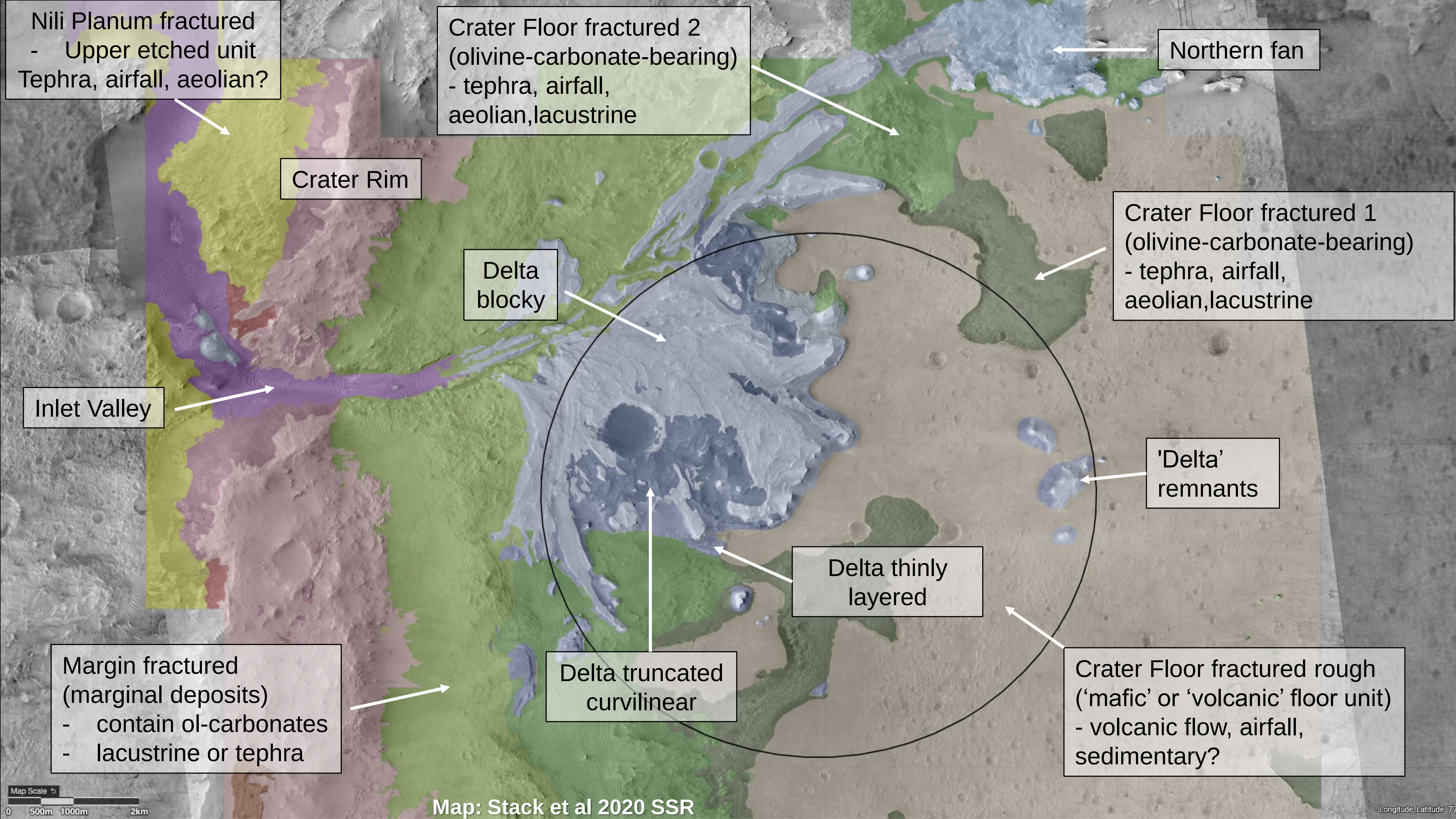
Jezero Crater Context





Mars 2020's Mission in Jezero crater

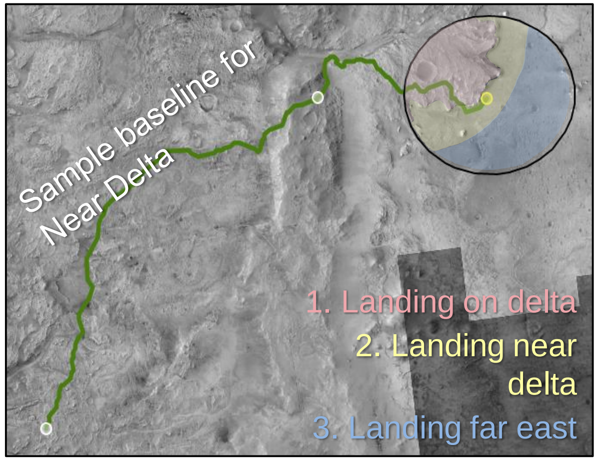
Exploring the hydrological and chemical evolution of an ancient crater lake basin and associated fluvio-deltaic environment from early Mars to probe ancient Martian climates and search for life


Nili Planum fractured
- Upper etched unit
Tephra, airfall, aeolian?
Crater Floor fractured 2
(olivine-carbonate-bearing)
- tephra, airfall,
aeolian,lacustrine
Northern fan
Crater Rim
Crater Floor fractured 1
(olivine-carbonate-bearing)
- tephra, airfall,
aeolian,lacustrine
Delta
blocky
Inlet Valley
'Delta'
remnants
Delta thinly
layered
Margin fractured
(marginal deposits)
- contain ol-carbonates
- lacustrine or tephra
Delta truncated
curvilinear
Crater Floor fractured rough
('mafic' or 'volcanic' floor unit)
- volcanic flow, airfall,
sedimentary?
Map Scale
0 500m 1000m 2km
Map: Stack et al 2020 SSR
Longitude, Latitude

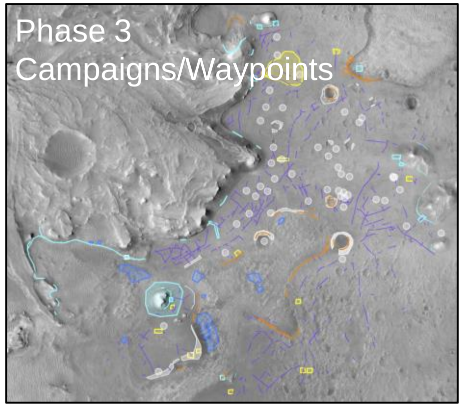
Mars 2020 Strategic Process: Developing notional traverse and sample cache

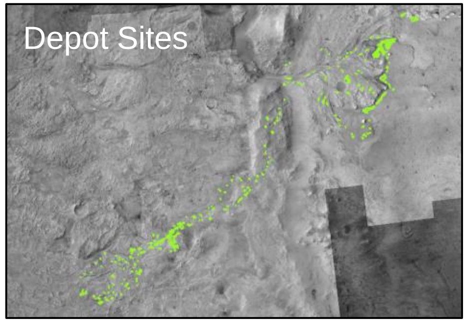
Task: to develop prime mission scenarios that lead to the creation of a depot that provides a return-worthy cache of Jezero samples and sets us up to begin exploration of the crater rim and NE Syrtis terrain in extended mission.

Begin with the “most efficient” baseline traverses

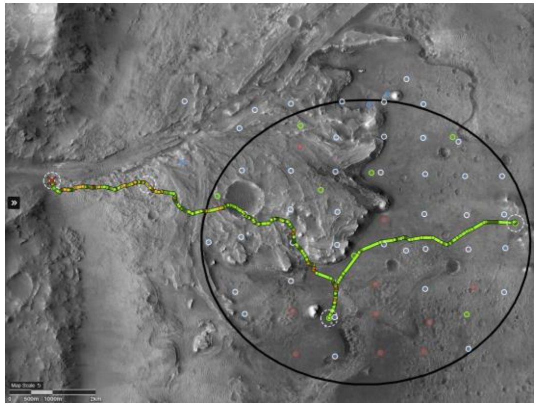


Consider location and priority of potential campaigns/waypoints; identify depot sites





Modify and iterate on mission duration and notional traverse using MTn and science sol guidelines



Outputs:

1. Mission duration
2. Campaign locations/waypoints
3. Strategic Drive Route
4. Sample cache
5. Liens list of locations

Prime and Extended Mission scenarios

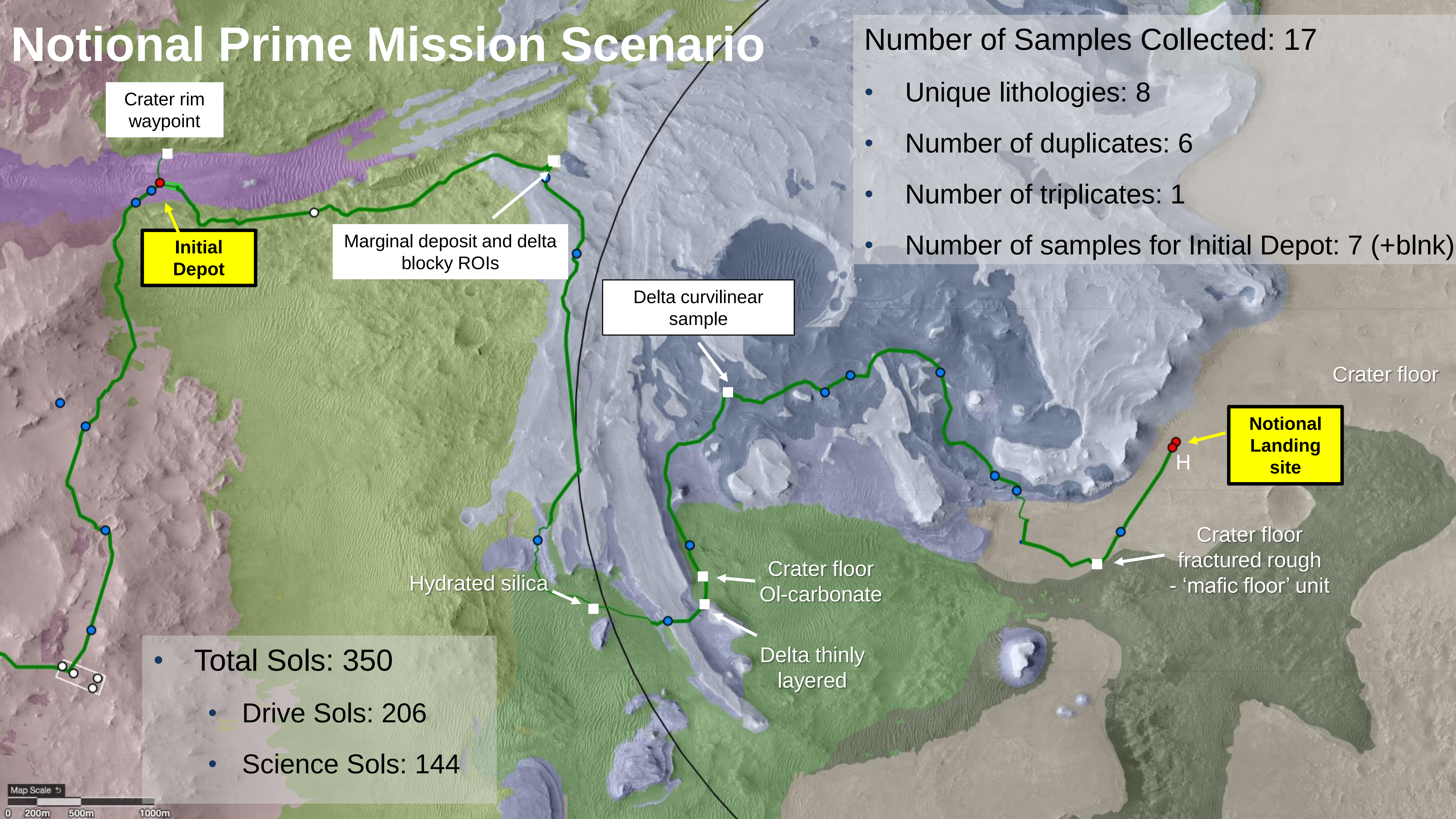
- The entire **prime mission** scenario must fit **within 1 Mars year (2 Earth years)**
- Notional sample cache of **~18 samples plus 2 blanks** that include the Jezero floor, delta, margin, and **"tagging" the crater rim**.
- A 1st sample depot location inside Jezero

- **Extended mission**: Rover must have reached the location of the Final Sample Cache **within 2 Mars years after the Prime Mission**
- Notional sample cache of **18 samples + 2 blanks**

Notional Prime Mission Scenario

Number of Samples Collected: 17

- Unique lithologies: 8
- Number of duplicates: 6
- Number of triplicates: 1
- Number of samples for Initial Depot: 7 (+blnk)



- Total Sols: 350
    - Drive Sols: 206
    - Science Sols: 144

Waypoint 2 ‘Mafic floor’ unit

- Proximity Science and Sampling
- 16 Sols
- Primary Science Goals
  - CF1: Determine the nature of CF units
  - CF5: Calibration of martian chronology
- In Situ Analyses
  - WATSON: Detailed physical structure
  - SCAM LIBS, RMI, Raman: Chemical structure
  - SHERLOC, PIXL: Detailed chemical structure

- Decode igneous processes and variability in igneous rocks in Jezero (if igneous)
- Determine absolute age of unit (igneous lithology/detrital grains
- Potential for igneous petrology, geochronology and palaeomagnetic study upon sample return.
- In combination with crater counting, calibrate planetary chronology

Crater Floor

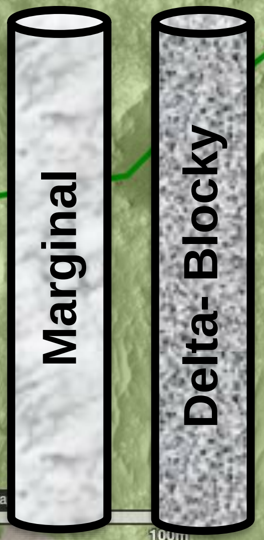
Sample 1 (triple) [3]

Dark-toned, fractured crater floor is of high priority for potential calibration of crater counting.

If contextual remote sampling does not indicate igneous, the triple sample could be reduced.

Marginal and Delta Blocky Units Campaign

- Proximity Science and Sampling
- 28 Sols
- Primary Science Goals
  - Sample strongest olivine-carbonate signature
  - Sample rock with macroscopic evidence for biosignature (stromatolite)
  - Aqueous history of Jezero
  - Compositional diversity from detrital grains



Marginal unit

- Lake chemistry
- Detrital or authigenic carbonates
- Martian carbon cycle
- Search for morphological biosignatures/organics

Delta Blocky unit

- What do detrital grains tell us about the diverse composition of bedrock units in Jezero watershed?
- What can we learn of weathering processes and climate in catchment?
- What does compositional diversity tell us about Mars planetary evolution?

Potential Science Questions Addressed in Prime Mission

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- What was the history of aqueous environments during the late Noachian-Hesperian?
- What does this tell us about the evolution of Martian climate?
- What diverse habitable niches were present in Jezero crater?
- What is the potential for biosignatures? Did life ever exist on Mars?
- Can we obtain absolute age dates on the crater-retaining unit to calibrate planetary chronology?
- What information about planetary evolution is recorded in primary igneous rocks and diverse mineral grains from the Jezero watershed?
- What is the origin and alteration history of the regional Noachian crust?

Potential Prime Mission Sample Cache – Land Near Delta

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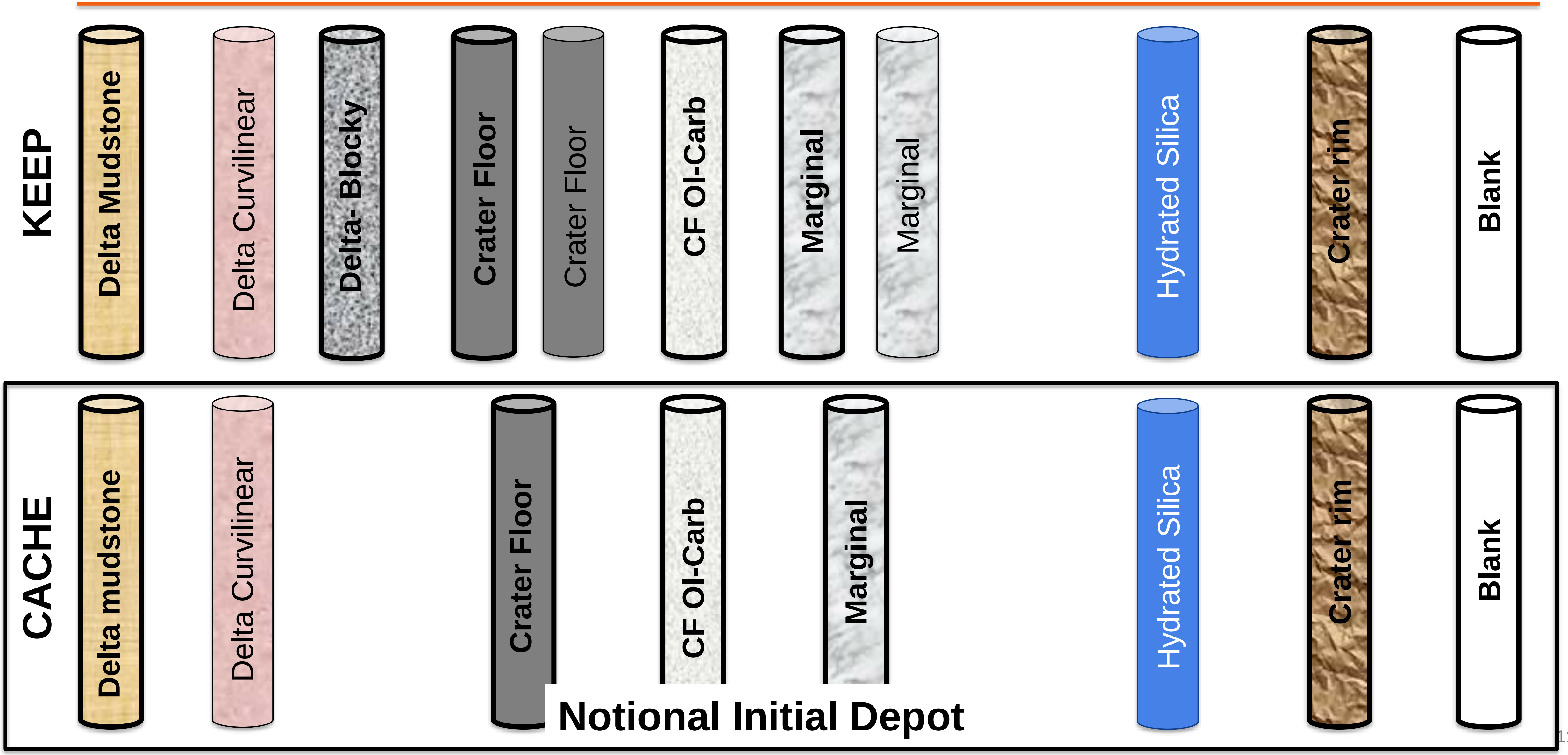

Science Value and Potential of Prime Mission Sample Cache

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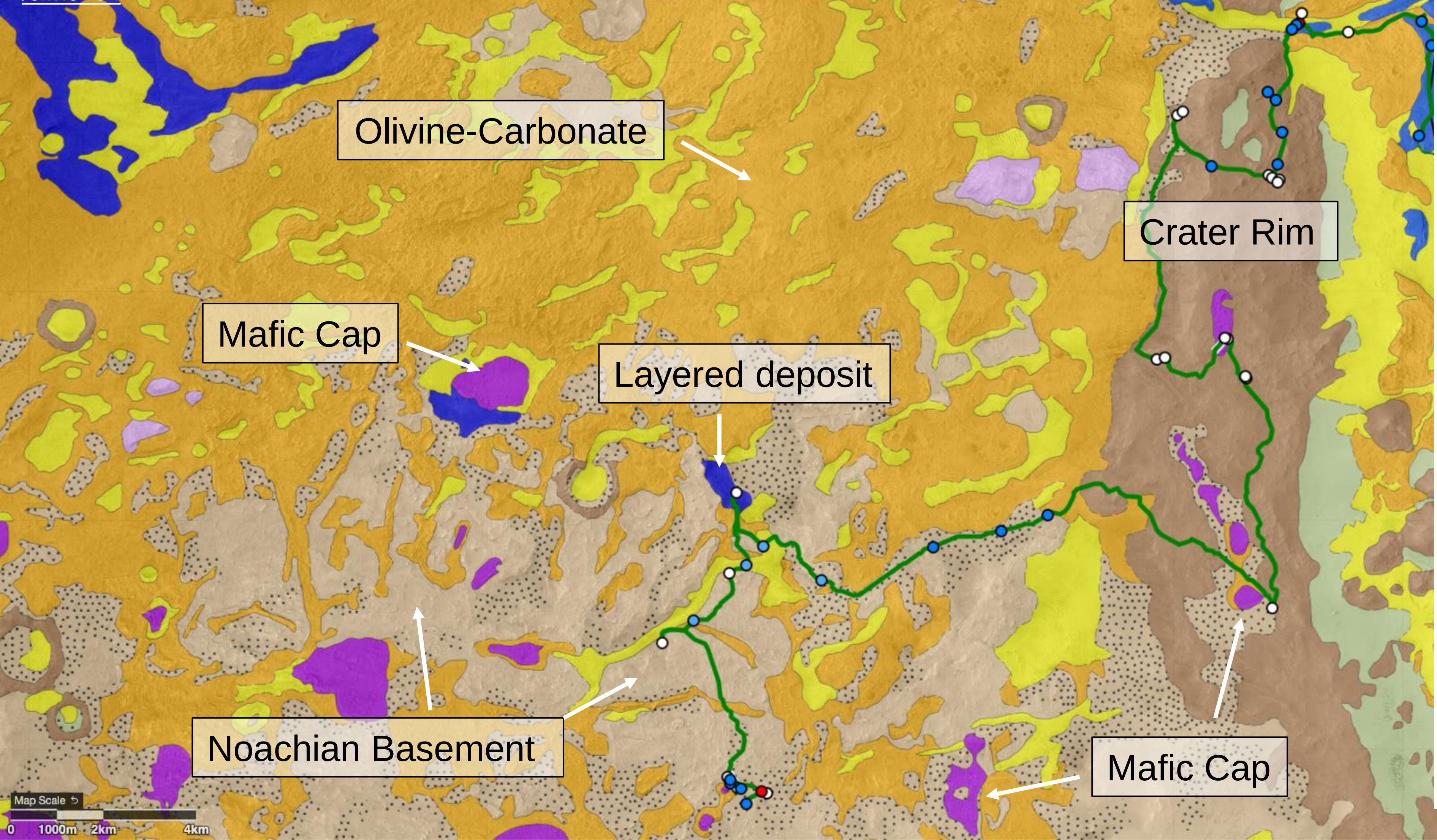
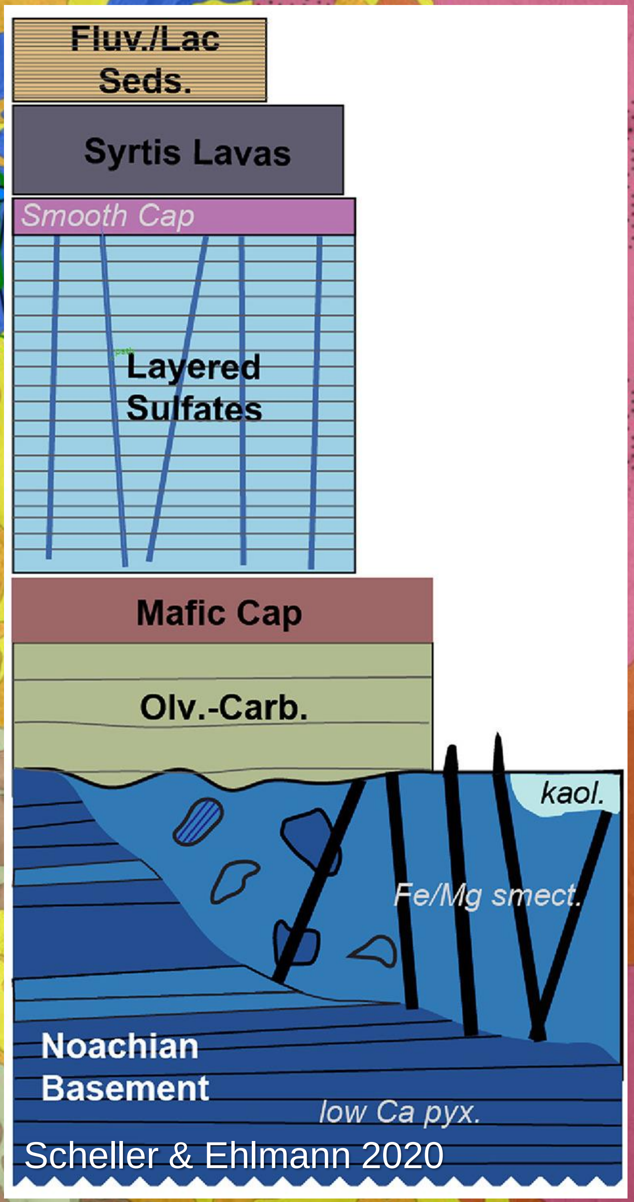
- Biosignature preservation potential and presence in habitable niches (olivine carbonates, fine-grained deltaic/lacustrine sediments, phyllosilicate-rich deposits, carbonates in Marginal deposits, hydrated silica deposits). Opportunities for *in situ* studies of morphological and chemical biosignatures.
- Analytical and sampling opportunities to understand the diversity of aqueous & paleo-atmospheric processes in early Mars history (clastic deposition, carbonate formation, alteration, weathering & erosion). Window into early Mars hydrology and climate.
- **Collection of suites of samples from time-ordered stratigraphic succession**
- Geochronology: constraining the timing of sedimentary deposition in Jezero using the crater floor deposits. If igneous, crater-retaining floor unit provides potential for calibrating martian chronology.
- Igneous processes and petrology, and potentially palaeomagnetism to understand regional and planetary-scale igneous and geodynamic processes following formation of Jezero crater from primary igneous material or detrital grains. Rim provides pre-Jezero basement?

Geology of the Jezero crater rim and Outside Jezero region

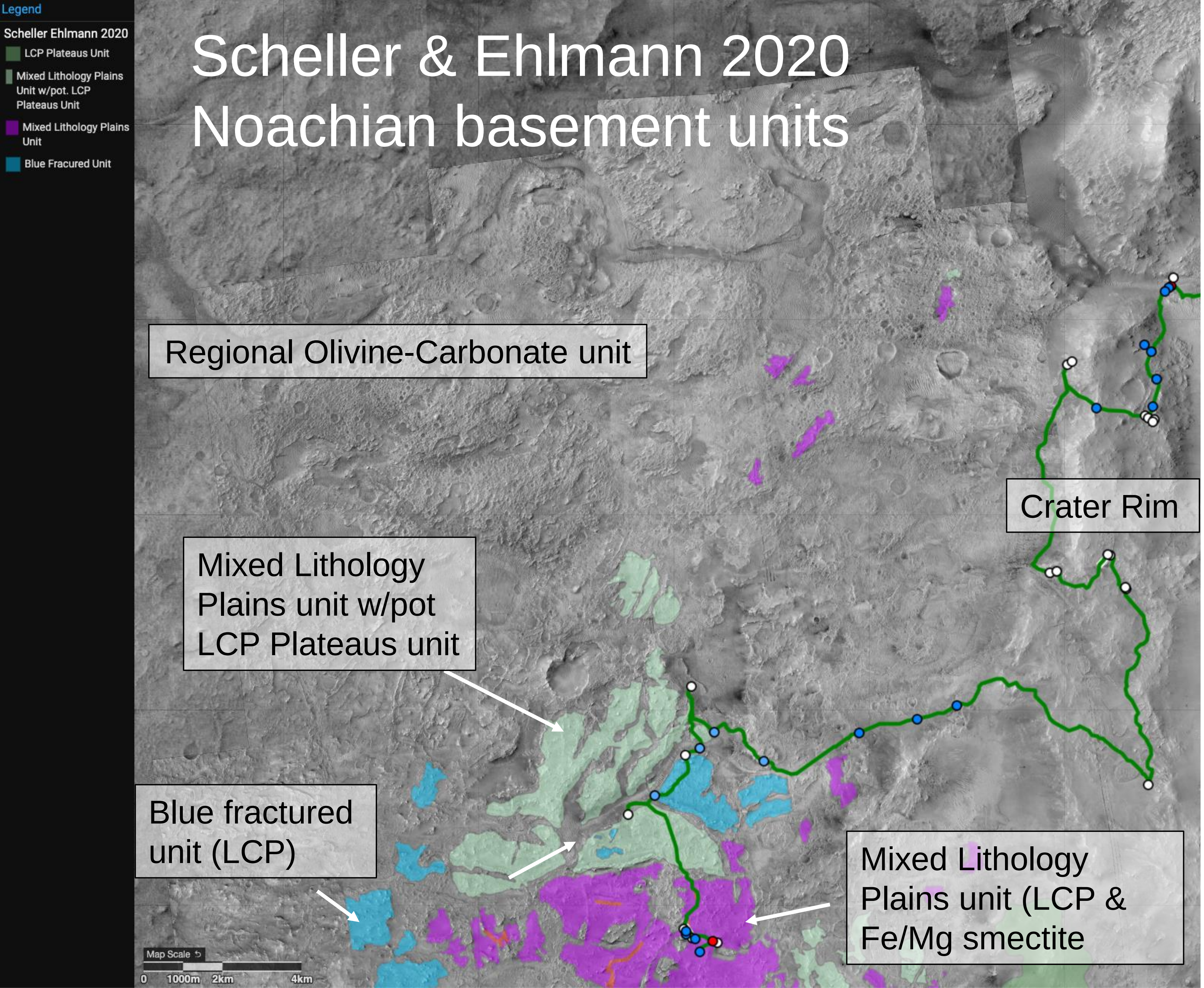
Overview of Crater rim and Outside Jezero Geology

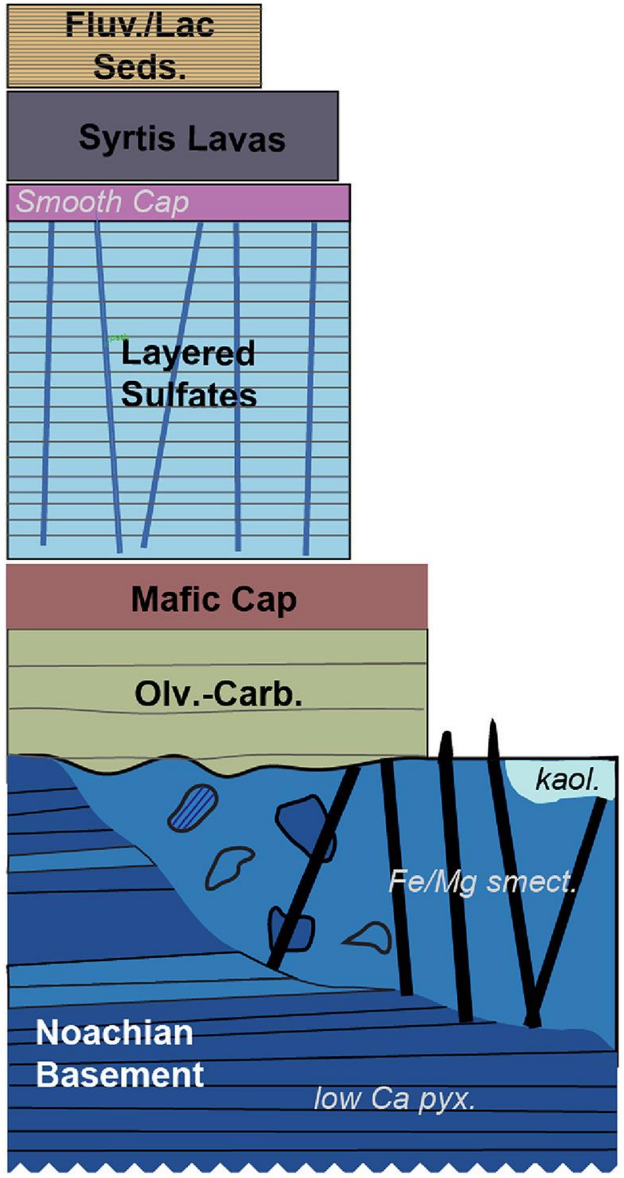
Map: Sun & Stack 2020
USGS SIM 3464
https://pubs.er.usgs.gov/publication/sim3464





Scheller & Ehlmann 2020 Noachian basement units





Scheller & Ehlmann 2020 JGR Planets

Potential Science Questions Addressed in Extended Mission

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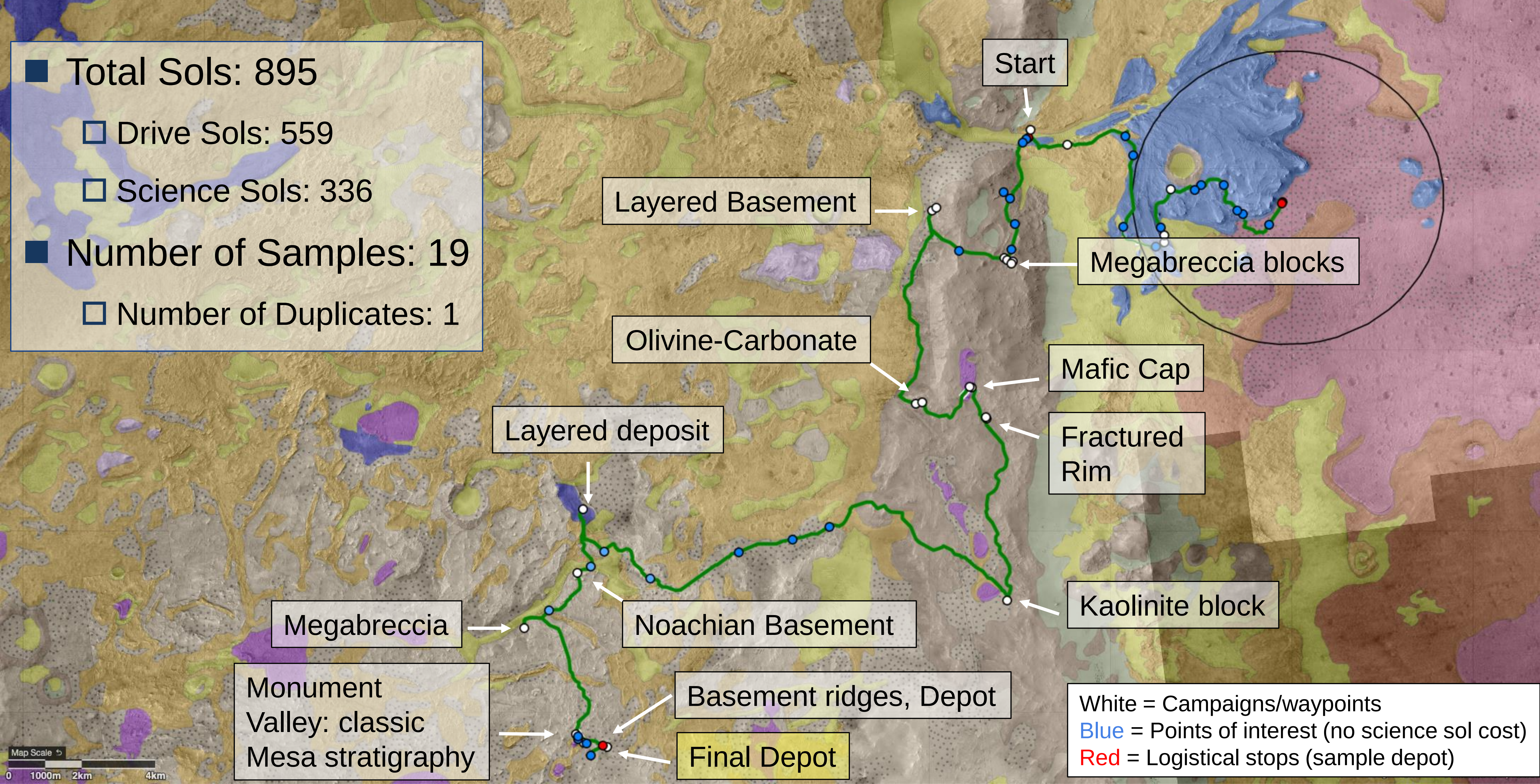
- Planetary geochemical and geophysical evolution and implications for habitability
  - Impact processes
  - Diversity of crustal formation and alteration processes
- Potential habitability and biosignatures in the subsurface
- Geochronology
  - Timing of Jezero impact
  - Timing of Isidis impact
- Diversity of aqueous and sedimentary processes in earliest Mars history

Overview of Potential Extended Mission Scenario

- Total Sols: 895
  - Drive Sols: 559
  - Science Sols: 336
- Number of Samples: 19
  - Number of Duplicates: 1



Campaign 1 – Crater Rim Megablock - Sampling Strategy

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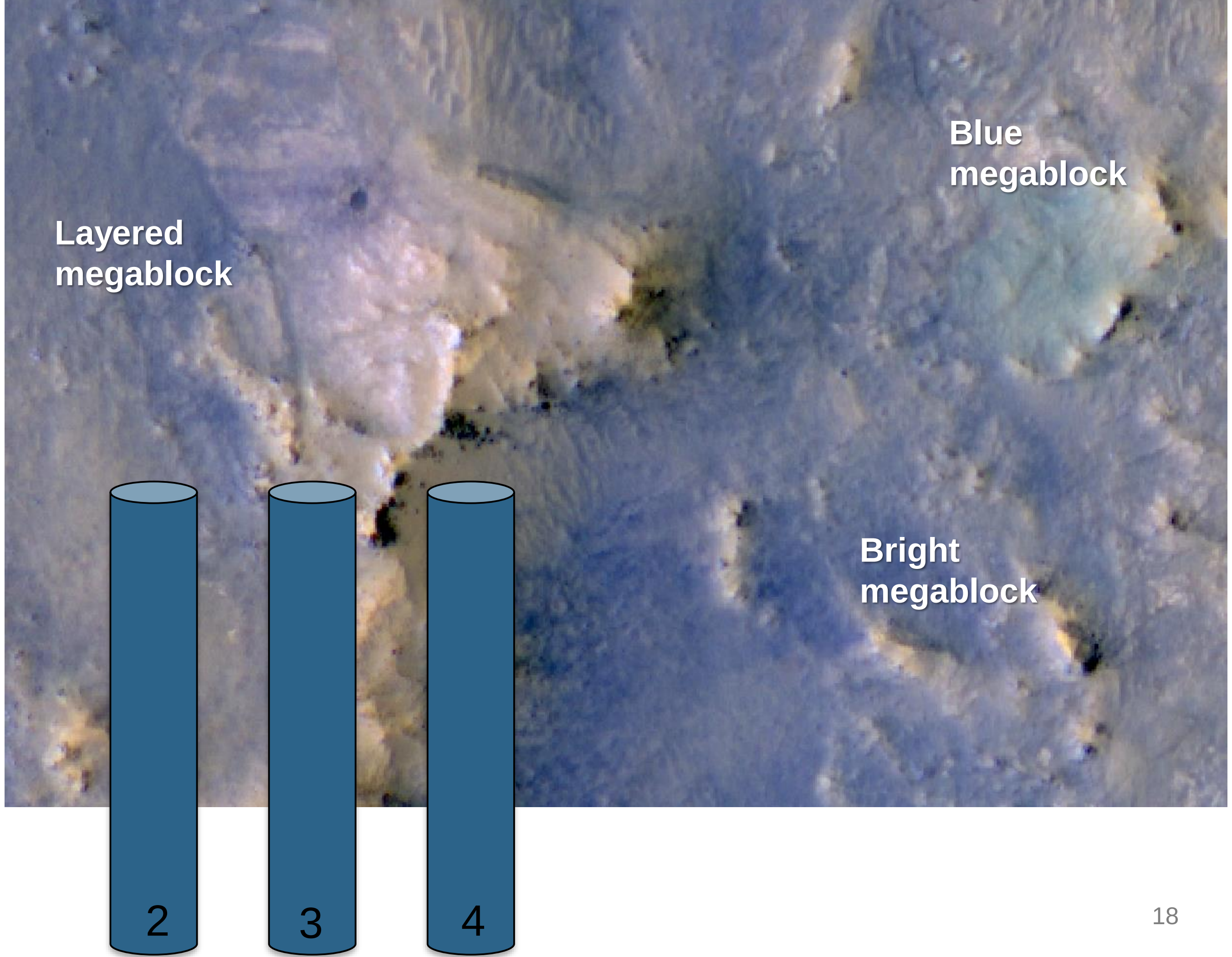
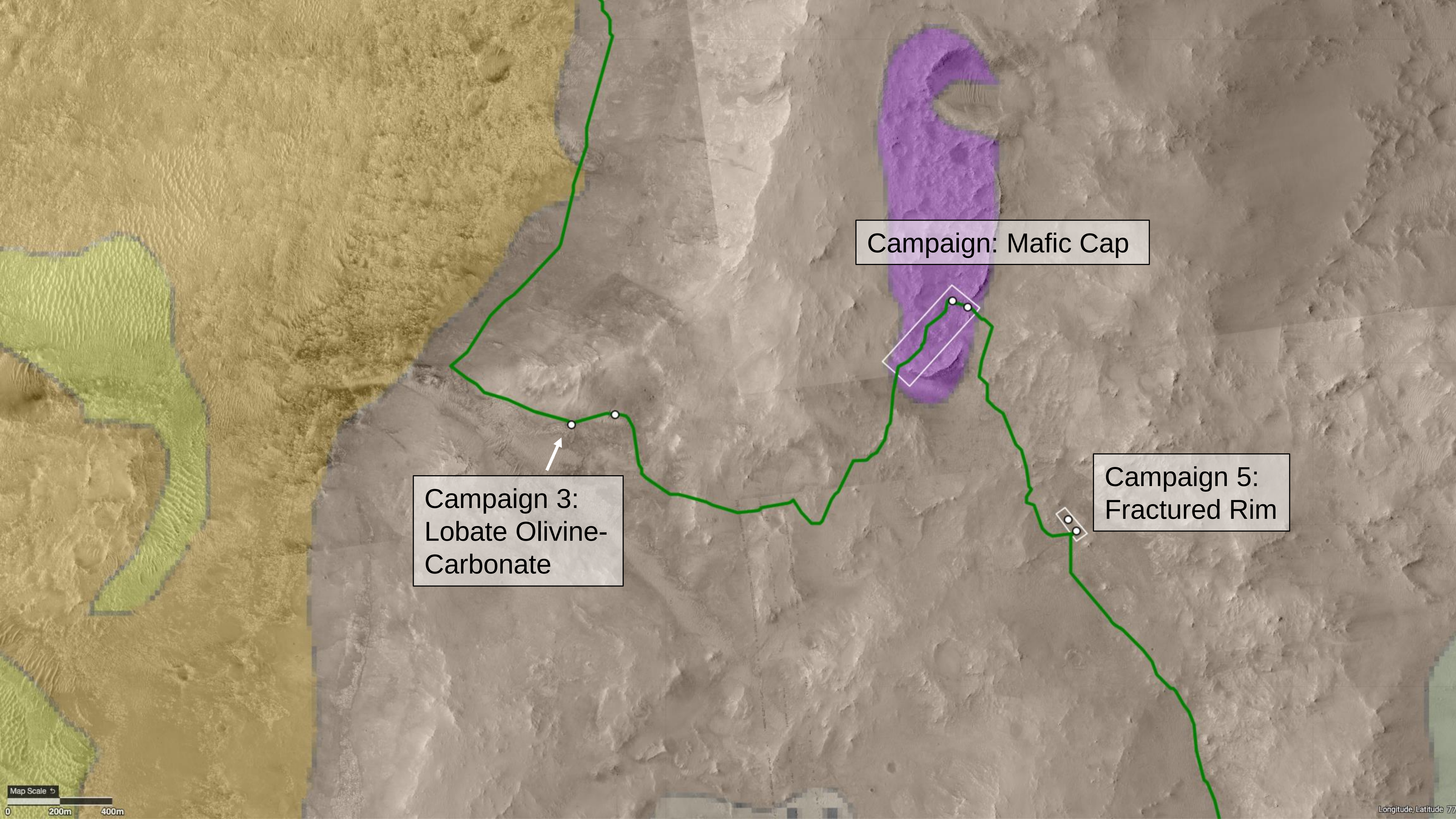
sample suite

- Sample # 2 – Layered megablock
  - Layered megabreccia are rare and potential pre-Isidis sediments (to access ancient Noachian environmental conditions before the Isidis impact)
- Sample # 3 – Blue megablock
  - Characterize diversity of pre-Isidis or pre-Jezero crust. Blue megablocks may be rich in low-Ca pyroxene (Scheller and Ehlmann, 2020) and may give insight into pre-Isidis igneous processes as LCP is common in the ancient martian crust.
- Sample # 4 – Yellow/bright megablock
  - Bright megablocks may be smectite-rich (Scheller and Ehlmann, 2020), giving insight into alteration/environmental conditions prior to Isidis or Jezero.

Objectives: Constrain their structure, composition, stratigraphic context, origin (e.g., sedimentary, igneous), and their diversity.

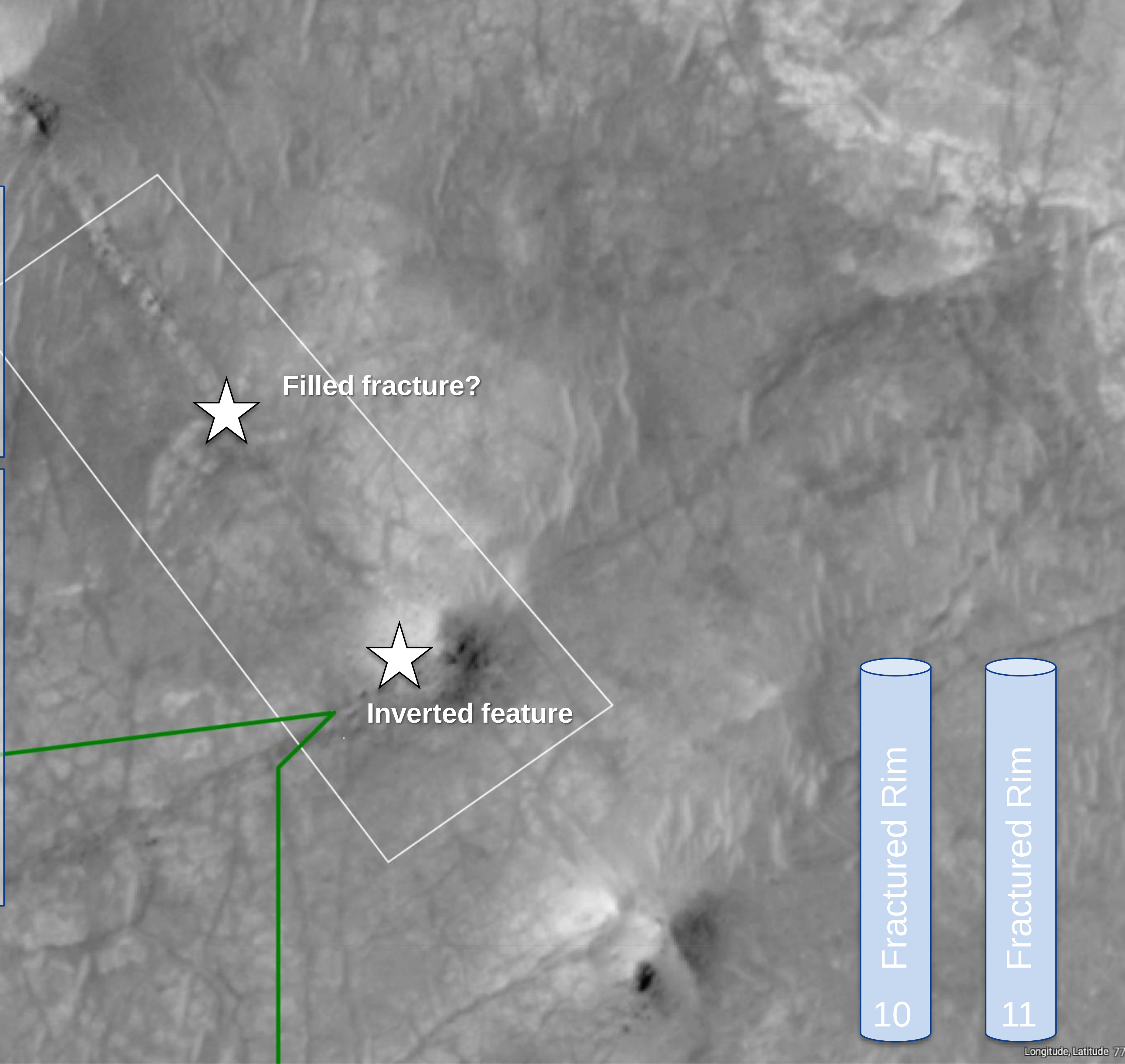



Campaign: Mafic Cap
Campaign 3: Lobate Olivine-Carbonate
Campaign 5: Fractured Rim
Map Scale
0
200m
400m
Longitude, Latitude

Campaign 5: Fractures

- Simple campaign, 25 sols.
- Science objectives:
  - **Identify Jezero crater-related hydrothermal sites along the rim traverse**

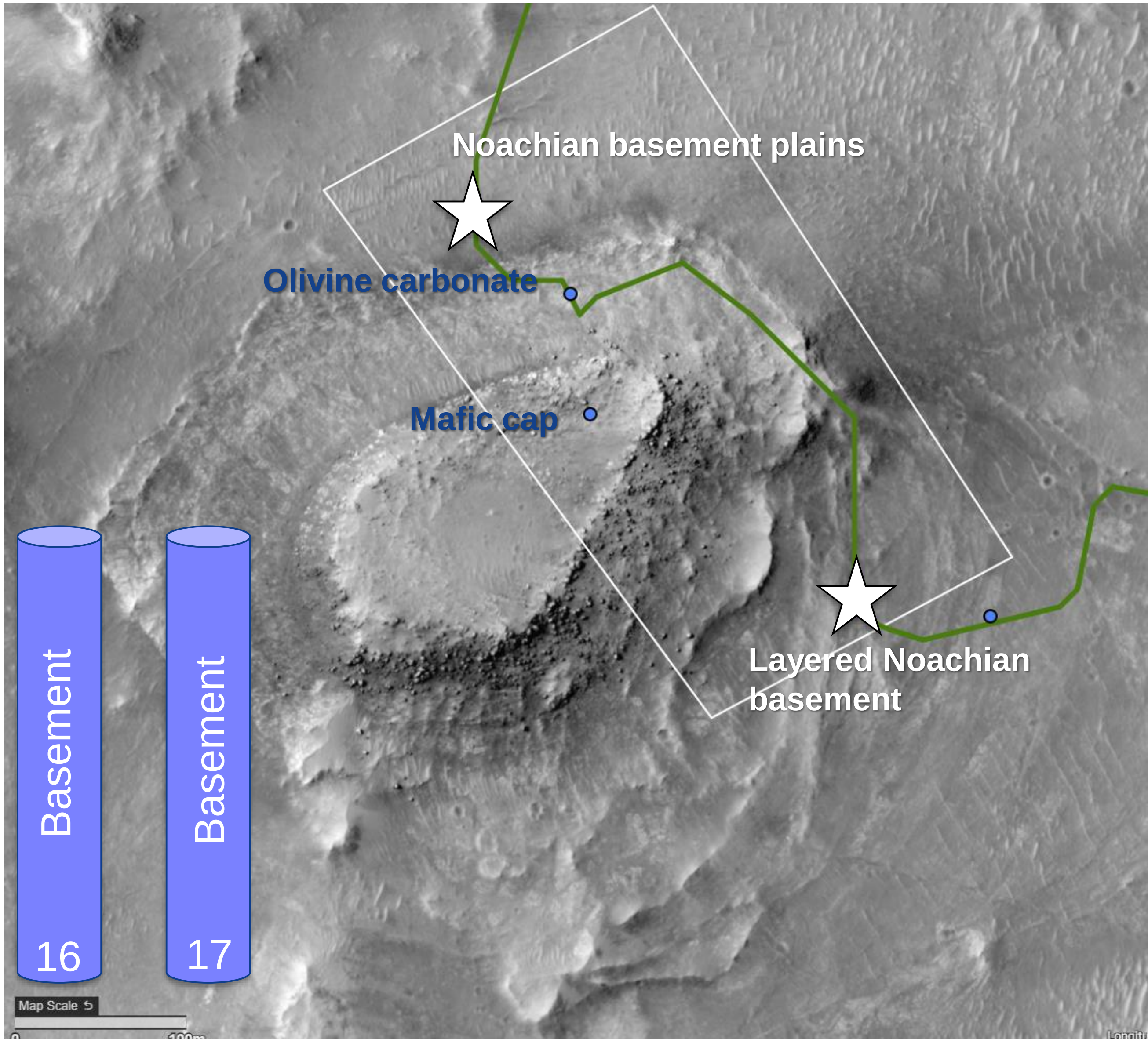
- Sample #10 Fracture/vein fill
  - Did life ever exist on Mars? Biosignature potential (double sample) fluid inclusions
- Sample #11 Fracture/vein fill
  - Did life ever exist on Mars? Biosignature potential (double sample) fluid inclusions



Campaign 8: Classic OJ Stratigraphy

- Complex campaign, 65 sols.
- Rationale: One of the best exposures of full mesa stratigraphy in the region, with rare example of layered basement unaffected by Jezero impact.
- **Objectives**:
  - Investigate the possibility of habitability and biosignature preservation in environments preceding and outside the Jezero lake environment
  - Evaluate the nature of ancient Noachian environments preserved in Nili Planum and their transitions through time

- Sample #16: layered basement
- Sample # 17: basement unit **stratigraphically distinct from first sample**.



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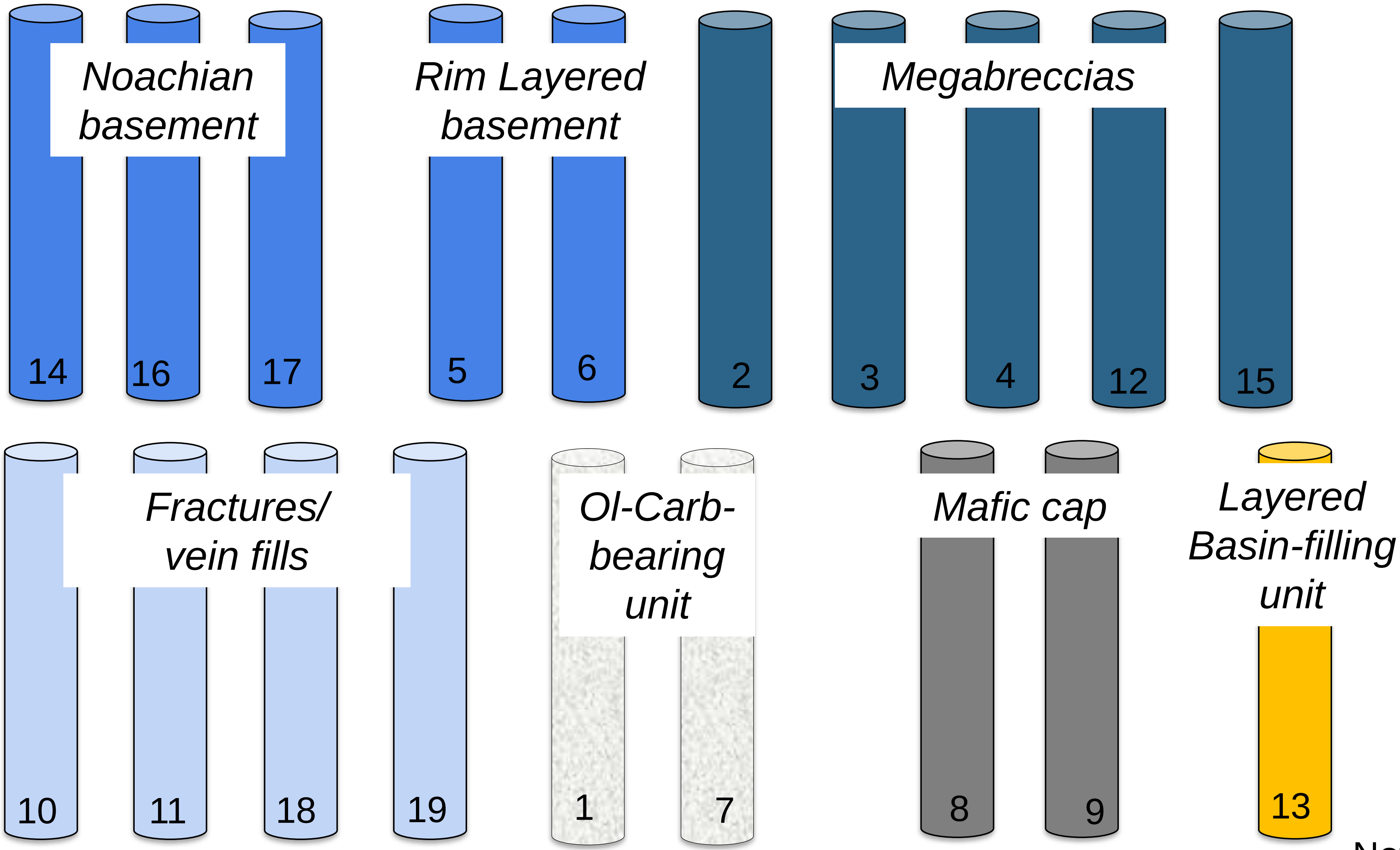
Notional Extended Mission Sample Cache



1. Noachian basement unit
2. Layered Noachian basement
3. Noachian basement
4. Crater rim layered unit
5. Crater rim layered unit
6. Layered megablock
7. “Blue” megablock
8. “Yellow/bright” megablock
9. Kaolinite block
10. Megablock
11. Fracture/vein fill
12. Fracture/vein fill
13. Ridge forming fracture
14. Ridge-forming fracture
15. Crater rim olivine-carb unit
16. Olivine-carb unit
17. Mafic cap unit
18. Mafic cap unit
19. Layered unit

Not including blanks/witness tubes

Potential Science Value of Extended Mission Sample Cache

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- Addresses 5 big sets of science investigations:
  - Characterizing early planetary evolution and habitability: planetary differentiation, igneous processes, geomagnetism and global tectonics
  - Possibility of calibrating Middle-Late Noachian crater chronology timescale
  - Biosignature preservation potential in habitable niches: carbonates, vein-fill deposits, phyllosilicate-rich deposits.
  - Diversity of aqueous and sedimentary processes in earliest Mars history: deposition precipitation, vein formation, alteration, and erosion. Megabreccia blocks provide pre-Isidis environmental conditions
  - Understanding Isidis-related basin-scale impact effects

Summary

- Prime and Extended missions present bold and exciting traverses that investigate and sample a broad variety of Martian geologic environments across ~2 billion years of Martian history, including
- A fluvio-lacustrine system that records early Mars climate, habitability, compositional diversity of watershed, and potentially life
- Impact processes and associated habitable impact-generated hydrothermal environments
- Aqueously altered ancient Martian crust with potential to reconstruct planetary evolution, date major geologic events and evaluate habitable subsurface environments
- Samples from inside and outside Jezero tackle different scientific questions but are nevertheless complementary

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Backup

Potential Prime Mission Sample Cache – Land Near Delta

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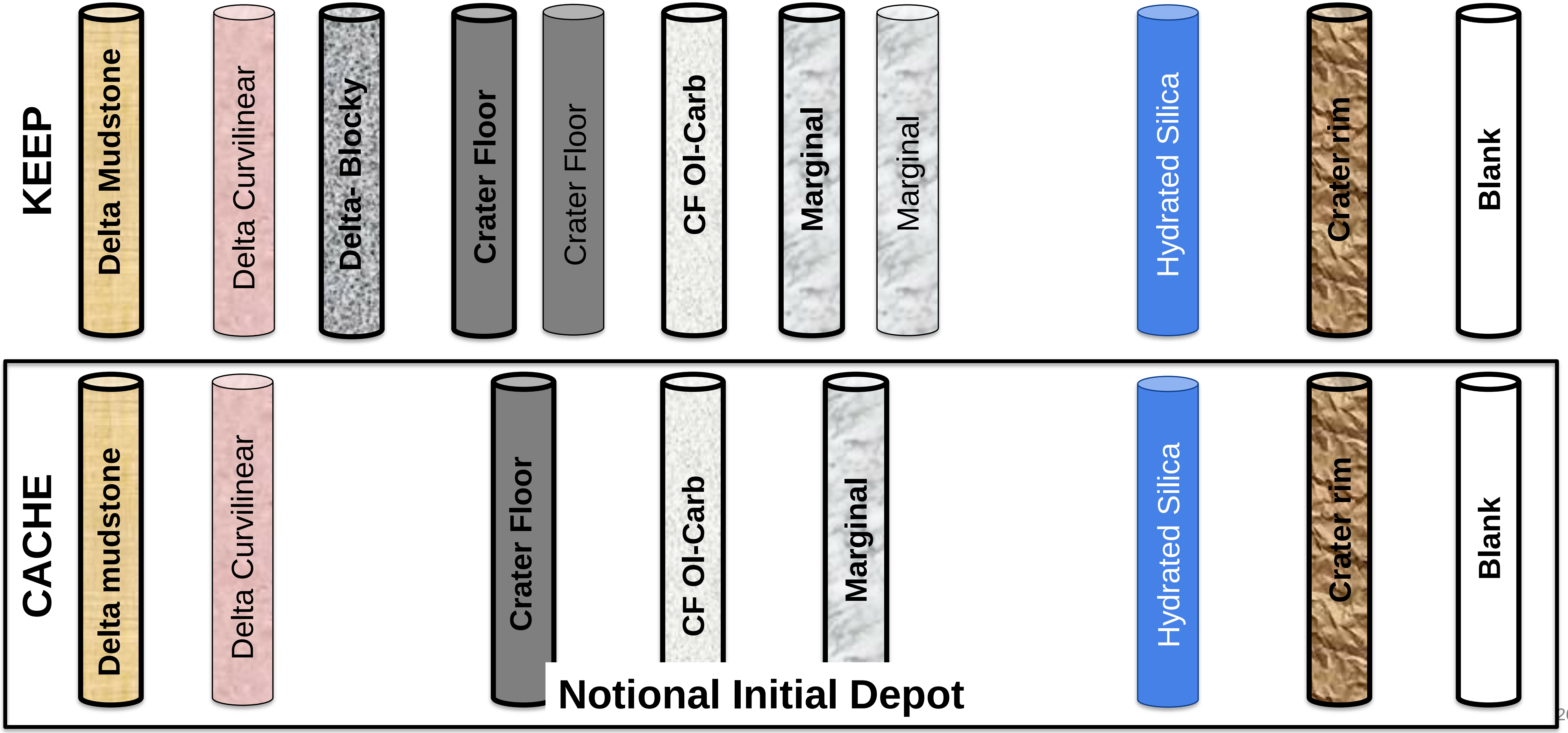
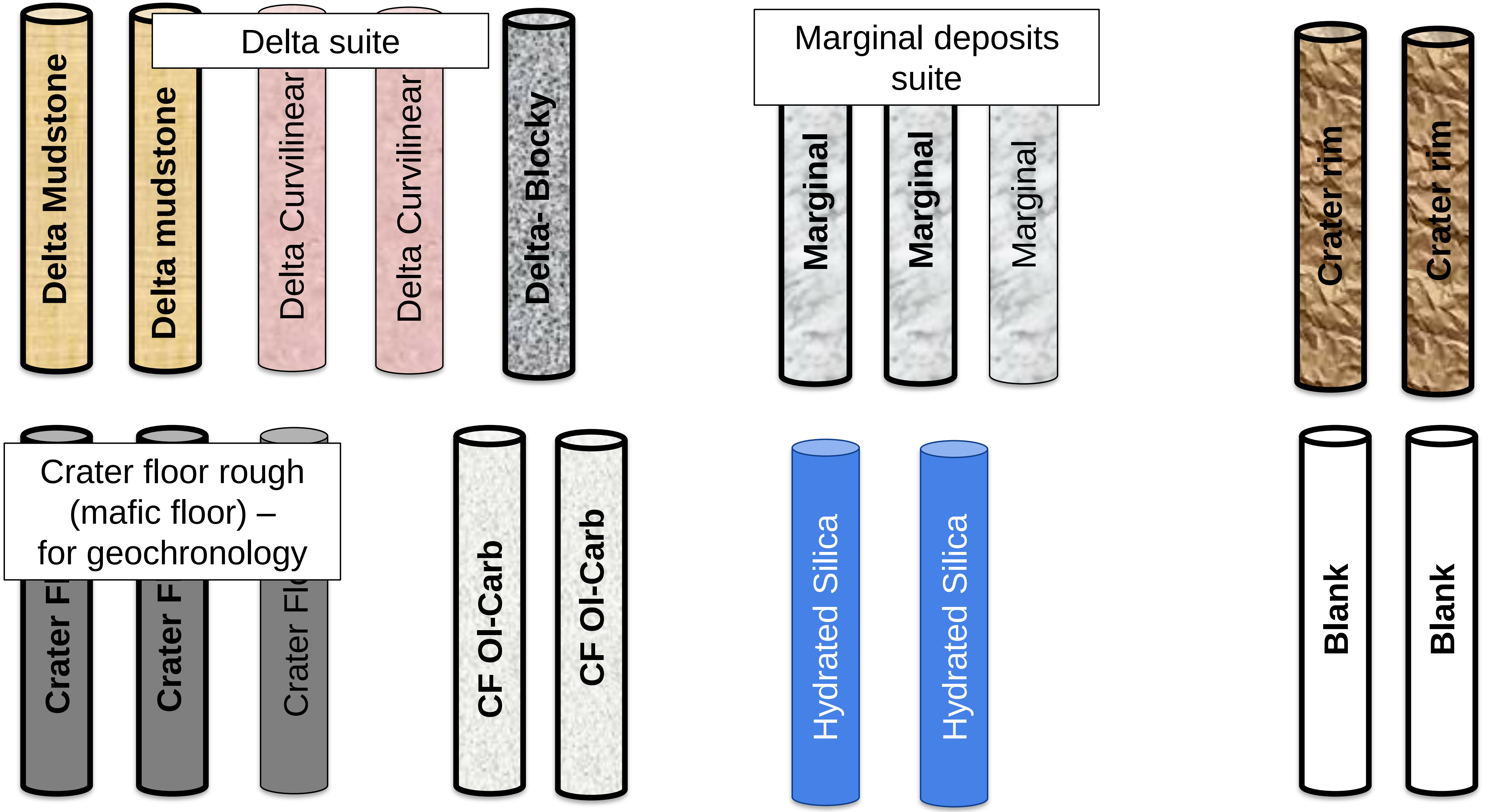
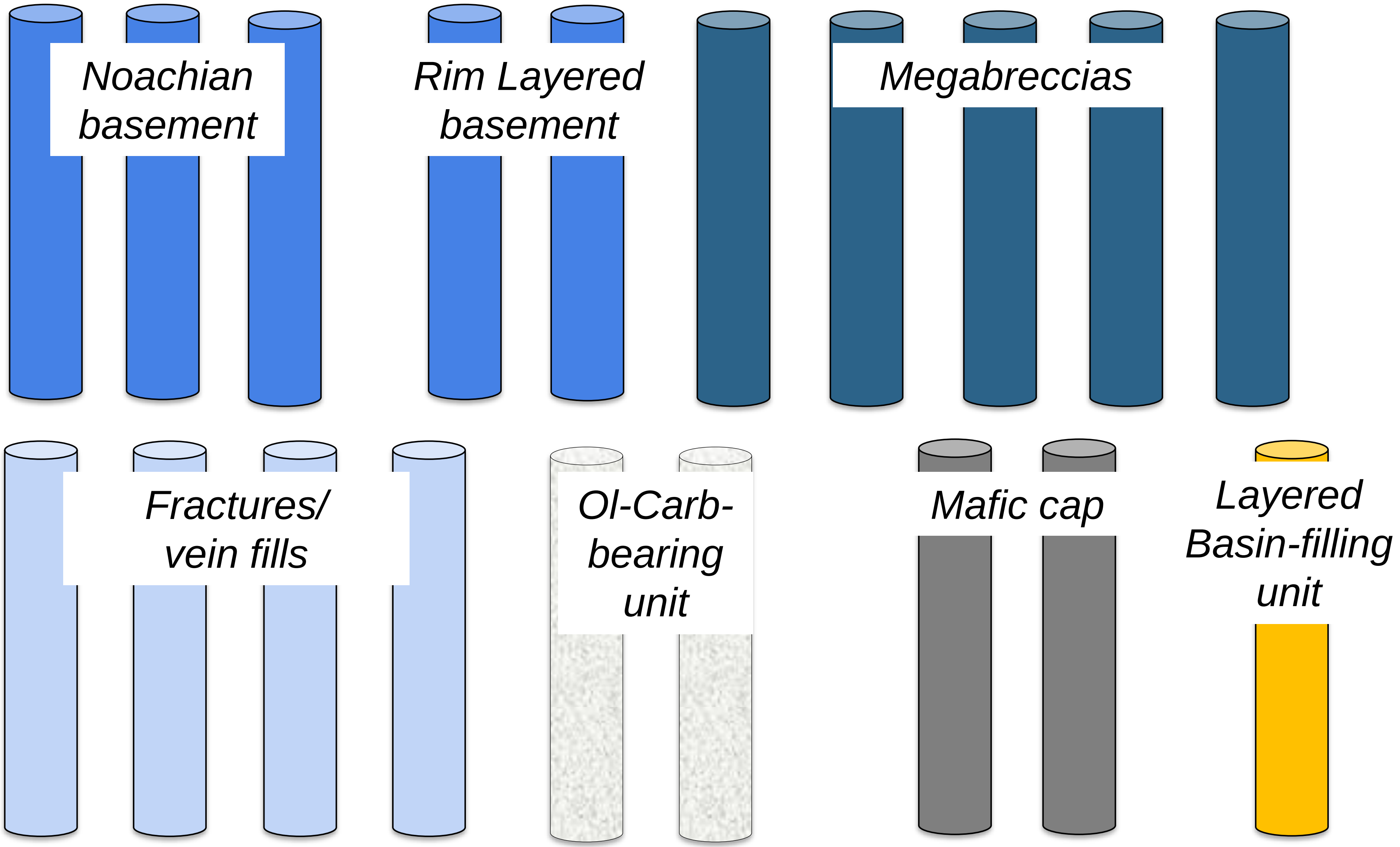


Prime Mission Sample Cache – sample suites



Notional Extended Mission Sample Cache



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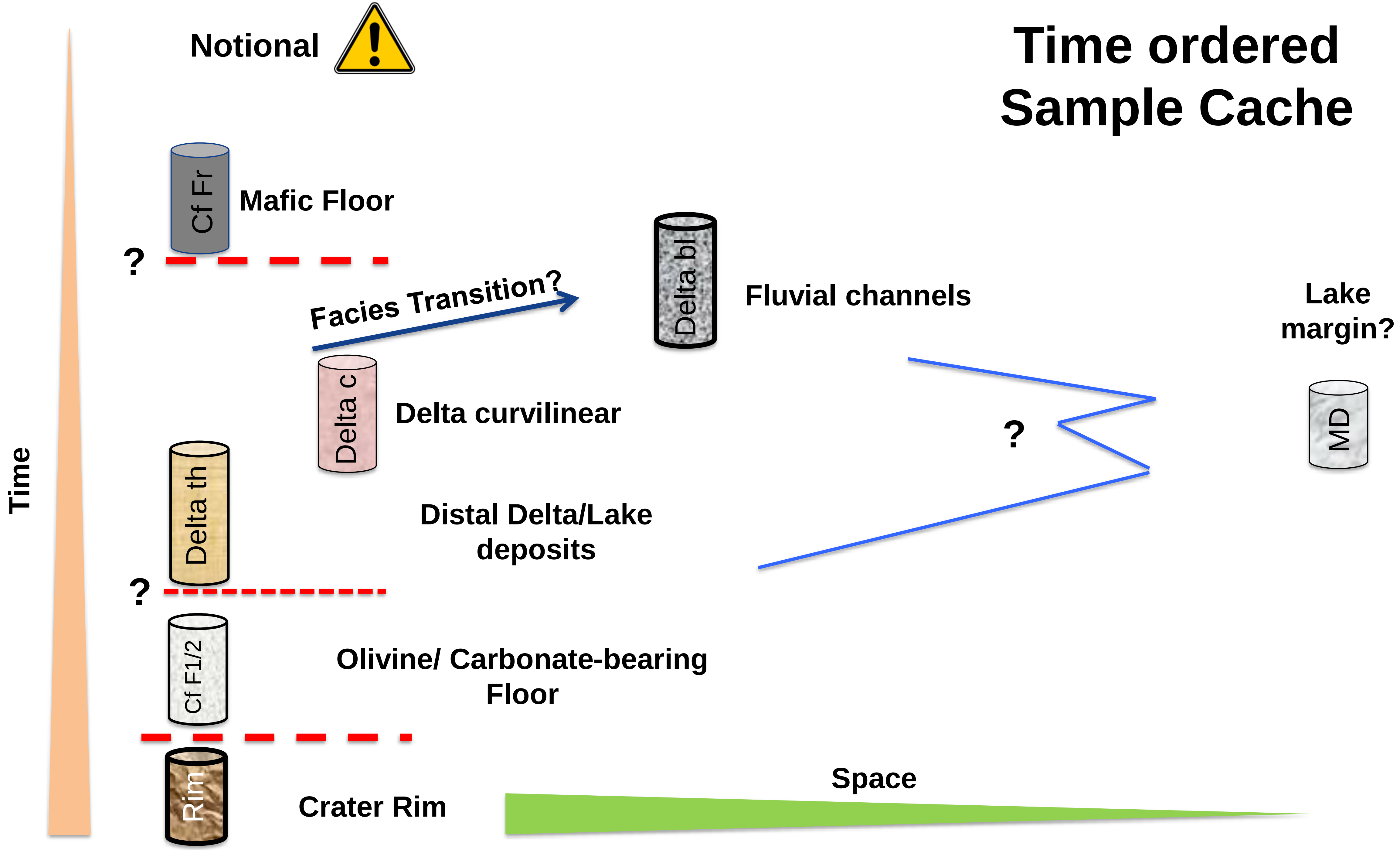
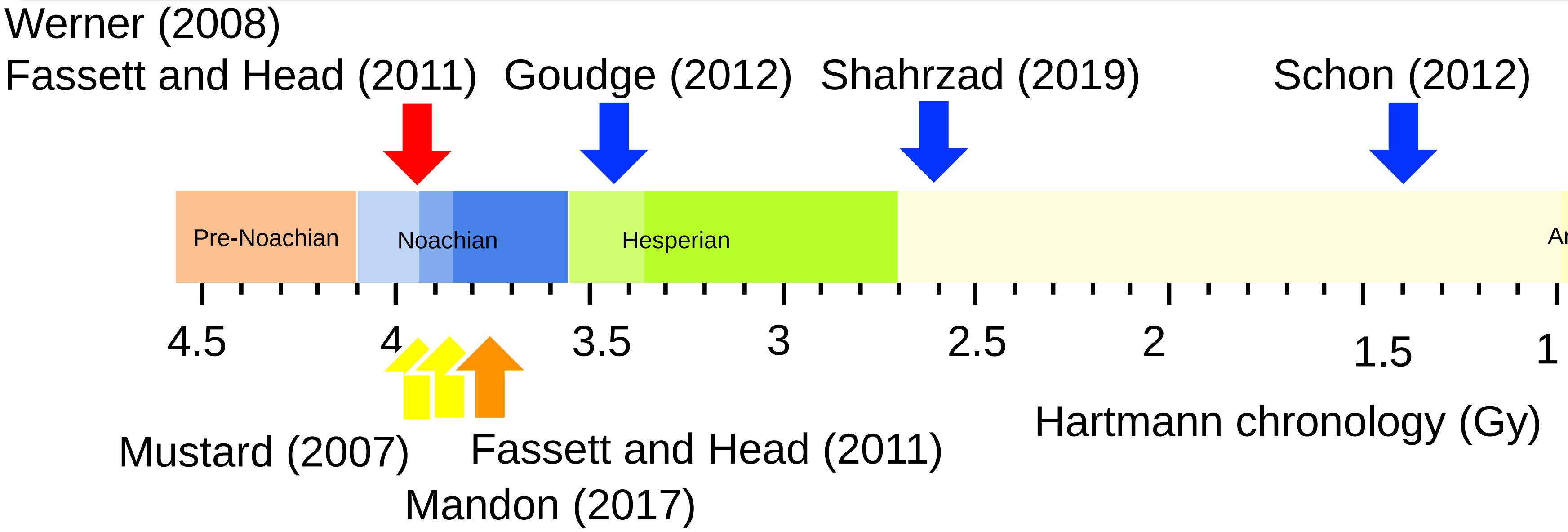
17. Mafic cap unit
18. Mafic cap unit
19. Layered unit

Time ordered Sample Cache



What about absolute ages?



Isidis impact

Mafic crater floor

"Regional" ol-carb-bearing unit

Age of Jezero valley system

- Jezero crater likely formed sometime in the mid-Noachian
- Questions remain about the age of units within Jezero:
    - What is the relationship between the Jezero delta and the mafic crater floor?
    - Is the age of the mafic crater floor an emplacement age or an exposure age?
    - Do we really know the age of the mafic crater floor?