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Mars 2020 Science Team Assessment of Northeast Syrtis and Midway

Mars 2020 4th Landing Site Workshop

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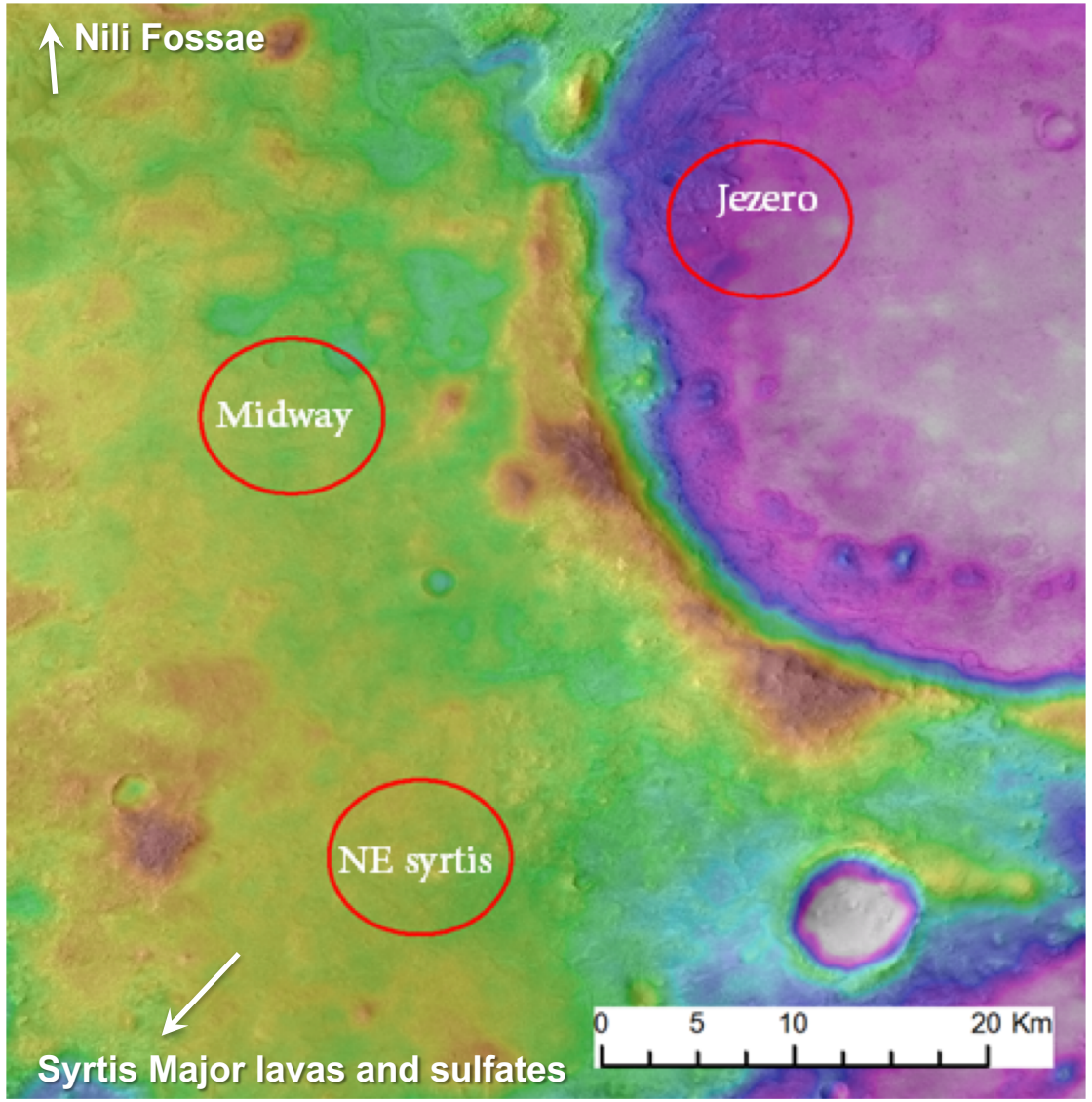
On behalf of the Mars 2020 Science Team Landing Site Working Group

October 16-18, 2018



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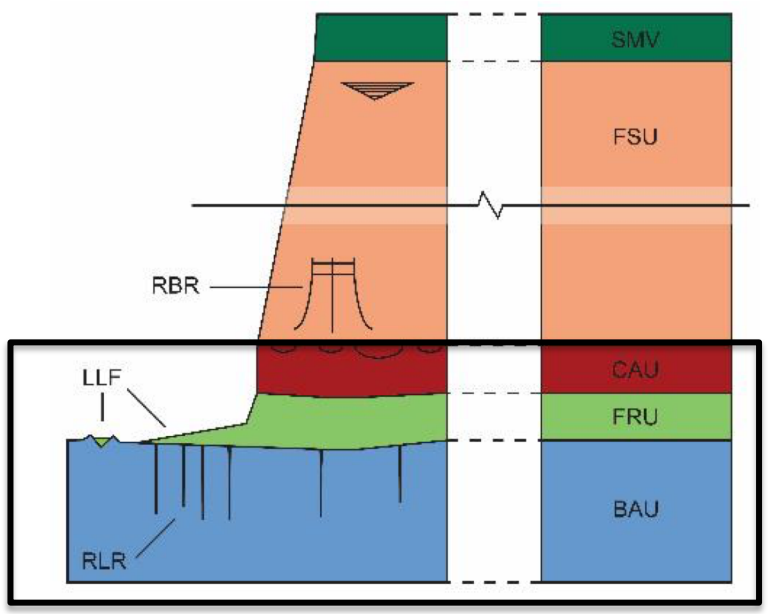
Overview of NE Syrtis and Midway

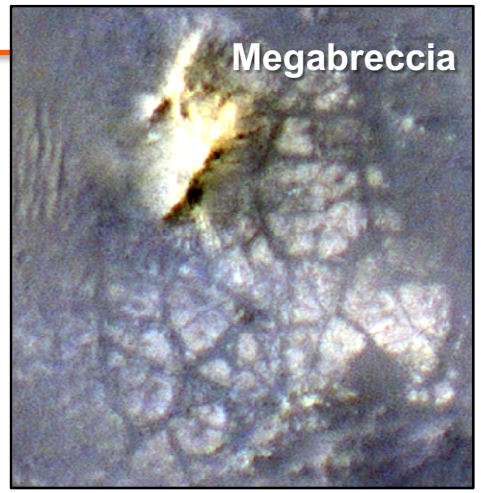
- Both sites preserve Isidis megabreccia and mesas with multiple units of ancient Noachian strata.
- Both sites contain basement materials - including megabreccia, low-Ca pyroxene enriched, and Fe/Mg smectite enriched units - and an olivine-enriched unit variably aqueously altered to Mg-carbonate.
- Different extended missions.



From M. Bramble LSW3

Mafic Cap Rock
Olivine–Carbonate Unit

LCP-bearing Mounds
Fe/Mg Smectite in
1) Megabreccia
2) Basement
3) Ridges



Goal that provides enduring focus to the mission

To explore mesas preserving <u>strata of ancient Martian crust</u> and search for life, understand changing climate, and determine the geology and landscape processes that formed clay and carbonate minerals during Mars' most active epoch

Summary of in-situ mission strategies and objectives

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- **Geologic Unit Origins:** Characterize all lithologies present, interpret their petrogenesis (igneous vs. sedimentary) and history of interaction with water (incl. hydrothermal alteration, diagenesis). Determine via macroscale/petrologic textures and mineralogy/chemistry (Mastcam-Z, SuperCam, PIXL, SHERLOC).
  - **Megabreccia:** Determine if the pre-Isidis crust was dominated by igneous rocks or sediments.
  - **Low-Ca pyroxene units:** Determine igneous conditions that generated; in the basement/mounds and megabreccia.
  - **Olivine-carbonate unit:** Determine if sedimentary/igneous origin, determine processes altering to Mg-carbonate and modes of serpentinization?
  - **Mafic cap unit:** Determine if sedimentary/igneous origin and regional extent of this unit.
  - **Fe/Mg smectite-bearing units:** Determine the number of aqueous alteration episodes, water chemistry, pH, Eh, T recorded in 1) megabreccia, 2) basement/mounds, 3) ridges.
  - **Kaolinite:** Determine spatial and temporal relationship with Fe/Mg smectite and unaltered units and origin.
  - **Impact melt:** Determine if present and investigate composition.
- **Global/Regional History:** Establish the time sequence of geological events by investigating the contact relationships between units and using RIMFAX to map the subsurface structure.
- **Habitability and Search for Biosignatures:**
  - Interpret habitability potential in the various environments (surface vs. subsurface) recorded by petrology and understand the relative roles of climate and groundwaters in creating the water-related minerals
  - Search for organic, textural, and mineral/chemical potential biosignatures in the altered megabreccia, Fe/Mg smectite-bearing megabreccia/basement/ridges, kaolinite-bearing materials, and carbonate unit

Notional Mission Scenarios for NE Syrtis and Midway

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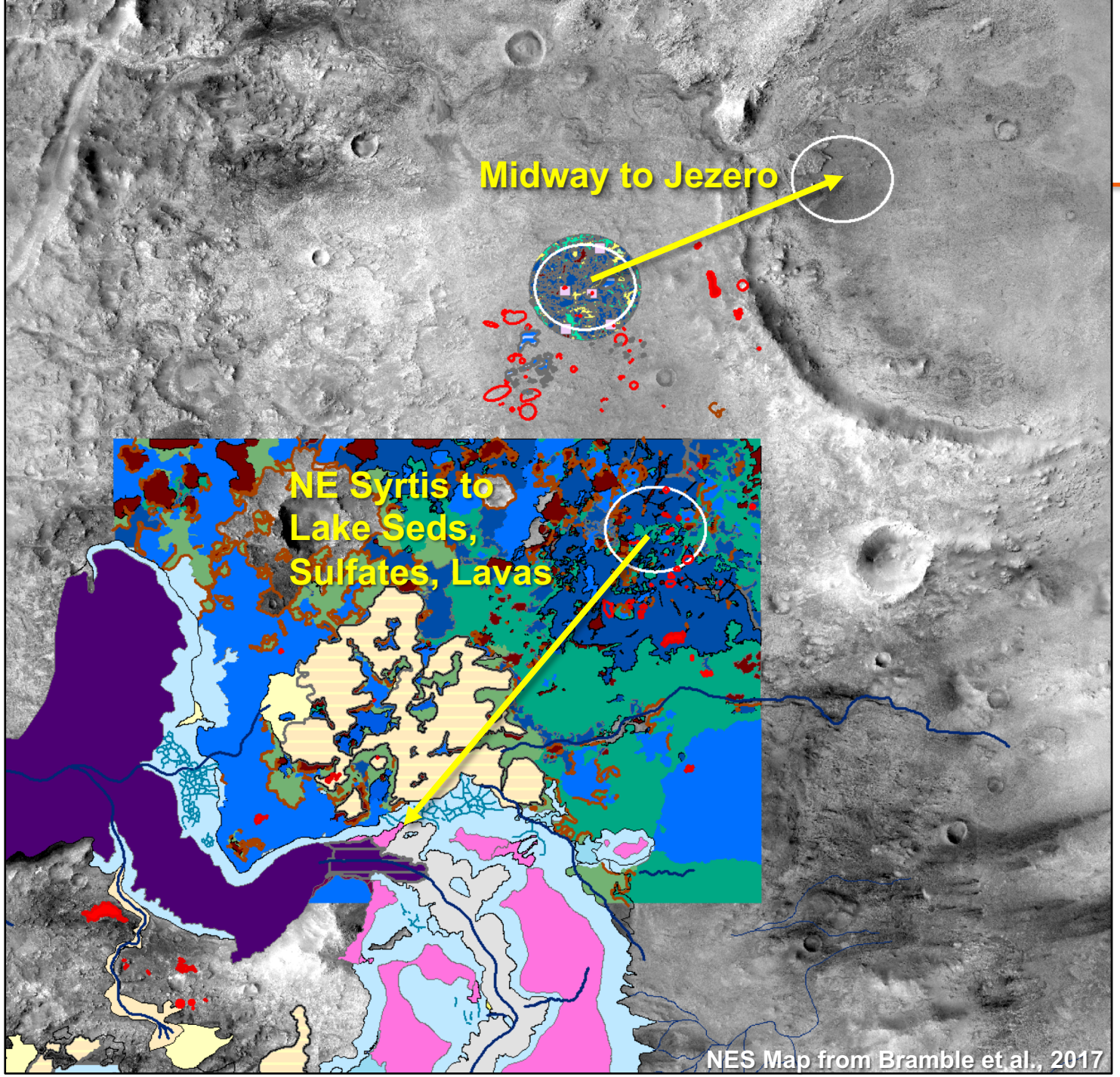
The mission scenario that follows is purely notional. We fully acknowledge that operations on the ground will be informed by what we learn on the surface. The notional scenario we present has been created to allow inter-site comparison based on our current understanding of the landing site.

”In preparing for battle I have always found that plans are useless but planning is indispensable.”

-Dwight D. Eisenhower



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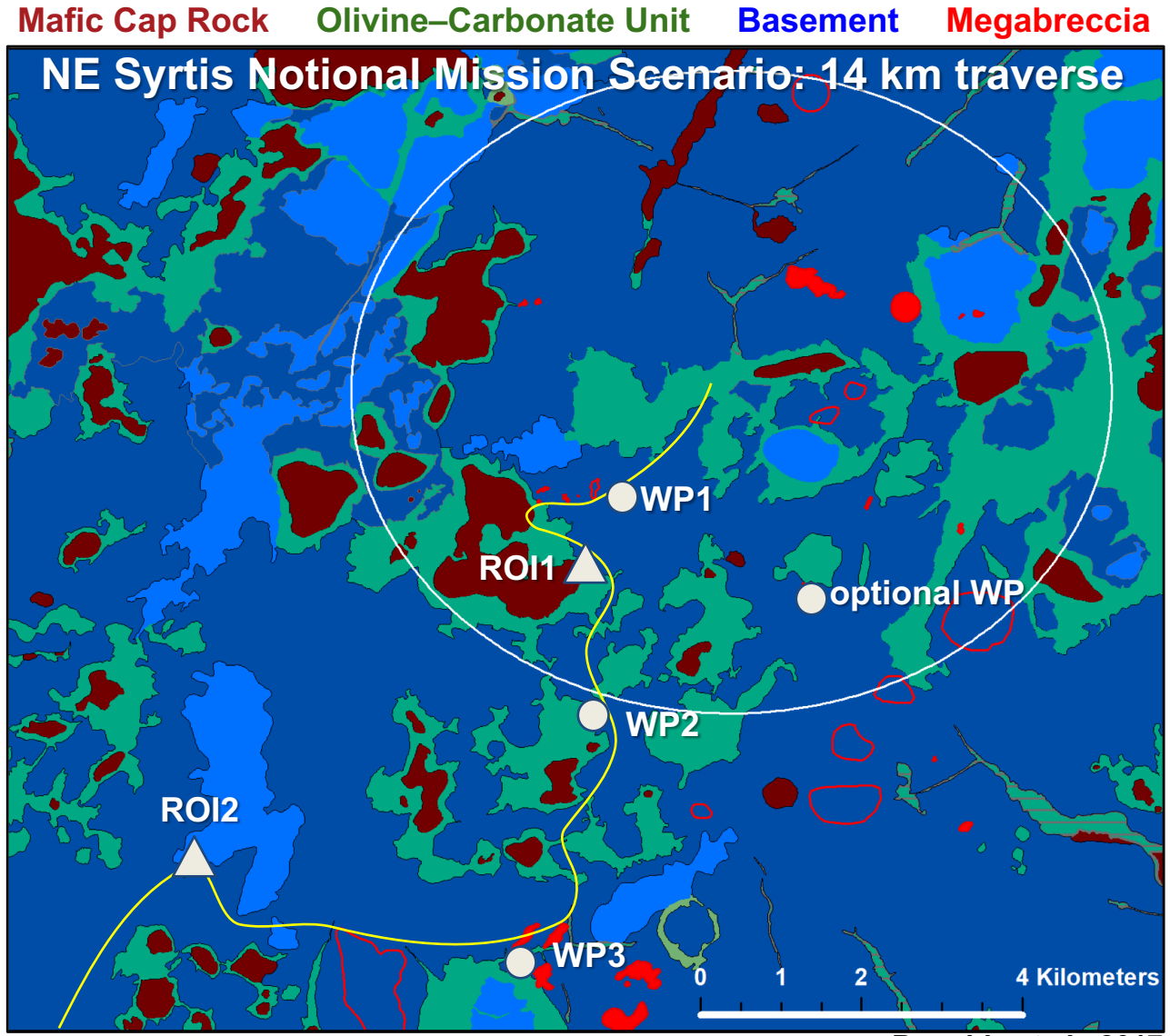
Two Ellipses That Land on Noachian Stratigraphy:

Different Extended Missions

1. NE Syrtis → Sediments, Lavas
2. Midway → Jezero crater

Notional Mission Scenario for NE Syrtis

- Traverse samples all unaltered and altered lithologies identified from orbit. Total traverse from landing to ROI2 = 14 km.
- Land. Drive to the nearest mesa in direction of sulfates, making in situ measurements during the traverse. Discovery-driven decisions:
  - Follow the fractures and redox boundaries to sample locations of groundwaters and possible habitats.
  - Follow the sedimentary facies to sample locations of surface waters and possible habitats.
- **Waypoint 1: Megabreccia.**
- **ROI 1: Mesa and Basement**
  Campaign 1: Scout the mesa for stratigraphic relationships and composition. Sample the olivine-carbonate unit, collecting altered and unaltered lithologies when possible.
  Campaign 2: Sample the basement unit (Fe/Mg-smectite, low-Ca pyroxene, ridges), collecting altered and unaltered lithologies.
- **Waypoint 2:** Second **olivine-carbonate unit**; sample for diversity.
- **Waypoint 3: Megabreccia.**
- **ROI 2: Basement unit**
  Campaign 1: Investigate contacts between Fe/Mg-smectite, kaolinite, low-Ca pyroxene, collecting altered and unaltered rocks.
  Campaign 2: Investigate second location exposing contact between Fe/Mg smectite and LCP.



Bramble et al., 2017

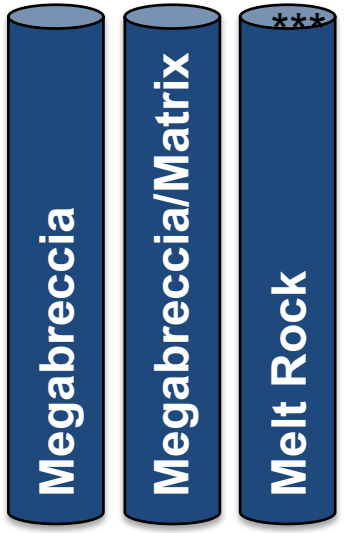
Waypoint 1 (NE Syrtis): Megabreccia

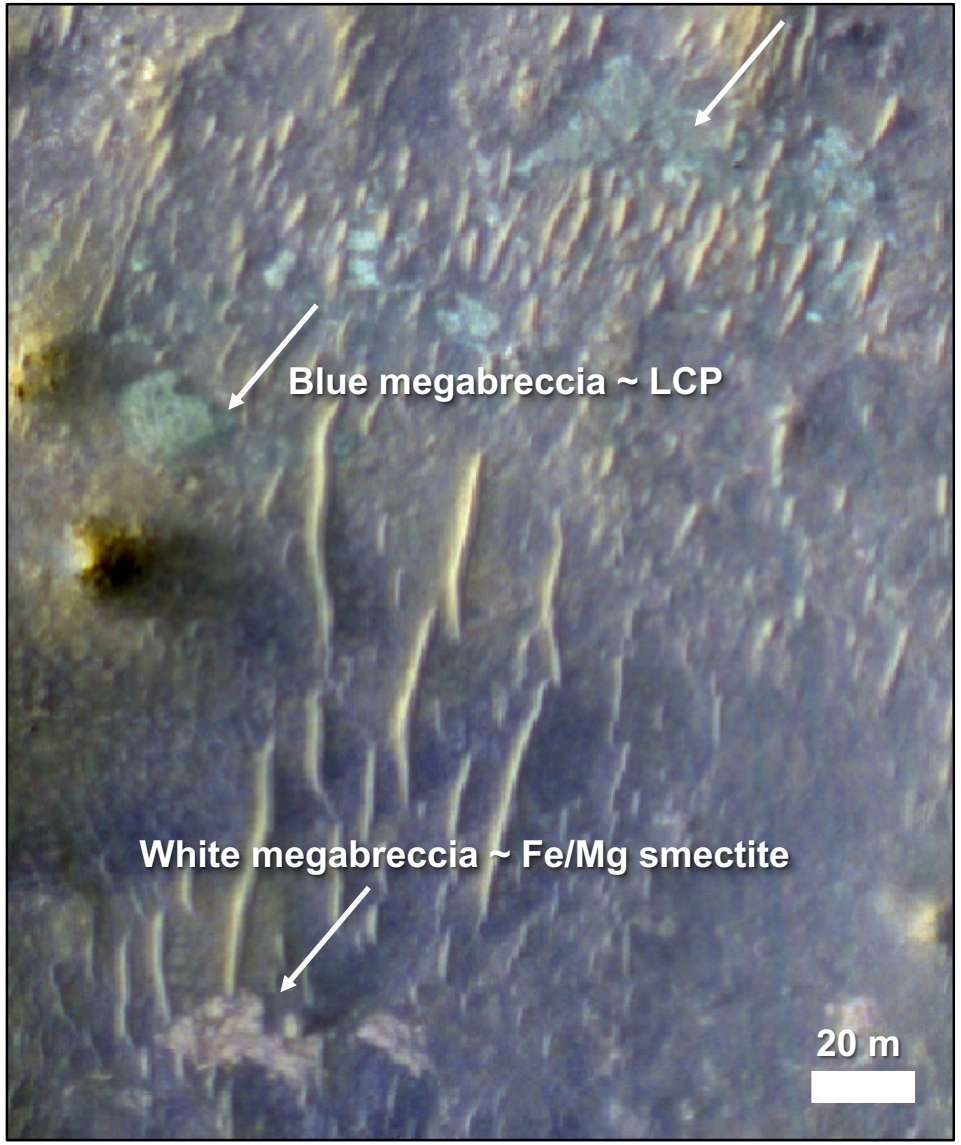
- **Objective:** Characterize early Noachian, pre-Isidis material preserved in megabreccia. Determine if pre-Isidis crust was igneous or sedimentary in origin.

- Use Mastcam-Z, Supercam, PIXL, SHERLOC/WATSON to identify different compositions and characterize any matrix, melt rock, or evidence for hydrothermal alteration.
- Use SHERLOC, Supercam to look for organics in altered megabreccia.
- Use Mastcam-Z, RIMFAX to characterize relationship with megabreccia host material.

Possible Sampling
To characterize pre-Isidis conditions
(note WP3 is also megabreccia)

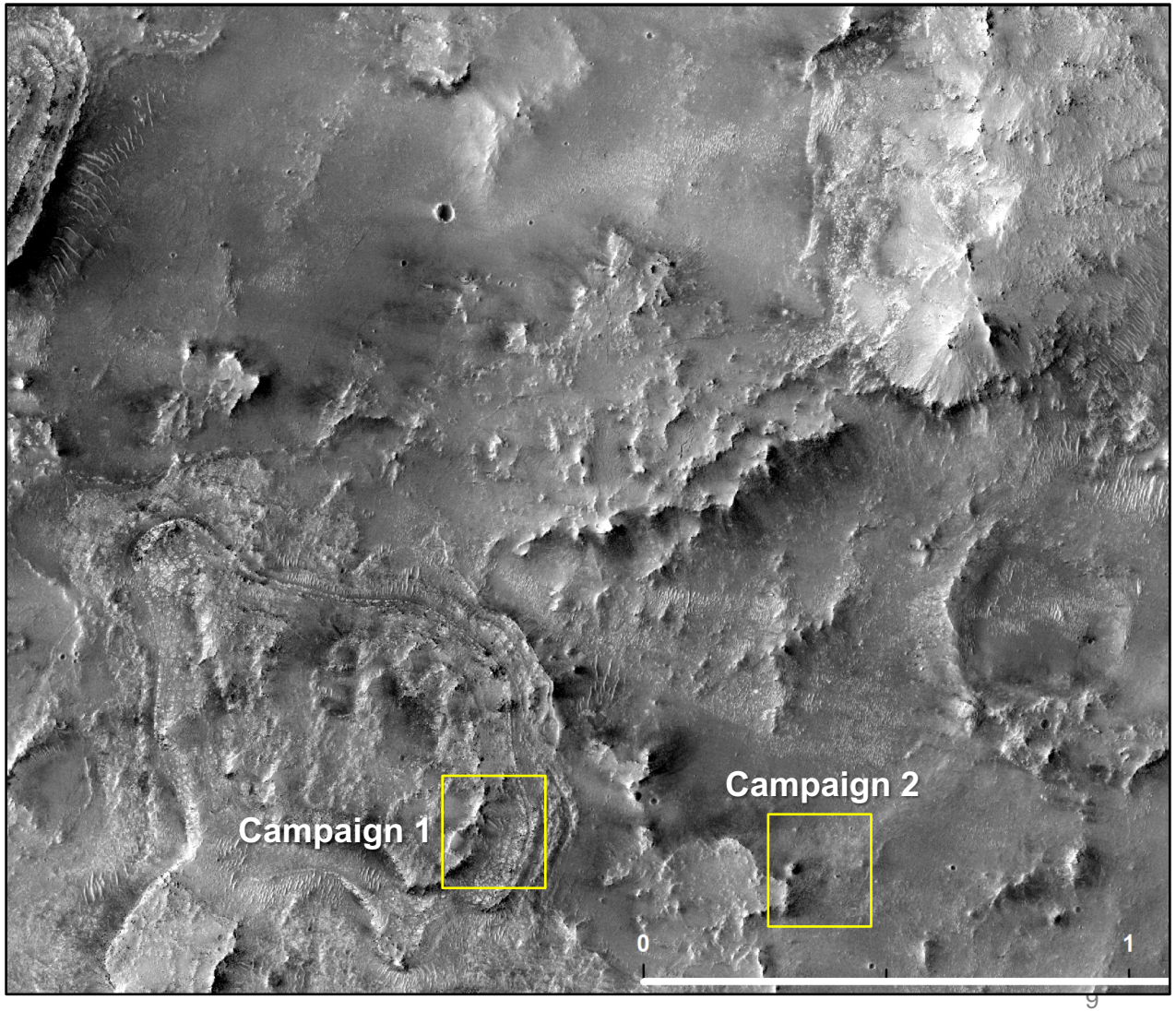
2 Megabreccia (different composition or matrix)
1 Melt Rock





ROI 1 Overview (NE Syrtis)

- **Campaign 1: Olivine-carbonate unit and mafic cap**
  - Establish petrogenesis
  - Determine contact relationships between olivine-carbonate and mafic cap
  - Establish carbonate formation process
  - Assess habitability, search for biosignatures, collect samples
- **Campaign 2: Basement unit**
  - Establish petrogenesis
  - Determine contact relationships between Fe/Mg smectite and LCP
  - Establish Fe/Mg smectite formation process
  - Assess habitability, search for biosignatures, collect samples



ROI 1- Campaign 1 (NE Syrtis): Ol-Carb-Cap

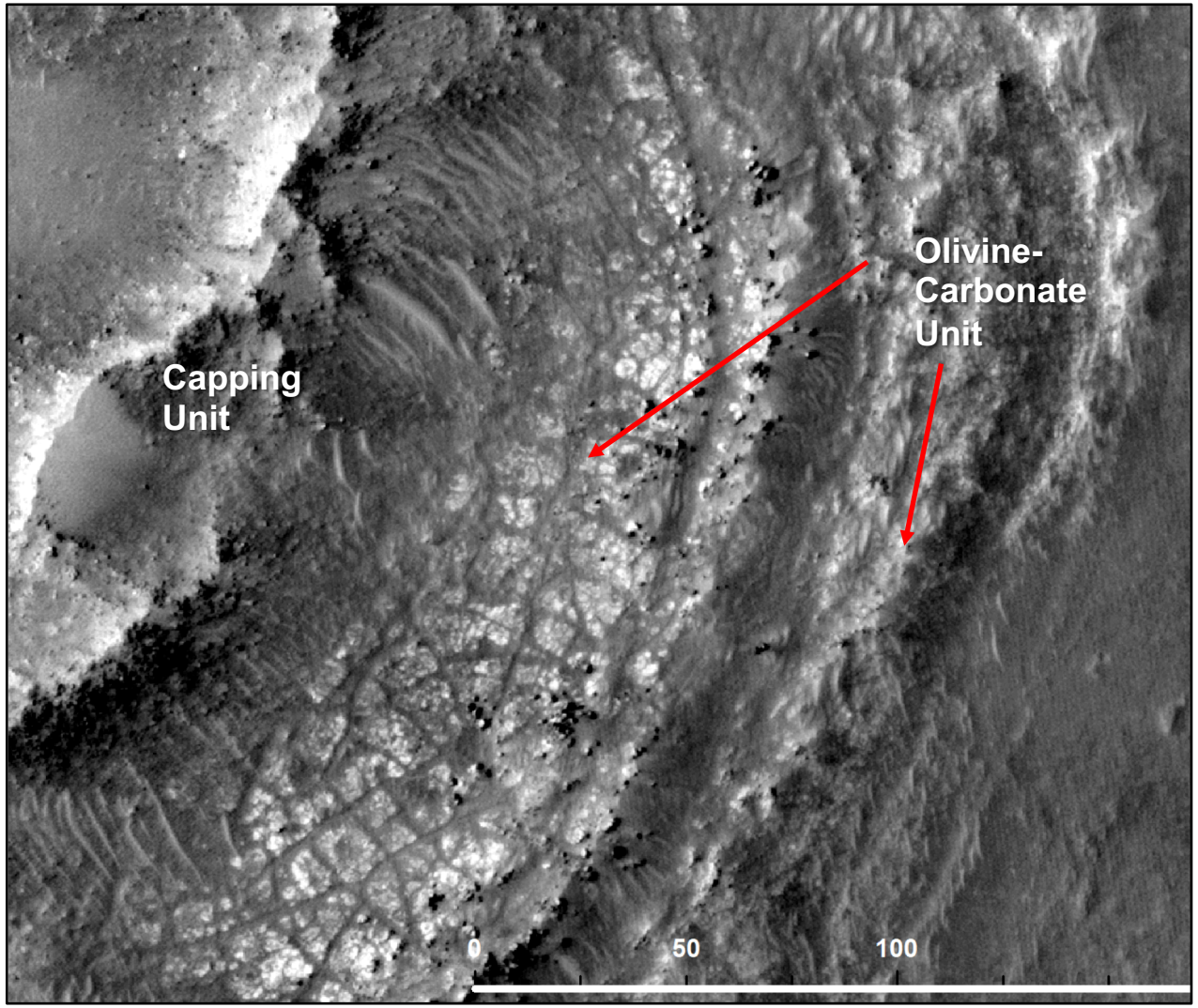
- **Objective:** Identify the lithologies in mesa-forming units, interpret their petrogenesis, history of interaction with water, and time sequence.

- Use Mastcam-Z, Supercam to characterize physical and compositional properties of units.
- Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine origin and alteration.
- Use SHERLOC, Supercam to look for organics in carbonates.
- Use RIMFAX to probe subsurface structure and contact.

Samples #1-3

2 Olivine-Carbonate Unit samples, variably altered

1 Cap Rock



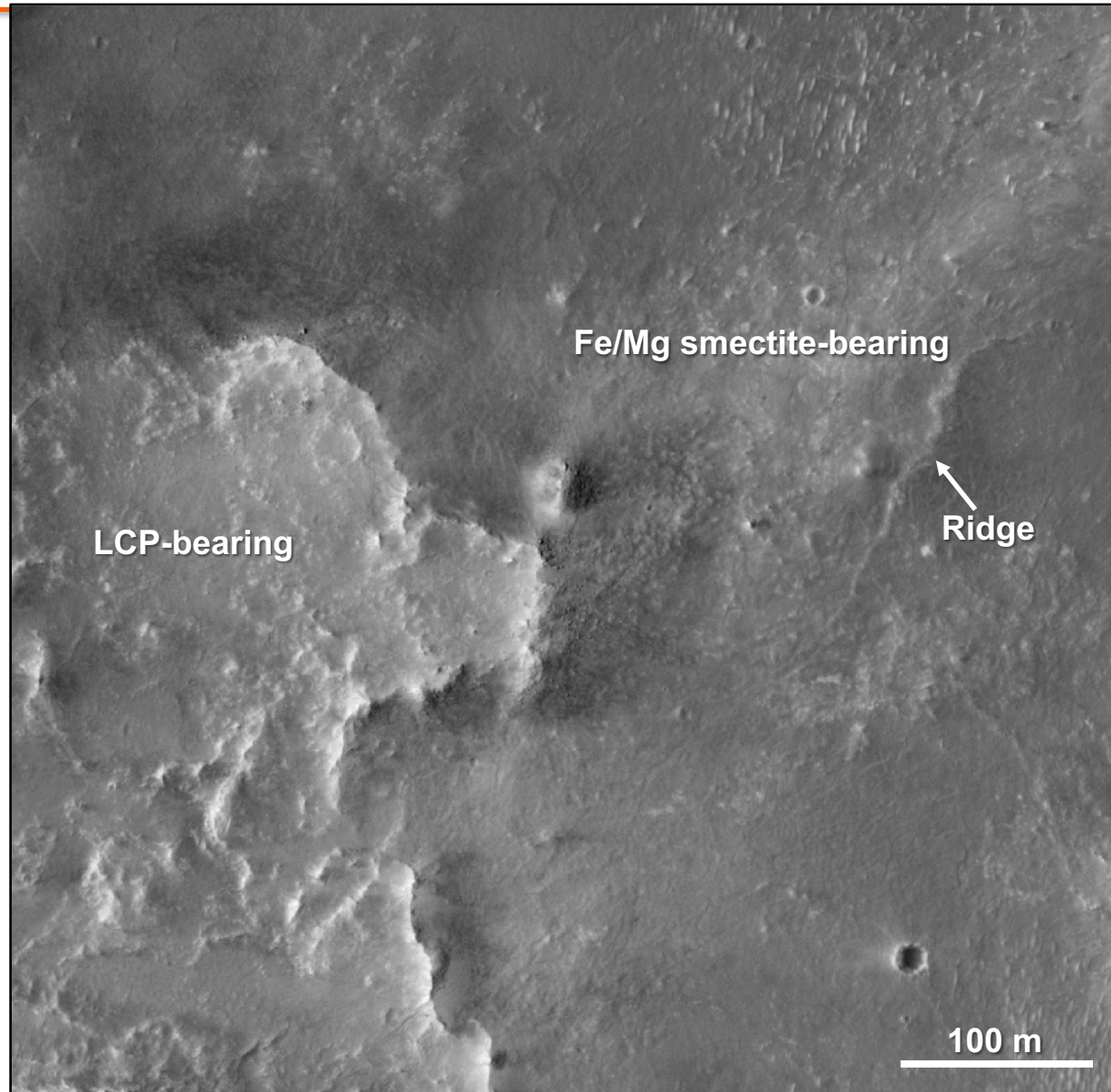
ROI 1- Campaign 2 (NE Syrtis): Basement

- **Objective:** Identify the altered and unaltered lithologies in basement, interpret their history of interaction with water and time sequence. Assess if Fe/Mg smectites in ridges represent a second episode of Fe/Mg smectite formation in the basement.

- Use Mastcam-Z, Supercam to characterize physical and compositional properties of units.
- Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine origin and alteration.
- Use SHERLOC, Supercam to look for organics in Fe/Mg smectite samples.
- Use RIMFAX to probe subsurface structure.

Samples #4-8

2 Low-Ca Pyroxene samples
1 Melt Rock if present
2 Ridge samples (interior and adjacent)



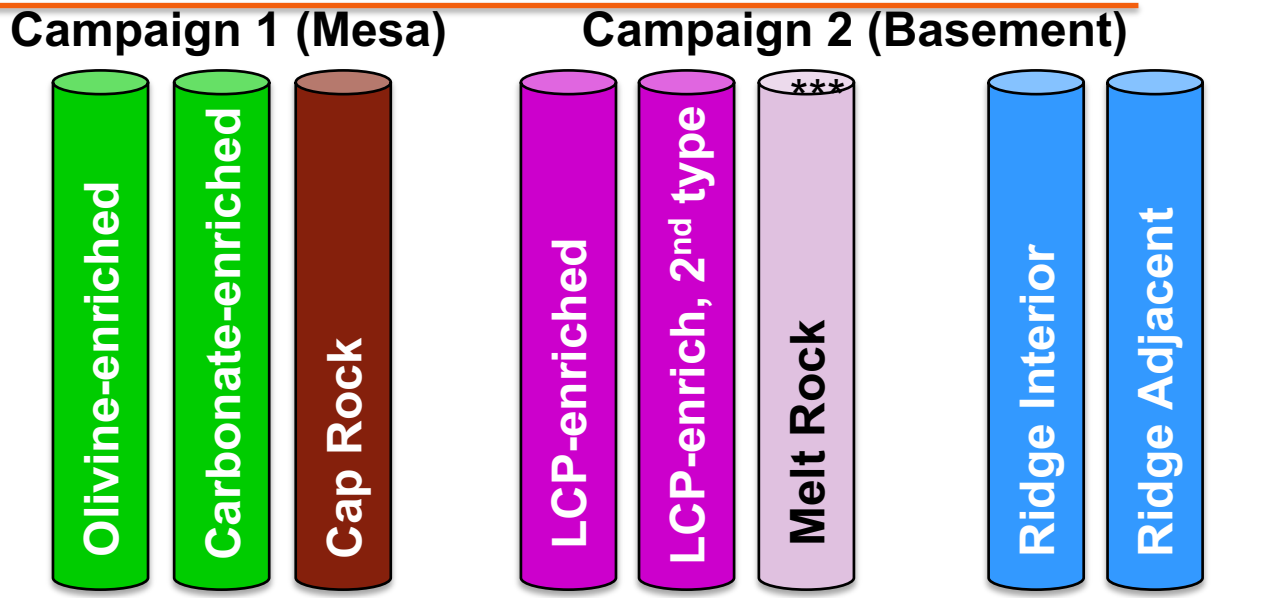
ROI 1 Sampling Strategy (NE Syrtis)

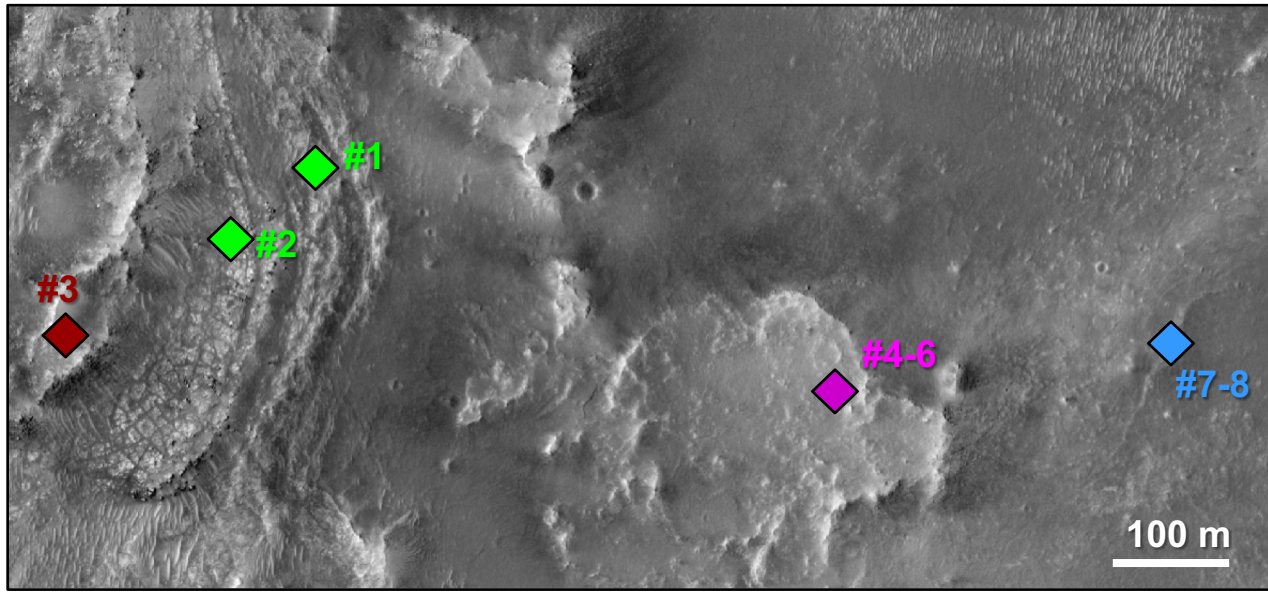
Campaign 1

- Samples #1-2: **Olivine-Carbonate Unit**
  - 2 variably altered samples to determine aqueous alteration conditions, habitability, look for biosignatures, and assess Martian carbon cycle.
- Sample #3: **Cap Rock**
  - Provides information on absolute age calibration, differentiation, and magnetic history.

Campaign 2

- Samples #4-6: **Low-Ca Pyroxene** (+Melt Rock if present)
  - 3 samples providing information on absolute age calibration, differentiation, and magnetic history.
- Samples #7-8: **Ridge interior and adjacent**
  - 2 samples providing information on subsurface habitability potential and aqueous conditions possibly leading to second episode of Fe/Mg smectite formation.

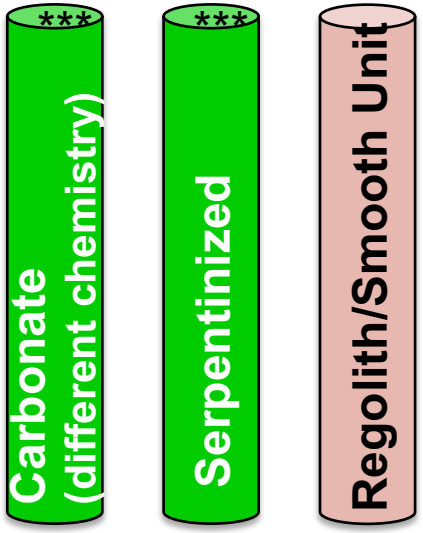




Waypoint 2 (NE Syrtis): Ol-Carb Unit

- **Objective:** Characterize variation in carbonate chemistry, especially at the small scale (e.g., talc, serpentine*), and implications for aqueous conditions and habitability.

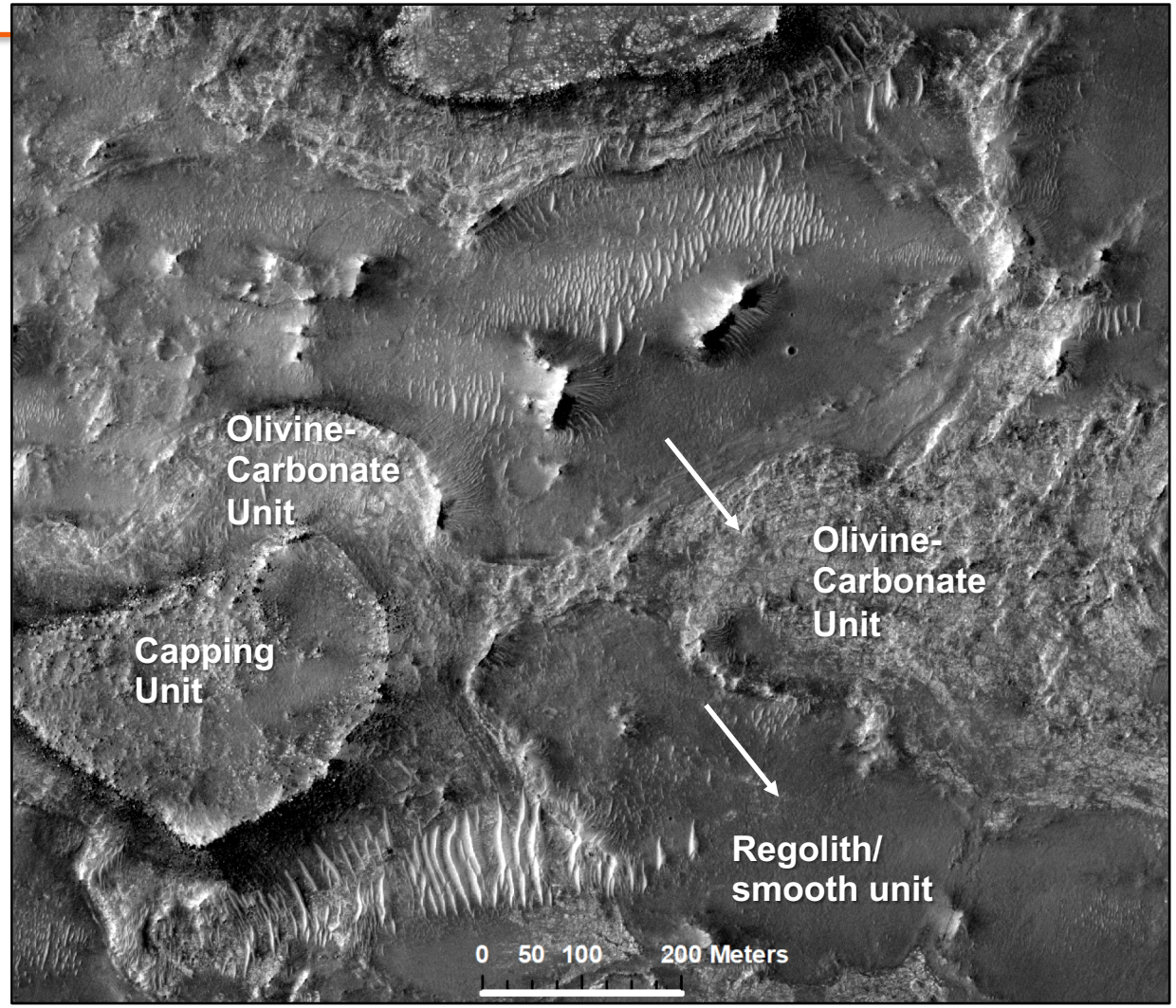
- Use Mastcam-Z, Supercam, and PIXL to triage and identify carbonate samples with varied compositions.
- Use SHERLOC, Supercam to look for organics in carbonate.
- Use RIMFAX to connect these units together and relate to observations at ROI1.



Samples #9-11

2 Carbonate samples with different chemistry

1 Regolith sample, for comparing with previous Martian regolith observations and to aid preparation for human exploration



*Serpentine not definitively identified here, but can be anticipated based on low-T serpentinization in olivine lithologies on Earth and may have high potential for hydrocarbon preservation.

Waypoint 3 (NE Syrtis): Megabreccia

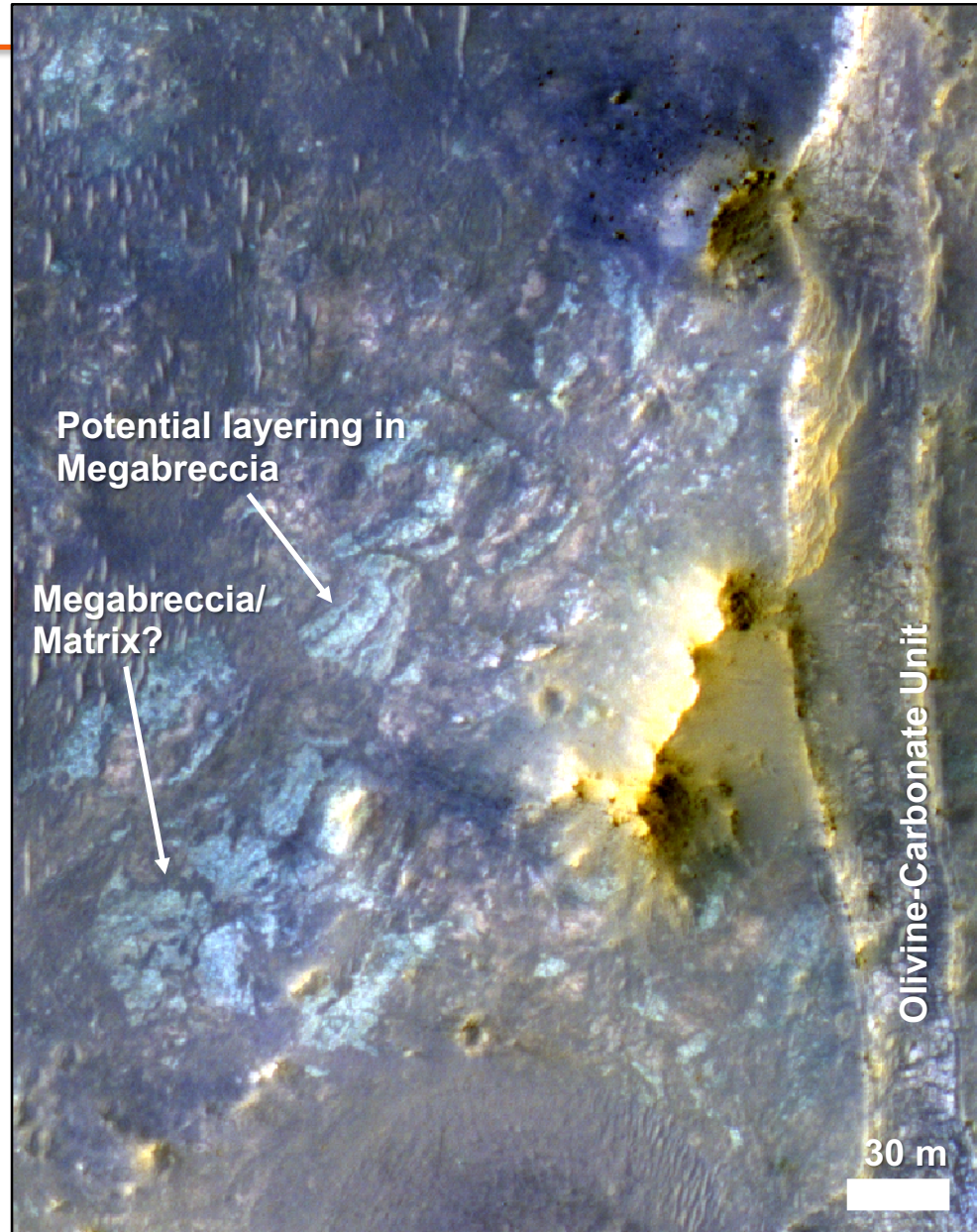
- **Objective:** Characterize early Noachian, pre-Isidis material preserved in megabreccia. Determine if pre-Isidis crust was igneous or sedimentary in origin.

- Use Mastcam-Z, Supercam, PIXL, SHERLOC/WATSON to identify different compositions and characterize any matrix, melt rock, or evidence for hydrothermal alteration.
- Use SHERLOC, Supercam to look for organics.
- Use Mastcam-Z, RIMFAX to characterize relationship with megabreccia host material.

Samples #12-14 characterizing pre-Isidis conditions

2 Megabreccia, sampling:
  a) different composition/matrix, or
  b) different strata

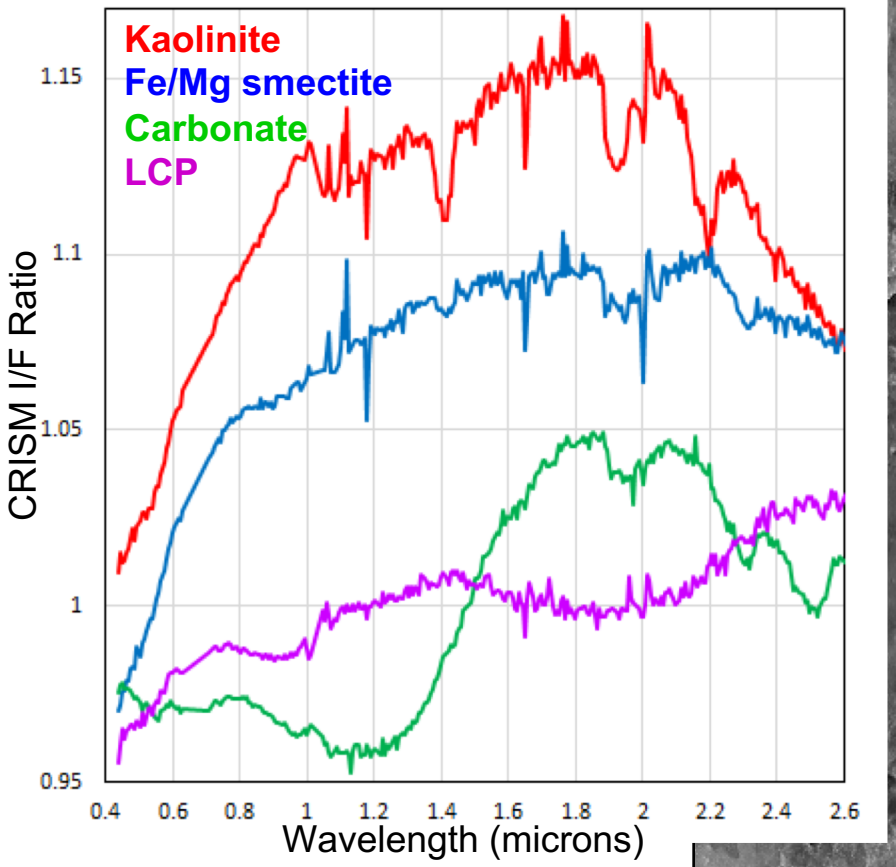
1 Melt Rock

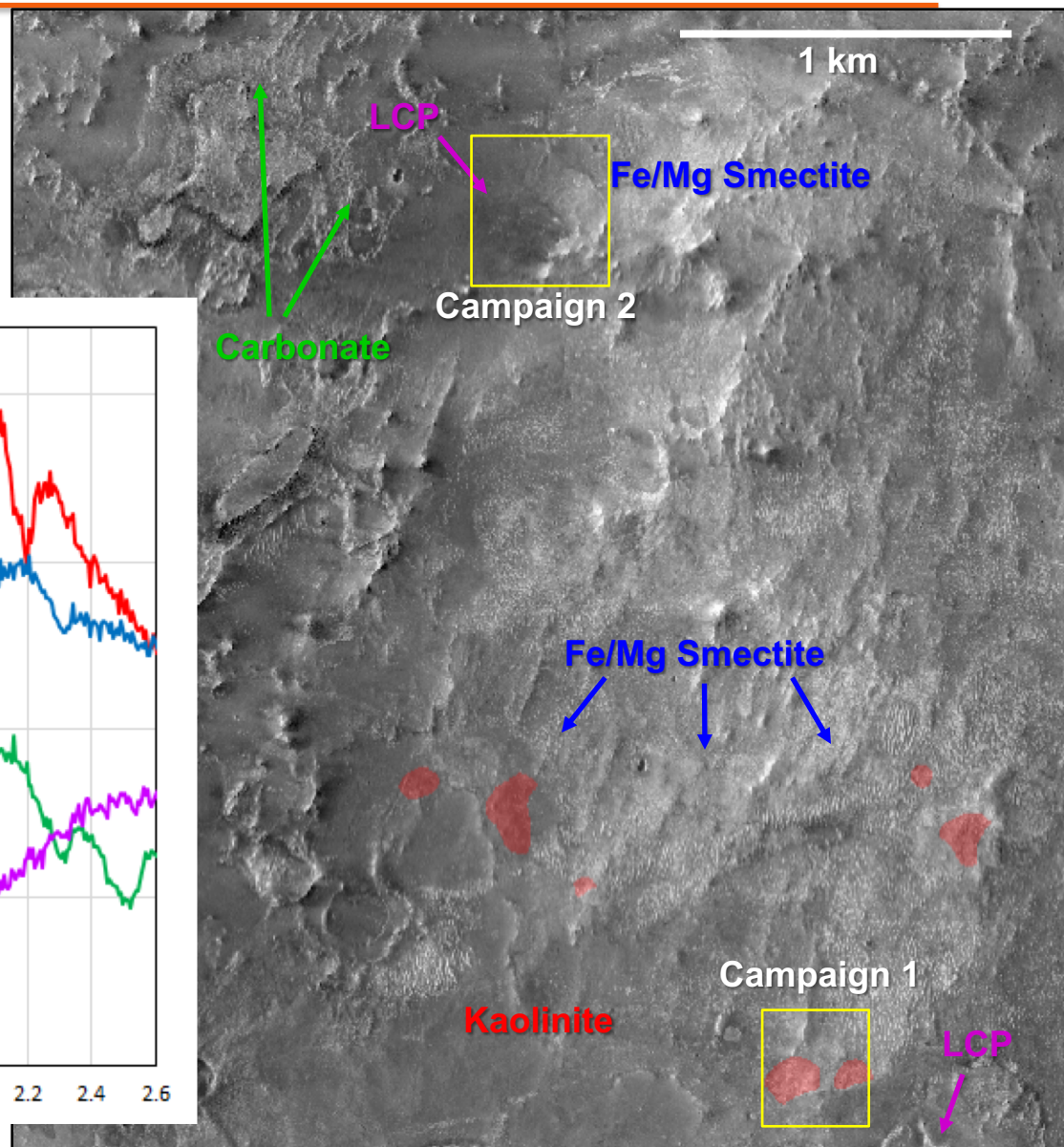


ROI 2 Overview (NE Syrtis)

- **Campaign 1: Basement unit (Kaolinite)**
  - Determine contact relationships between kaolinite, Fe/Mg smectite, and LCP.
  - Establish kaolinite and Fe/Mg smectite formation process.
  - Assess habitability, search for biosignatures, collect samples.

- **Campaign 2: Basement unit (Fe/Mg smectite)**
  - Investigate larger outcrop bearing Fe/Mg smectite.
  - Determine contact relationships between Fe/Mg smectite and LCP.
  - Establish Fe/Mg smectite formation process.
  - Assess habitability, search for biosignatures.





ROI 2- Campaign 1 (NE Syrtis): Altered Lithologies in Basement

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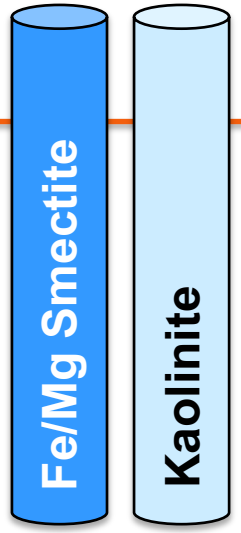
- **Objective:** Determine the timing and formation mechanism of kaolinite. Assess implications for habitability and biosignature preservation. Document contacts and stratigraphic relationships between the unaltered (LCP) and altered lithologies (kaolinite, Fe/Mg smectite, carbonate).

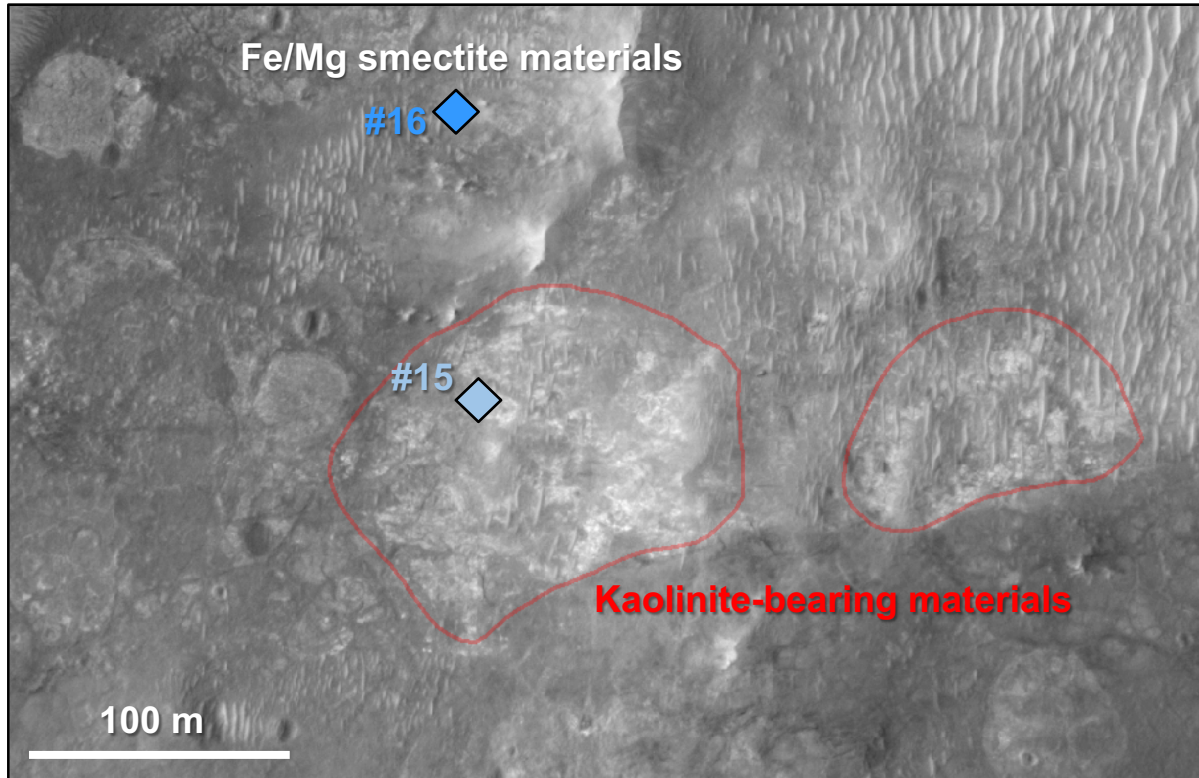
- Use Mastcam-Z and Supercam to characterize physical and compositional properties of units.
- Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine origin and alteration.
- Use SHERLOC, Supercam to look for organics in kaolinite and Fe/Mg smectite samples.
- Use RIMFAX to probe subsurface structure in basement.



Samples #15-16 to characterize different aqueous alteration conditions

1 Fe/Mg Smectite

1 Kaolinite



ROI 2- Campaign 2 (NE Syrtis): Altered Lithologies in Basement

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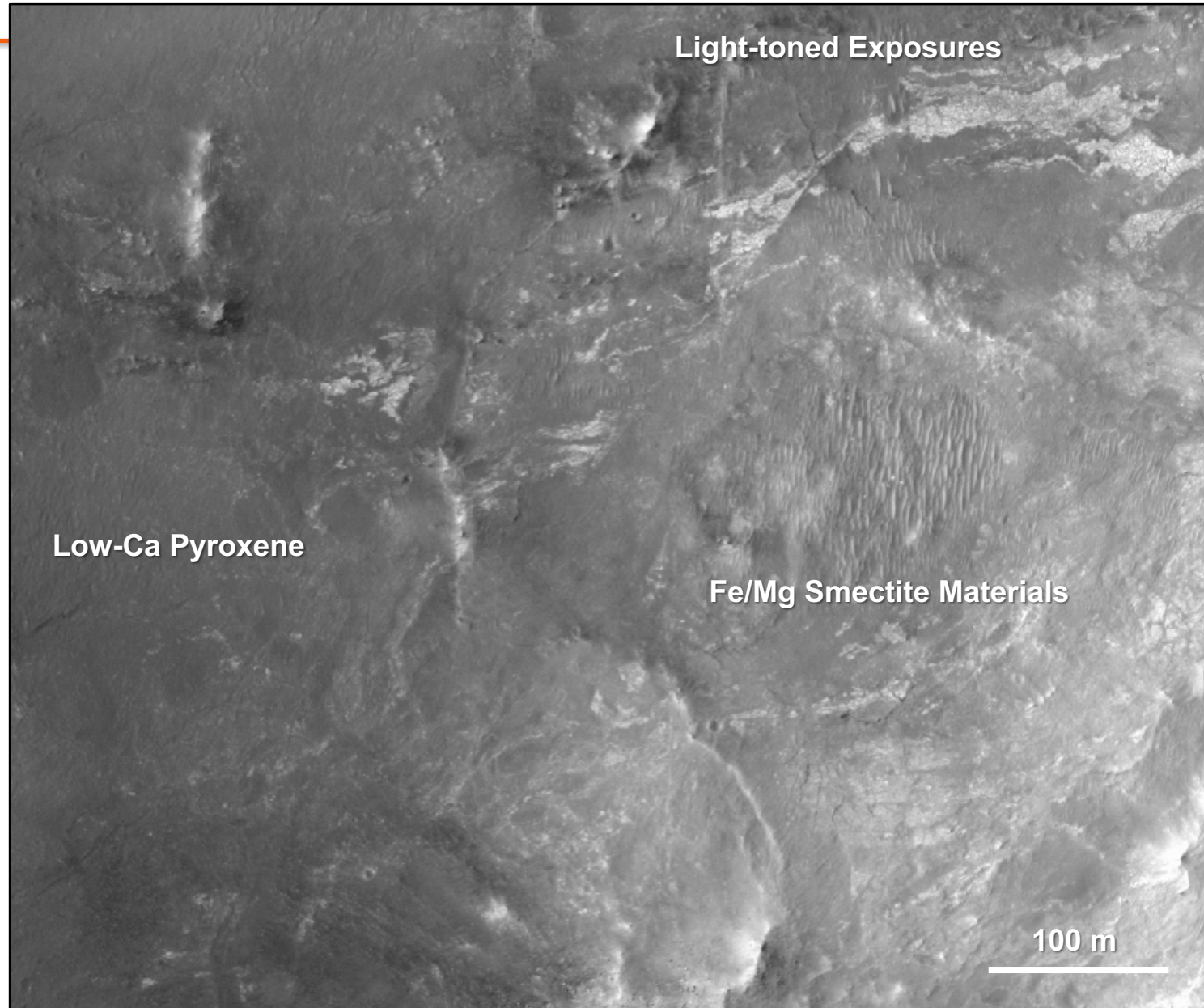
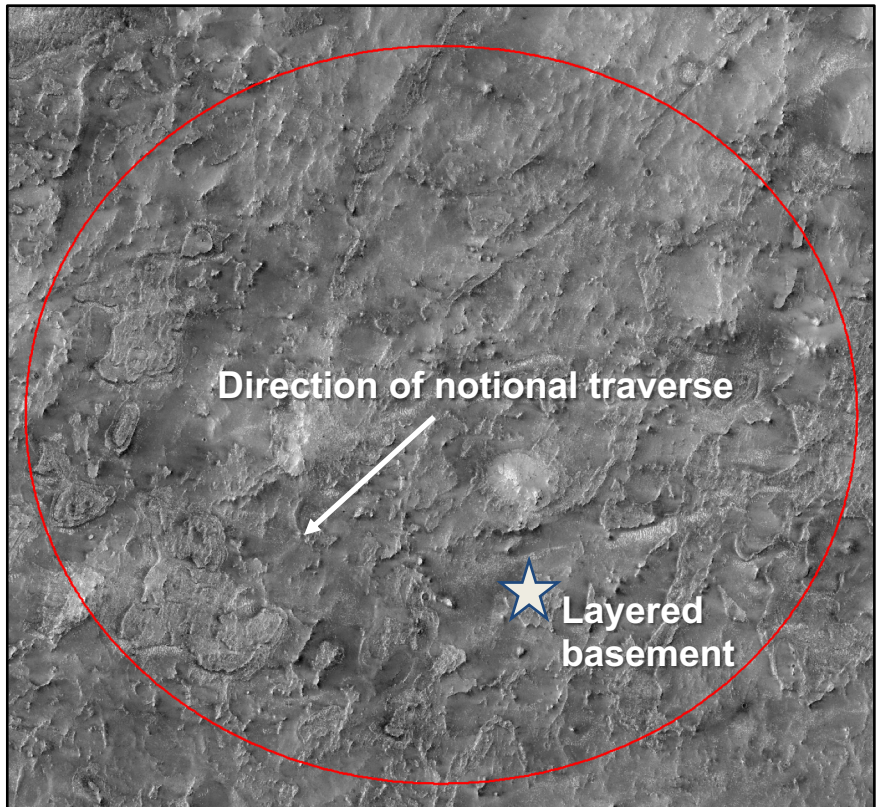
- **Objective:** Investigate a larger exposure of Fe/Mg smectite-bearing outcrop and the contact with LCP-enriched basement material. Determine the origin and composition of light-toned exposures in the basement unit.

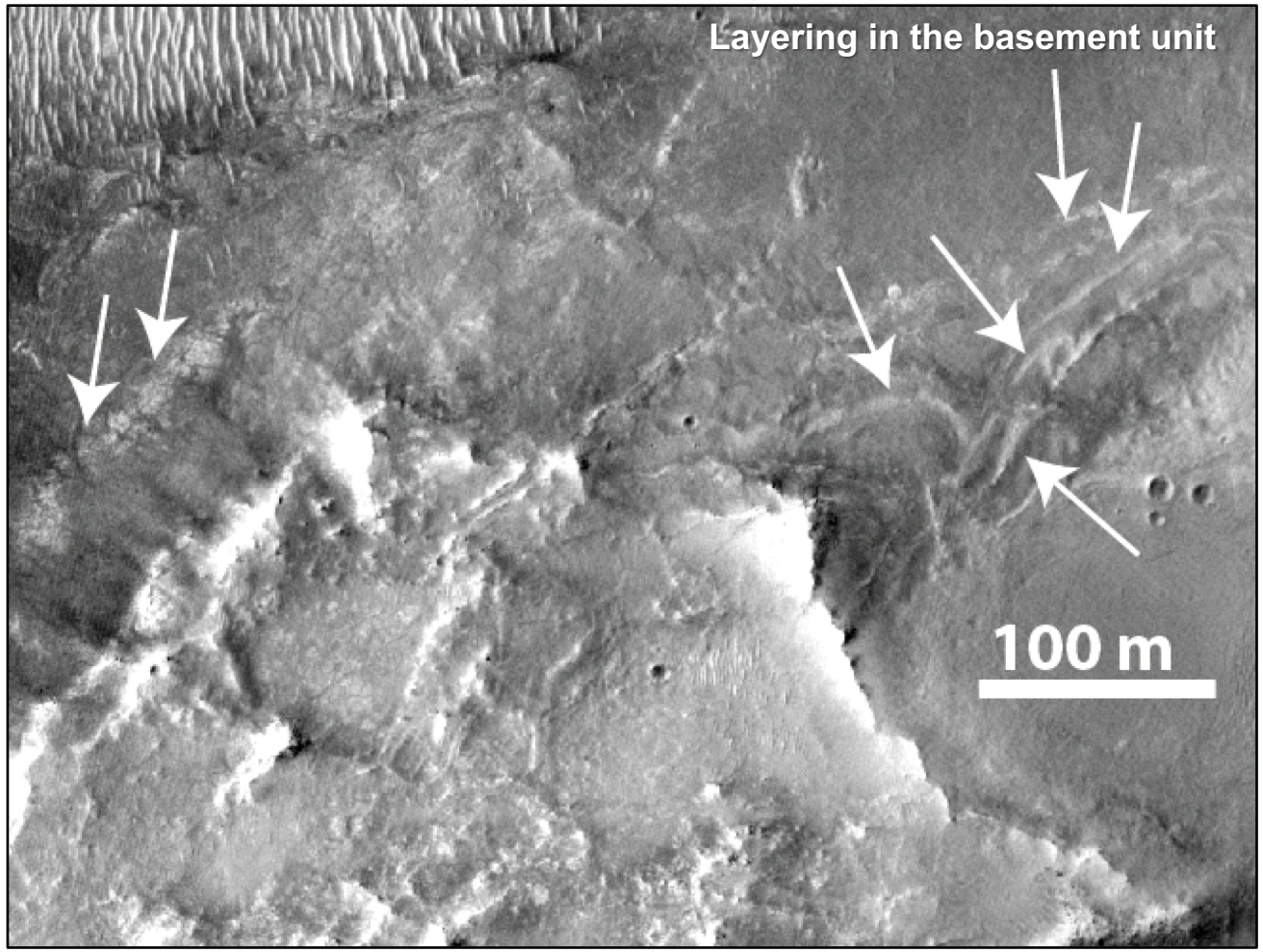
- Use Mastcam-Z and Supercam to characterize physical and compositional properties of units.
- Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine origin and alteration.
- Use SHERLOC, Supercam to look for organics in kaolinite, Fe/Mg smectite samples.
- Use RIMFAX to probe subsurface structure in basement.



Optional Waypoint: Layered Basement

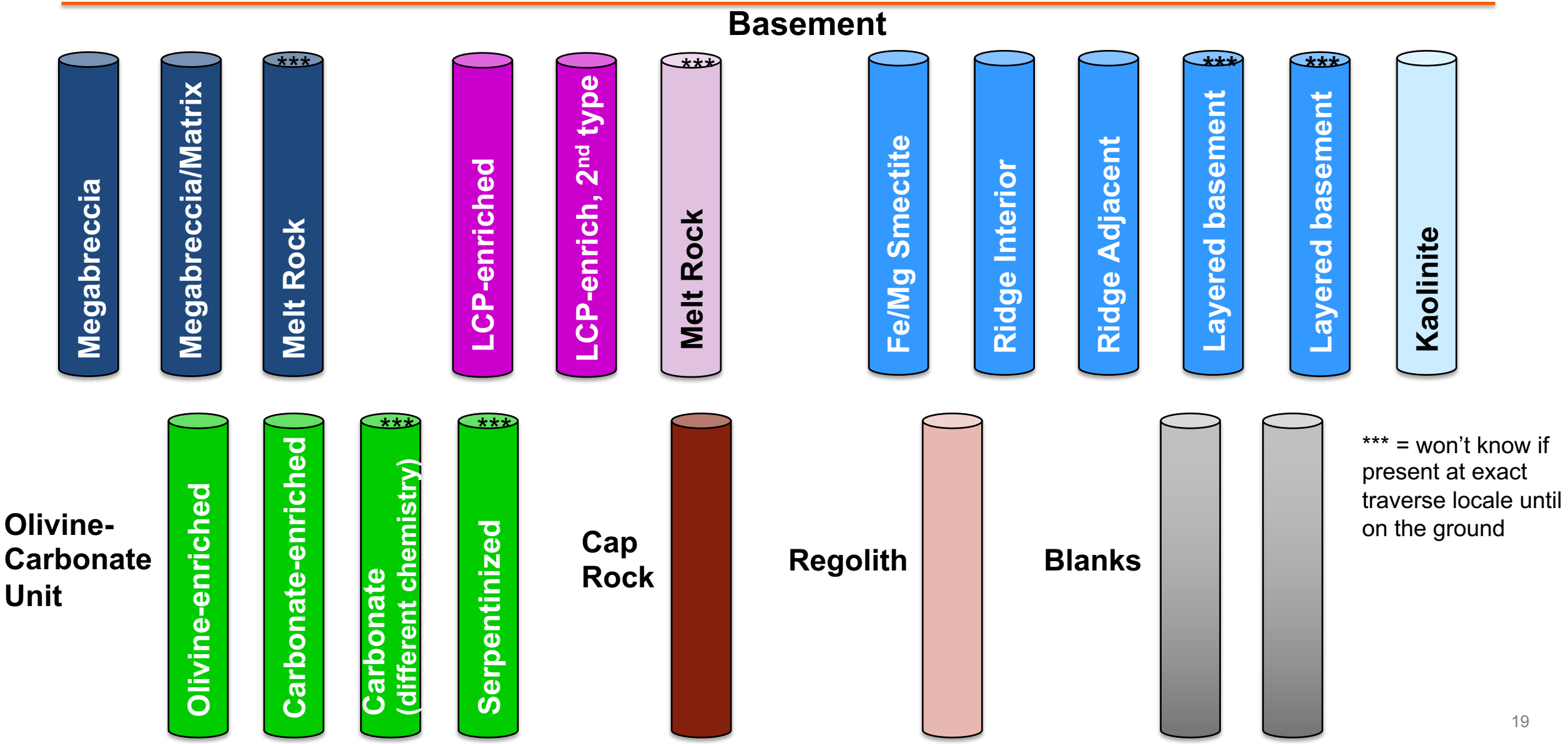
- **Objective:** Investigate the composition and petrogenesis of layered strata in the basement, which offers a unique window into early Noachian stratigraphy not exposed at other sites.





100 m

Baseline NE Syrtis Mission Sample Cache



Extended Mission Exploration (NE Syrtis)

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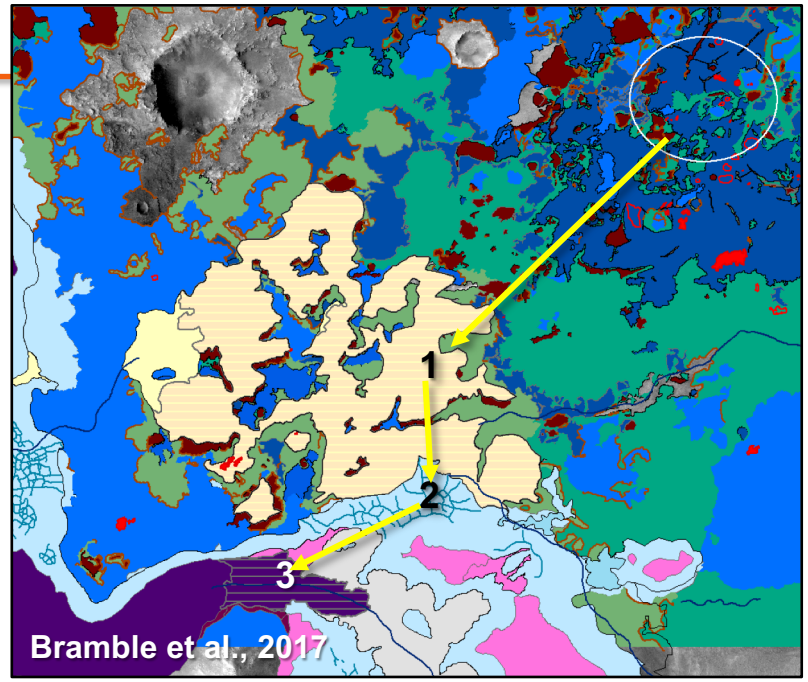
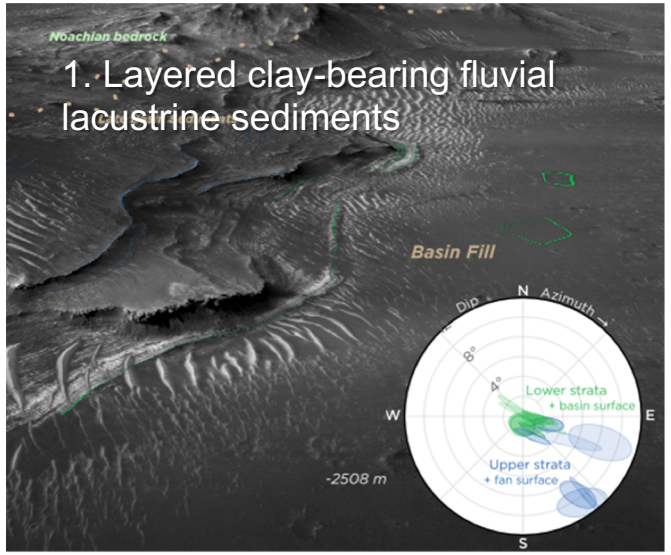
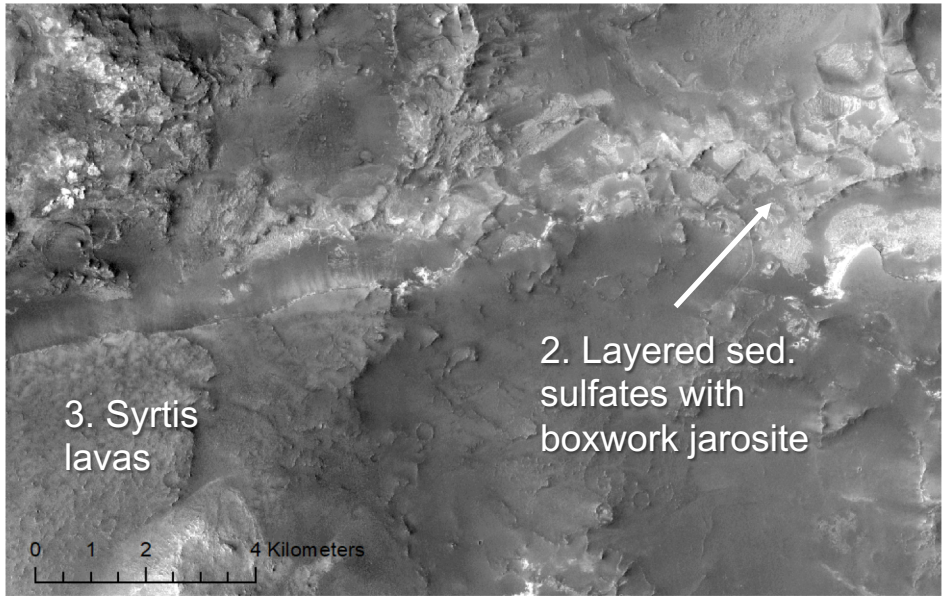
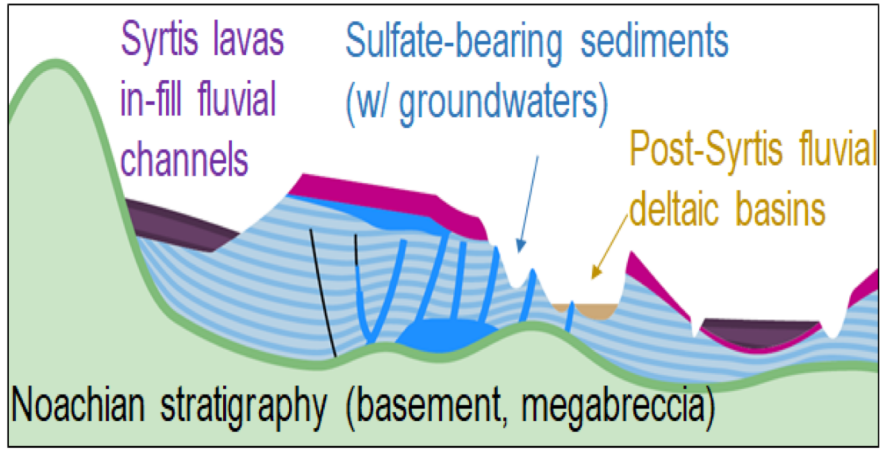
1. **Late Hesperian/Amazonian sediments** (16 km SW): Post-Syrtis lava episode of lakes and streams. Search for concentrated organics.
2. **Sulfates** (24 km SW): Sedimentary sequence representing deep basin sedimentation or airfall deposition and alteration, recording Martian S cycle. Groundwater-driven jarosite mineralization of fractures formed by dewatering allow age dating. Search for sulfate-mineralized biosignatures.
3. **Syrtis Major lavas** (35 km SW): Samples of Hesperian lavas could help constrain evolution of the martian interior and provide an age date high in the stratigraphy.

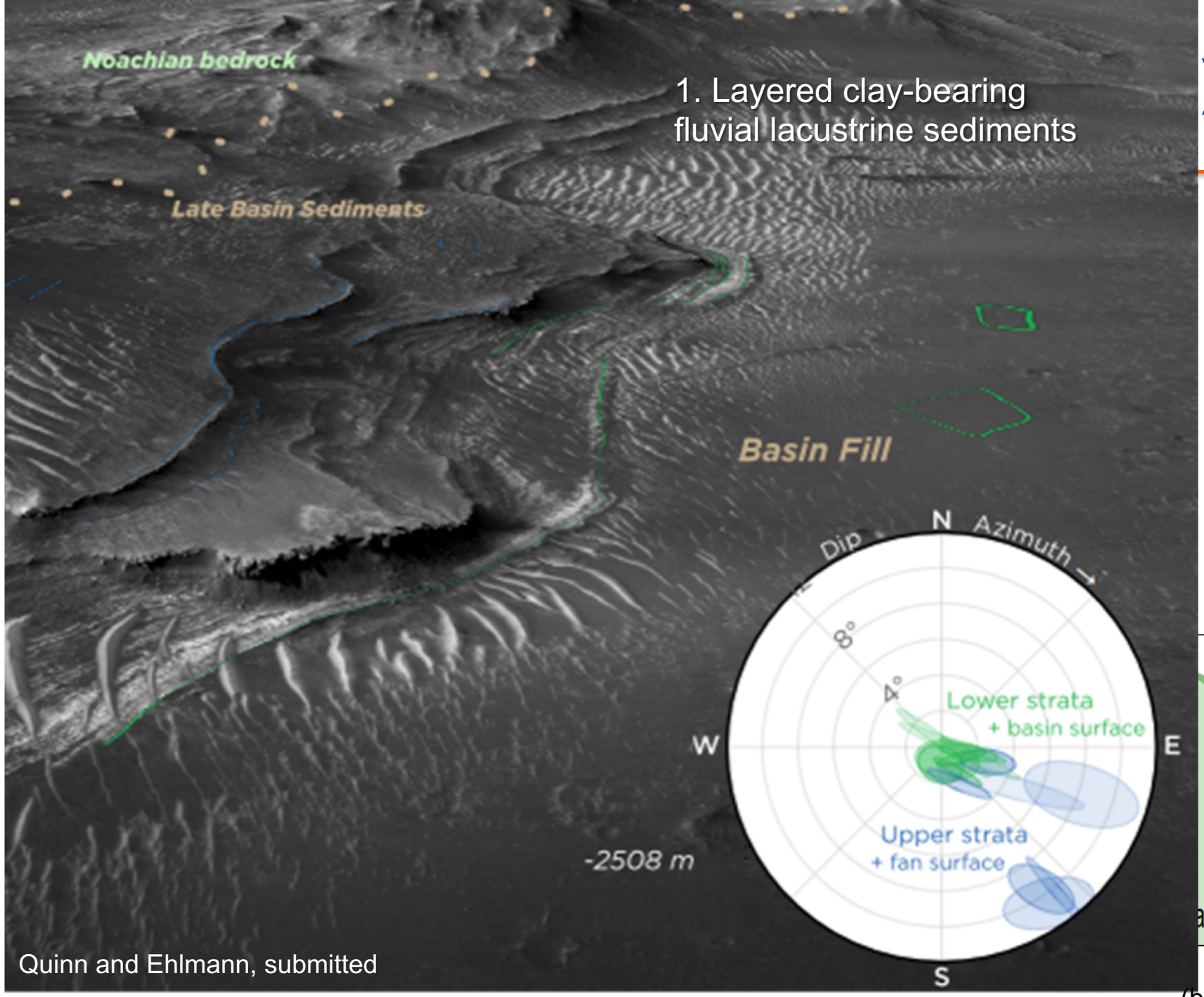








(bottom figures) Quinn and Ehlmann, submitted



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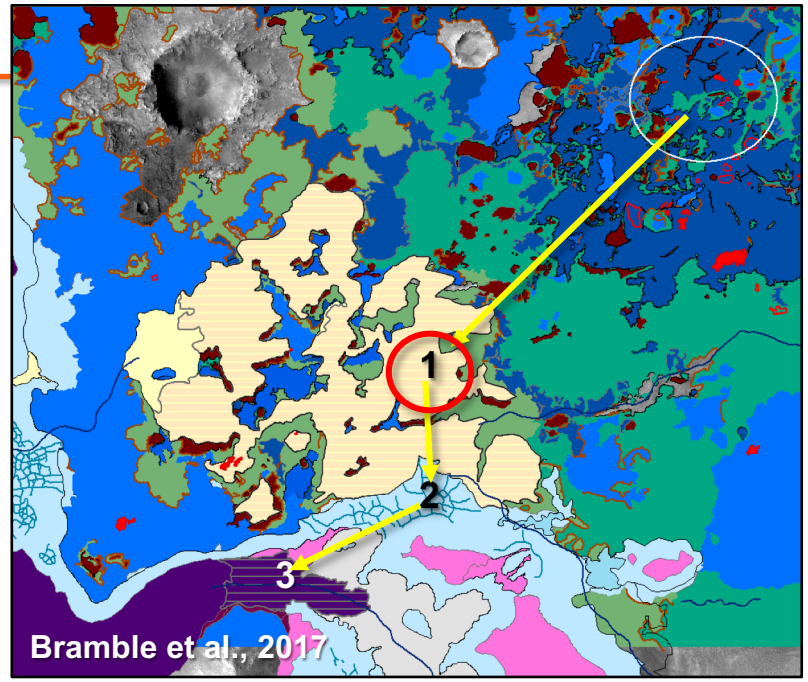

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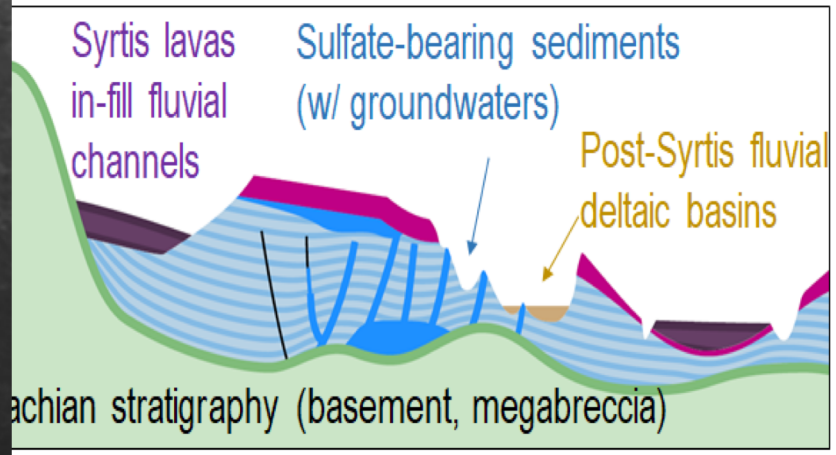

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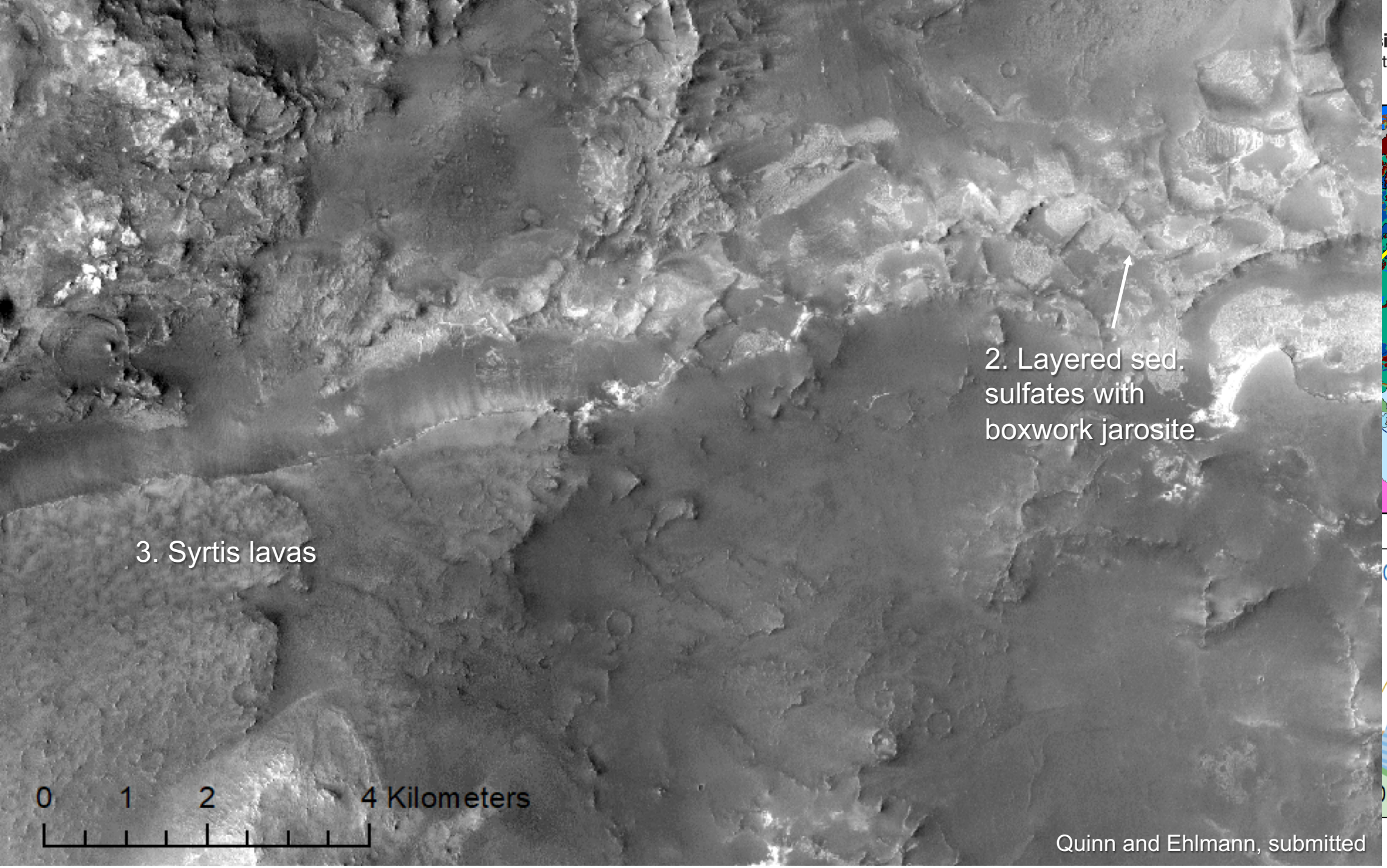

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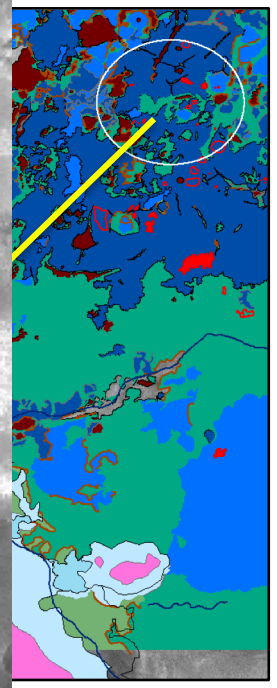

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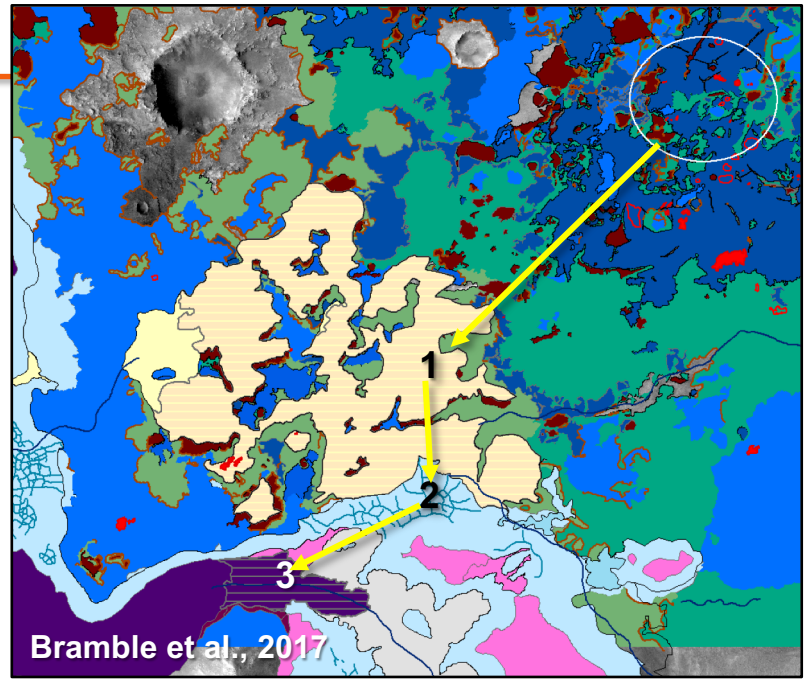
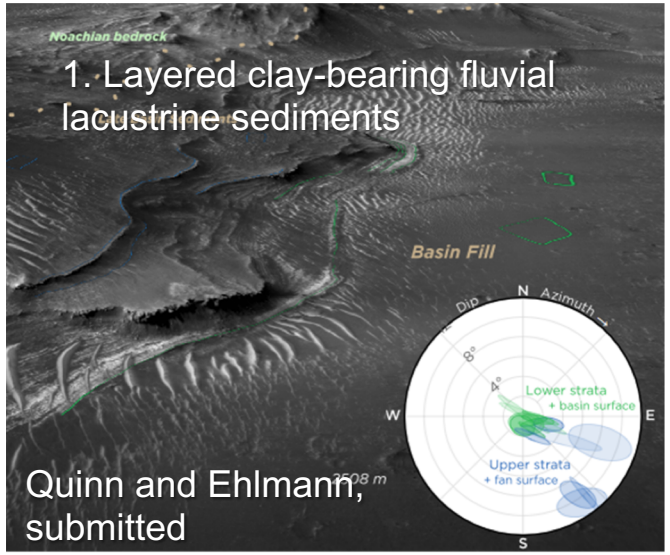
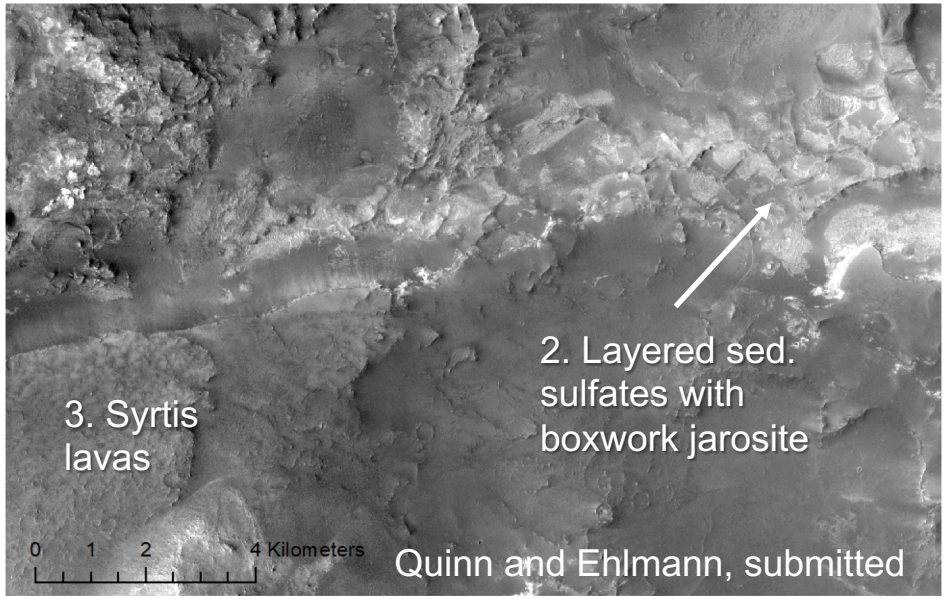
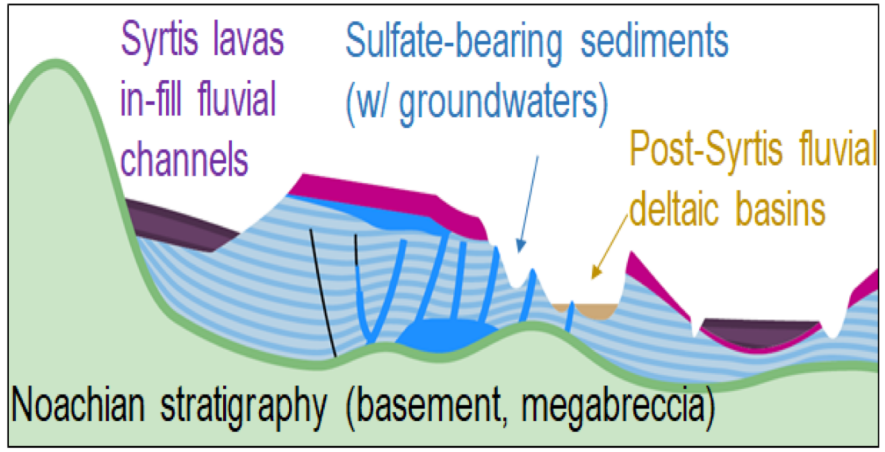
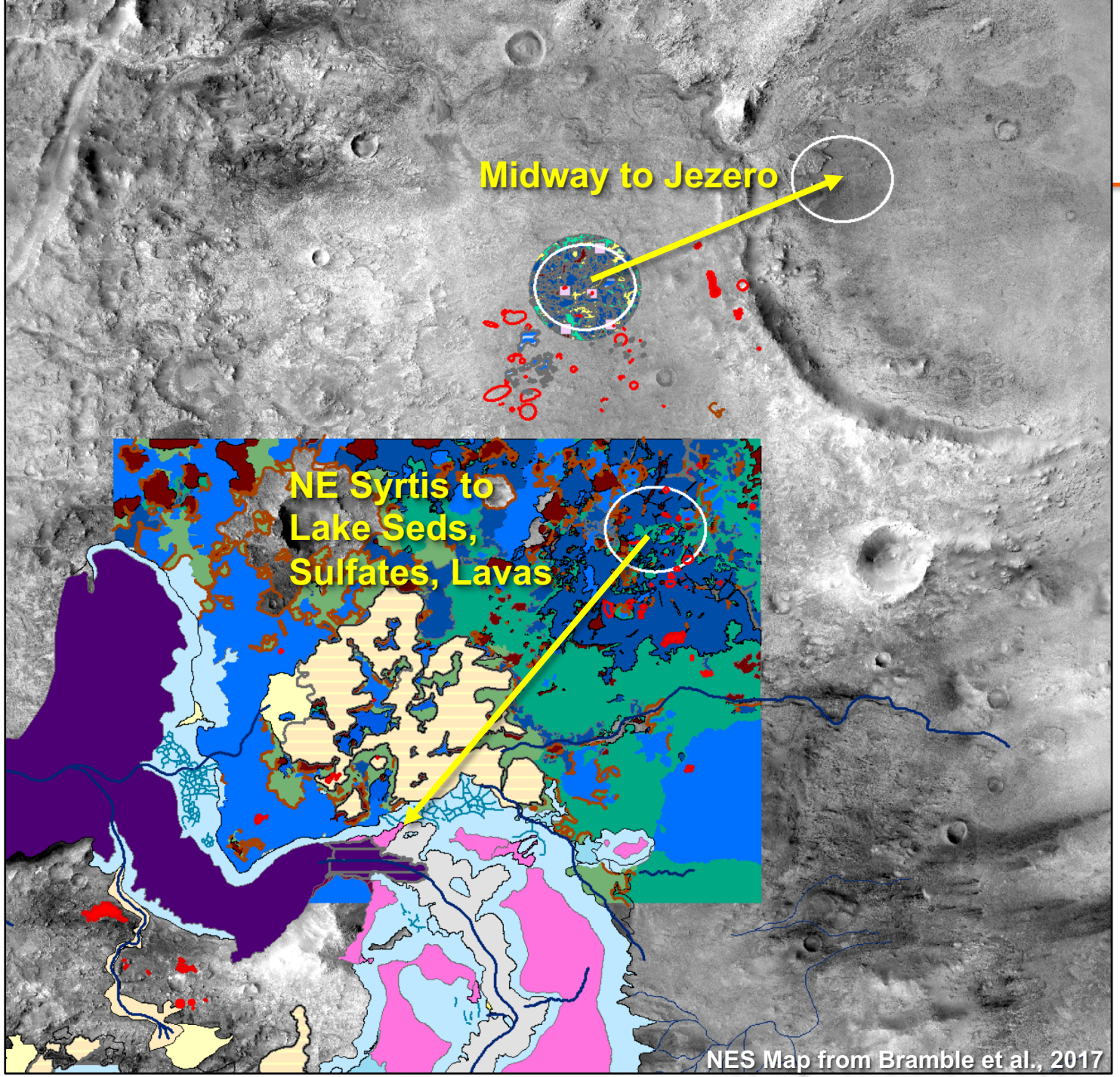








(bottom figures) Quinn and Ehlmann, submitted



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Two Ellipses That Land on Noachian Stratigraphy:

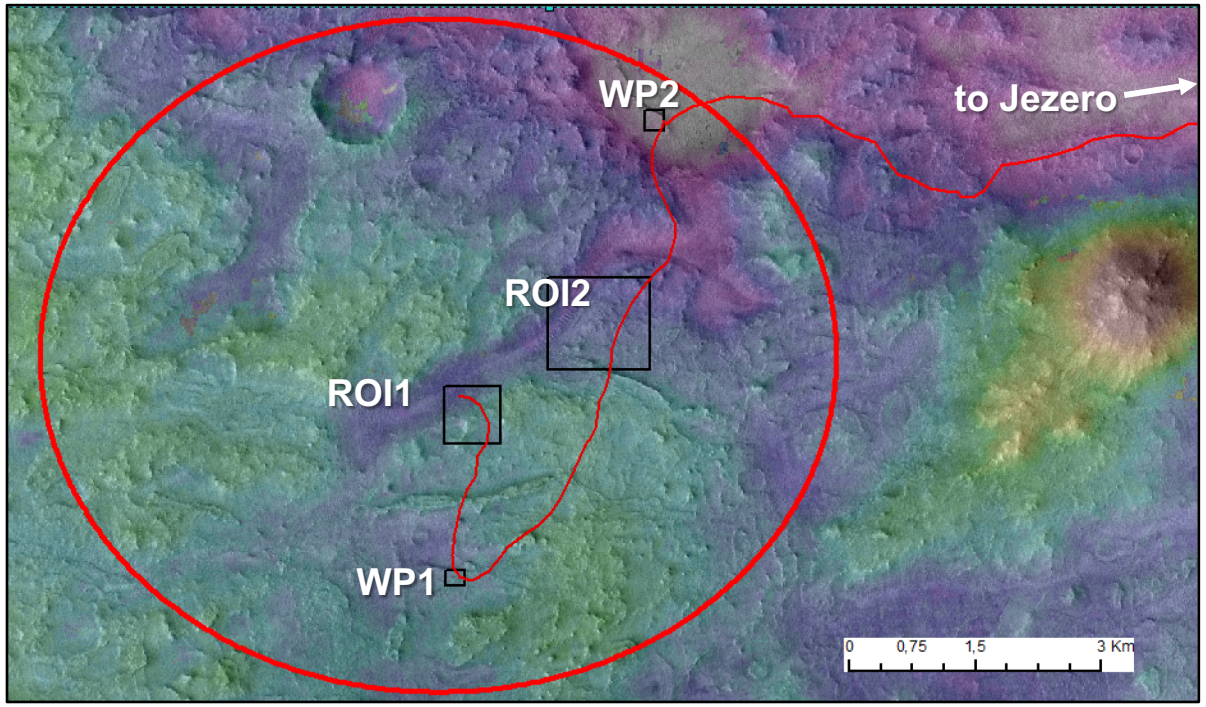
Different Extended Missions

1. NE Syrtis → Sediments, Lavas
2. Midway → Jezero crater

Notional Mission Scenario for Midway

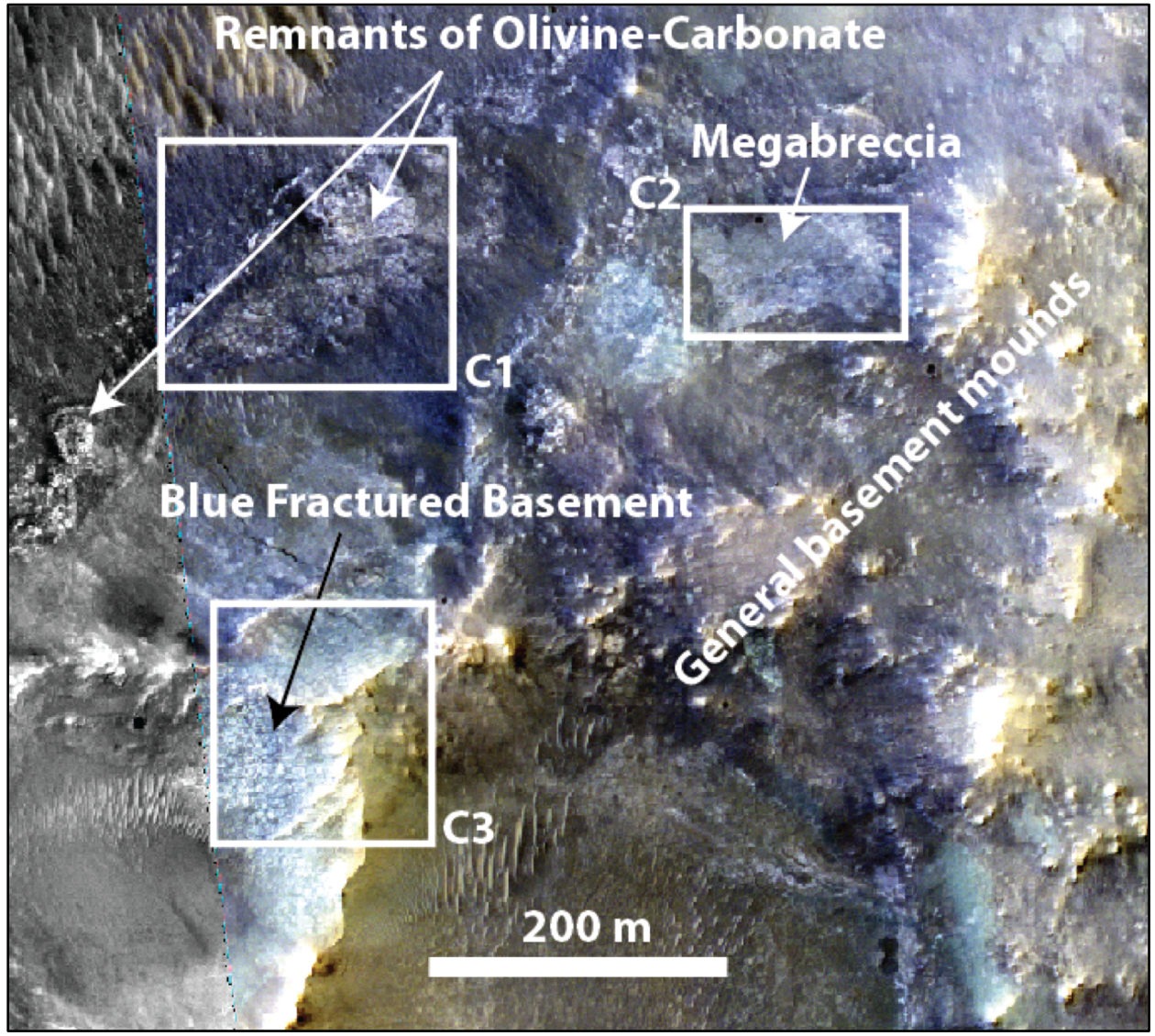
- Traverse samples all unaltered and altered lithologies inferred to be present based on morphologic similarities with NES units. Total traverse from landing to WP2 = 10 km.
- Land. Drive in the direction of Jezero crater, making in situ measurements along the traverse. Discovery-driven decisions:
  - Follow the fractures and redox boundaries to sample locations of groundwaters and possible habitats.
  - Follow the sedimentary facies to sample locations of surface waters and possible habitats.
- **ROI 1: Olivine-Carbonate, Megabreccia, and Basement**
  Campaign 1: Characterize olivine-carbonate unit exposed in channel wall. Collect a sample for comparison with typical ol-carb unit.
  Campaign 2: Characterize large megabreccia block and collect variably altered samples.
  Campaign 3: Sample the unaltered (LCP) basement unit.
- **Waypoint 1: Basement ridge.** Collect altered and unaltered samples.
- **ROI 2: Olivine-Carbonate and Basement Unit**
  Campaign 1: Characterize typical olivine-carbonate unit, collecting samples with varied alteration states when possible.
  Campaign 2: Characterize the fractured basement unit and relationship with the basement mounds. Collect altered and unaltered lithologies when possible (Fe/Mg-smectite, low-Ca pyroxene).
- **Waypoint 2: Layered deposit** in a closed depression.

Midway Notional Mission Scenario: ~10 km traverse



ROI 1 Overview (Midway)

- **Campaign 1: Olivine-carbonate unit in channel wall**
  - Establish petrogenesis
  - Determine contact relationships
  - Establish carbonate formation process
  - Assess habitability, search for biosignatures, collect samples
- **Campaign 2: Megabreccia**
  - Characterize pre-Isidis materials
  - Examine relationship between megabreccia and basement mounds
  - Assess habitability, search for biosignatures, collect samples
- **Campaign 3: Basement unit**
  - Establish petrogenesis
  - Determine contact relationships between basement and overlying material
  - Collect unaltered basement lithologies (LCP)



ROI 1- Campaign 1 (Midway): Ol-Carb Unit in Channel Wall

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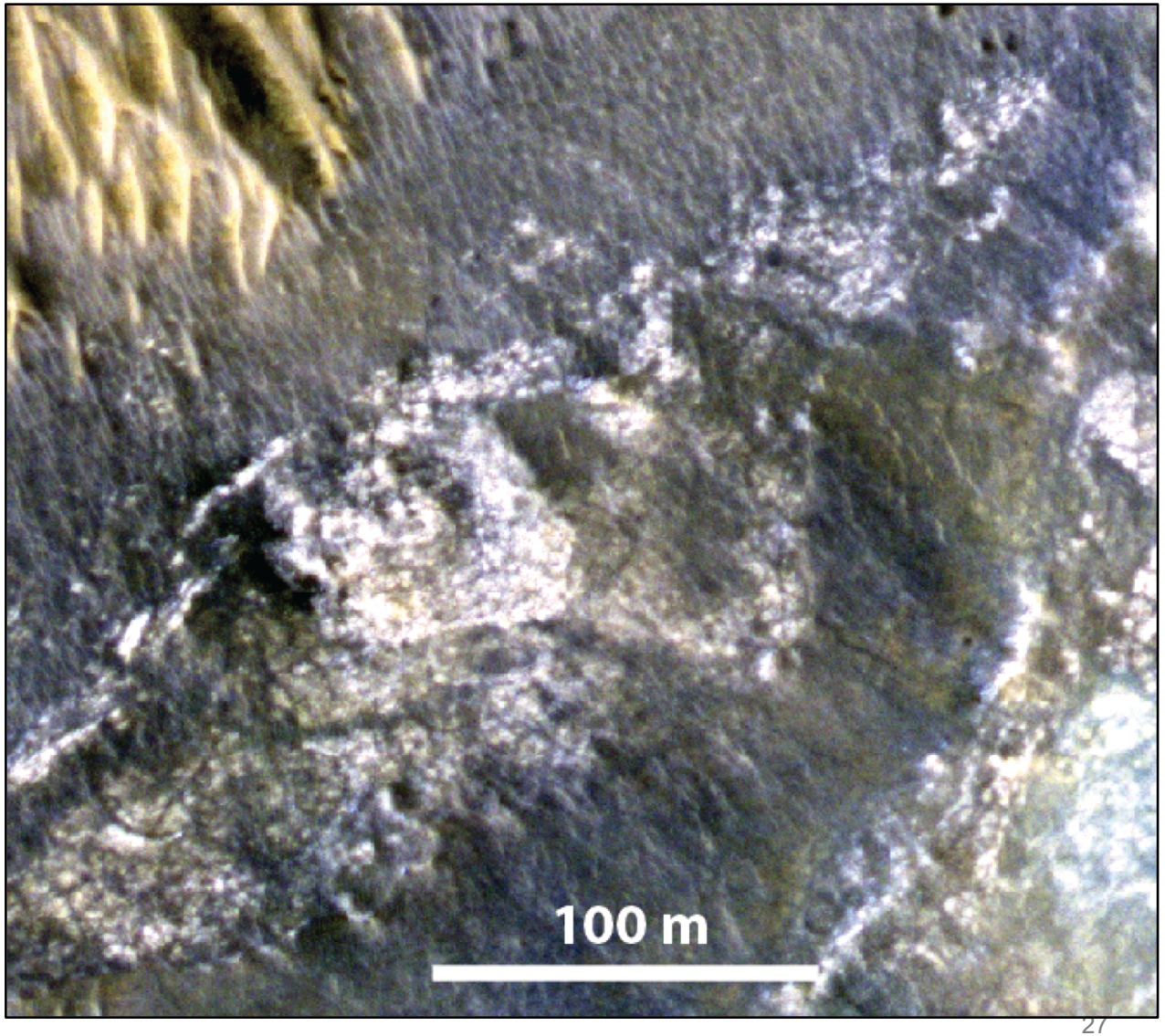
- **Objective:** Identify the lithologies exposed in channel wall, interpret their petrogenesis, history of interaction with water, and time of emplacement.

- Use Mastcam-Z, Supercam to characterize physical and compositional properties of units.
- Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine origin and alteration.
- Use SHERLOC, Supercam to look for organics in carbonates.
- Use RIMFAX to probe subsurface structure and contact.

Sample #1

1 Olivine-Carbonate Unit sample for comparison with others in the suite



ROI 1- Campaign 2 (Midway): Megabreccia

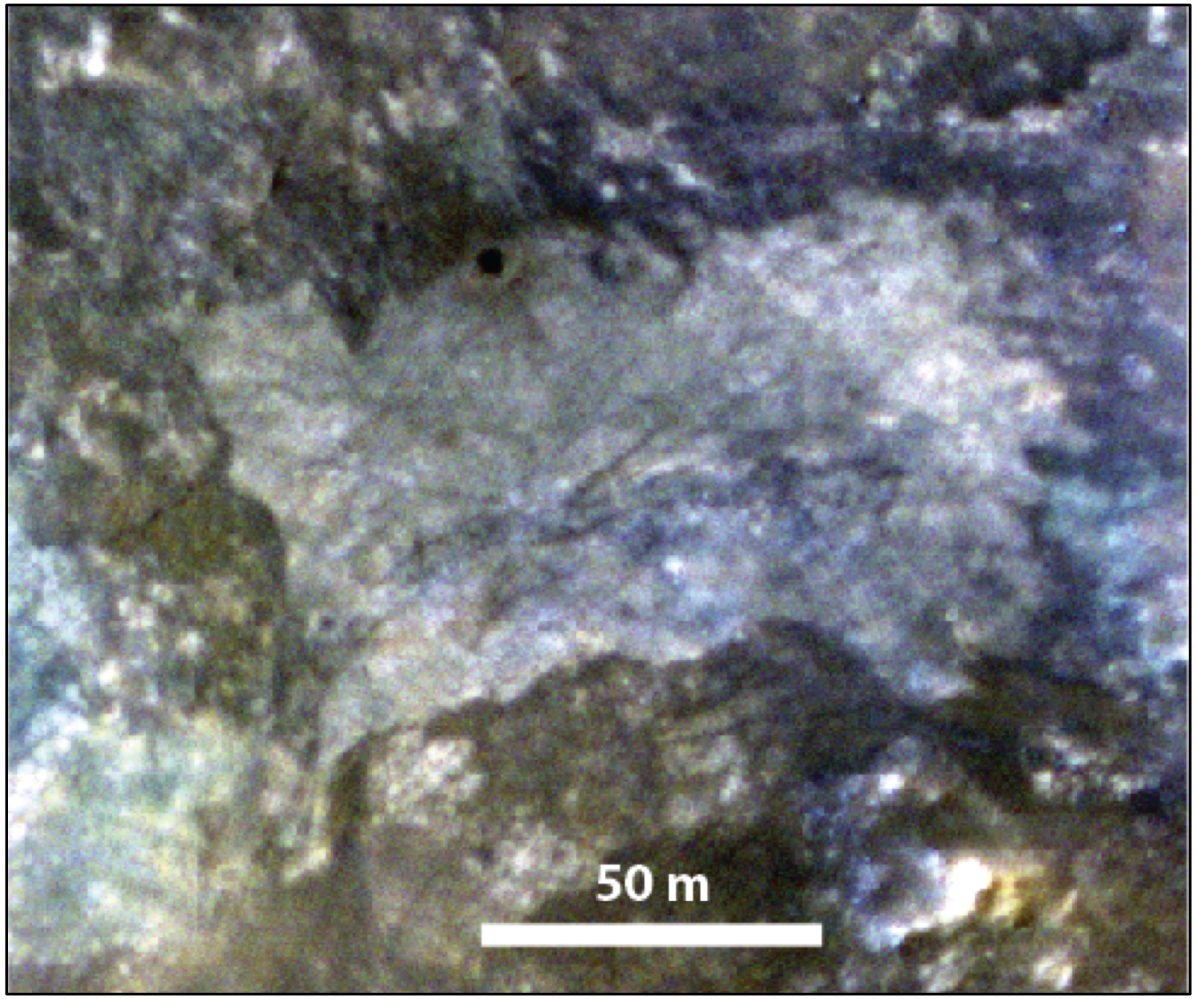
- **Objective:** Characterize early Noachian, pre-Isidis material preserved in megabreccia. Determine if pre-Isidis crust was igneous or sedimentary in origin.

- Use Mastcam-Z, Supercam, PIXL, SHERLOC/WATSON to identify different degrees of alteration and characterize any matrix, melt rock, or evidence for hydrothermal alteration.
- Use SHERLOC, Supercam to look for organics.
- Use Mastcam-Z, RIMFAX to characterize relationship with megabreccia host material.

Samples #2-4
Characterizing pre-Isidis conditions

2 Megabreccia, sampling:
a) different compositions/matrix
b) different strata

1 Melt Rock



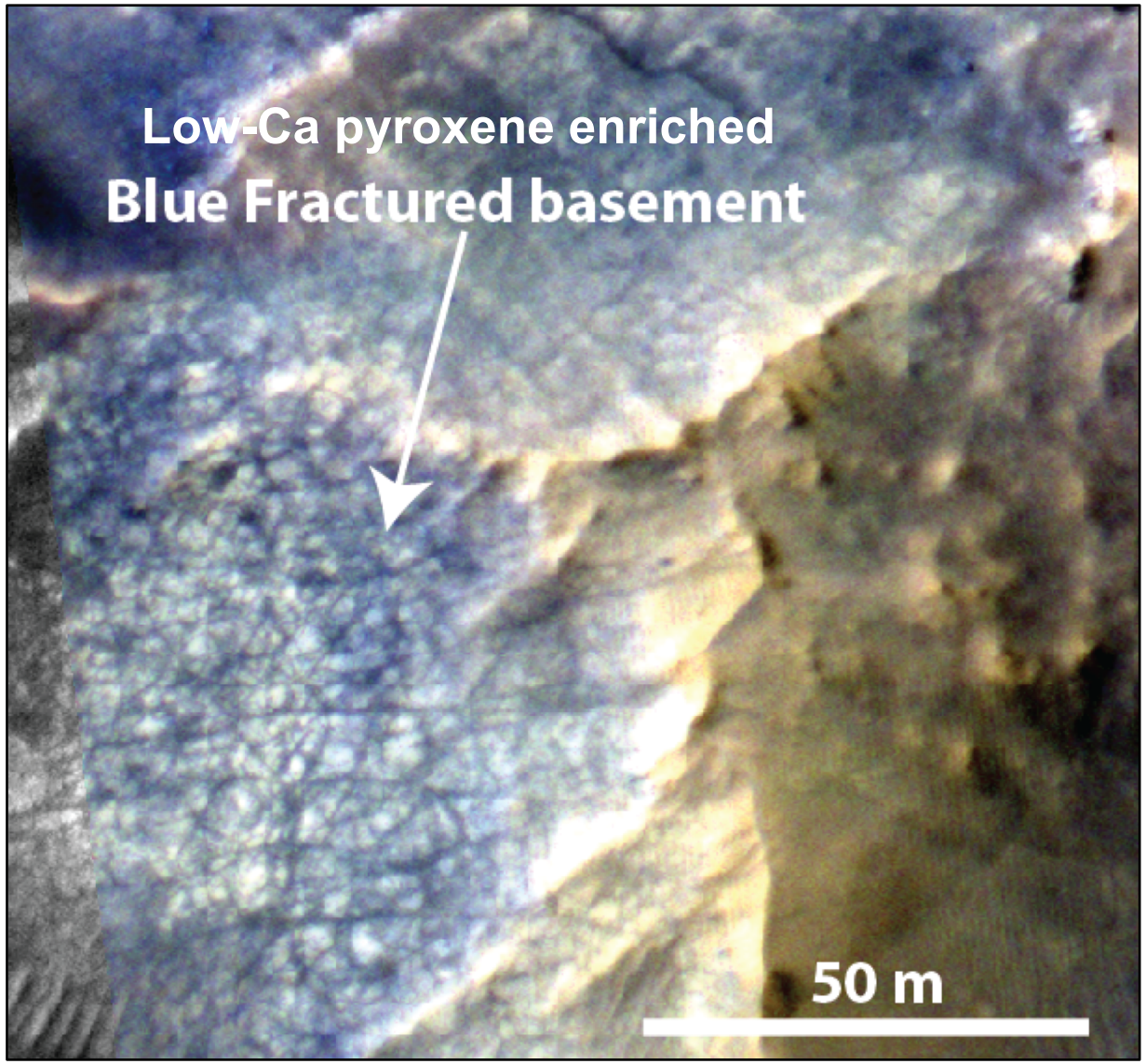
ROI 1- Campaign 3 (Midway): Basement

- **Objective:** Understand the origin and composition of unaltered lithologies (low-Ca pyroxene) in the Early Noachian basement. Assess fractures for subsurface habitability potential.

- Use Mastcam-Z, Supercam to characterize physical and compositional properties of units.
- Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine origin and alteration.
- Use SHERLOC, Supercam to look for organics in Fe/Mg smectite samples.
- Use RIMFAX to probe subsurface structure.

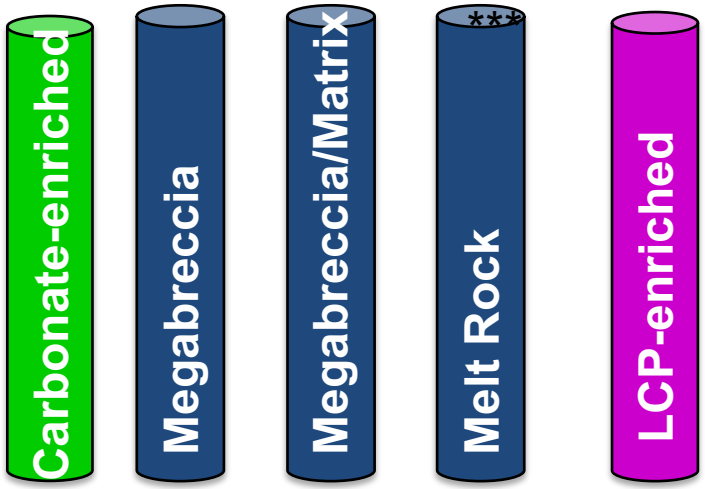
Sample #5

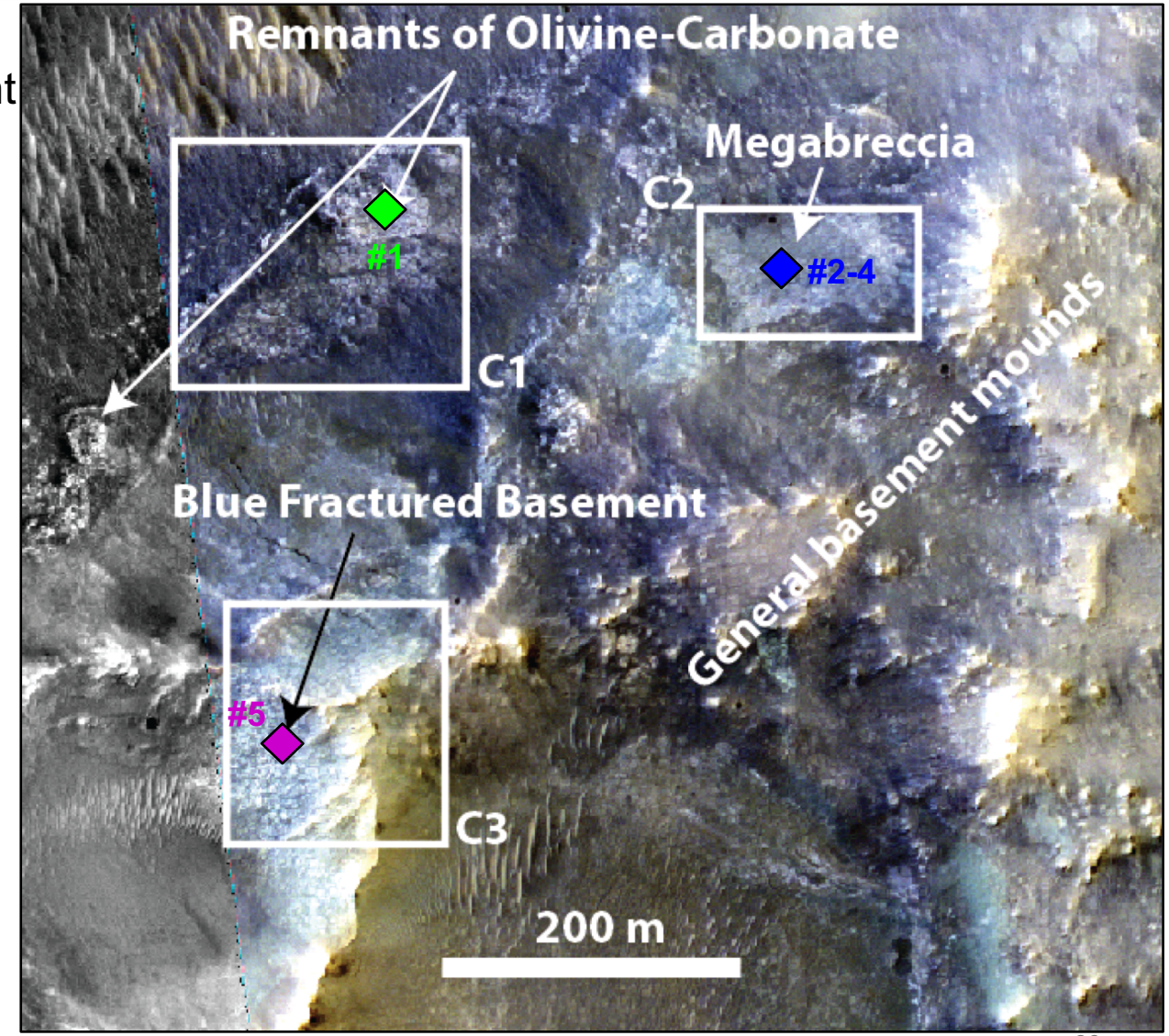
1 Low-Ca Pyroxene basement sample



ROI 1 Sampling Strategy (Midway)

- **Campaign 1**, Sample #1: **Olivine-carbonate unit**
  - Assess aqueous alteration conditions, emplacement age, habitability, and look for biosignatures.
- **Campaign 2**, Sample #2-4: **Megabreccia**
  - Study/date pre-Isidis crust and impact-related materials with different alteration degrees.
- **Campaign 3**, Sample #5: **Basement unit**
  - Unaltered basement provides information on absolute age calibration, differentiation, and magnetic history

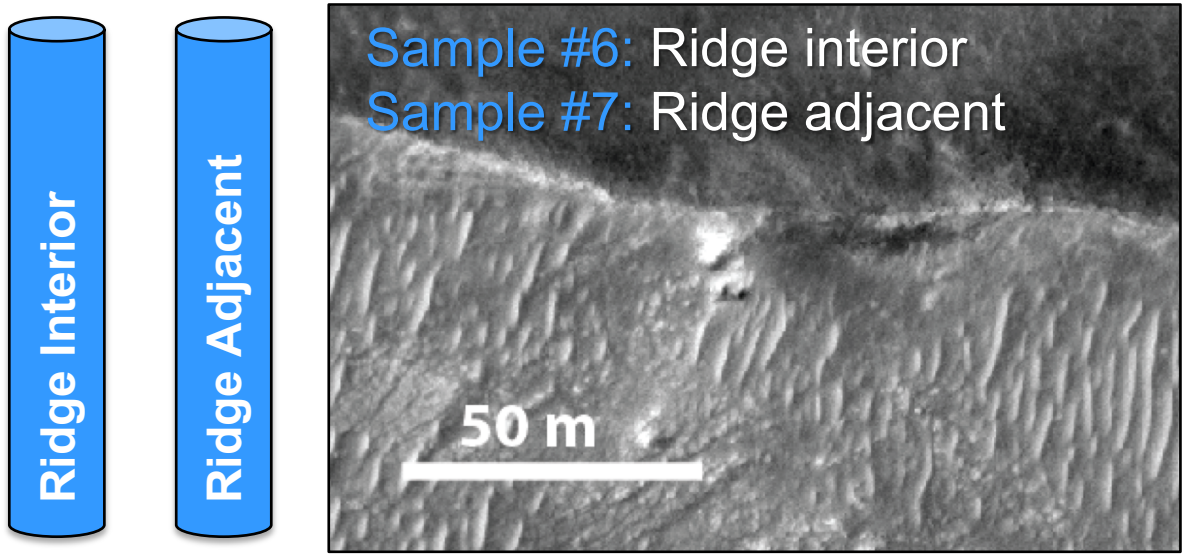


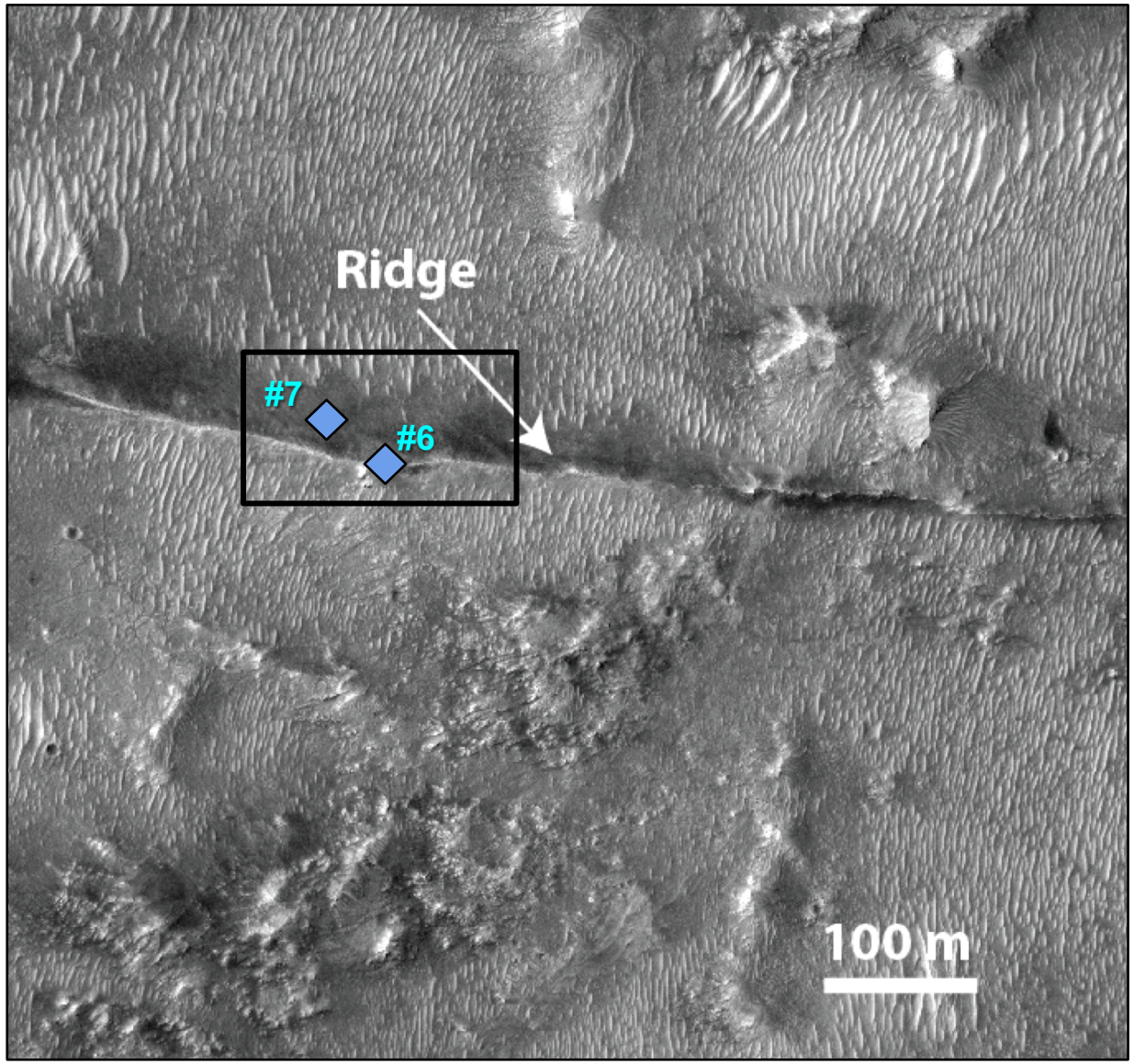


Waypoint 1 (Midway): Basement Ridge

- **Objective:** Determine if Fe/Mg smectites are present in ridges and represent a second episode of Fe/Mg smectite formation in the basement. Assess habitability potential in subsurface.

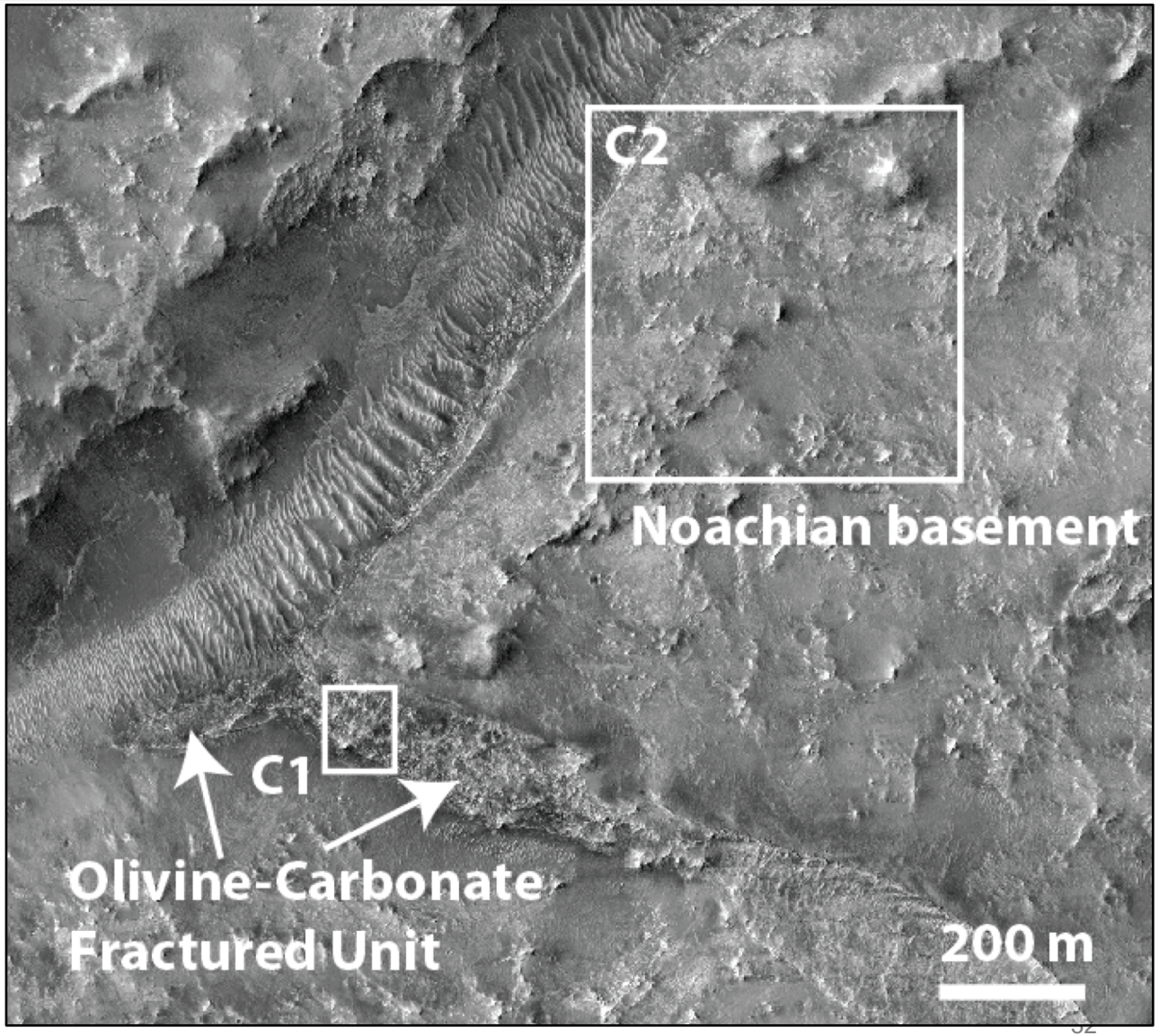
- Use Mastcam-Z, Supercam, PIXL, SHERLOC, WATSON to map microscale chemistry, mineralogy, and texture to determine origin and alteration.
- Use SHERLOC, Supercam to look for organics in Fe/Mg smectite samples.
- Use RIMFAX to probe subsurface structure.





ROI 2 Overview (Midway)

- **Campaign 1: Olivine-carbonate Unit**
  - Establish petrogenesis
  - Determine contact relationships between ol-carb and basement unit
  - Establish carbonate formation process, compositional variability
  - Assess habitability, search for biosignatures, collect samples
- **Campaign 2: Basement unit**
  - Establish petrogenesis
  - Characterize basement mounds
  - Determine relationship between unaltered and altered lithologies if both present
  - Assess habitability, search for biosignatures in any altered samples, collect samples



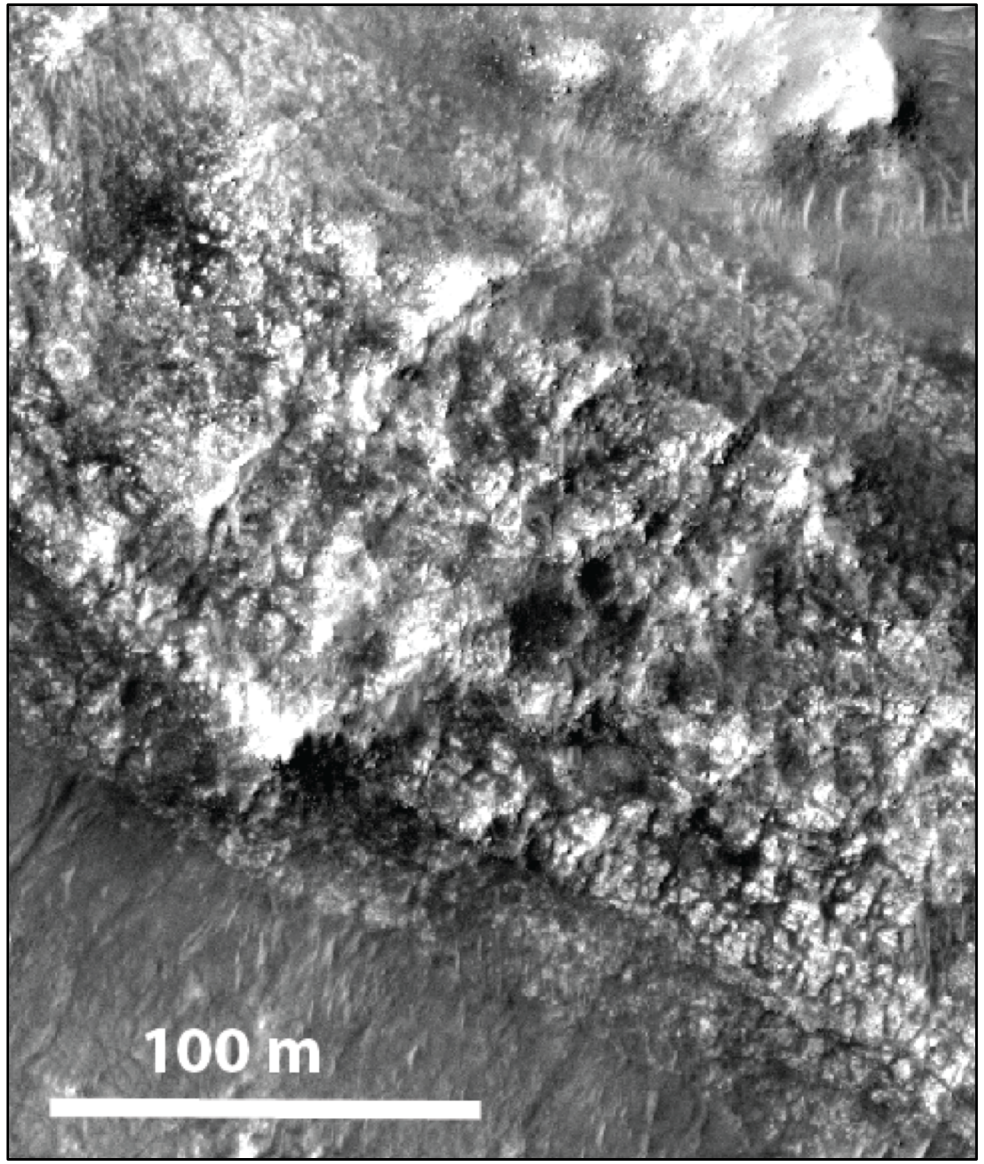
ROI 2- Campaign 1 (Midway): Ol-Carb Unit

- **Objective:** Characterize variation in carbonate chemistry, especially at the small scale (e.g., talc, serpentine), implications for aqueous conditions and habitability. Interpret petrogenesis, history of interaction with water, and contact relationships with the basement unit.

- Use Mastcam-Z, Supercam, and PIXL to triage and identify carbonate samples with varied compositions.
- Use SHERLOC, Supercam to look for organics in carbonate.
- Use RIMFAX to connect these units together and relate to observations at ROI1.

Samples #8-10

3 Olivine-Carbonate Unit samples, variably altered and serpentinized if present



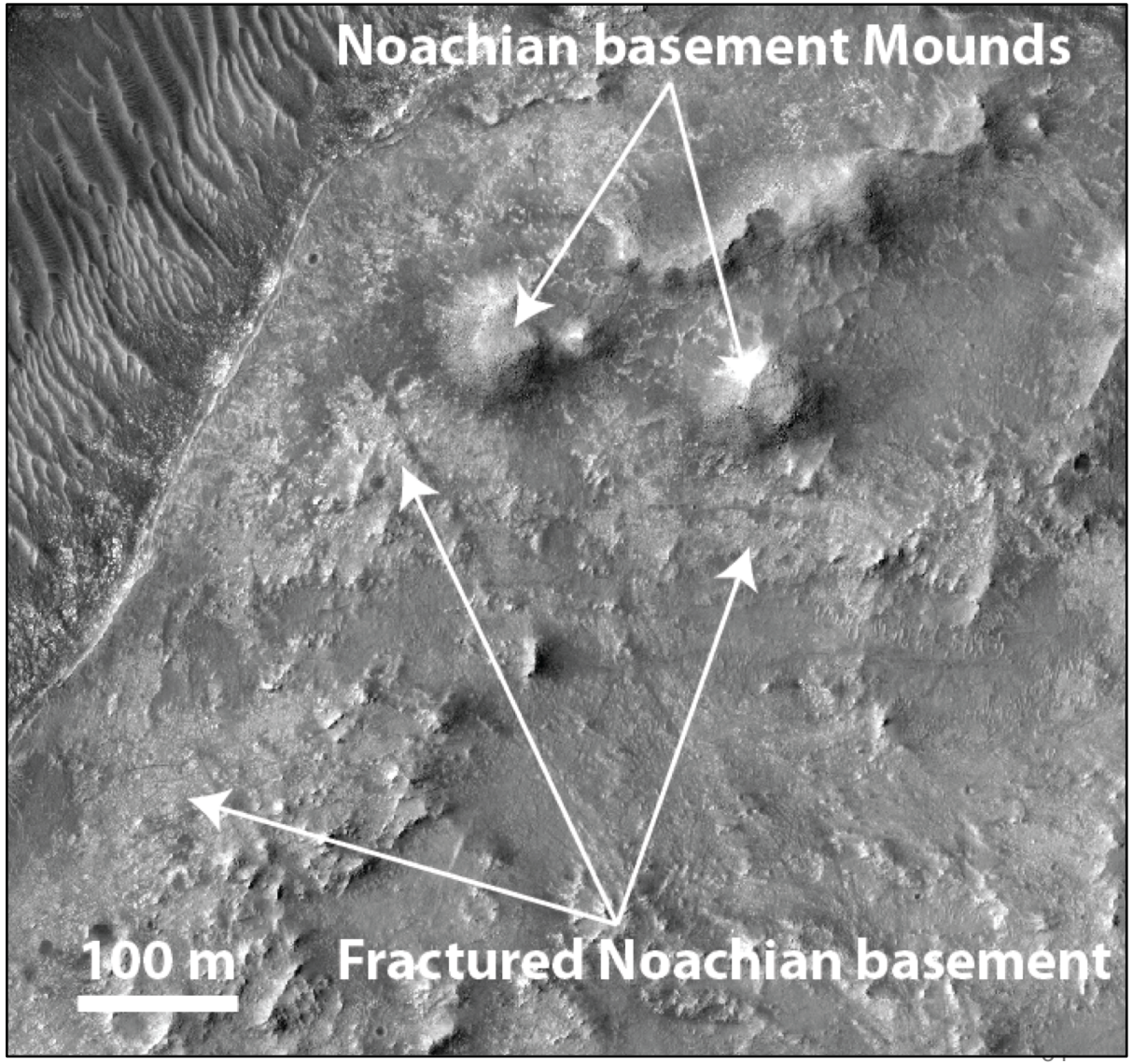
ROI 2- Campaign 2 (Midway): Basement

- **Objective:** Understand the origin and composition of altered (Fe/Mg-smectite, kaolinite if present) and unaltered lithologies (LCP) in Noachian basement. Document contacts and stratigraphic relationships, and assess habitability and biosignature preservation.

- Use Mastcam-Z and Supercam to characterize physical and compositional properties of the fractured basement and basement mounds.
- Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine petrogenesis and alteration.
- Use SHERLOC, Supercam to look for organics in Fe/Mg smectite (and kaolinite) samples.
- Use RIMFAX to probe subsurface structure.

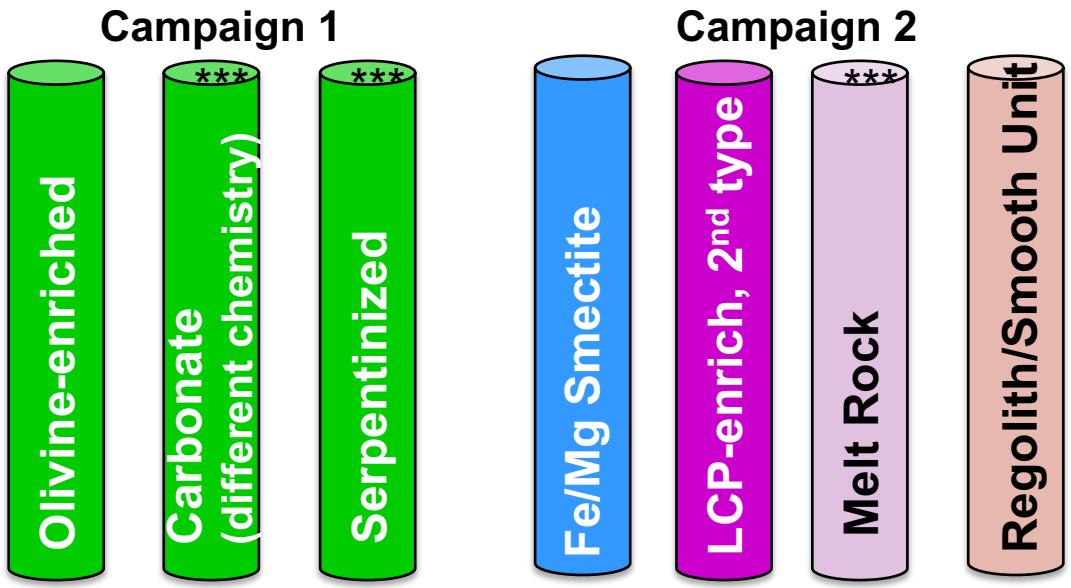
Samples #11-13

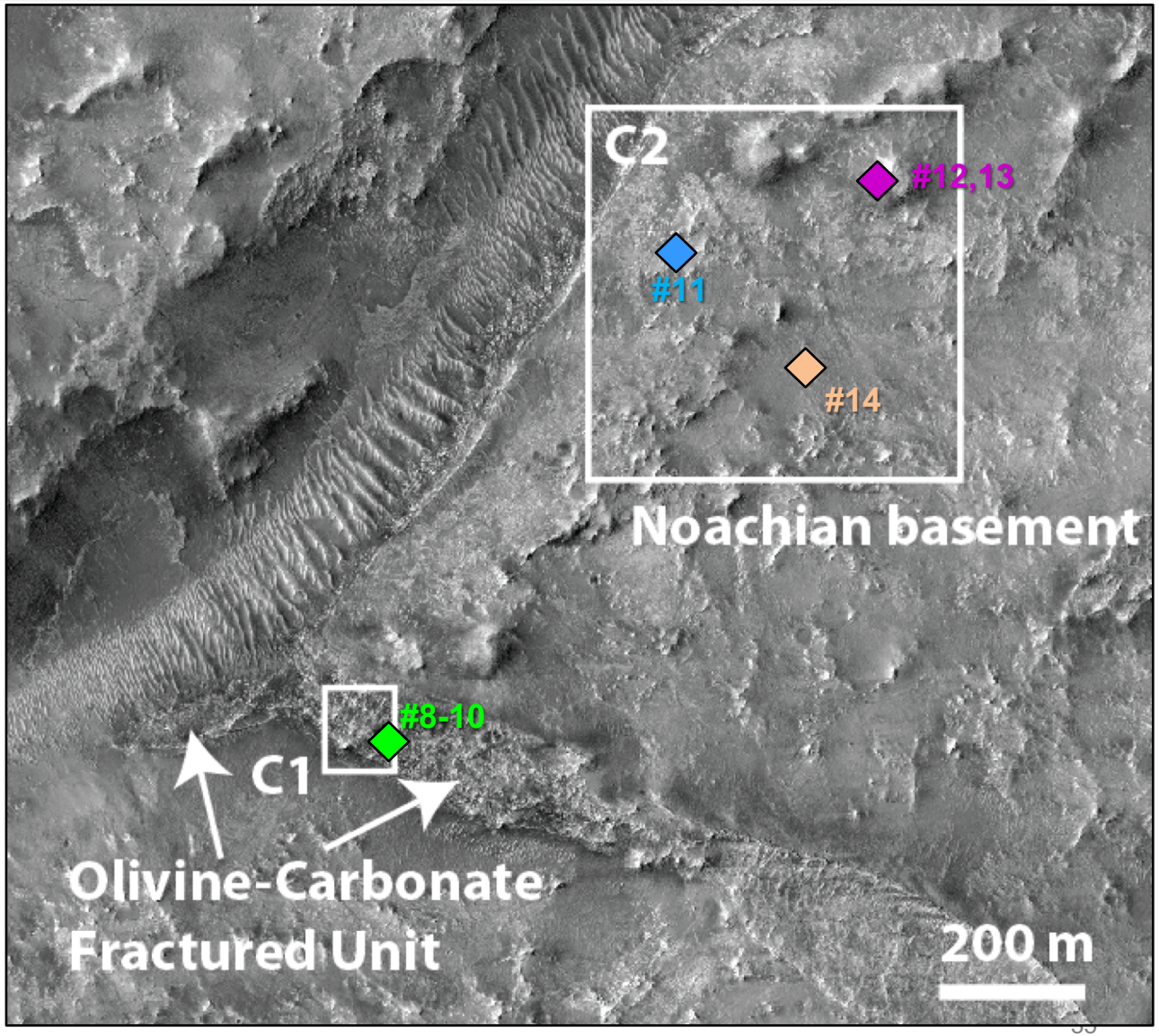
1 Fe/Mg smectite-bearing basement sample
1 LCP-enriched sample
1 Melt Rock sample



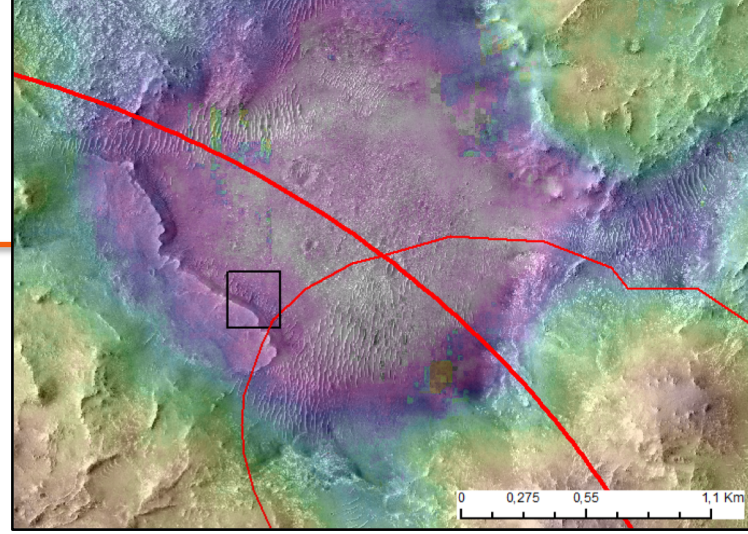
ROI 2 Sampling Strategy (Midway)

- **Campaign 1,** Sample #8-10: **Olivine-carbonate**
  - Assess aqueous alteration conditions, chemical variability, habitability, look for biosignatures.
- **Campaign 2,** Sample #11-13: **Noachian basement**
  - Unaltered samples provide information on absolute age calibration, differentiation, and magnetic history.
  - Altered samples provide information on aqueous alteration conditions, habitability.
- Sample #14: **Regolith** for comparison with previous martian regolith; applications for human exploration.



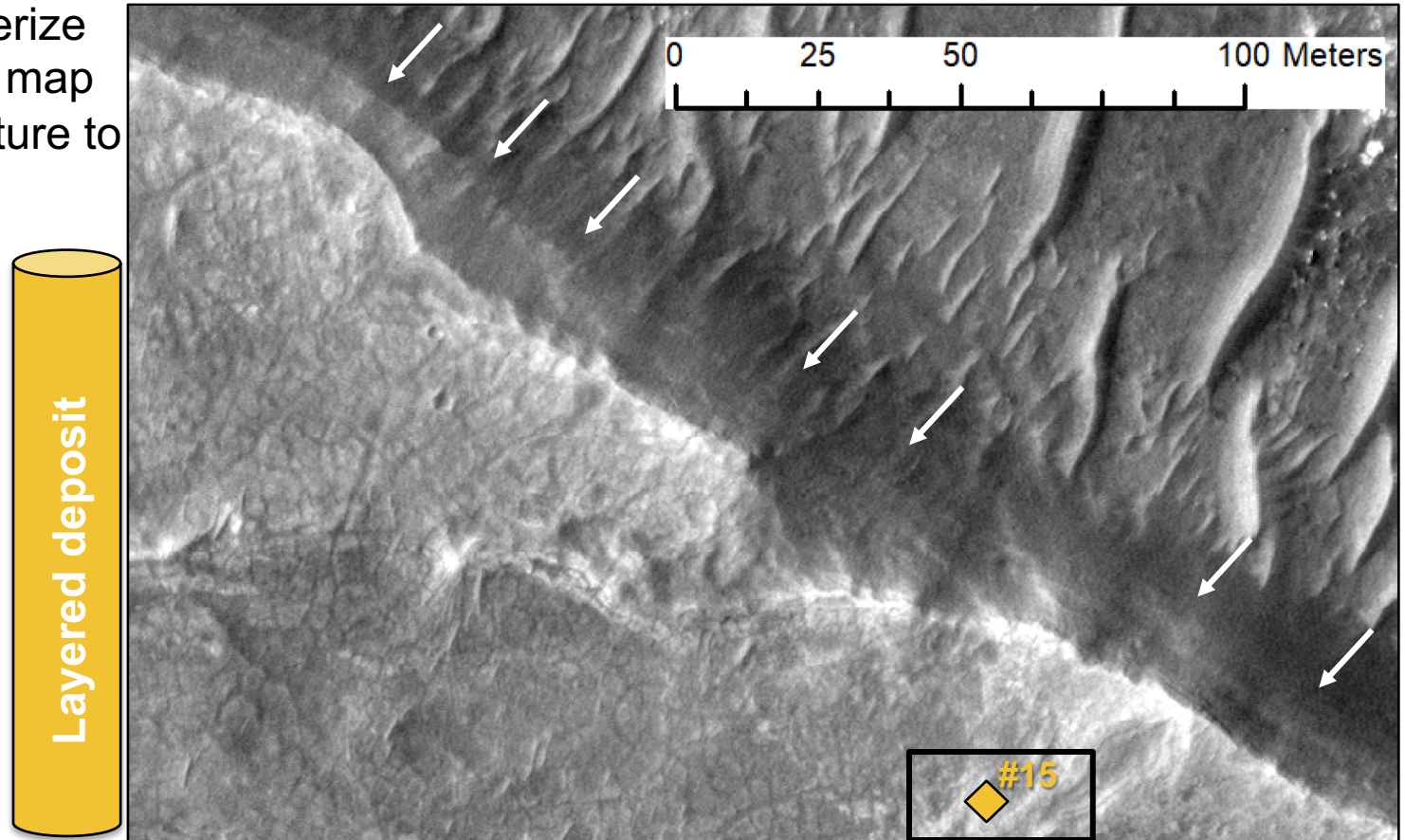


Waypoint 2 (Midway): Layered Deposit in Closed Depression



- **Objective:** Understand composition and origin of a layered deposit in an enclosed depression; determine if this unit is related to regional fluvial/lacustrine processes.

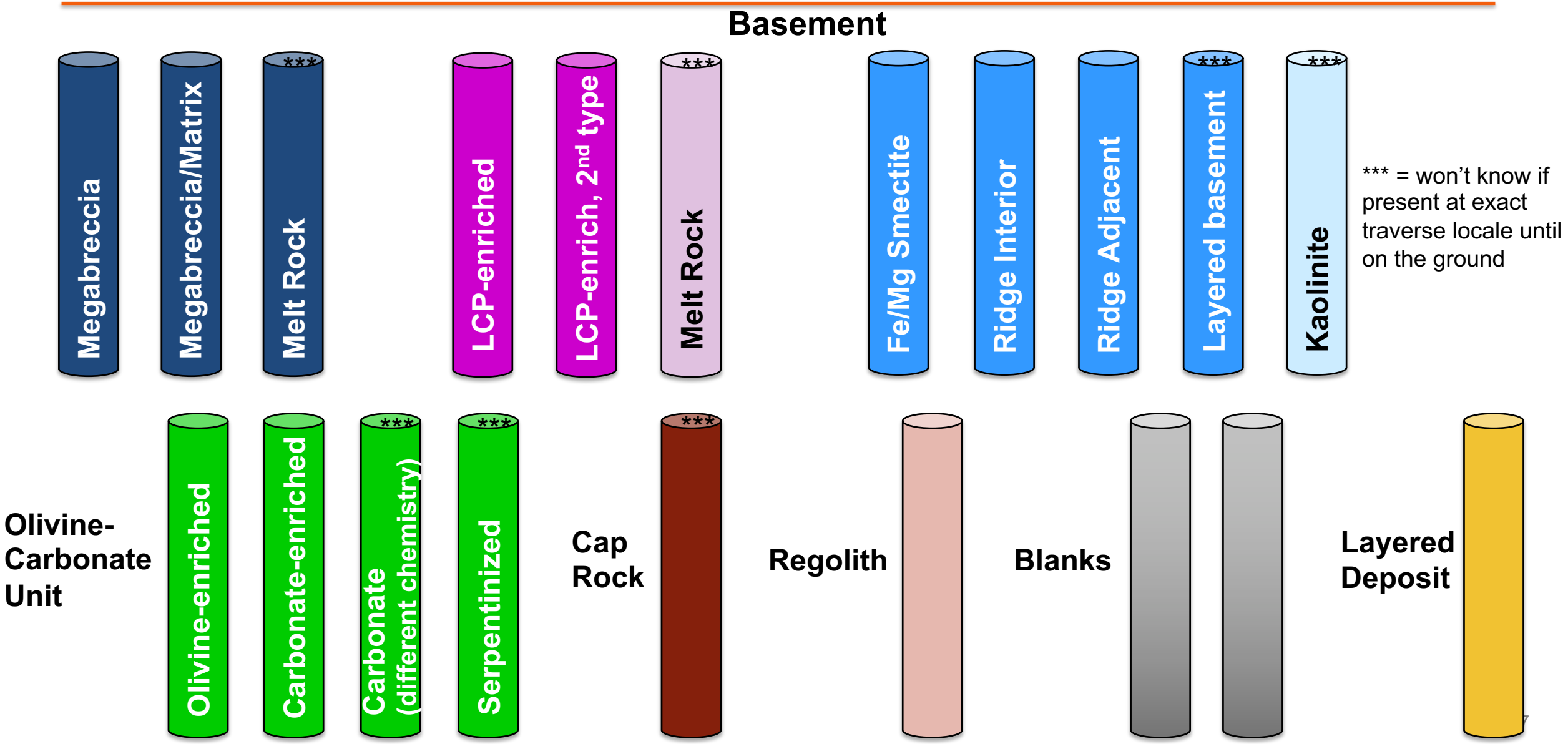
- Use Mastcam-Z and Supercam to characterize layers; Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine petrogenesis and alteration.
- Use SHERLOC, Supercam to look for organics.
- Use RIMFAX to probe subsurface structure.



Layered deposit

Sample #15: Polygonally fractured, layered material

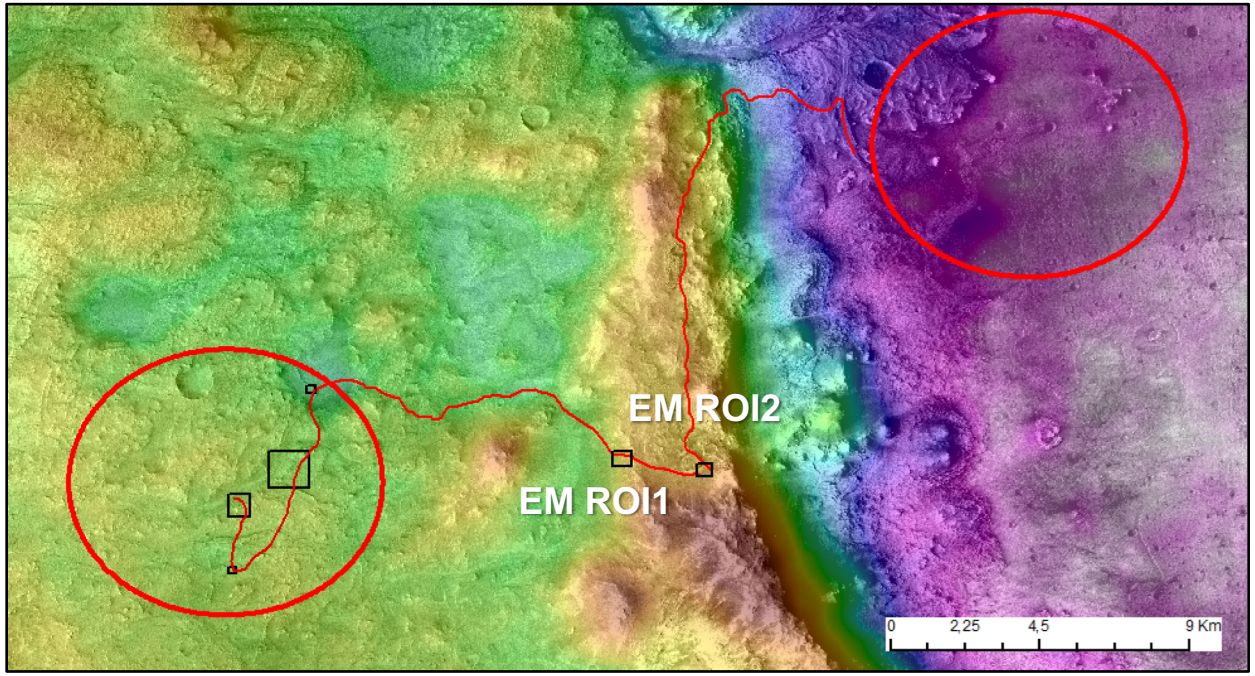
Baseline Midway Mission Sample Cache



Extended Mission Exploration (Midway)

- Jezero crater
  - Constrain source-to-sink scenario by tracing similar lithologies from Midway to Jezero interior.
  - Comparison of similar orbital units (olivine-carbonate, mafic cap) at both sites to constrain regional extent of these units.
  - Examination of sedimentary structures and nature of flow.
  - Search for biosignatures in clay-carbonate sediments.

*see detailed presentation 08:30 Thursday on Extended Mission Traverse possibilities Midway-Jezero or Jezero-Midway



  - **Extended Mission ROI 1:** Sample megabreccia exposed on the Jezero rim.
  - **Extended Mission ROI 2:** Mafic cap unit and kaolinite megablock on Jezero rim. Acquire these samples if not obtained in baseline mission.

Extended Mission ROI 1 (Midway): Megabreccia Exposed on Jezero Rim

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- **Objective:** Examine megabreccia exposed on the rim of Jezero crater. Compare with in-ellipse megabreccia and determine if likely Isidis or Jezero megabreccia, and if igneous or sedimentary in origin.

- Use Mastcam-Z, Supercam to identify different degrees of alteration and characterize any matrix, melt rock, or evidence for hydrothermal alteration.
- Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine origin and alteration.
- Use SHERLOC, Supercam to look for organics in any altered blocks.
- Use RIMFAX to probe subsurface structure and contact.

Extended Mission ROI 2 (Midway): Cap Unit and Kaolinite on Jezero's Rim

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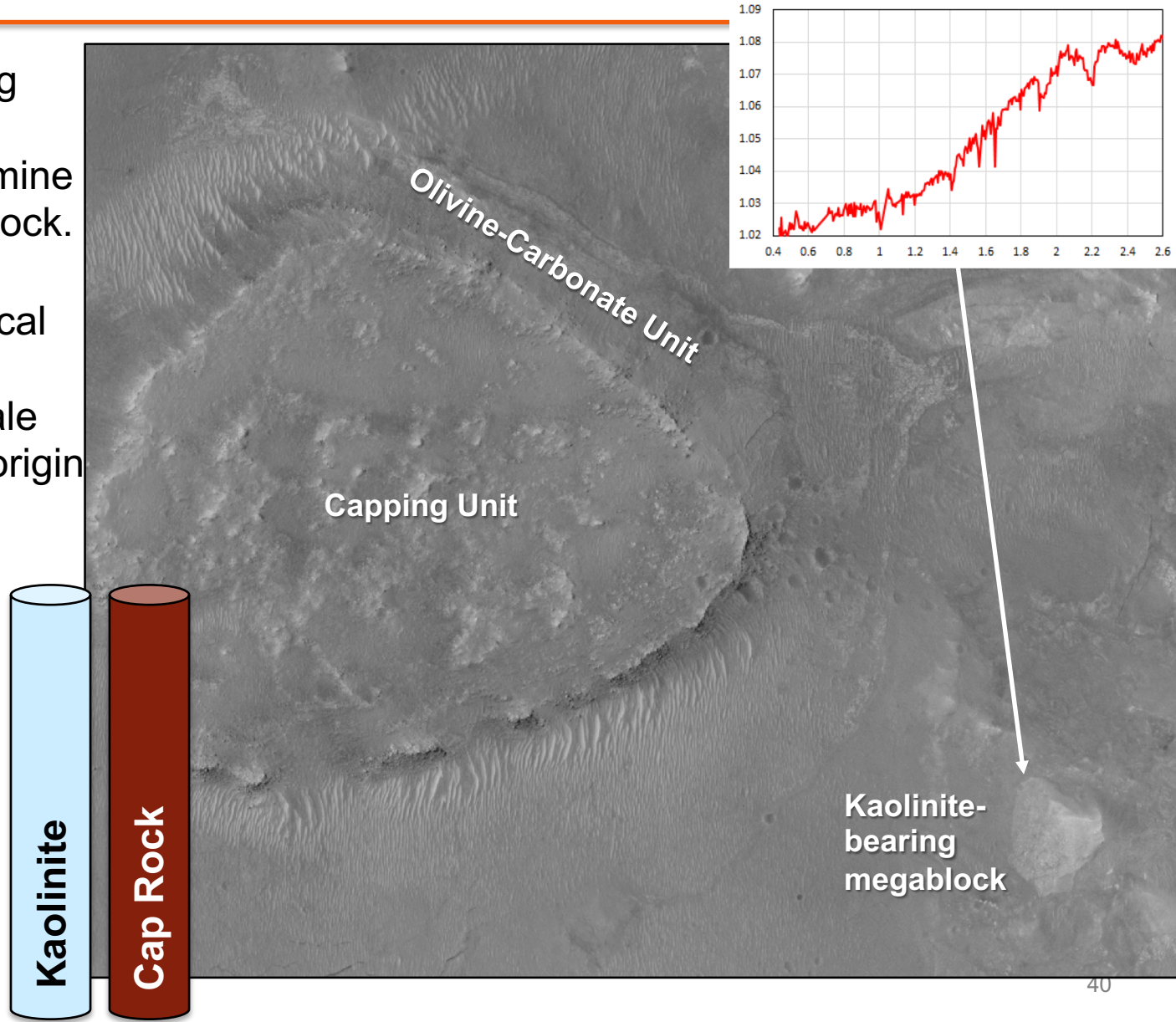
- **Objective:** Identify the lithologies in mesa-forming units, interpret their petrogenesis, history of interaction with water, and time sequence. Determine the formation mechanism of kaolinite in a megablock.

- Use Mastcam-Z, Supercam to characterize physical and compositional properties of units.
- Use PIXL, SHERLOC/WATSON to map microscale chemistry, mineralogy, and texture to determine origin and alteration.
- Use SHERLOC, Supercam to look for organics in carbonates.
- Use RIMFAX to probe subsurface structure and contact.



Samples if not acquired in Baseline Mission

1 Capping Unit sample
1 Kaolinite-bearing sample

Summary of Returned Sample Science Mission Strategies and Objectives

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The History of Water and Habitable Environments on Noachian Mars:

- Determine the various aqueous environments (Eh, pH, water/rock ratio, fluid chemistries) recorded in 5 altered lithologies: Fe/Mg smectite basement, megabreccia, mineralized ridges, kaolinite-bearing materials, and the olivine-carbonate unit.
  - Measurements: mineral assemblages, fluid inclusion analysis
- Date and characterize aqueous/diagenetic events to reconstruct pre-Isidis crust and evolution of the Noachian environment.
  - Measurements: Rb-Sr, Pb-Pb, Ar-Ar

Biosignatures: Assess biosignatures in the above aqueously altered lithologies.

- Measurements: isotopic composition of organic C, spatially varying patterns in C, S, O in minerals, 3D mapping at nm-scale to understand morphology of organics and mineral deposits

Evolution of Martian Volcanism and Magnetism: Determine if primary igneous lithologies - LCP megabreccia and basement, olivine unit, mafic cap rock - preserve the ancient magnetic field or signatures of evolving magmatism.

- Measurements: petrologic and isotope geochemistry techniques (SEM, EMP, Synchrotron), trace element chemistry; SQUiD micro-magnetic analyses

Geochronology: Determine absolute age of the above igneous lithologies; determine/constrain age of the Isidis impact event from impact melt; calibrate our understanding of Martian chronology and crater count dating techniques.

- Measurements: Ar-Ar, U-Pb, etc.

Martian Carbon Cycle: Determine how carbon cycle evolved, origin of the C (mantle vs. surface-derived), formation temperature.

- Measurements: carbon isotopic ratios (^{3}C, clumped isotopes) from carbonate samples

Martian Hydrologic Cycle: Determine how the hydrologic cycle is recorded or influenced by the clay minerals.

- Measurements: ^{18}O, D/H, synchrotron analysis of structure in Fe/Mg smectite basement, ridges, megabreccia, and kaolinite

Benefits of a Mars 2020 Mission at NE Syrtis and Midway

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- Sequence of multiple Noachian units that are regionally extensive with **well-understood, constrained timing in Martian relative stratigraphy and chronology**.
- **Multiple unaltered lithologies available** (low Ca-pyroxene mounds, olivine-enriched deposit, mafic cap rock) to track Martian petrogenesis over time.
- Access to three different lithologies formed from liquid water at different times: Fe/Mg smectite megabreccia, basement, and later ridges; kaolinite; Mg-carbonate. In situ exploration will decide between competing hypotheses for Noachian habitats: serpentinization vs. sedimentary carbonate. **Opportunity to search multiple environmental settings and times for preserved biosignatures.**
- **Uniquely offers access to Isidis megabreccia during the baseline mission.** Enables radiometric dating of the Isidis impact and the multiple igneous units, information about early martian magnetic field, access to very early crust from the region.
- **Extensive regional carbonate-bearing units** allow insight into evolution of martian carbon cycle, interaction b/w atmosphere and lithosphere, constraints on alteration temperature.
- **Extended mission access to subaqueous sedimentary deposits** (Midway: Jezero delta, NE Syrtis: late fluvial-lacustrine smectites and sulfates)

Mars 2020 Science Team Concerns About NE Syrtis and Midway

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- Because multiple hypotheses exist for the carbonate and clay mineral units (ranging from aquifer origin to hydrothermal origin to sedimentary origin), the astrobiology exploration strategy to be employed will only be known once on the ground where petrology definitively reveals the rock type. This contrasts with the Jezero delta and Gusev silica where a simpler approach is obvious a priori.
- On Earth, most fossil biomass is preserved in sedimentary deposits, and there are well-demonstrated strategies for finding such biomass. Only in the extended mission would we get to clear sedimentary rocks.
- Multiple units are complex and likely represent multiple geologic events that may be challenging to disentangle, i.e., science decision-making and operations decisions might be initially slower.
- Midway ellipse will not have complete coverage of full spatial resolution CRISM data (though 200m/pix does exist). It will be difficult to identify specific locations with clays/carbonates from orbital data.

Summary

- A mission to NE Syrtis or Midway would explore ancient Noachian stratigraphy and sample multiple environments that were exposed to liquid water at different times.
  - In situ exploration would test competing hypotheses for Noachian habitats: serpentinization vs. sedimentary carbonate.
  - Multiple episodes of clay formation are recorded.
  - Access to in-ellipse megabreccia, allowing for reconstruction of the pre-Isidis crust.
- Returned samples from NE Syrtis or Midway would enable age dating of martian volcanism, dynamo, and aqueous events, and provide constraints on the evolution of the carbon cycle, Noachian atmosphere, and surface conditions.
- In-ellipse science is similar at both NE Syrtis and Midway, but extended missions choices are different.
  - NE Syrtis EM would explore late Hesperian/Amazonian subaqueous lacustrine sediments, sedimentary sulfate sequence, and Syrtis Major lavas.
  - Midway EM would explore Jezero crater, tracing similar lithologies from Midway to the Jezero interior and investigating a lacustrine environment.