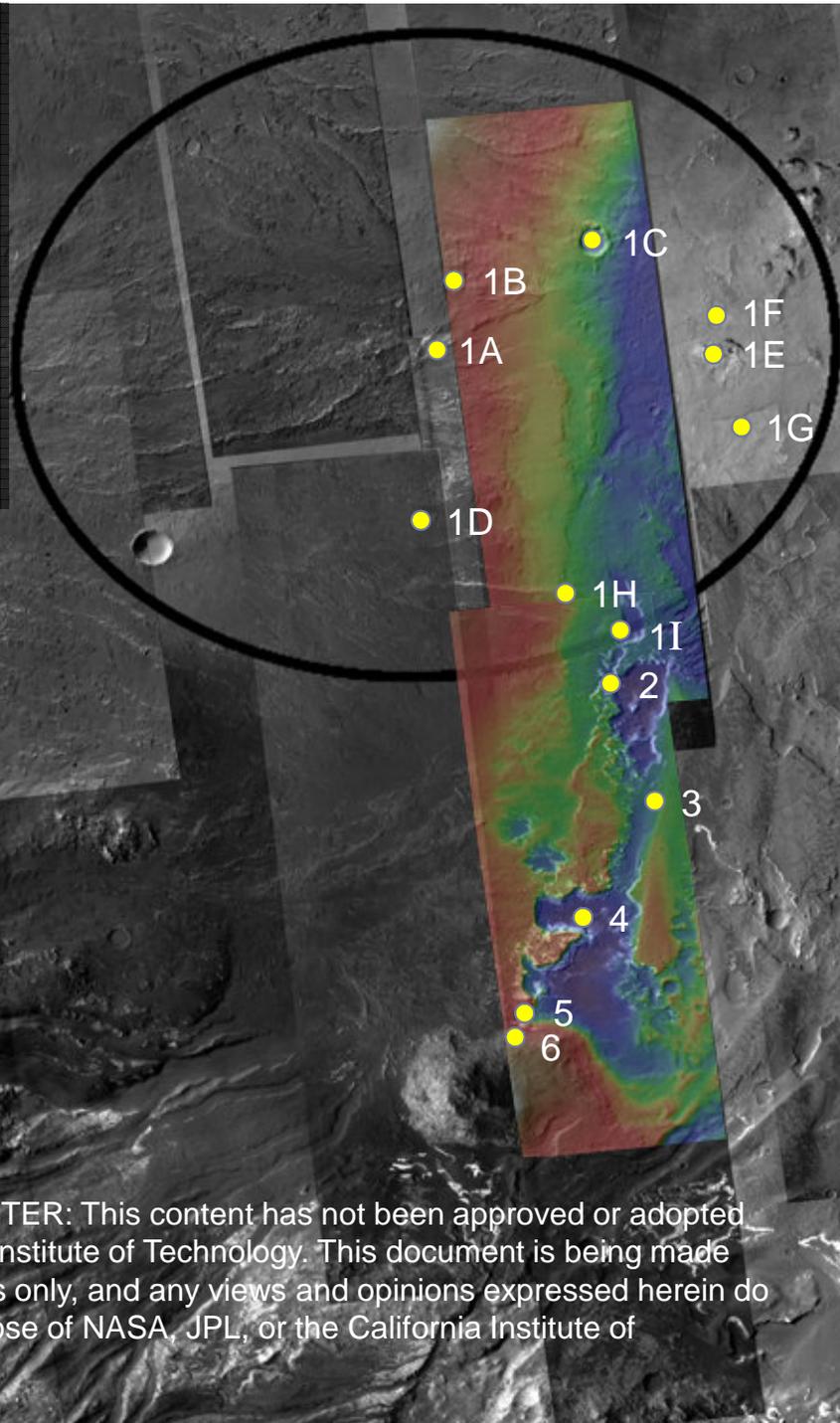


Holden Crater Rover Targets

Ross Irwin
Smithsonian Institution
1st Mars 2020 Workshop
May 16, 2014



Inside ellipse

- 1A: inverted channels at ellipse center
 - 1B-D: craters with layered outcrops on fan surface
 - 1E: knob of underlying material (megabreccia)
 - 1F: upper LTL outcrops
 - 1G: coarse material (distal Uzboi, poss. megabreccia)
 - 1H: fan toe (exposed contact between alluvium and underlying material)
 - 1I: LTL outcrop
- [Other outcrops of each material type are available]

Outside ellipse

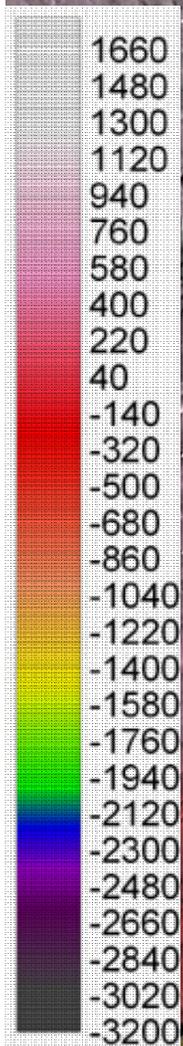
- 2: many LTL outcrops
- 3: bedded coarse deposits (proximal Uzboi)
- 4: LTL outcrops, higher phyllosilicate abundance

Extended mission

- 5: topographically higher LTL section
- 6: knob of underlying material (megabreccia)

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Holden Crater Overview



50 km

- 26°S, 34°W
- 155 km diam.
- -2 km floor
- Phyllosilicate-rich LTL rocks
- Alluvial fans and bajada from deeply dissected wall alcoves
- Coarse flood deposit from Uzboi Vallis rim breach
- Underlying bedrock outcrops

Diversified Habitability Investigation

Alluvial fans

- Paleoclimate and atmospheric evolution: Paleohydrology and runoff requirements for observed sediment load from a well-defined watershed
- Mineralogy, weathering, and diagenetic alteration: Alluvial gravel/cobbles sample top 1-2 km of highland crust, up to 800 Myr of the Noachian Period

Light-toned, layered materials with Fe,Mg phyllosilicates

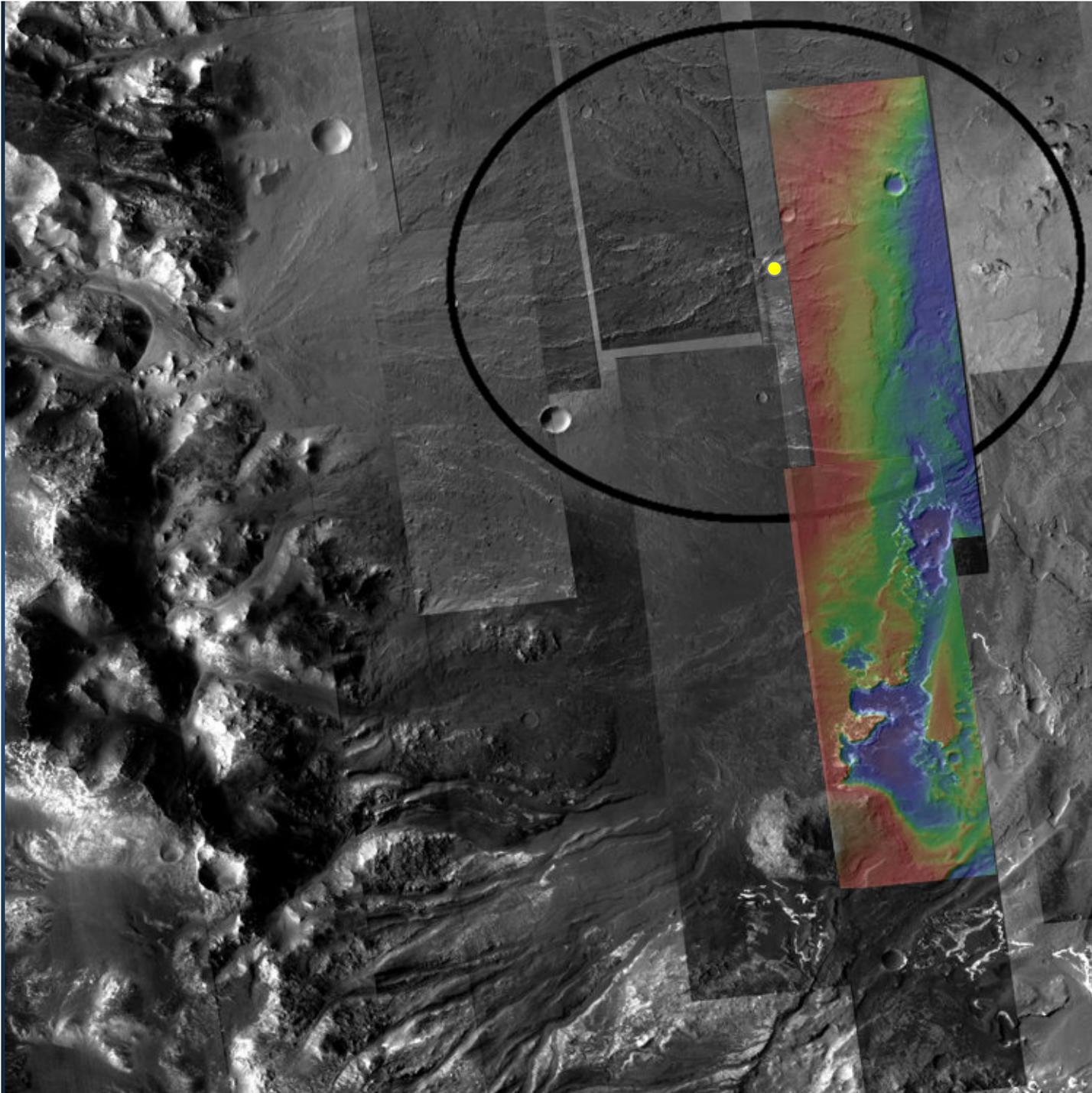
- Stratigraphy, sedimentology, and geochemistry of 100-m-thick medium to fine-grained section reflects depositional environment and change over time
- Ideal site to search for organics and effects of biological processes

Flood deposits

- Paleoflood hydrology, rocks from rim breach & Uzboi, late-stage weathering

Bedrock outcrops

- Ancient bedrock uplifted during impact, possible hydrothermal system



**Holden target 1A:
Inverted channels on
alluvial bajada**

-26.38 North, 325.15 East
Km from ellipse center: 0

Rationale:

*Alluvial deposits derived
from crater wall, fluvial
hydrology, sample reworked
upper highland crust*

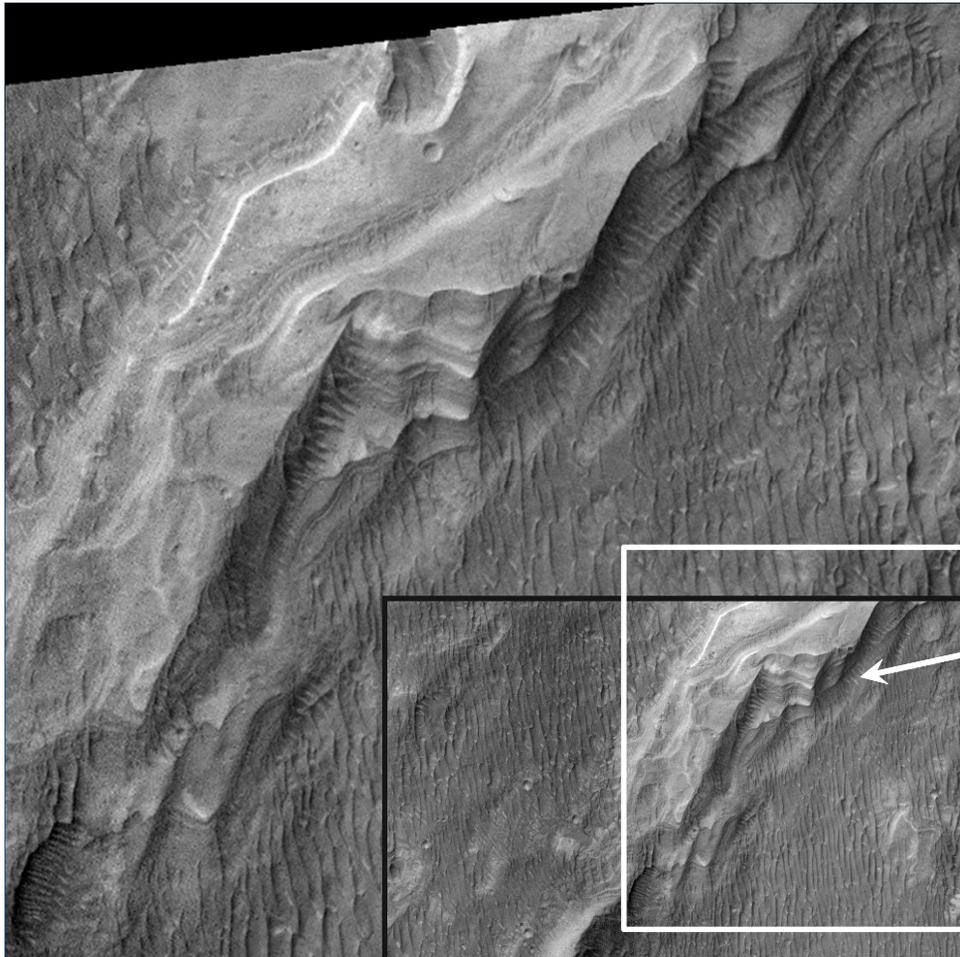
Morphology and

Mineralogy:

*Inverted paleochannels:
basaltic, possibly altered*

What will the rover
specifically do here?

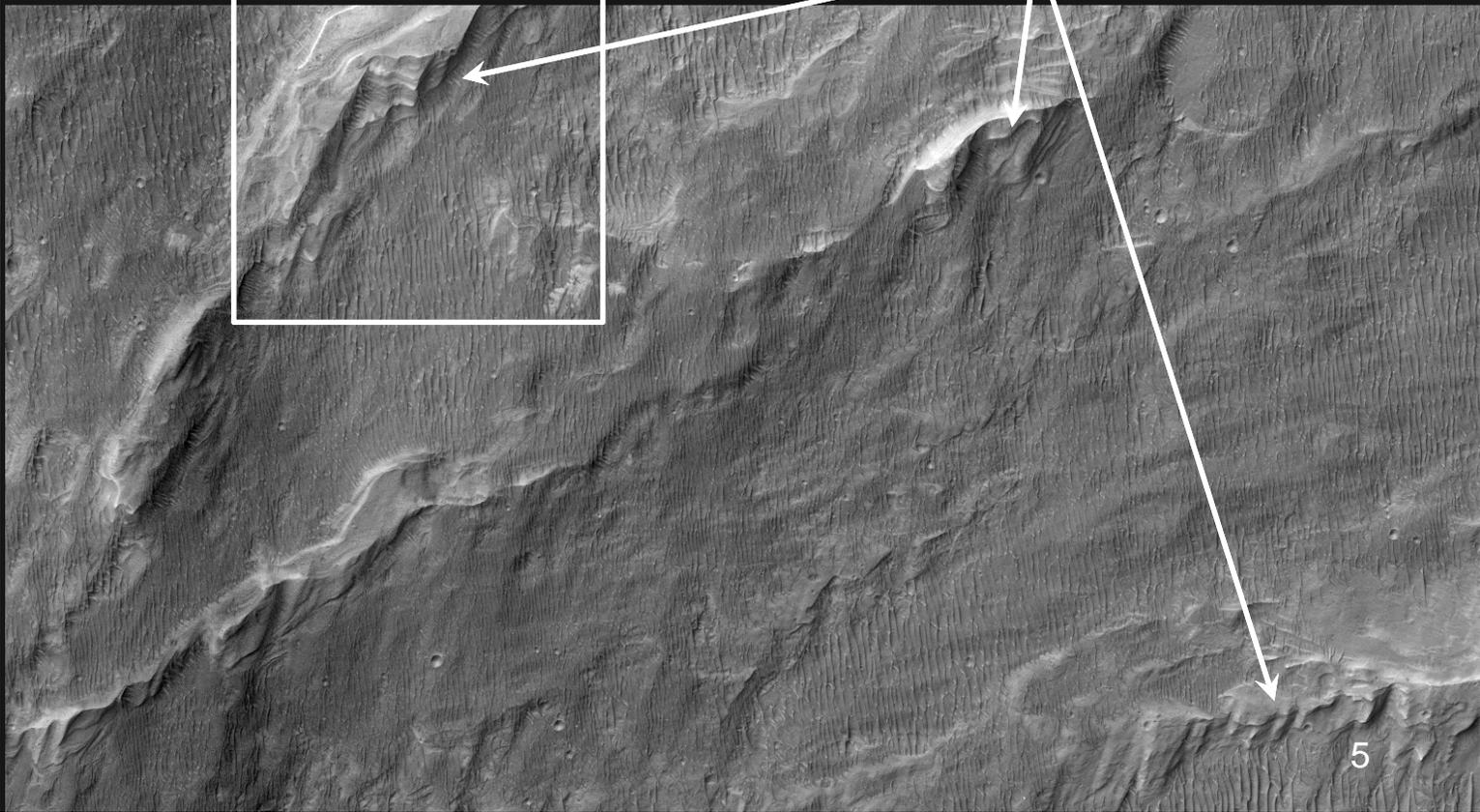
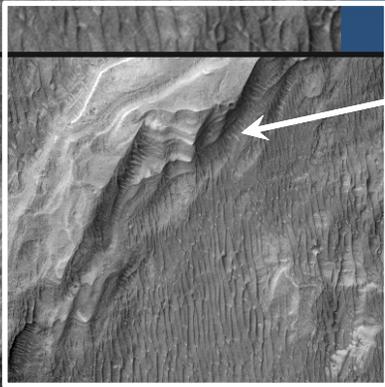
*Determine diversity of
materials in upper >1 km of
highland crust, determine
emplacement mechanism
for fans, examine
stratigraphy within inverted
channels for temporal
change in environment*



100 m

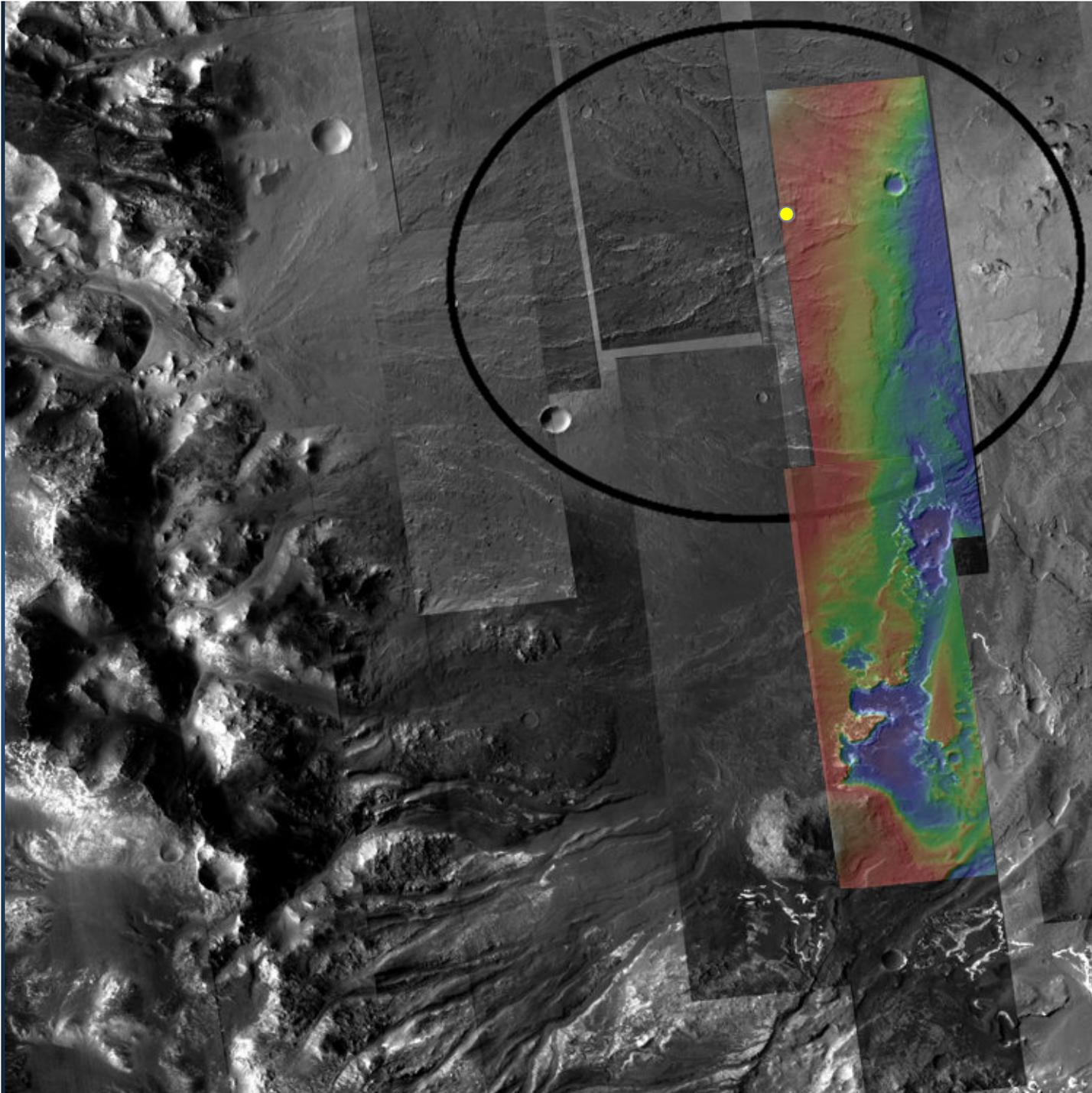
Ellipse center
PSP_002154_1530
Left: 397 m across
Below: 1.59 km across

Targets of interest: select 1-2 after landing based on landing site and optimal traverse. Similar outcrops located elsewhere in ellipse.



200 m

5



**Holden target 1B:
Layered outcrop in
crater wall on bajada**

-26.35 North, 325.15 East
km from ellipse center: 1.9
(Use if MSL lands nearby)

Rationale:

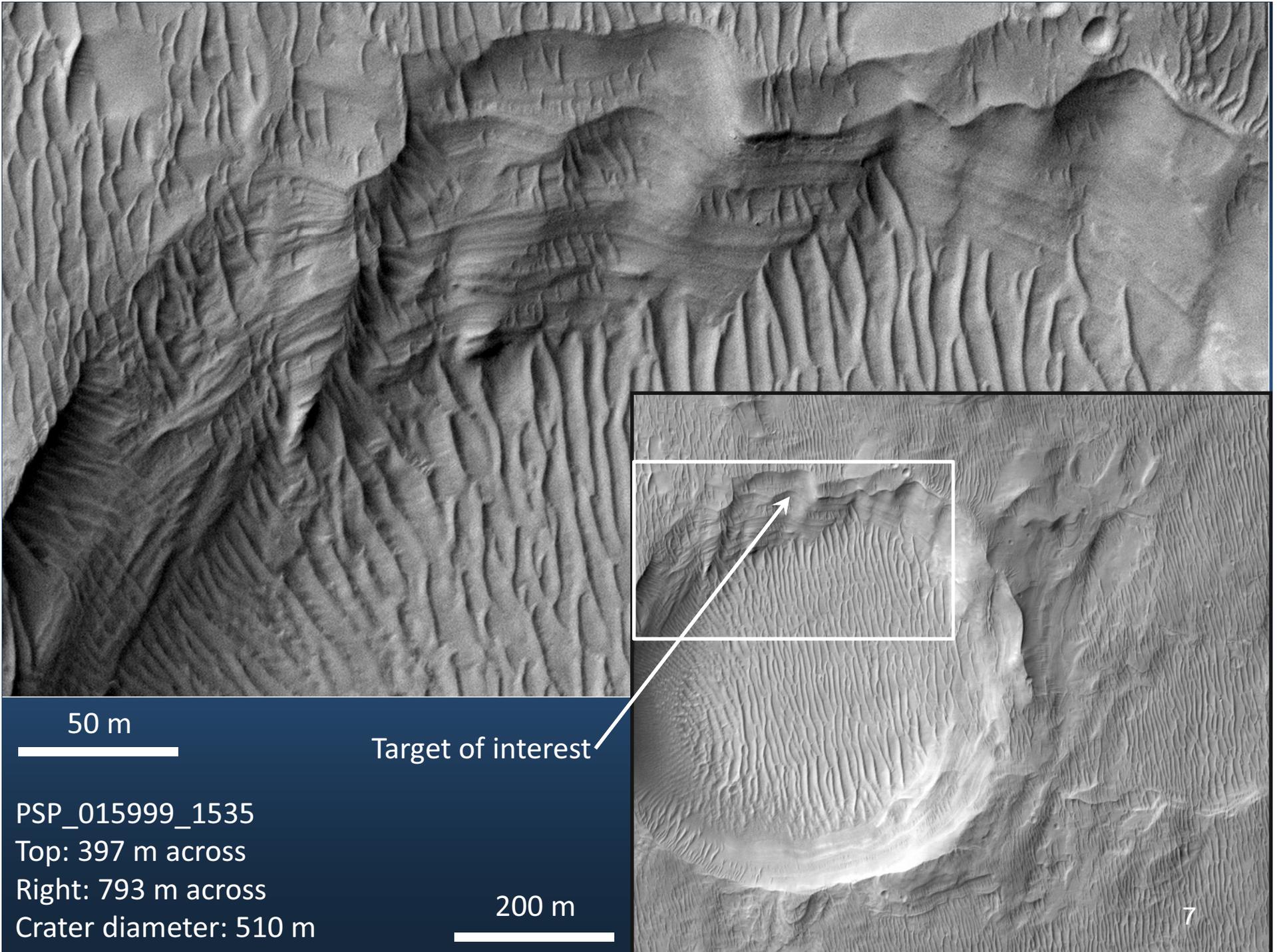
*Alluvial deposits derived
from crater wall, alluvial fan
stratigraphy, samples of
upper highland crust*

Morphology and
Mineralogy:

*Inverted paleochannels:
basaltic, possibly altered*

What will the rover
specifically do here?

*Determine diversity of
materials in upper >1 km of
highland crust, determine
emplacement mechanism
for fans, examine
stratigraphy in crater wall
for temporal change in
environment*

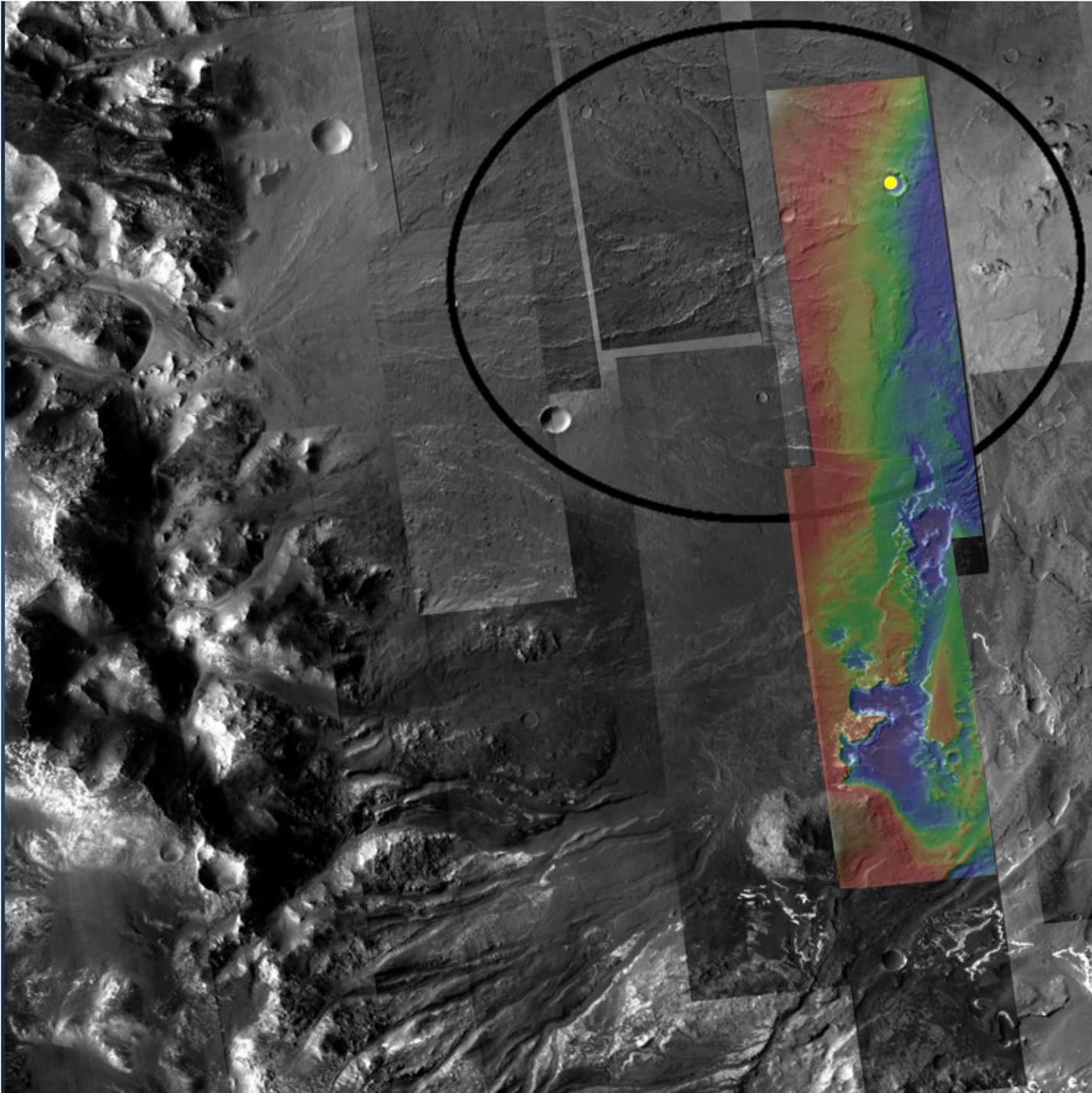


50 m

Target of interest

PSP_015999_1535
Top: 397 m across
Right: 793 m across
Crater diameter: 510 m

200 m



Holden target 1C:
Layered outcrop in
crater wall on bajada

-26.33 North, 325.22 East
km from ellipse center: 5.2

Rationale:

*Alluvial deposits derived
from crater wall, alluvial fan
stratigraphy, samples of
upper highland crust*

Morphology and

Mineralogy:

*Inverted paleochannels:
basaltic, possibly altered*

What will the rover
specifically do here?

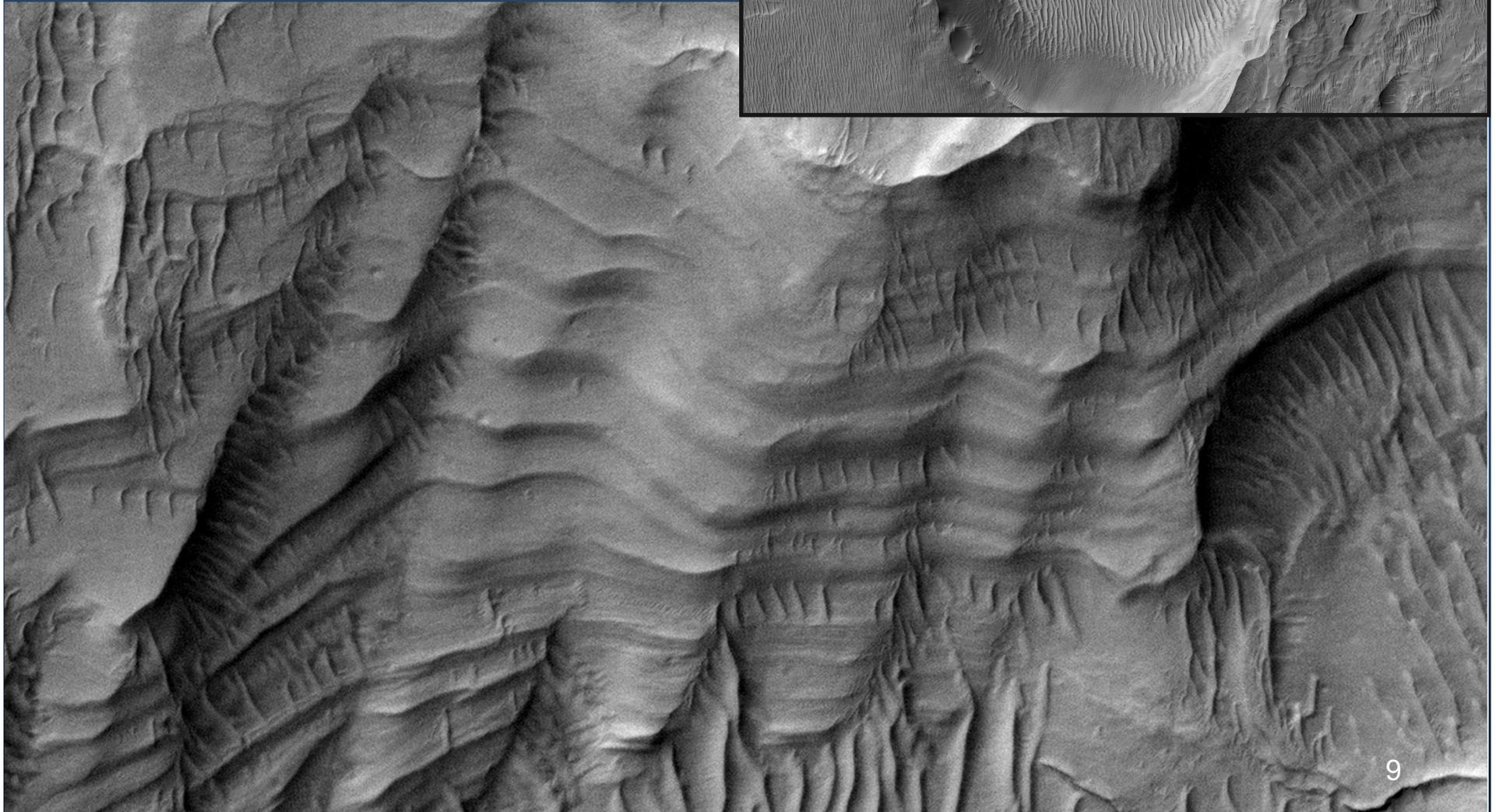
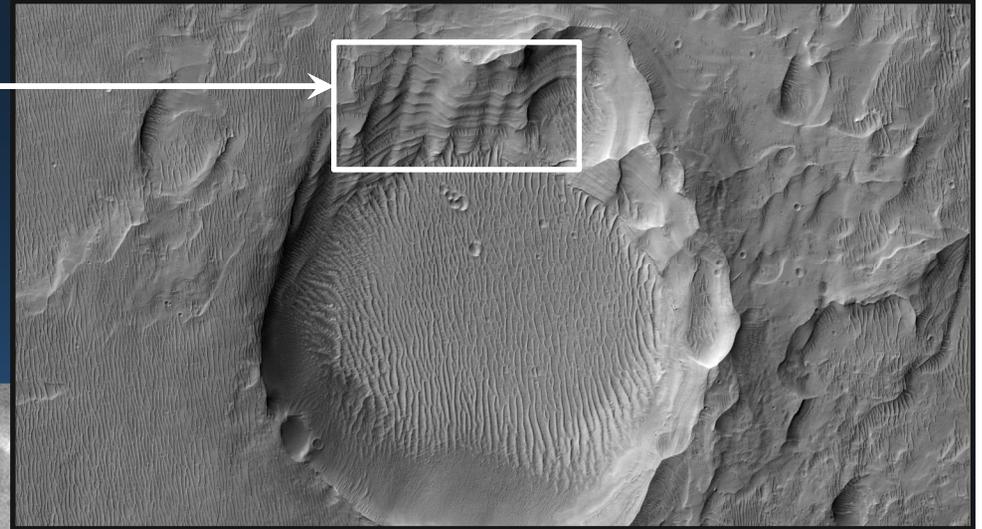
*Determine diversity of
materials in upper >1 km of
highland crust, determine
emplacement mechanism
for fans, examine
stratigraphy in crater wall
for temporal change in
environment*

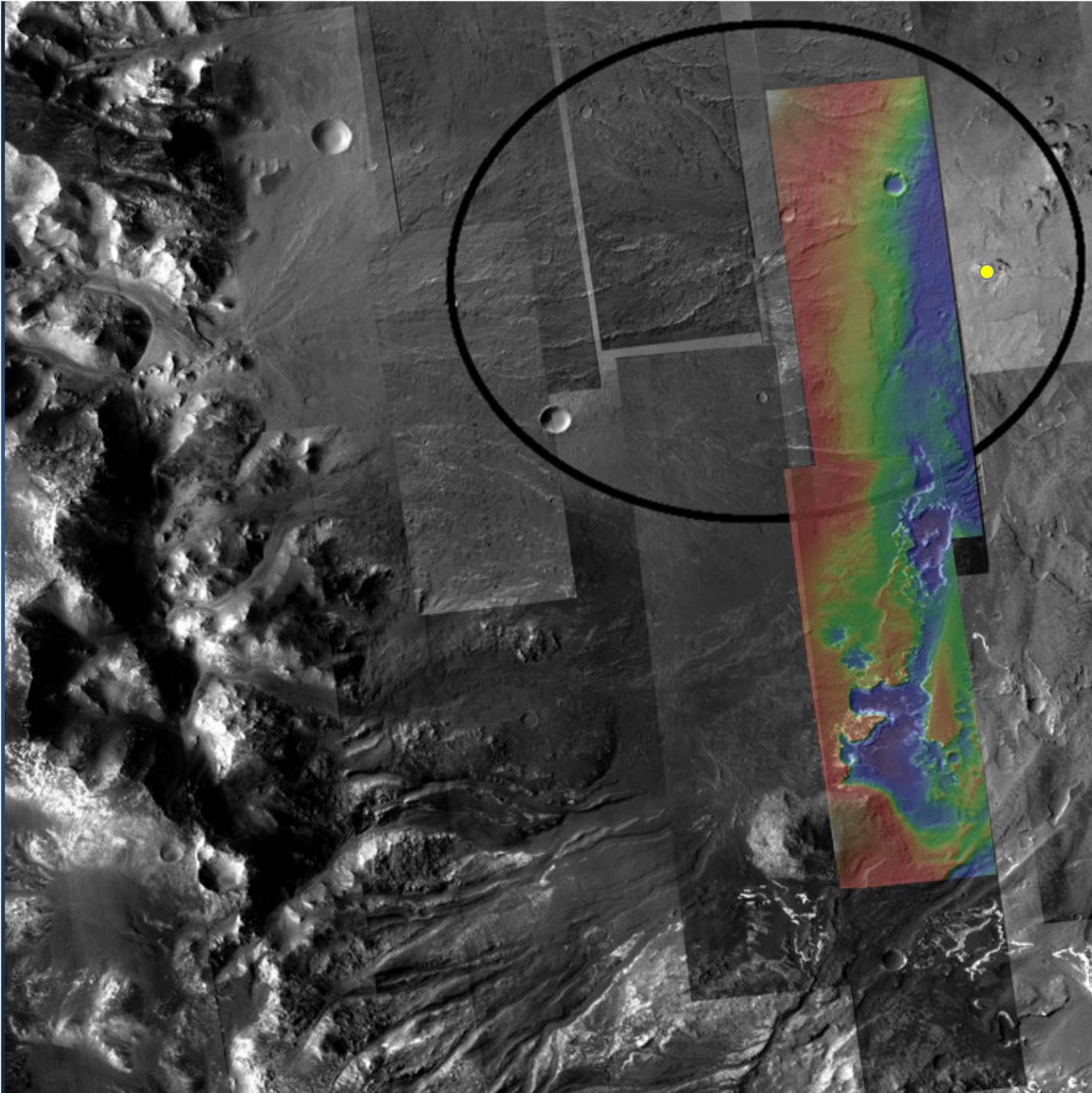
PSP_015999_1535
Right: 1.59 km across
Below: 397 m across
Crater diameter: 740 m

50 m

Target of interest

300 m





Holden target 1E:
Knob of underlying
rocks (megabreccia)

-26.39 North, 325.28 East
km from ellipse center: 7.0

Rationale:

*Megabreccia on Holden
floor, light-toned veins in
rock, possible former
hydrothermal environment*

Morphology and
Mineralogy:

*Knob of coarse rocks with
tone/color contrasts and
veins*

What will the rover
specifically do here?

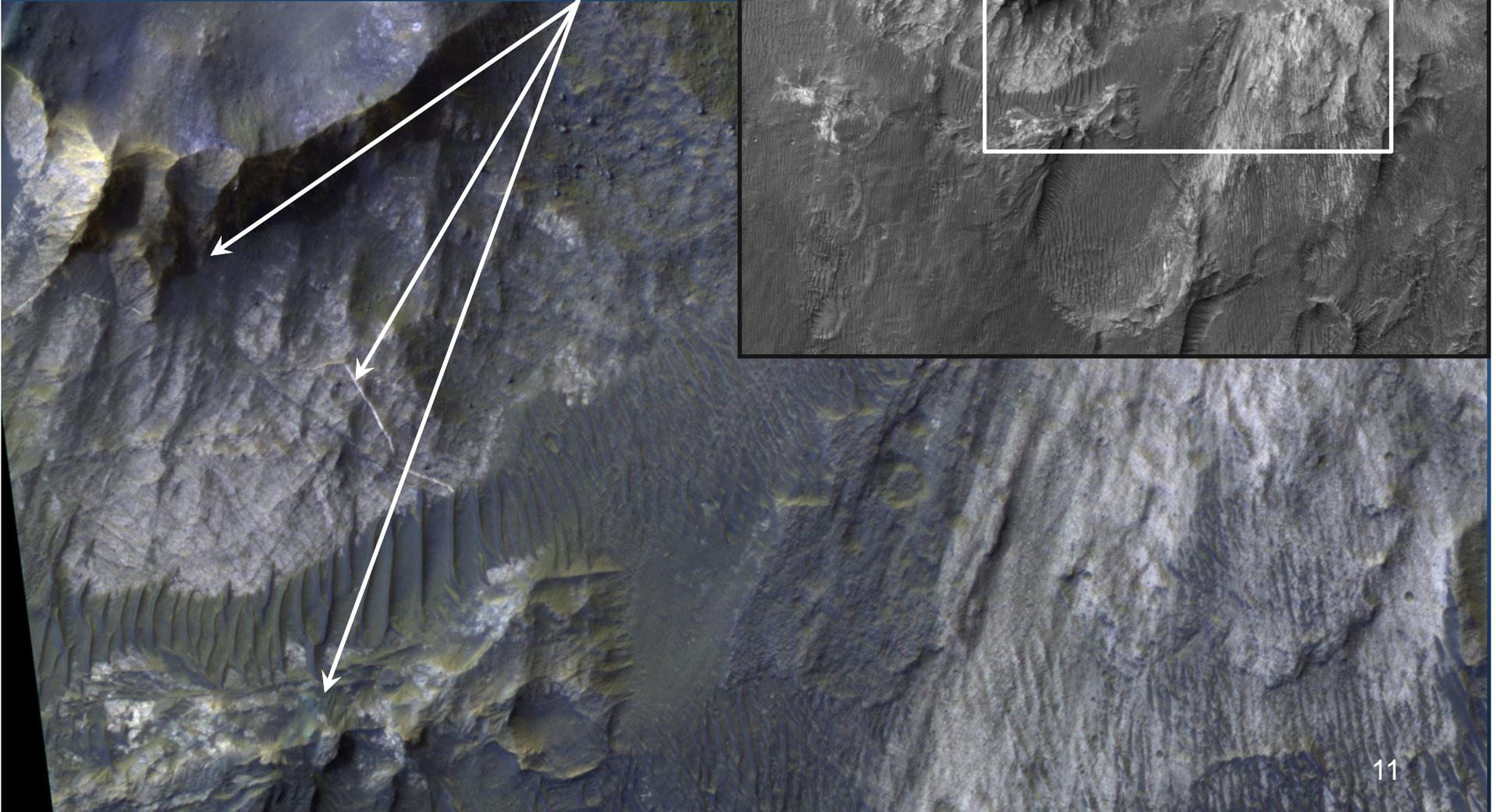
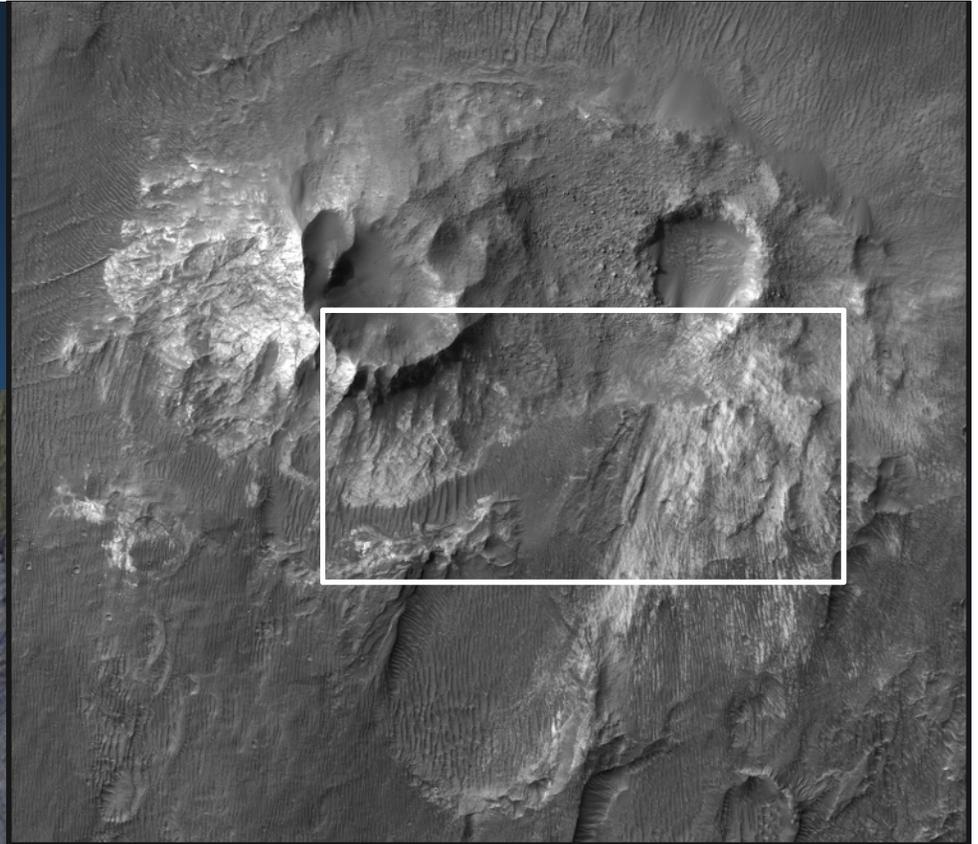
*Examine rocks and veins for
possible hydrothermal
deposits, chemical energy
sources, organics, and
alteration; determine
diversity of materials
exposed on crater floor*

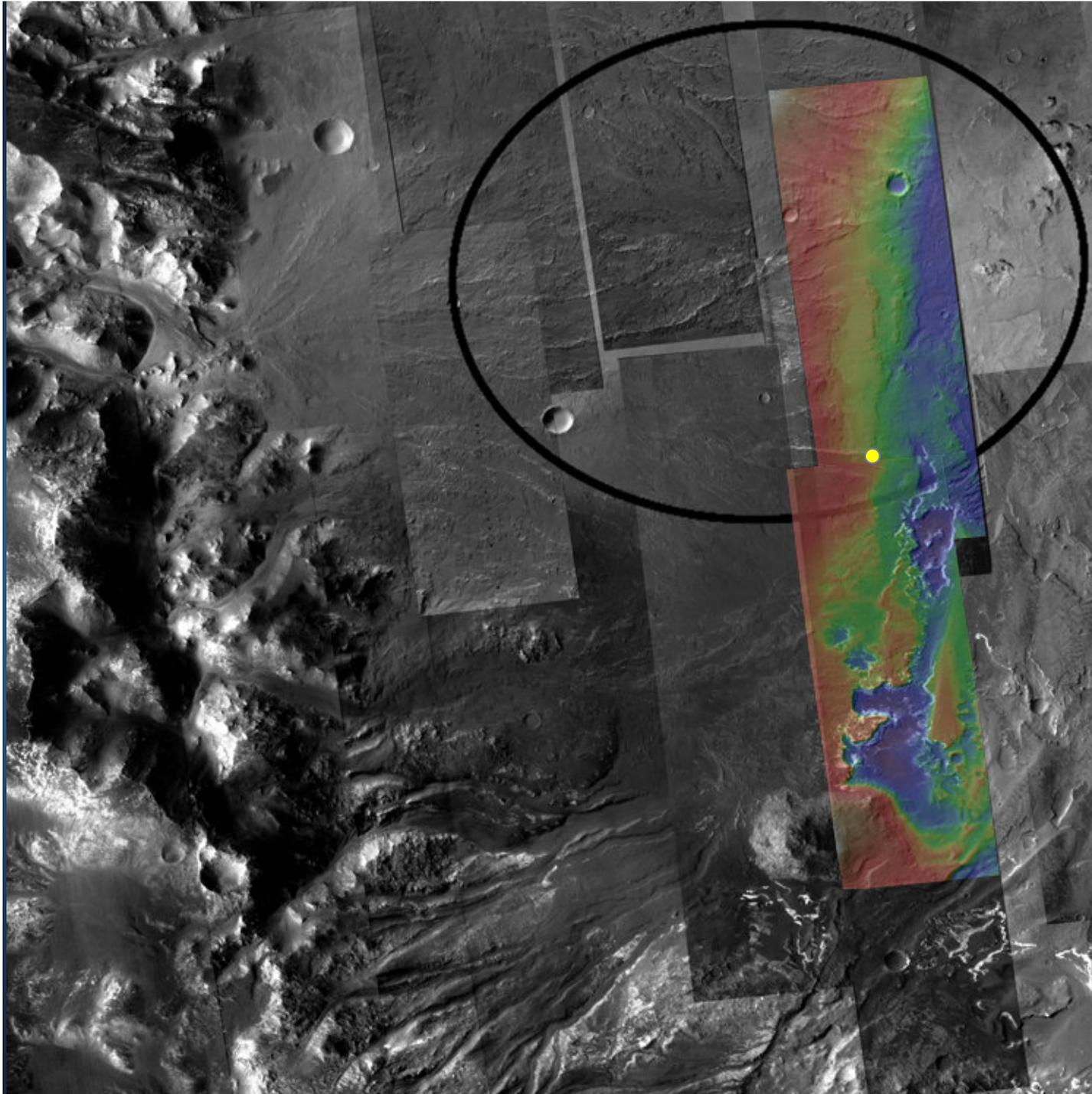
ESP_019678_1535
Right: 1.59 km across
Below: 793 m across

300 m

100 m

Targets of interest





Holden target 1H: Alluvial fan toe

-26.50 North, 325.19 East
km from ellipse center: 7.5

Rationale:

*Exposed contact between
alluvial fan deposits and
underlying lighter-toned
material*

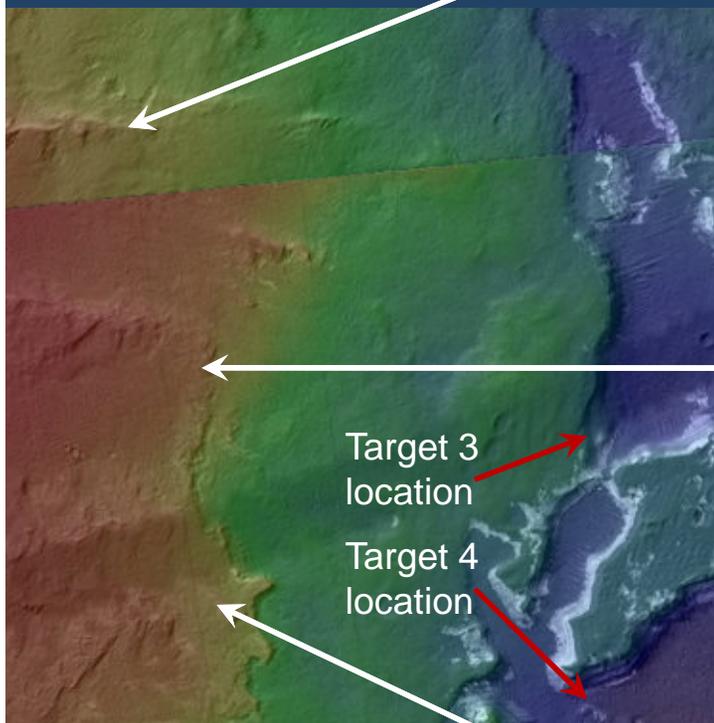
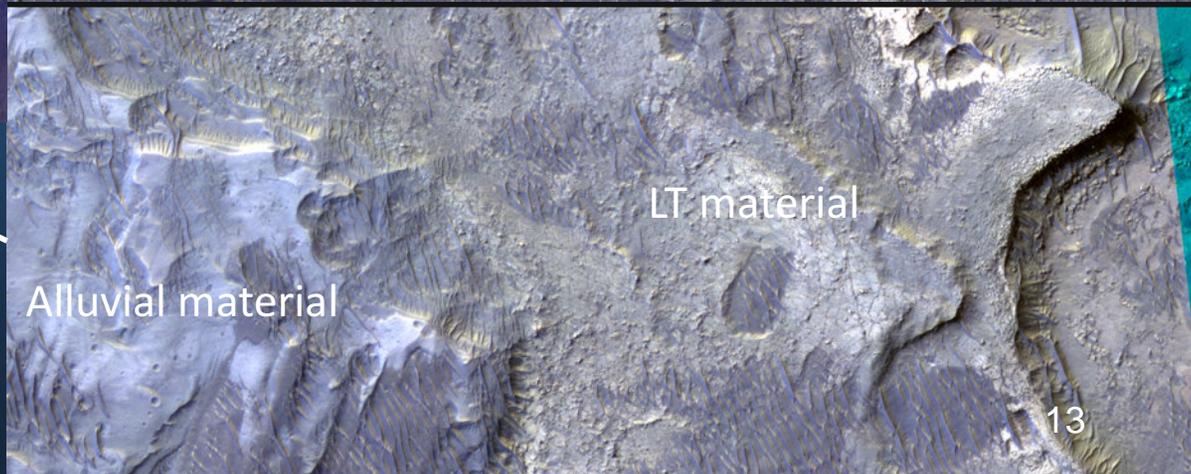
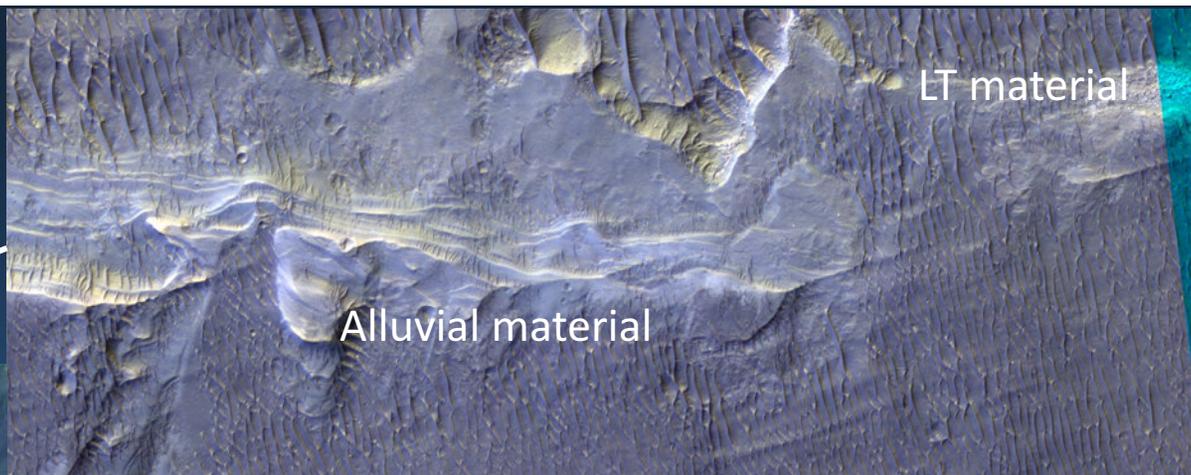
Morphology and Mineralogy:

*Inverted paleochannels:
basaltic, possibly altered;
light-toned material: finer-
grained, likely phyllosilicate-
bearing, fractured*

What will the rover specifically do here?

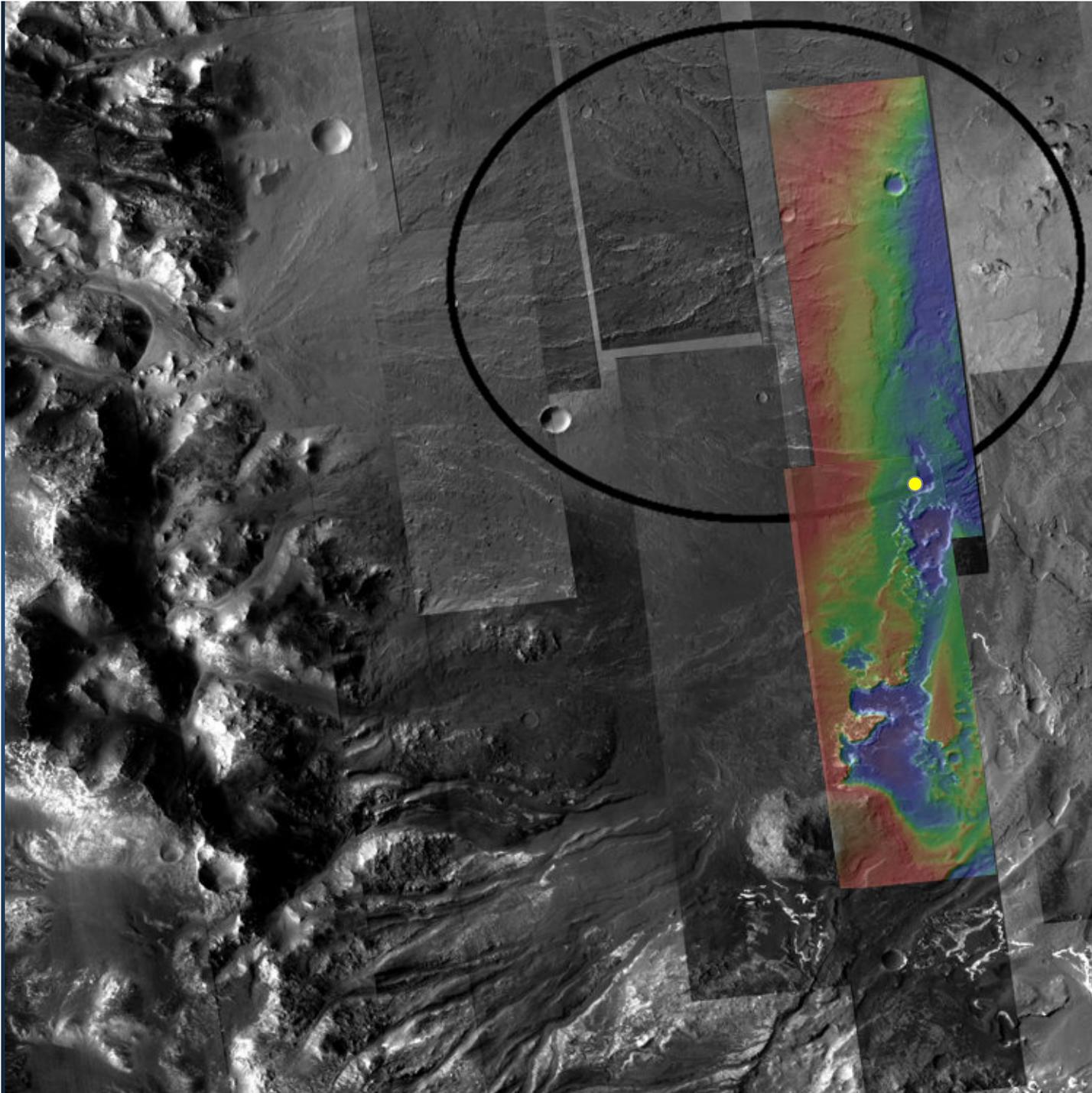
*Sample light-toned, layered
material, compositional
and stratigraphic analyses,
search for organics,
determine if alluvial and LTL
materials are interbedded*

Layered alluvial deposits overlie fractured, lighter-toned material at the fan toe.



PSP_001468_1535
Each 793 m across

100 m



Holden target 1I: Light-toned, layered materials

-26.52 North, 325.23 East
Km from ellipse center: 9.5

Rationale:

*Section of light-toned,
layered strata, suggestive of
a quiescent depositional
environment*

Morphology and

Mineralogy:

*Thinly bedded, laterally
continuous, fine-grained
strata*

What will the rover specifically do here?

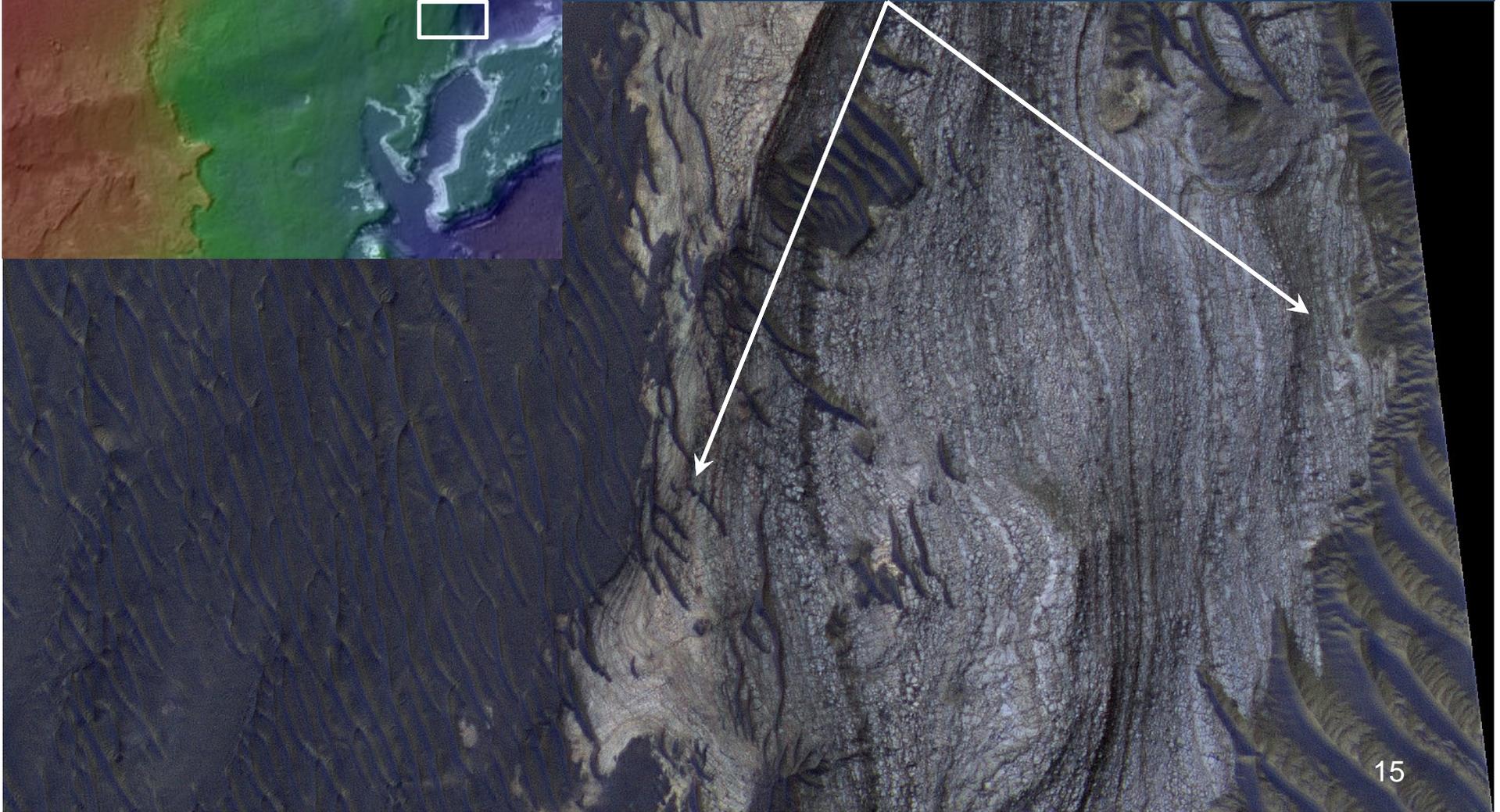
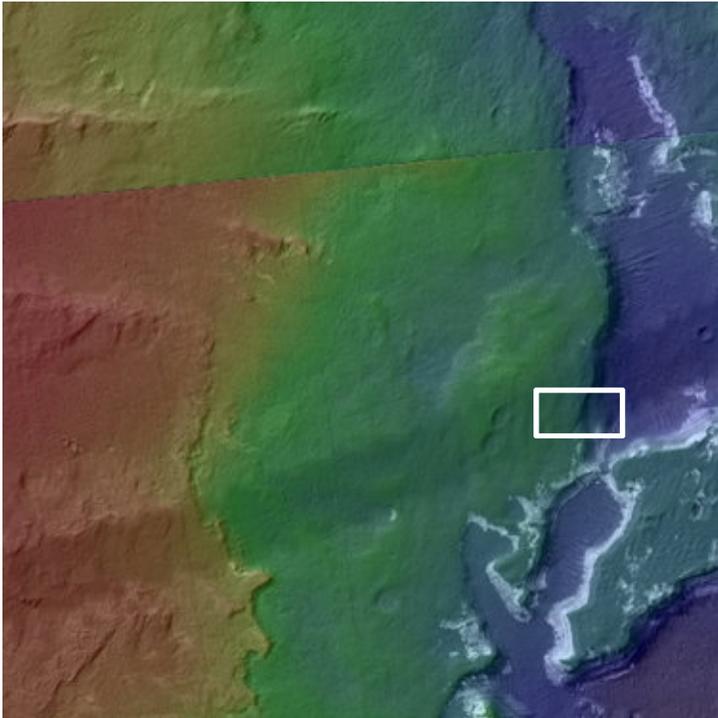
*Stratigraphic and
compositional analyses,
identify depositional
environment, suggest
consistent sediment source
and weathering history,
search for organics*

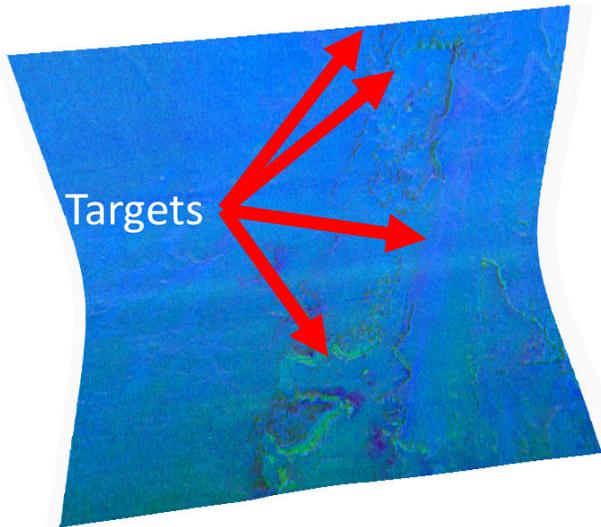
33 m section
8° slope
>40 light/dark pairs

ESP_016276_1535
397 m across

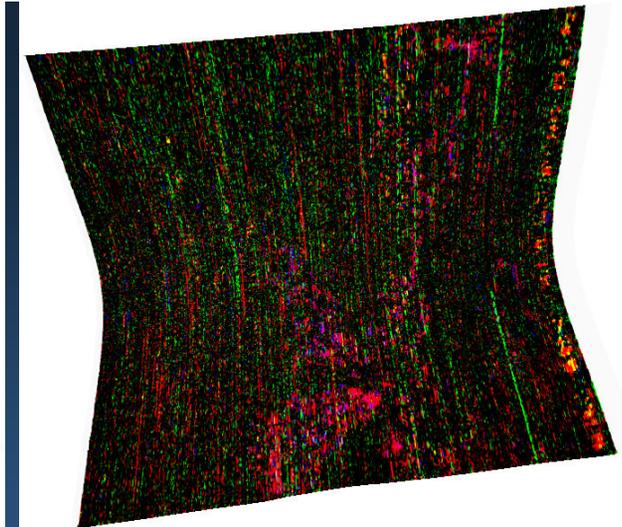
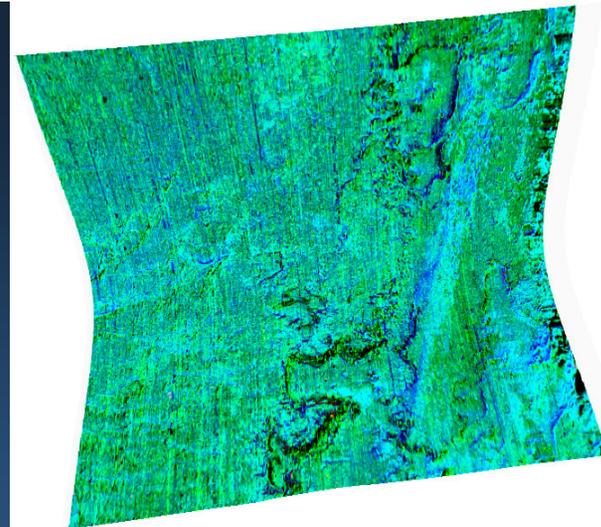
50 m

Target of interest.





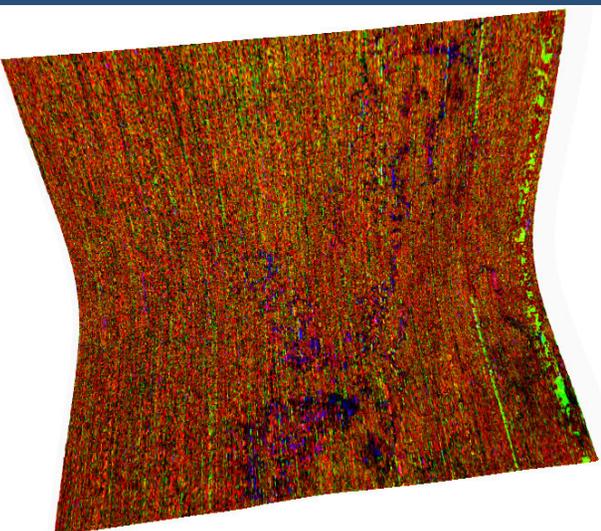
Targets



Oxidized iron minerals
 red = BD530 (ferric minerals)
 green = SH600 nm (coatings)
 blue = BDI1000nm (variety of iron minerals)

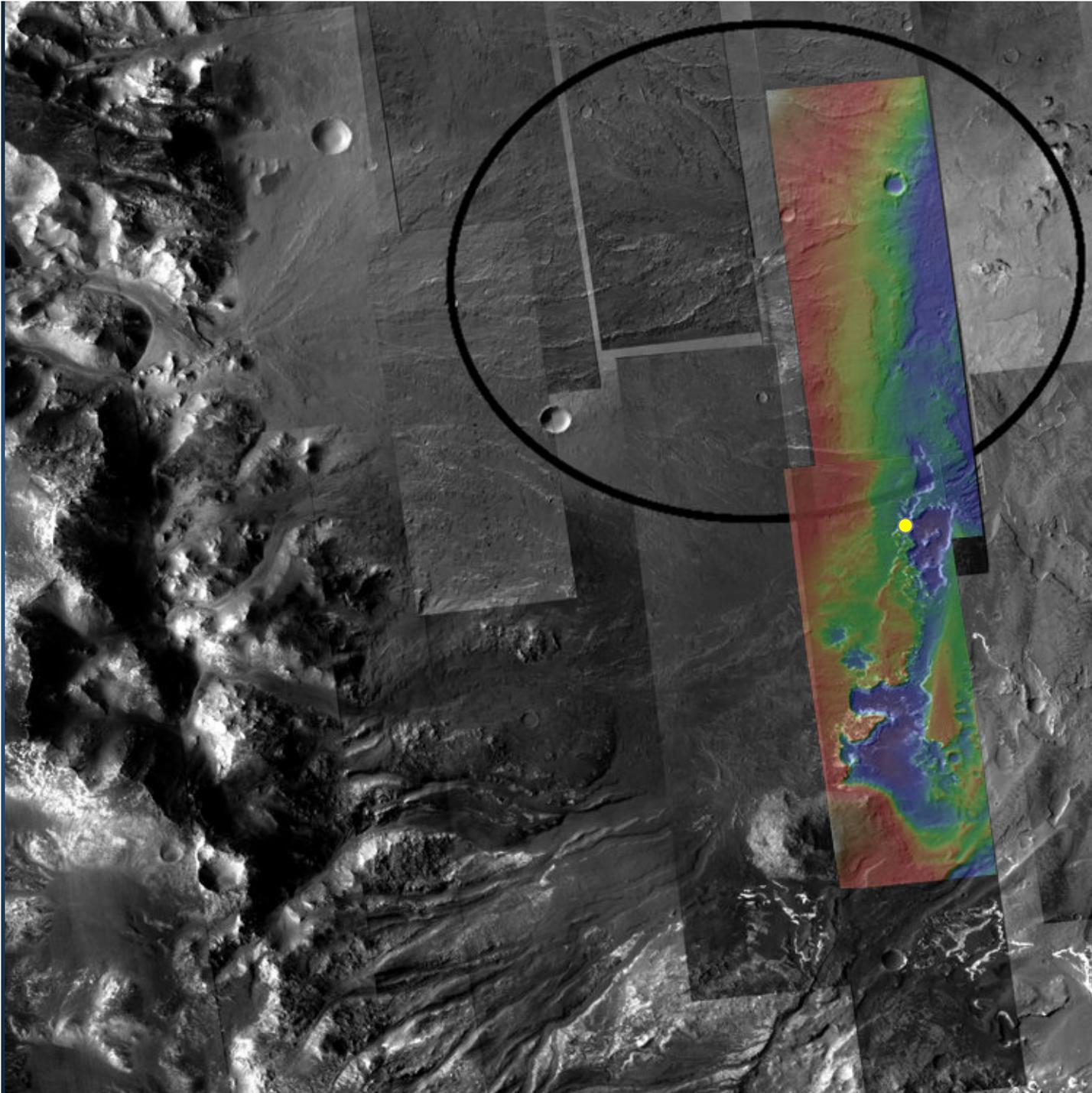
Mafic mineralogy
 red = OLINDEX (olivine or iron phyllosilicates)
 green = LCPINDEX (low-Ca pyroxene)
 blue = HCPINDEX (high-Ca pyroxene)

Hydroxylated silicates
 red = BD2300 (Fe/Mg phyllosilicate)
 green = BD2210 (Al phyllosilicate or hydrated glass)
 blue = BD1900 (hydrated sulfates, clays, glass, or water ice)



Bound water
 red = SINDEXT (water-containing minerals or water ice)
 green = BD2100 (monohydrated sulfates or water ice)
 blue = BD1900nm. (hydrated sulfates, clays, glass, or water ice)

CRISM FRT0000C1D1, derived products
 Credit: NASA/Johns Hopkins University Applied Physics Laboratory



Holden target 2: Light-toned, layered materials

-26.55 North, 325.22 East
Km from ellipse center: 10.5

Rationale:

Section of light-toned, layered strata, suggestive of a quiescent depositional environment

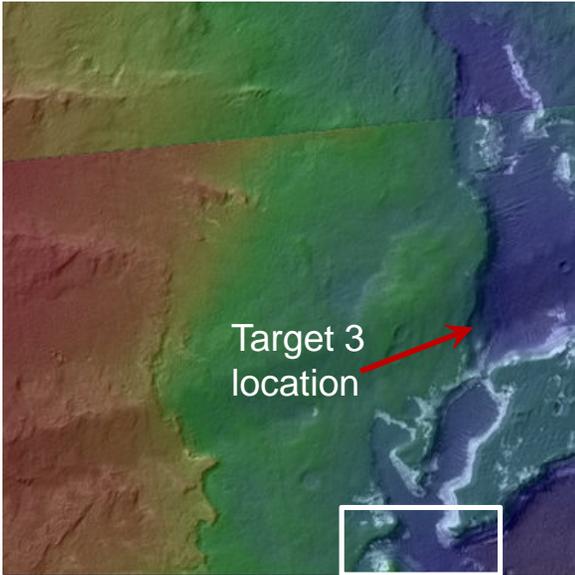
Morphology and

Mineralogy:

Thinly bedded, laterally continuous, fine-grained strata

What will the rover specifically do here?

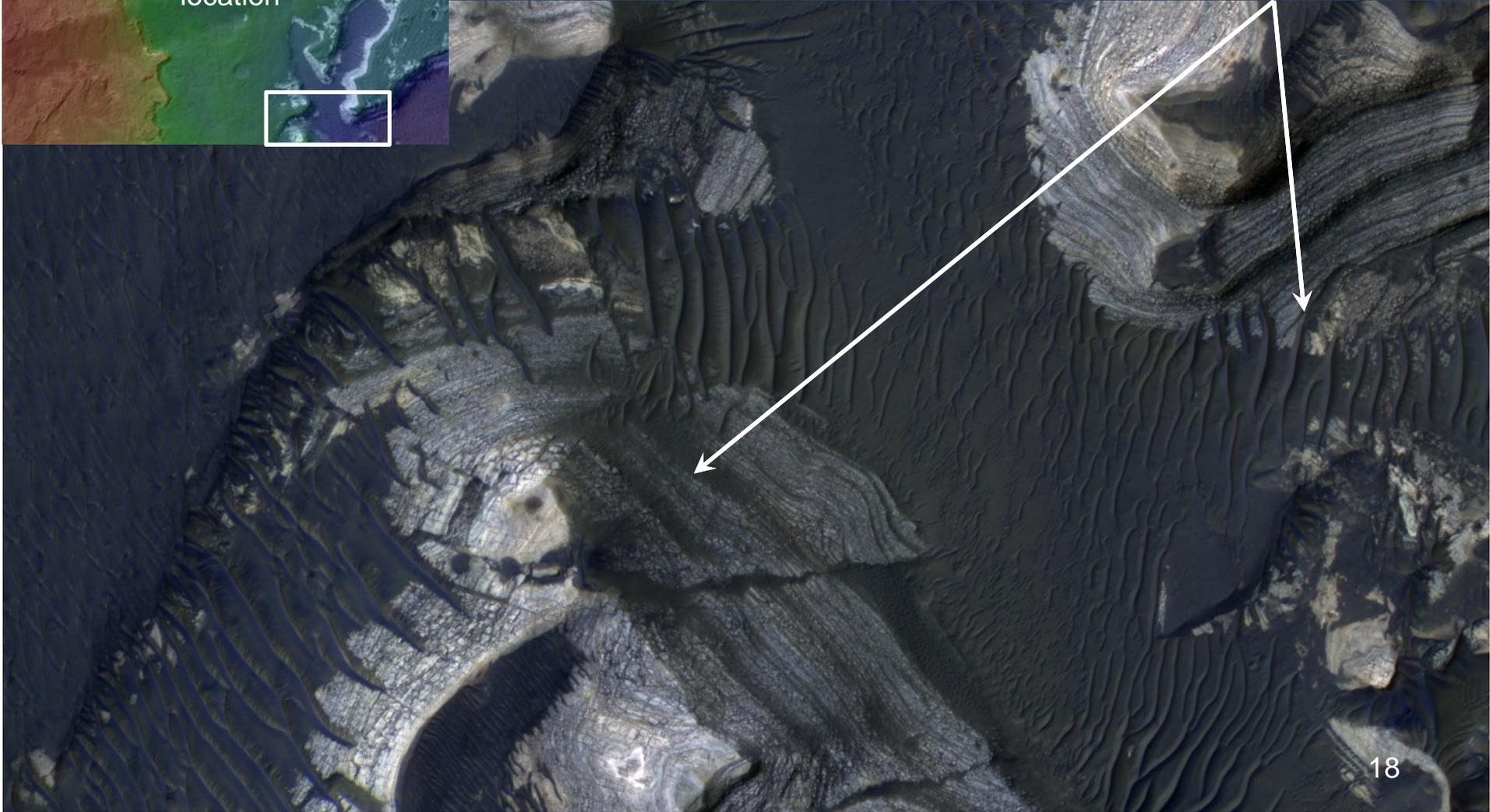
Stratigraphic and compositional analyses, identify depositional environment, suggest consistent sediment source and weathering history, search for organics



ESP_015999_1535
783 m across

Targets of interest.
Many other LTL outcrops
are available along the
notional traverse

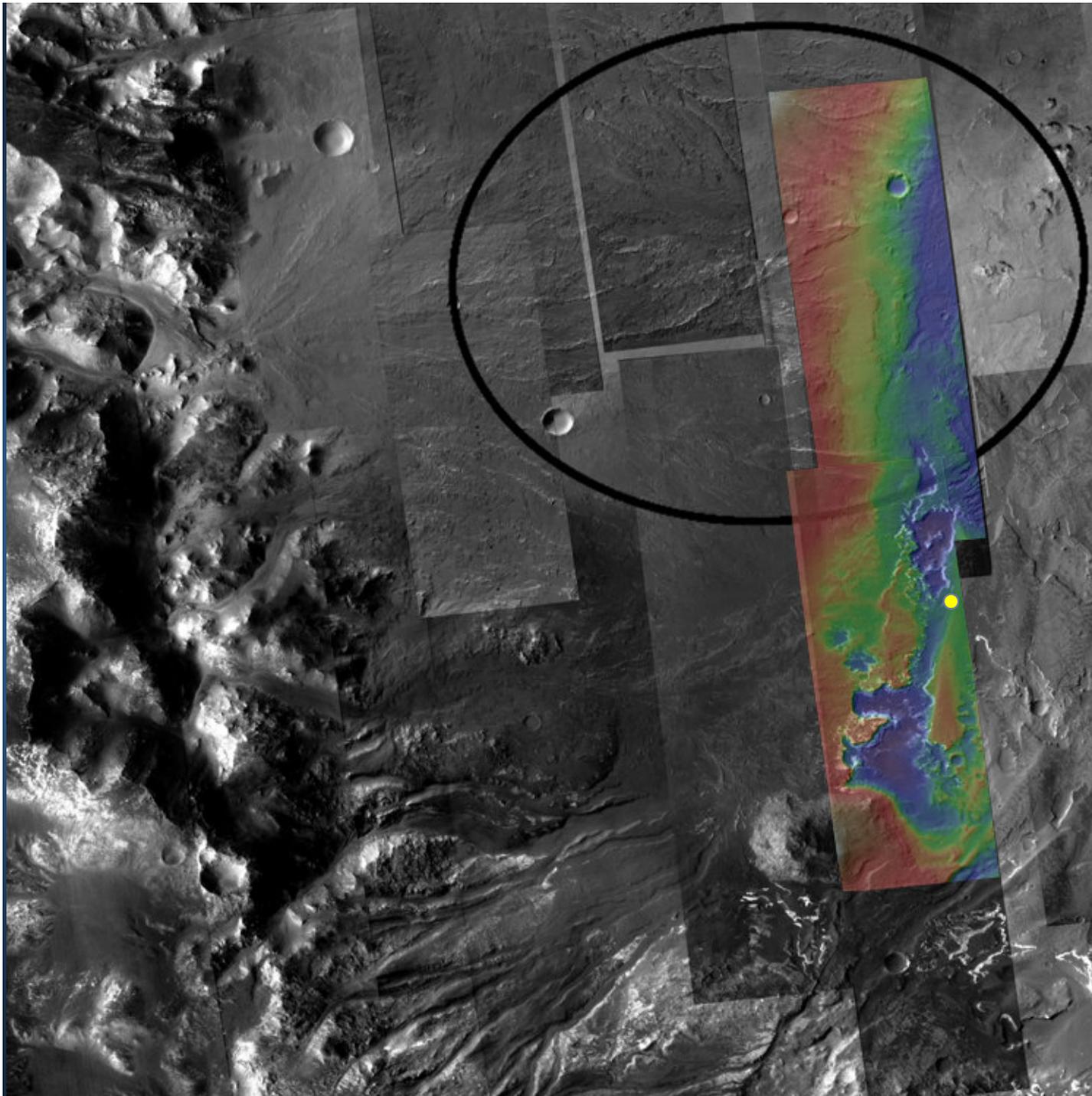
100 m



Holden Crater LTL Materials



100 m



Holden target 3:
Coarse deposits
(proximal Uzboi Vallis)

-26.59 North, 325.25 East
km from ellipse center: 13.6

Rationale:

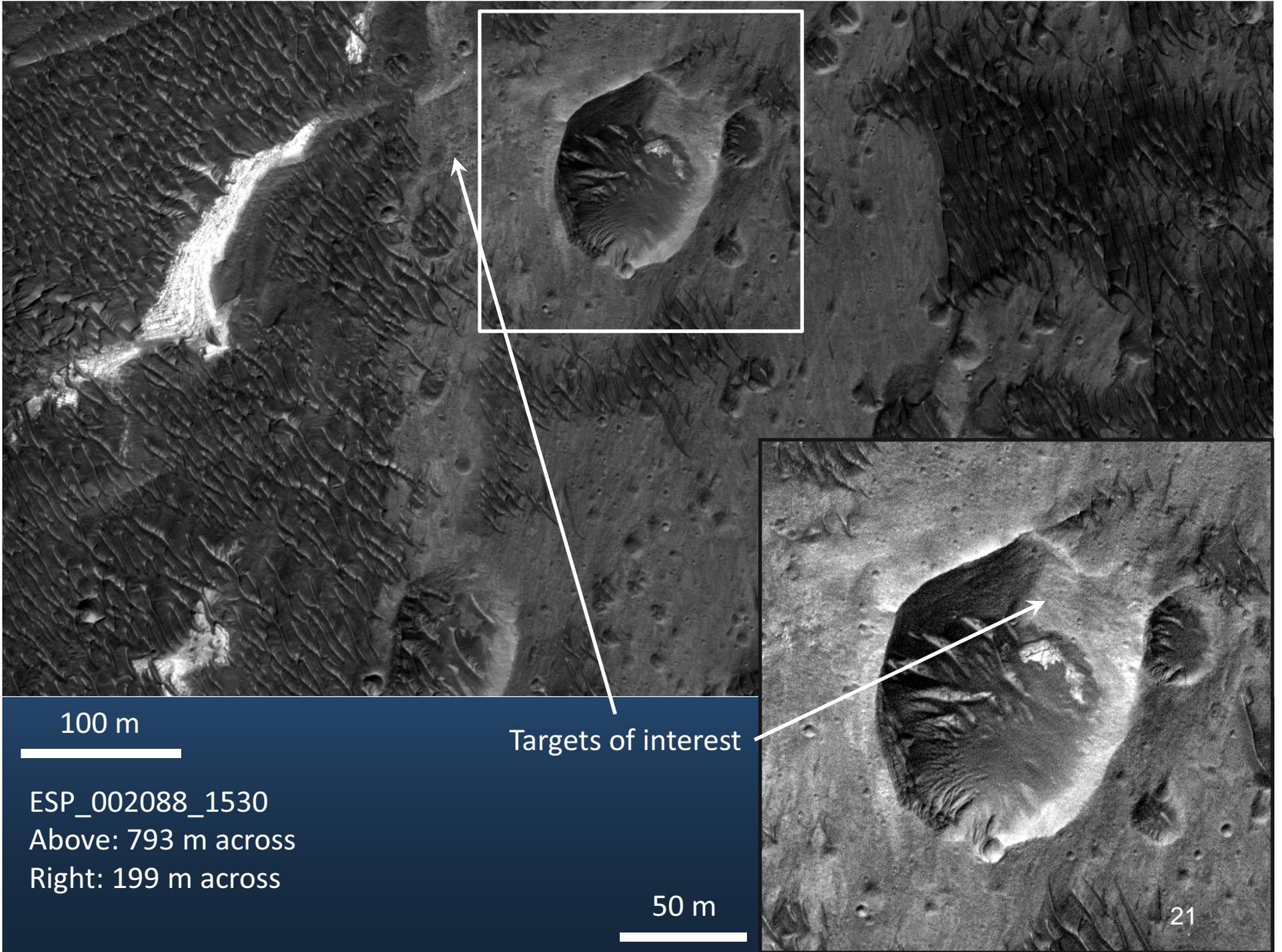
*Rocks likely derived from
Uzboi Vallis, late-stage
flooding of Holden crater
floor*

Morphology and
Mineralogy:

*Coarse-grained, cross-
bedded deposits, likely
basaltic, possibly altered*

What will the rover
specifically do here?

*Examine deposits from
late-stage lake,
weathering environment,
chemical energy sources,
organics; determine
diversity of materials
exposed on floor*

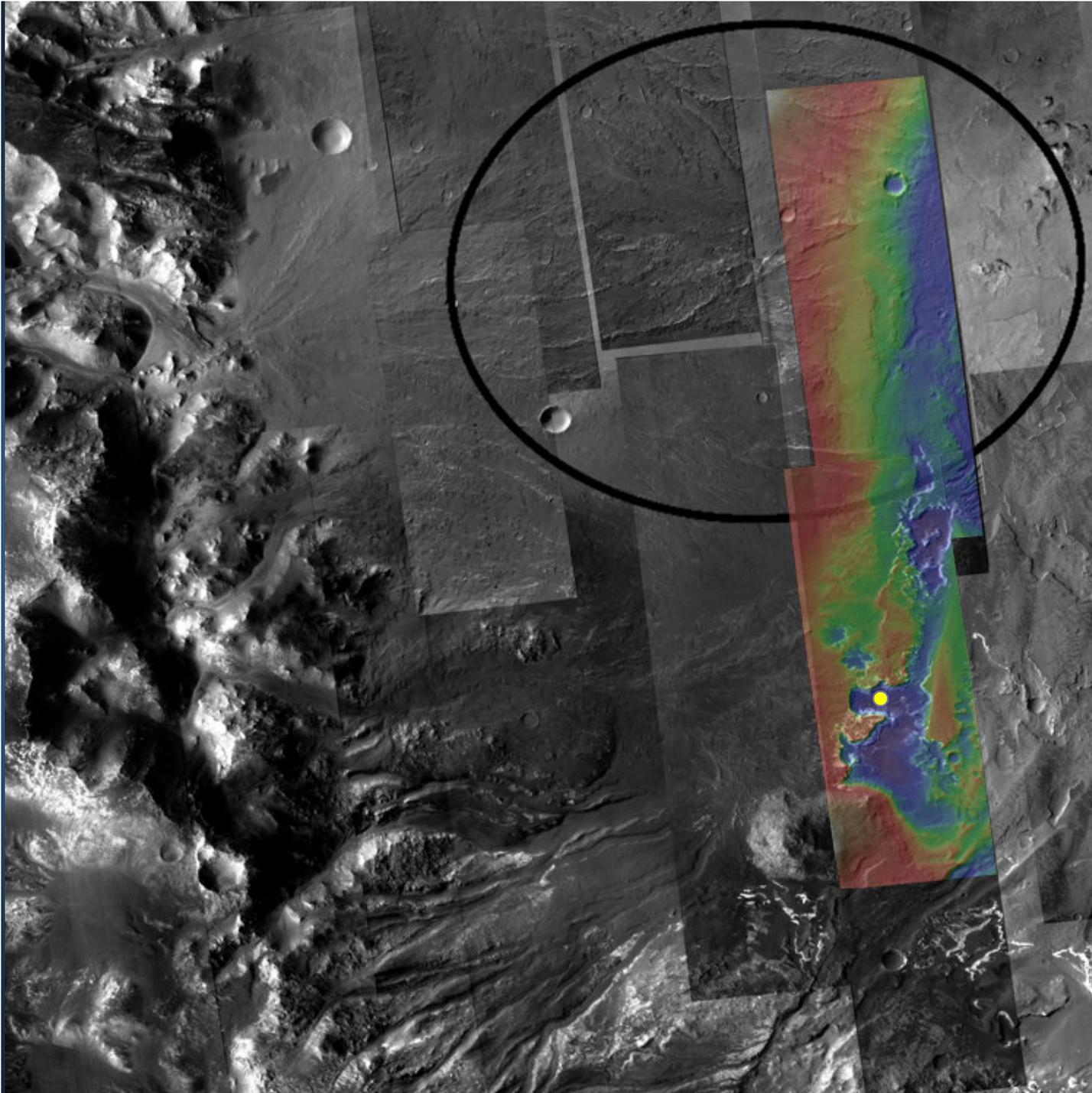


100 m

Targets of interest

ESP_002088_1530
Above: 793 m across
Right: 199 m across

50 m



Holden target 4:
Best phyllosilicate
signature, light-toned,
layered outcrop

-26.64 North, 325.21 East
km from ellipse center: 17.2

Rationale:

*Section of light-toned,
layered strata, suggestive of
a quiescent depositional
environment*

Morphology and
Mineralogy:

*Thinly bedded, laterally
continuous, fine-grained
strata*

What will the rover
specifically do here?

*Stratigraphic and
compositional analyses,
identify depositional
environment, suggest
consistent sediment source
and weathering history,
search for organics 22*



200 m



ESP_002088_1530

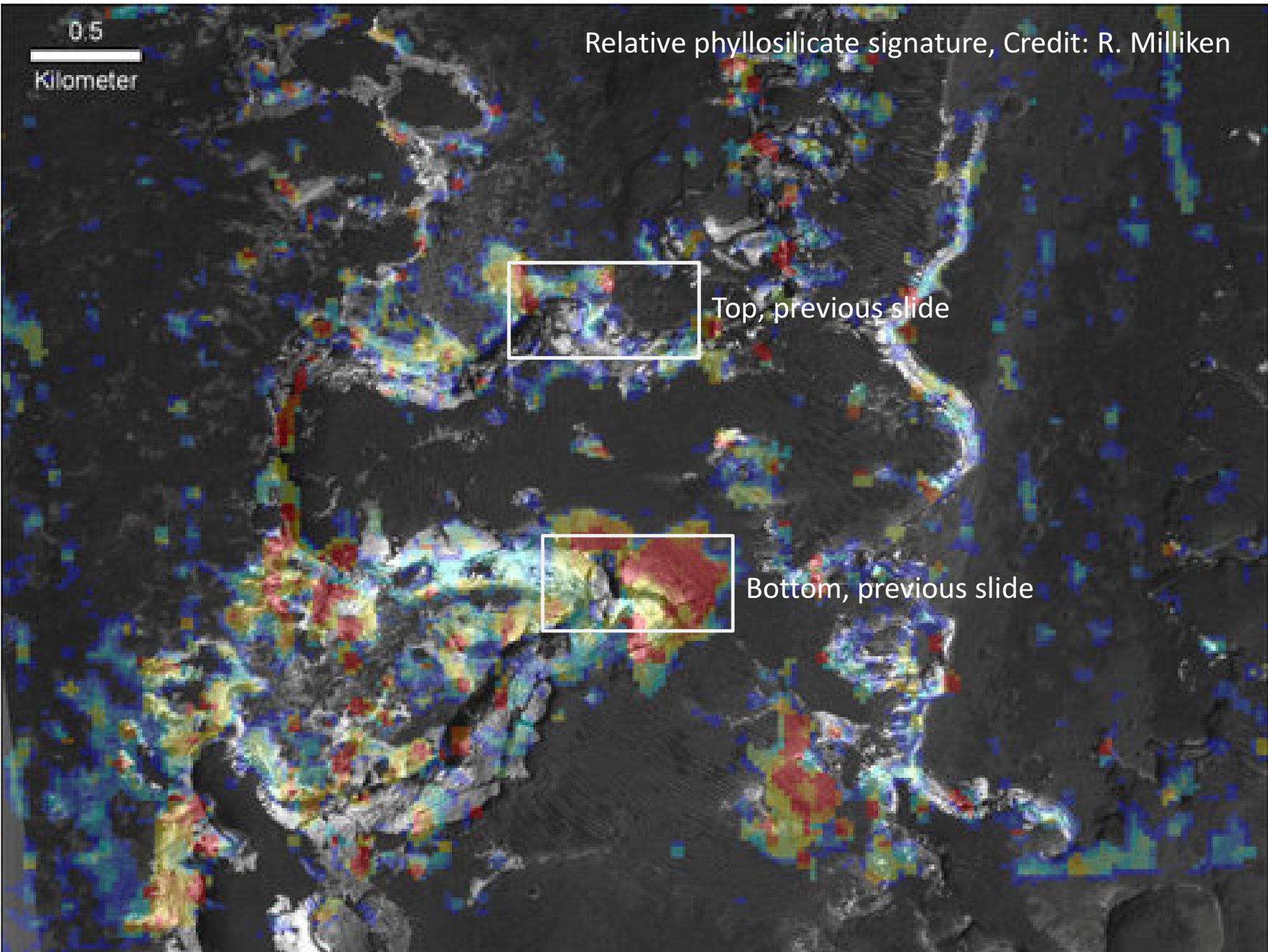
Left: 793 m across

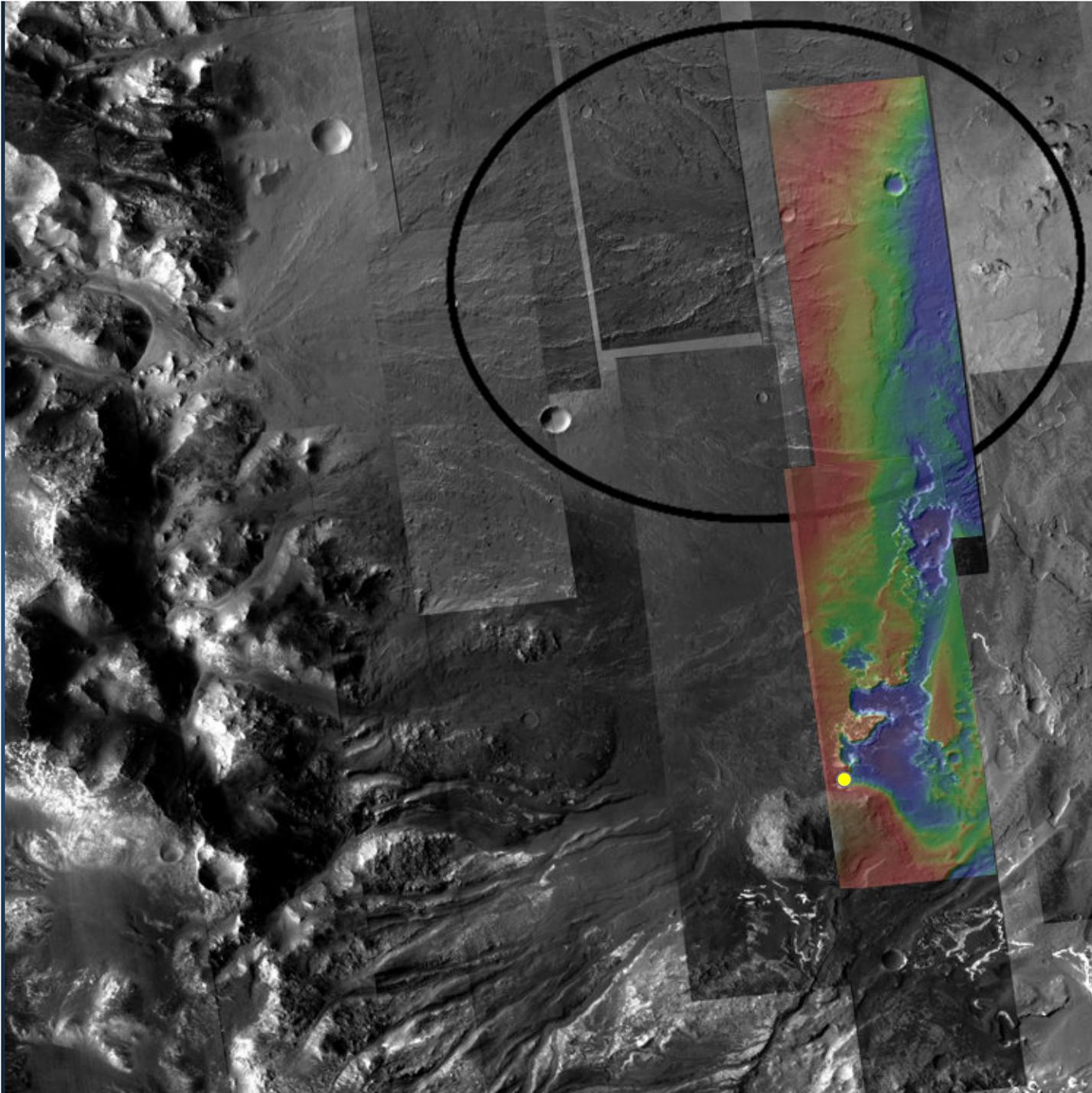
Below: 793 m across

Targets of interest

100 m







Holden target 5:
Topographically
higher light-toned,
layered outcrop

-26.70 North, 325.18 East
km from ellipse center: 19.8

Rationale:

*Section of light-toned,
layered strata, suggestive of
a quiescent depositional
environment*

Morphology and
Mineralogy:

*Thinly bedded, laterally
continuous, fine-grained
strata*

What will the rover
specifically do here?

*Stratigraphic and
compositional analyses,
identify depositional
environment, examine LTL
spatial variability, search for
organics*

100 m

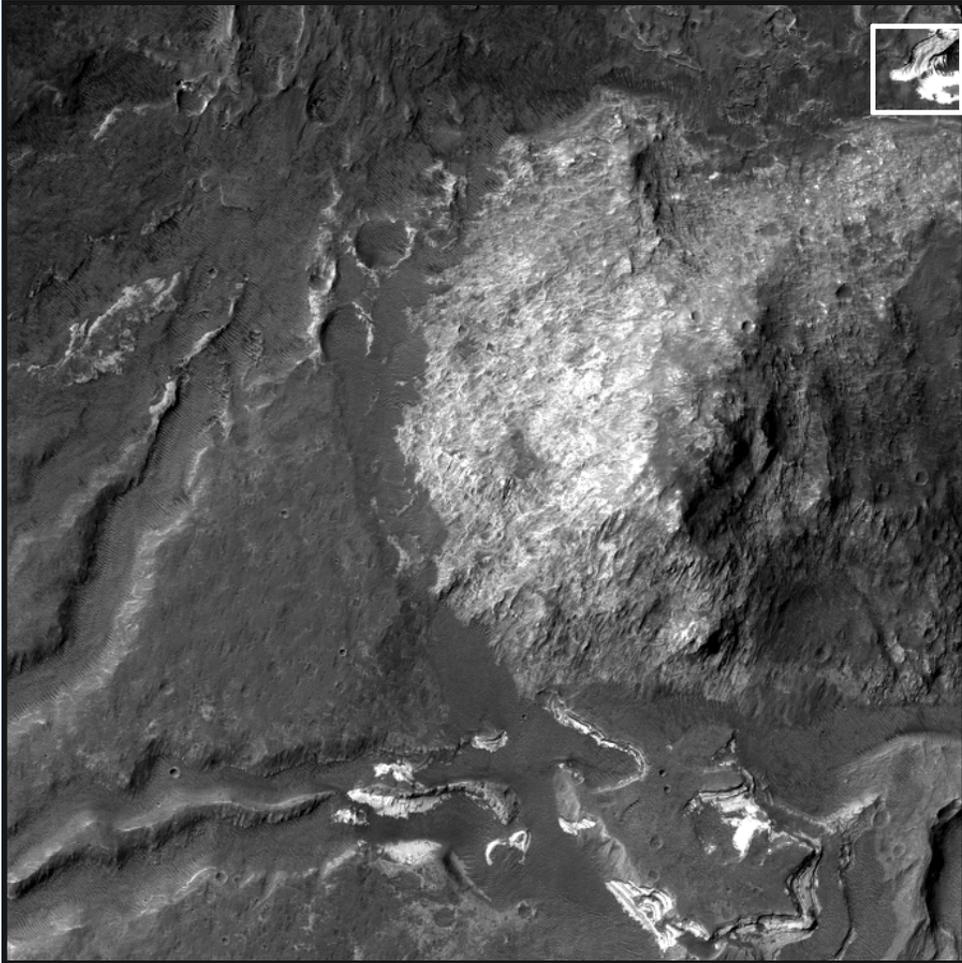
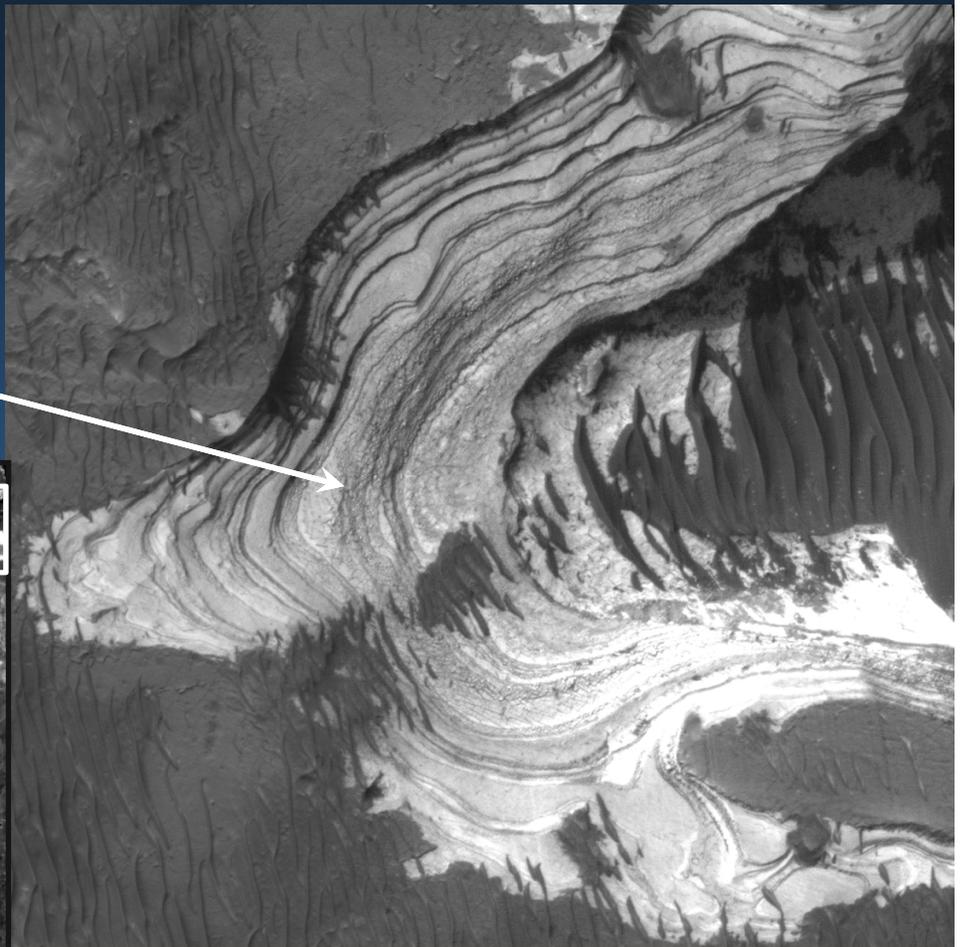
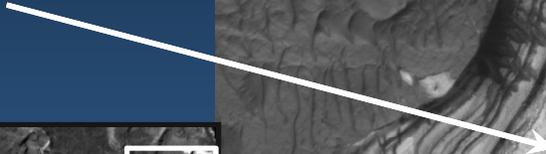


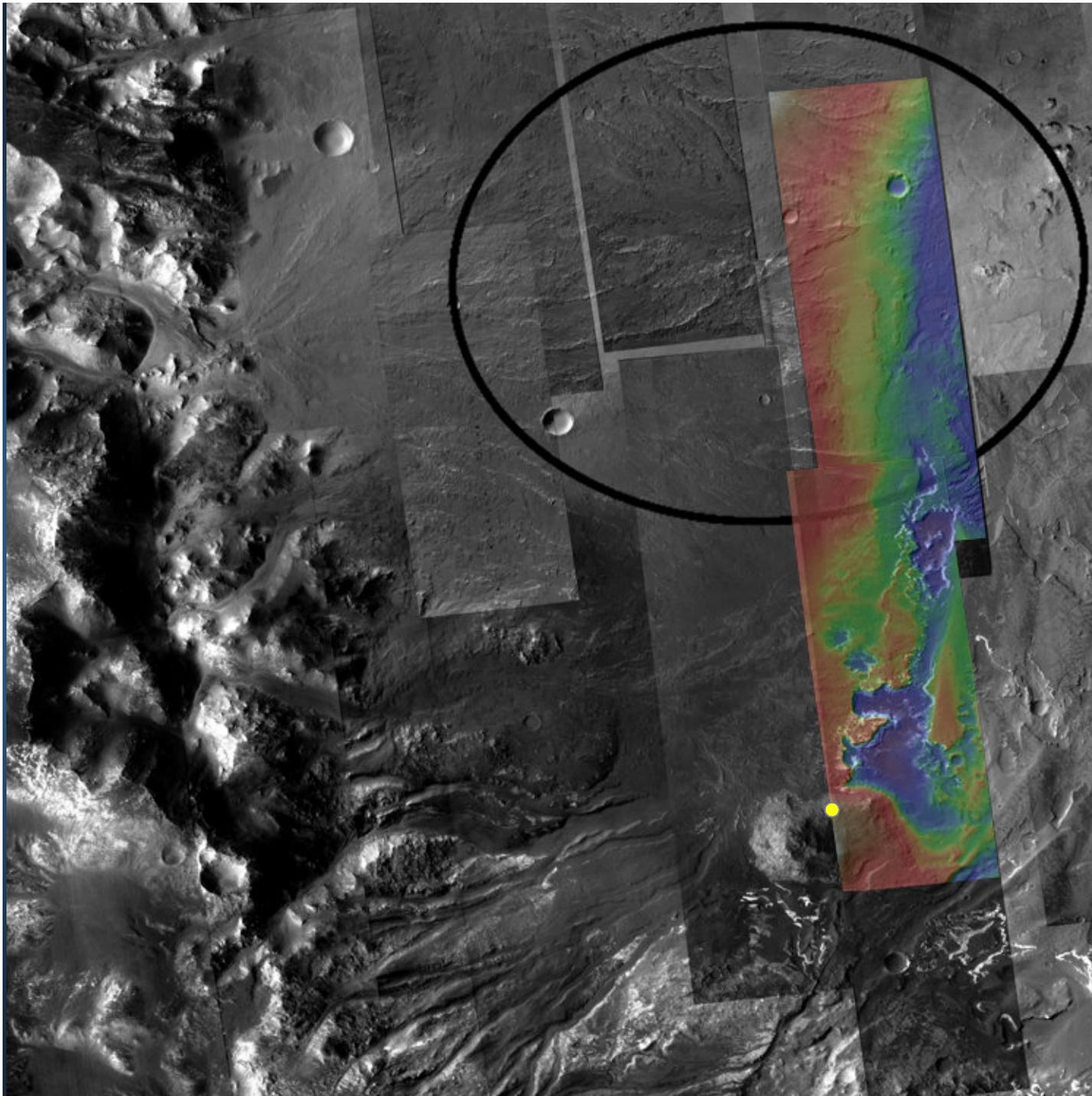
ESP_019322_1530
Right: 433 m across
Below: 5.5 km across

800 m



Target of interest





**Holden target 6: Knob
of underlying rocks
(megabreccia)**

-26.71 North, 325.18 East
km from ellipse center: 20.2
[Extended mission]

Rationale:

*Megabreccia on Holden
floor, light-toned veins in
rock, possible former
hydrothermal environment*

Morphology and

Mineralogy:

*Knob of coarse rocks with
tone/color contrasts and
veins*

What will the rover
specifically do here?

*Examine rocks and veins for
possible hydrothermal
deposits, chemical energy
sources, organics, and
alteration; determine
diversity of materials
exposed on crater
floor*

100 m

Targets of interest

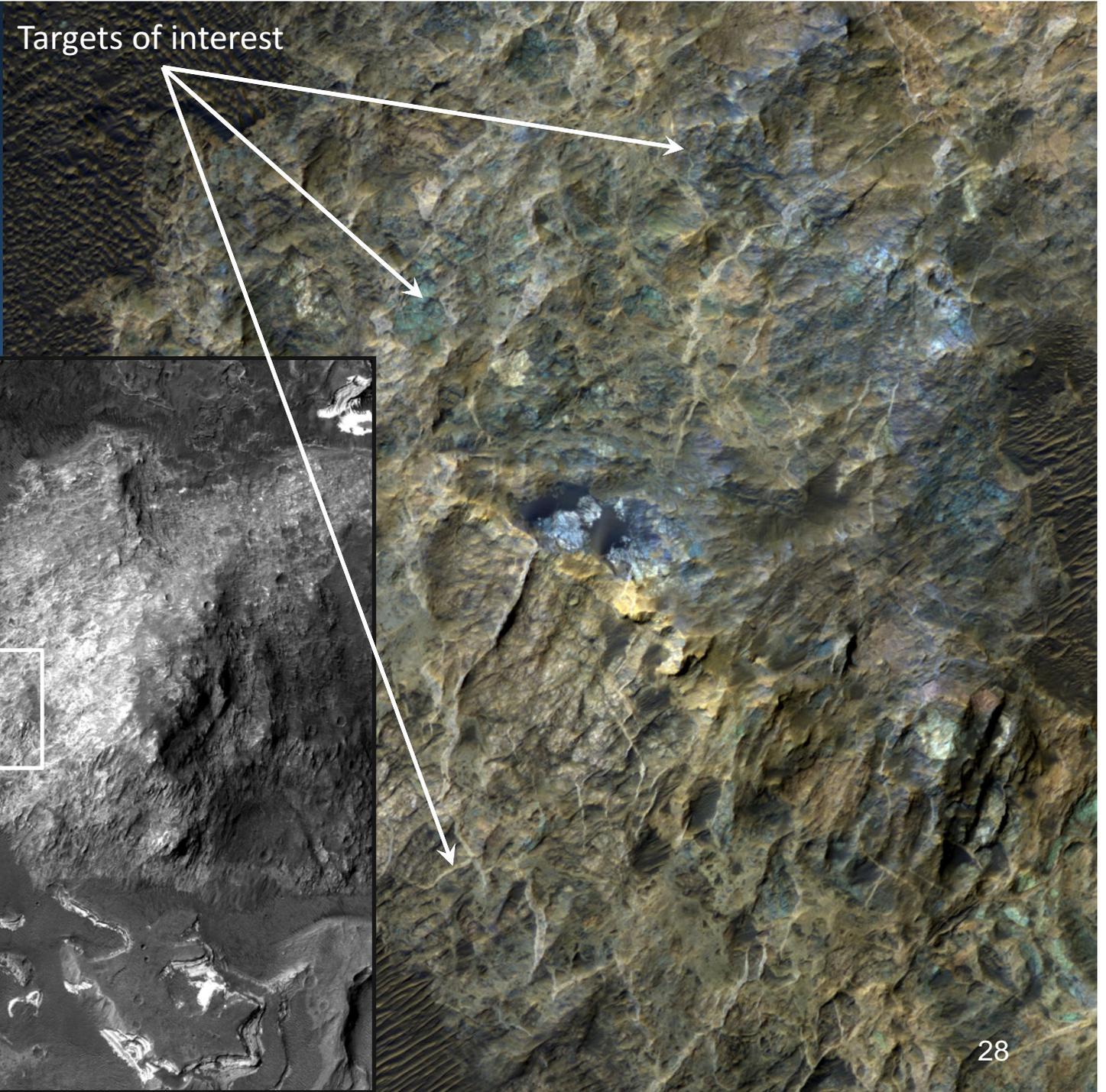
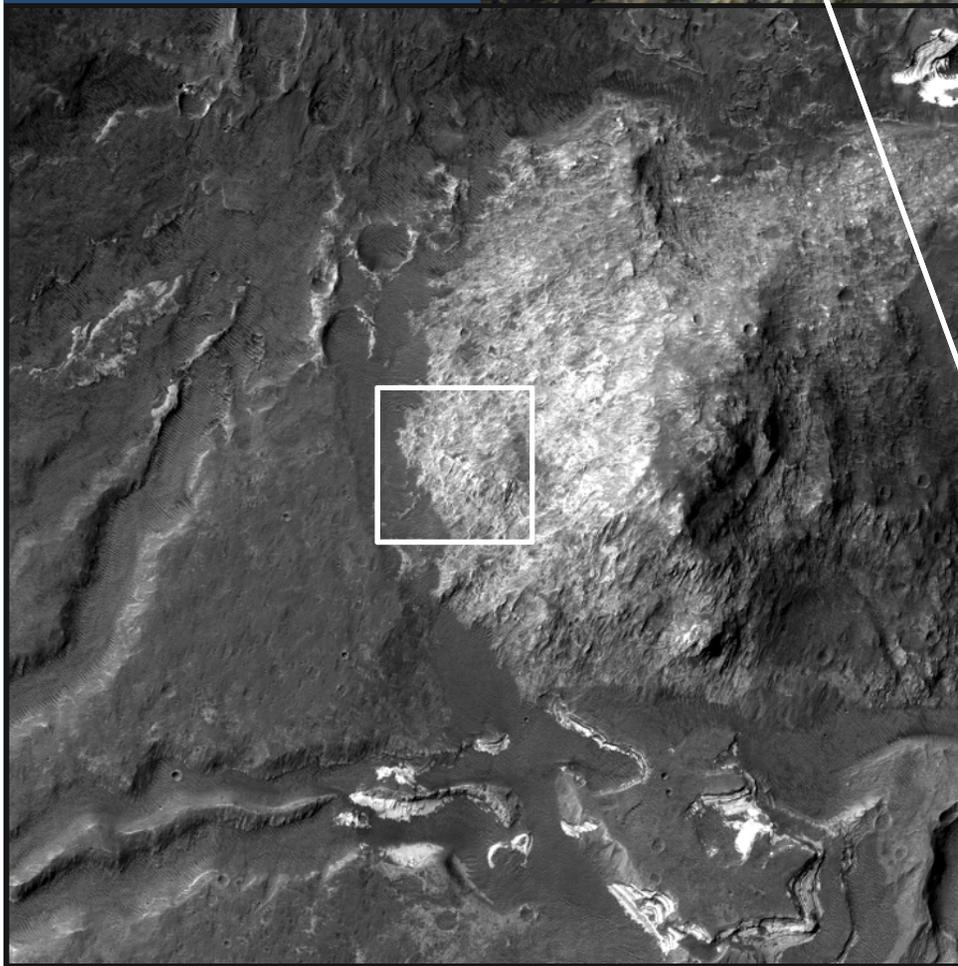
ESP_019322_1530

Right: 793 m across

Below: 5.5 km across

Veins in positive relief

800 m



Holden Crater Site



26S, 325E

Overarching Hypothesis:

- Holden crater preserves evidence of a closed fluvial-lacustrine system that provides the opportunity to apply a geomorphic systems approach to evaluating and preserving evidence for a sustained, habitable environment.

Specific Cons of Site:

- Origin of stratified light-toned materials as lacustrine versus alternate depositional processes remains uncertain, but in situ evaluation of bedding character and chemistry is likely to distinguish origin.
- Relatively limited variety of phyllosilicate minerals known to preserve organics detected from orbit.

Specific Pros of Site:

Setting -

- The bajada in the ellipse and light-toned layered materials comprise one of the largest and best preserved alluvial systems on Mars. The diverse and potentially weathered sediments likely record the environmental conditions responsible for their formation during the Hesperian perhaps into the Early Amazonian. This sequence is underlain by the light-toned layered deposits and overlying Uzboi flood deposits and enable the age of the target deposits to be related to global stratigraphy.
- Collectively, additional diverse and widespread megabreccias in and outside the ellipse and alluvial materials in the ellipse suggests sampling of rocks ranging in age from early crustal Noachian to perhaps into the Hesperian or even Early Amazonian.

Diversity -

- Diversity is represented by fan sediments, phyllosilicate-bearing light-toned layered deposits, Uzboi flood deposits, and mega-breccias in the crater walls/floor.
- The mineralogical diversity in the light-toned layered deposits and crater walls/floor include both altered and primary compositions.

Preservation -

- Strata comprising the light-toned layered materials may be the equivalent of bottom set beds emplaced in a lacustrine setting, which might preserve organics for interrogation by the MSL.

Exploration Targets -

- Well-defined exploration targets exist within and outside the landing ellipse. Targets within the ellipse offer access to all major units for interrogation, though thicker sections of the light-toned layered materials and megabreccias occur farther to the south. Putative bottomset beds provide a target for evaluating any preserved organics

Remaining Uncertainties:

- There are no shorelines or stratal geometries and limited evidence for other properties associated with the light-toned layered deposits and fans that can be used to more confidently define their origin and genetic relationships.
- Diverse megabreccia occurrences within the ellipse, walls, and rims may include evidence that they supported an impact-induced hydrothermal system.
- Light-toned layers high on the west wall of Holden may relate to older beds excavated from the pre-existing Holden basin.
- Age of light-toned layered deposits and adjacent alluvial fan surfaces are no older than Early Hesperian and fans may be as young as Early Amazonian, though there is no consensus whether this is an issue for habitability and evaluating conditions for life.

Conclusions

- Good outcrops of all four target materials are available within the MSL ellipse
- More outcrops and lower strata of all four are accessible to the south
- One of the most deeply eroded crater rims on Mars: abundant water
- Diversified habitability investigation minimizes risk
- Sampling and chronology opportunities
- Safe landing site, trafficable route, low elevation

20 km

