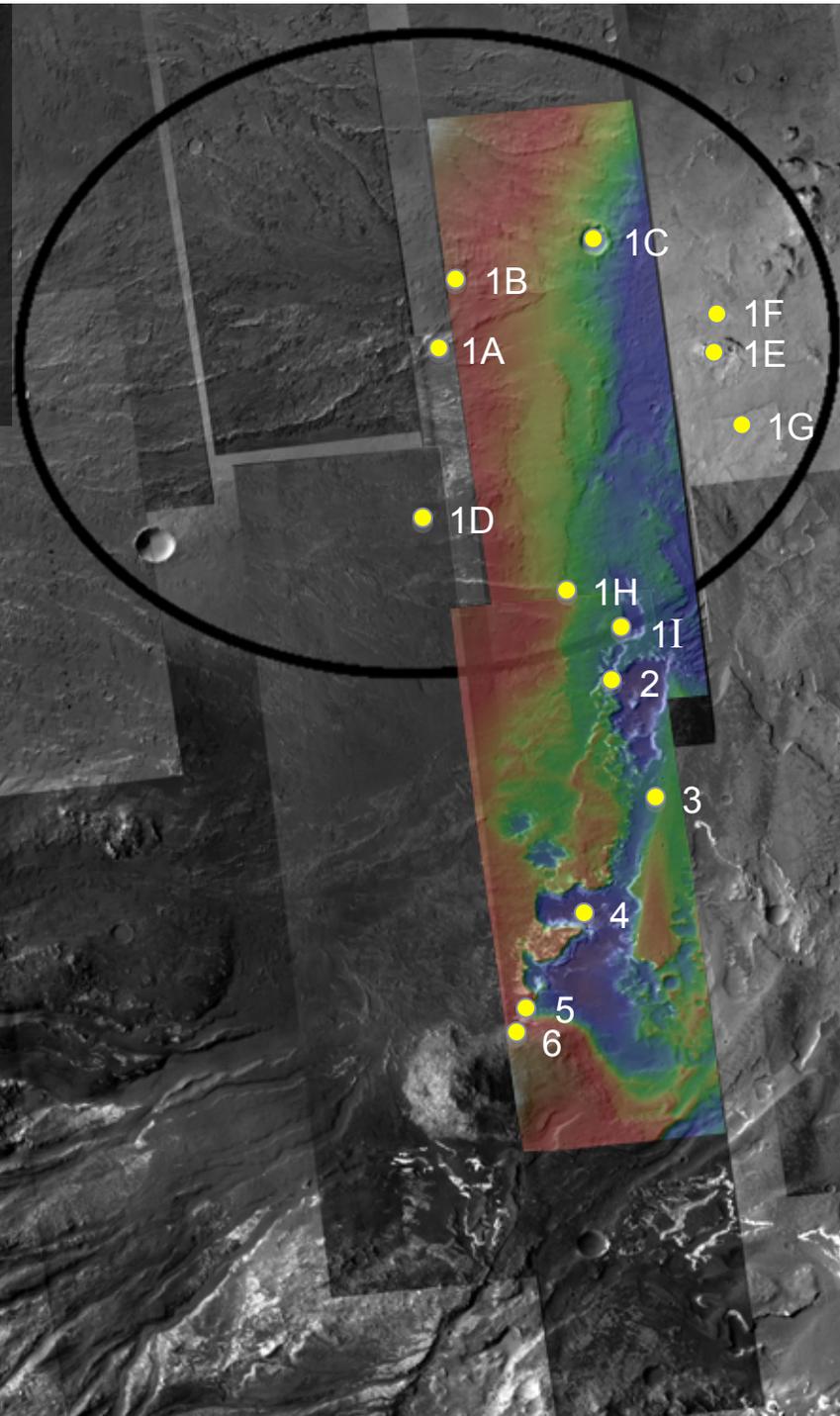


Holden MSL Targets

Ross Irwin
Planetary Science Institute
5th MSL Workshop
May 17, 2011



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]

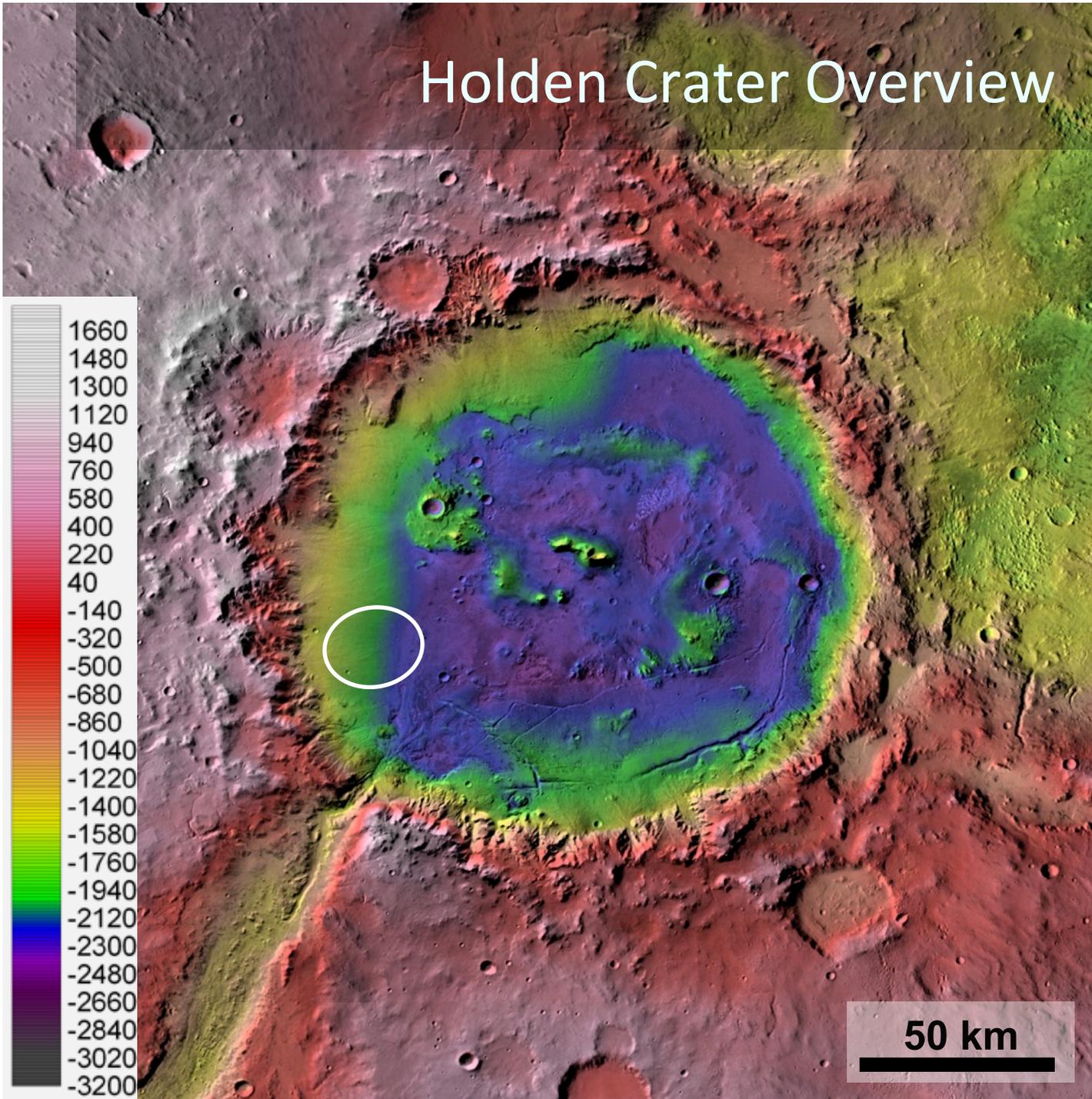
Outside ellipse

- 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)

Holden Crater Overview



- 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

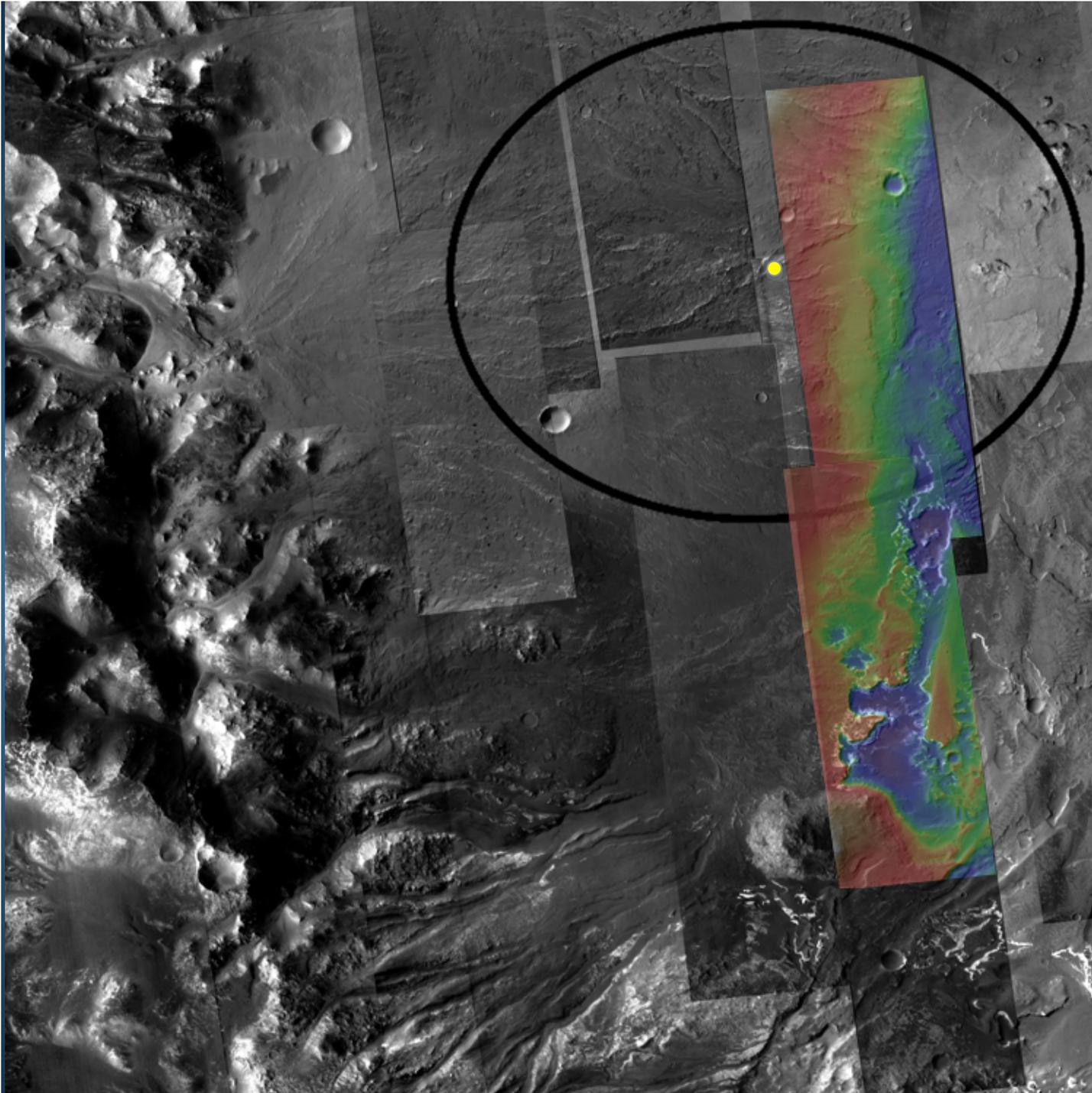
- Stratigraphy, sedimentology, and geochemistry of 100-m-thick medium to fine-grained section reflects depositional environment and change over time
- Ideal site to search for organics and effects of biological processes

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*

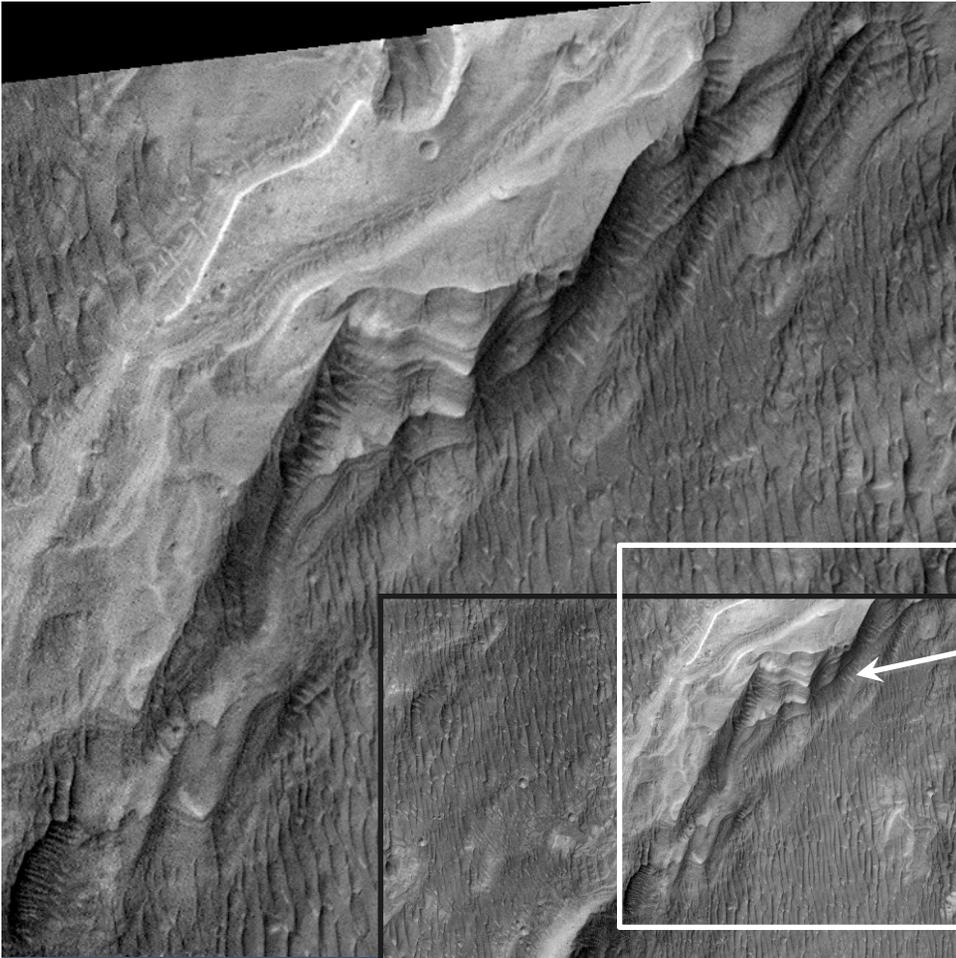
Morphology and

Mineralogy:

*Inverted paleochannels:
basaltic, possibly altered*

What will the rover
specifically do here?

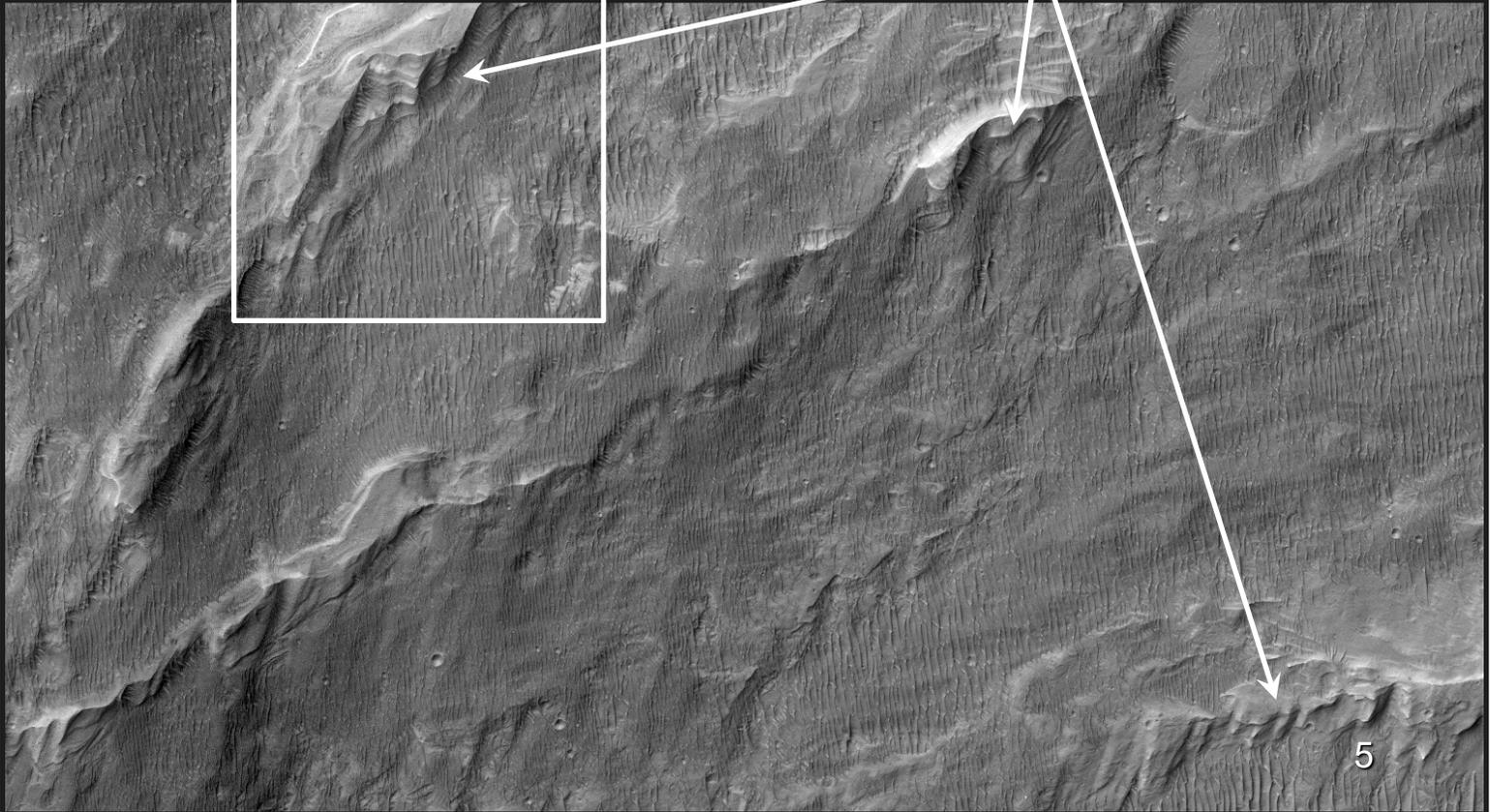
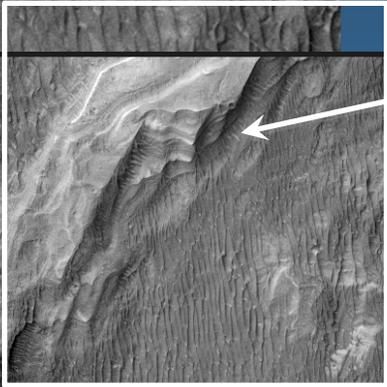
*Determine diversity of
materials in upper >1 km of
highland crust, determine
emplacement mechanism
for fans, examine
stratigraphy within inverted
channels for temporal
change in environment*



100 m

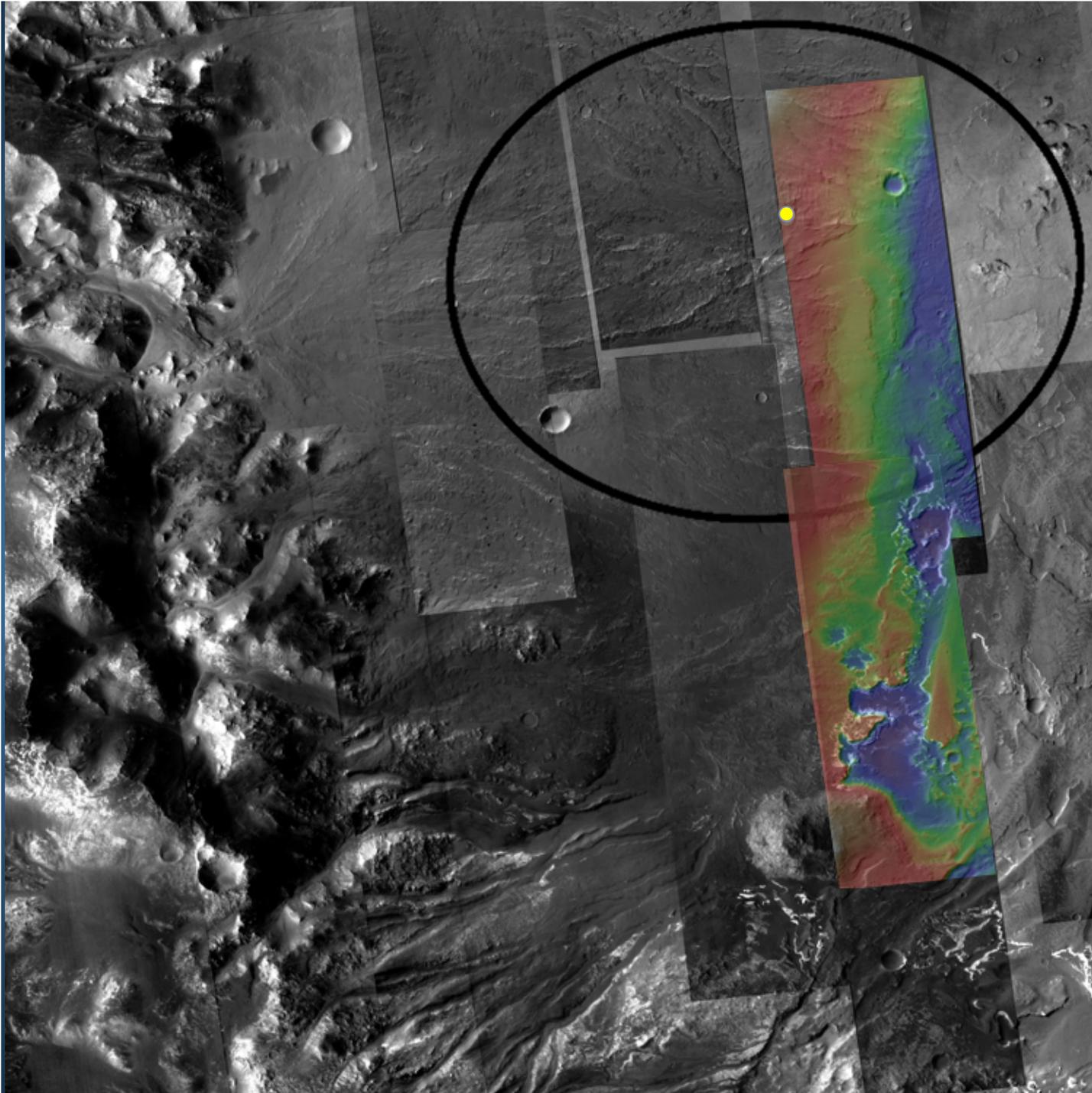
Ellipse center
PSP_002154_1530
Left: 397 m across
Below: 1.59 km across

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*

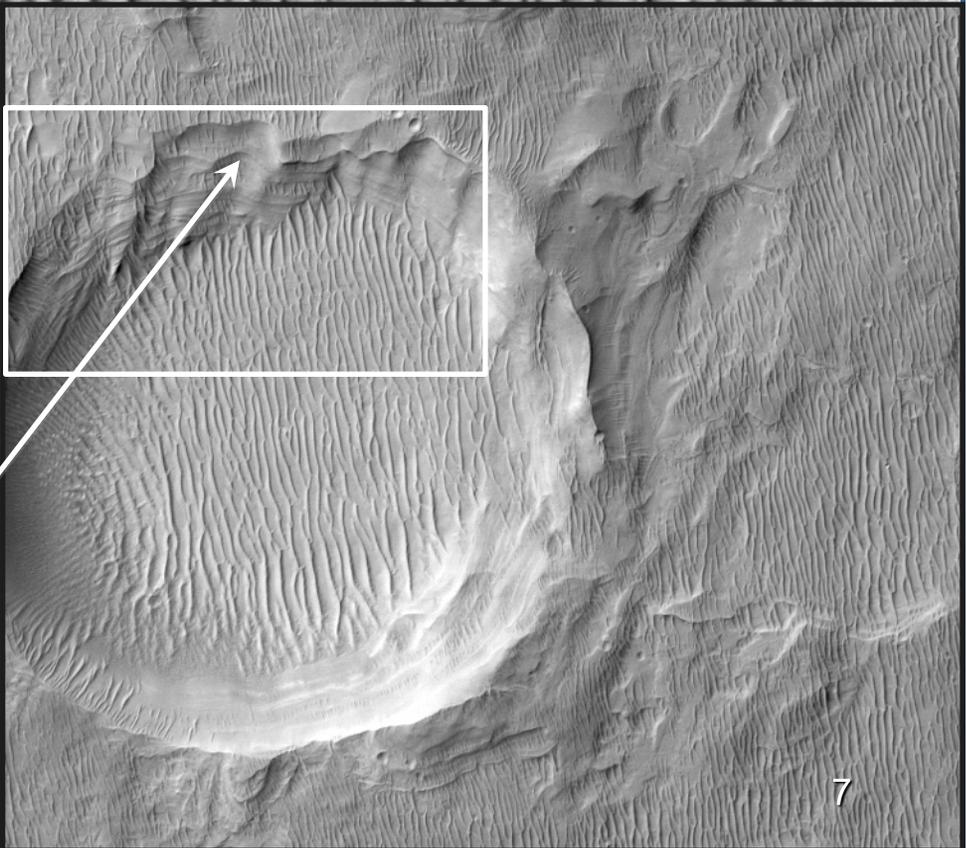
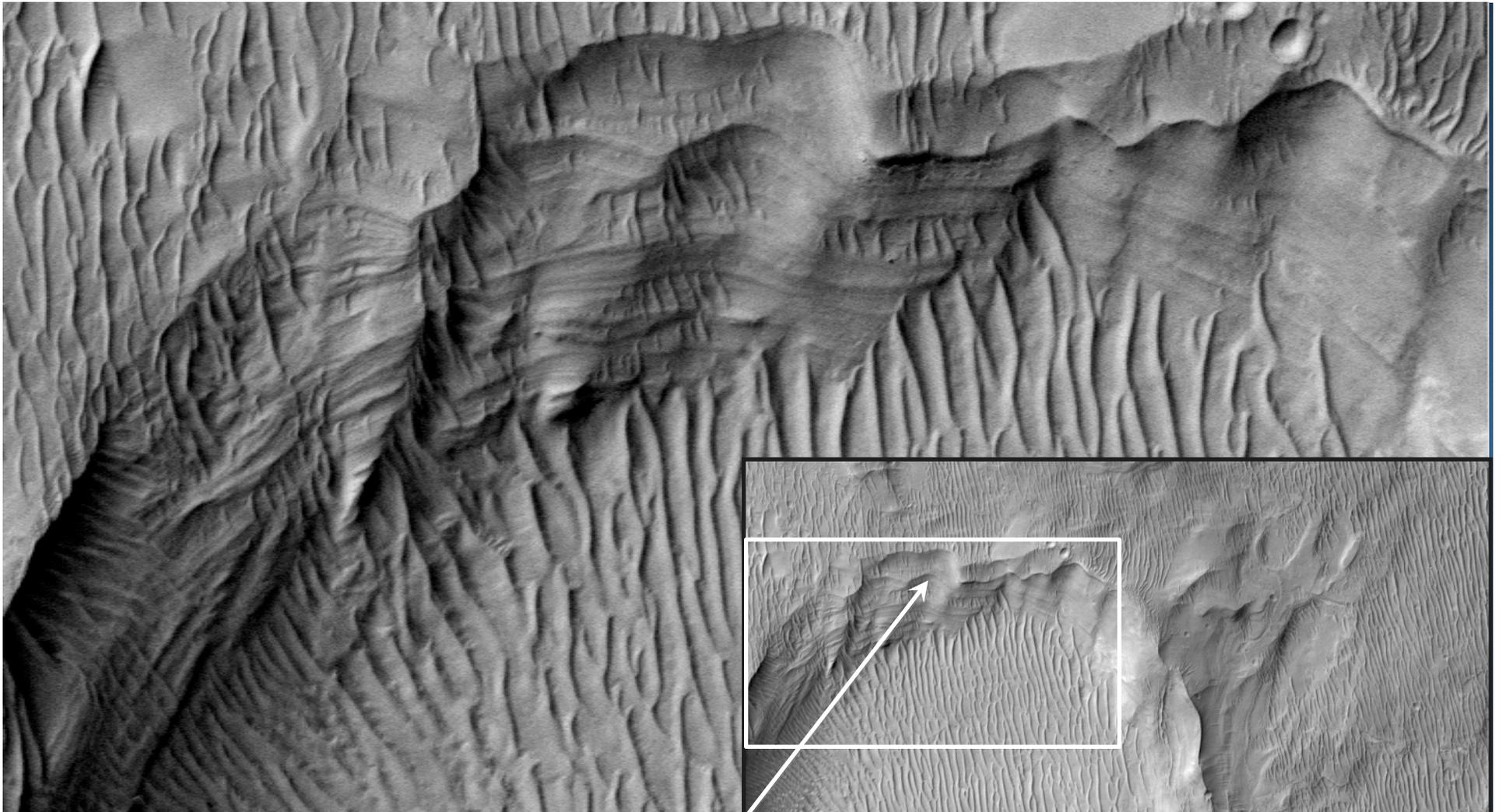
Morphology and

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*

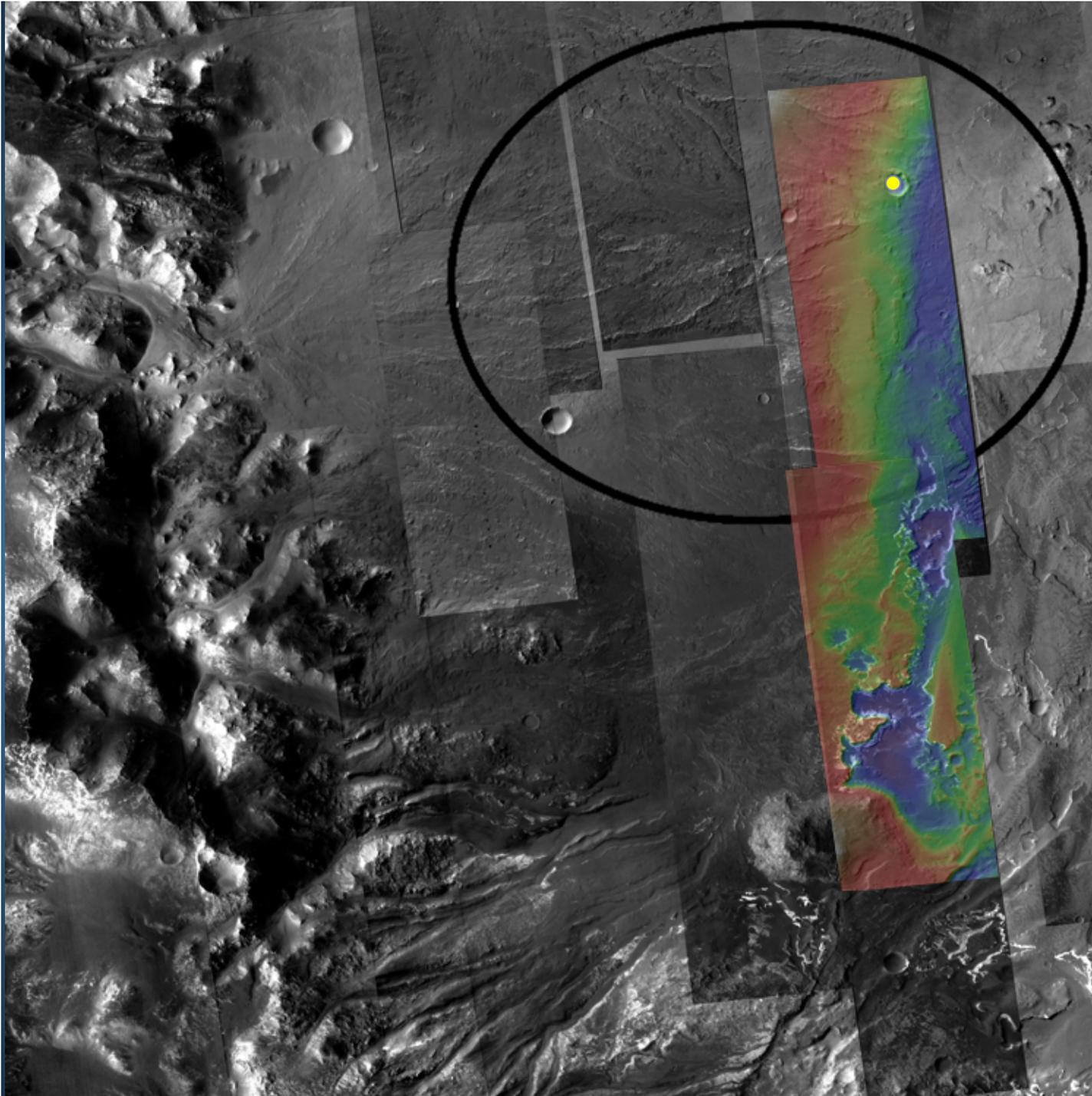


50 m

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?

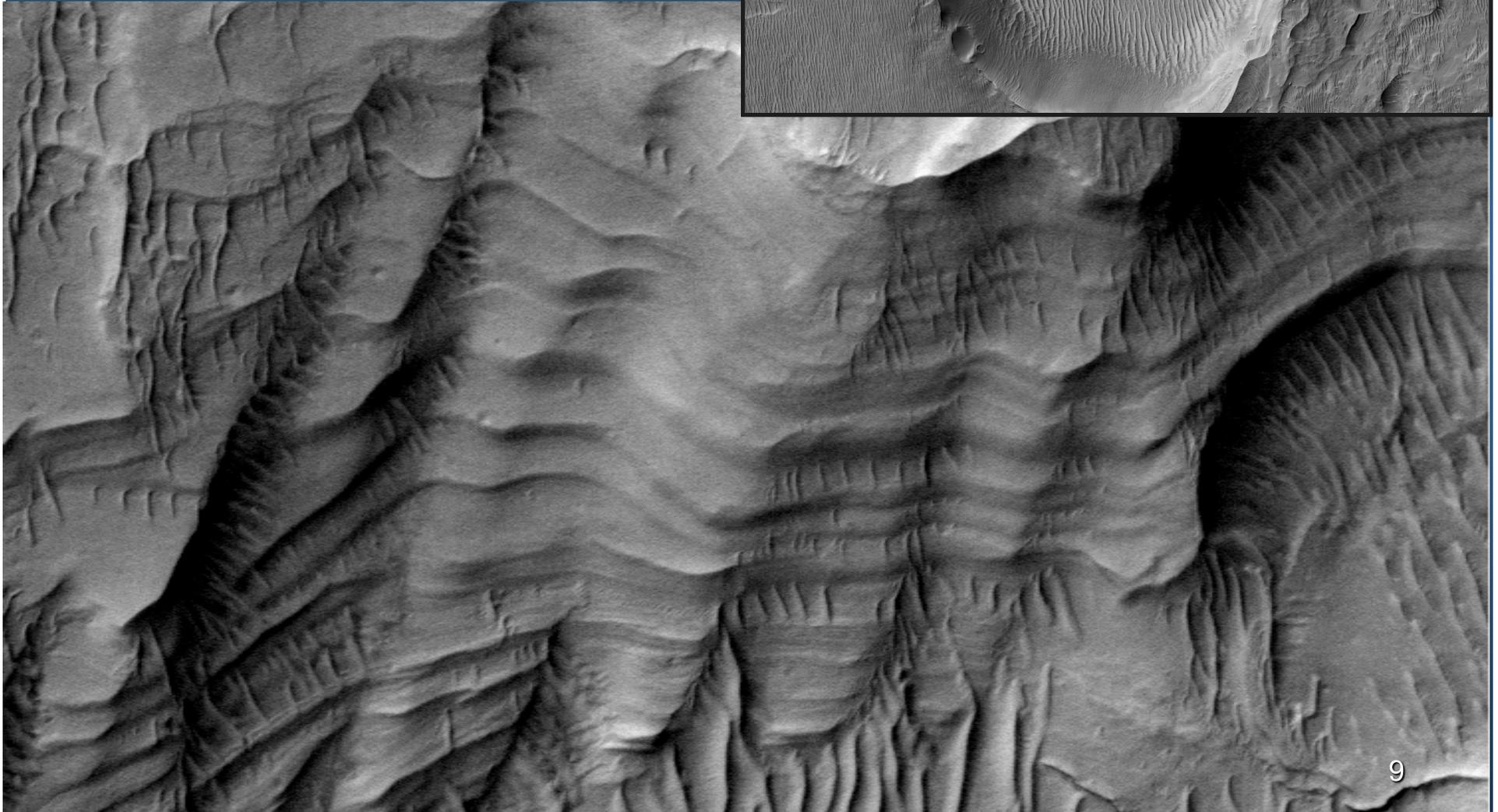
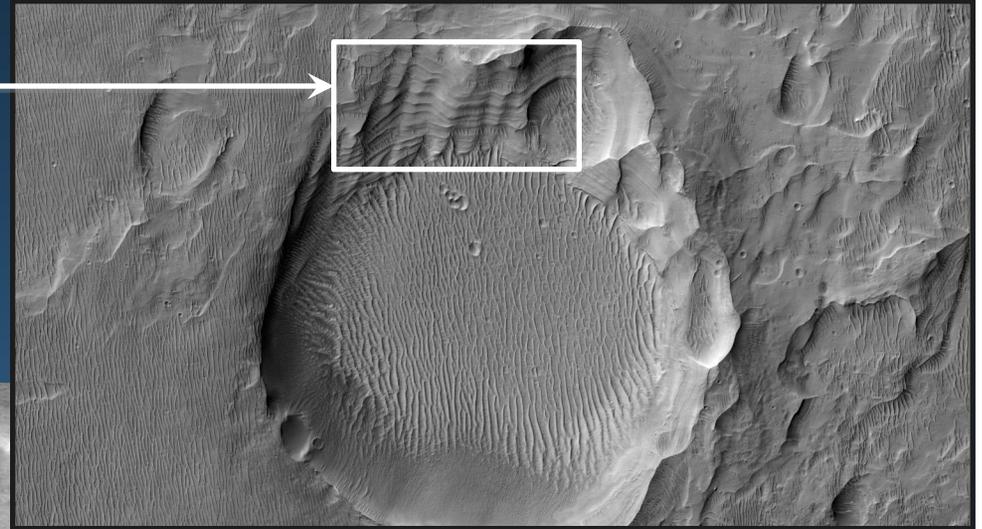
*Determine diversity of
materials in upper >1 km of
highland crust, determine
emplacement mechanism
for fans, examine
stratigraphy in crater wall
for temporal change in
environment*

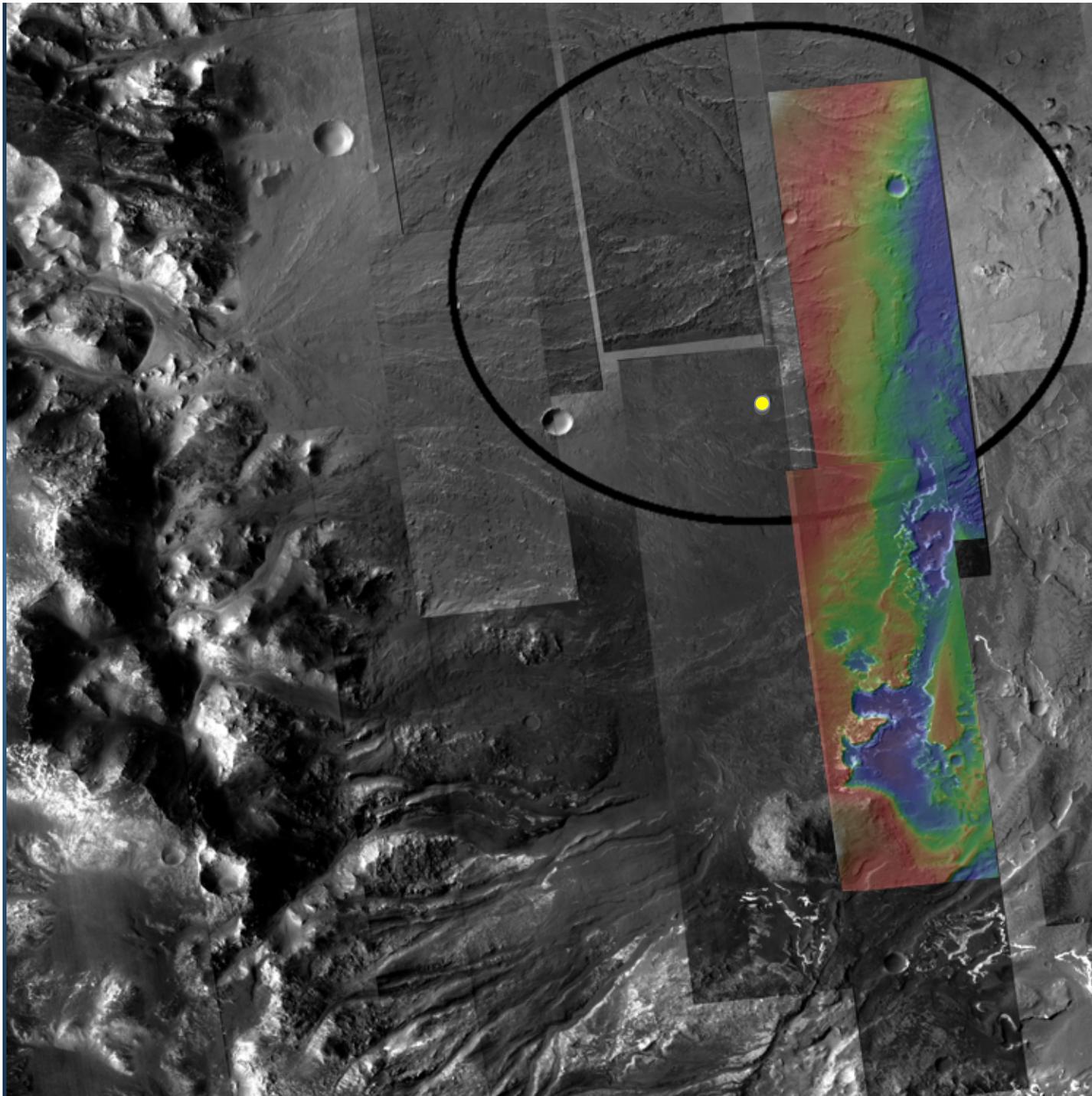
PSP_015999_1535
Right: 1.59 km across
Below: 397 m across
Crater diameter: 740 m

50 m

Target of interest

300 m





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

-26.46 North, 325.13 East
km from ellipse center: 4.7
(Use if MSL lands near or W)

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?

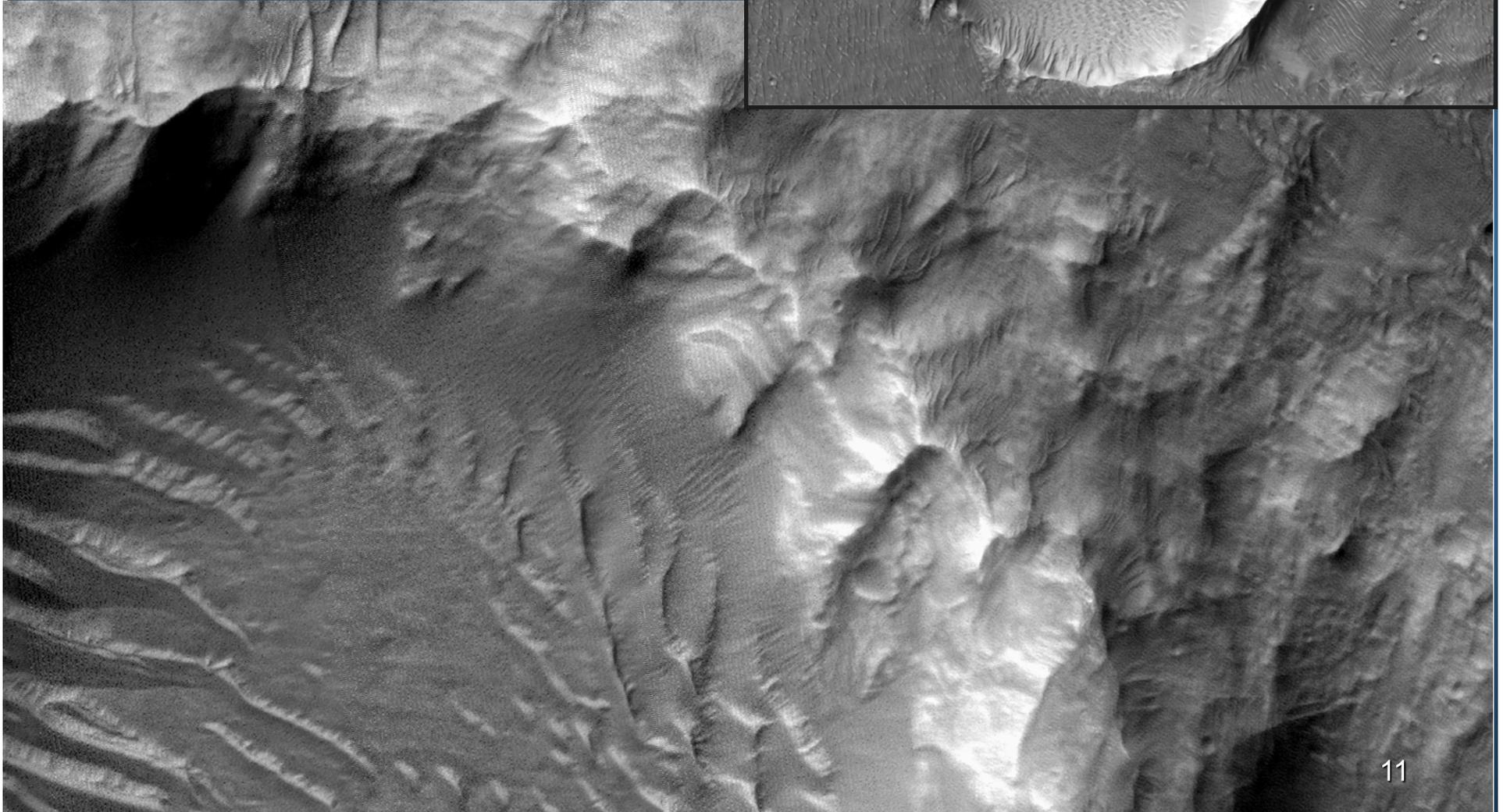
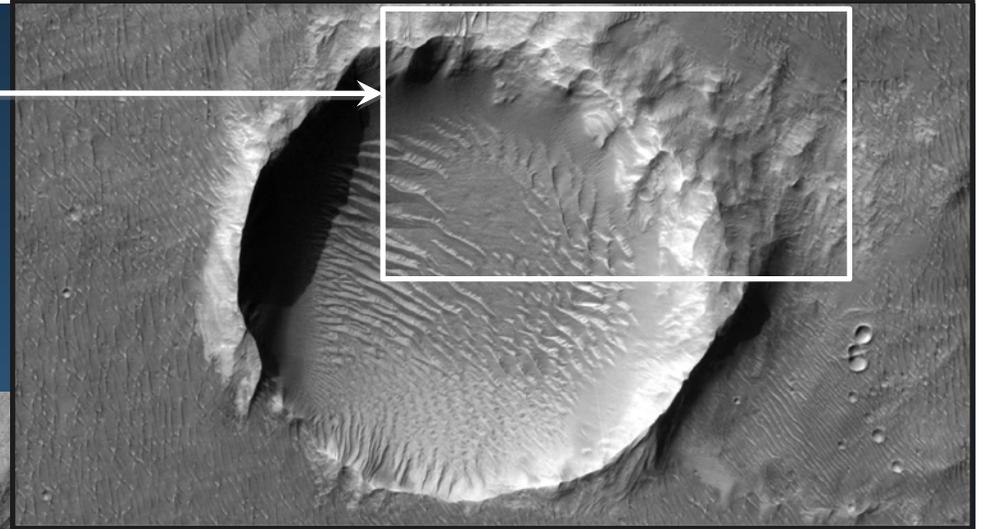
*Determine diversity of
materials in upper >1 km of
highland crust, determine
emplacement mechanism
for fans, examine
stratigraphy in crater wall
for temporal change in
environment*

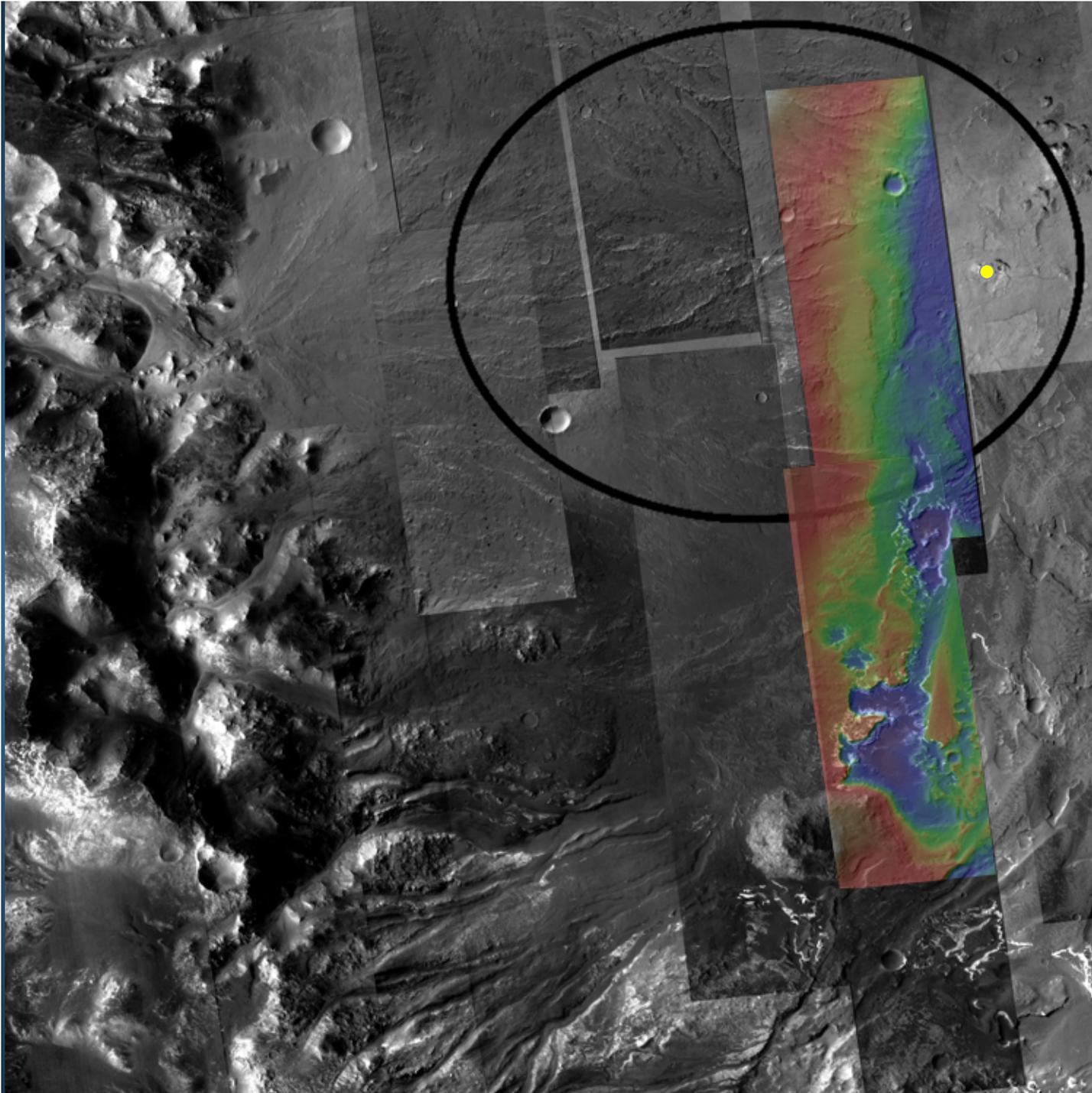
PSP_015999_1535
Right: 793 km across
Below: 397 m across
Crater diameter: 400 m

50 m

Target of interest

200 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?

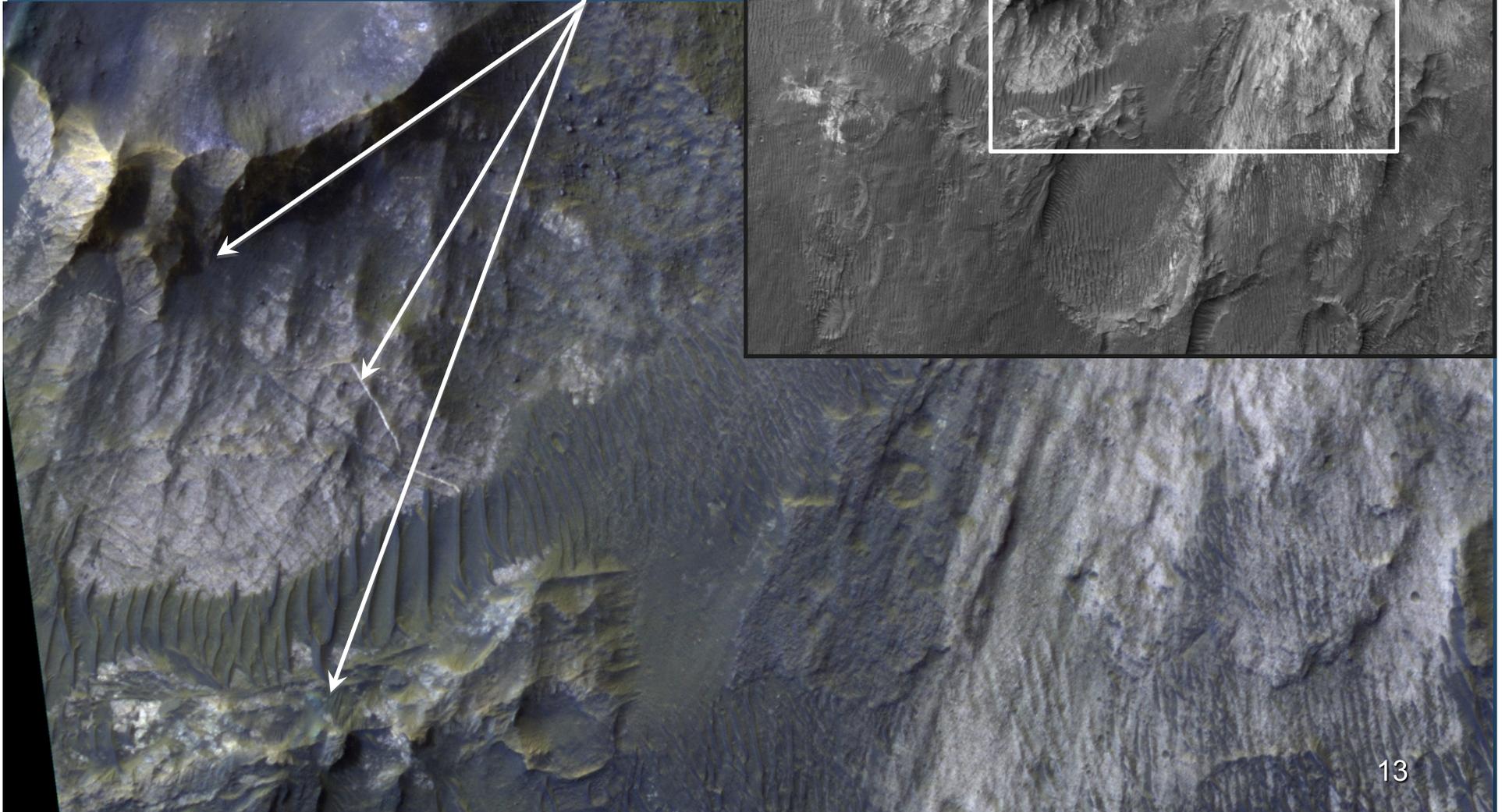
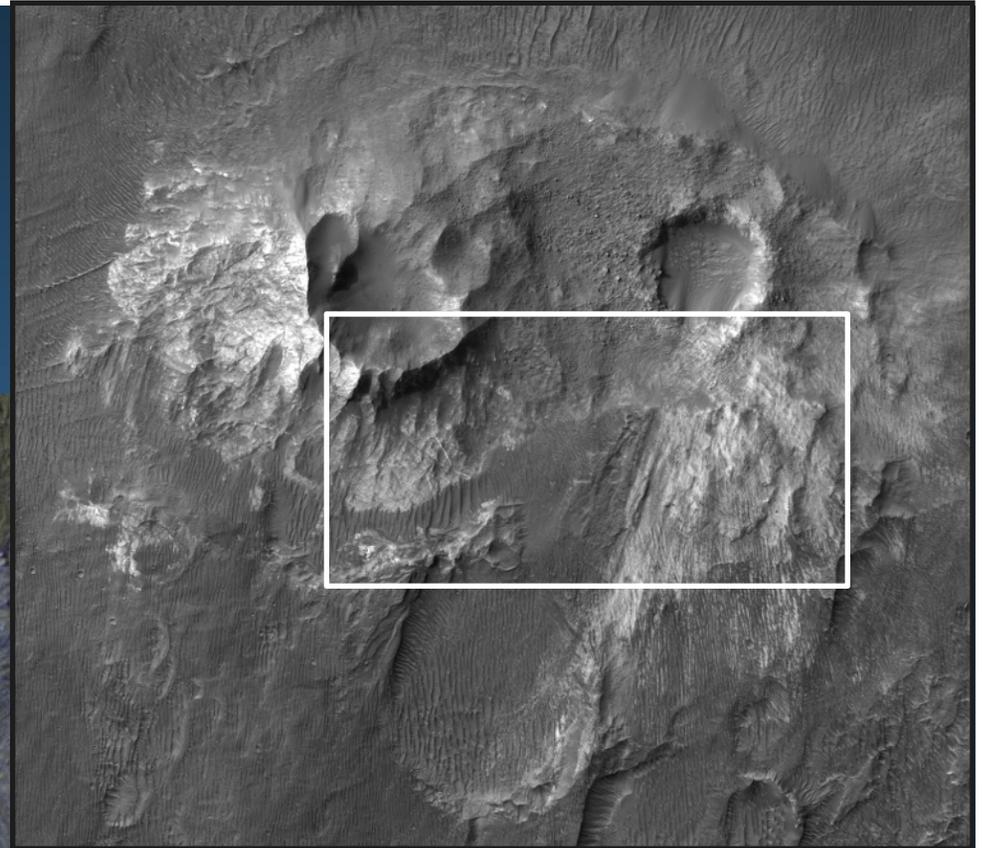
*Examine rocks and veins for
possible hydrothermal
deposits, chemical energy
sources, organics, and
alteration; determine
diversity of materials
exposed on crater floor*

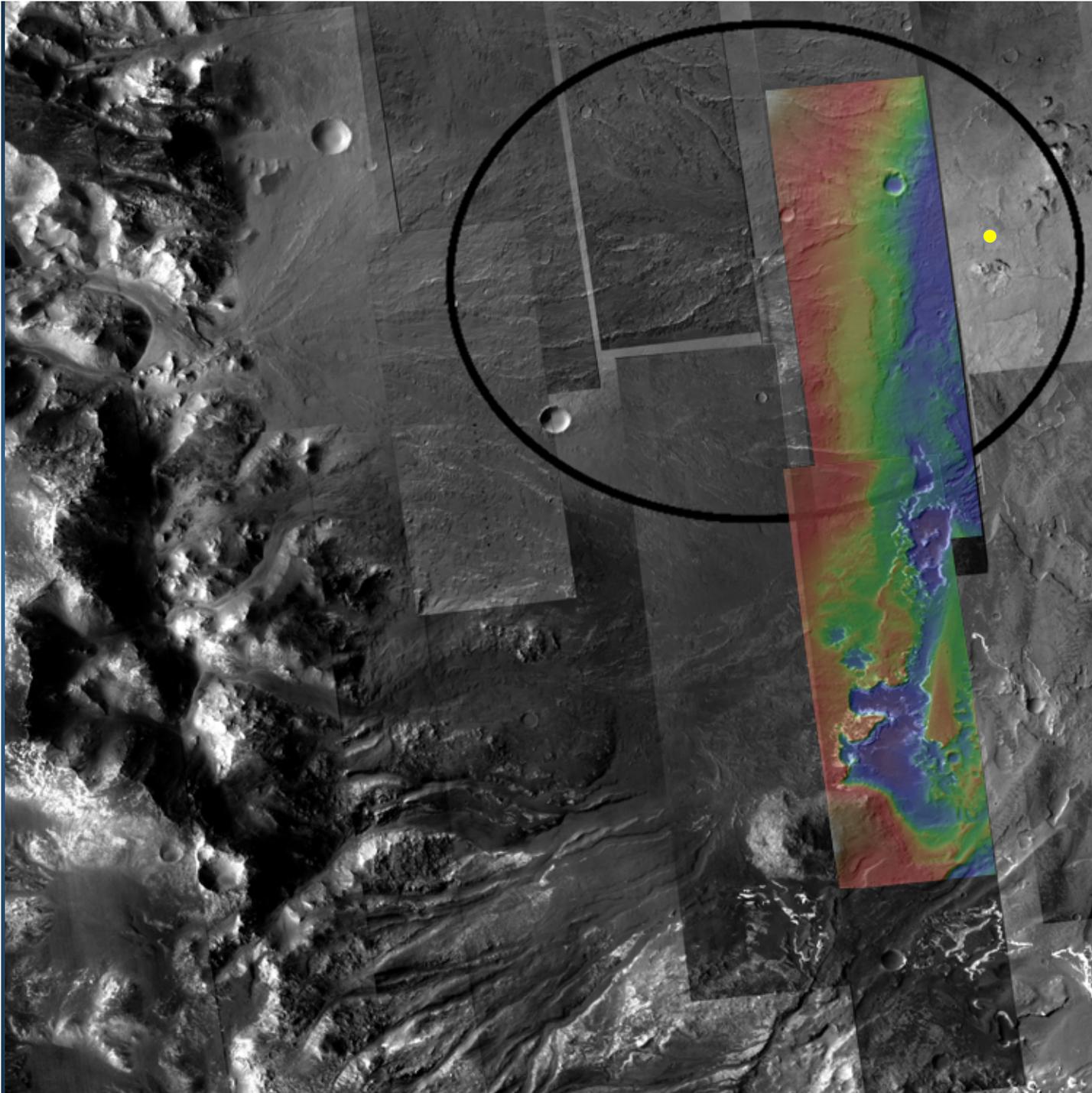
ESP_019678_1535
Right: 1.59 km across
Below: 793 m across

300 m

100 m

Targets of interest





Holden target 1F:
Light-toned, layered
materials

-26.36 North, 325.28 East
Km from ellipse center: 7.6

Rationale:

Upper 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?

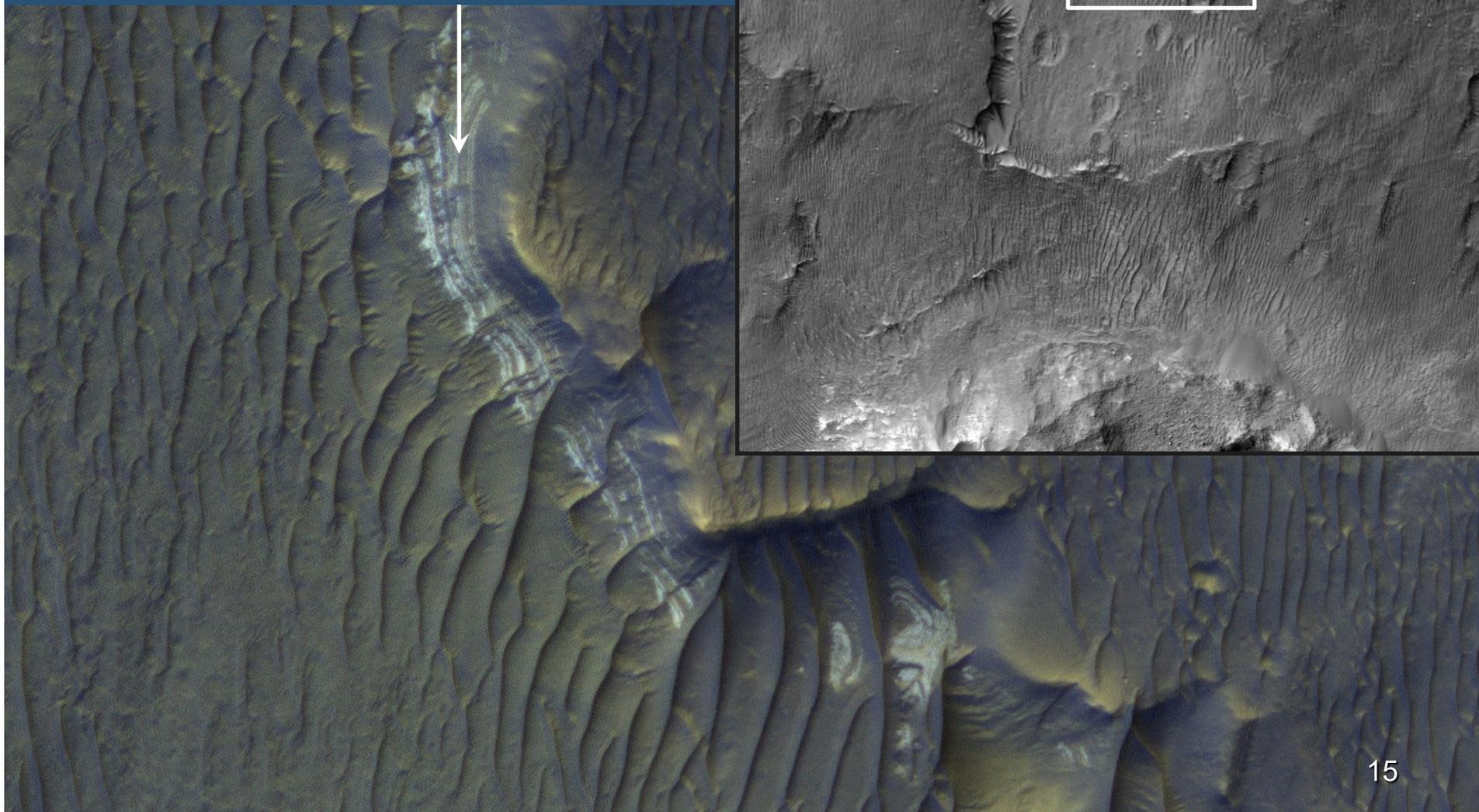
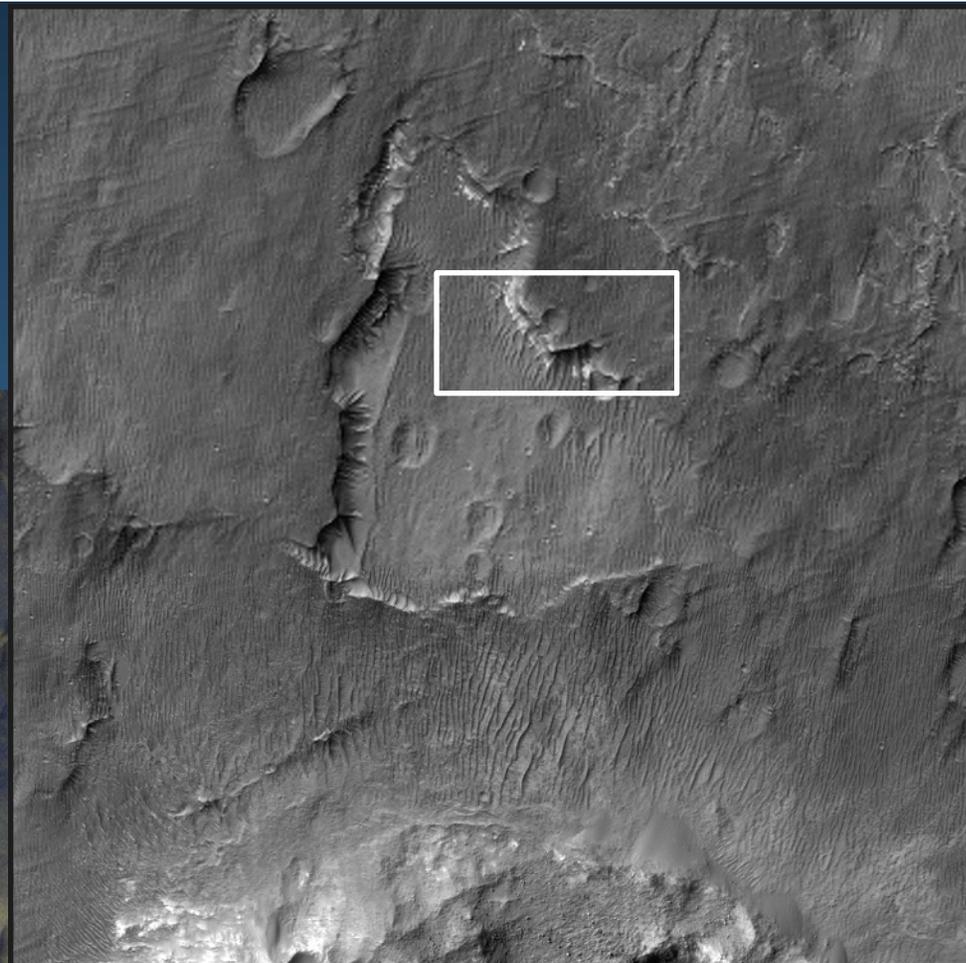
Stratigraphic and compositional analyses, identify depositional environment, suggest consistent sediment source and weathering history, search for organics

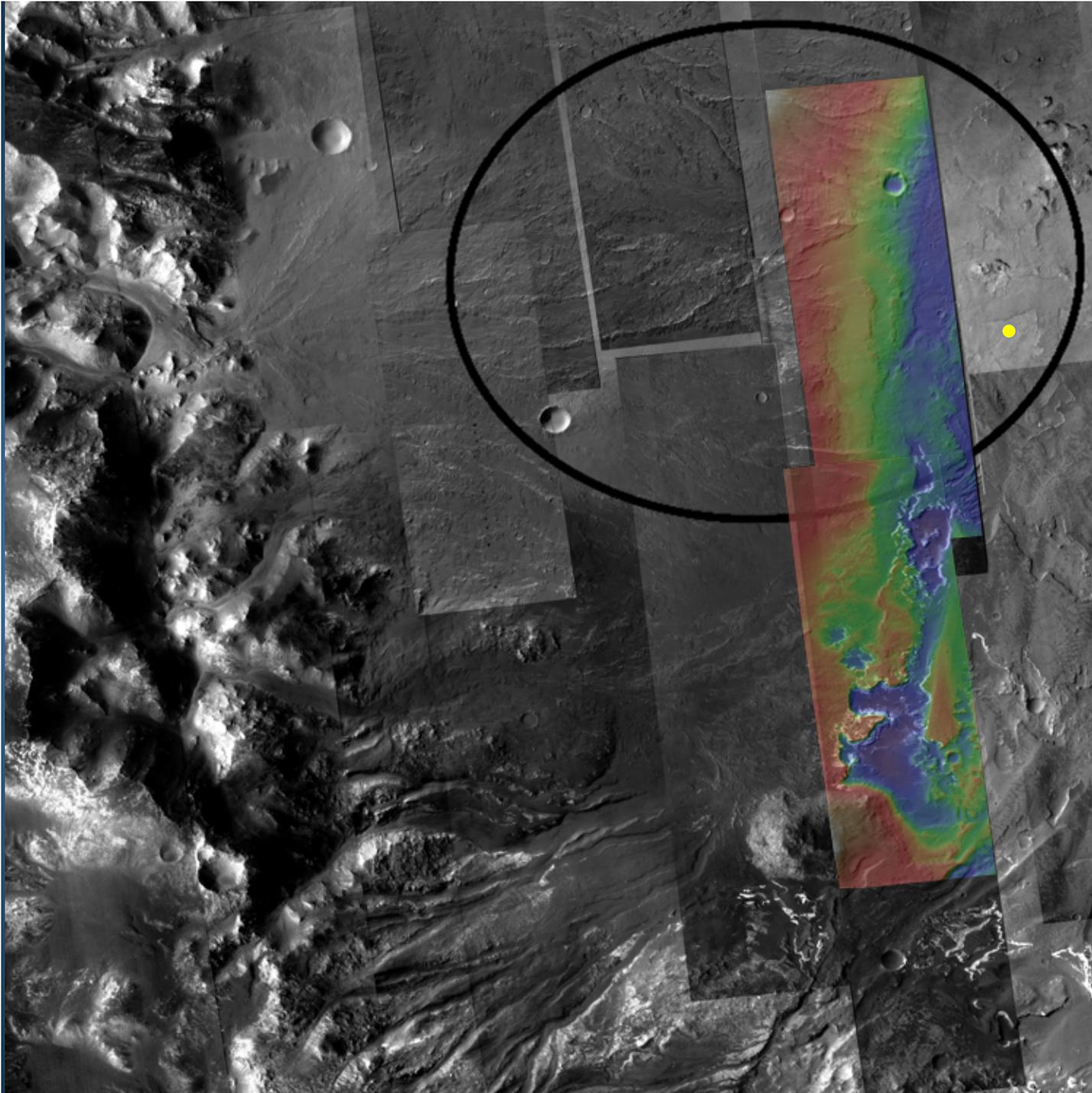
ESP_019678_1535
Below: 397 m across
Right: 1.59 km across

300 m

50 m

Target of interest.





Holden target 1G:
Coarse material (distal
Uzboi or megabreccia)

-26.42 North, 325.29 East
km from ellipse center: 8.2

Rationale:

*Rocks possibly derived
from Uzboi Vallis flooding,
megabreccia on Holden
floor, flooded surfaces*

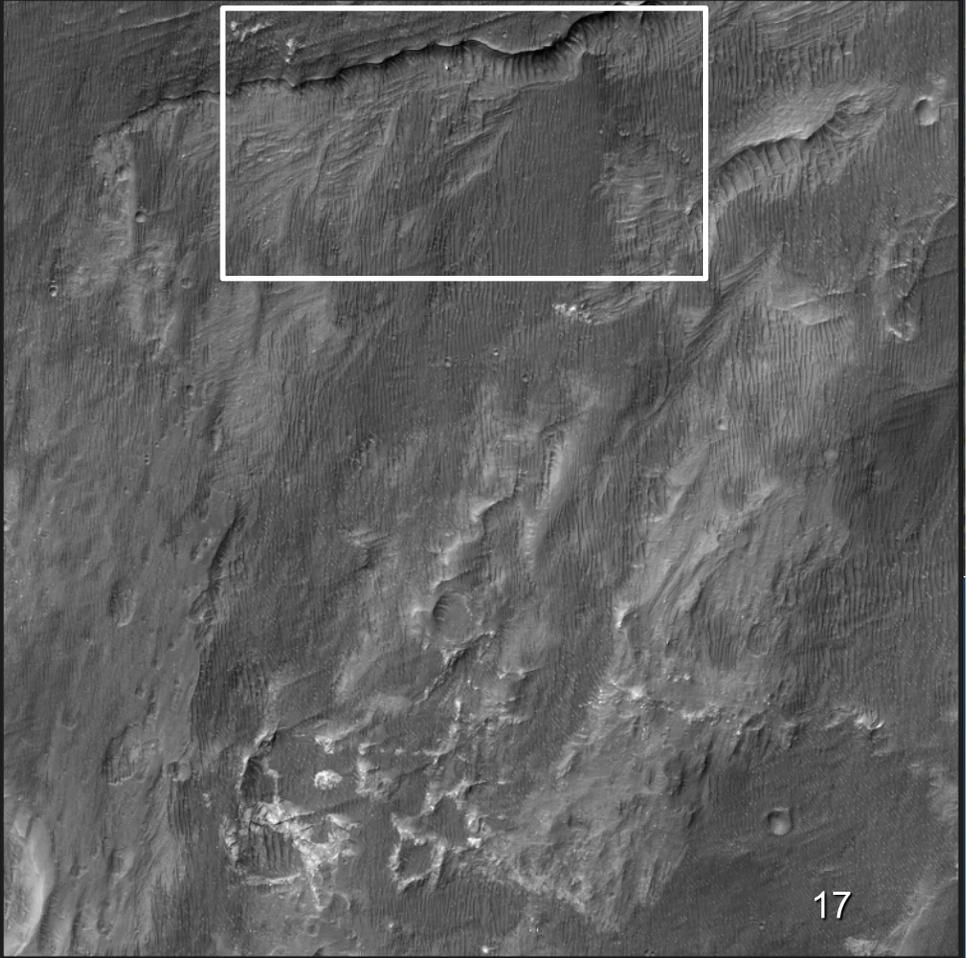
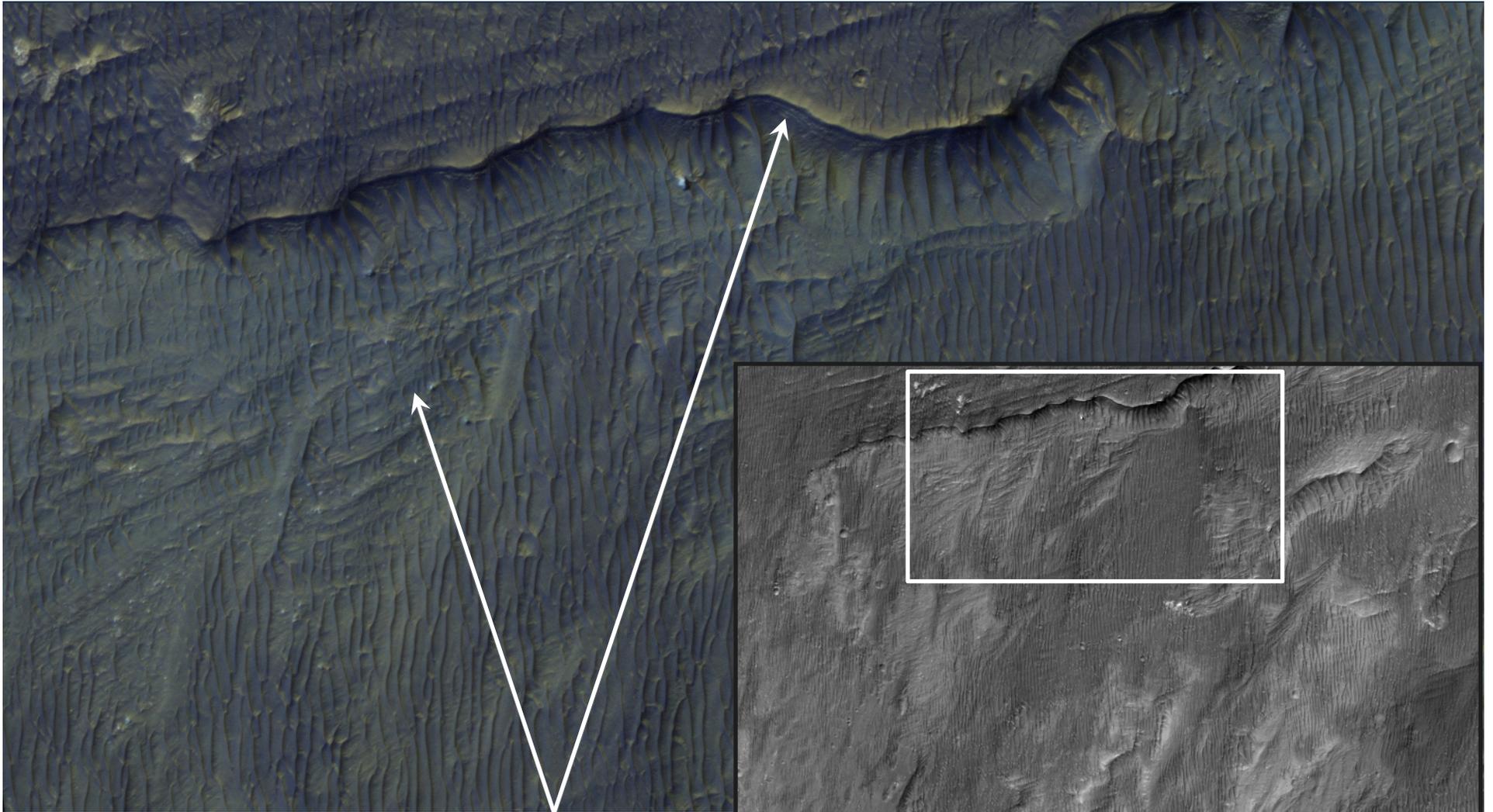
Morphology and

Mineralogy:

*Coarse rocks with tone/
color contrasts, possible
local cross-bedding*

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

Possible upward-fining deposits

ESP_019678_1535

Above: 793 m across

Right: 1.59 km across

300 m

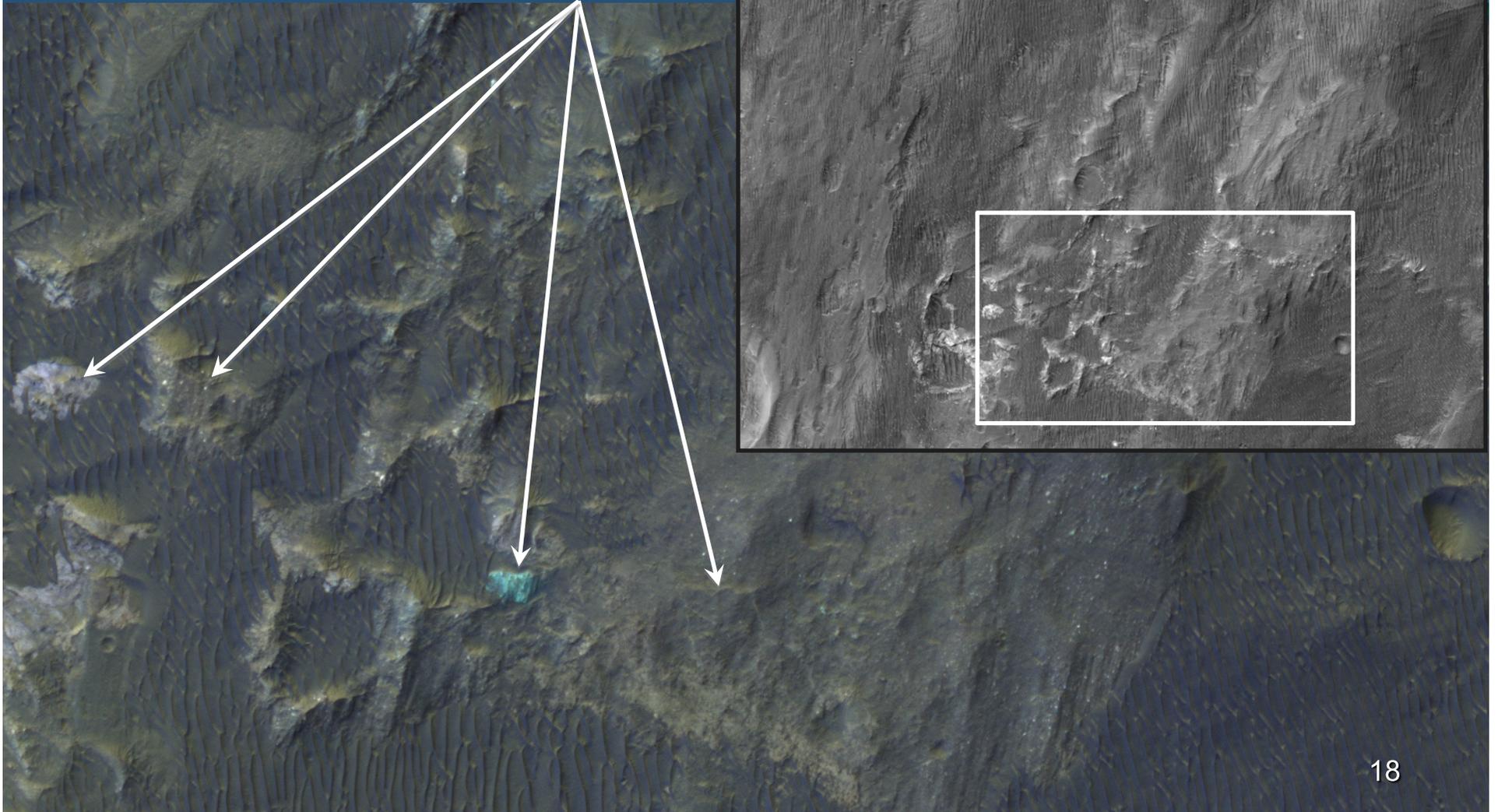
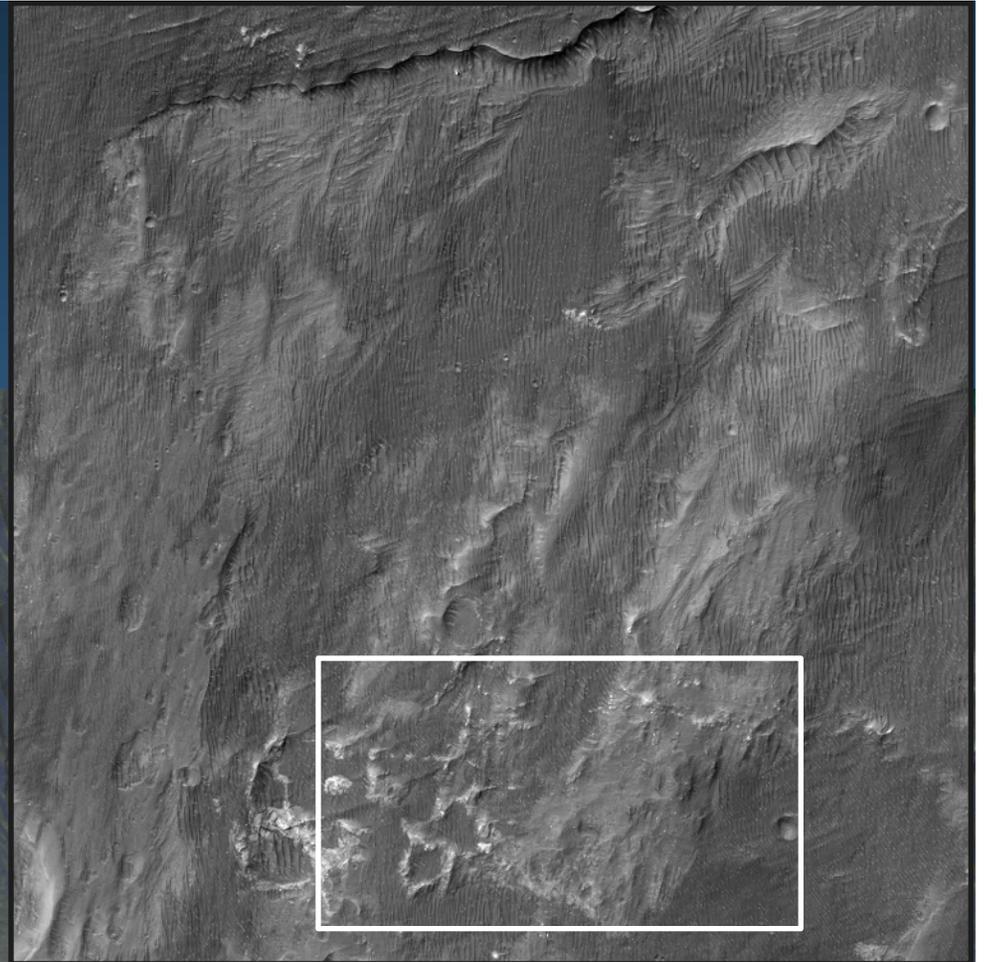


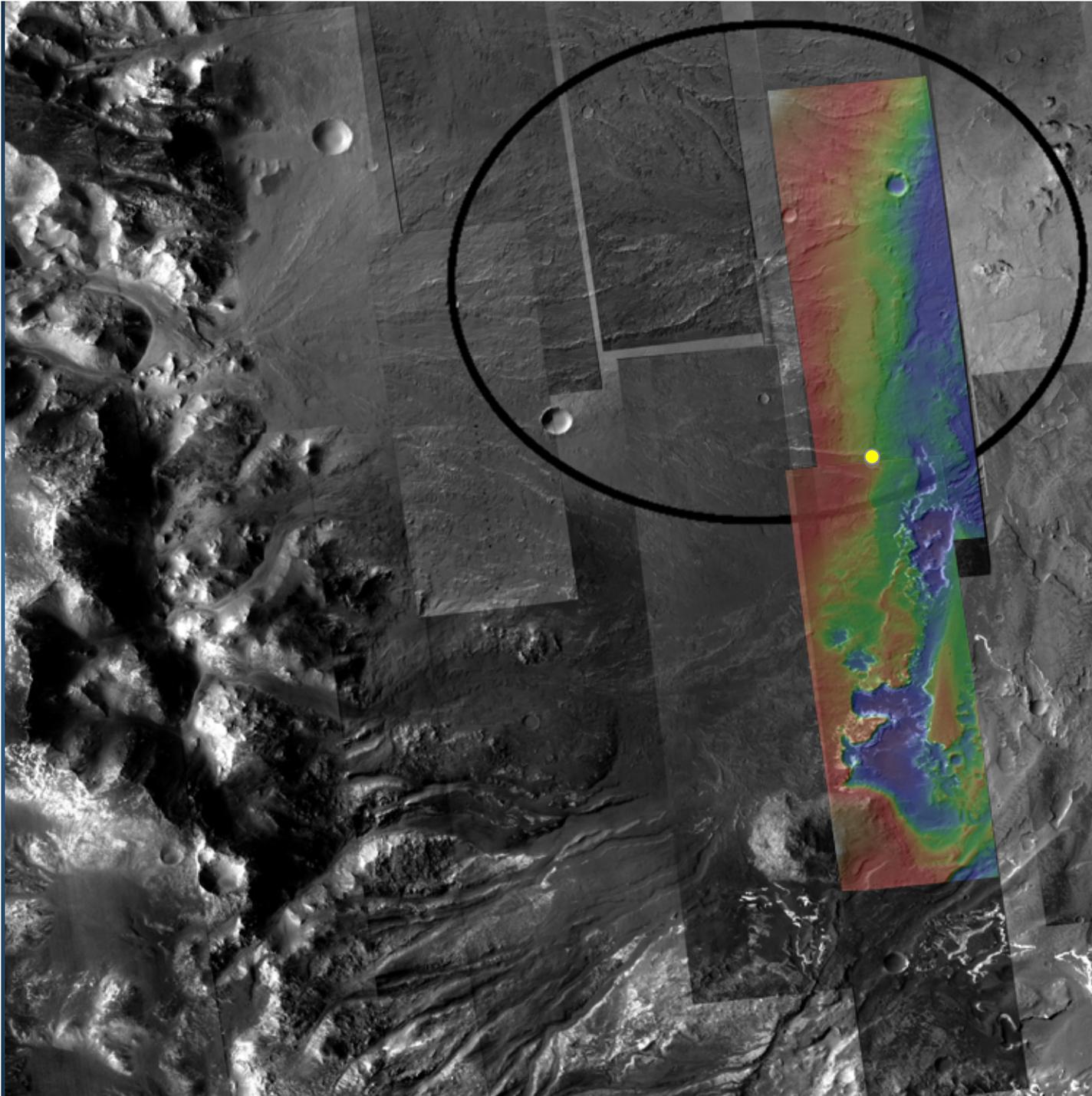
Possible megabreccia
ESP_019678_1535
Right: 1.59 km across
Below: 793 m across

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*

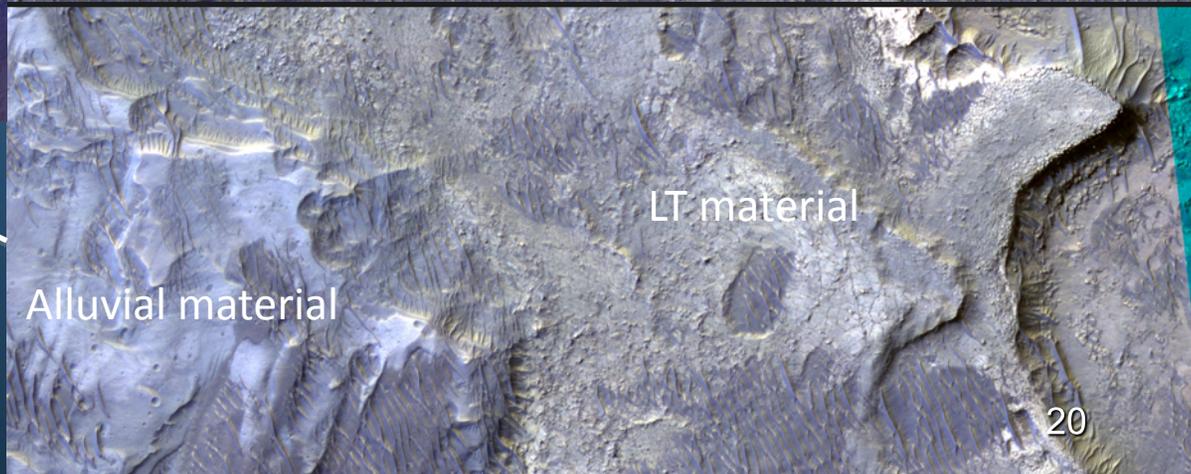
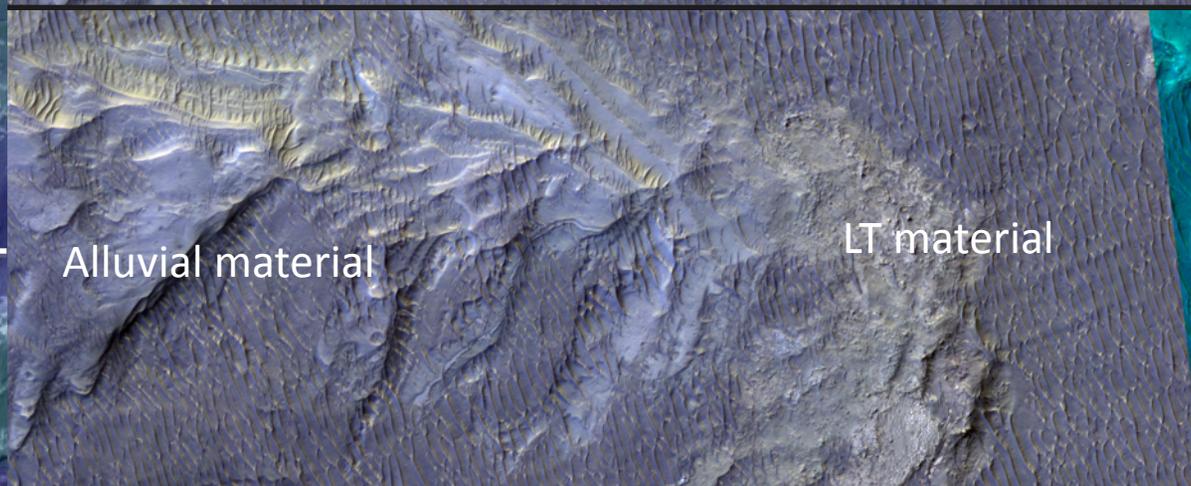
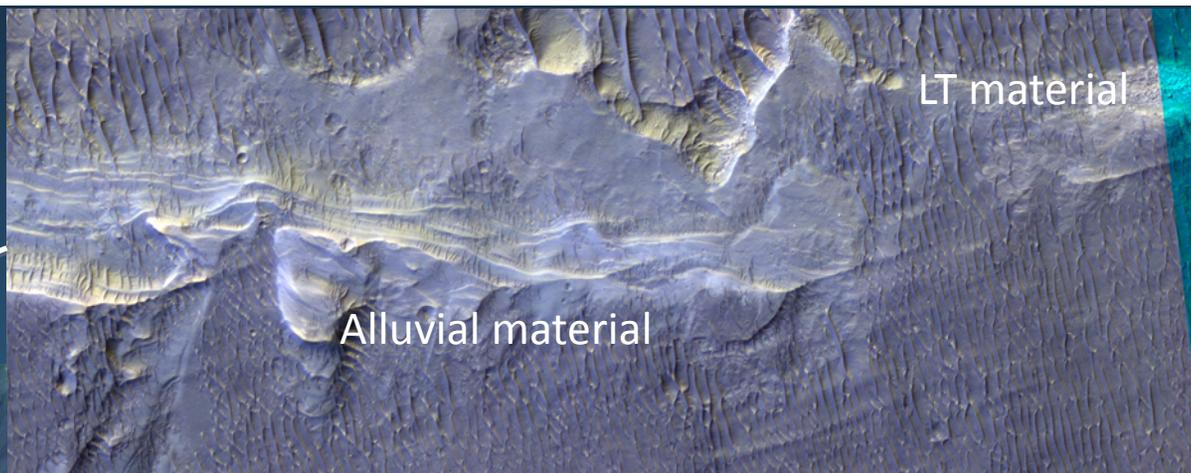
Morphology and
Mineralogy:

*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*

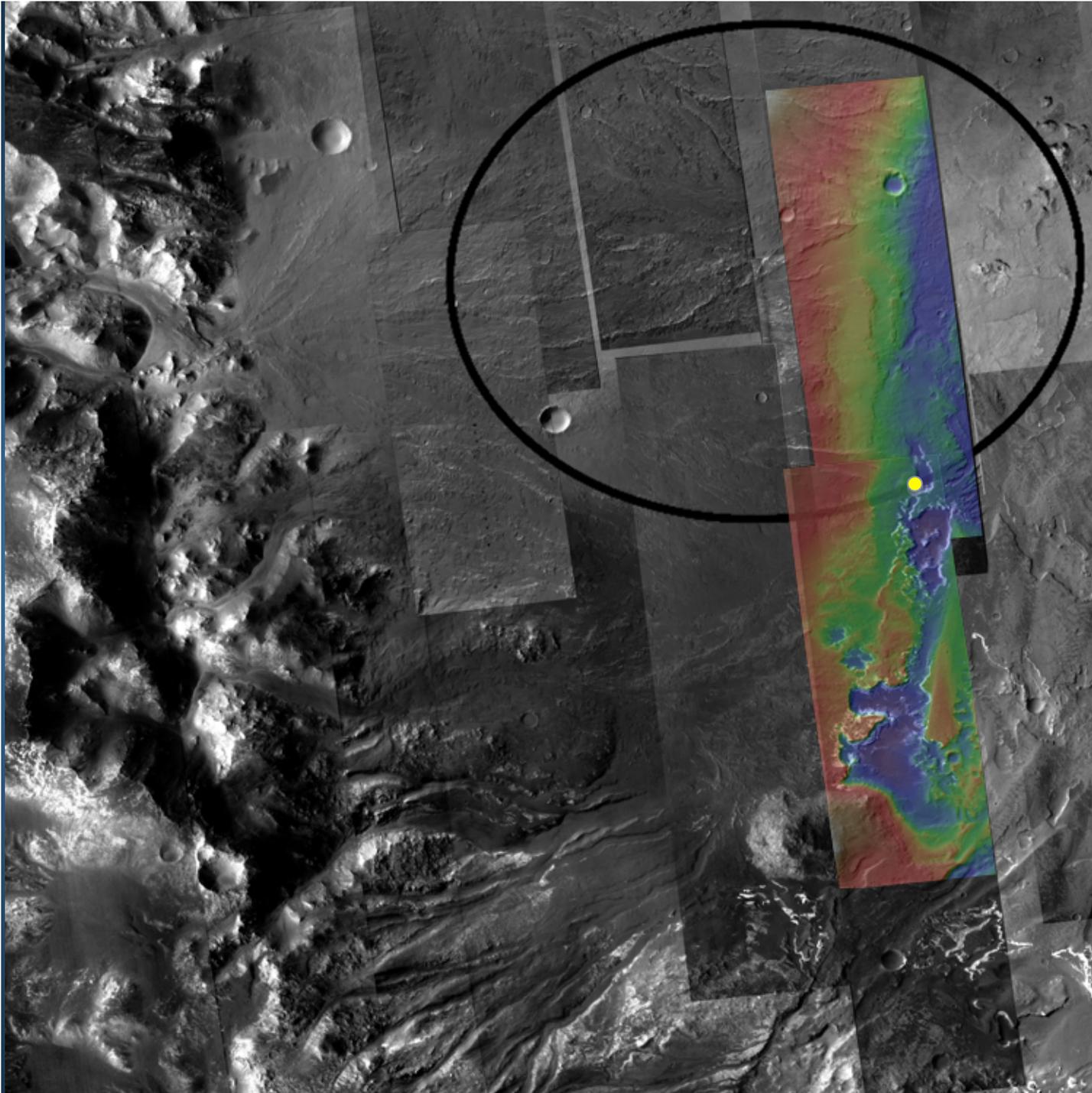
Layered alluvial deposits overlie fractured, lighter-toned material at the fan toe.



Target 3 location
Target 4 location

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?

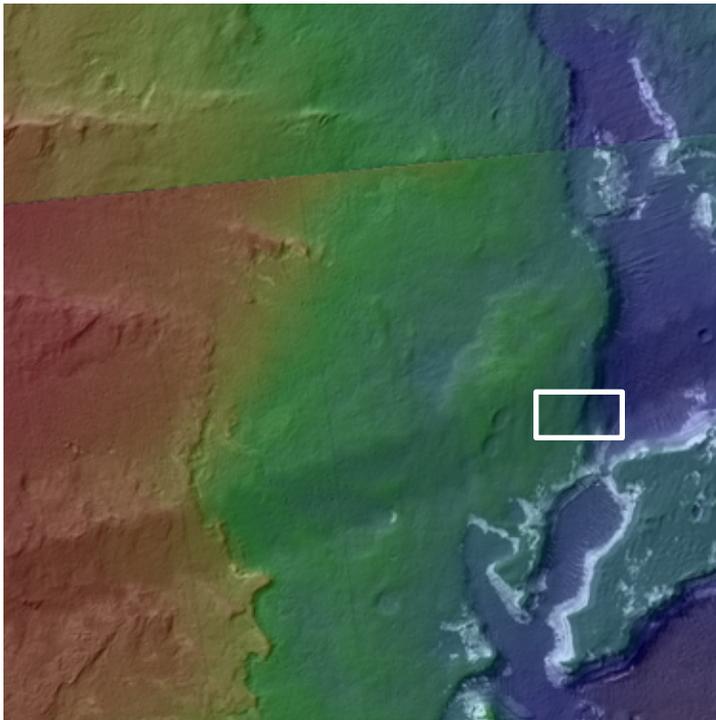
*Stratigraphic and
compositional analyses,
identify depositional
environment, suggest
consistent sediment source
and weathering history,
search for organics*

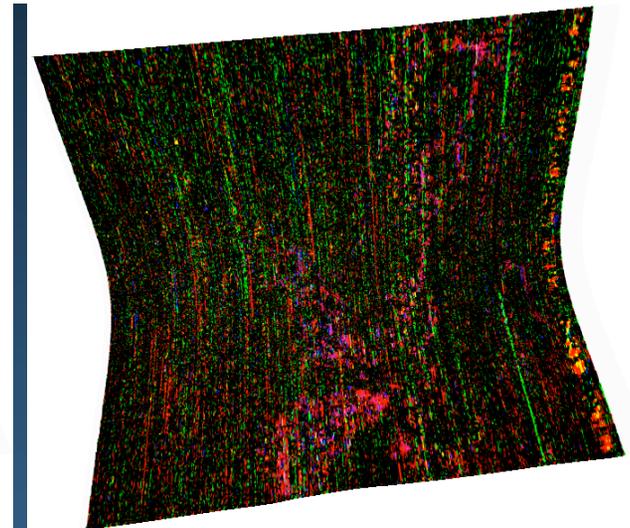
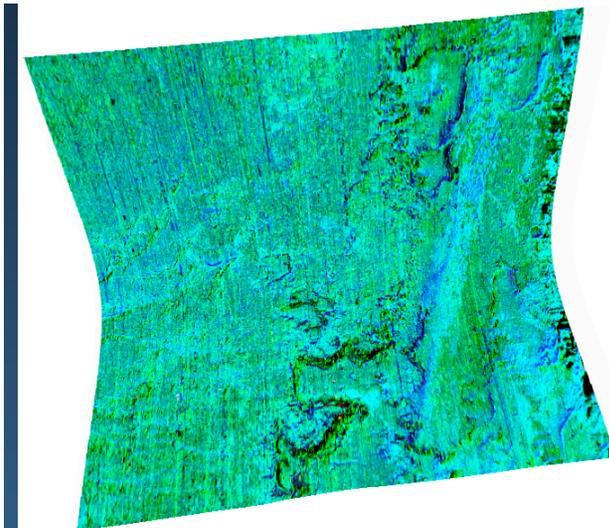
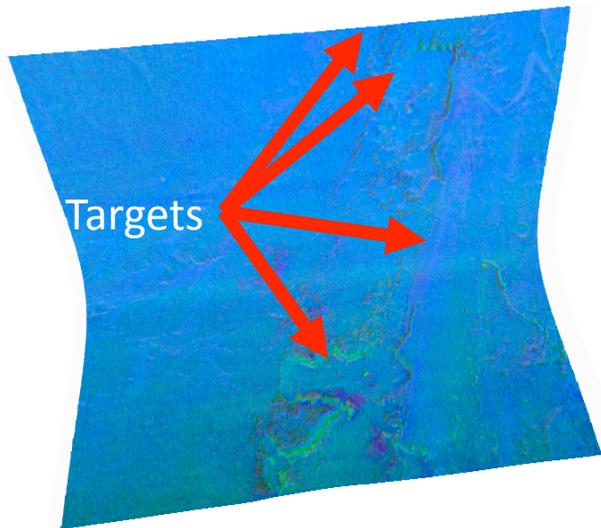
33 m section
8° slope
>40 light/dark pairs

ESP_016276_1535
397 m across

50 m

Target of interest.





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)

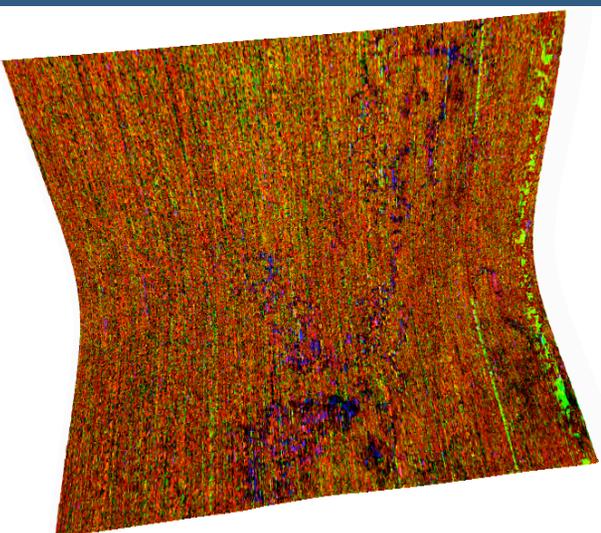
blue = HCPINDEX (high-Ca pyroxene)

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

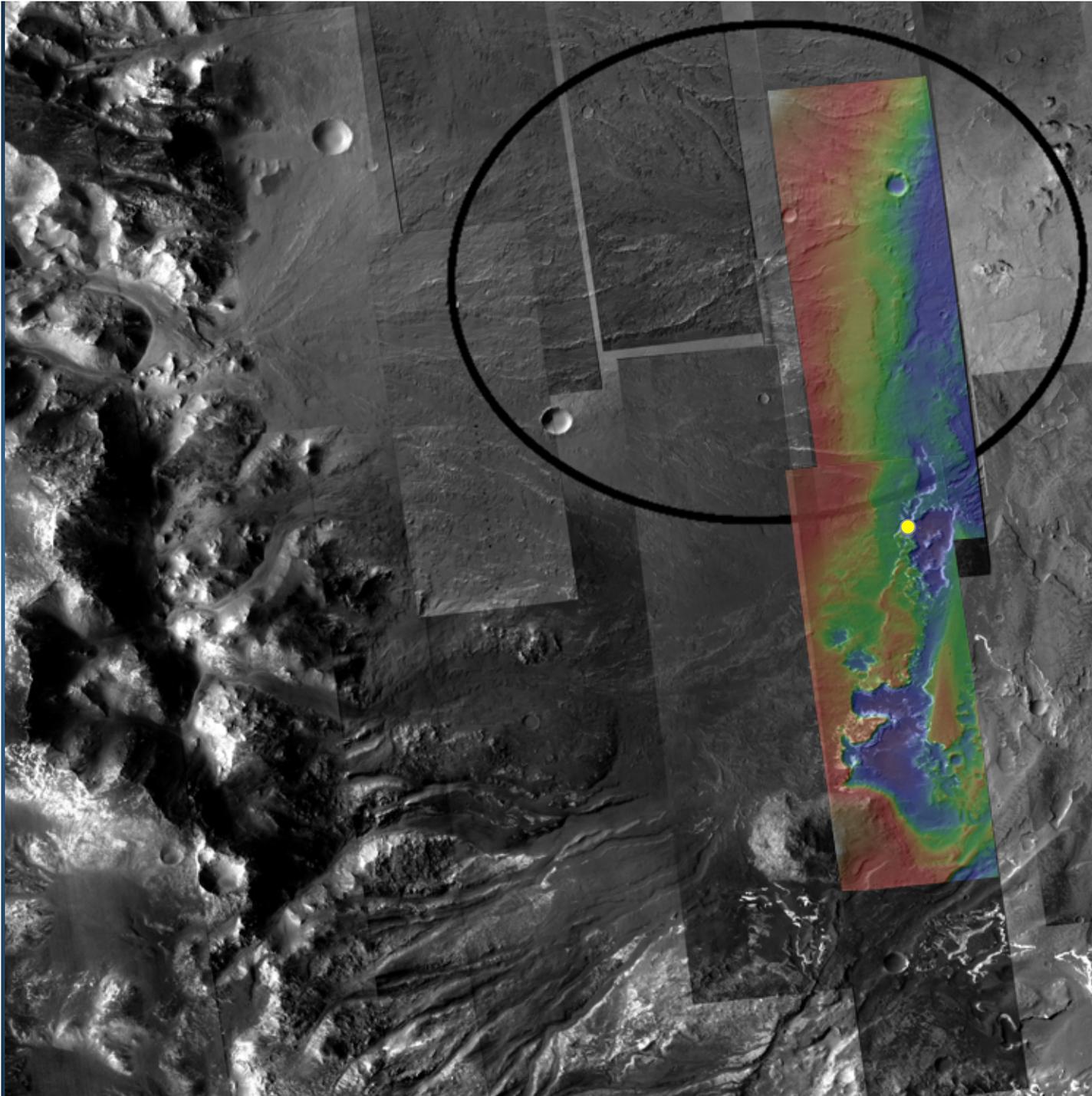
red = SINDEXT (water-containing minerals or water ice)

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

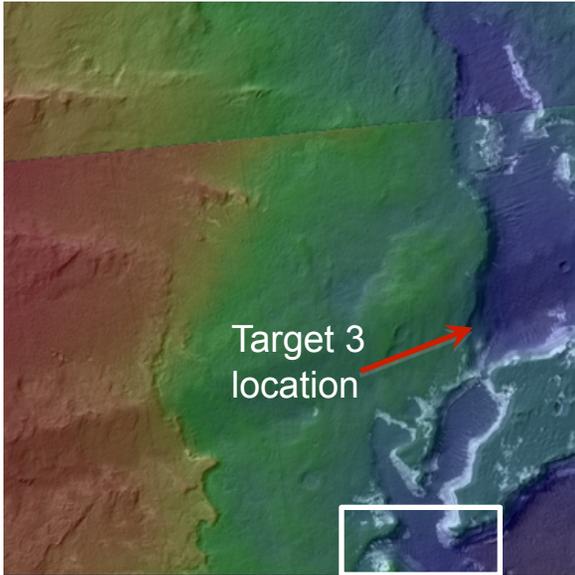
Morphology and

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

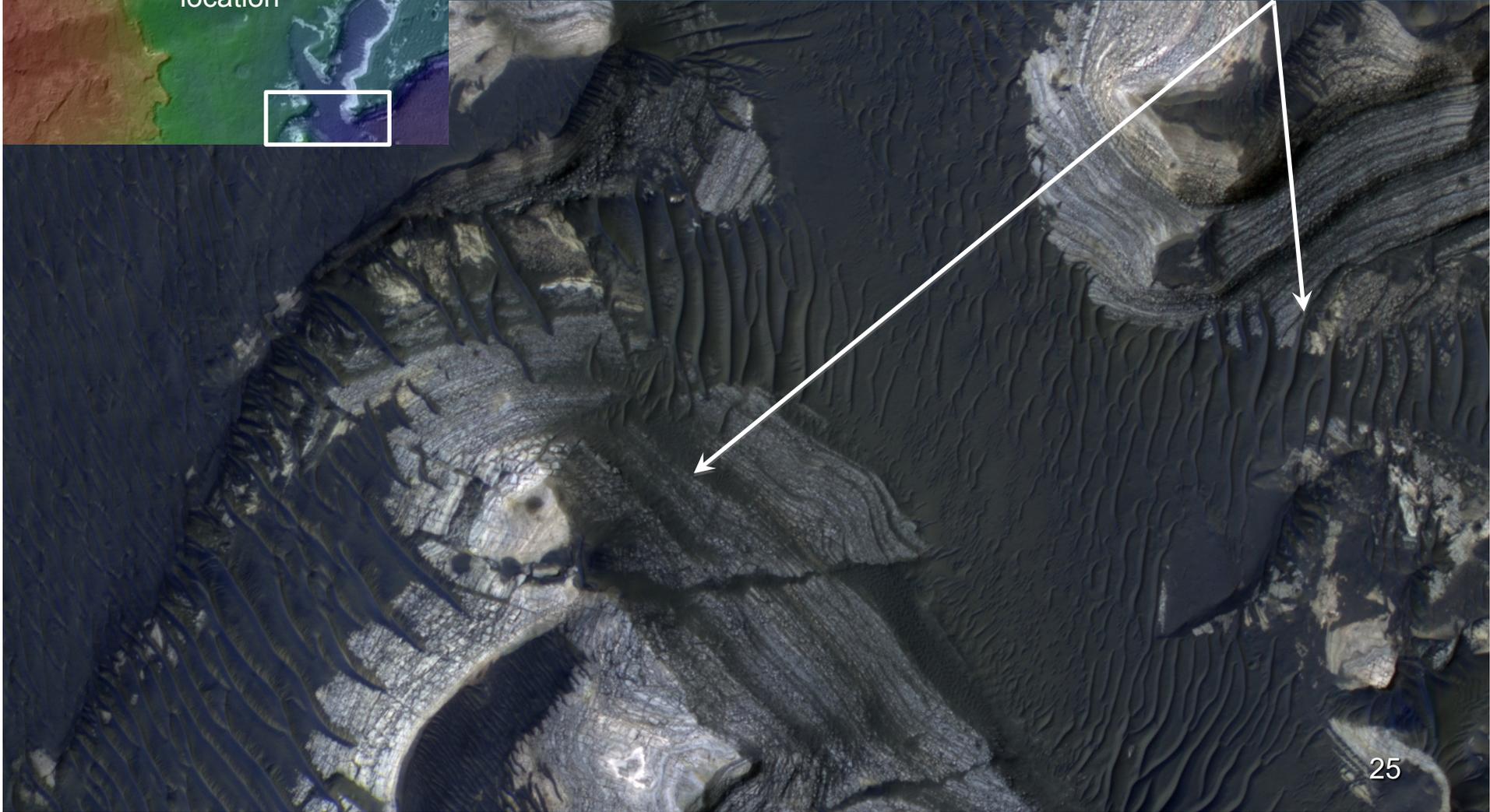


Target 3
location

100 m

ESP_015999_1535
783 m across

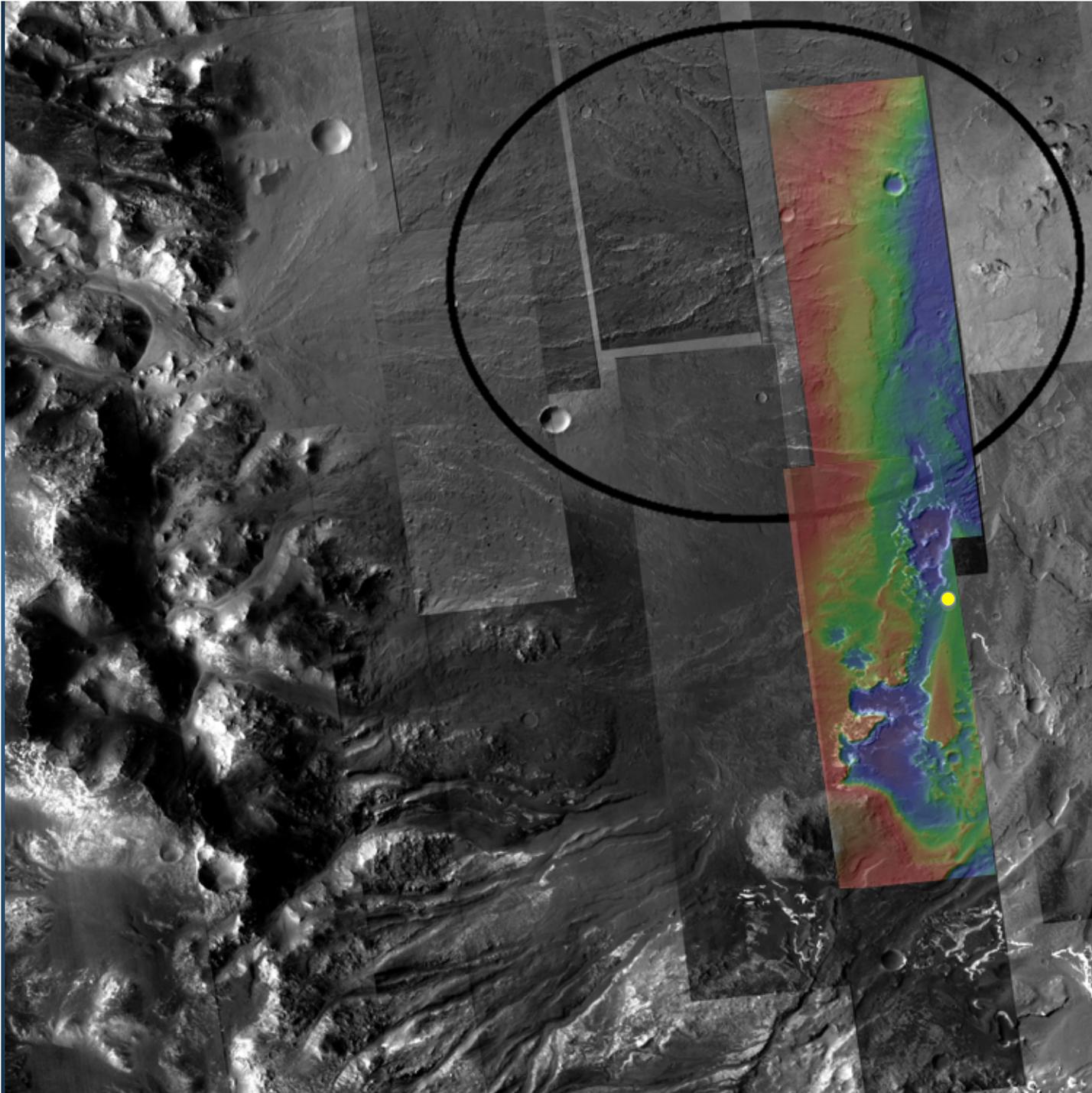
Targets of interest.
Many other LTL outcrops
are available along the
notional traverse



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:

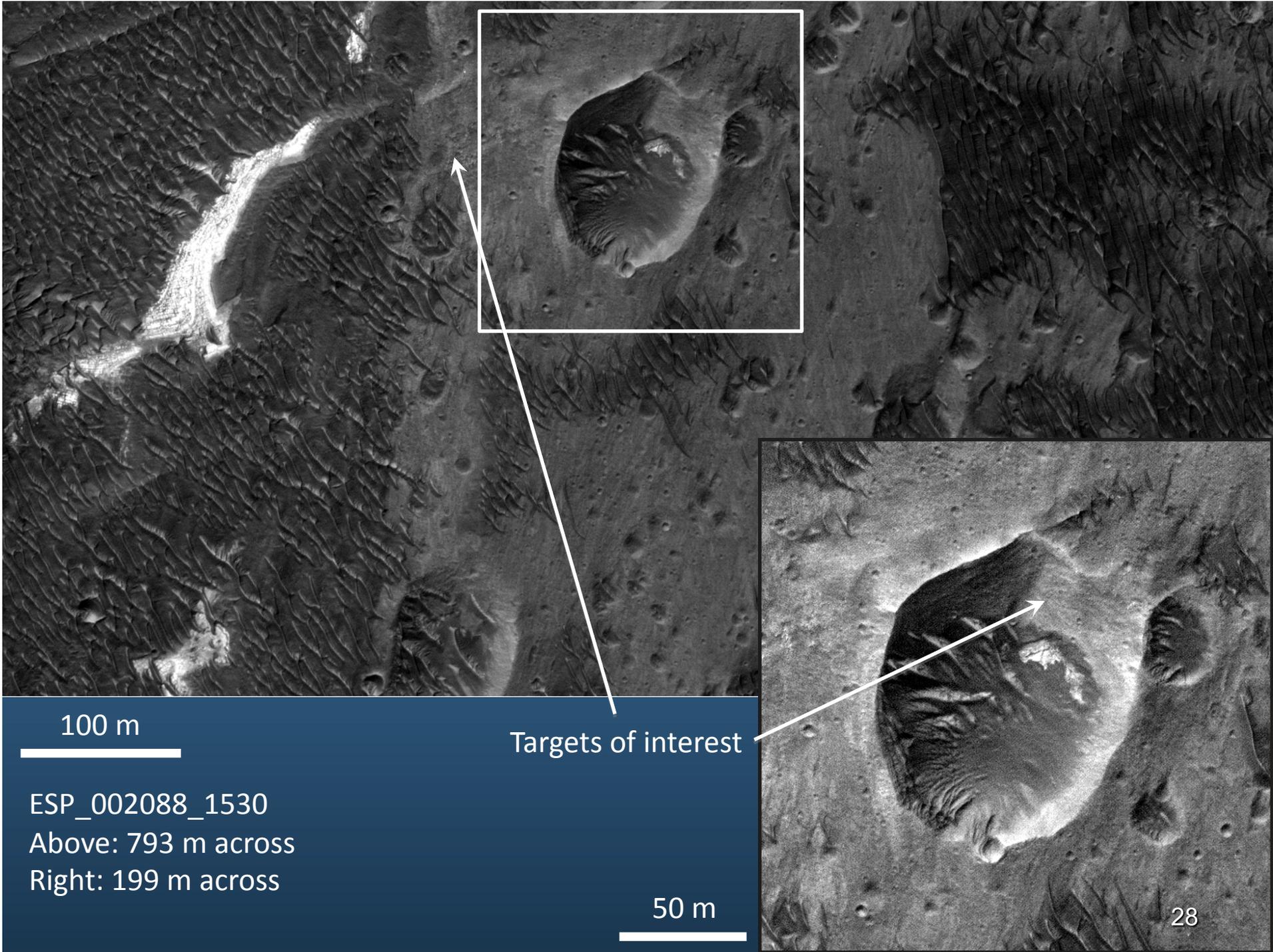
Rocks likely derived from Uzboi Vallis, late-stage flooding of Holden crater floor

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



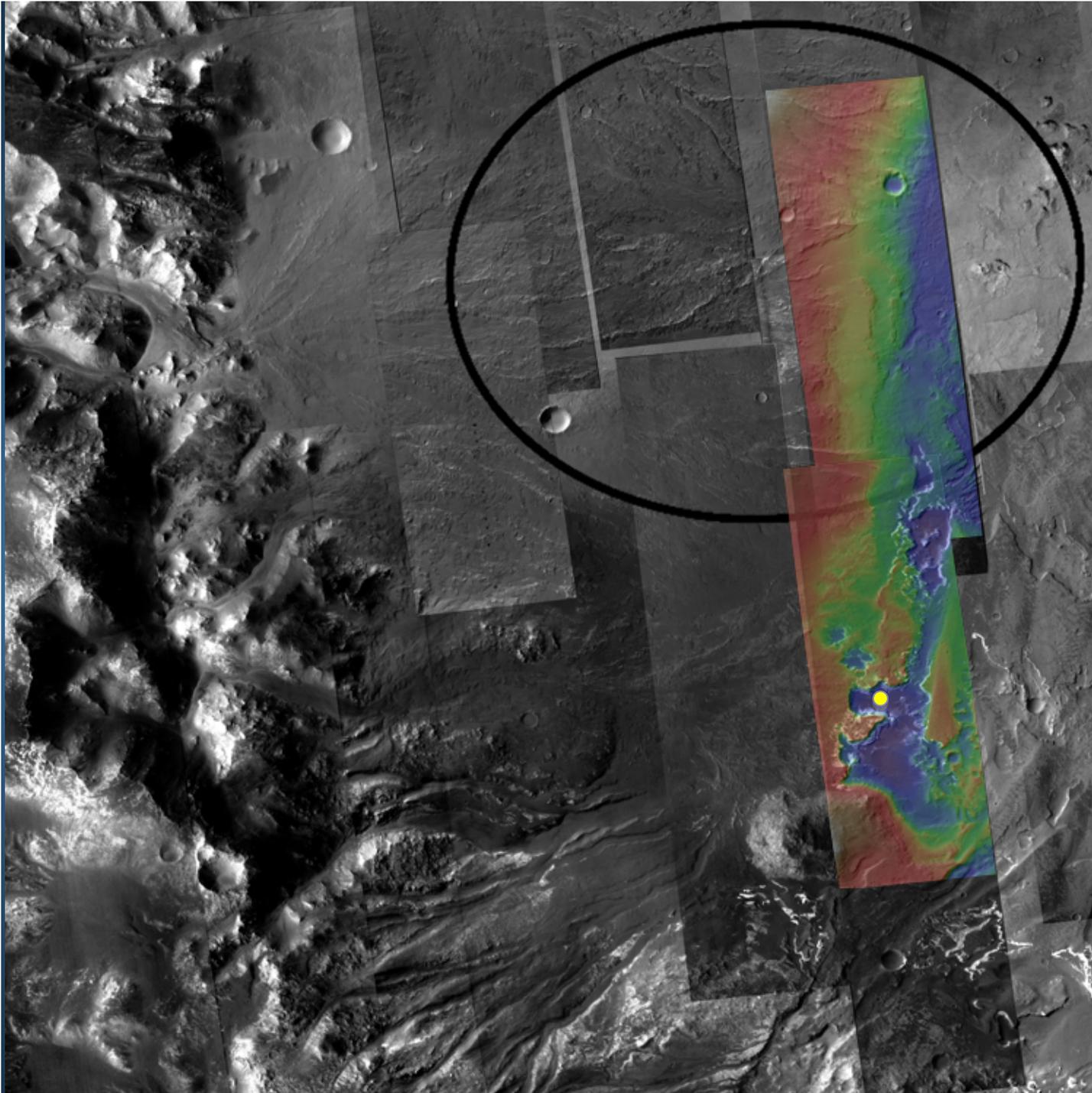
100 m

Targets of interest

ESP_002088_1530
Above: 793 m across
Right: 199 m across

50 m

28



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:

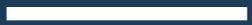
*Thinly bedded, laterally
continuous, fine-grained
strata*

What will the rover
specifically do here?

*Stratigraphic and
compositional analyses,
identify depositional
environment, suggest
consistent sediment source
and weathering history,
search for organics 29*



200 m



ESP_002088_1530
Left: 793 m across
Below: 793 m across

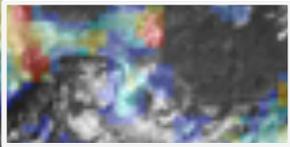
Targets of interest

100 m



Relative phyllosilicate signature, Credit: R. Milliken

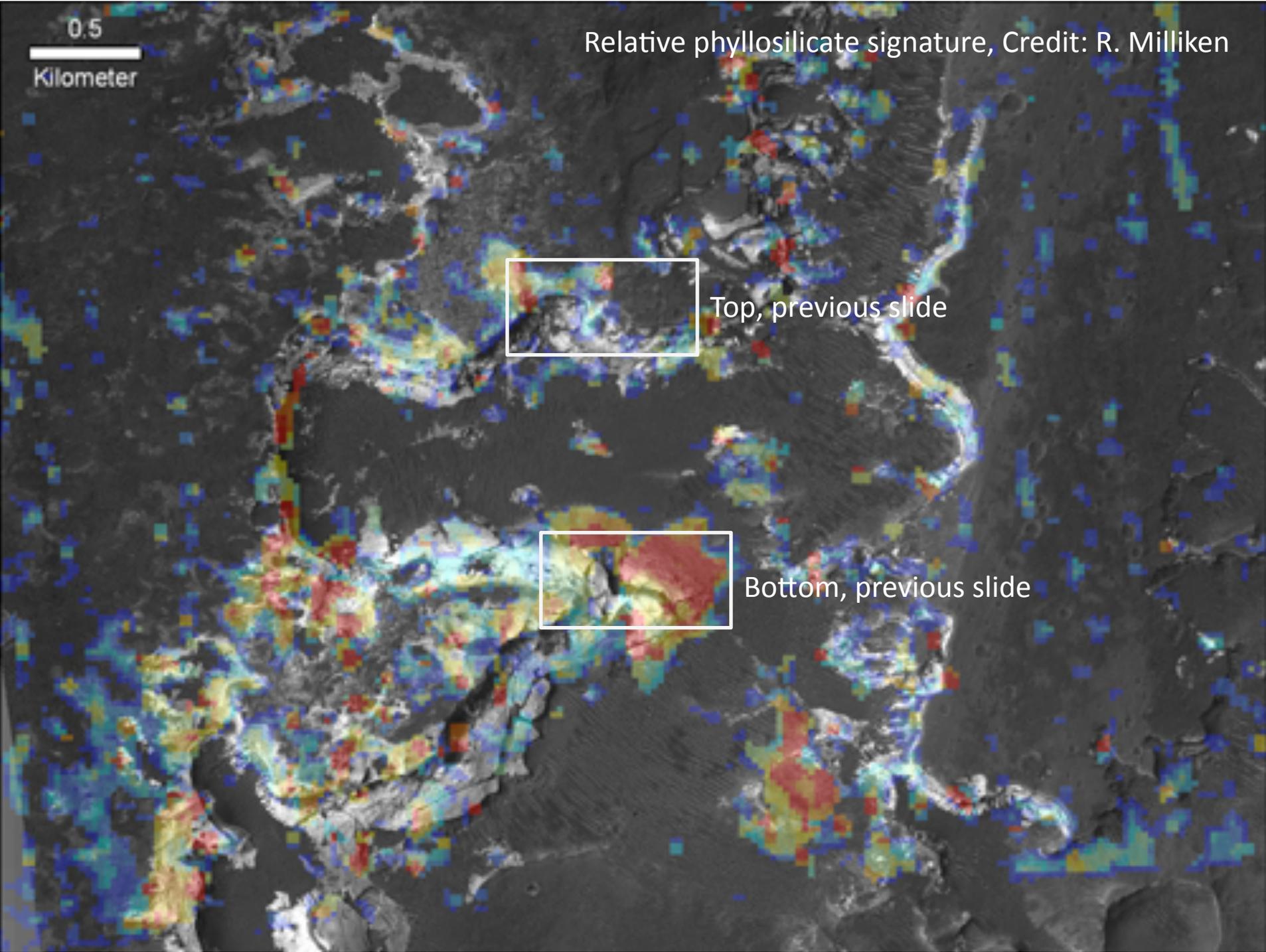
0.5
Kilometer

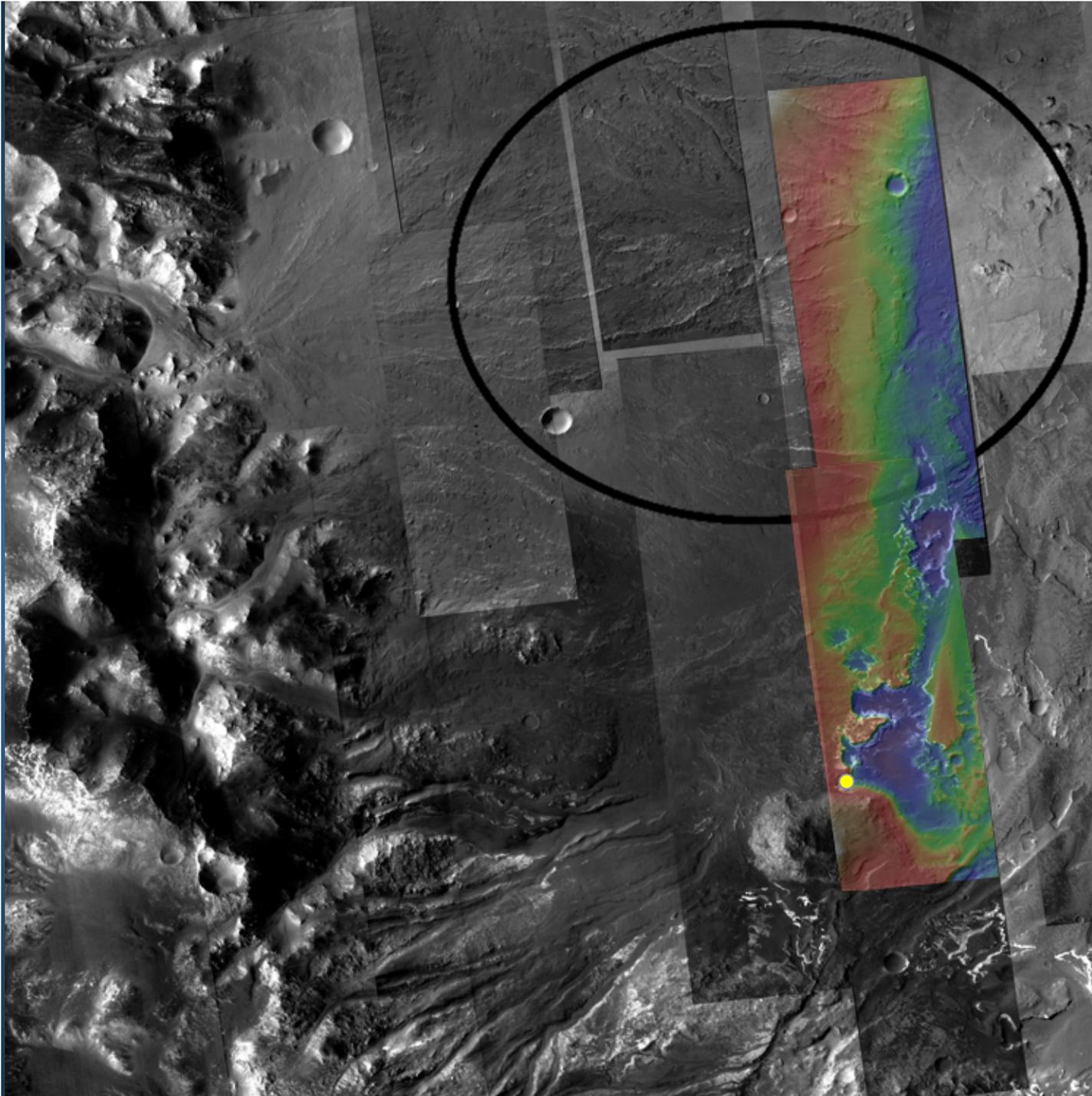


Top, previous slide



Bottom, previous slide





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

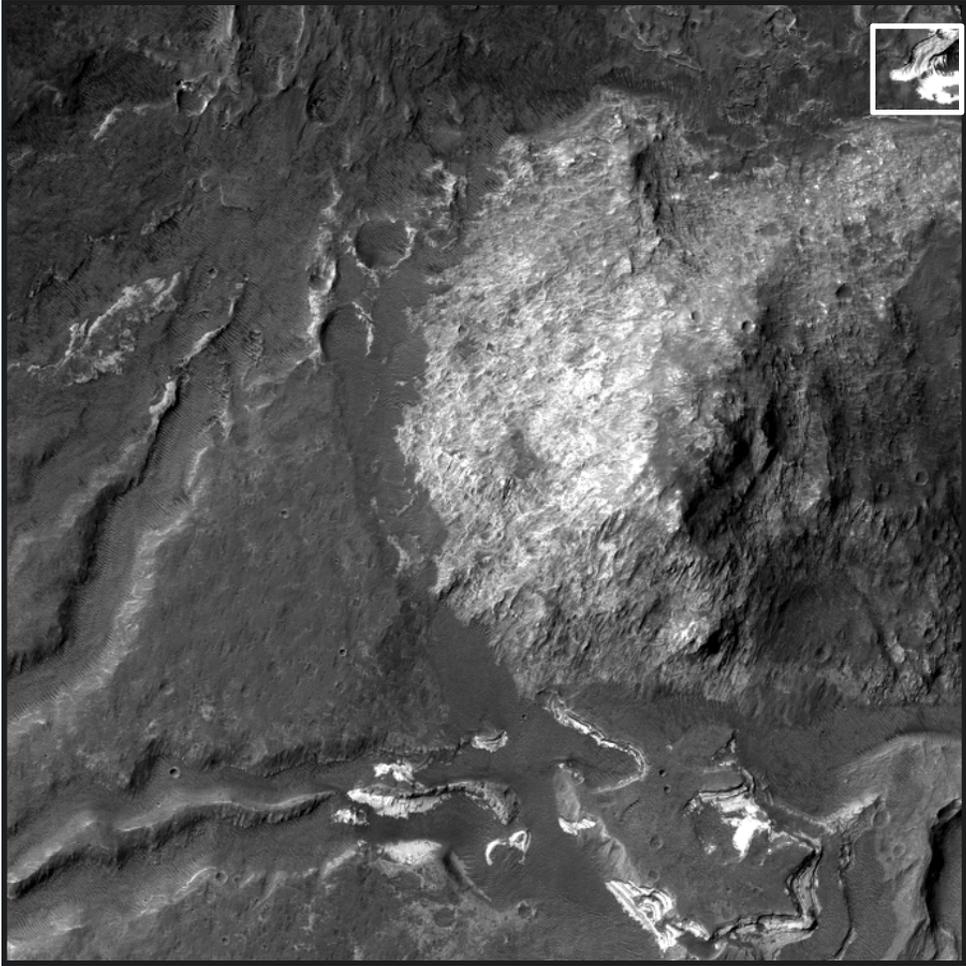
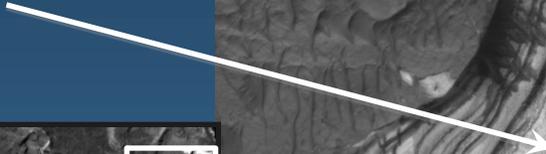


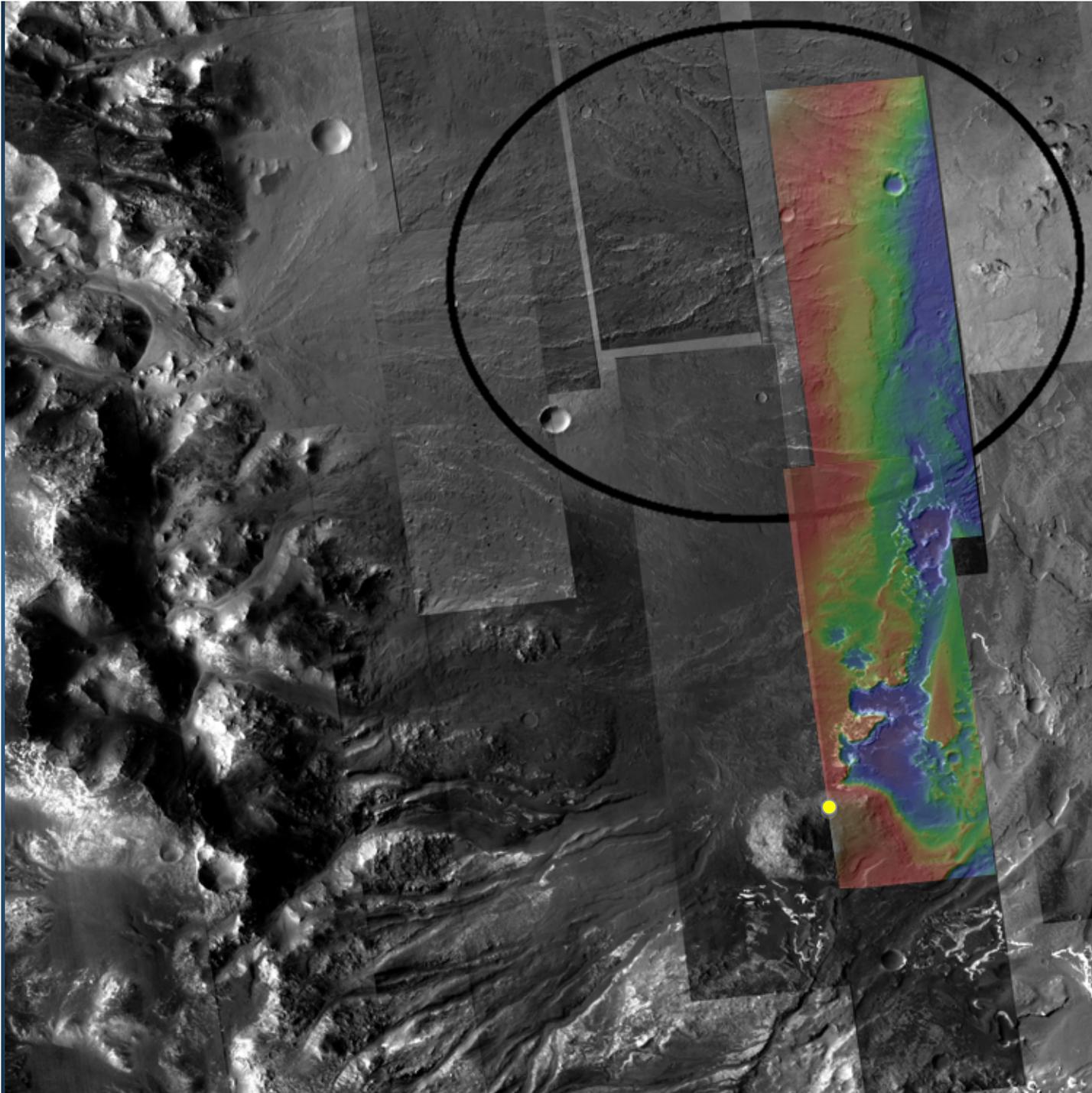
ESP_019322_1530
Right: 433 m across
Below: 5.5 km across

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

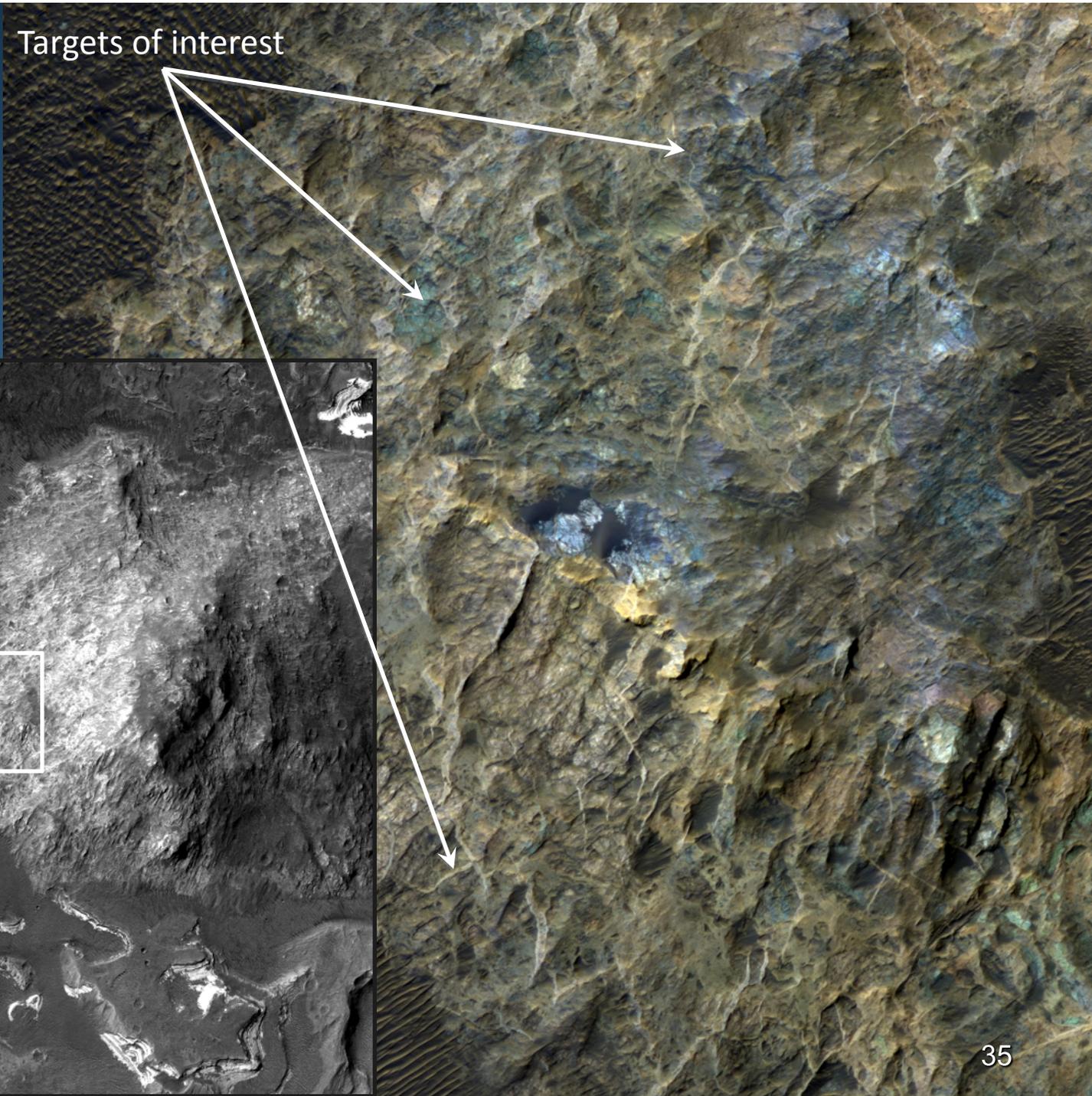
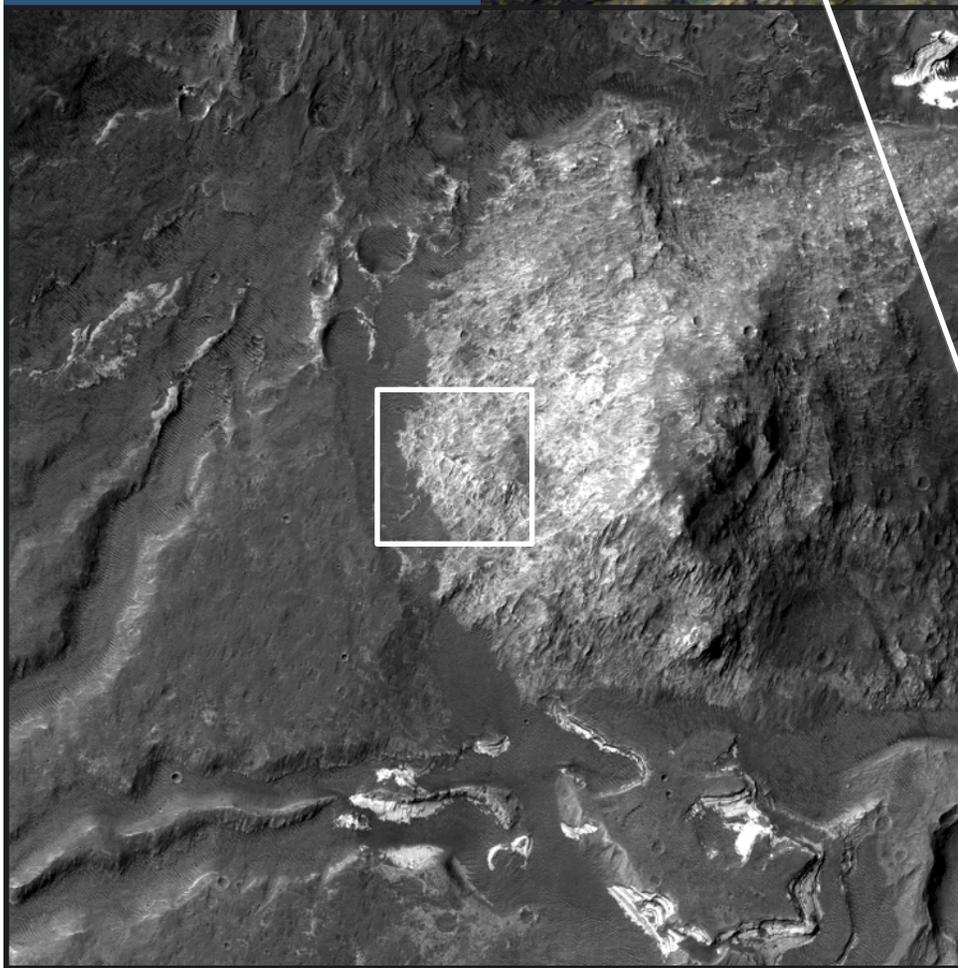
ESP_019322_1530

Right: 793 m across

Below: 5.5 km across

Veins in positive relief

800 m



Extended Mission Potential

2 km

LTL

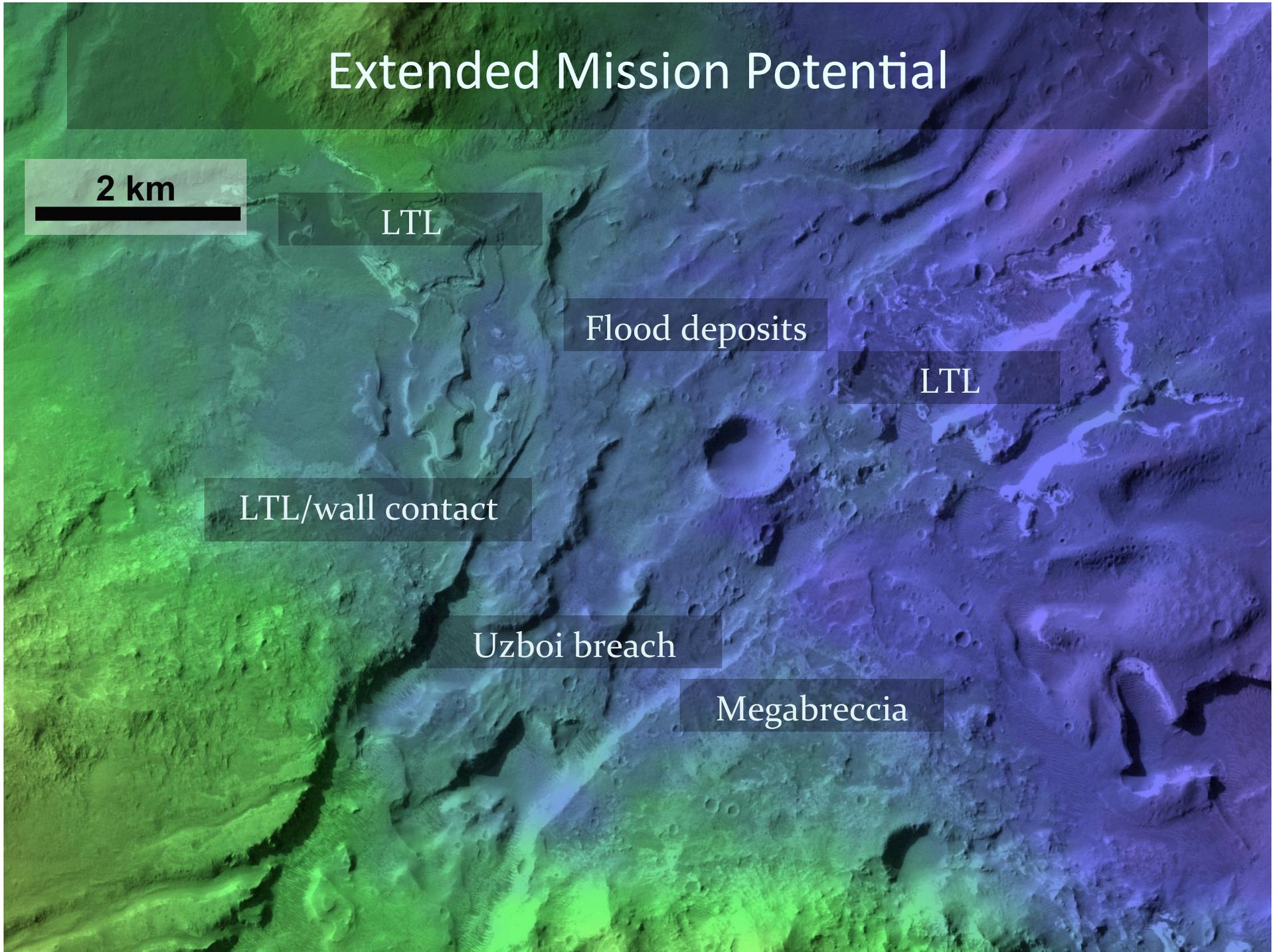
Flood deposits

LTL

LTL/wall contact

Uzboi breach

Megabreccia



Merits of the Holden Site

- **Diverse habitable environments**
 - + **Fluvial/lacustrine setting**: Main geologic units indistinguishable from Eberswalde, plus later flooding from Uzboi Vallis
 - + **Impact hydrothermal setting**: Size of the crater and landing inside it matter, bedrock knobs better exposed than at Gale
 - + **Upper Noachian crust**: Rocks in alluvial fans eroded from up to >1 km below surface, exhumation depth unclear at Mawrth ellipse
- **Most eroded source area of any site**: Likely requires 100s – 1000s m of runoff
- **Location**: Large alluvial deposits concentrated in 19 - 30° S latitude band
- **Relative youth**: Preservation of stratigraphy, context, and organics is key
- **Phyllosilicates**: As strong as any crater site, possible fluvial pathways preserved
- **Geologic units & context**: Understood as well as any site
- **Safety (roughness and rocks)**: First among equals
- **Mobility**: Excellent, stratigraphic sections more closely spaced than at Meridiani
- **Not Go-To**: Outcrops of all four target materials inside ellipse

Conclusions

- Good outcrops of all four target materials are accessible within the current ellipse, so go-to capability outside the ellipse is not necessary
- More outcrops and lower strata are accessible to the south
- One of the most deeply eroded crater rims on Mars: abundant water
- Diversified habitability investigation minimizes risk
- Safe landing site and trafficable route

20 km

