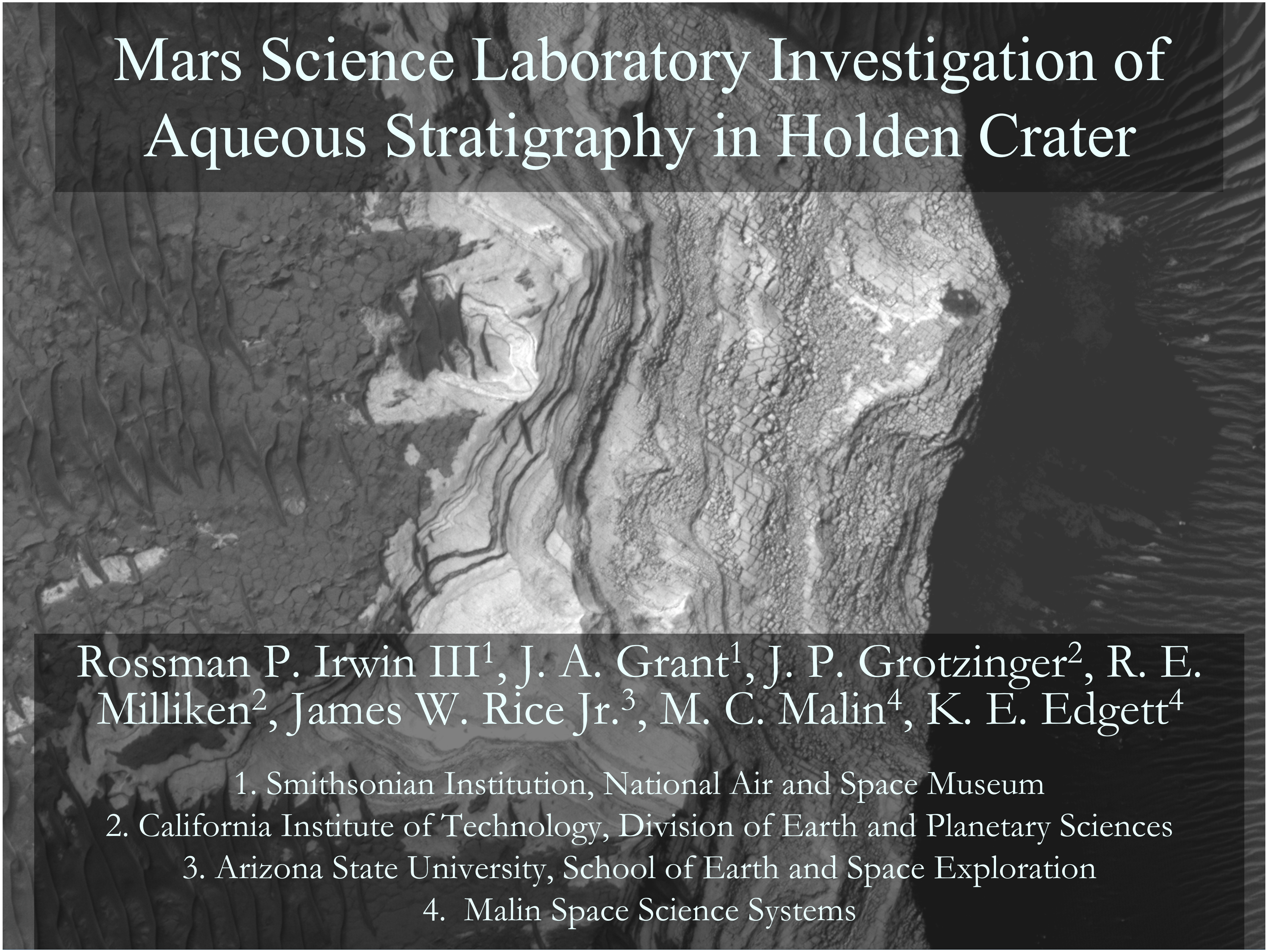
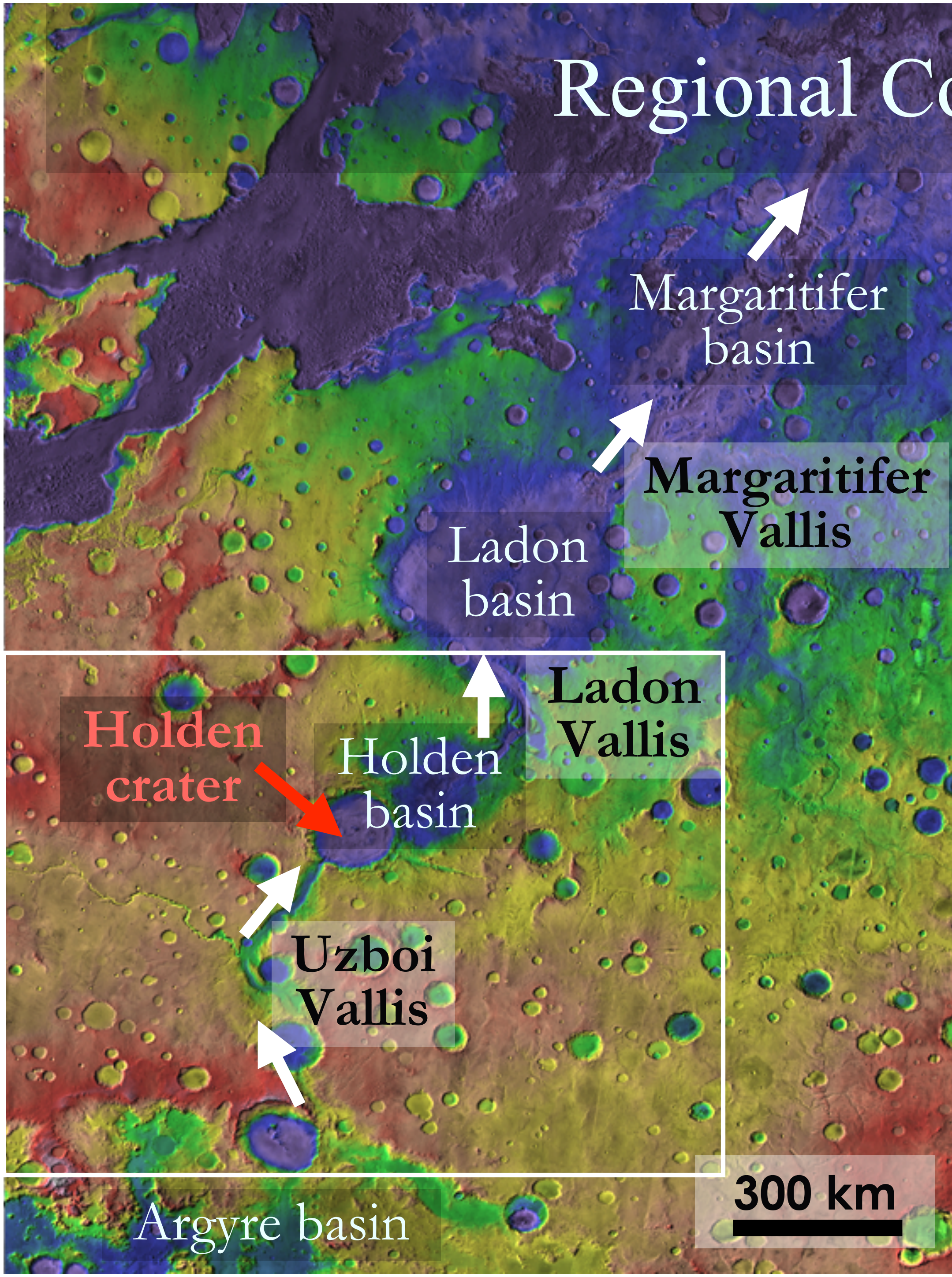
Mars Science Laboratory Investigation of Aqueous Stratigraphy in Holden Crater

Rossman P. Irwin III[1], J. A. Grant[1], J. P. Grotzinger[2], R. E. Milliken[2], James W. Rice Jr.[3], M. C. Malin[4], K. E. Edgett[4]

1. Smithsonian Institution, National Air and Space Museum
2. California Institute of Technology, Division of Earth and Planetary Sciences
3. Arizona State University, School of Earth and Space Exploration
4. Malin Space Science Systems

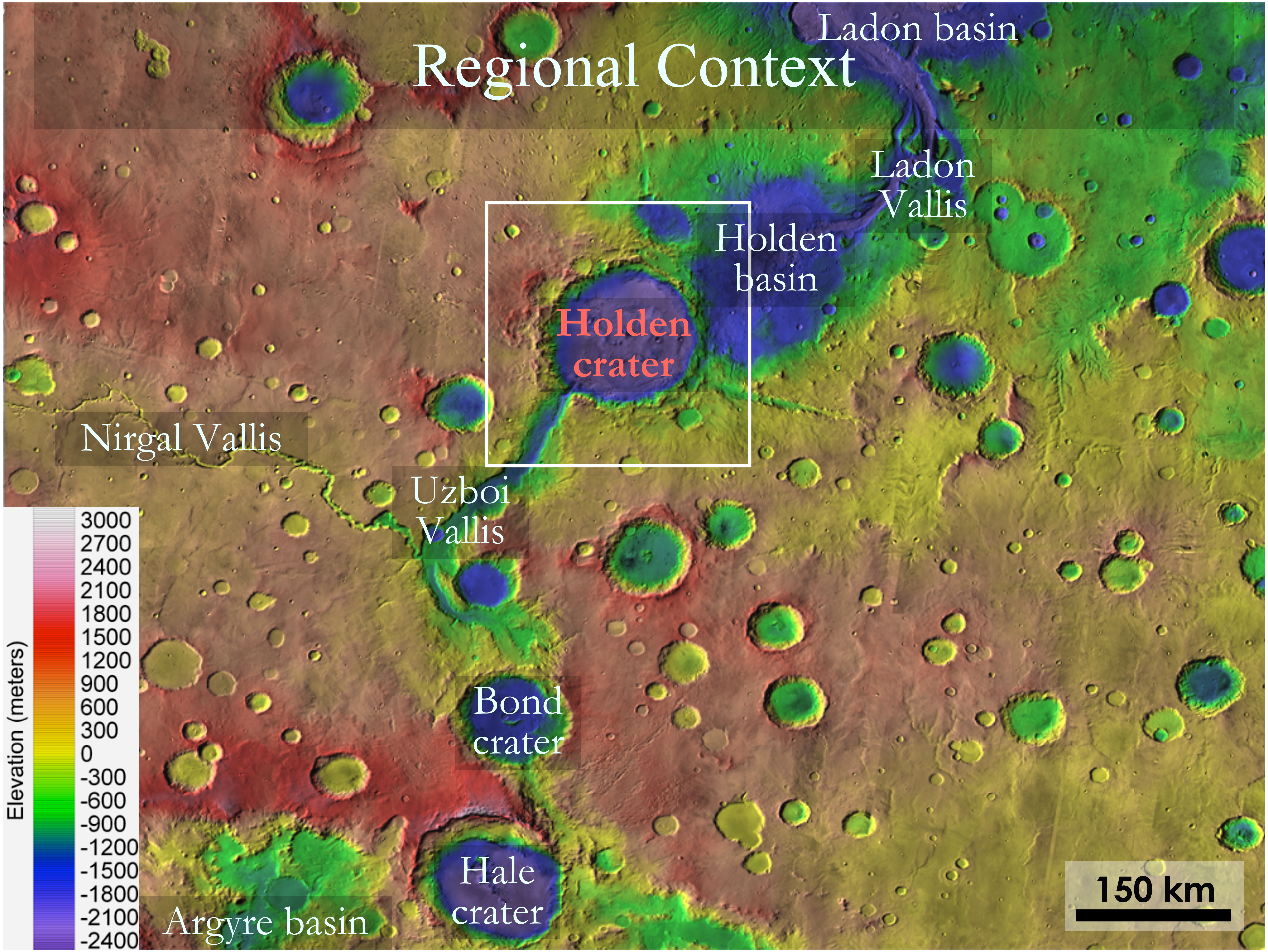


Regional Context

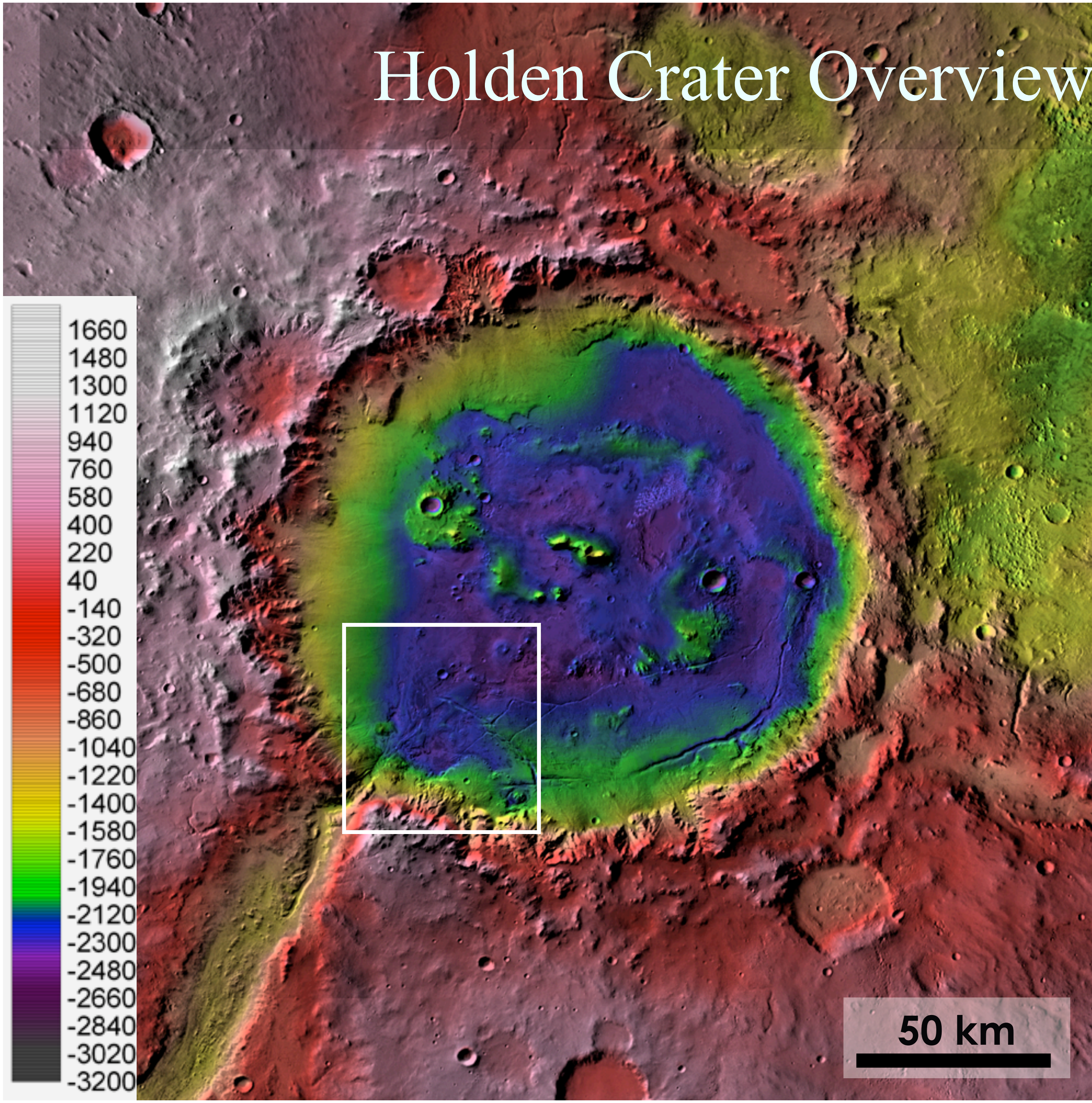


Holden crater formed in the Late Noachian Epoch and interrupted the Uzboi-Ladon-Margaritifer Valles segmented outflow system, excavating sedimentary material from an Early Noachian impact basin. Holden is the deepest large crater within 700 km.

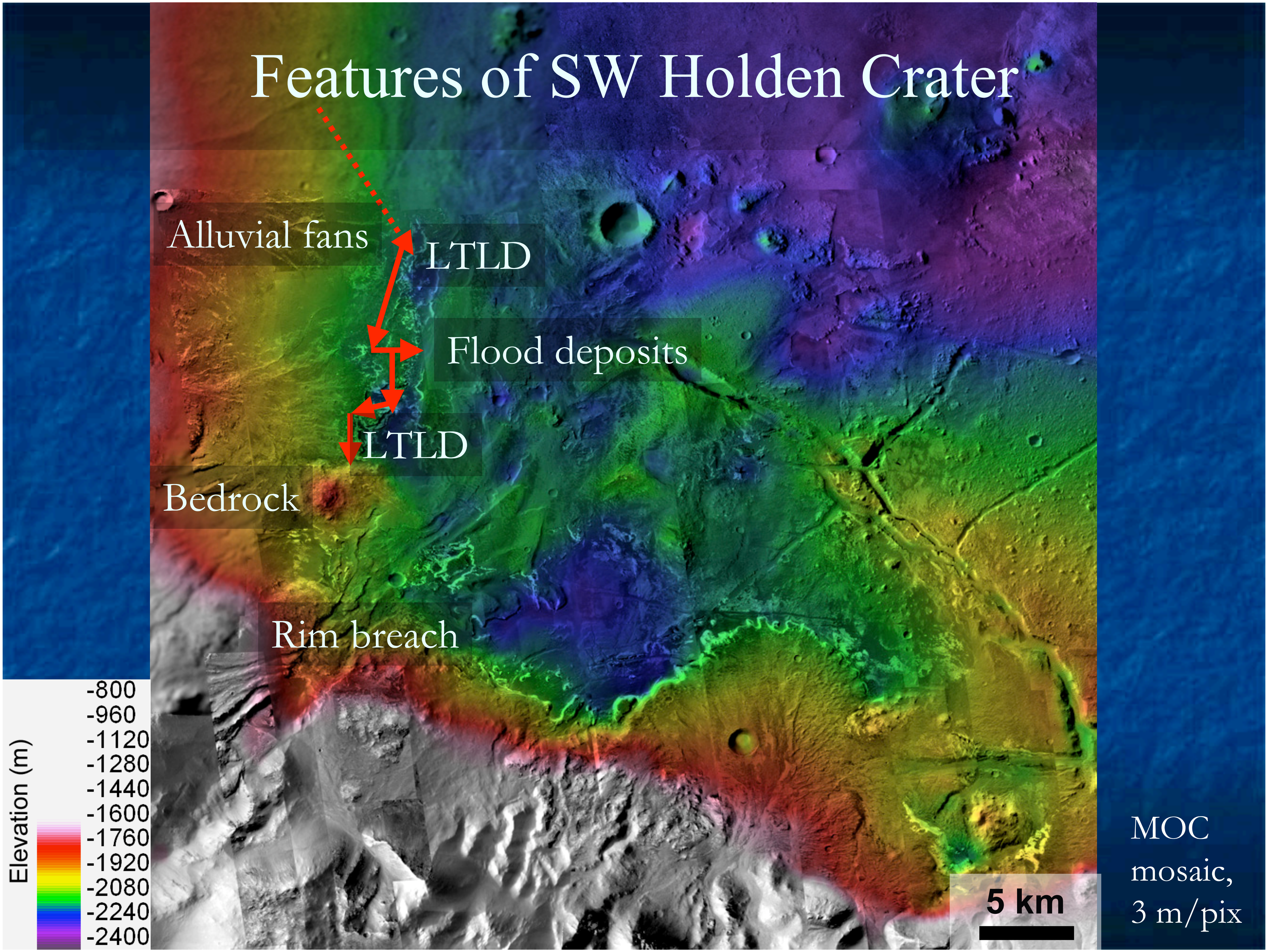
Drainage in Margaritifer Sinus is well integrated relative to other areas on Mars, with concentrations of dense valley networks and coarse-grained alluvial deposits.


Regional Context
Ladon basin
Ladon Vallis
Holden basin
Holden crater
Nirgal Vallis
Uzboi Vallis
Bond crater
Hale crater
Argyre basin
Elevation (meters)
3000
2700
2400
2100
1800
1500
1200
900
600
300
0
-300
-600
-900
-1200
-1500
-1800
-2100
-2400
150 km

Holden Crater Overview

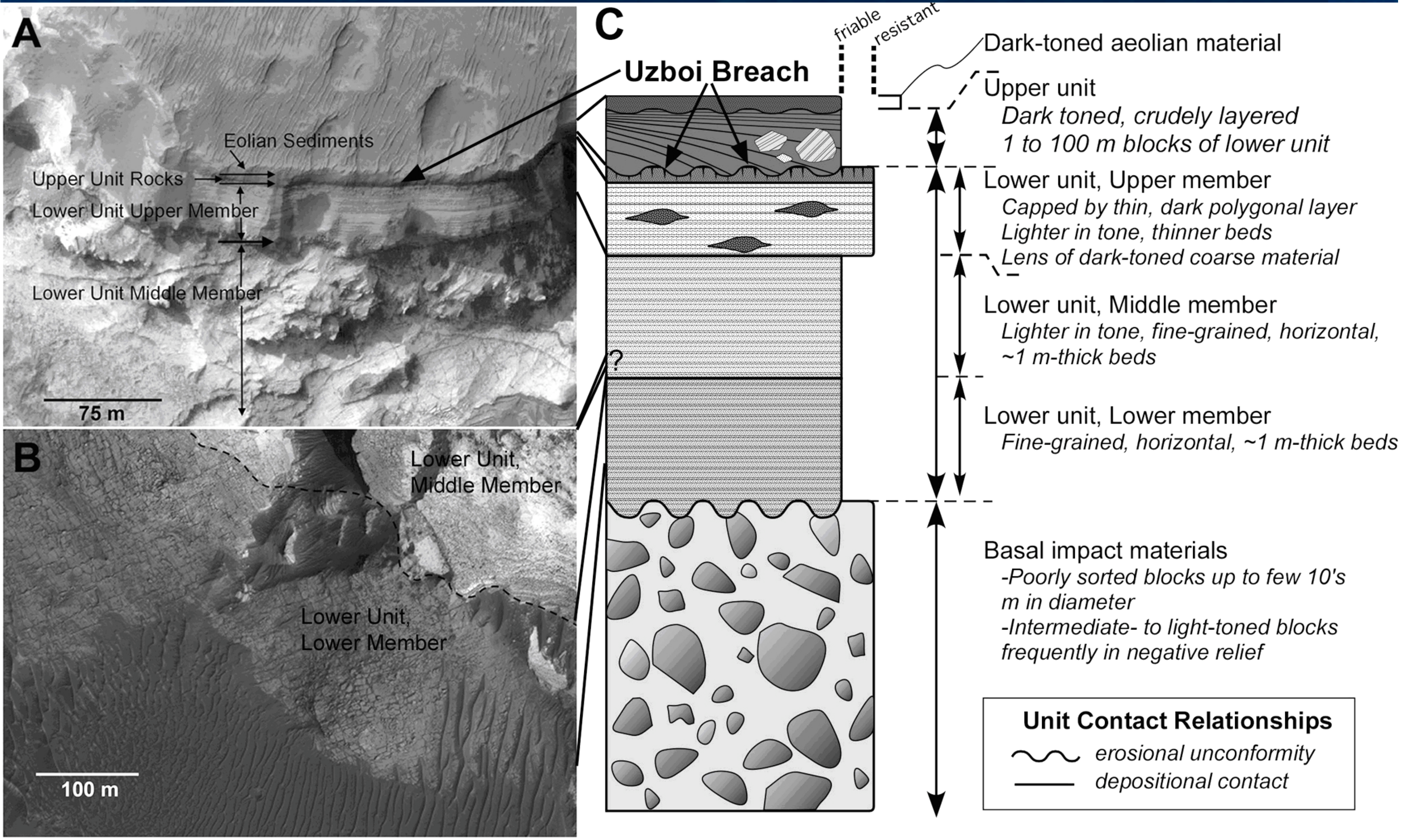


- 26°S, 34°W
- 150 km diam.
- –2 km floor
- Late Noachian
- Phyllosilicate-rich LTLD
- Alluvial fans and bajada from dissected wall alcoves
- Coarse flood deposit from Uzboi Vallis rim breach



Features of SW Holden Crater
Alluvial fans
LTLD
Flood deposits
LTLD
Bedrock
Rim breach
Elevation (m)
-800
-960
-1120
-1280
-1440
-1600
-1760
-1920
-2080
-2240
-2400
5 km
MOC mosaic, 3 m/pix

Stratigraphy



Grant et al., *Geology*, in press.

WHAT WE KNOW OF PLANET MARS

Professor Edward S. Holden Draws Line Between Facts and Fancies.

THINGS SEEN ON MARS.

No Direct Evidence of Human Life—Little Water or Air.

TESLA'S IDEAS CRITICISED.

[BY EDWARD S. HOLDEN.]

Astronomy has done so many wonderful things in the past, and is accomplishing such marvels in the present, that it is sometimes difficult to realize its limitations. If, by merely examining the spectrum of a star, astronomers can determine the velocity with which the earth, and the whole solar system, is now approaching that star, why should it be so difficult to say whether it is, or is not, likely that the planets are fitted to sustain human life? If the spectroscope can do so much, how is it that our greatest telescopes can do so little towards settling a question that seems to be comparatively simple? At first sight, the problem appears to be a mere matter of observation, and the solution to be close at hand and obvious.

Let us see what the obstacles really are. When the planet Mars is nearest to the earth its distance is never less than 35,000,000 miles. Usually it is much greater. The moon's distance is about 240,000 miles, so that Mars is always 146 times more distant than the moon. It is seldom possible to use a magnifying power of more than 600 diameters to examine Mars, even with the largest telescopes. We see Mars, under such conditions, no better than the moon can be seen in a field-glass magnifying about four times. If any one will examine the moon with a common opera-glass he will appreciate the difficulty of making out an answer to so far-reaching a question by mere gazing.

No Direct Evidence Human Life.

Under ordinary circumstances a square patch on the planet with sides of twenty miles would go entirely unnoticed. The best telescopes can never show us markings of the size of most of the great cities on the earth. Direct evidence of human life is not to be expected. All such evidence must be indirect. We must ask what is the climate of Mars. If it is much colder than the arctic regions (as it is), human life (that is, of the kind we know about) cannot exist there. Is there an atmosphere about the planet with sufficient air, and air of the right kind, to sustain human life? Is there water? It is upon the answers to questions of this kind that our final judgment must depend. The fundamental problem reduces itself to an inquiry whether the planet is inhabitable—whether it presents the conditions of habitability—and not whether it is actually inhabited by human beings.

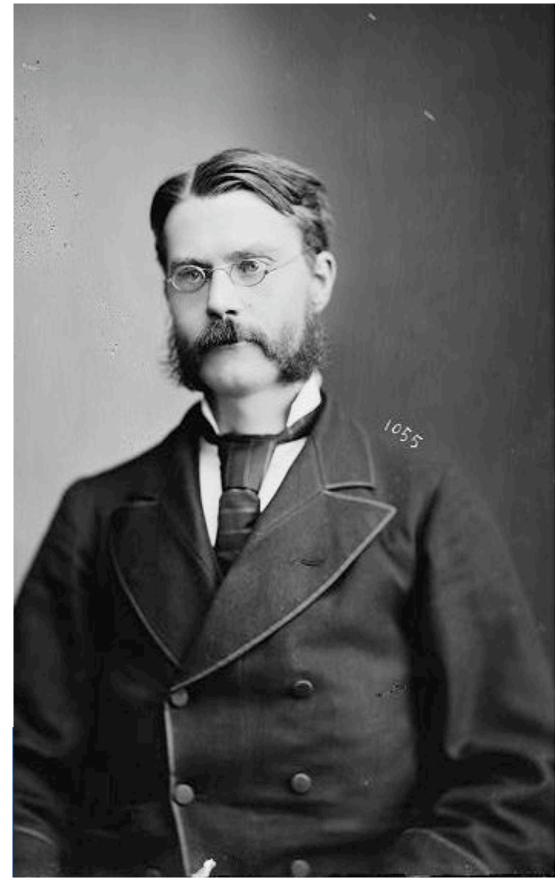
There are many other kinds of life besides human life. If there were no land at all on the earth—if it were all a single ocean—there might be a vigorous population of fishes. Or, if there were not enough air surrounding it for men to breathe, still there might be animals which could exist and multiply. Or, if the terrestrial temperature were too high for human beings, it might be perfectly suitable for reptiles. Or, again, if all conditions were unfavorable for animals, a vigorous plant life might still exist.

Things Seen on Mars Multitudinous.

A complete account of the appearances observed on the planet Mars would fill volumes. During a single opposition many hundreds of drawings and sketches are secured, to say nothing of measures, etc. The illustrations presented here will serve to show the kind of evidence afforded by good drawings made at the telescope. No thorough-going discussion of the material available has yet been printed. Mr. Percival Lowell has published a volume dealing with his recent work at Flagstaff, in Arizona, and M. Camille Flammarion has issued a useful book on Mars; but many valuable series are yet unpublished.

The instant we imagine human life anywhere—on the earth or on a distant planet—the place where this life may be takes on an entirely new relation to us. Love can be there, and joy and sorrow; and we realize that we have a deep and new interest in any and every spot where such human life is possible. One of the first and most natural questions asked about the moon, or about a distant planet, is, and always will be, "Is it inhabited?" or, "Is it fitted to be the abode of men?" If the answer is "No," a lively scientific curiosity may remain, but the nature of this curiosity is completely changed. There is no lack of such inquisitiveness in regard to the moon, for example, and yet the general public has long ago accepted the fact that the moon is to be studied like a specimen in a museum; that it has no life now, and that, in all probability, it never had any.

"The fundamental problem reduces itself to an inquiry whether the planet is inhabitable - - whether it presents the conditions of habitability - and not whether it is actually inhabited…"
(E. S. Holden, 1901)



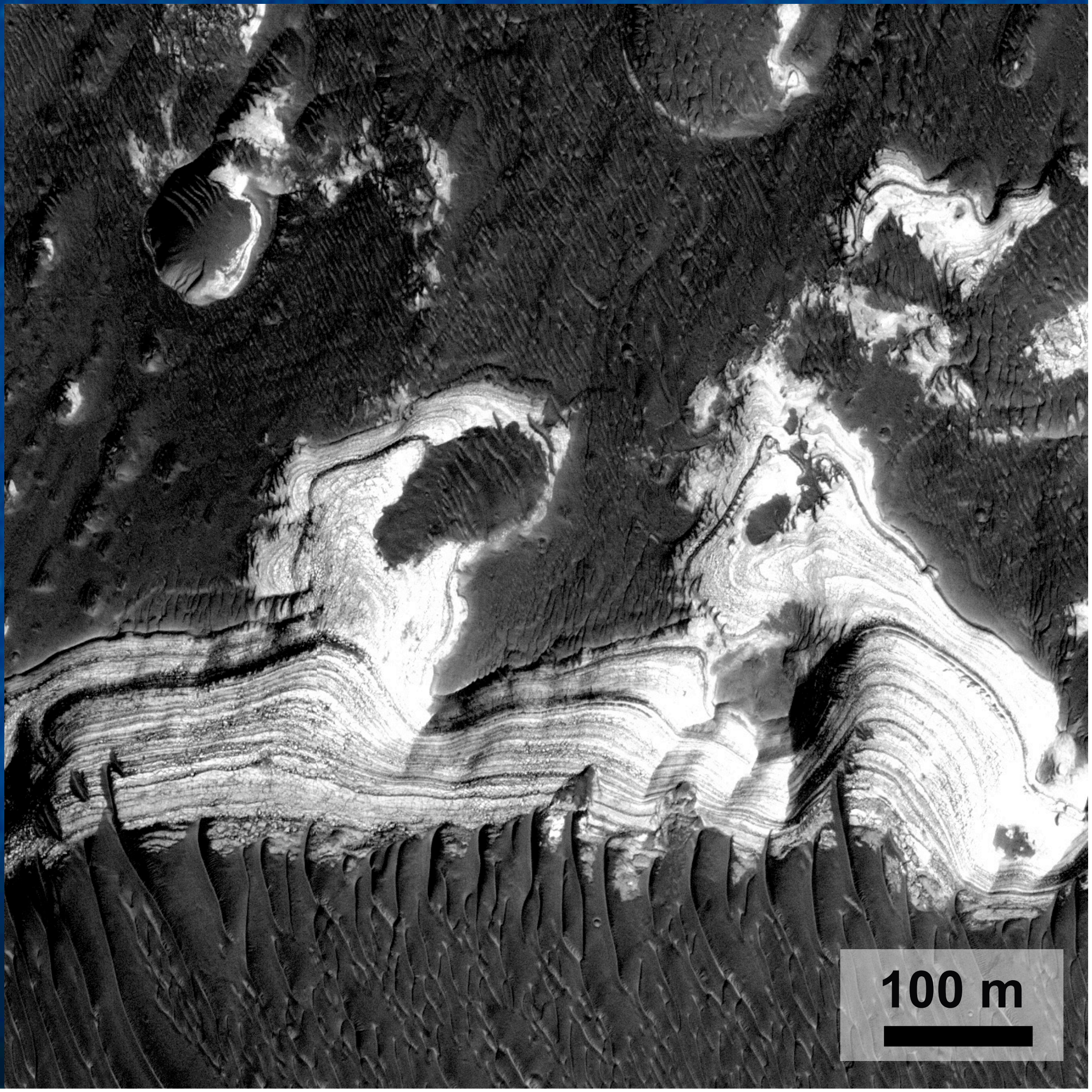
Edward S. Holden (1846-1914)

Professor, U.S. Naval Observatory; Director, Washburn and Lick Observatories; and President, University of California

In Situ Investigation of Past Habitability

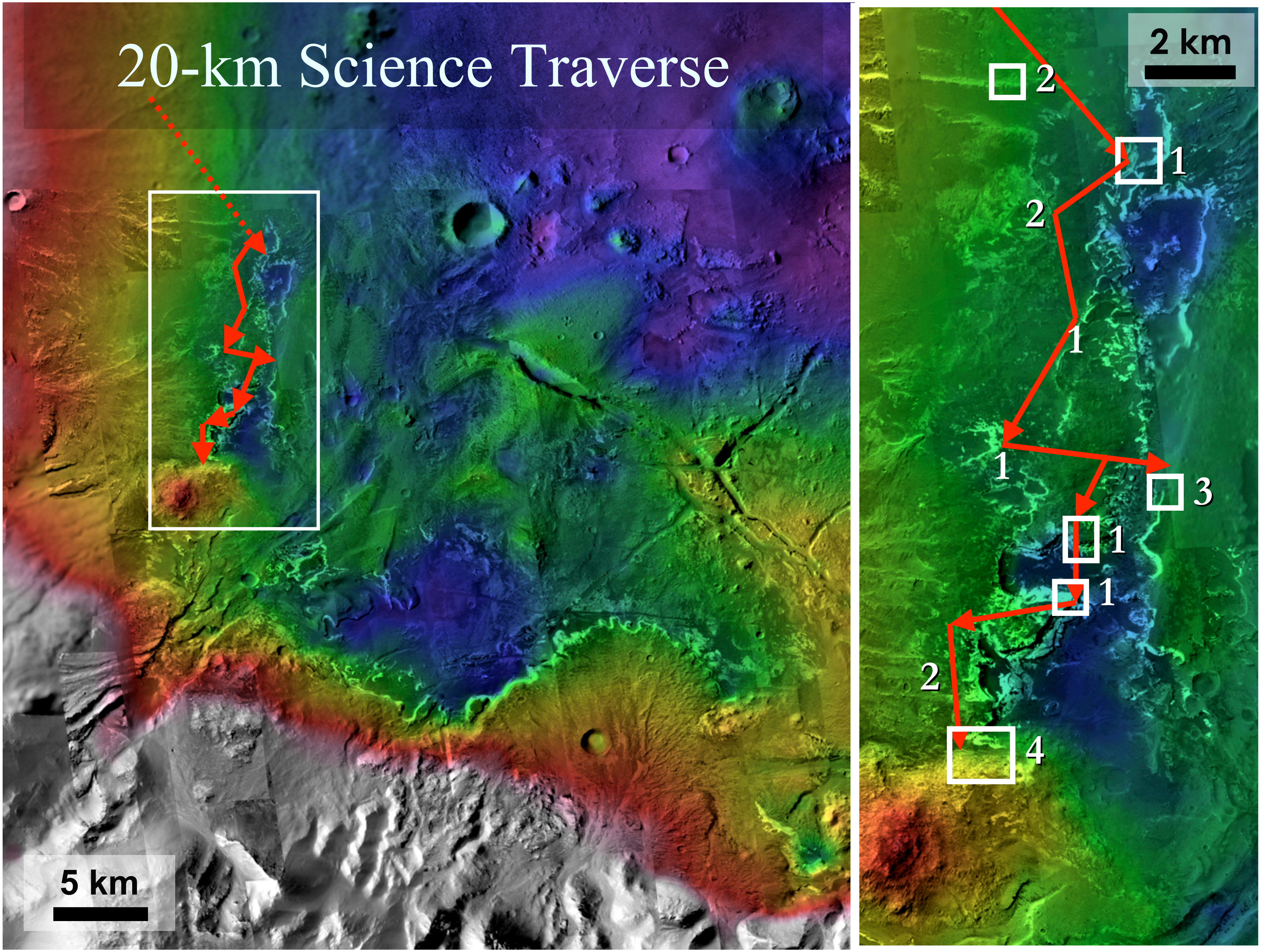
Stable, wet, quiescent depositional settings are ideal.

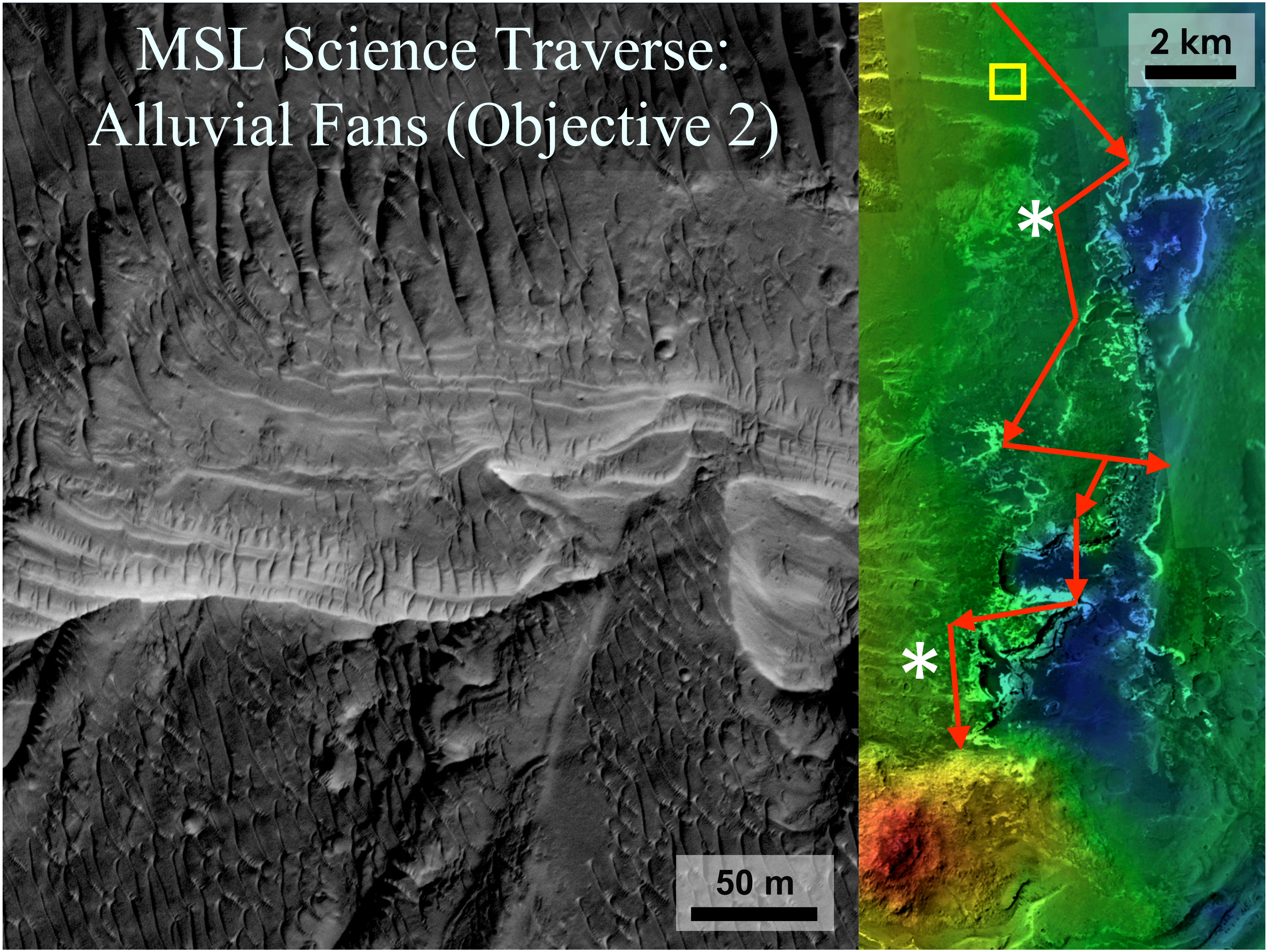
- Thin, mechanically weak, laterally continuous bedding
- Geochemical evidence for aqueous alteration
- Clear stratigraphic context
- Relationship to fluvial networks (paleoclimate)
- Hypotheses testable with rover instruments
- Safe landing site and trafficable traverse
- Accessible outcrops

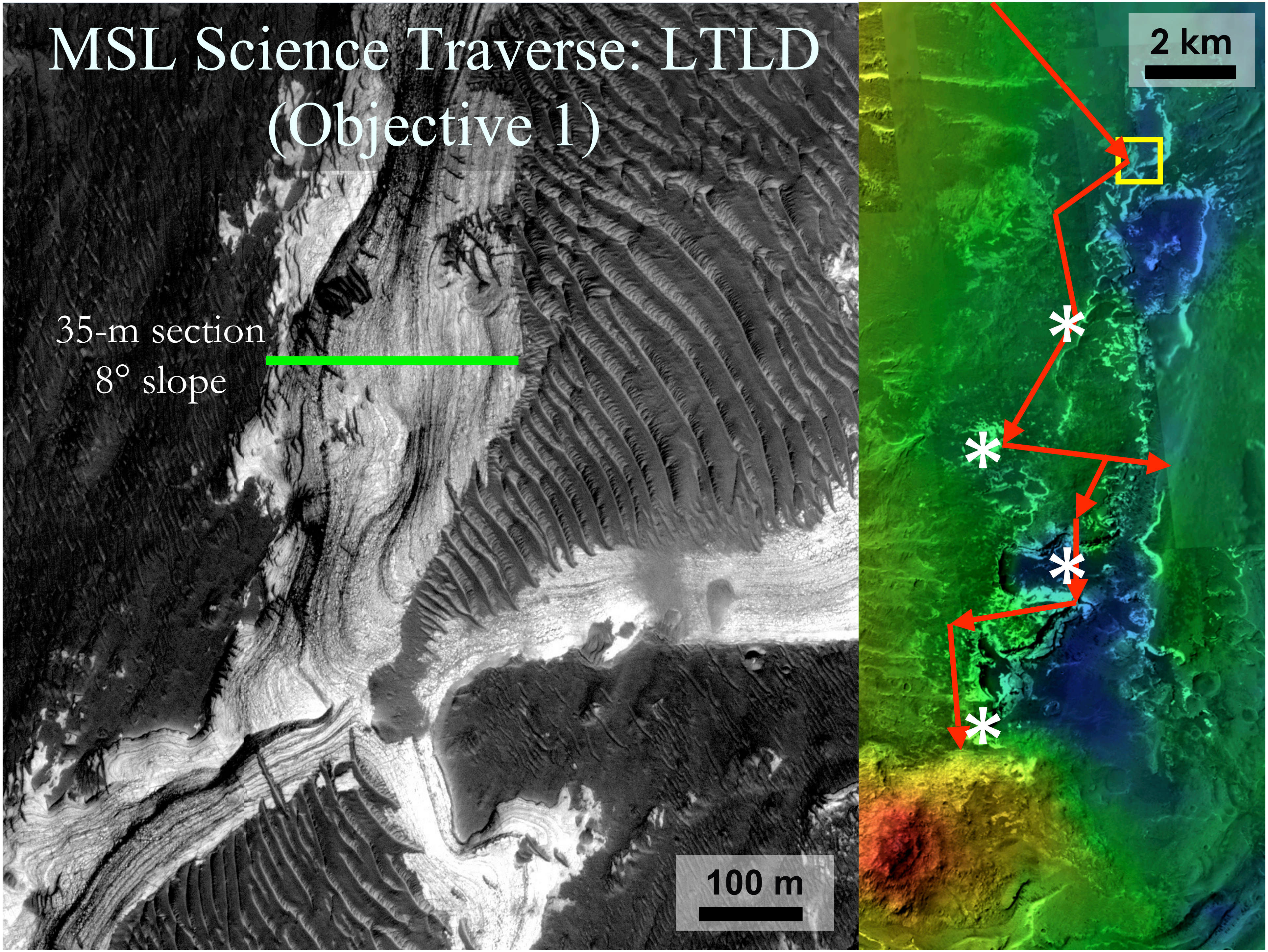


Major Science Objectives

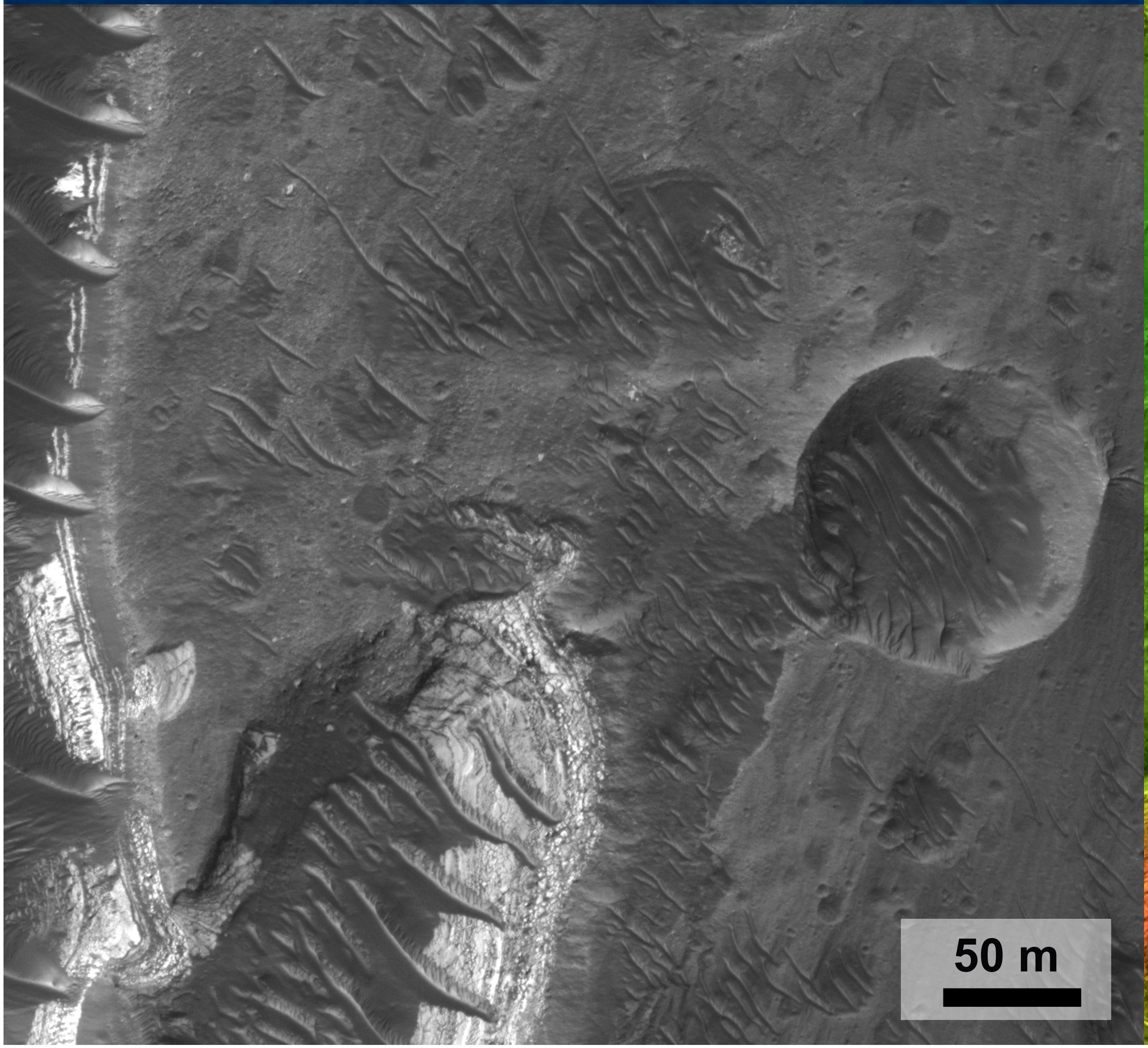
- **Objective 1 – Light-toned, layered deposits with phyllosilicates:** Stratigraphy, sedimentology, and geochemistry of an 80-m-thick section will reflect depositional environment and change over time.
- **Objective 2 – Alluvial fans**: Paleohydrology, sediment load, rock weathering, and runoff requirements; the first in situ study of deposits derived from Noachian valleys in a crater wall.
- **Objective 3 – Flood deposits**: Paleoflood hydrology, lithological diversity in the crater rim breach, late-stage weathering environment.
- **Objective 4 – Bedrock**: Lithology and alteration of ancient basal rocks that were uplifted during impact.

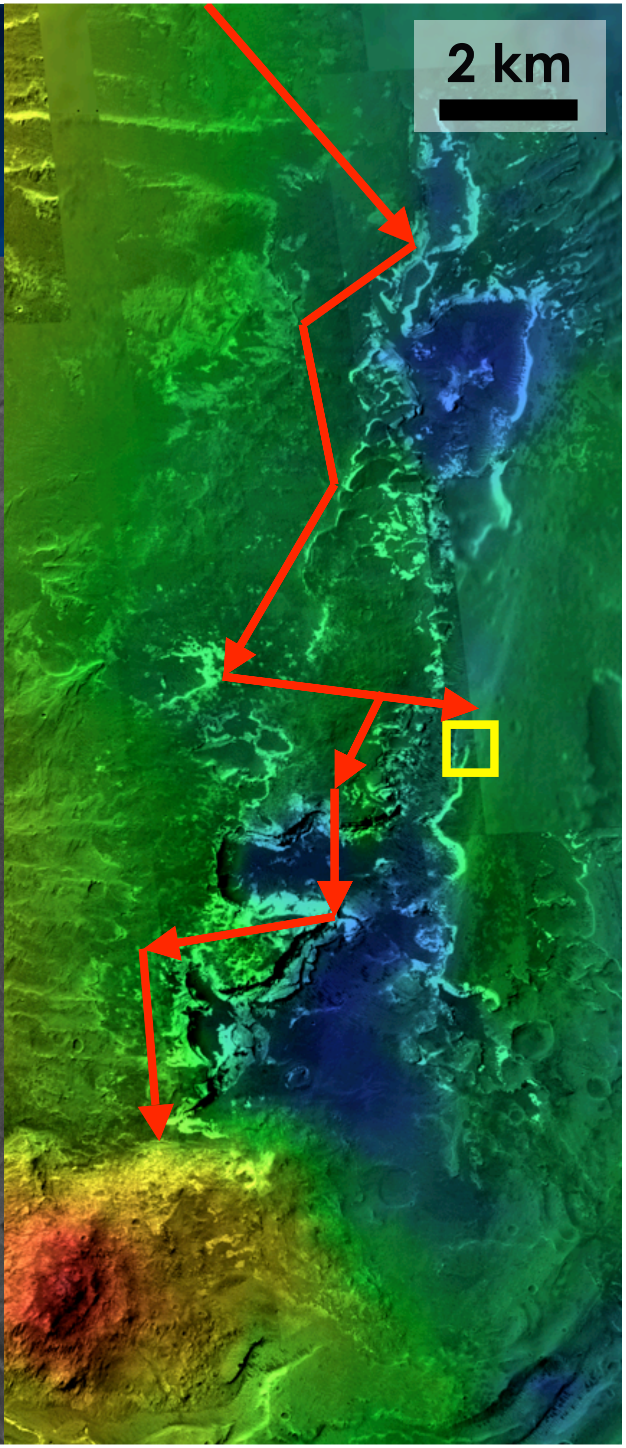

20-km Science Traverse
5 km
2 km
2
1
2
1
1
3
1
1
2
4


MSL Science Traverse:
Alluvial Fans (Objective 2)
50 m
2 km

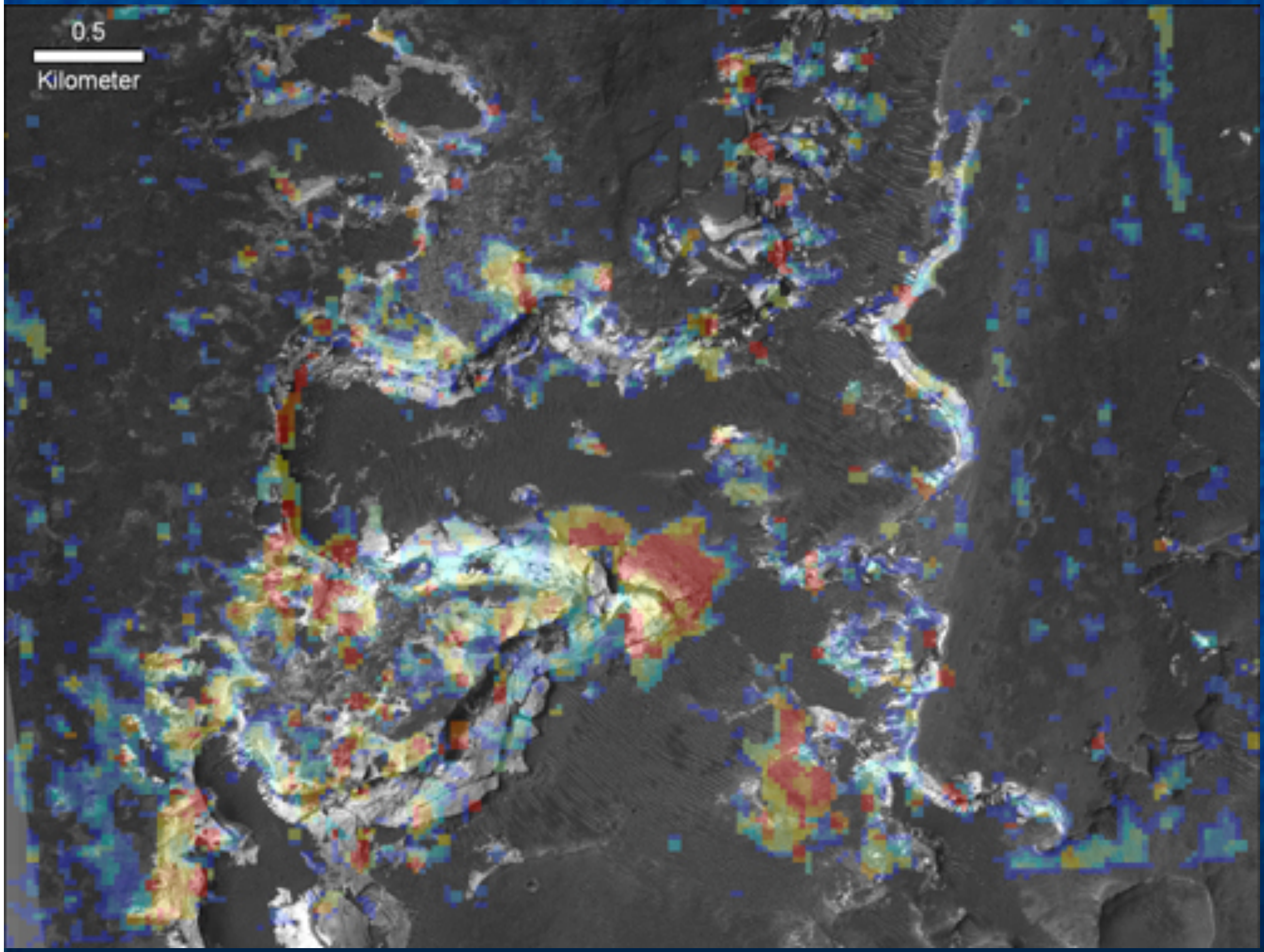

MSL Science Traverse: LTLD
(Objective 1)
35-m section
8° slope
100 m
2 km
*
*
*
*

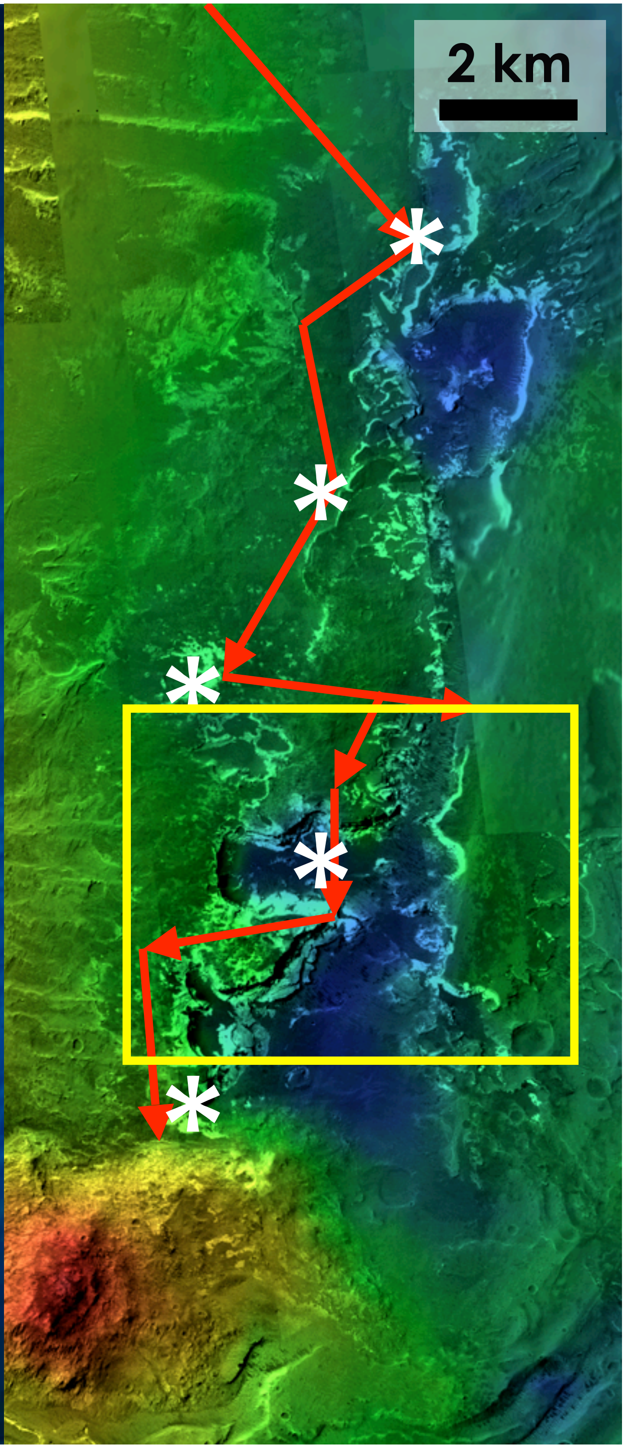
MSL Science Traverse: Flood Deposits (Objective 3)



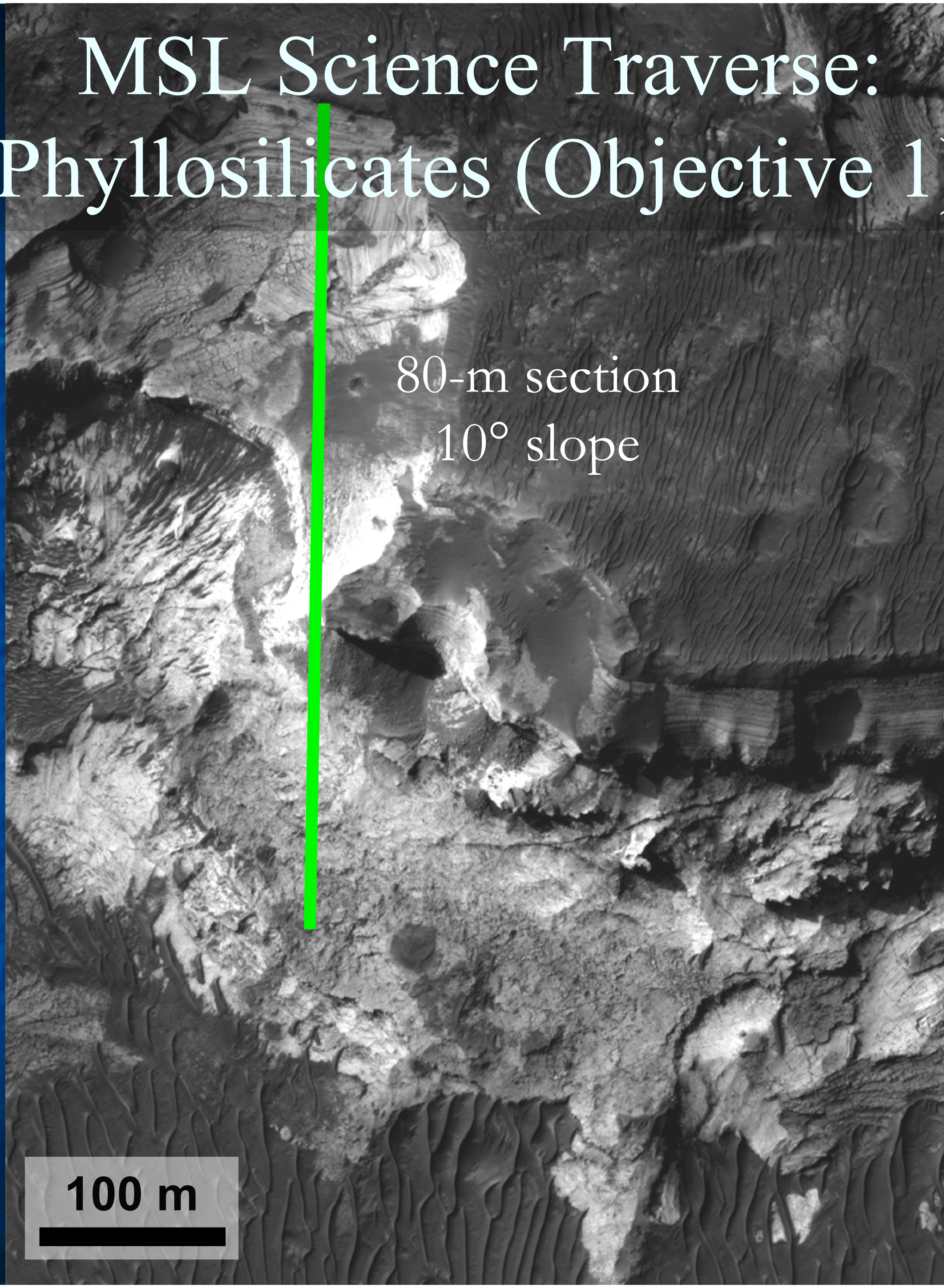


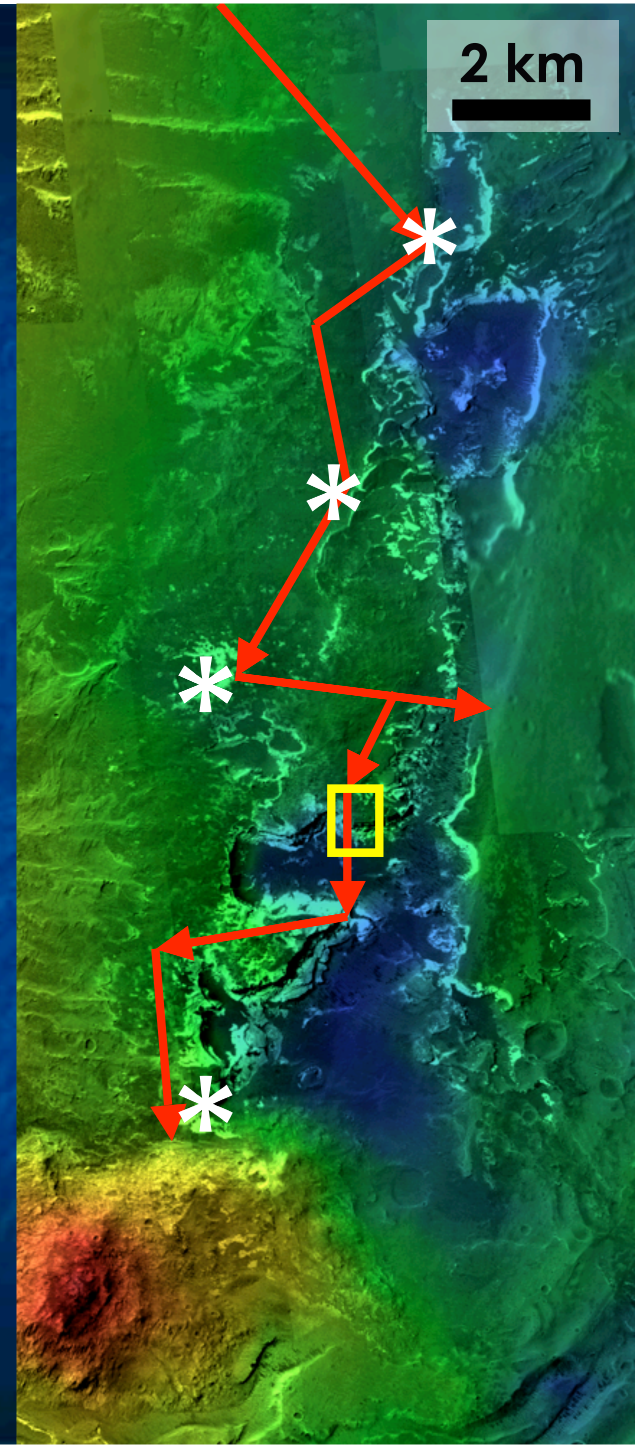
MSL Science Traverse: Phyllosilicates (Objective 1)



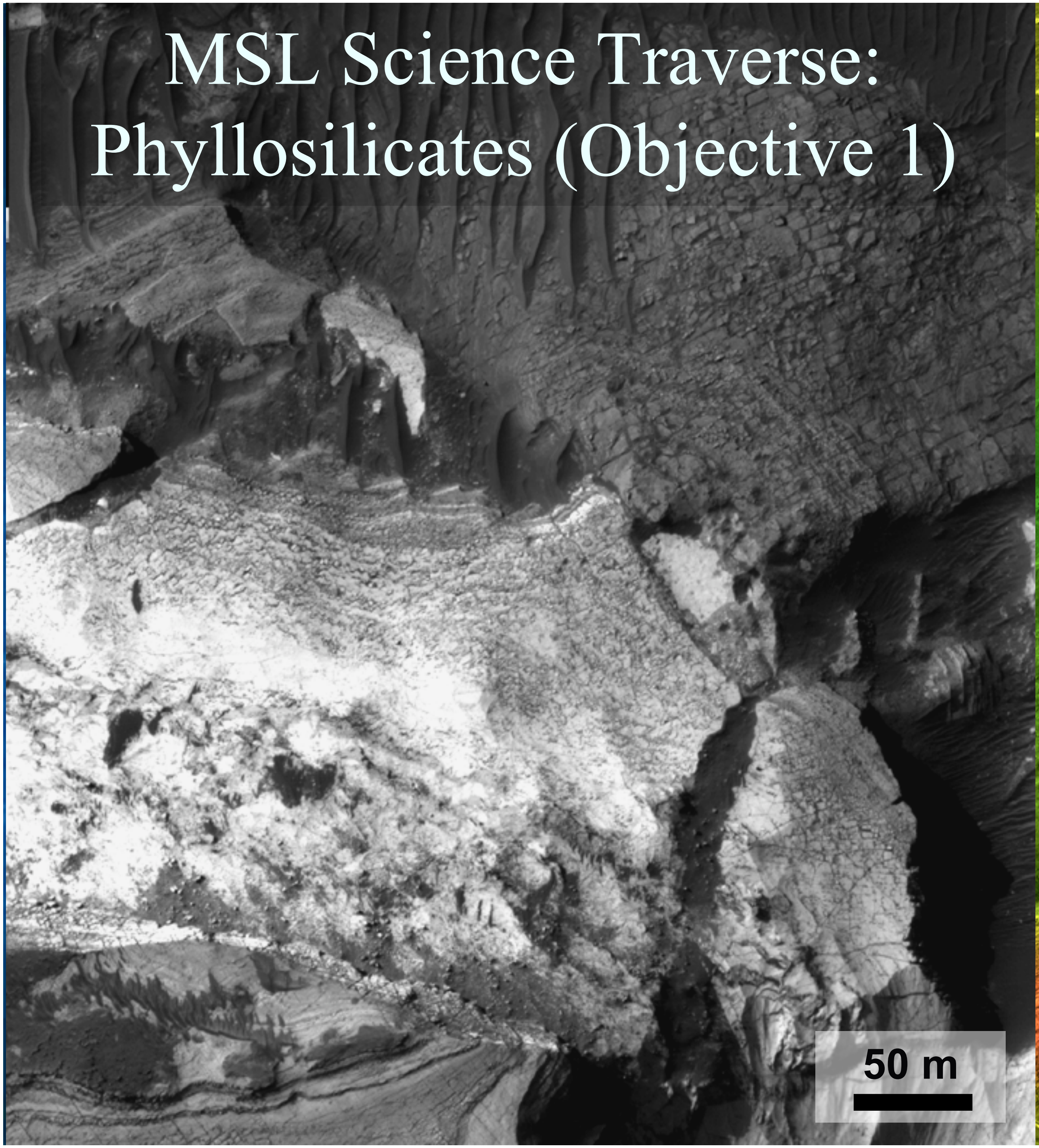


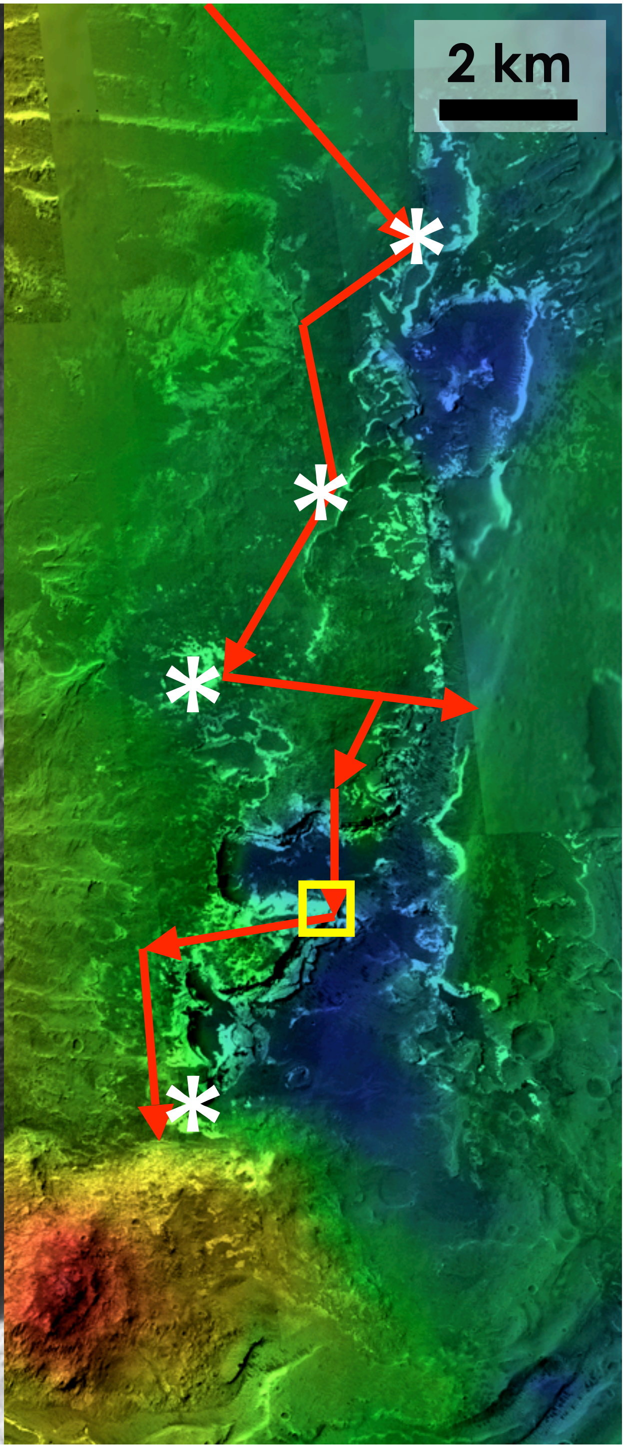
MSL Science Traverse: Phyllosilicates (Objective 1)



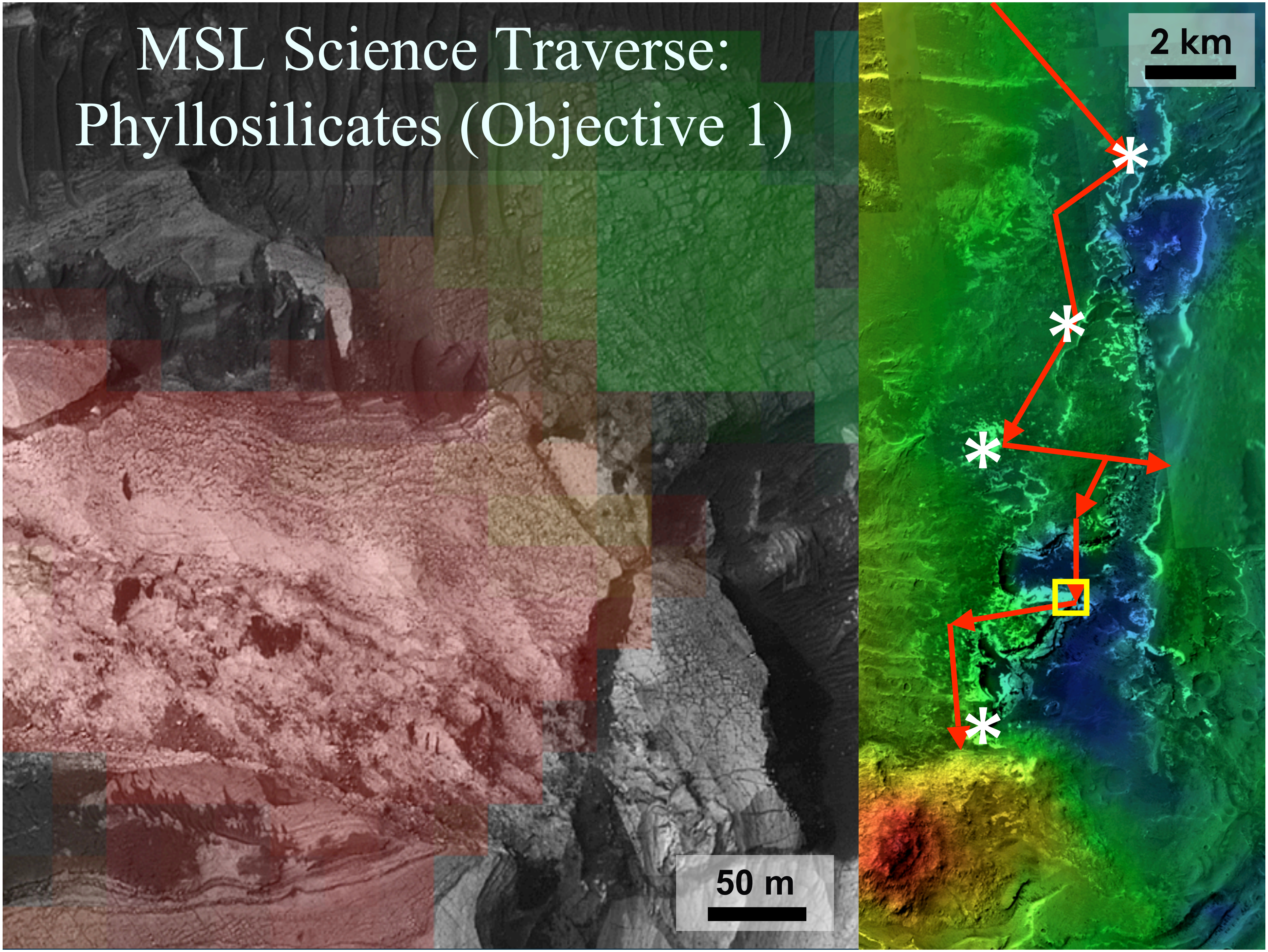


MSL Science Traverse: Phyllosilicates (Objective 1)

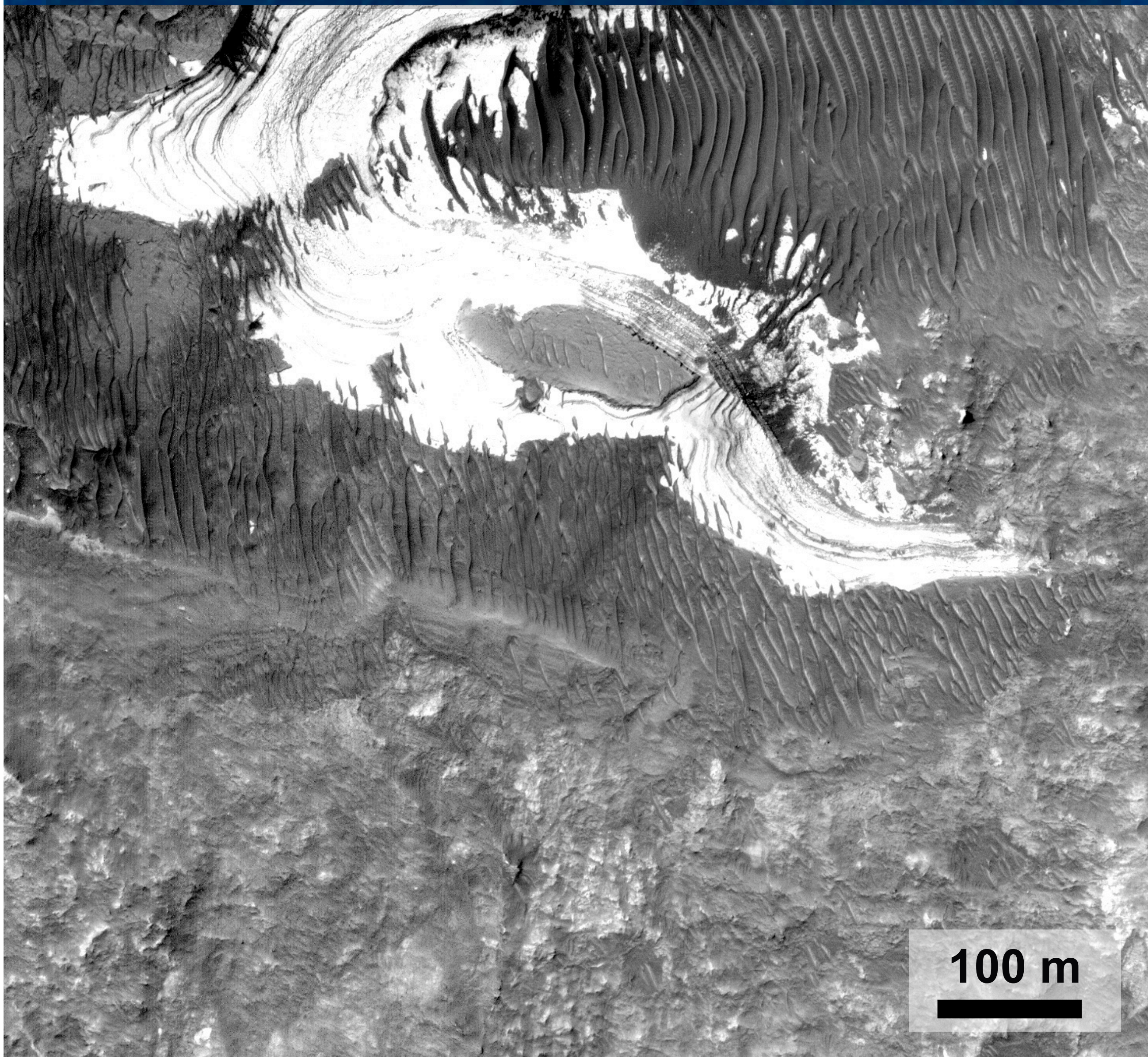


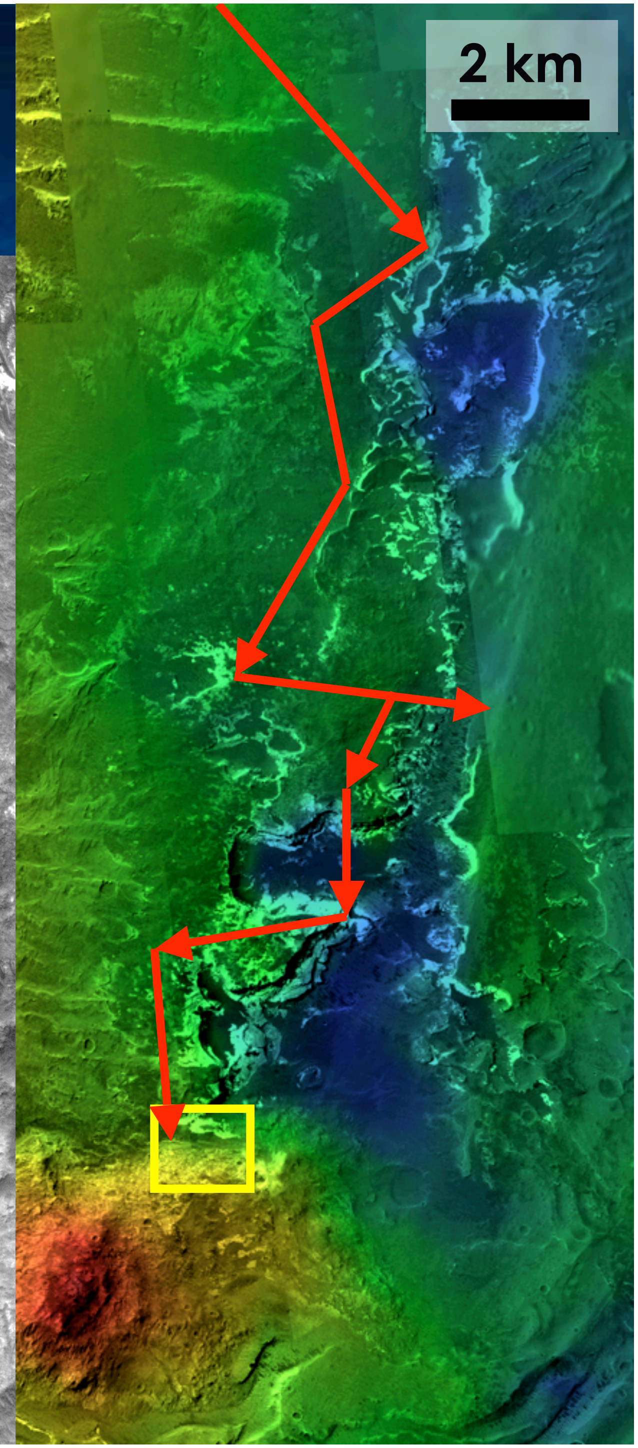


MSL Science Traverse: Phyllosilicates (Objective 1)



MSL Science Traverse: Bedrock (Objective 4)



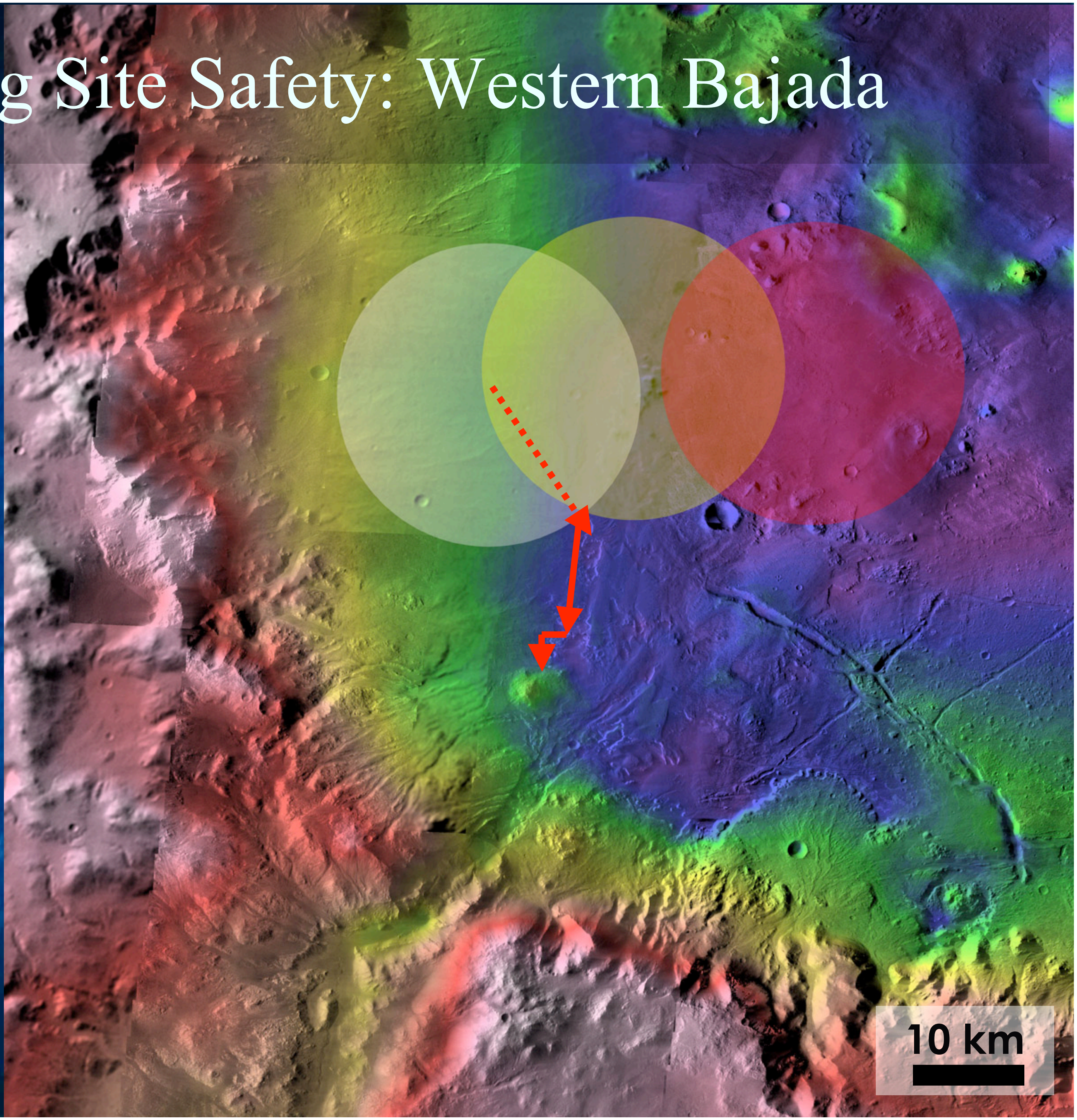


Landing Site Safety: Western Bajada

Holden is not a go-to site.

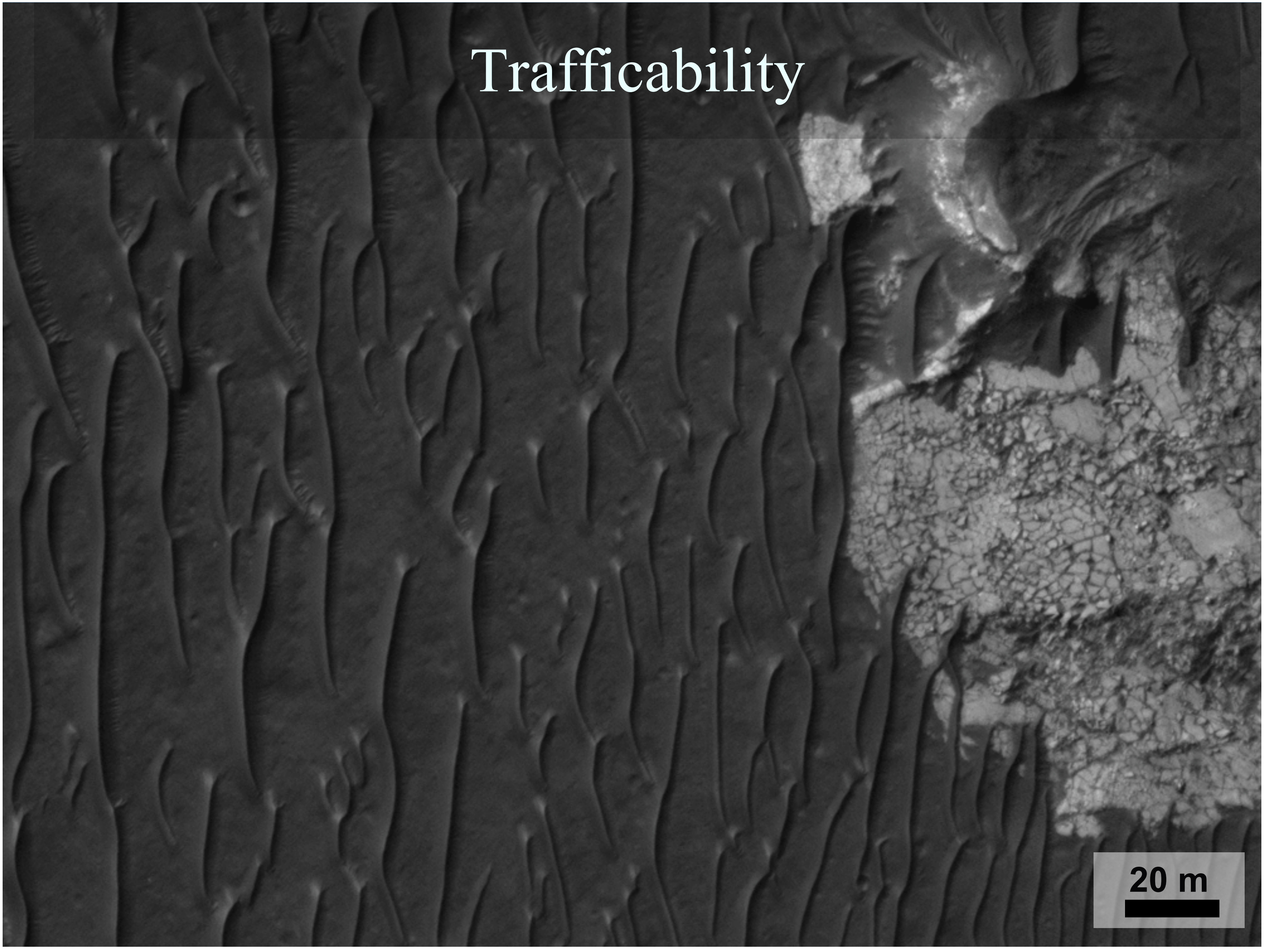
MSL can safely land on and study one of the most compelling alluvial landforms on Mars.

A higher priority objective is located a few km outside the ellipse, along a 20-km traverse.



Engineering Parameter		***Requirement***	***Observations***	***Notes***
Latitude		45°N to 45°S	26.3°S, 34.9°W	Sites poleward of 30°N have degraded EDL column
Elevation		≤ +1000 m	–1600 to –2300 m	MOLA-derived elevation
Landing ellipse radius		≤ 12.5 km	12.5 km	Due to wind-induced uncertainty during parachute descent
Terrain Relief/ Slopes	2 to 10 km	≤ 20°	1.6° on bajada	Radar altimetry errors to start powered descent
	1 to 2 km	≤ 2.46° at 1 km	<~2° on bajada	Radar spoofing in preparation for powered descent
	200–1000m	≤ 43 m relief	Inverted channels < 15m, few craters	Control authority and fuel consumption during powered descent
	2–5 m	≤ 15°	*HiRISE stereo DEMs*	Rover landing stability and trafficability in loose granular material
Rock height		≤ 0.55 m	Bajada is mostly gravel and sand-sized material	Probability that a rock higher than 0.55 m occurs in a random sampled area of 4 m^2 should be less than 0.5%. Suggests low to moderate rock abundance.
Radar reflectivity		Ka band reflective	*Radar data*	Adequate Ka band radar backscatter cross-section (>-20 db and <15 dB)
Load bearing surface		Not dominated by dust	TI 288–504, albedo low	Thermal inertia >100 J m^{-2} $s^{-0.5}$ K^{-1} and albedo <0.25; radar reflectivity >0.01 for load bearing bulk density
Winds, steady Wind gusts		≤ 15 m/s ≤ 30 m/s	*Models*	Constraints apply over all seasons and times of day at 1 m above the surface.
Atmospheric engineering thresholds			*Models*	

Trafficability



Conclusions

Holden crater offers an excellent combination of:

- Phyllosilicate-rich LTLD with clear stratigraphic context in Late Noachian fluvial deposits
- Alluvial fans with discrete source areas (implications for runoff)
- Late-stage flood deposits
- Accessible bedrock outcrops
- 80-m stratigraphic section
- Safe landing ellipse containing one key objective (alluvial fans)
- Trafficable route