

# A Second Field Season In Them Thar Columbia Hills

Jim Rice  
Planetary Science Institute  
May 16, 2014

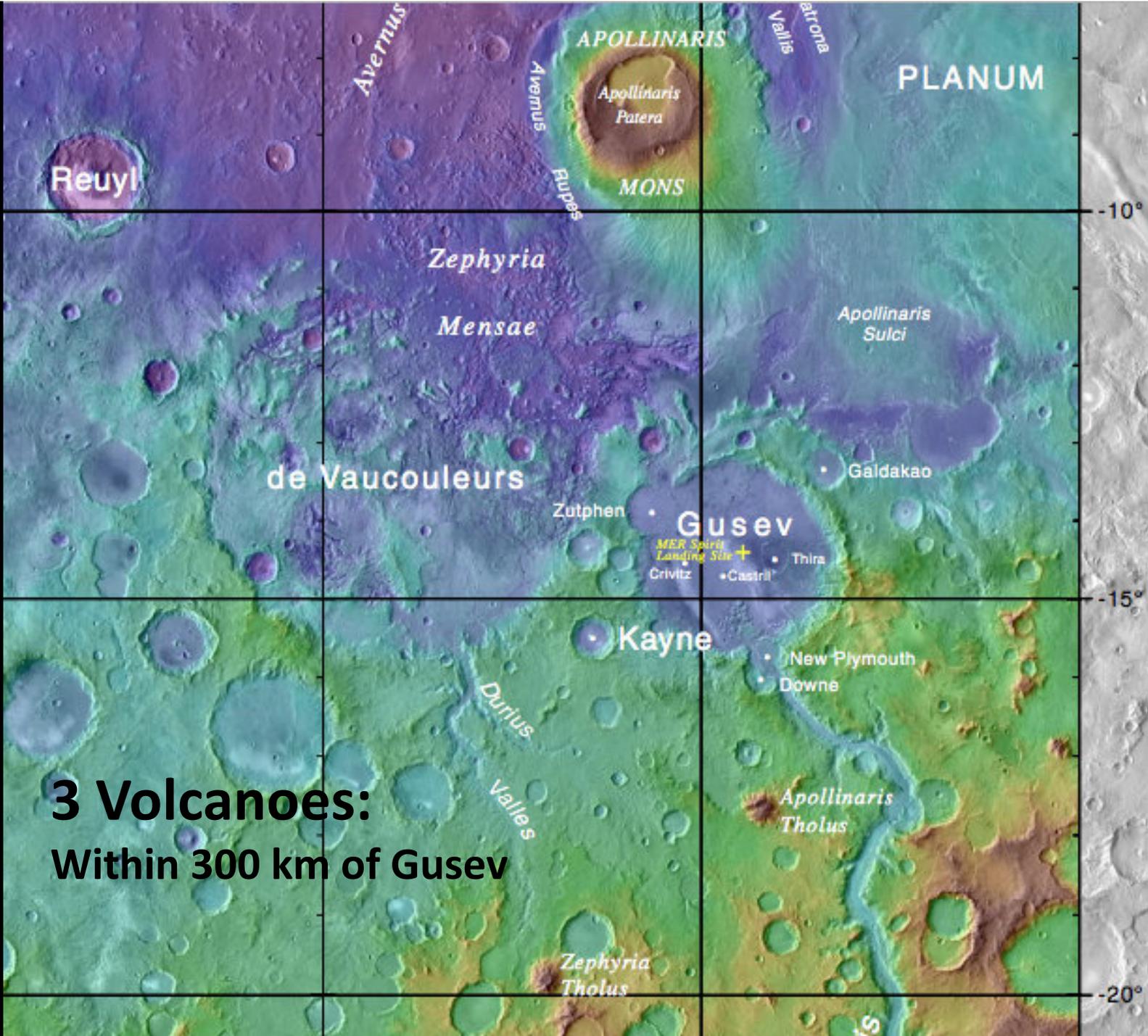
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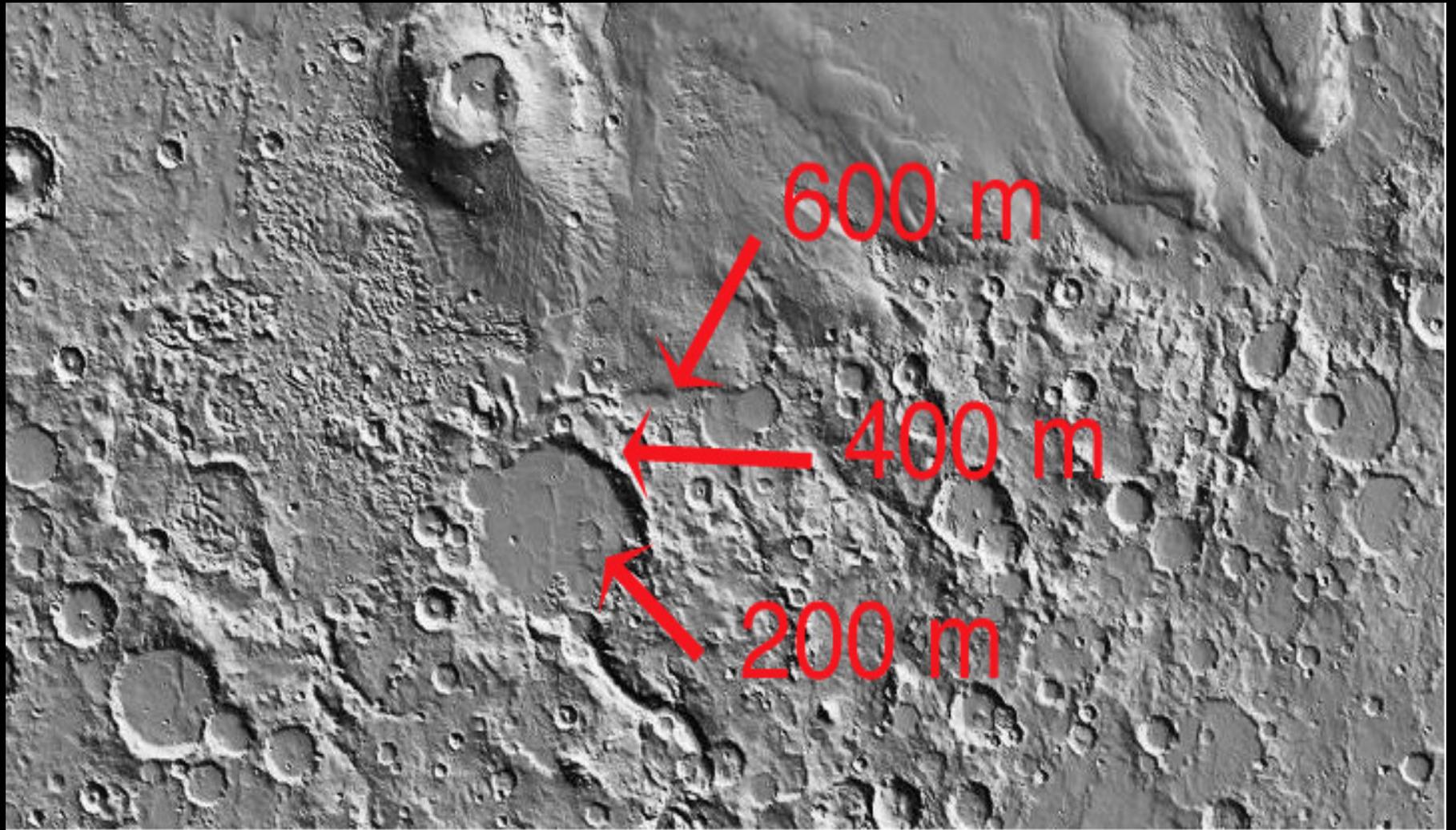
# How did the Columbia Hills form?

1. Portion of Old Eroded Crater Rim\*
2. Remnants of Interior Crater Fill Deposits
3. Volcano
4. Central Peak\*
5. Wrinkle Ridge
6. Fluvial / Lacustrine Deposits
7. Exhumed Layered Intrusion\*

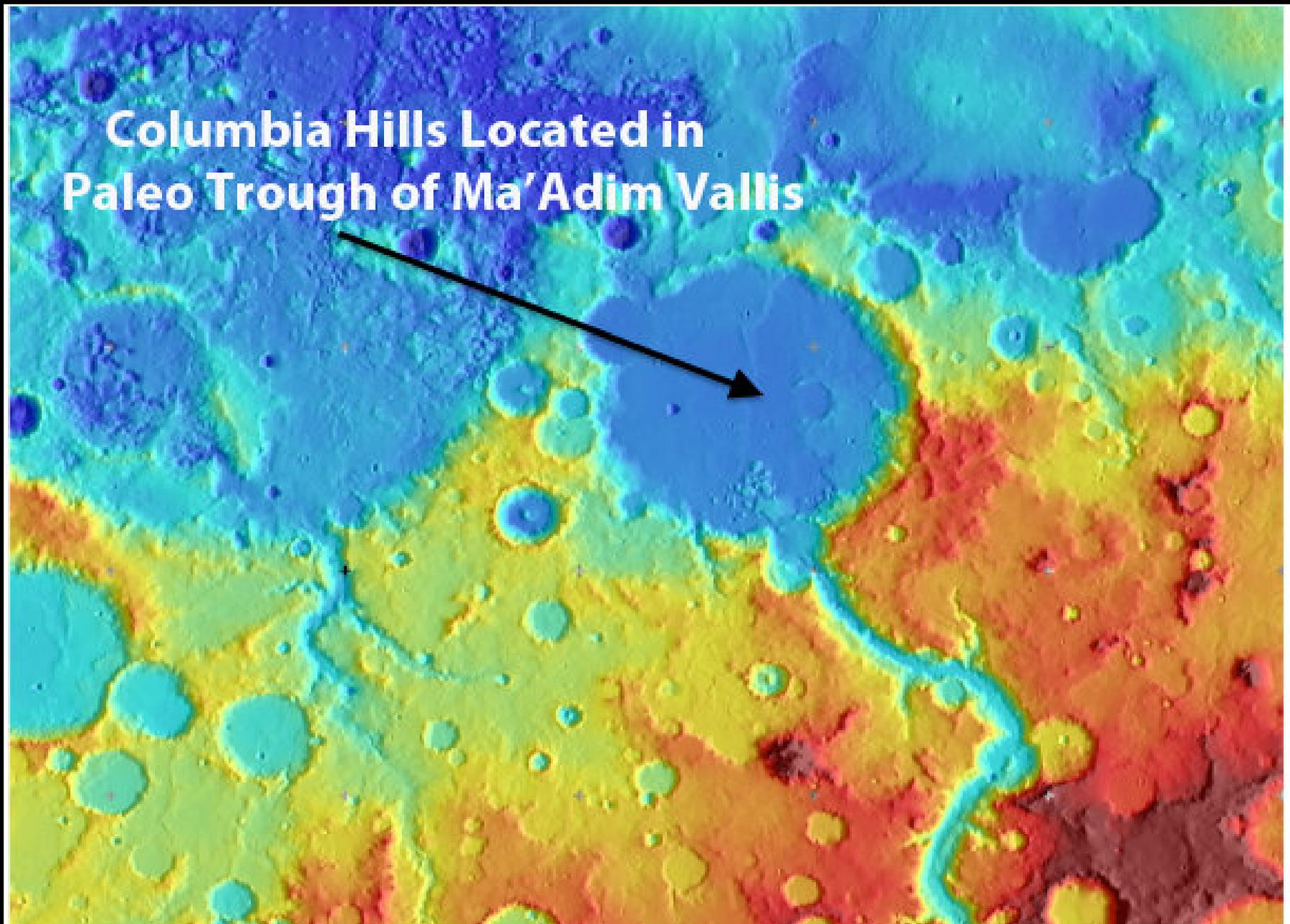
**\*Columbia Hills Rocks (Noachian) formed prior to Gusev impact event:  
Provide insights into nature of early magmatism and crustal  
development on Mars.**



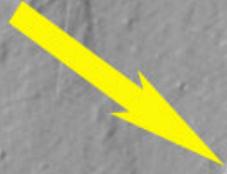
**3 Volcanoes:  
Within 300 km of Gusev**



# Gusev Crater

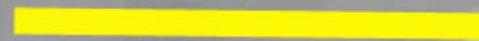


**COLUMBIA  
HILLS**

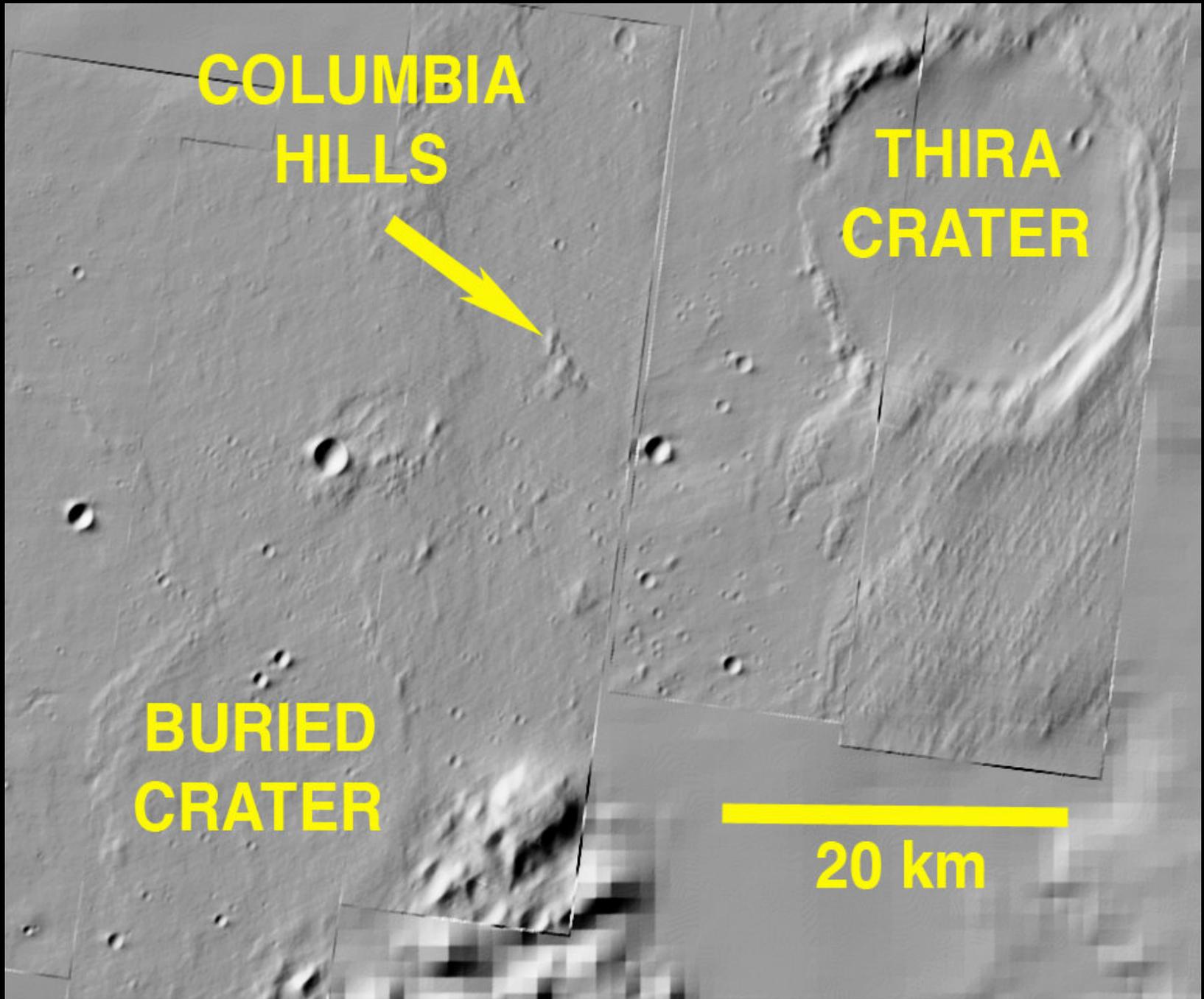


**THIRA  
CRATER**

**BURIED  
CRATER**

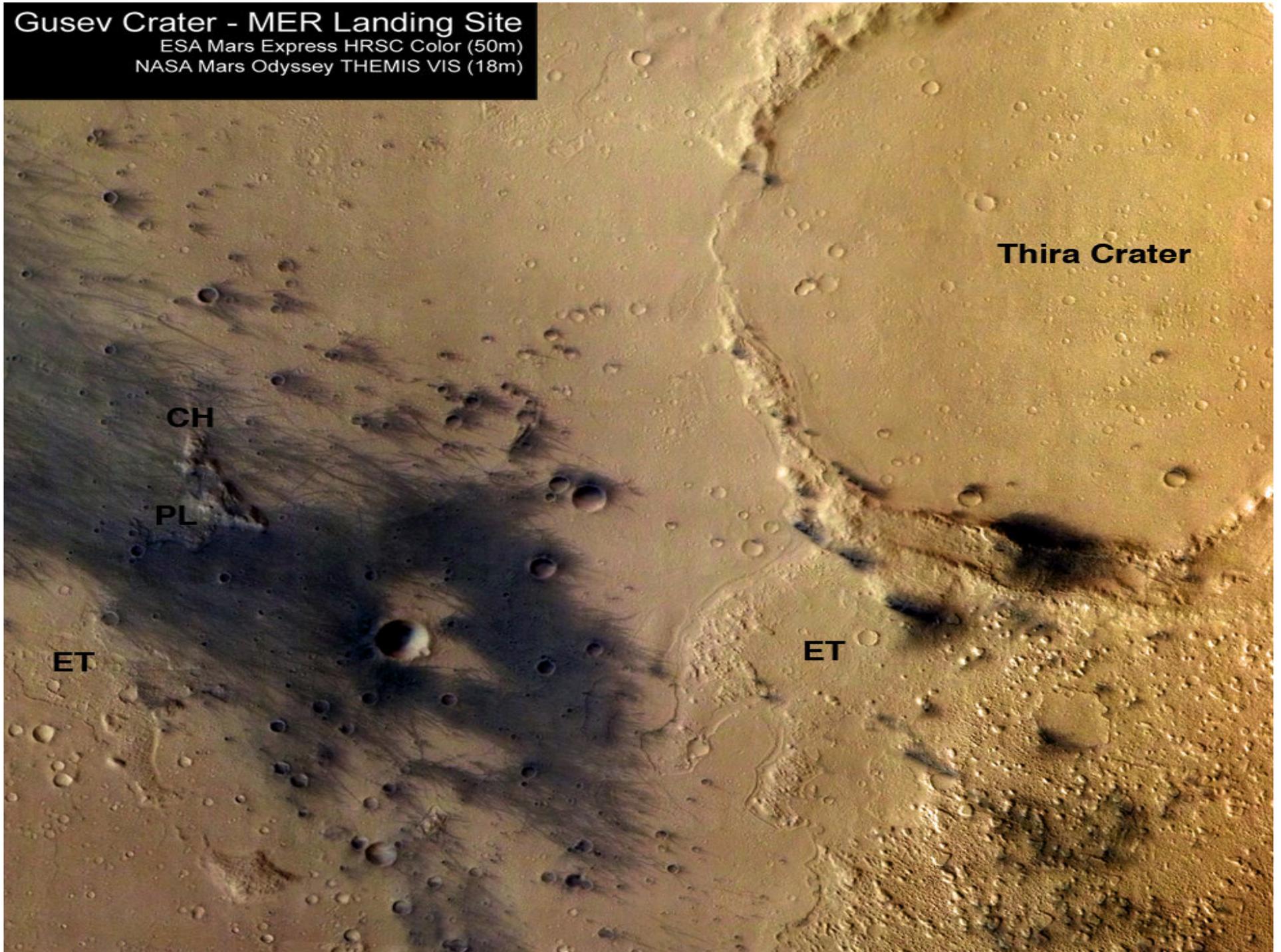


**20 km**



# Gusev Crater - MER Landing Site

ESA Mars Express HRSC Color (50m)  
NASA Mars Odyssey THEMIS VIS (18m)



**Thira Crater**

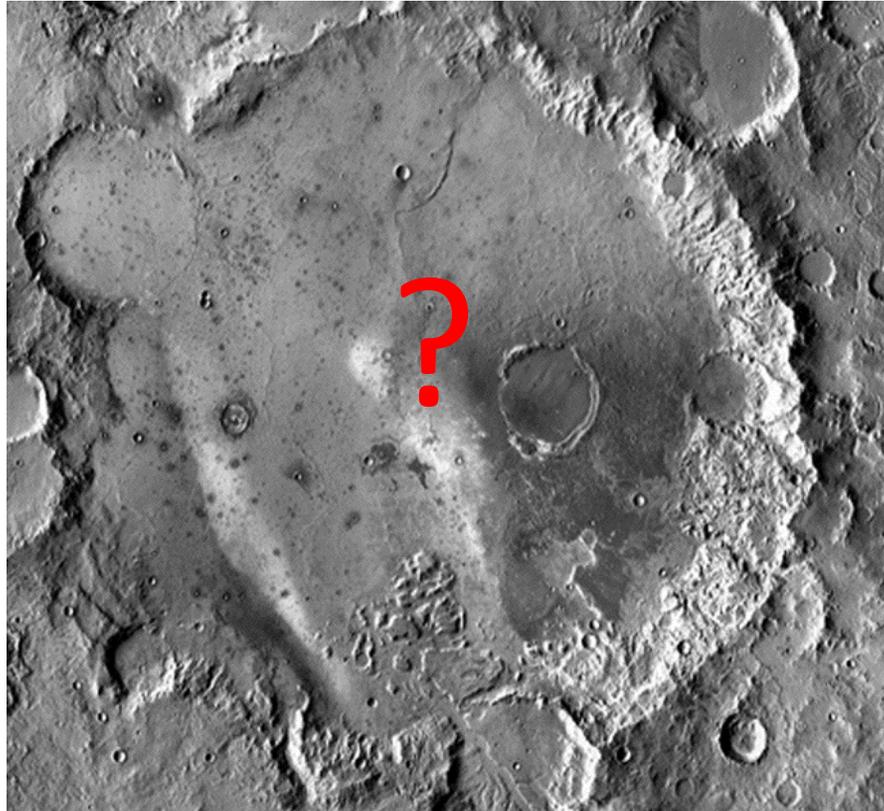
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**ET**

# Where is Gusev's Central Peak?



**Gusev D = 165 km**

**Martian central peak craters: 135 - 150km**

**Martian peak ring craters: 145 - 470km (Wood&Head 1976)**

# Are the Columbia Hills Part of Gusev's Central Peak??

Central peak diam:  $D_{cp} = 0.22 D$  (Pike 1985)

Gusev  $D = 165$  km

$D_{cp} = 36.3$  km

Central peak height:  $H_{cp} = \sim 3$  km

(Hale&Grieve 1982)

Complex crater depth-diam:

$d = 0.2D^{0.53}$  (Garvin et al. 2000)

Depth of unfilled Gusev = 3 km

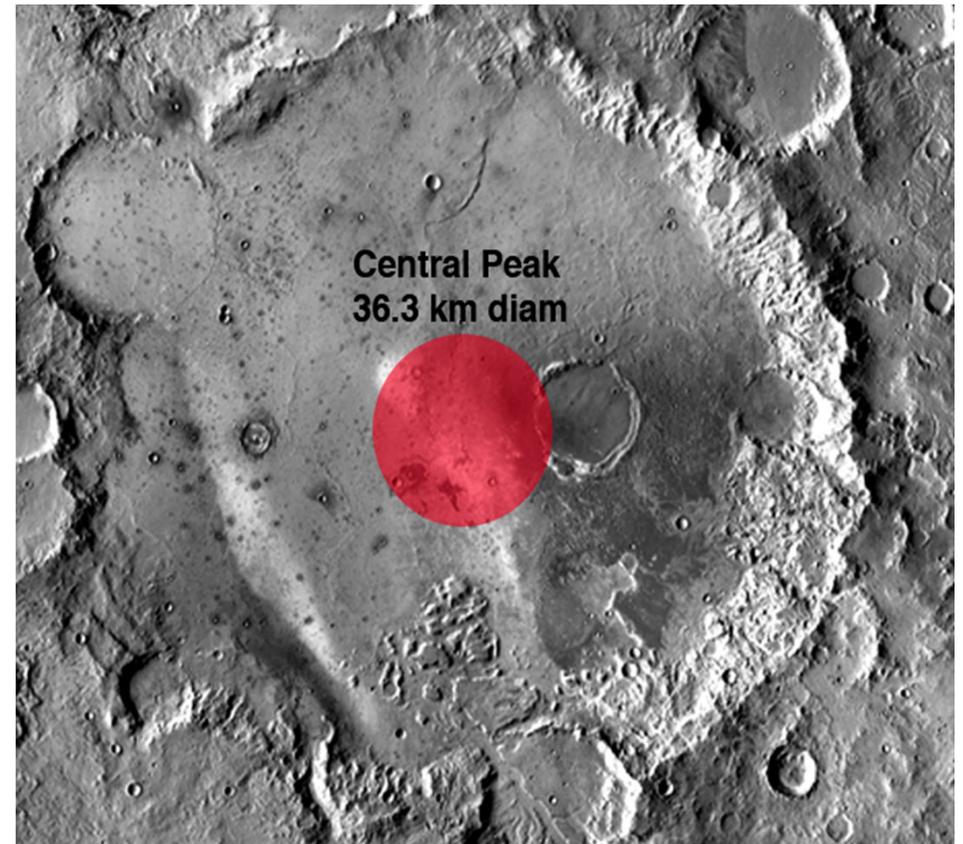
Gusev crater fill  $\sim 2.2$  to 3 km

(Carter et al. 2001; Howenstine&Kiefer 2005)

Estimated central peak height above crater fill:

Up to 800 meters high

CH Rocks (Noachian) formed prior to impact



# Home Plate



# **Hydrovolcanic Eruptions**

**Phreatomagmatic eruptions occur when ascending magma contacts ground water, ice and or wet sediments resulting in an explosion and forming one of the following volcanic edifices; tuff cones, tuff rings and maars.**

**Tuff cones and tuff rings form by shallow explosions and tend to have finer grained deposits with better sorting than maars which are formed by deeper more powerful eruptions.**

Rogan: Massive stratified ash indicates fall or surge deposit w/ higher water component (xbeds)

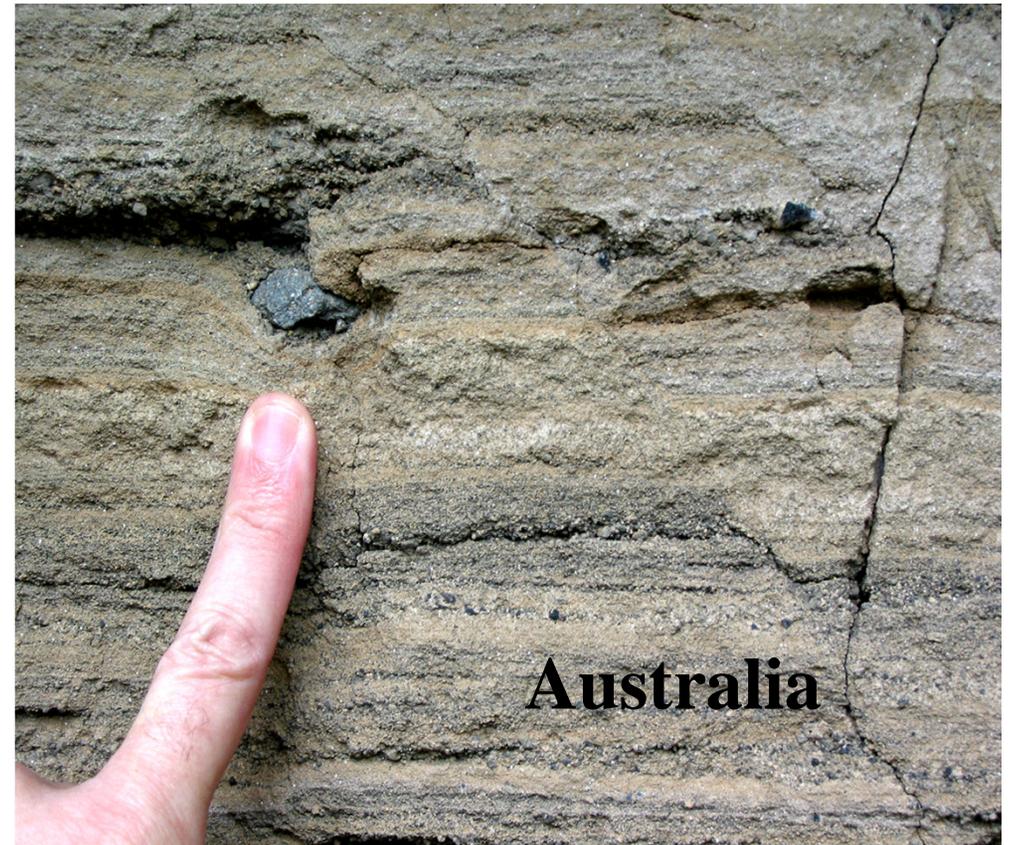
Barnhill: Coarser stratified lapilli rich tuff indicates dryer fall or surge deposits, fining upward as more water is encountered in eruption (bomb sag, pinch and swell structures)



**Rogan Unit**

**Barnhill Unit**

# Bomb Sags

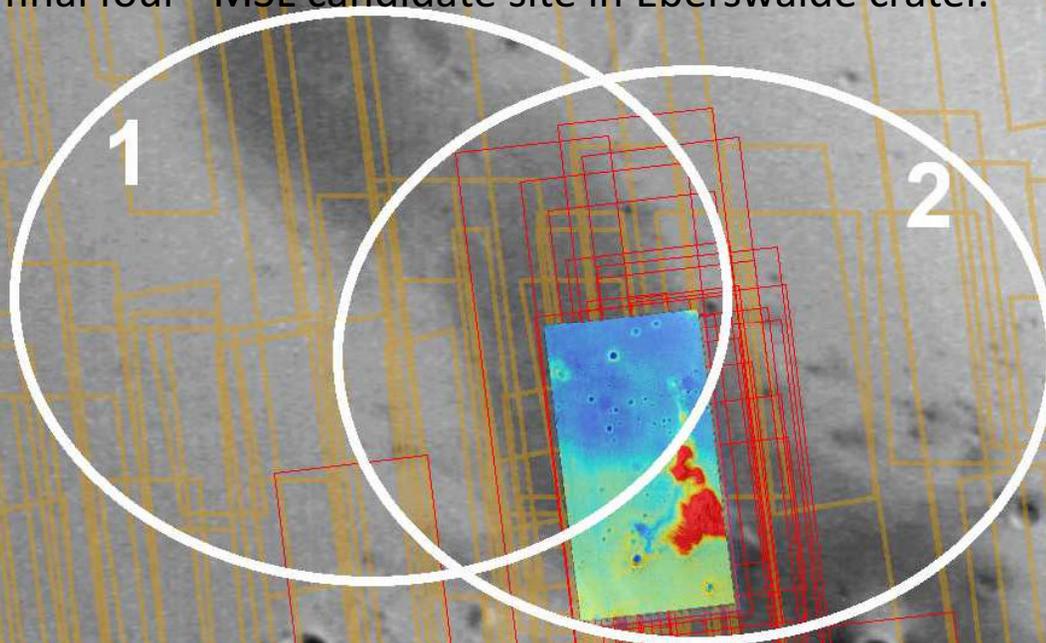


**Bomb sags characteristic of hydrovolcanic deposits. Amount of water necessary for soft sediment deformation in fine-grained sediment is 15-20% (Heiken, 1971)**

## Land On/In Site

### No New EDL System Required (Range Trigger, TRN)

Columbia Hills site **completely accessible without augmented EDL capabilities**. E2E-iSAG (2012) and JSWG (2012) studies assumed Gusev landing ellipse would place Columbia Hills at SE margin of 20 x 25 km ellipse but, in fact, including the Columbia Hills inside ellipse would actually be possible for the as-flown MSL EDL system, as this terrain is less rugged than portions of the “final four” MSL candidate site in Eberswalde crater.



-  Landing Ellipse (25x20 km)
-  Proposed HiRISE Stereo
-  HiRISE Stereo Pair
-  HiRISE (25 cm)
-  MOC Narrow Angle (~2-6m)

# Columbia Hills

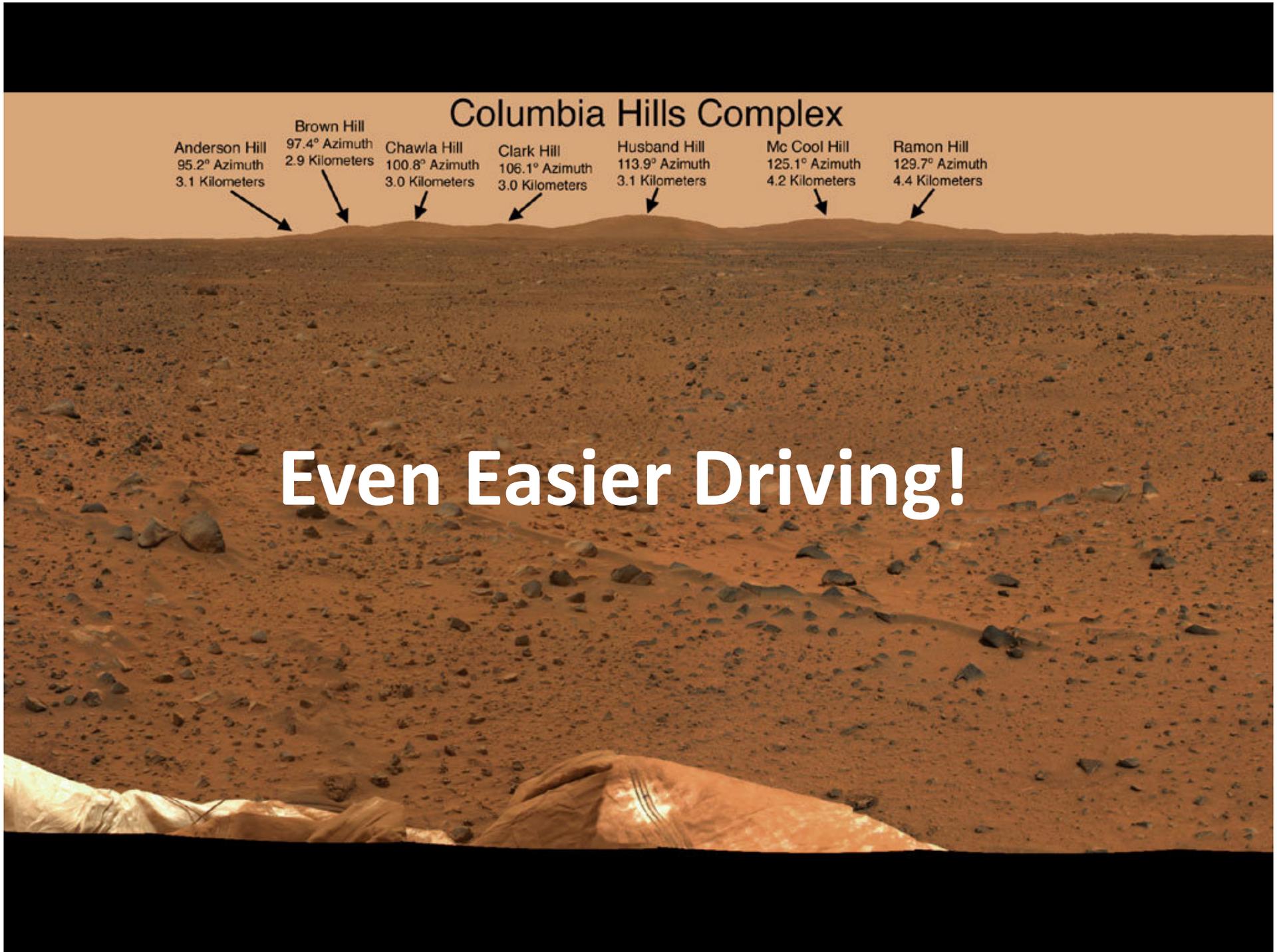
# Easy Driving



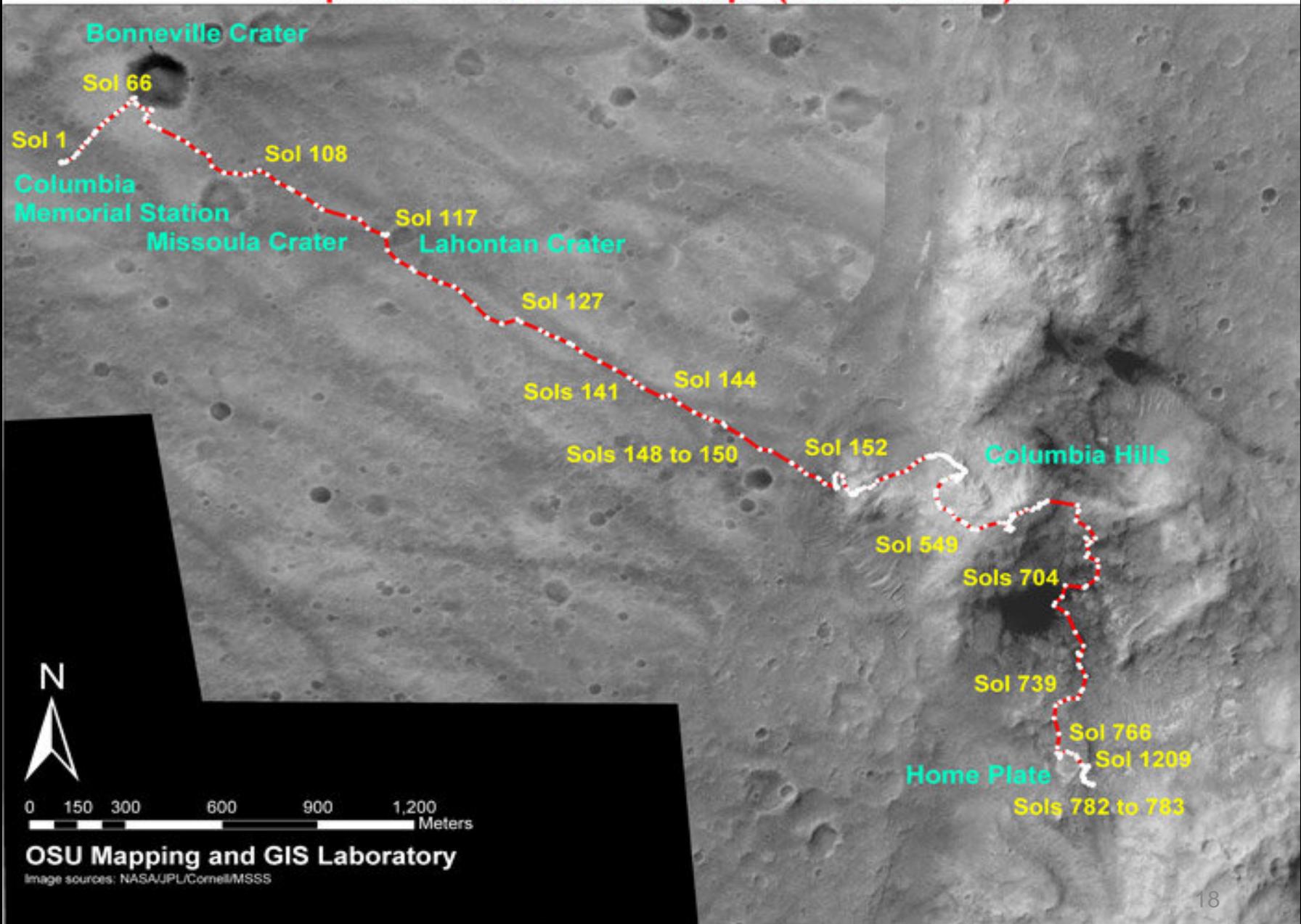
## Columbia Hills Complex

Anderson Hill 95.2° Azimuth 3.1 Kilometers	Brown Hill 97.4° Azimuth 2.9 Kilometers	Chawla Hill 100.8° Azimuth 3.0 Kilometers	Clark Hill 106.1° Azimuth 3.0 Kilometers	Husband Hill 113.9° Azimuth 3.1 Kilometers	Mc Cool Hill 125.1° Azimuth 4.2 Kilometers	Ramon Hill 129.7° Azimuth 4.4 Kilometers
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Even Easier Driving!

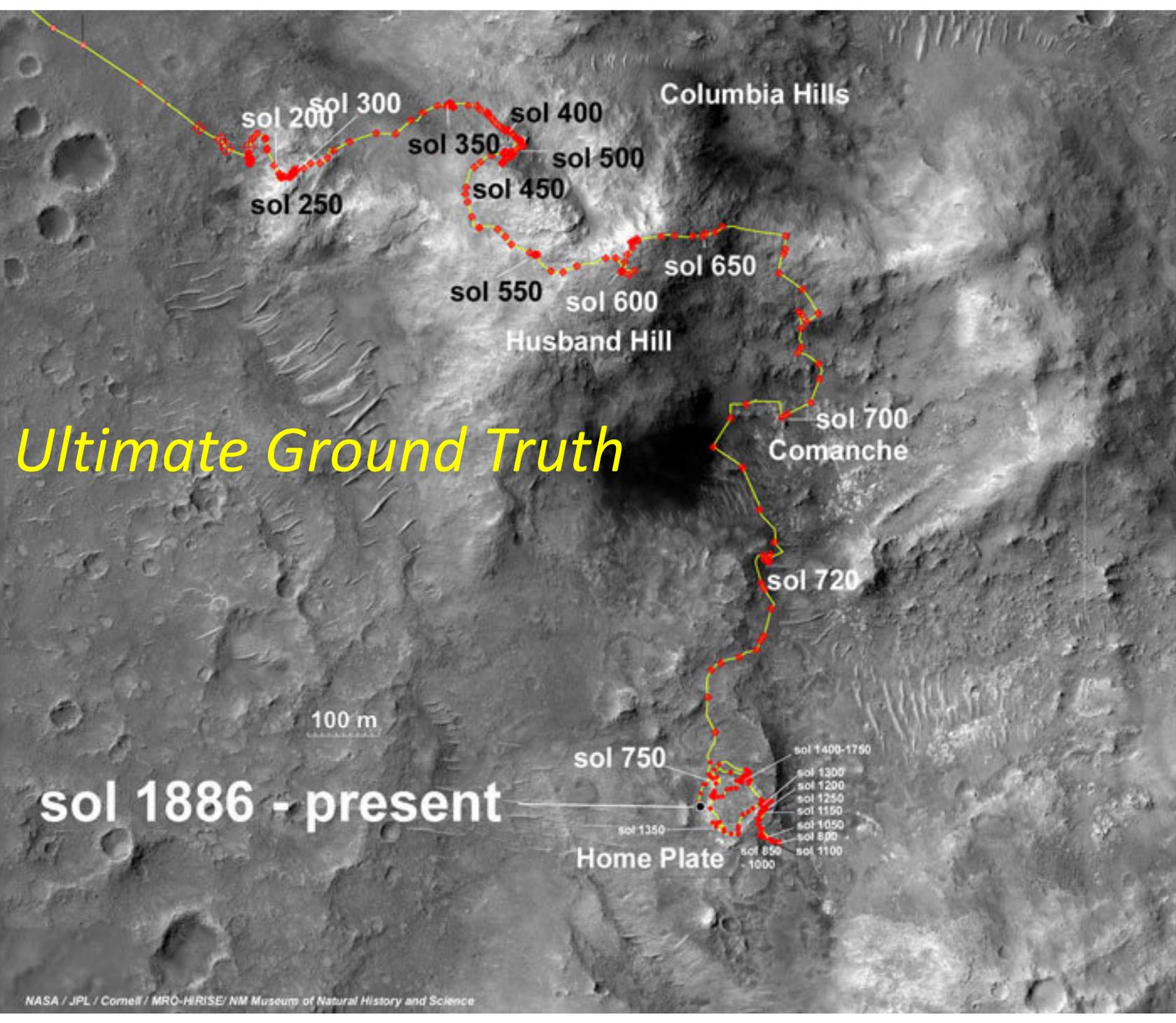


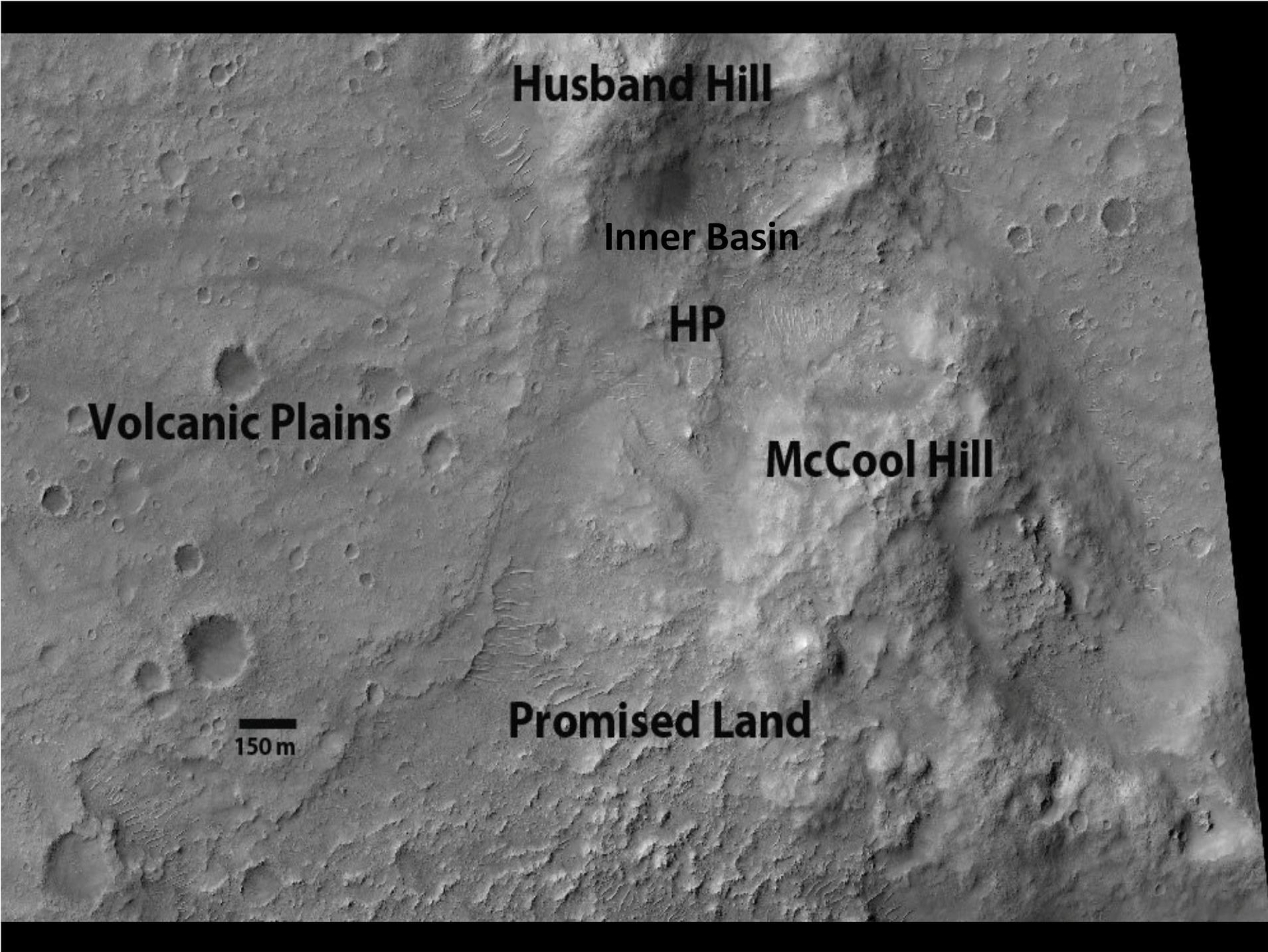
# Spirit Traverse Map (Sol 1209)



# Ultimate Ground Truth

sol 1886 - present





**Husband Hill**

**Inner Basin**

**HP**

**Volcanic Plains**

**McCool Hill**

**150 m**

**Promised Land**

# Compact Geology

Carbonates



Silica and  
Sulfates



Hesperian  
Basalts



Fe/Mg  
Clays

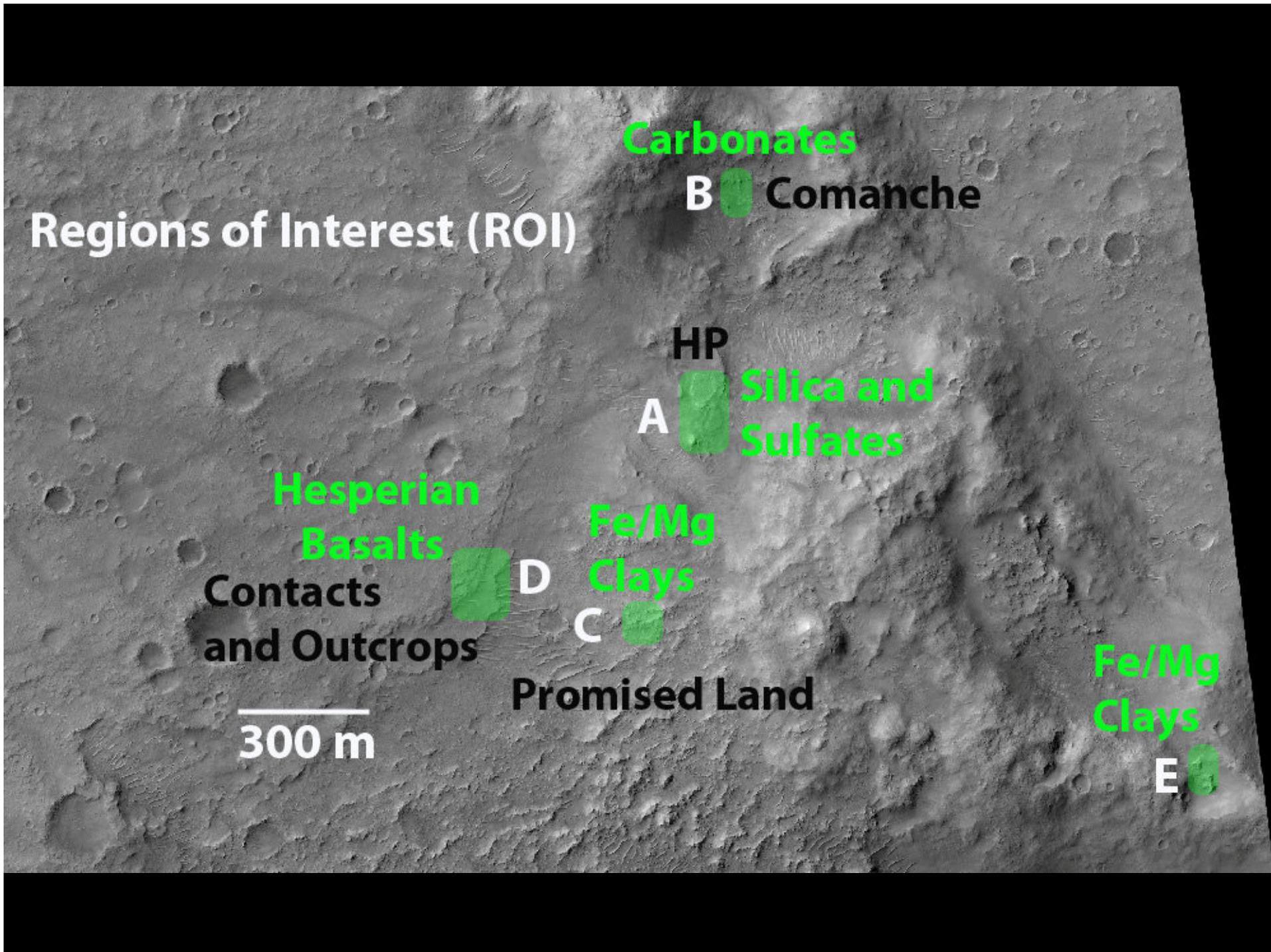


Fe/Mg  
Clays



300 meters





HP to Comanche 630m  
HP to von Braun/Goddard 150 m  
HP to Promised Land 700 m  
HP to Hesperian Lava Flow 845 m  
HP to East Clays 1800 m

2.4 km Inner Basin ROIs  
4.2 km with East Clays

**Carbonates**

**Comanche**

**HP**

**Silica and  
Sulfates**

**Hesperian  
Basalts**

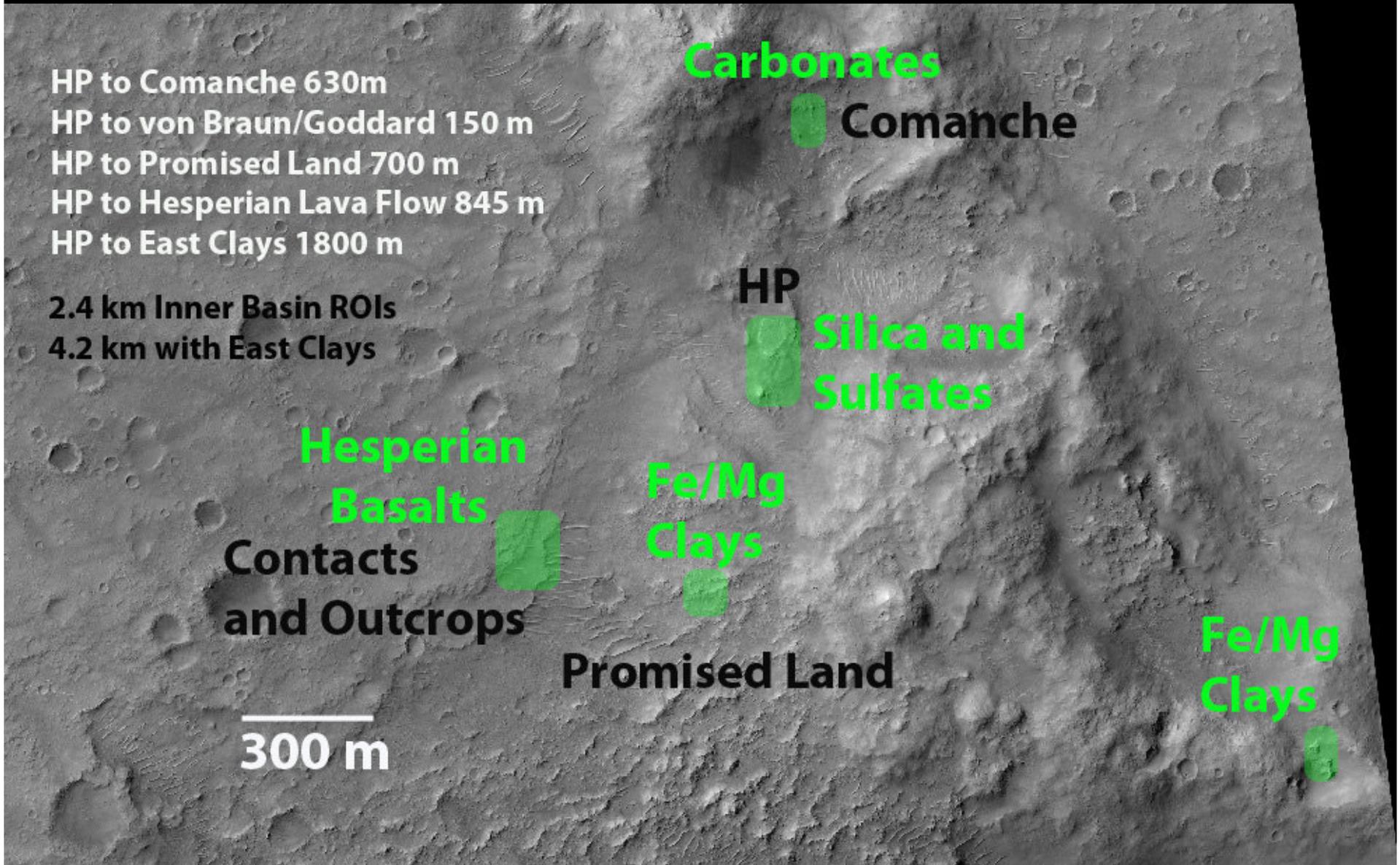
**Contacts  
and Outcrops**

**Fe/Mg  
Clays**

**Promised Land**

**Fe/Mg  
Clays**

**300 m**



**Compact Geology:  
Rich and Diverse Samples**  
\*ROIs A thru D within 1km Footprint

**Carbonates**

**B**  **Comanche**

**HP**

**A**

 **Silica and Sulfates**

**Hesperian Basalts**

**Fe/Mg Clays**

**Contacts and Outcrops**

**D**

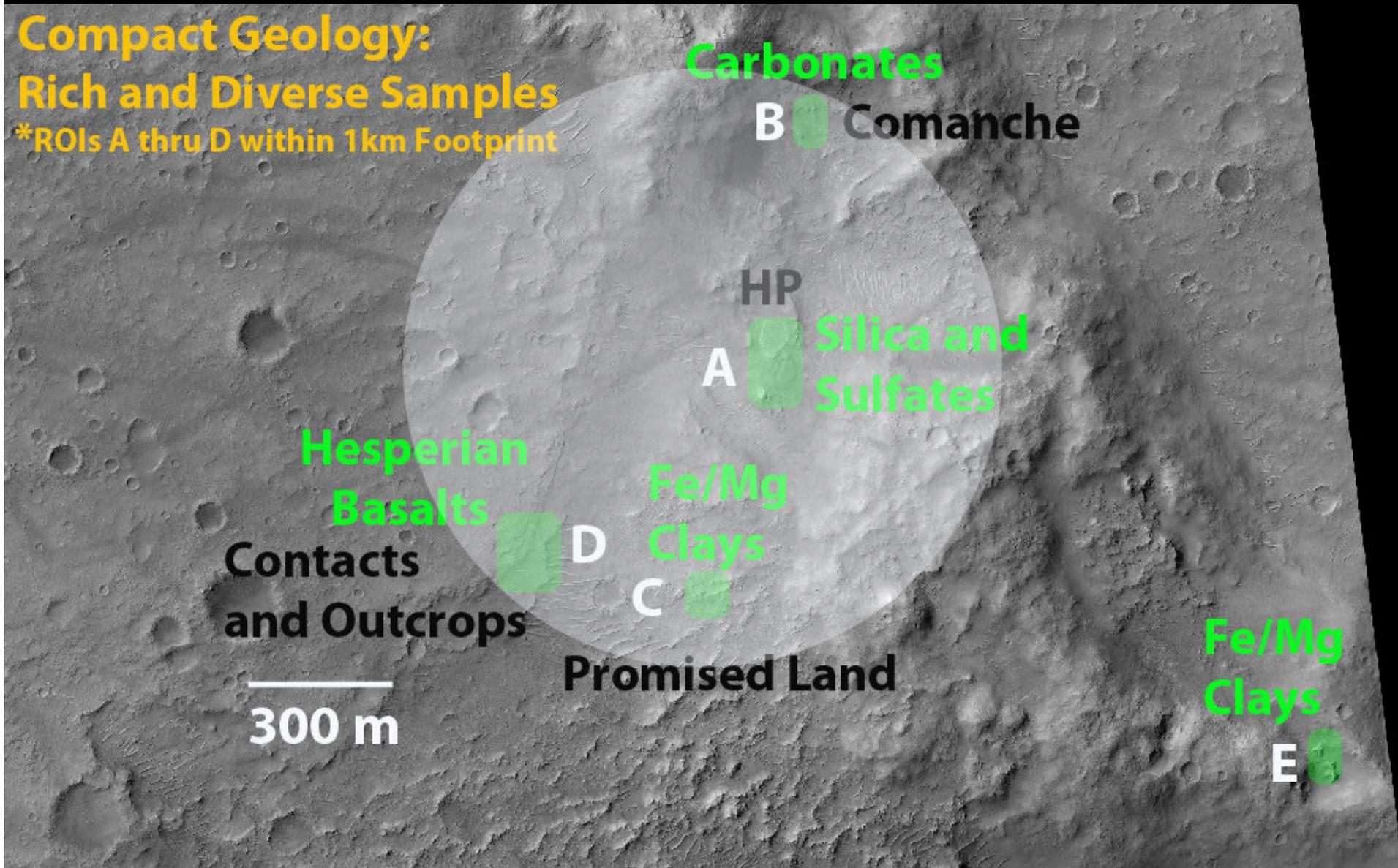
**C**

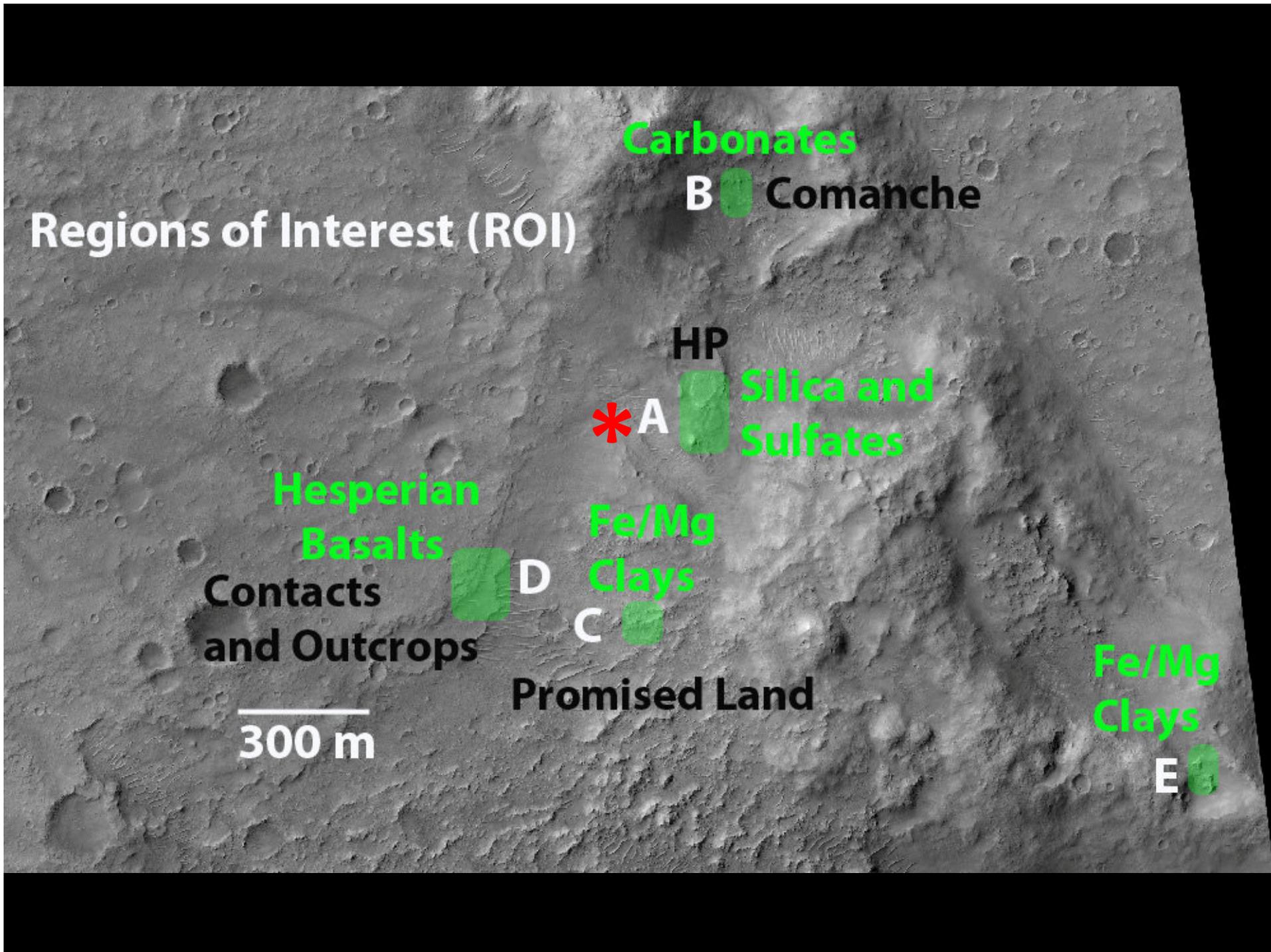
**Promised Land**

**Fe/Mg Clays**

**E** 

**300 m**





# ROI A

Spirit

Home Plate

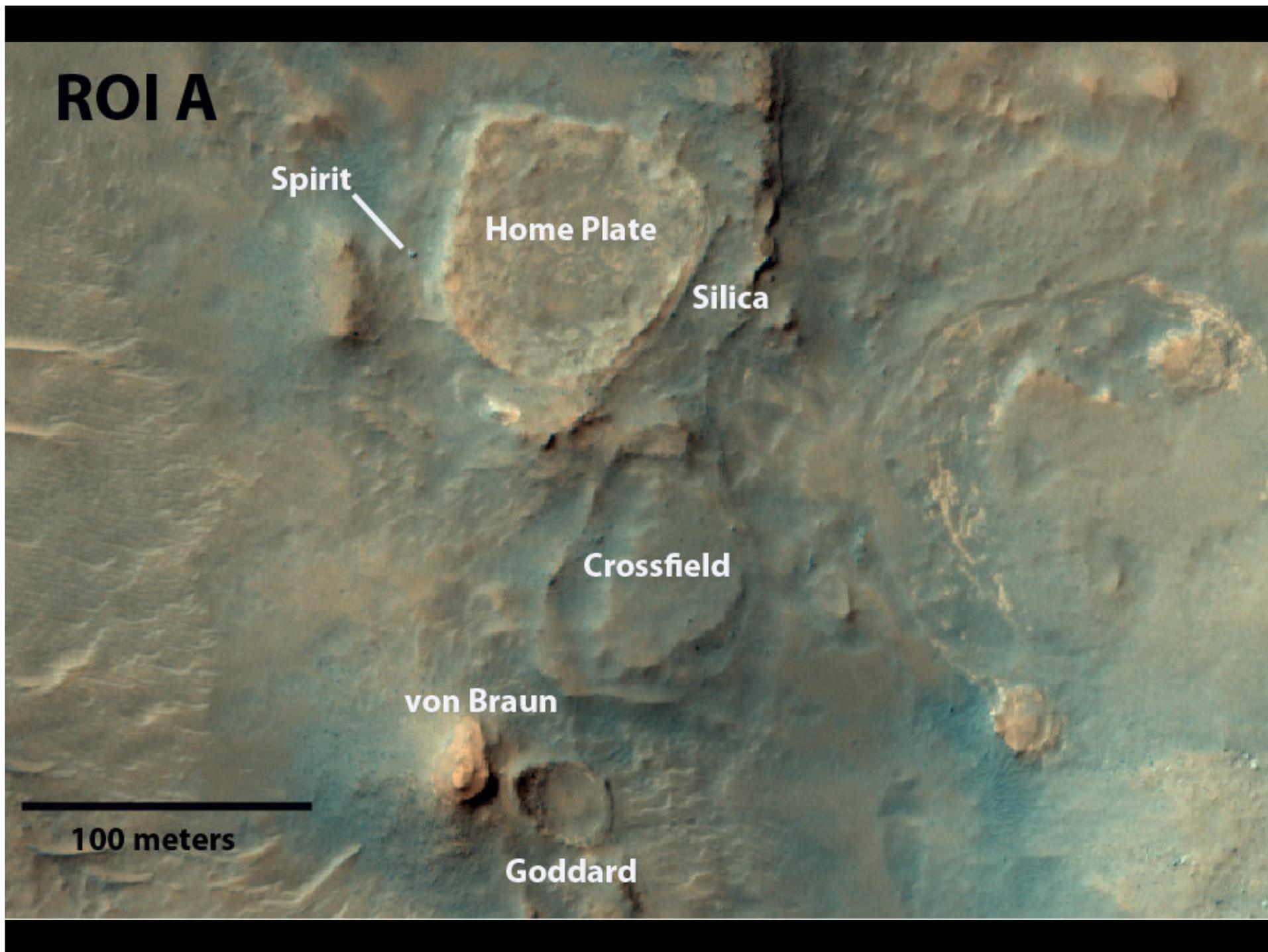
Silica

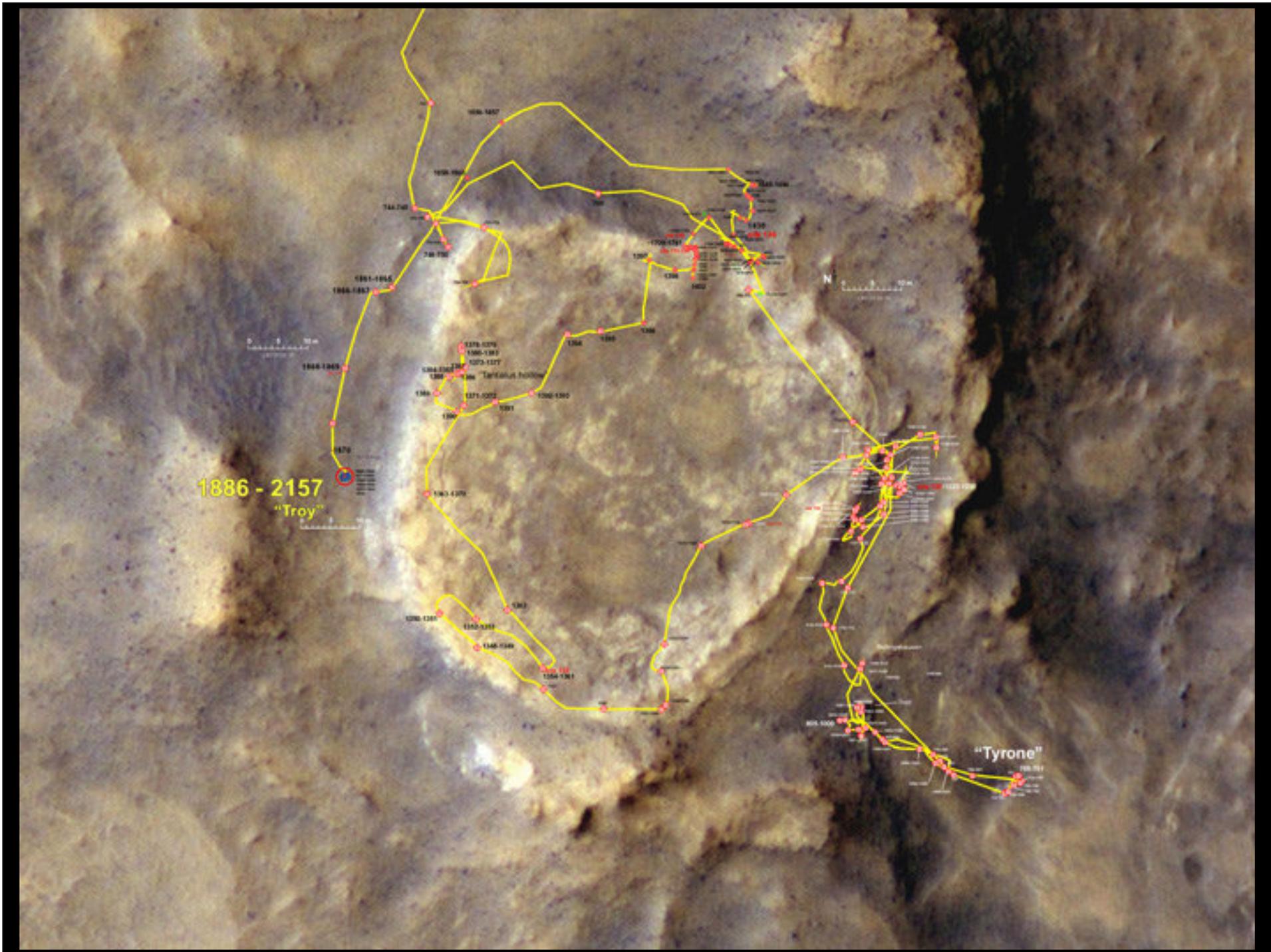
Crossfield

von Braun

100 meters

Goddard







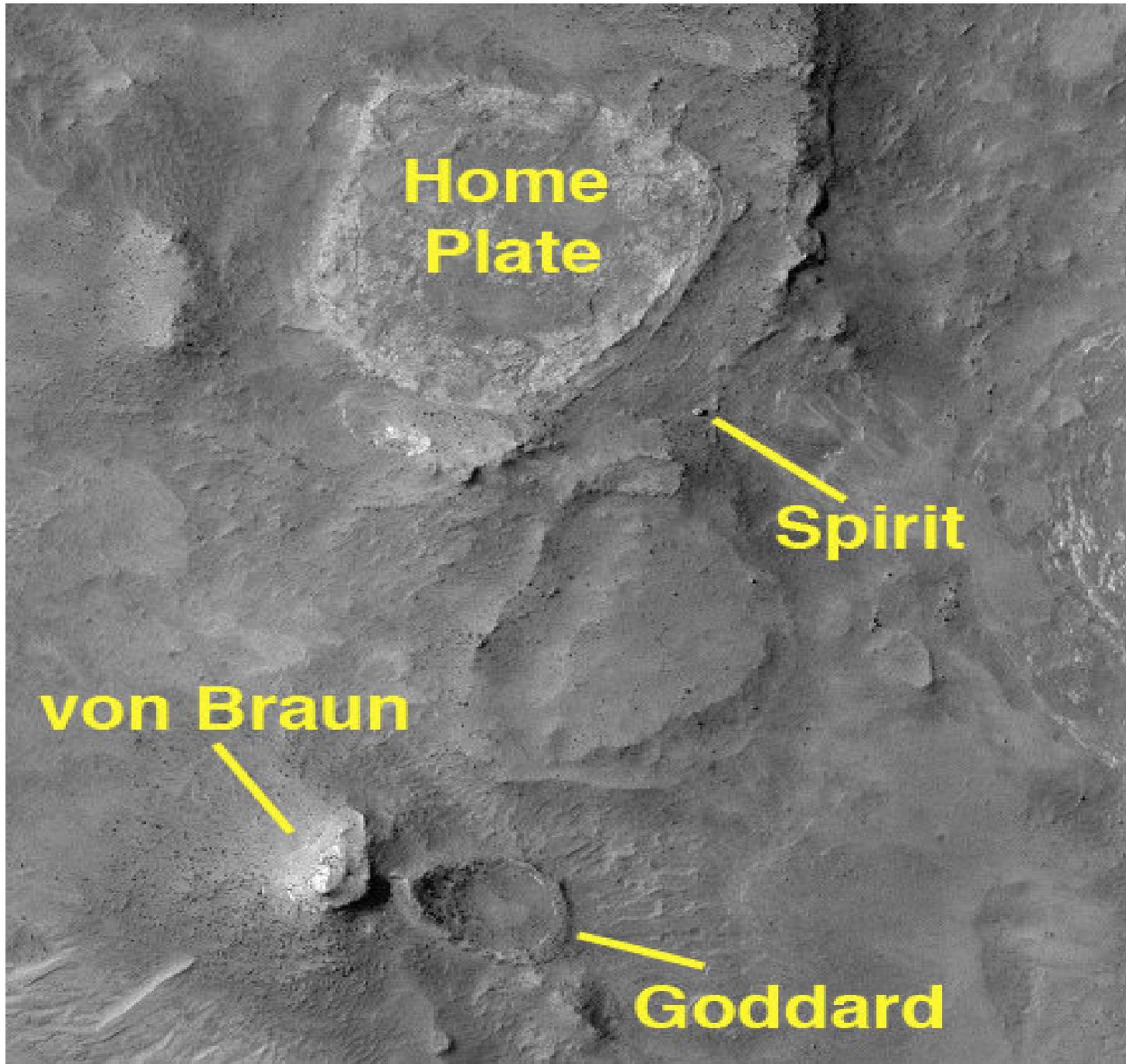
Hot Springs

Fumaroles



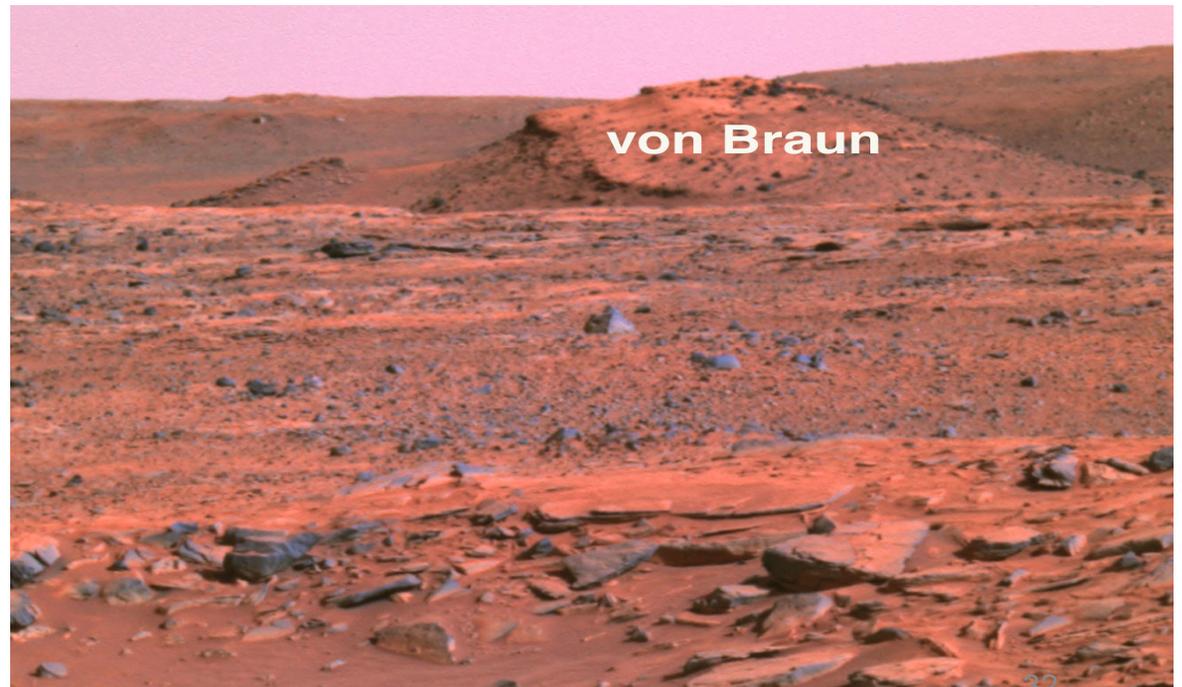






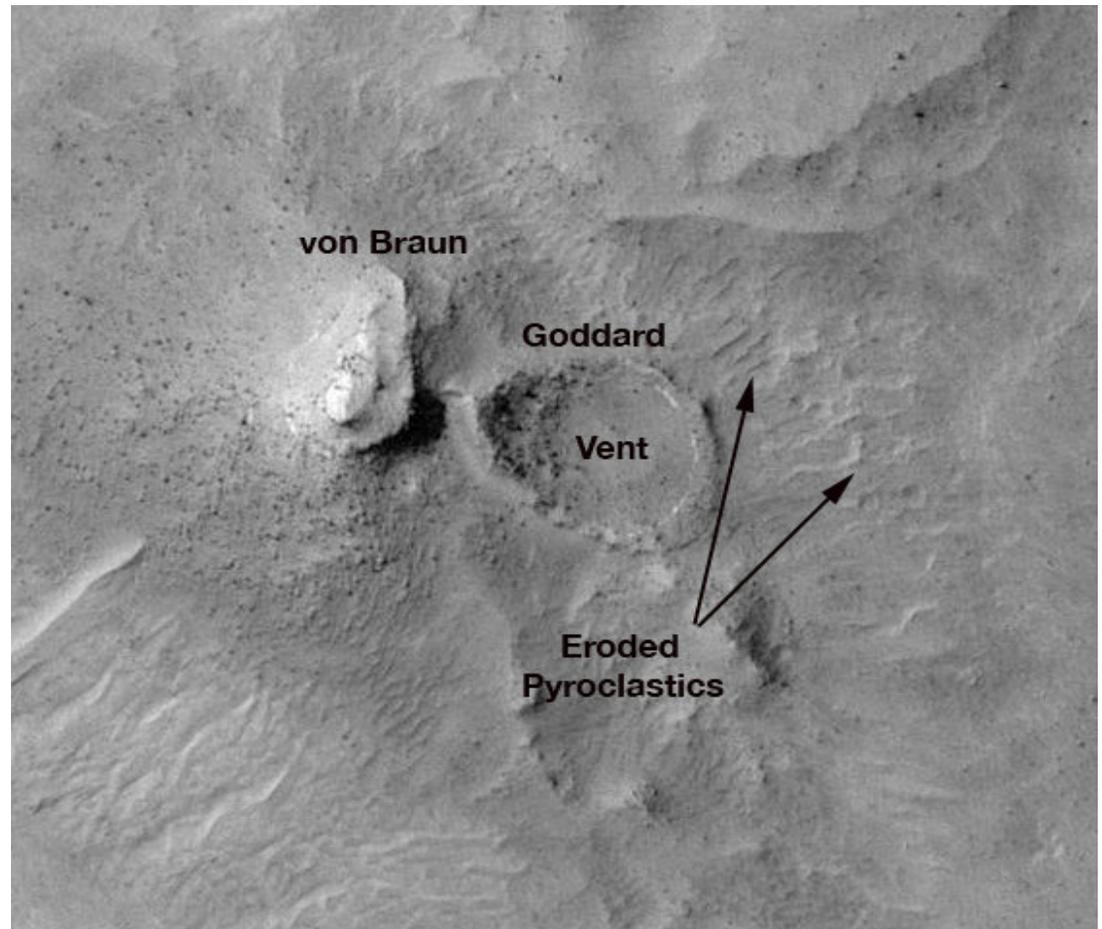
## von Braun Butte:

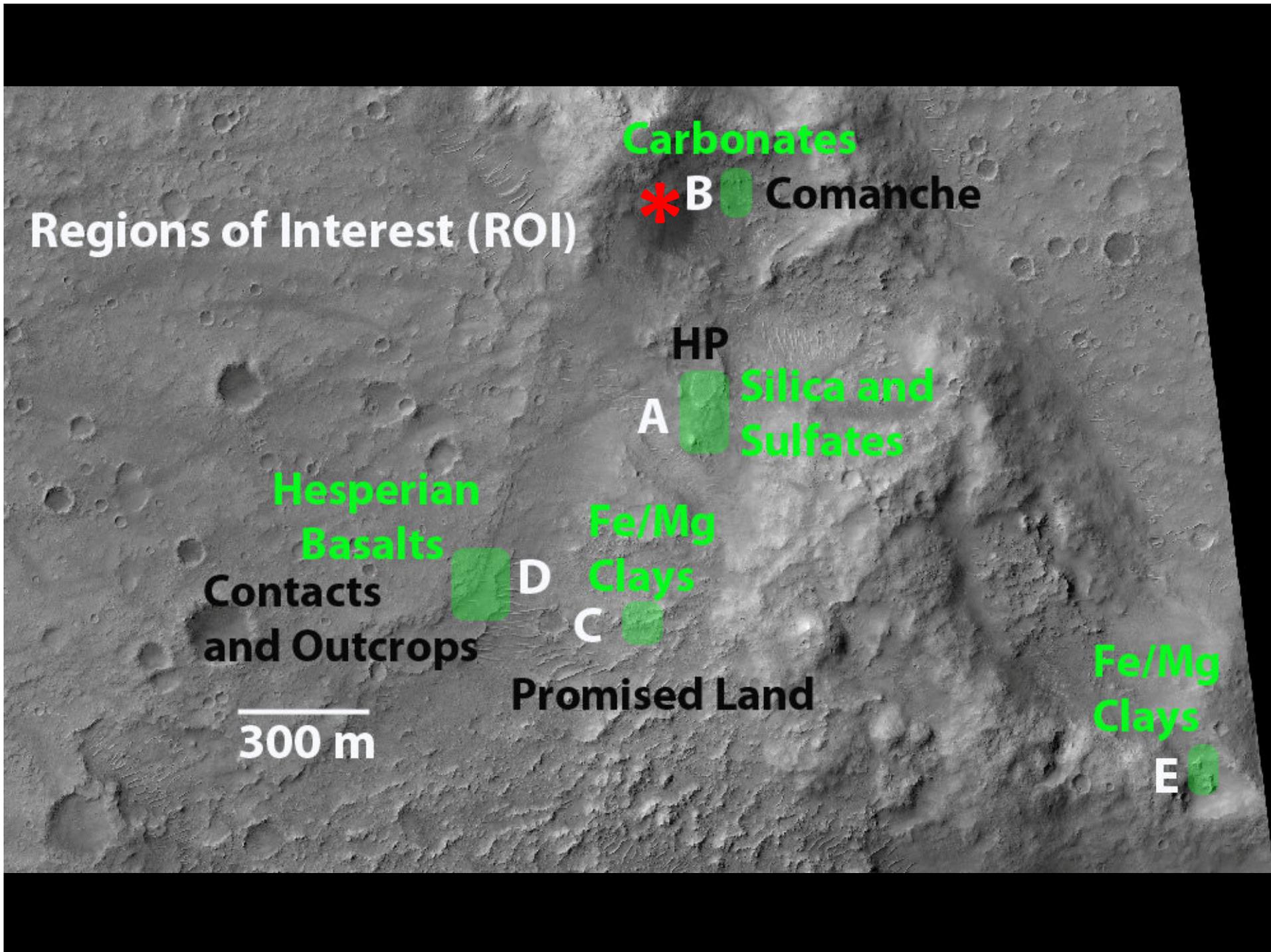
Forms layered butte (cliff and ledge forming members) appears to be capped with Home Plate-like material. von Braun interpreted to be erosional remnant of a once more extensive unit that covered the Inner Basin. Oberth, Korolev and Faget outcrops, located along the lower flanks of McCool Hill, appear morphologically similar to von Braun Butte and are located near the same elevations. **These observations indicate that the Inner Basin may have once been filled to a depth of ~20 m with the material that makes up these outcrops.**



## Goddard Crater:

Elliptical depression 35 m x 25 m, ranging in depth from 2.6 to 3.5 m. Light toned outcrop inside eastern rim and blocky western interior. Crater also has rim collar ranging from 2.5 m to 5 m wide. **Goddard Crater appears to be a volcanic vent and not an impact crater** based on its morphology, geometry, context, and associated eroded materials interpreted to be pyroclastics.



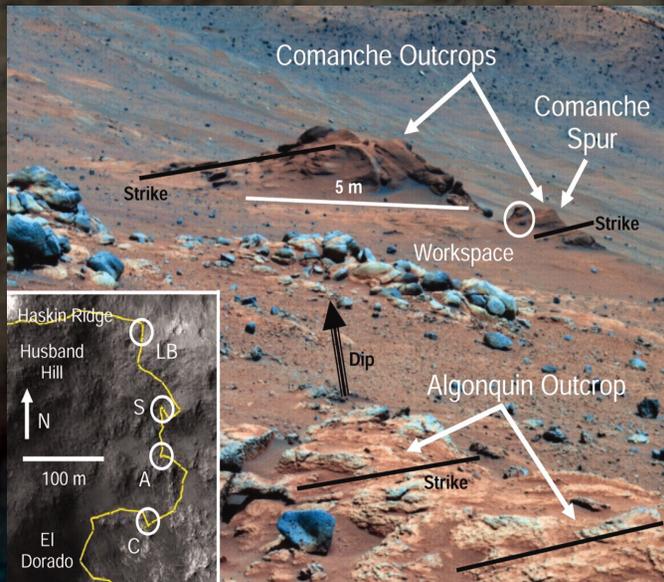


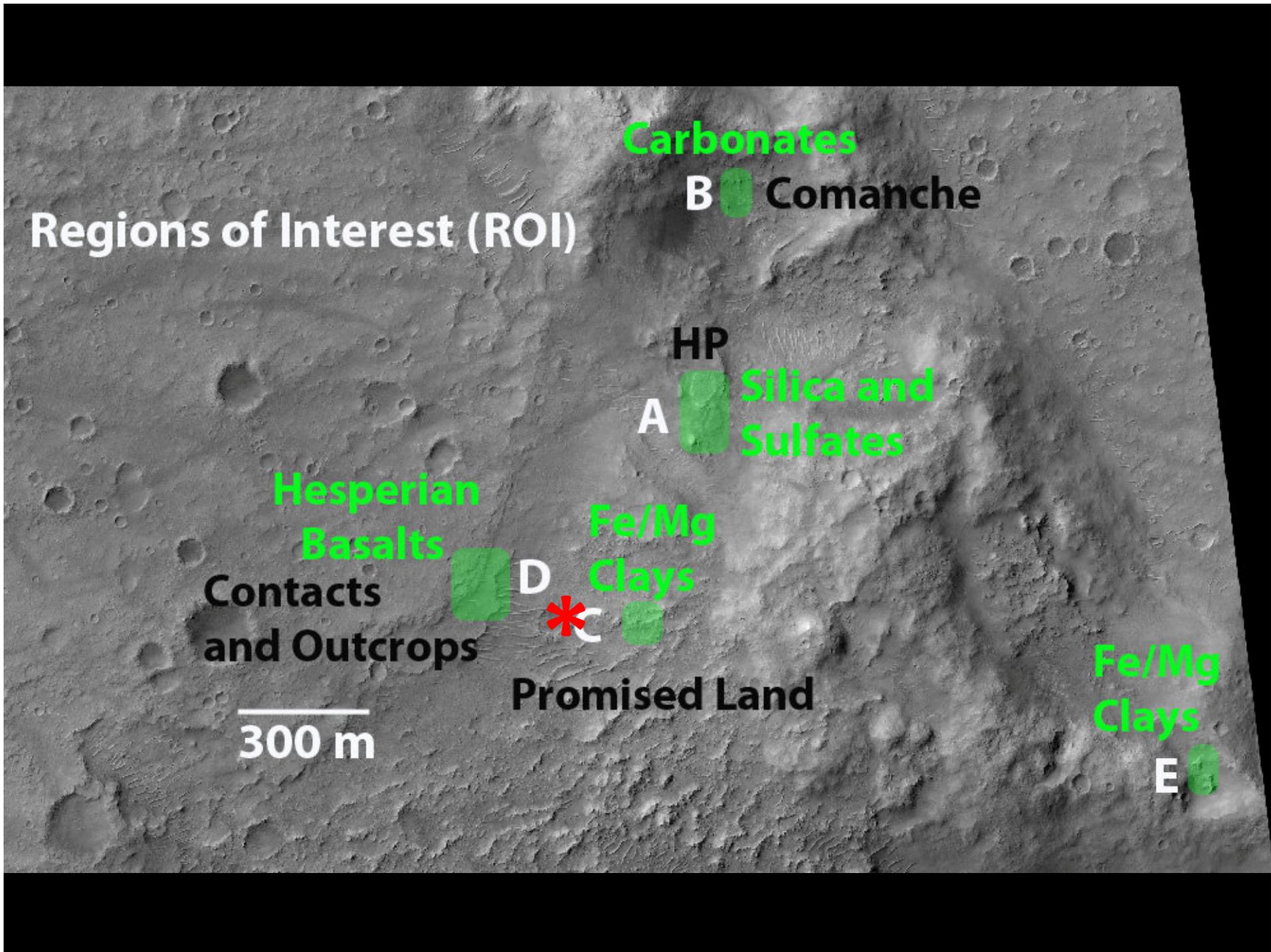
**ROI B**

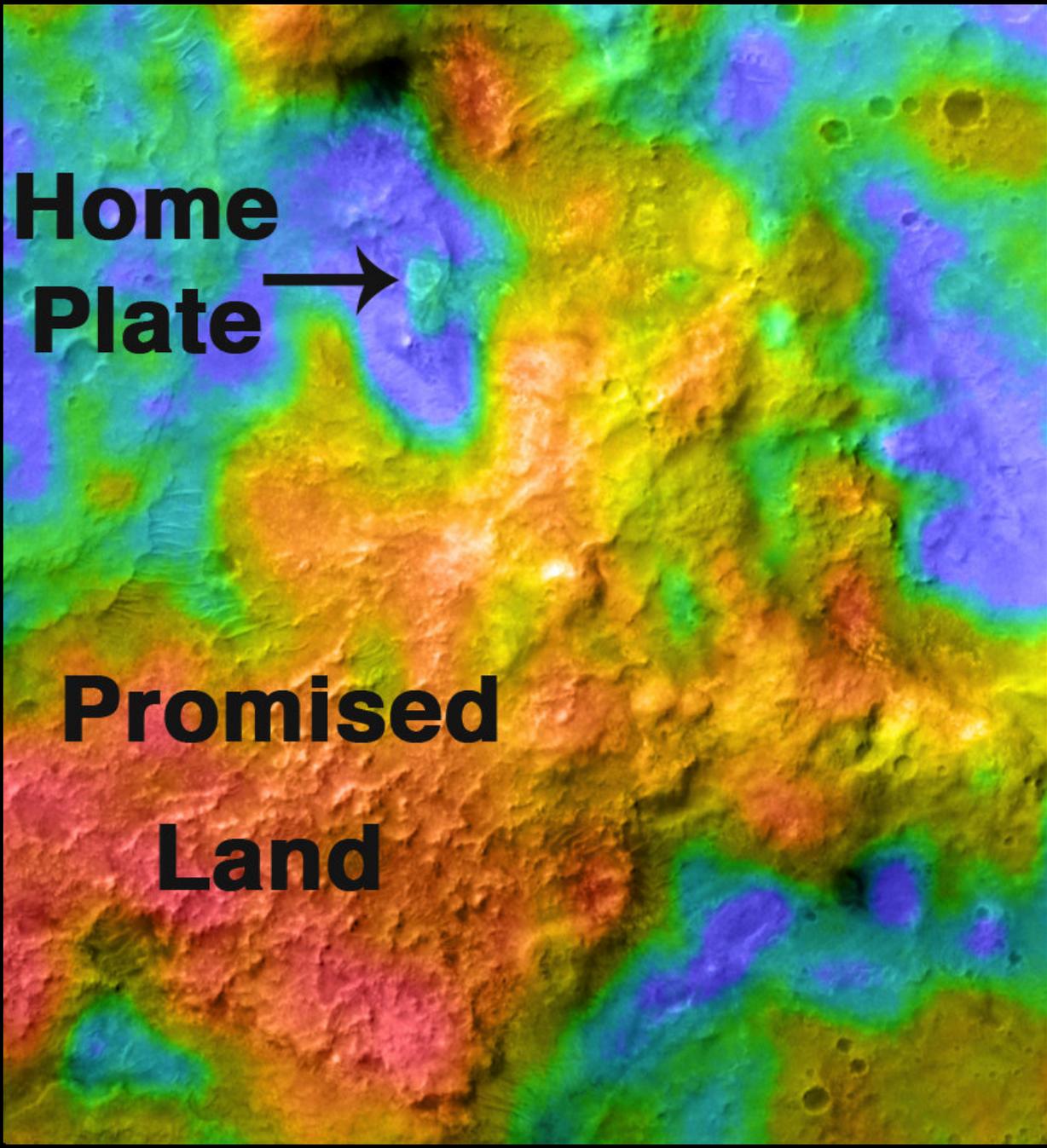
**Olivine and Pyroxene  
Rich Outcrops**

**Algonquin**

**Comanche  
(Mg-Fe Carbonates)**



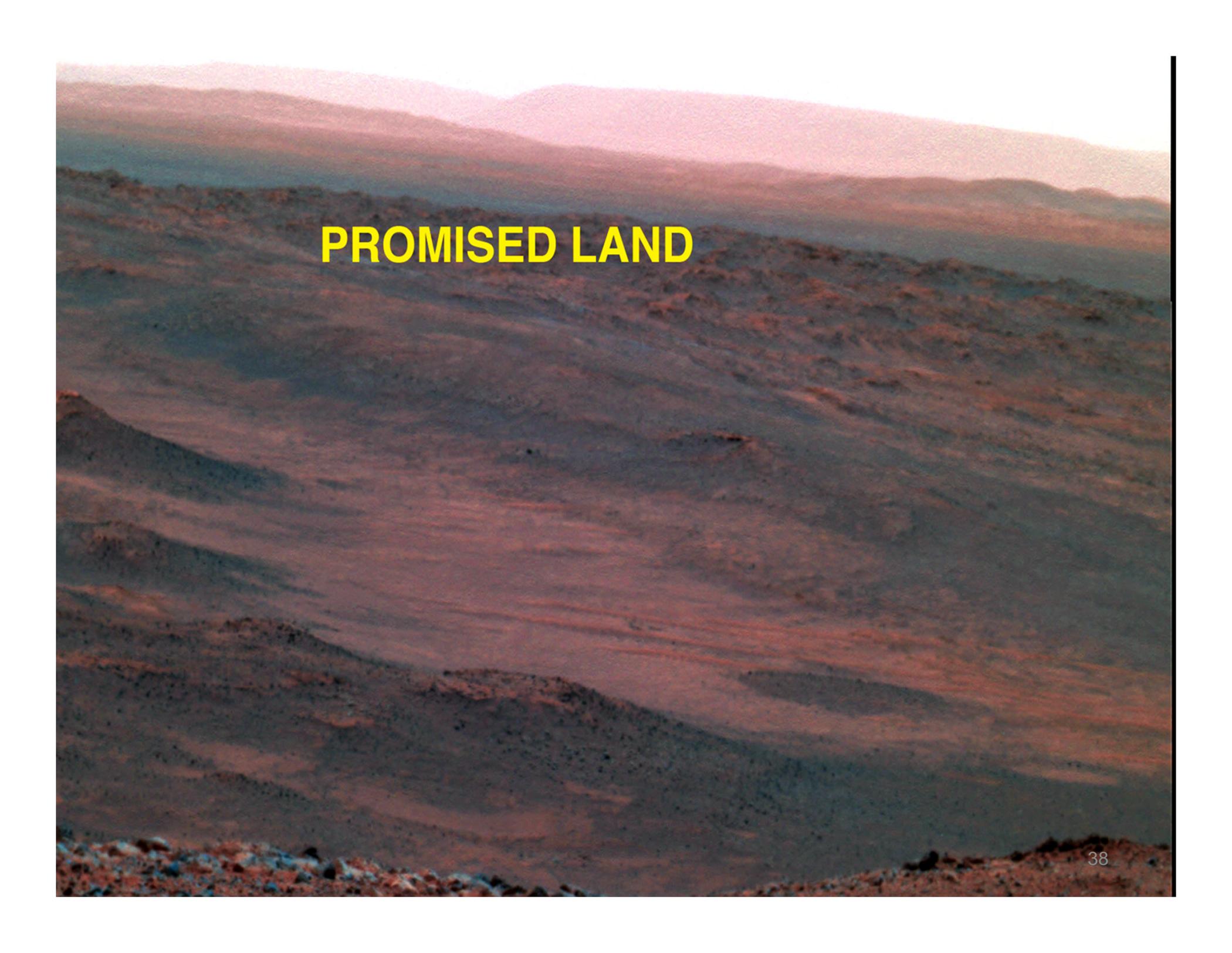




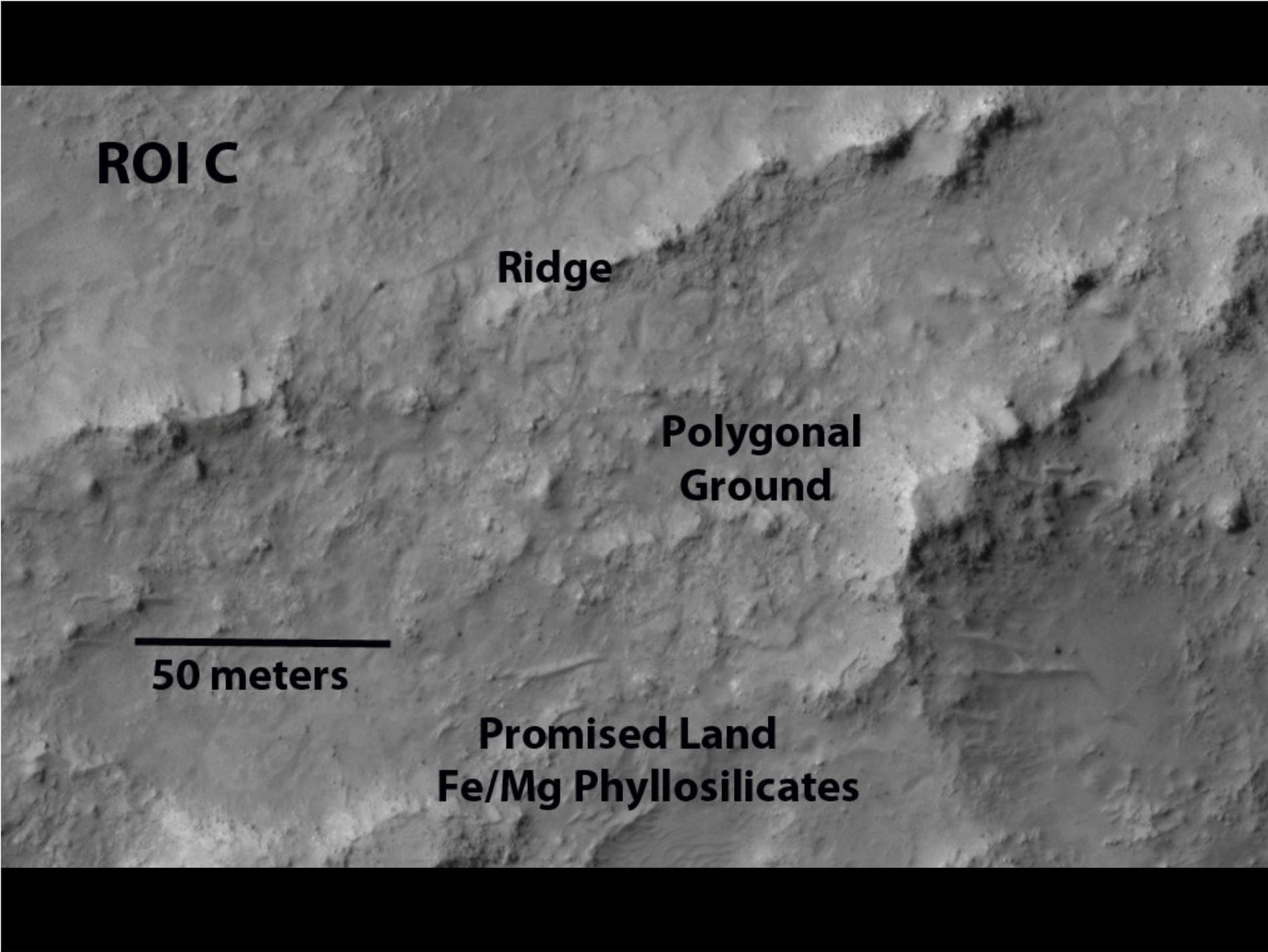
**Home  
Plate**



**Promised  
Land**

A wide-angle photograph of a vast, hazy landscape. The foreground and middle ground consist of rolling hills and mountains, their details softened by atmospheric haze. The sky is bright and clear. The overall color palette is dominated by soft, muted tones of blue, grey, and brown, with a yellow text overlay in the center.

# PROMISED LAND



**ROI C**

**Ridge**

**Polygonal  
Ground**

**50 meters**

**Promised Land  
Fe/Mg Phyllosilicates**



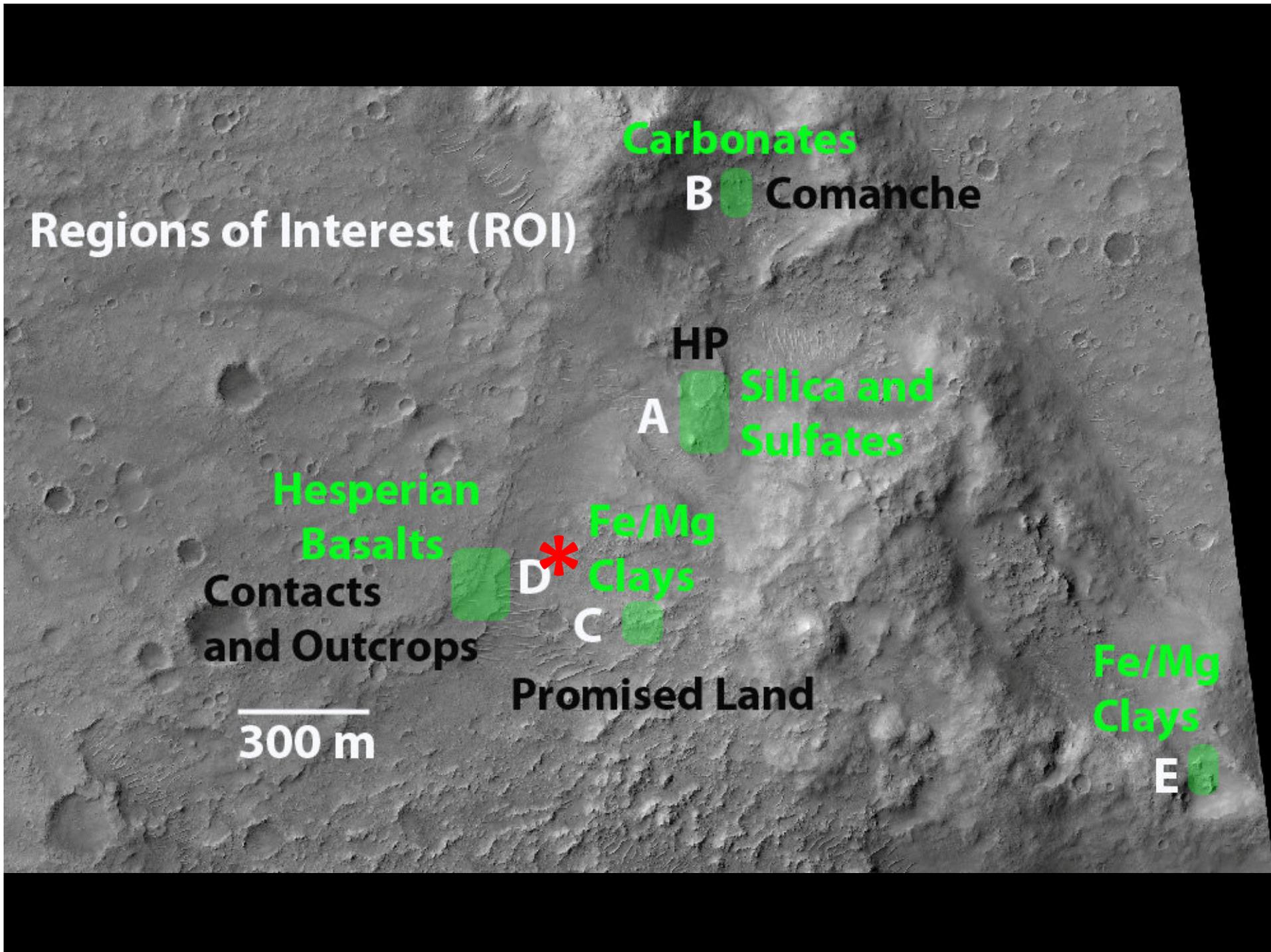
# Promised Land

Bouldery Cap Unit: Ma'Adim Vallis Flood Deposits

Polygonal Terrain: Lacustrine Clays



Polygons ~ 5-10 m across



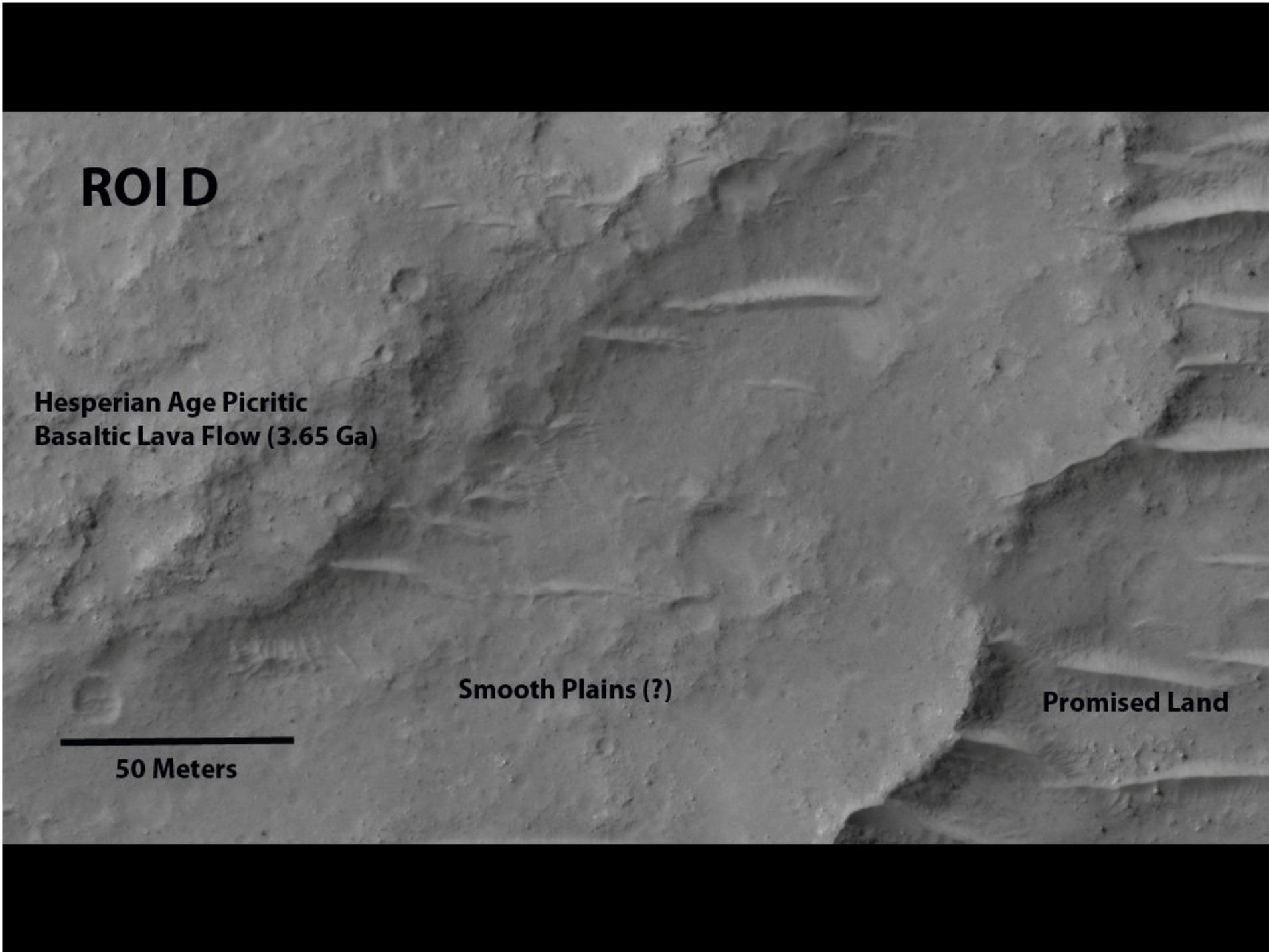
# ROI D

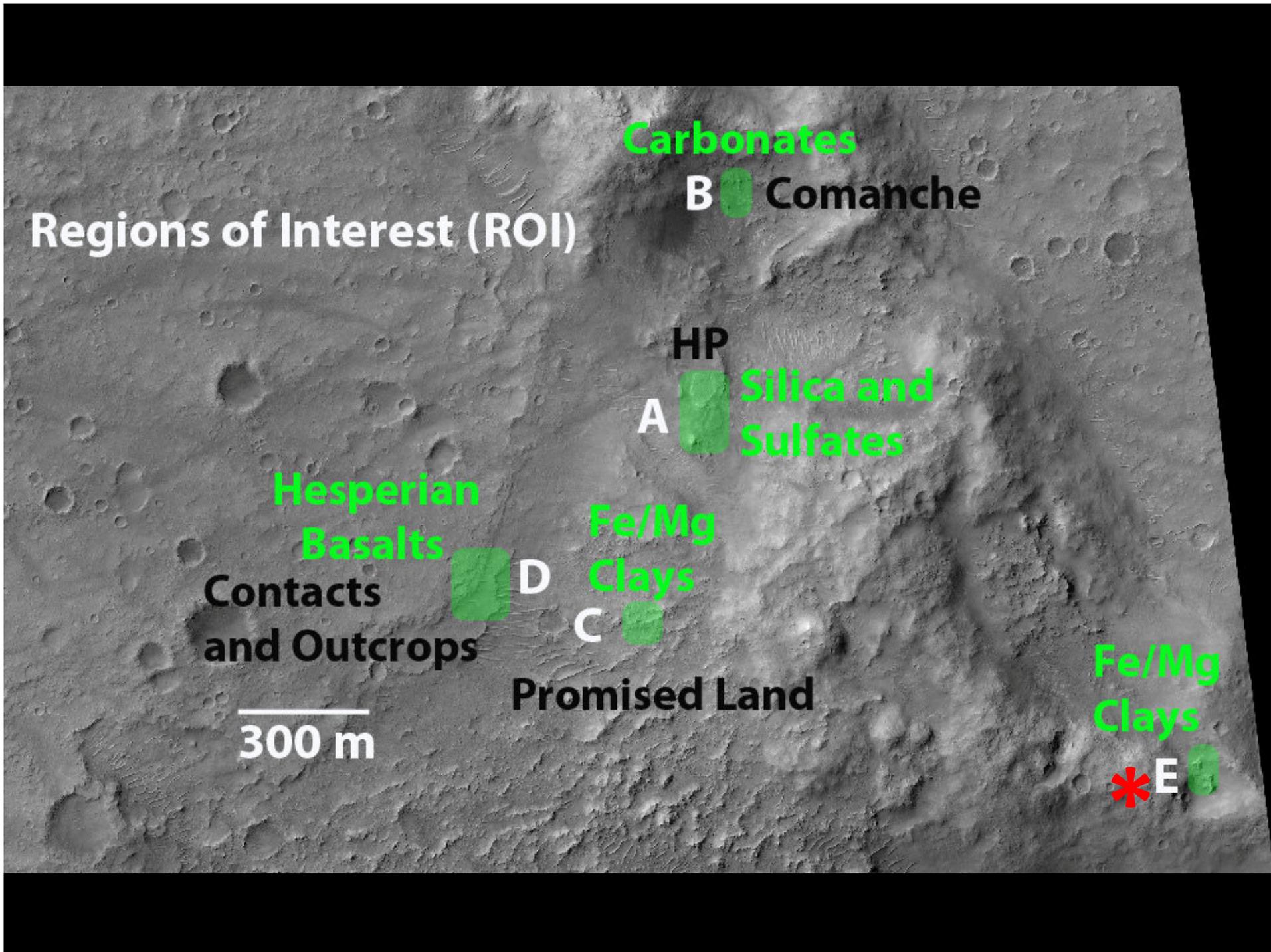
Hesperian Age Picritic  
Basaltic Lava Flow (3.65 Ga)

Smooth Plains (?)

Promised Land

50 Meters

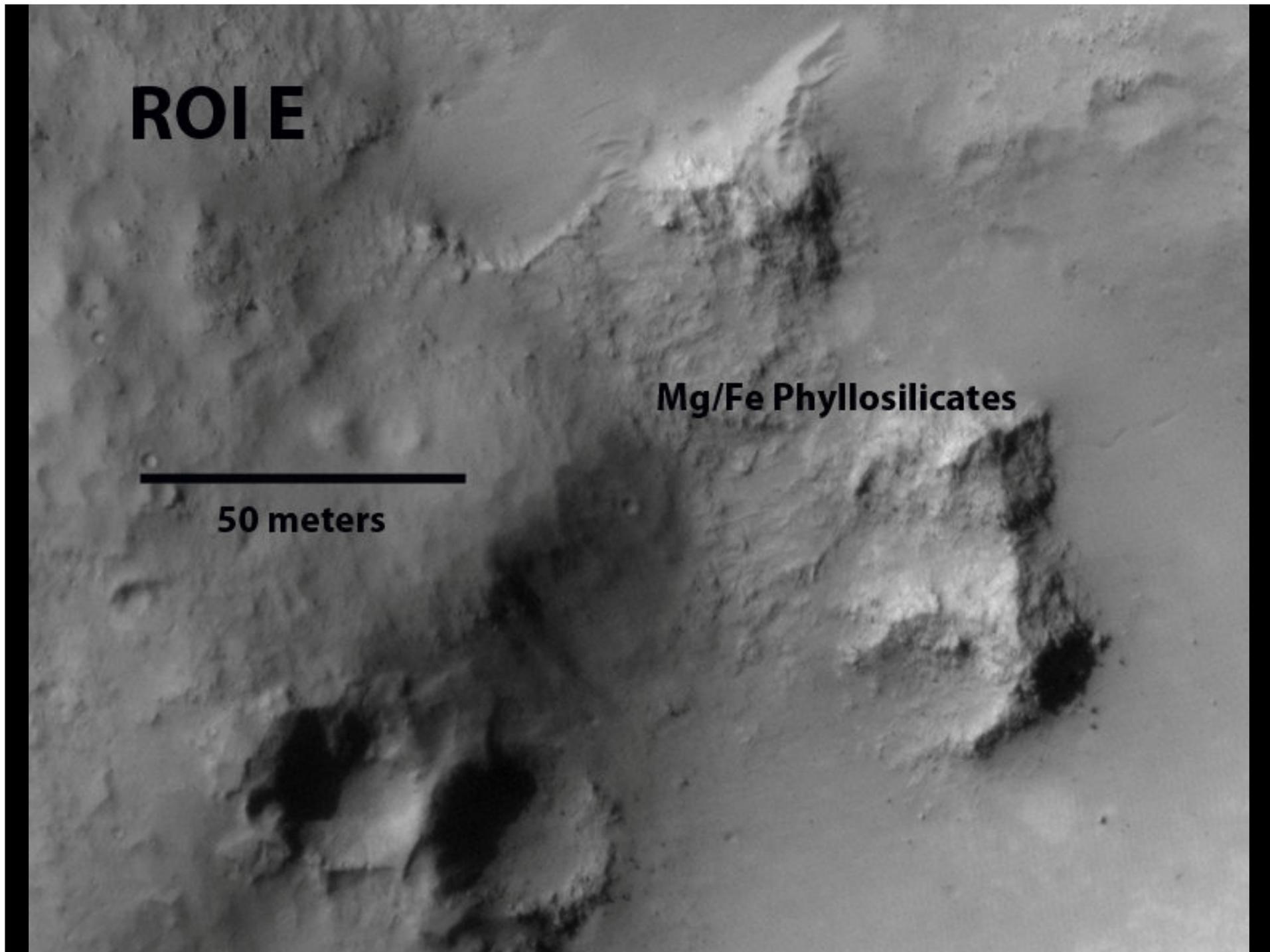




**ROI E**

**Mg/Fe Phyllosilicates**

**50 meters**



# Extra incentive for revisiting site is that Spirit can be located and inspected via imagery on 2020 Rover (Apollo 12 and Surveyor III)

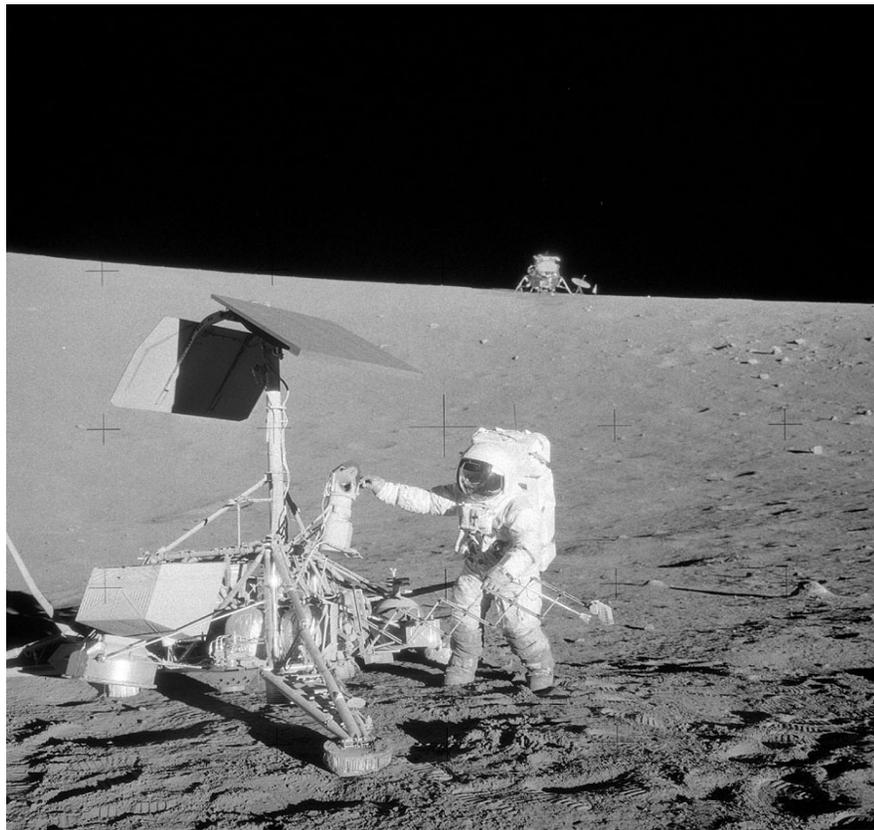
By this time Spirit exposed to Martian environment for 17 yrs

Excellent long duration exposure experiment providing long term data on the Martian environment (Weathering, Micrometeorites) and its effects on materials  
Degradation: Solar Arrays (cracks, discoloration, broken wires), Cable Ties and Lacing (delamination, discoloration, degradation), Cal Target Paint Chips  
Condition, Did Batteries Leak?

Data will aid in design of surface systems, equipment and structures for both future robotic and manned exploration of Mars.

# Previous Long Duration Exposure Experiments

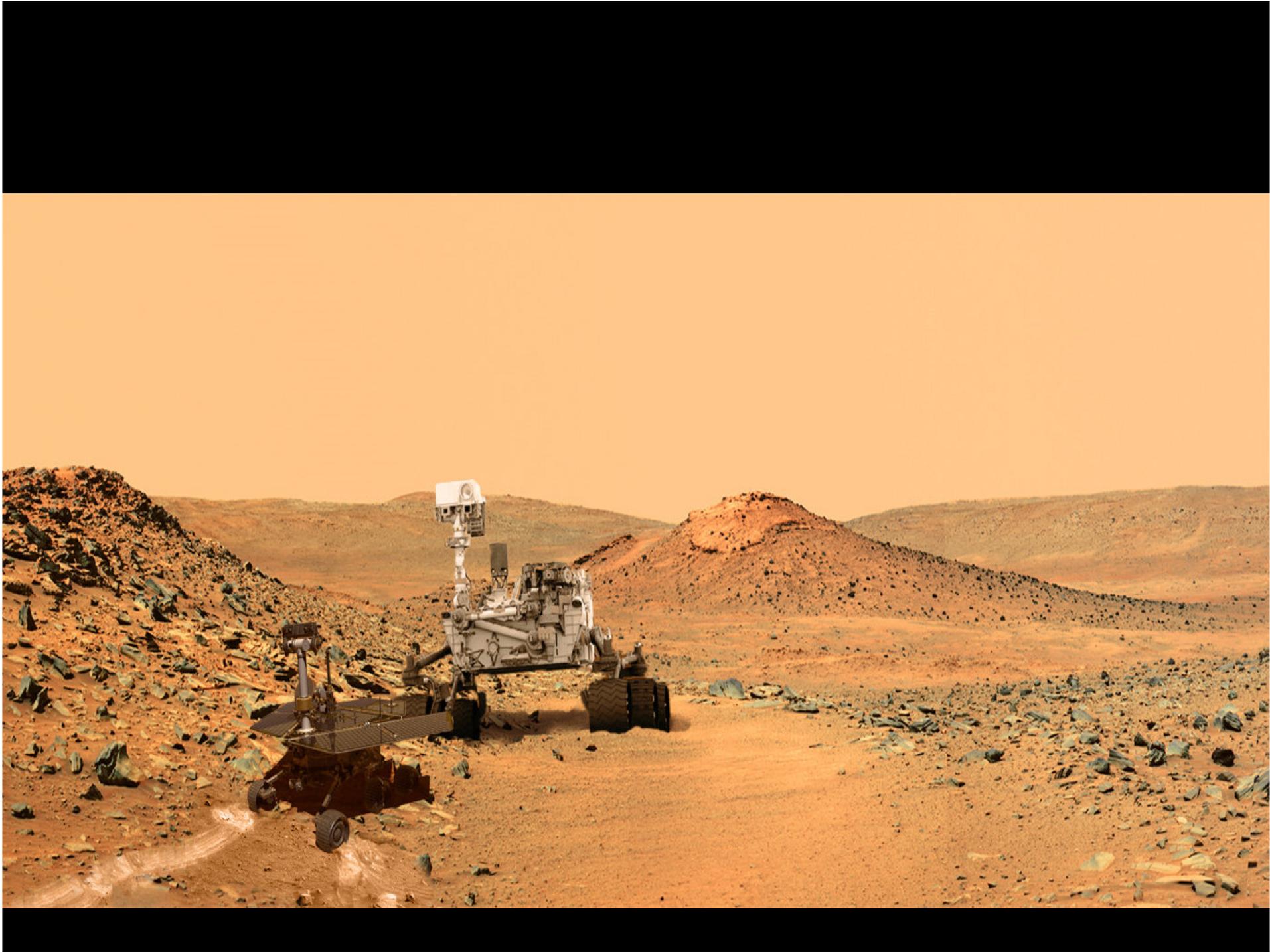
**Apollo 12 retrieved components from S-III exposed 2.5 yrs**



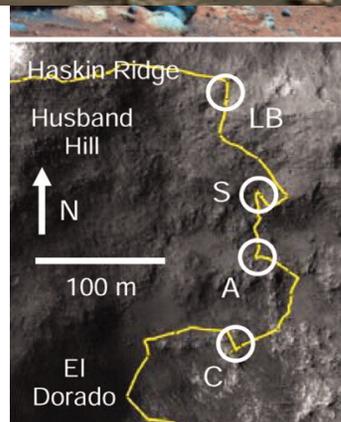
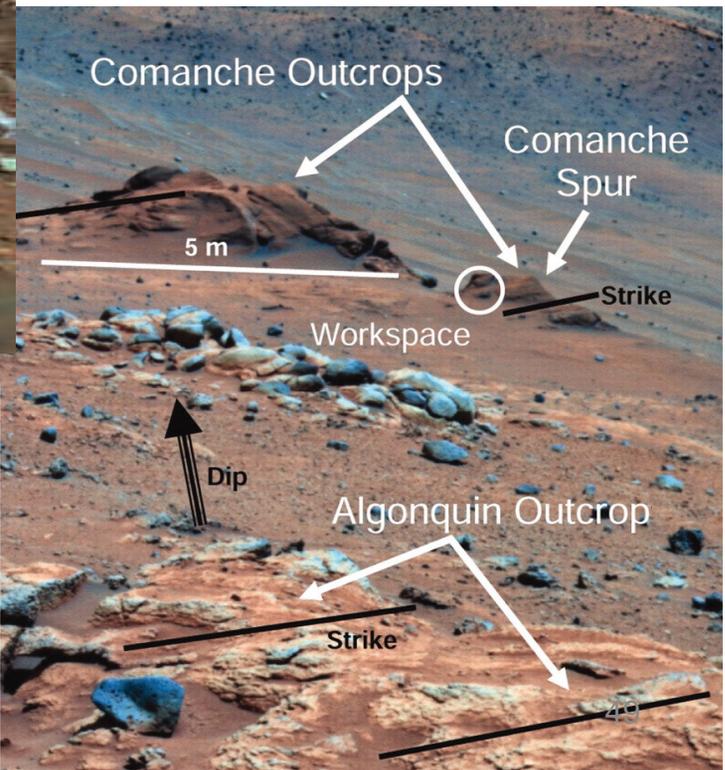
**LDEF: materials, coatings, electronics, optics, thermal systems exposed 5.7 yrs**







# Spirit has already given us birds in the hand:



MAXIMUM RETURN ON INVESTMENT!\$!

