

Ground Systems Architecture Workshop 2024

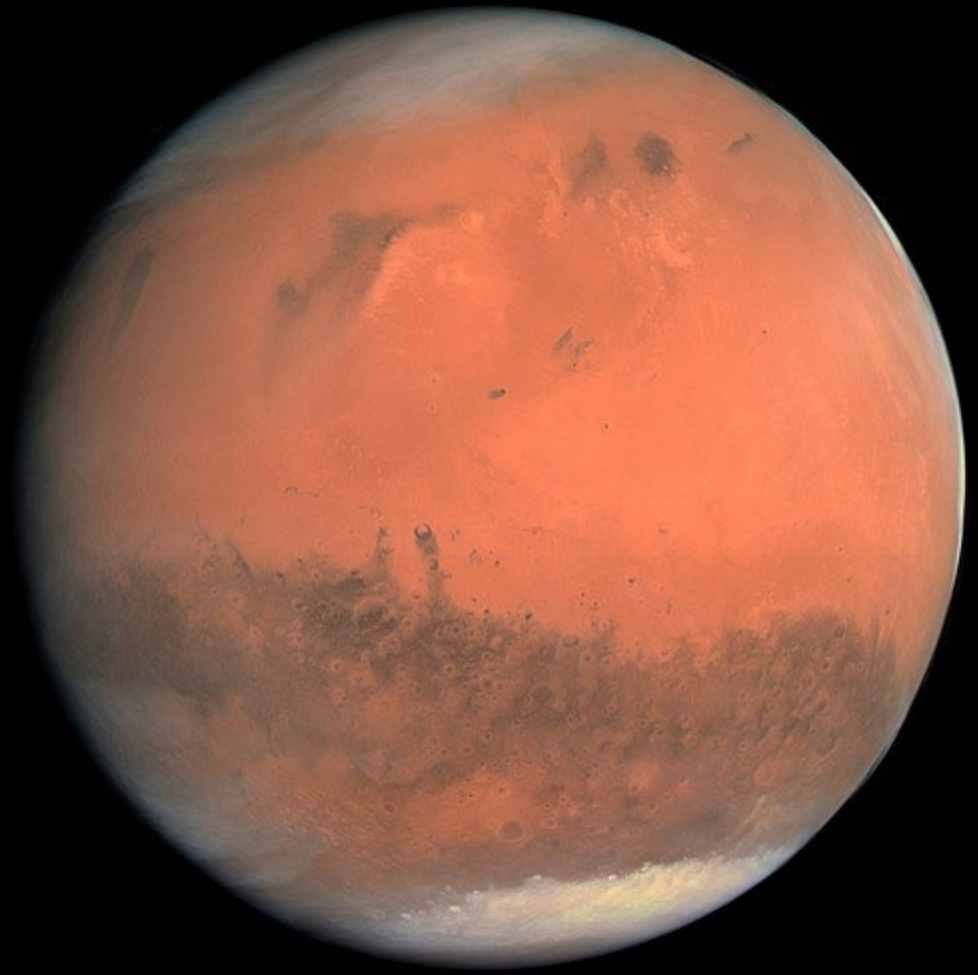
# Mars 2020 Mission and its Ground System

Presented by Guy Pyrzak, Mars 2020 Mission Lead

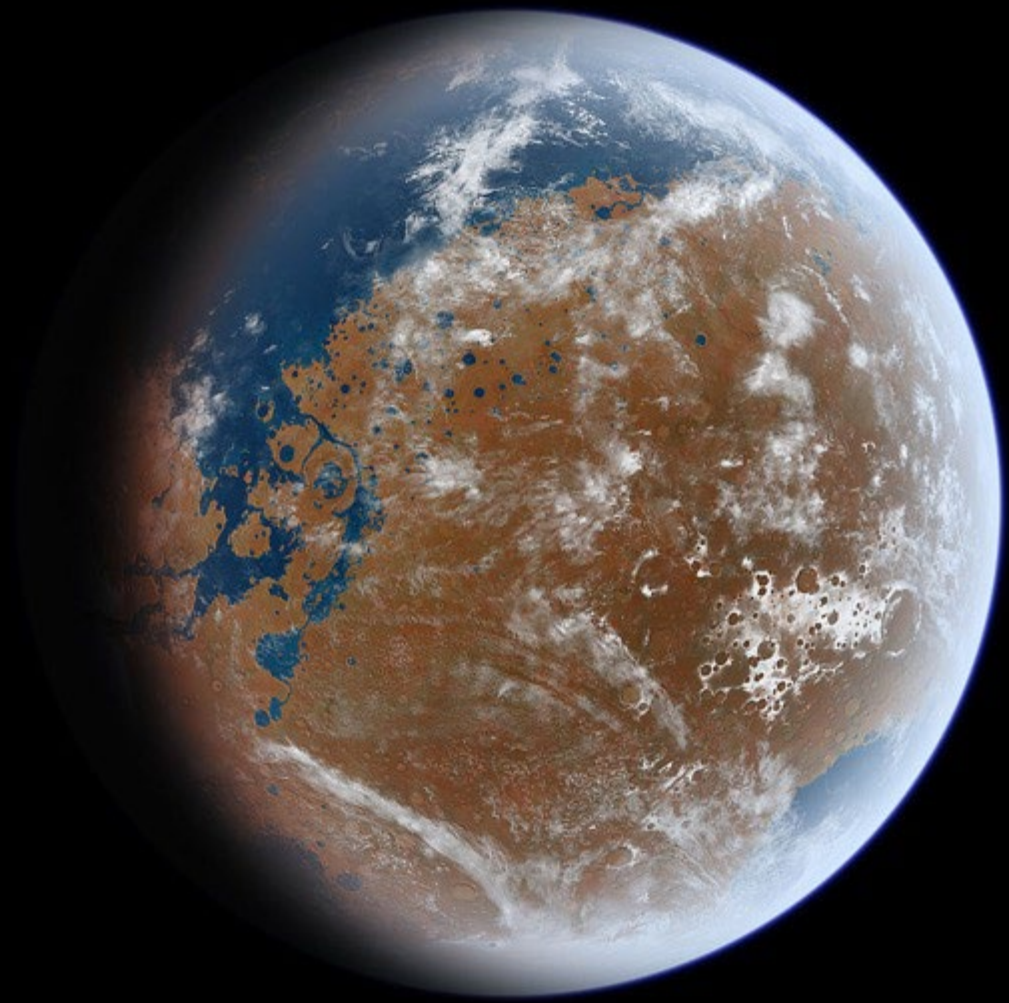


Jet Propulsion Laboratory
California Institute of Technology

# Mars Global Climate Change



Modern Mars

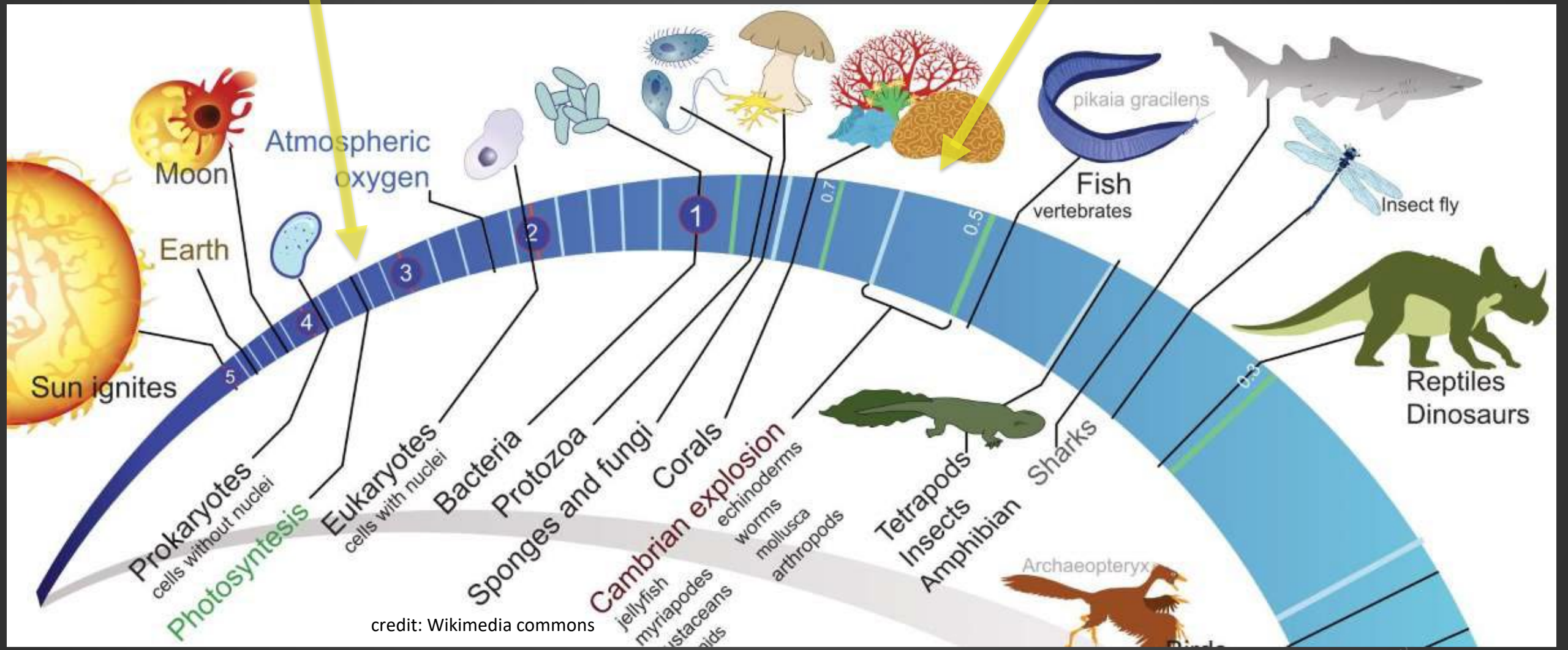


Mars ~ 3.6 billion years ago (?)

# Terrestrial Biological Time Line

Mars climate change ~here

First Familiar "fossils"




credit: Wikimedia commons

# What Should We Look For?

VS

Classic Fossils:
Less than
~ 650 million years old

Microbial and/or chemical biosignatures:
up to 3.6 billion years old

# To understand the possibilities for life on Mars, we seek to fulfill four ambitious goals

# Why Sample Return?

- **Rover instruments can only do so much**
- **Analyses on Earth are much more advanced**
  - *Required for detection of life/biomarkers, age of rock, etc.
  - Samples remain available for future generations, as technology advances
- **Context is everything**
  - We get to pick where the samples are collected!

# The Rover

**Mastcam-Z**
Zoomable Panoramic Cameras

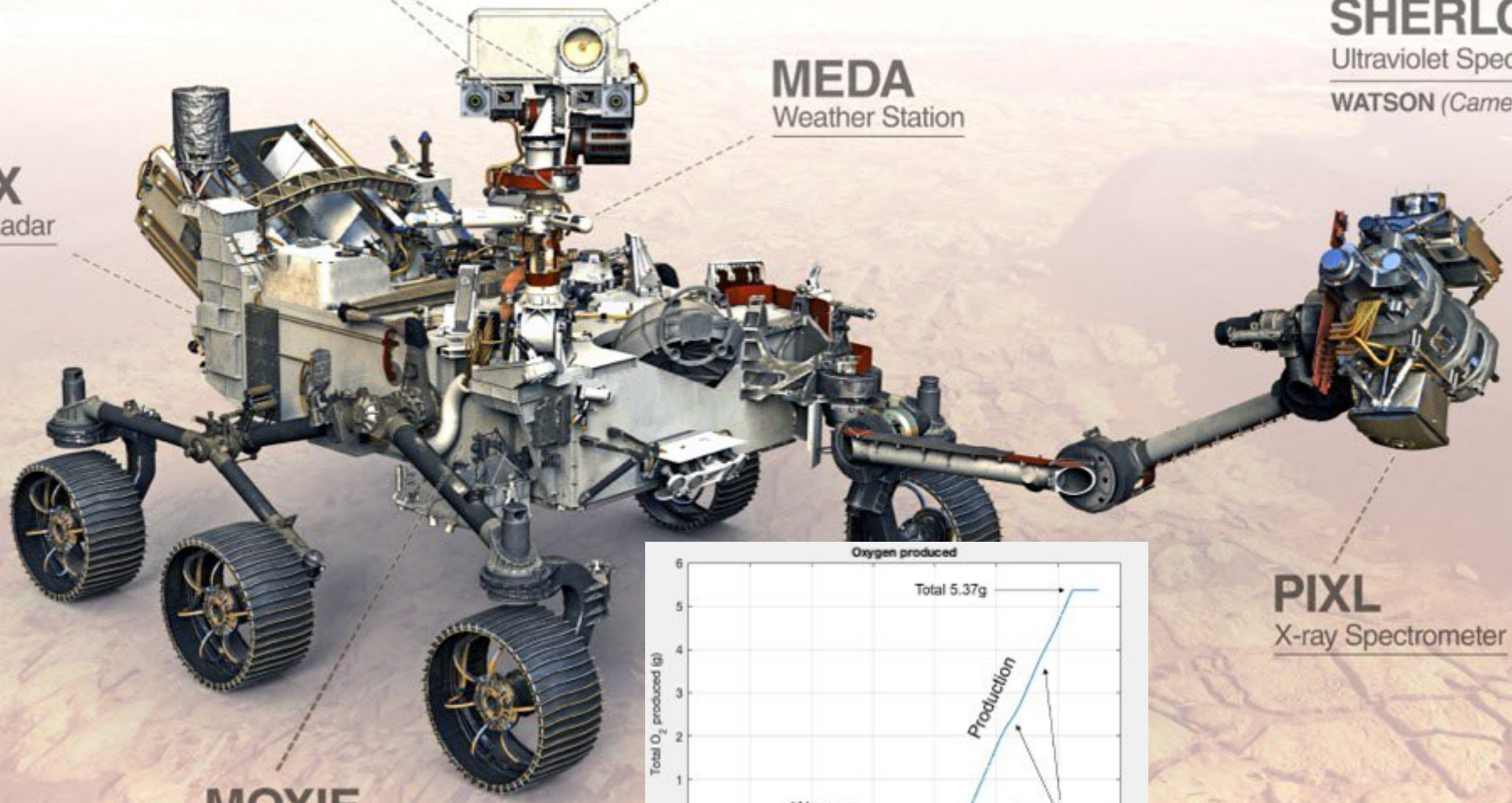
**SuperCam**
Laser Micro-Imager

**SHERLOC**
Ultraviolet Spectrometer

**WATSON** *(Camera)*

**MEDA**
Weather Station

**RIMFAX**
Subsurface Radar



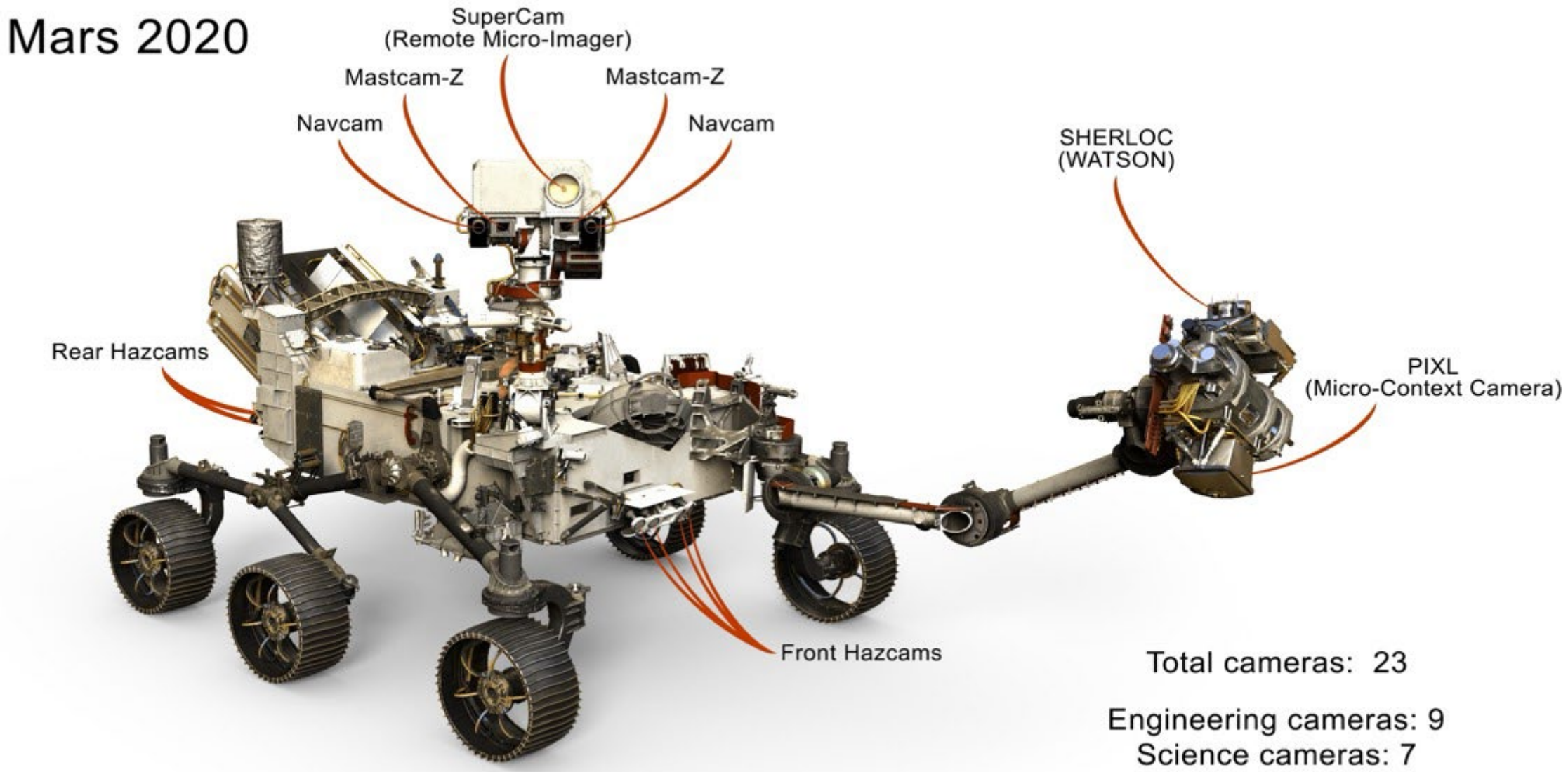
**PIXL**
X-ray Spectrometer

**MOXIE**
Produces Oxygen from Martian $CO_2$




MOXIE first test done on April 20, 2022
(MIT Haystack Observatory)

# Lots of cameras!




Total cameras: 23

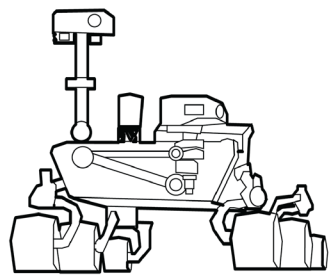
Engineering cameras: 9
Science cameras: 7
Entry, descent and landing cameras: 7

# The Ground Data System

# 1.25 MARS YEARS

context

## MSL



MARS YEARS:

**1.25**

DISTANCE COVERED:

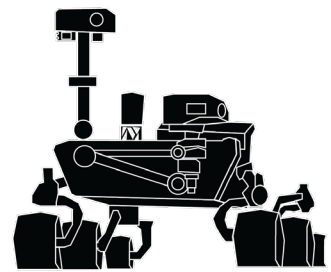
**10.6 km**

SAMPLES COLLECTED:

**2 scooped**

**6 drilled samples**

## M2020



MARS YEARS:

**1.25**

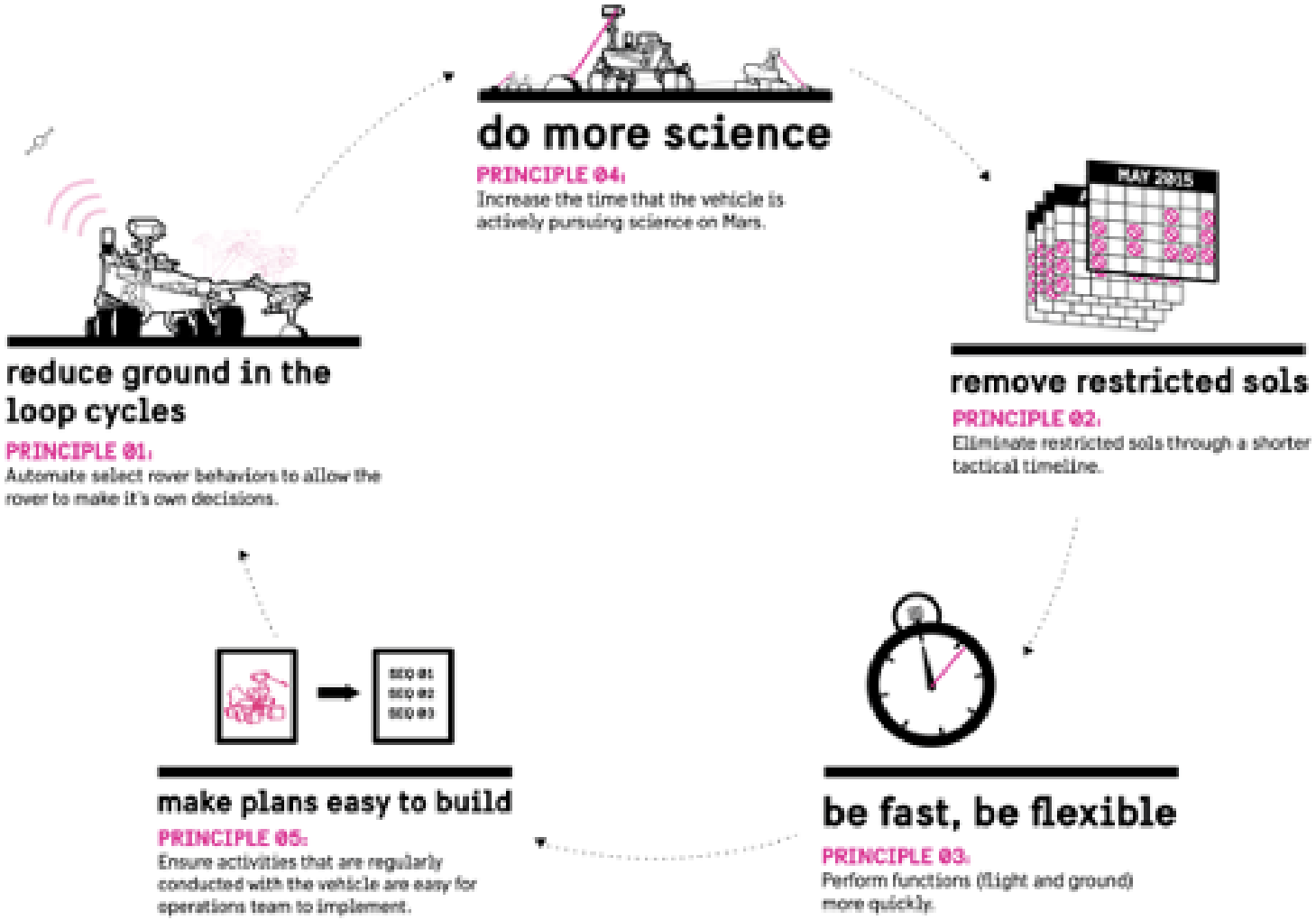
DISTANCE TO COVER:

**15 km**

SAMPLES TO COLLECT:

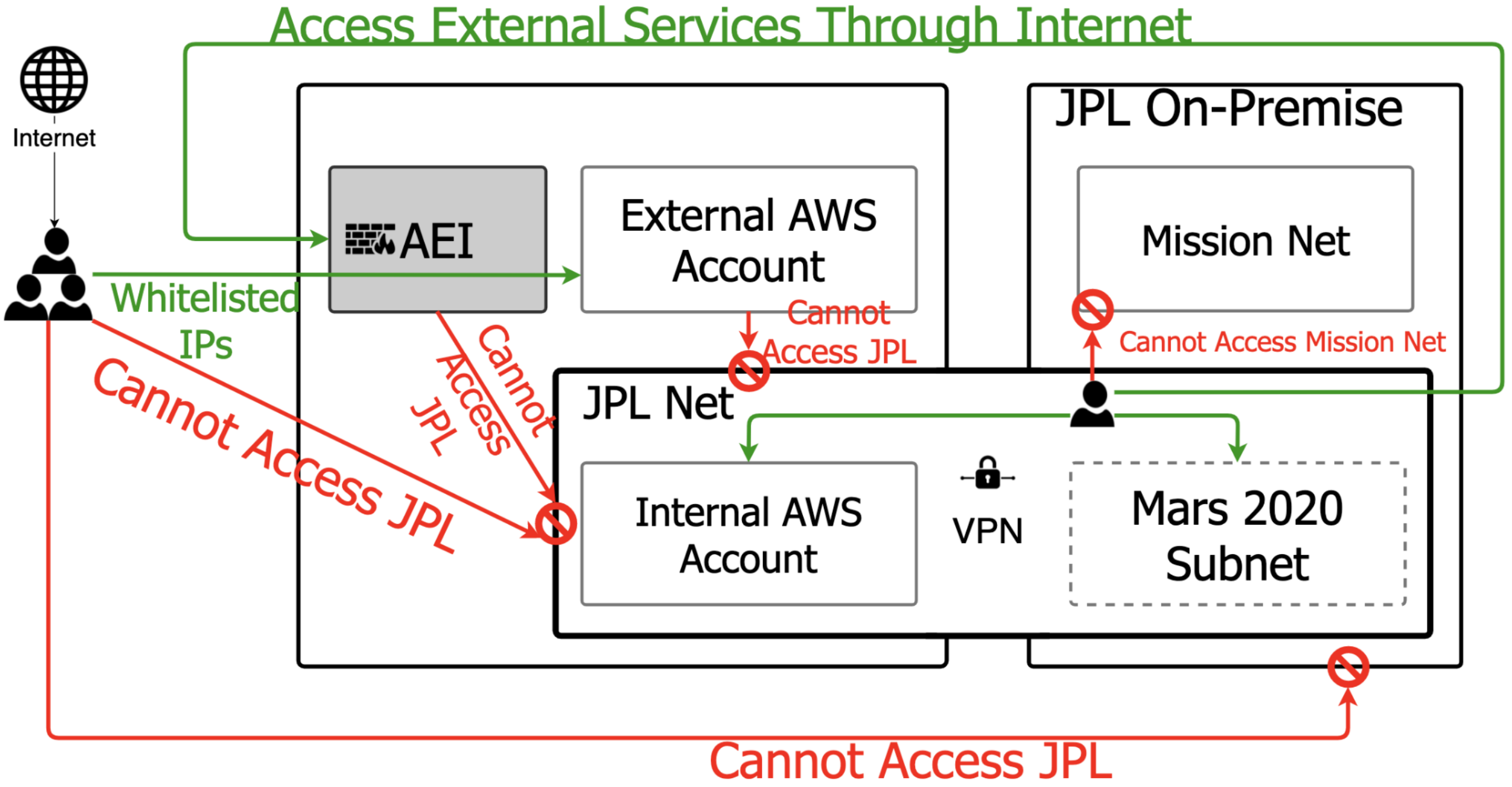
**20 drilled samples**

# Mission System Principals

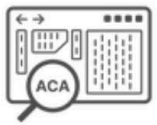


## Challenges

- **Monolith Applications**
  - MSLICE and MPCS
- **The Rise of Analytics and COTS tools**
- **Search in so many places**
- **Significant Evolutions in team tools and html and cloud technologies**
- **Previous GDS releases took months due to deployment challenges**
- **Increasing Cybersecurity requirements from NASA and the world**


Access External Services Through Internet
Internet
AEI
External AWS Account
JPL On-Premise
Mission Net
Whitelisted IPs
Cannot Access JPL
Cannot Access JPL
Cannot Access JPL
Cannot Access Mission Net
JPL Net
Internal AWS Account
VPN
Mars 2020 Subnet
Cannot Access JPL

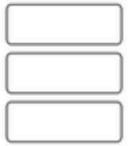
Search



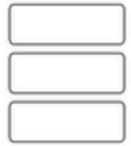

**ACA Viewer**
RPS
*ACA Viewer*

**AD Editor**
APSS
*AD Editor*

**ASTTRO**
RPS
*ASTTRO*



**CACHER**
CS3
*CACHER*



**CACHER API**
CS3
*CACHER API*

**CAMP**
IDS
*CAMP*

**COCPIT**
APSS
*COCPIT*

**CREDSS CLI download**
CS3
*CREDSS CLI*

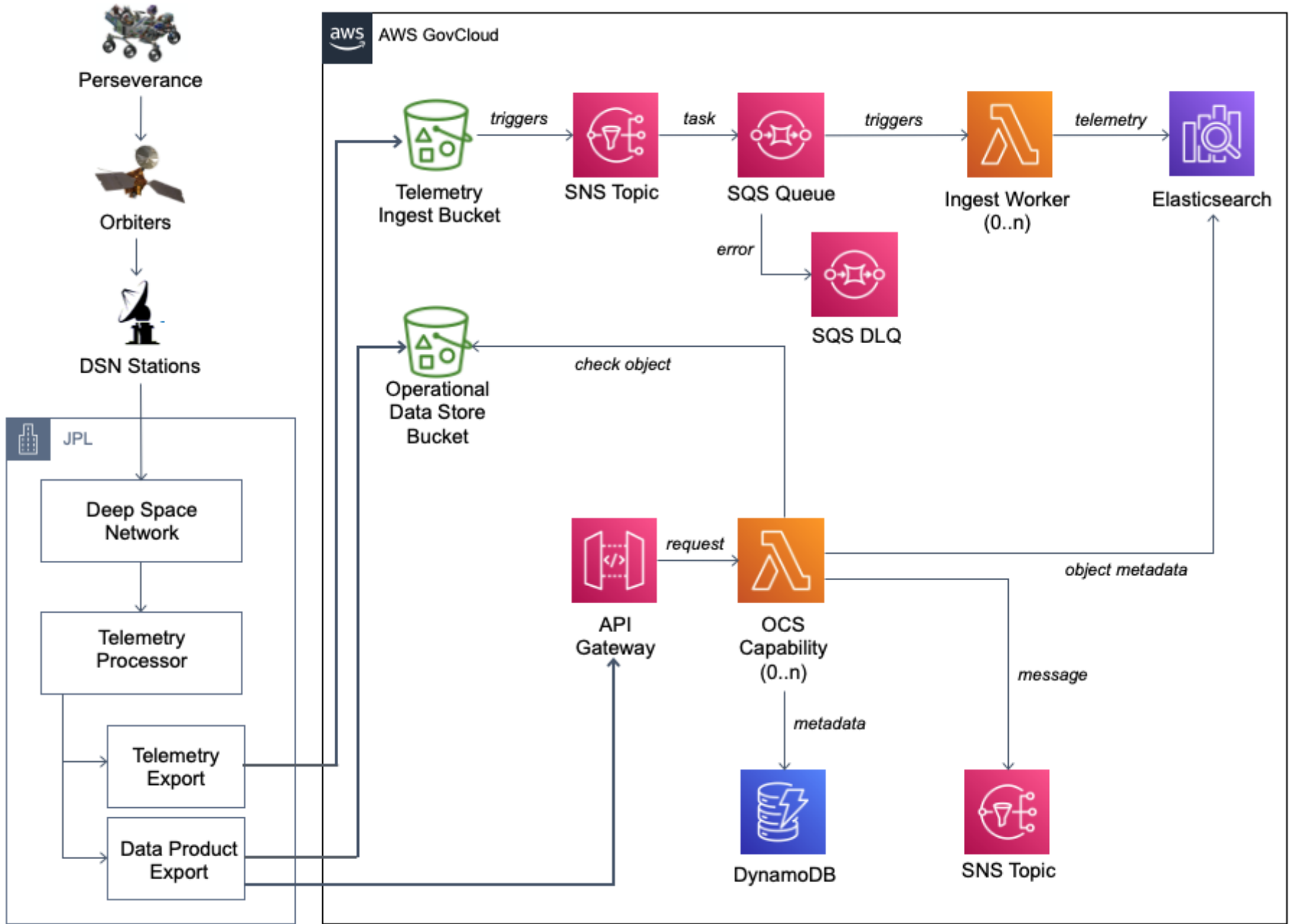
**CSSO (API Endpoint)**
CS3
*CSSO Endpoint*

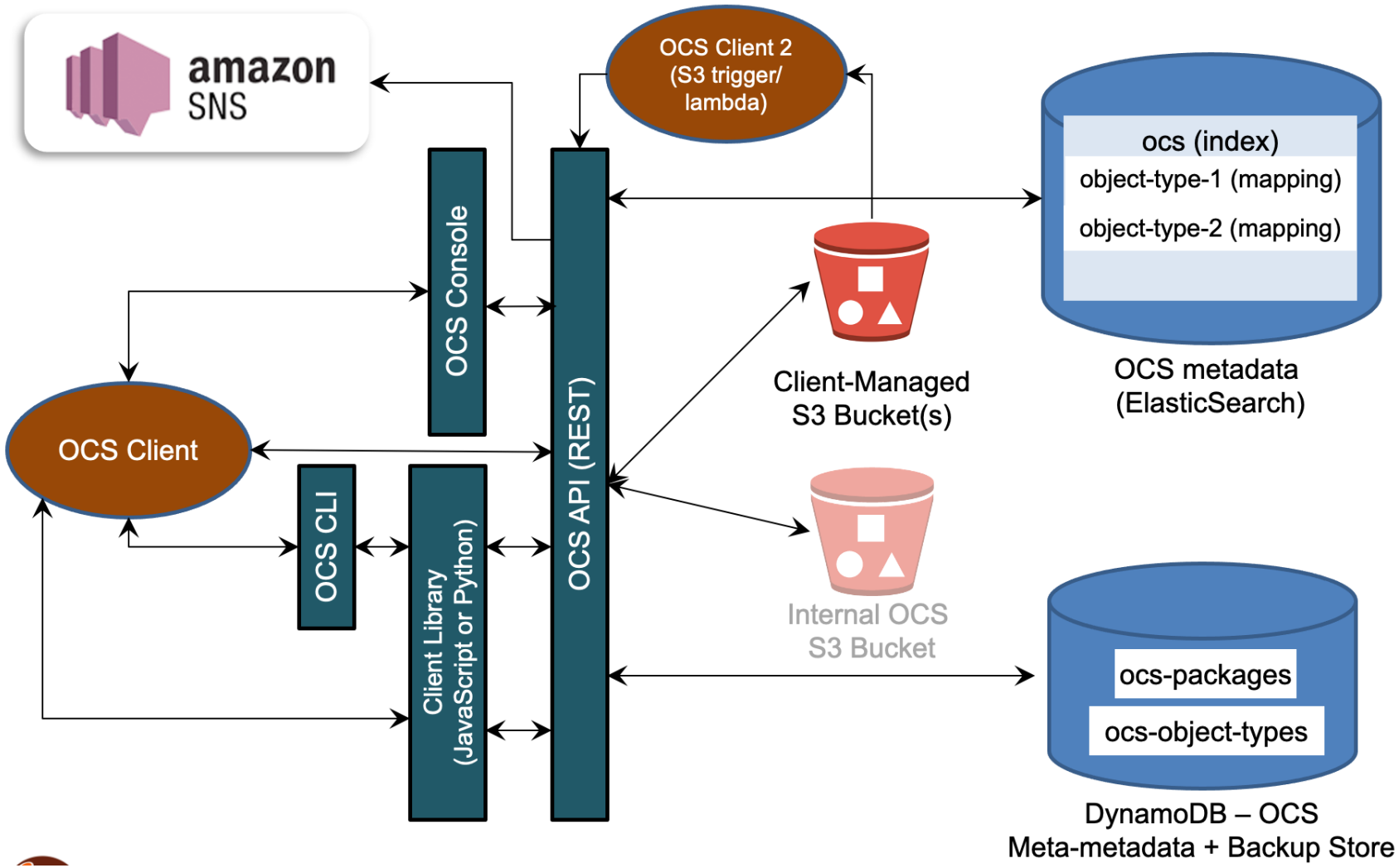
**Help:** Slack

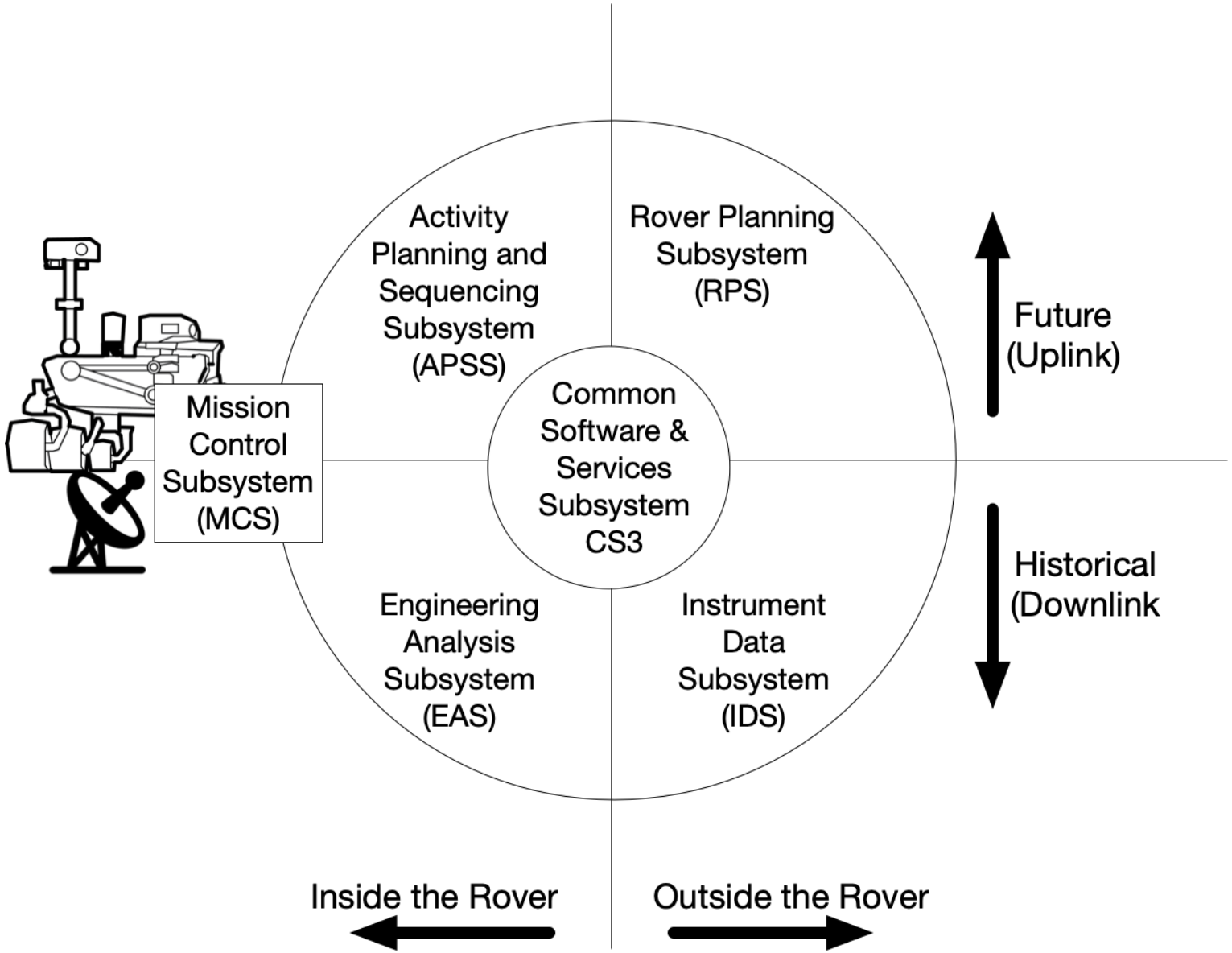
**Channel Viewer**
EAS
*Channel Viewer*

**Comm Tracker**
EAS
*Comm Tracker*

**Cross Check**
APSS
*Cross Check*

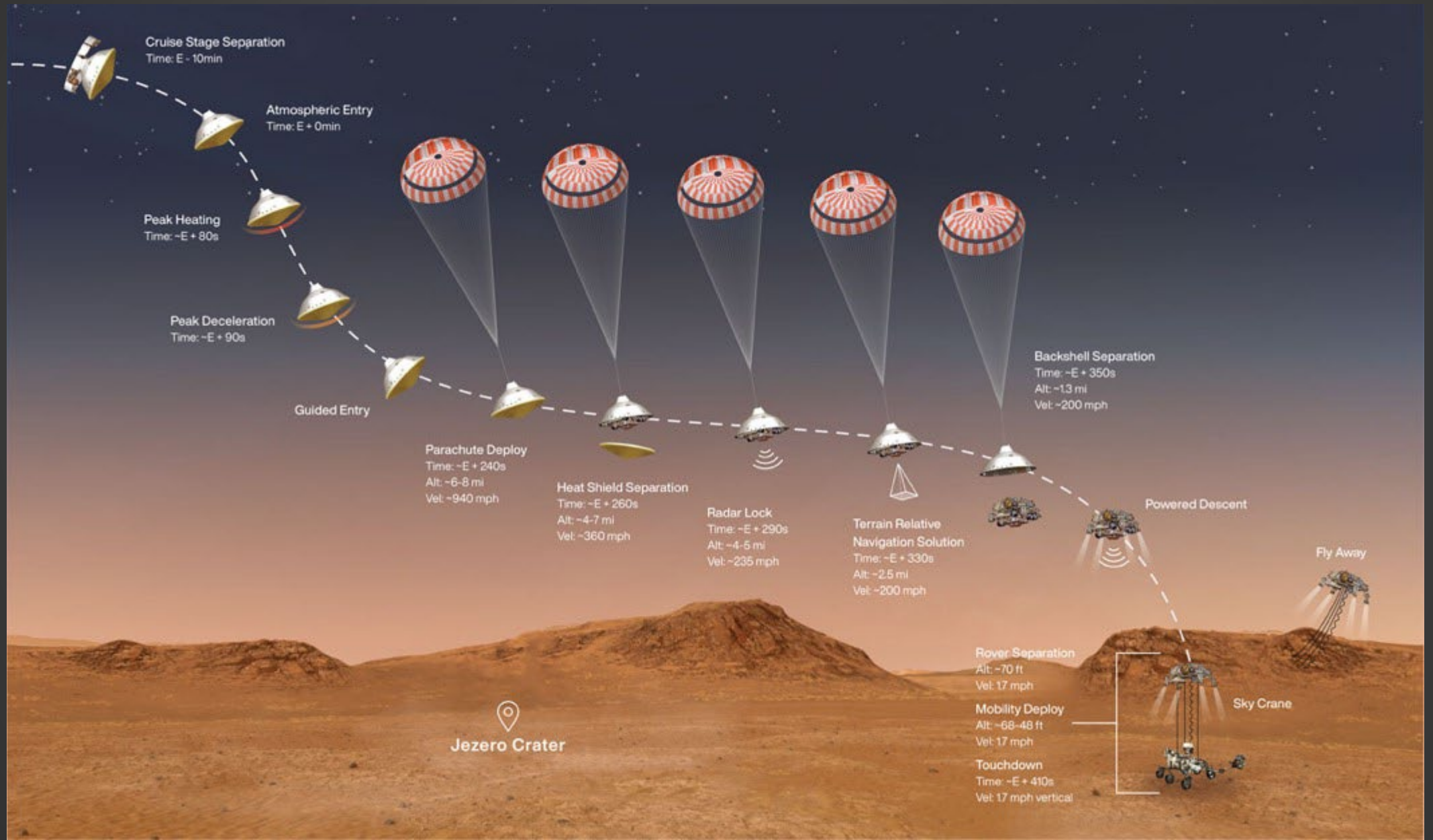

Perseverance
Orbiters
DSN Stations
JPL
Deep Space Network
Telemetry Processor
Telemetry Export
Data Product Export
AWS GovCloud
Telemetry Ingest Bucket
triggers
SNS Topic
task
SQS Queue
triggers
Ingest Worker (0..n)
telemetry
Elasticsearch
error
SQS DLQ
Operational Data Store Bucket
check object
request
API Gateway
OCS Capability (0..n)
object metadata
message
metadata
DynamoDB
SNS Topic


amazon
SNS
OCS Client 2
(S3 trigger/
lambda)
ocs (index)
object-type-1 (mapping)
object-type-2 (mapping)
OCS Console
OCS Client
OCS CLI
Client Library
(JavaScript or Python)
OCS API (REST)
Client-Managed
S3 Bucket(s)
OCS metadata
(ElasticSearch)
Internal OCS
S3 Bucket
ocs-packages
ocs-object-types
DynamoDB – OCS
Meta-metadata + Backup Store


Activity Planning and Sequencing Subsystem (APSS)
Rover Planning Subsystem (RPS)
Common Software & Services Subsystem CS3
Engineering Analysis Subsystem (EAS)
Instrument Data Subsystem (IDS)
Mission Control Subsystem (MCS)
Future (Uplink)
Historical (Downlink
Inside the Rover
Outside the Rover

# Operations

# Entry, Descent and Landing (aka *7 minutes of terror*)

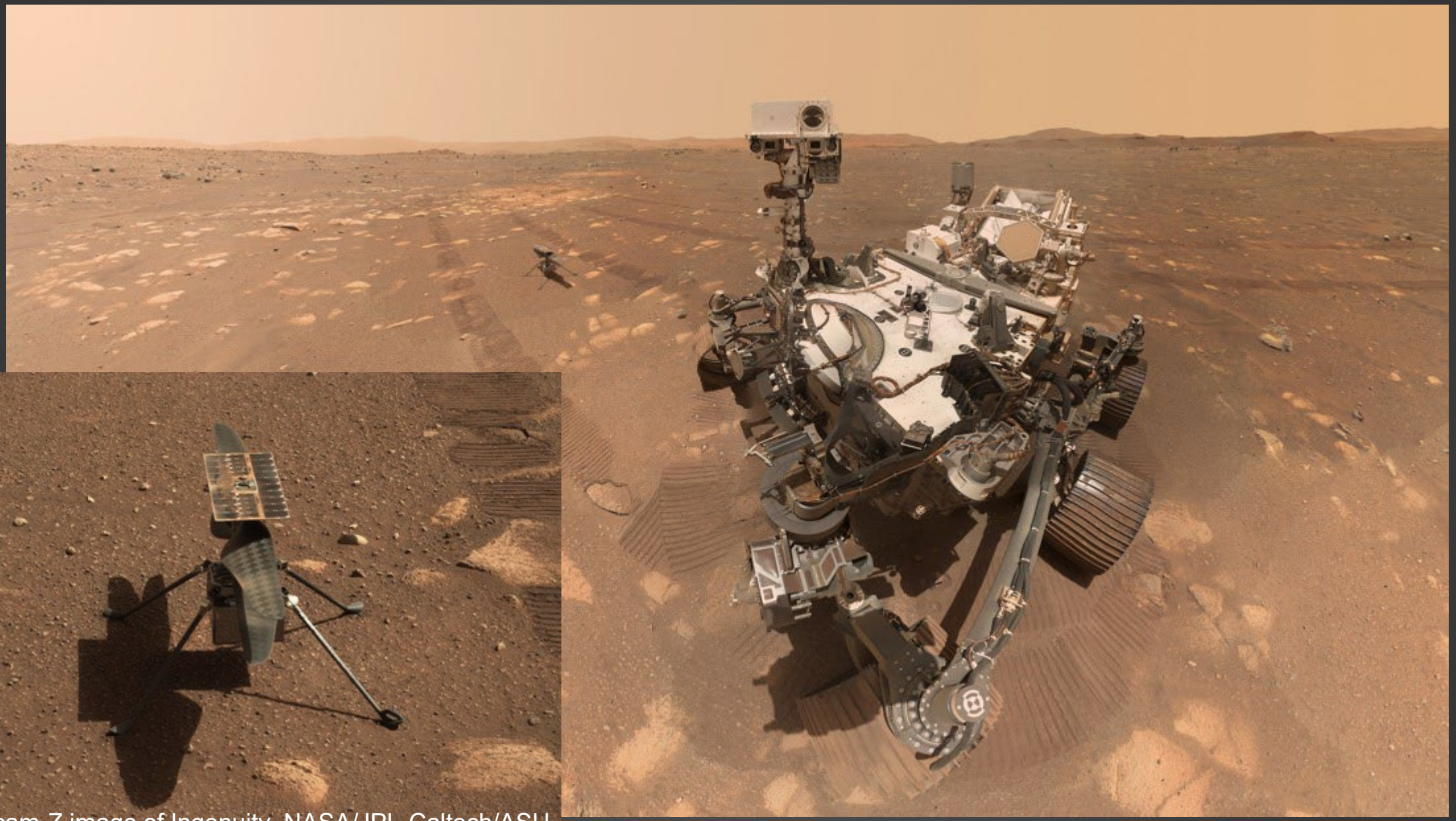



NASA/JPL-Caltech

# Perseverance has also delivered *Ingenuity*, a small helicopter, to the surface


NASA/JPL-Caltech/MSSS

# This technology demonstration is the first powered flight on another planet!





Mastcam-Z image of Ingenuity. NASA/JPL-Caltech/ASU

NASA/JPL-Caltech/Doug Ellison

# From first images…

Mastcam-Z first 360° panorama, from Sol 3.
NASA/JPL-Caltech/ASU/MSSS

# …to firsts

## Mars 2020: By the numbers*

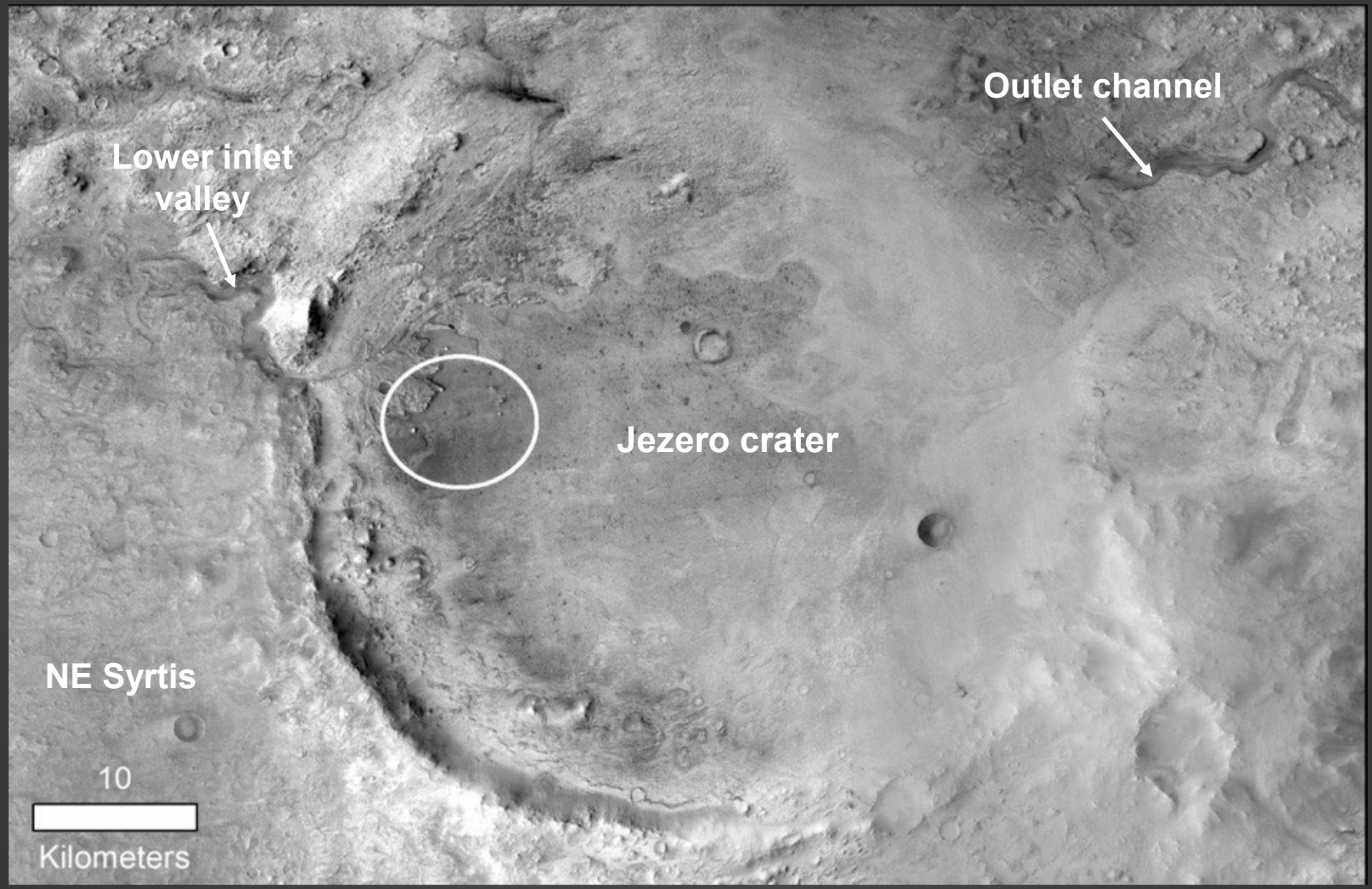
***Perseverance:***

- **Over 578,000 images taken**
- **25.8 km traversed**
  - Longest autonomous single-day drive by any rover (320 m)
- **26 sample tubes processed**
  - First ever samples acquired for return to Earth

***Ingenuity*:**

- **72 flights completed**
  - First ever powered flight on another planet
- **17 km flown; over 128.8 minutes total flying time**

*As of February 20, 2024, sol 1064


Outlet channel
Lower inlet valley
Jezero crater
NE Syrtis
10
Kilometers

NASA/JPL-Caltech. Artist’s impression of Jezero Crater ~3.8 billion years ago.


Where we are now
*Perseverance* odometry: 23.2 km
*Ingenuity*: 67 flights, 15.3 km
ERETVA VALLIS
Belva
*Perseverance* Path
Séítah
*Ingenuity*
Flight Paths
Octavia E. Butler
(OEB) Landing Site
0 200m 500m 1000m
From https://mars.nasa.gov/mars2020/mission/where-is-the-rover/ NASA/JPL-Caltech

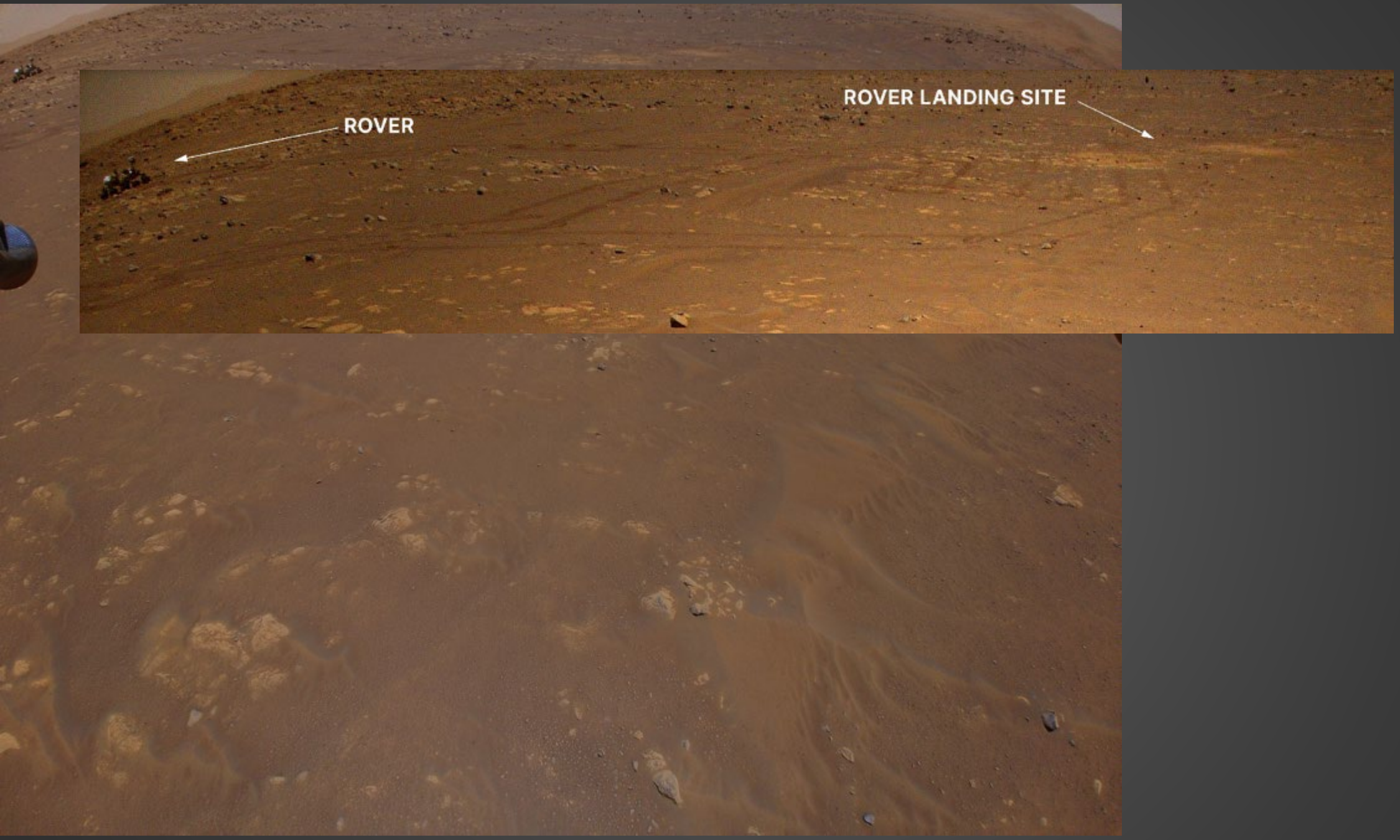
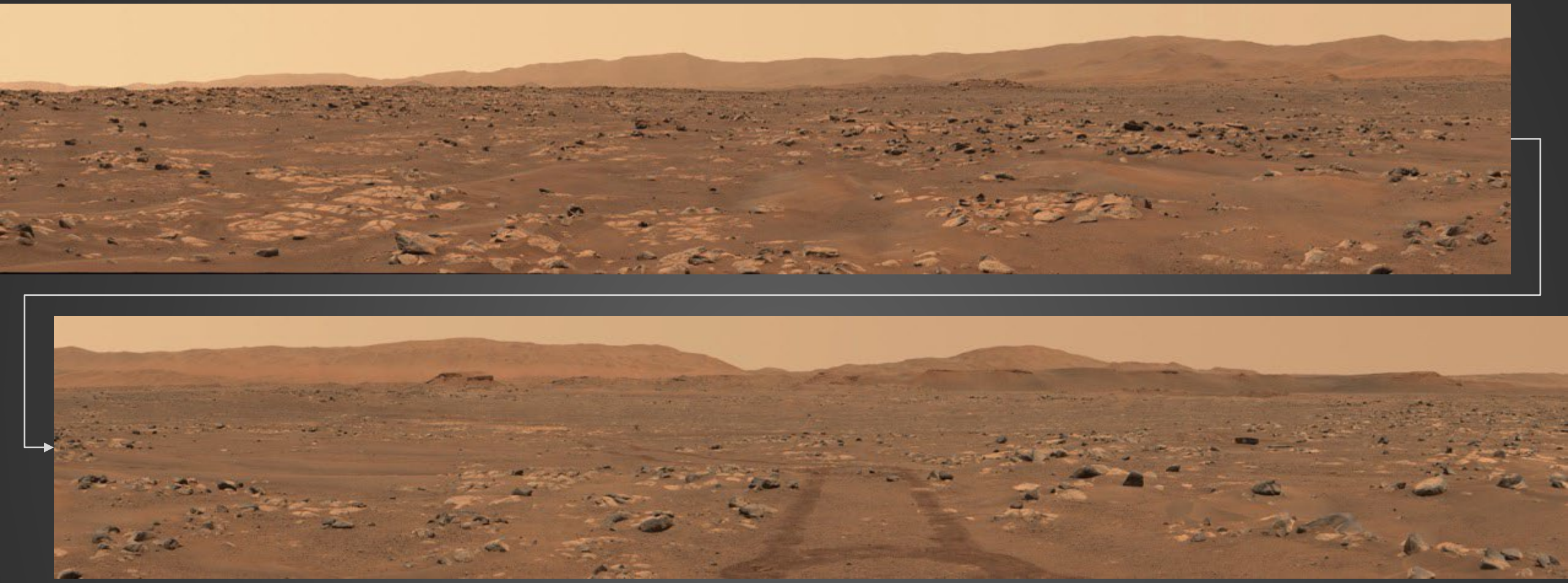



Image taken from the Return to Earth (RTE) camera on Ingenuity during Flight #3. (NASA/JPL-Caltech)

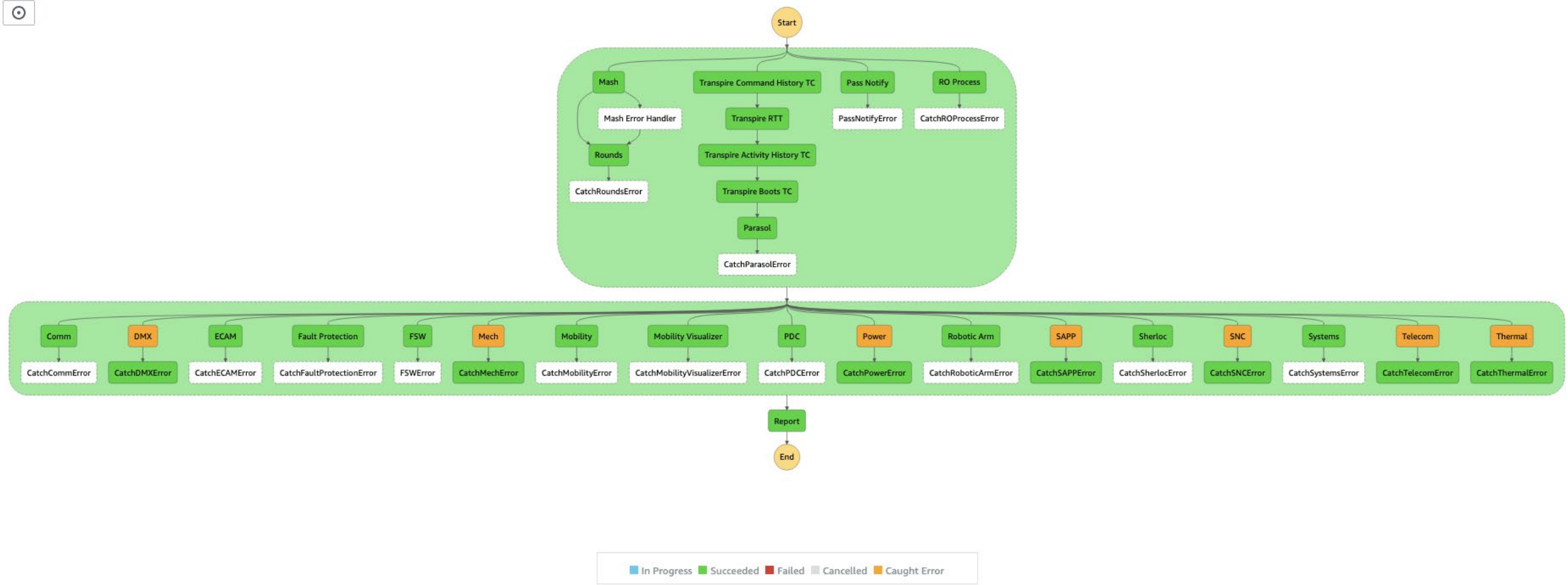


Panorama of the Van Zyl Overlook, from sols 53-64. NASA/JPL-Caltech/ASU/MSSS

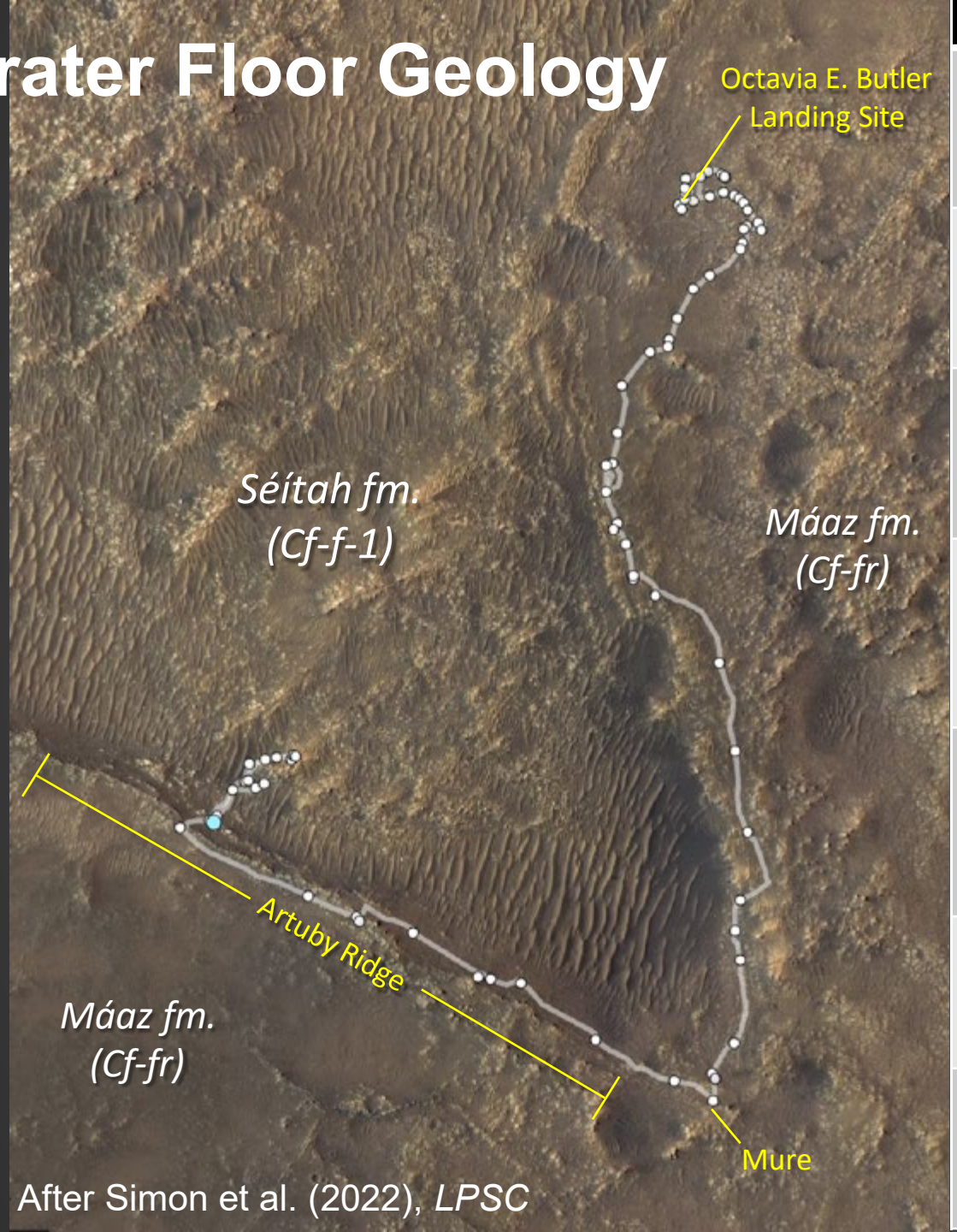
# MRO_M20_2021_274_03-32191

Succeeded

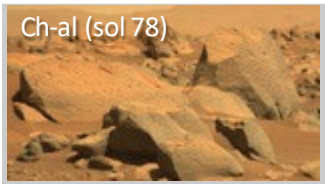
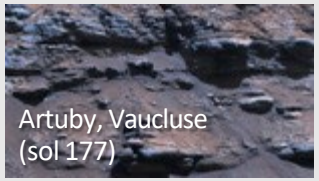
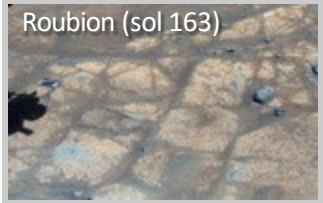
## Visual workflow



# Crater Floor Geology




After Simon et al. (2022), *LPSC*

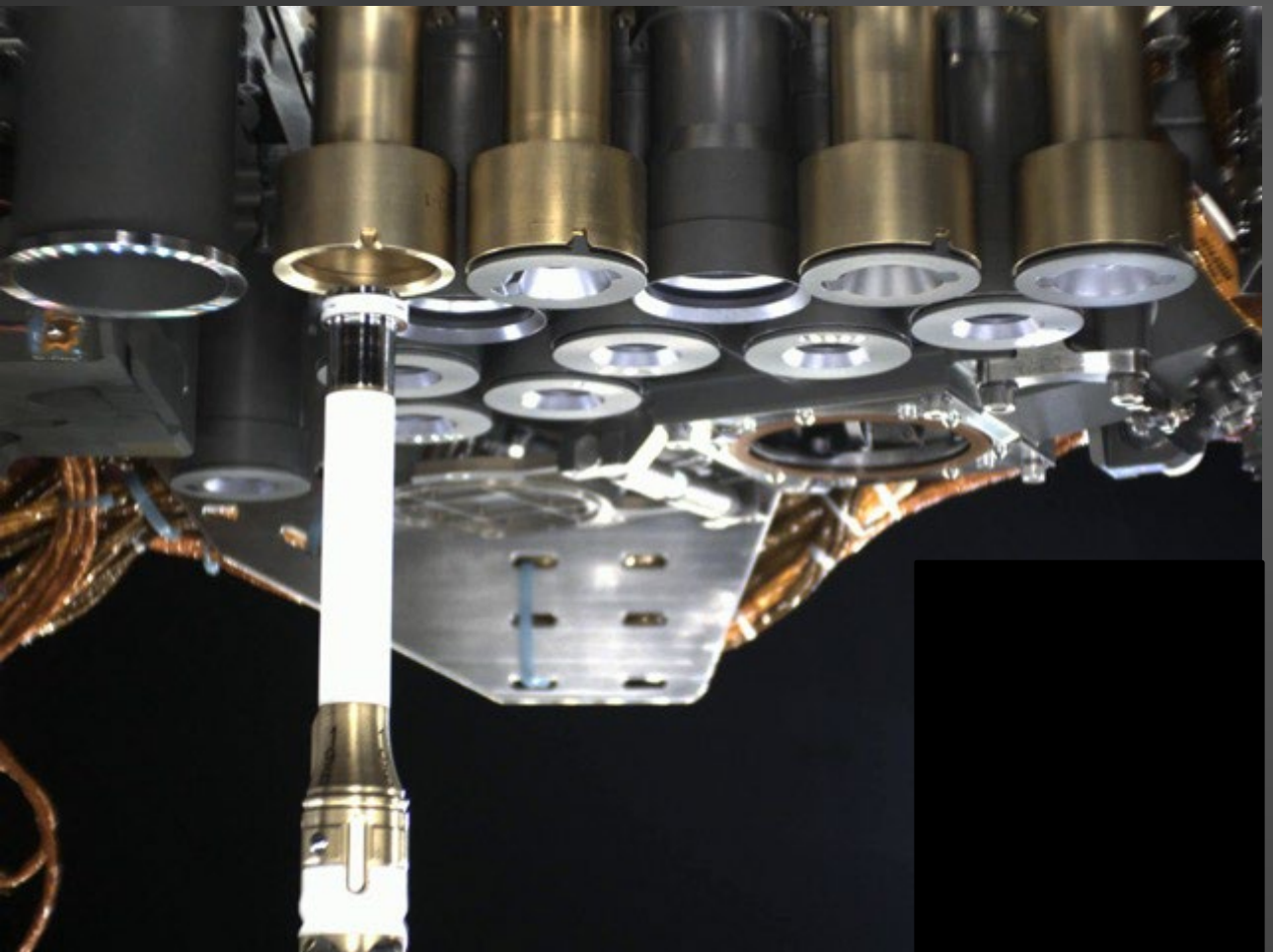
| Member | Description | Type Example |
|---|---|---|
| **Ch'ał** *(Máaz fm)* | Massive, blocky, "hummocky" rocks found predominantly east of OEB |  Ch-al (sol 78) |
| **Nataani** *(Máaz fm)* | Polygonal, low-lying, granular-weathering "pavers" to the south of OEB |  Baa_big_han (sol 66) |
| **Rochette** *(Máaz fm)* | Variably massive to layered to pitted resistant cap rocks along Artuby ridge |  Rochette (sol 197) |
| **Artuby** *(Máaz fm)* | Granular-weathering, layered outcrops observed at Mure and Artuby |  Artuby, Vaucluse (sol 177) |
| **Roubion** *(Máaz fm)* | Polygonal, low-lying, granular-weathering "pavers" in lower elevation Máaz fm |  Roubion (sol 163) |
| **Content** *(Séítah fm)* | Pitted rocks at top of Martre outcrop |  Content (sol 239) |
| **Bastide** *(Séítah fm)* | Layered rocks comprising middle-lower part of Martre outcrop |  Bastide (sol 209) |

Máaz formation

Séítah formation

Front HazCam image of sampling the Ch-al member (*Hahonih*) NASA/JPL-Caltech

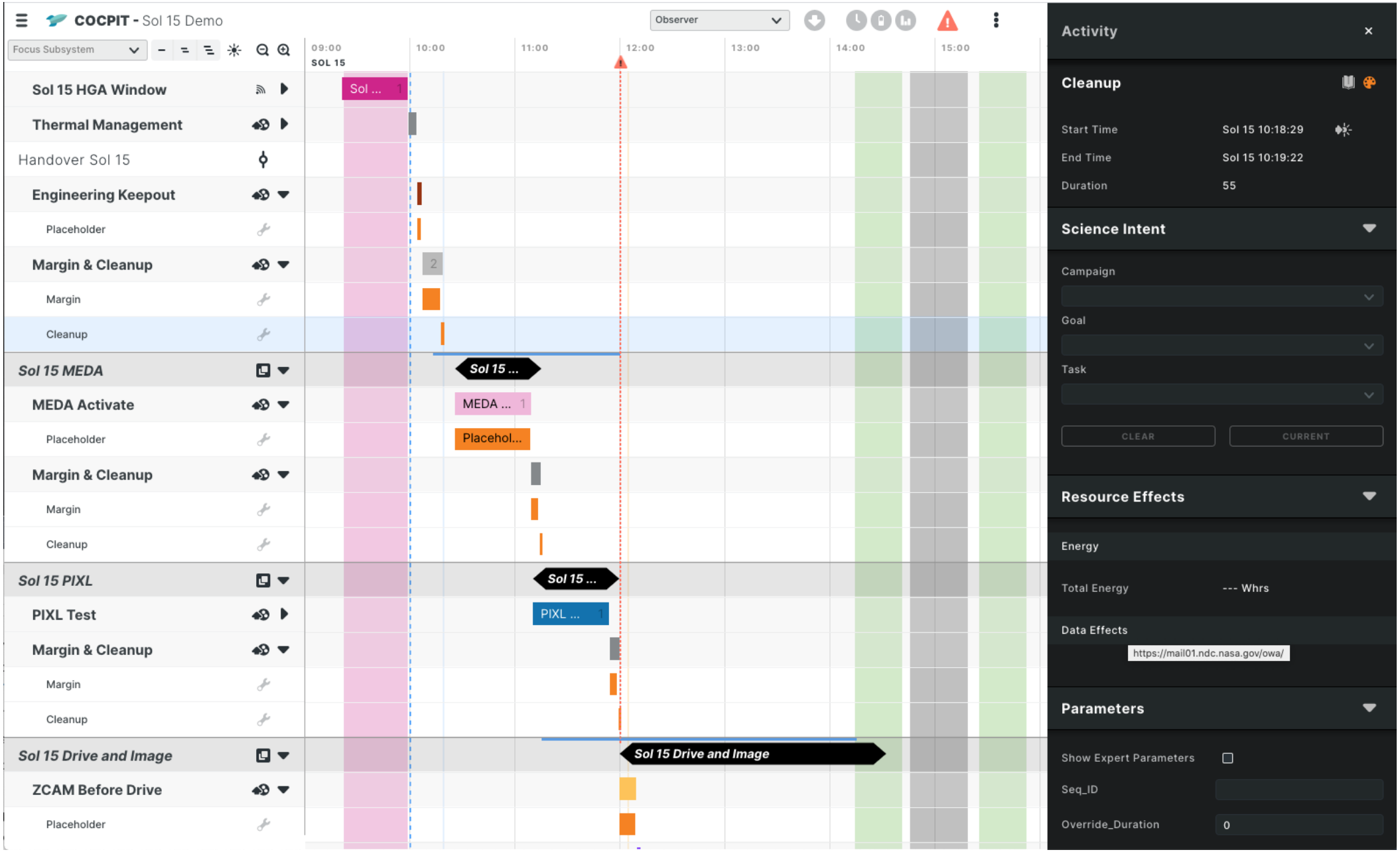

~ 5.5 cm long, 1 cm dia core

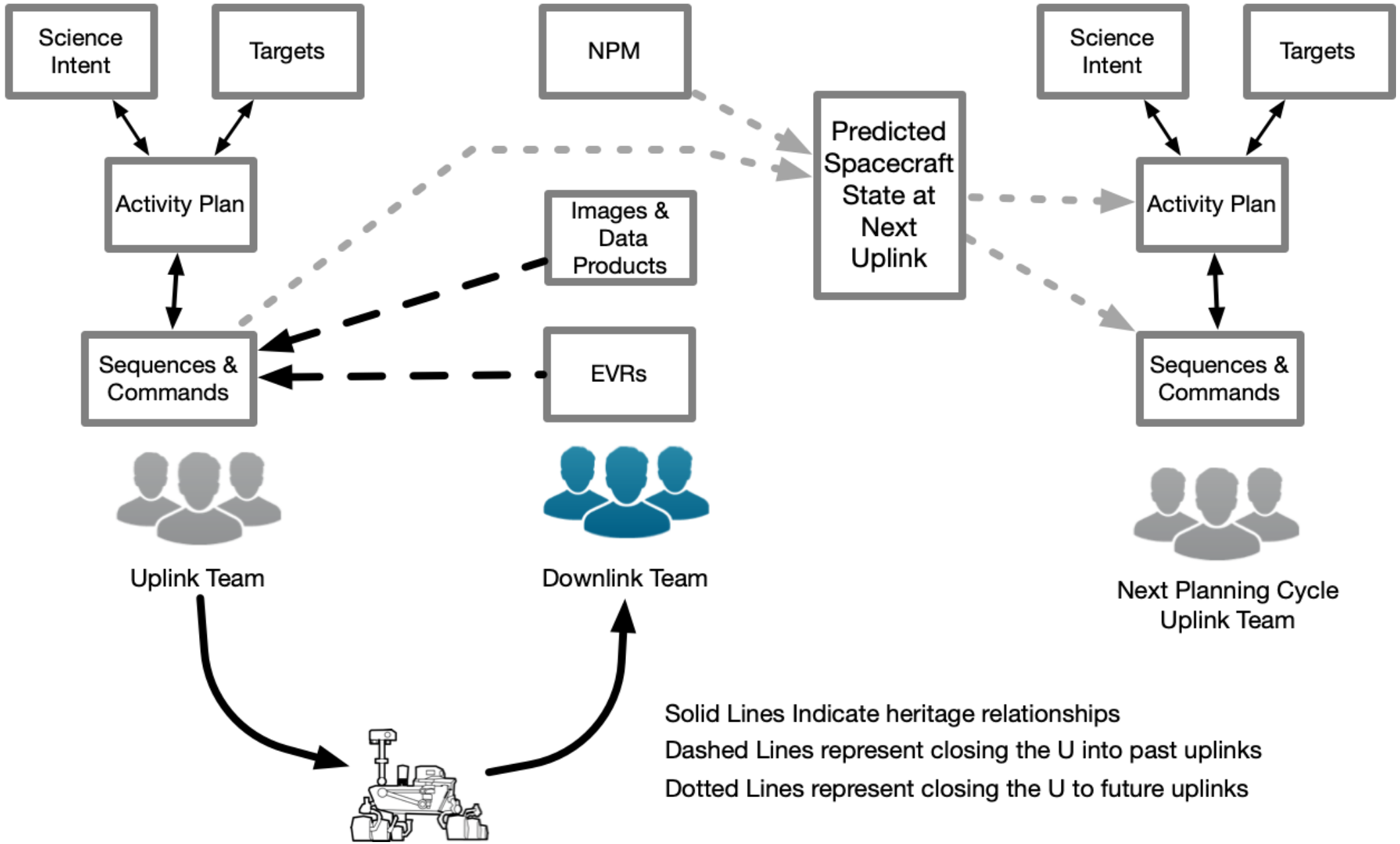


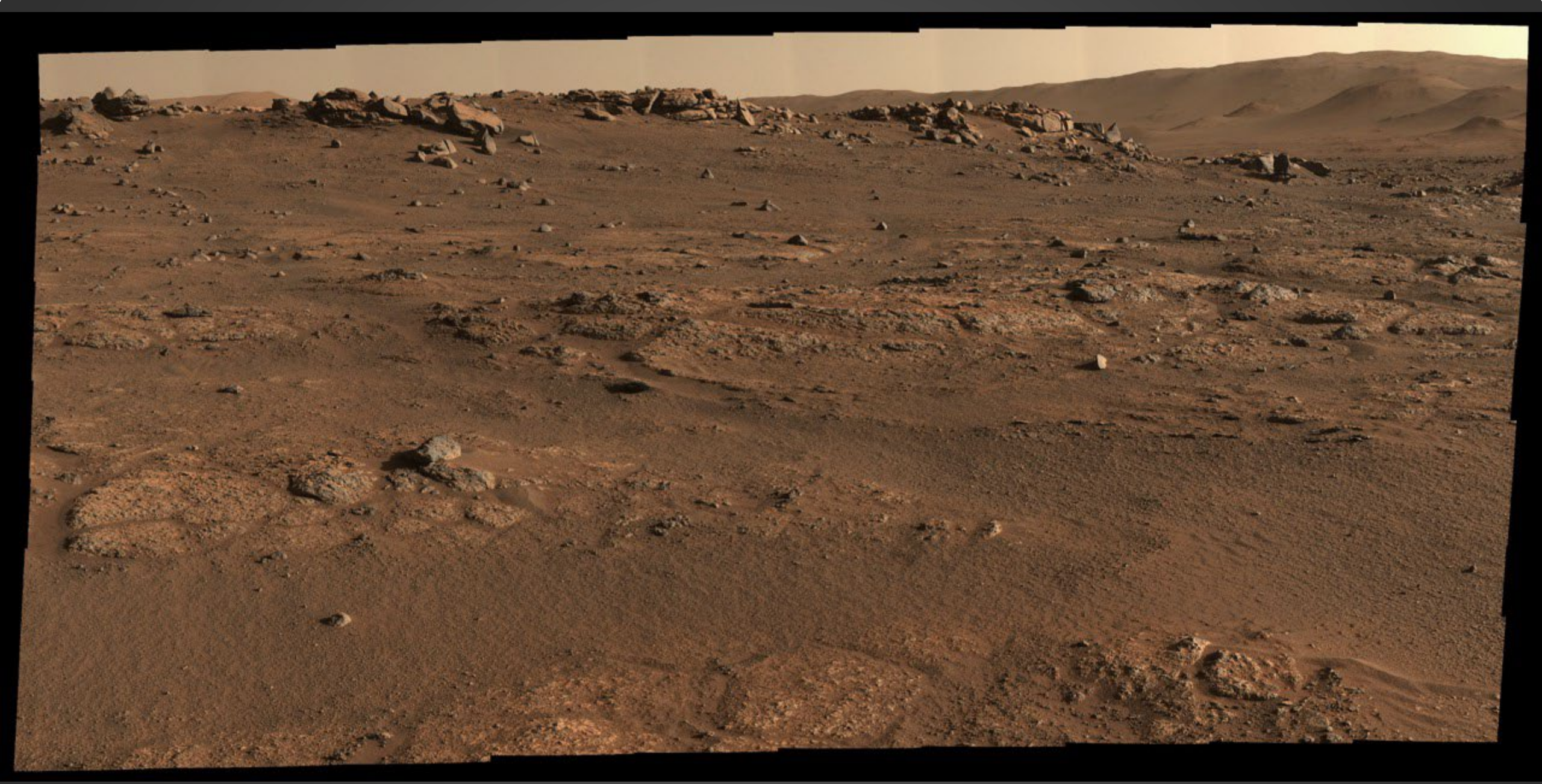
## *Perseverance* carries

- 38 identical sample tubes
  - for rock, regolith, atmosphere
- 5 witness tubes
  - for contamination knowledge

*Of these, 26 tubes have been used so far, including 20 rock samples, 2 regolith samples,1 atmospheric sample, and 3 witness tubes*

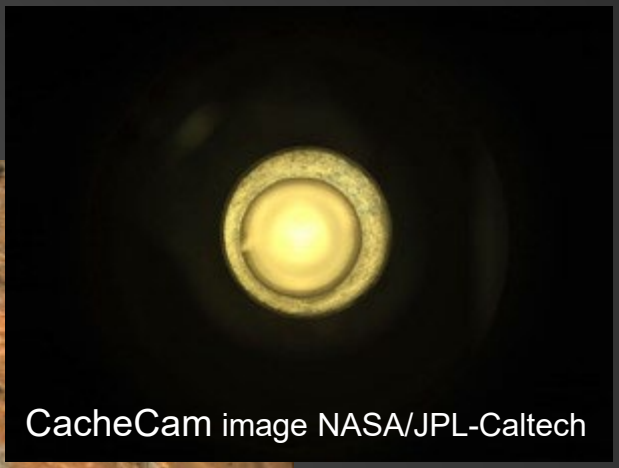

COCPIT - Sol 15 Demo
Observer
Focus Subsystem
09:00
SOL 15
10:00
11:00
12:00
13:00
14:00
15:00
Sol 15 HGA Window
Sol ...
Thermal Management
Handover Sol 15
Engineering Keepout
Placeholder
Margin & Cleanup
Margin
Cleanup
Sol 15 MEDA
Sol 15 ...
MEDA Activate
MEDA ...
Placehol...
Margin & Cleanup
Margin
Cleanup
Sol 15 PIXL
Sol 15 ...
PIXL Test
PIXL ...
Margin & Cleanup
Margin
Cleanup
Sol 15 Drive and Image
Sol 15 Drive and Image
ZCAM Before Drive
Placeholder
Activity
Cleanup
Start Time
Sol 15 10:18:29
End Time
Sol 15 10:19:22
Duration
55
Science Intent
Campaign
Goal
Task
CLEAR
CURRENT
Resource Effects
Energy
Total Energy
--- Whrs
Data Effects
https://mail01.ndc.nasa.gov/owa/
Parameters
Show Expert Parameters
Seq_ID
Override_Duration
0


Science Intent
Targets
Activity Plan
Sequences & Commands
NPM
Images & Data Products
EVRs
Predicted Spacecraft State at Next Uplink
Science Intent
Targets
Activity Plan
Sequences & Commands
Uplink Team
Downlink Team
Next Planning Cycle Uplink Team
Solid Lines Indicate heritage relationships
Dashed Lines represent closing the U into past uplinks
Dotted Lines represent closing the U to future uplinks



Panorama of first coring attempt location, from sol 155. NASA/JPL-Caltech/ASU/MSSS

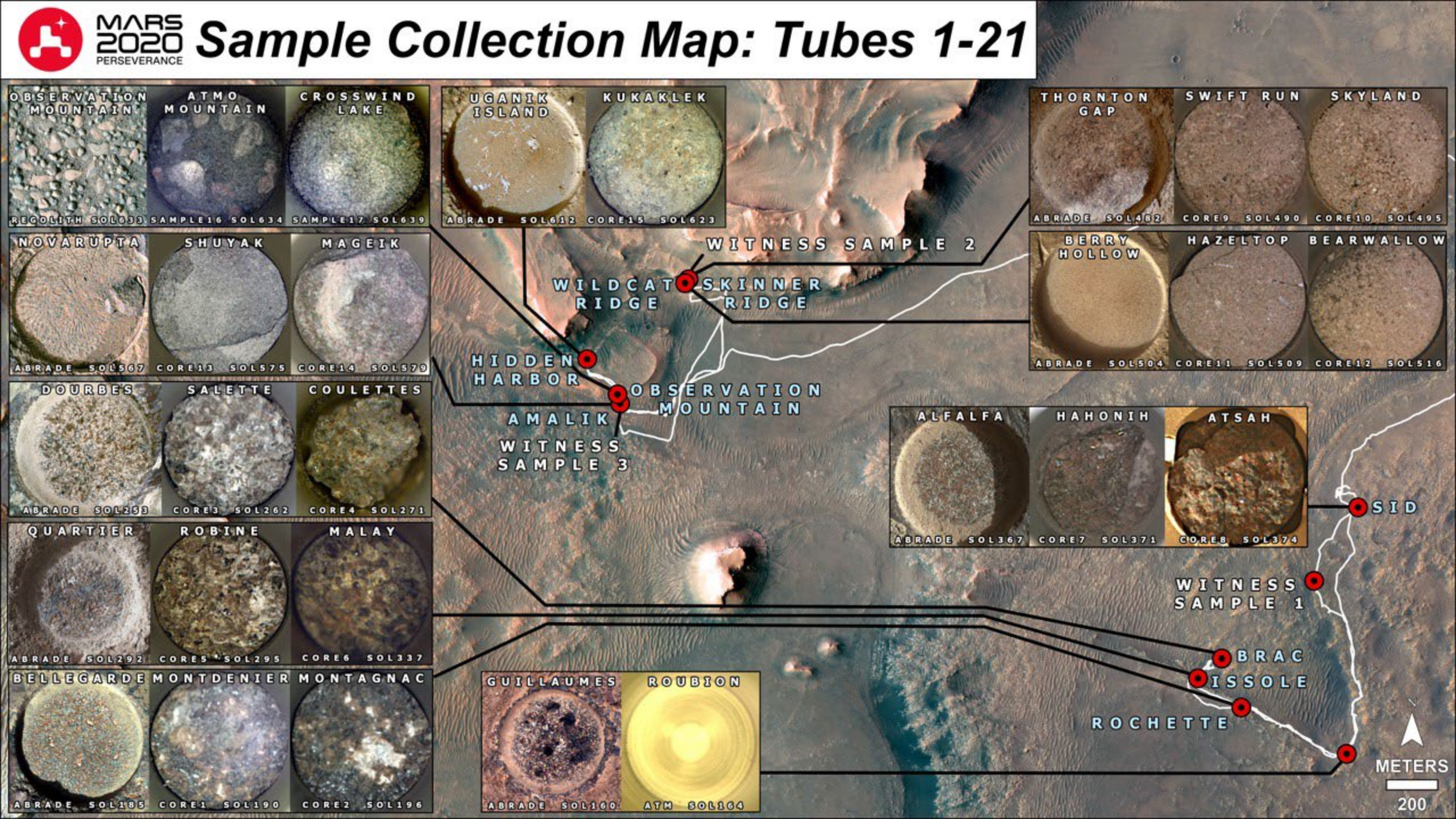
# Sample #1: target “Roubion”



CacheCam image NASA/JPL-Caltech

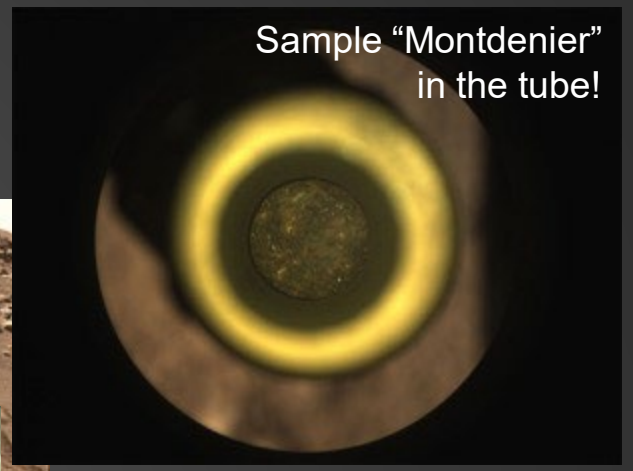
Front HazCam image from Aug 6, 2021
NASA/JPL-Caltech

# MARS 2020 PERSEVERANCE Sample Collection Map: Tubes 1-21



# Sample #2: target “Rochette”





Sample “Montdenier” in the tube!

NASA/JPL-Caltech

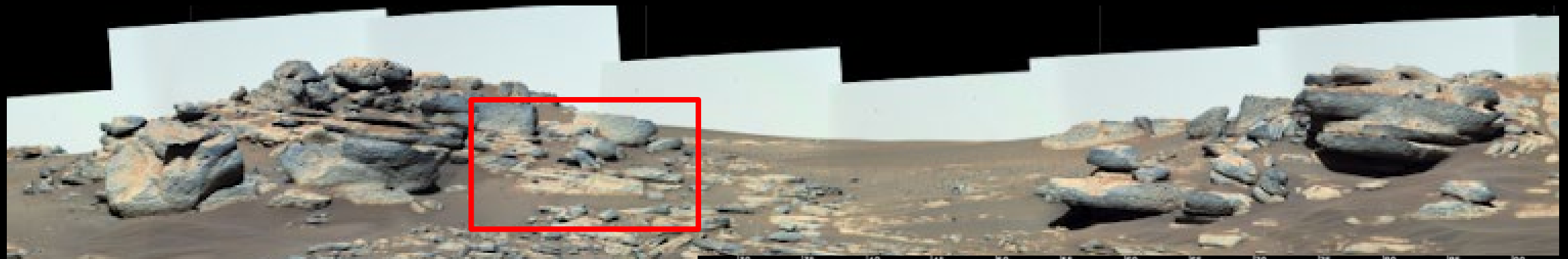
# Sample #3: target “Rochette”

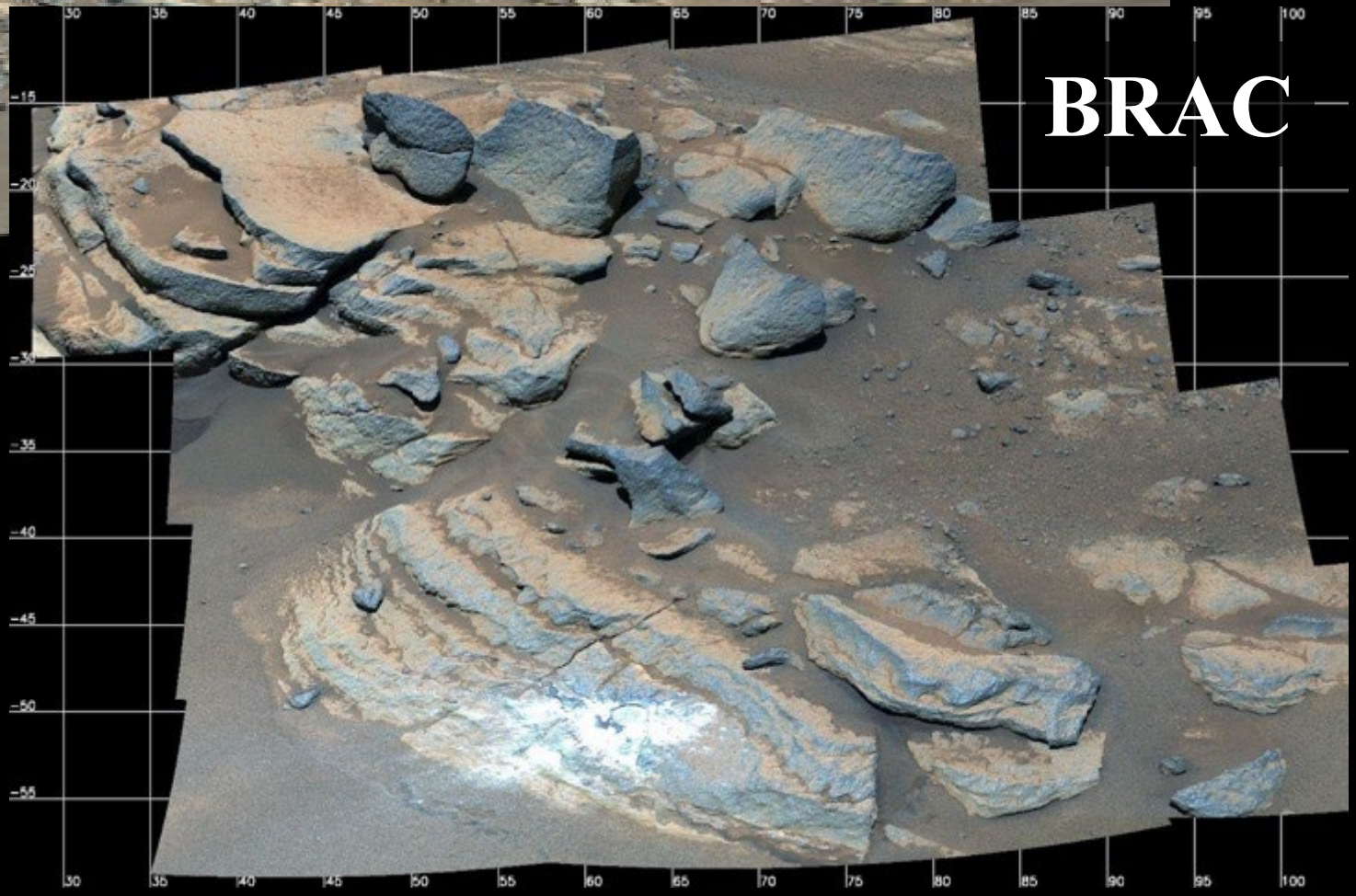


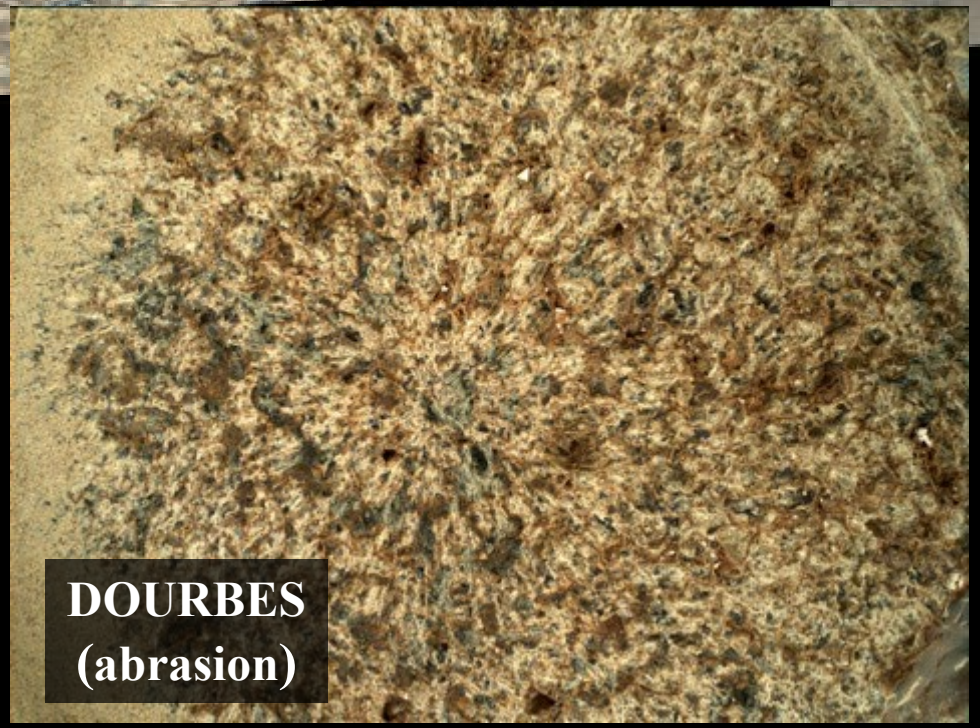


Sample “Montagnac”
in the tube!

NASA/JPL-Caltech



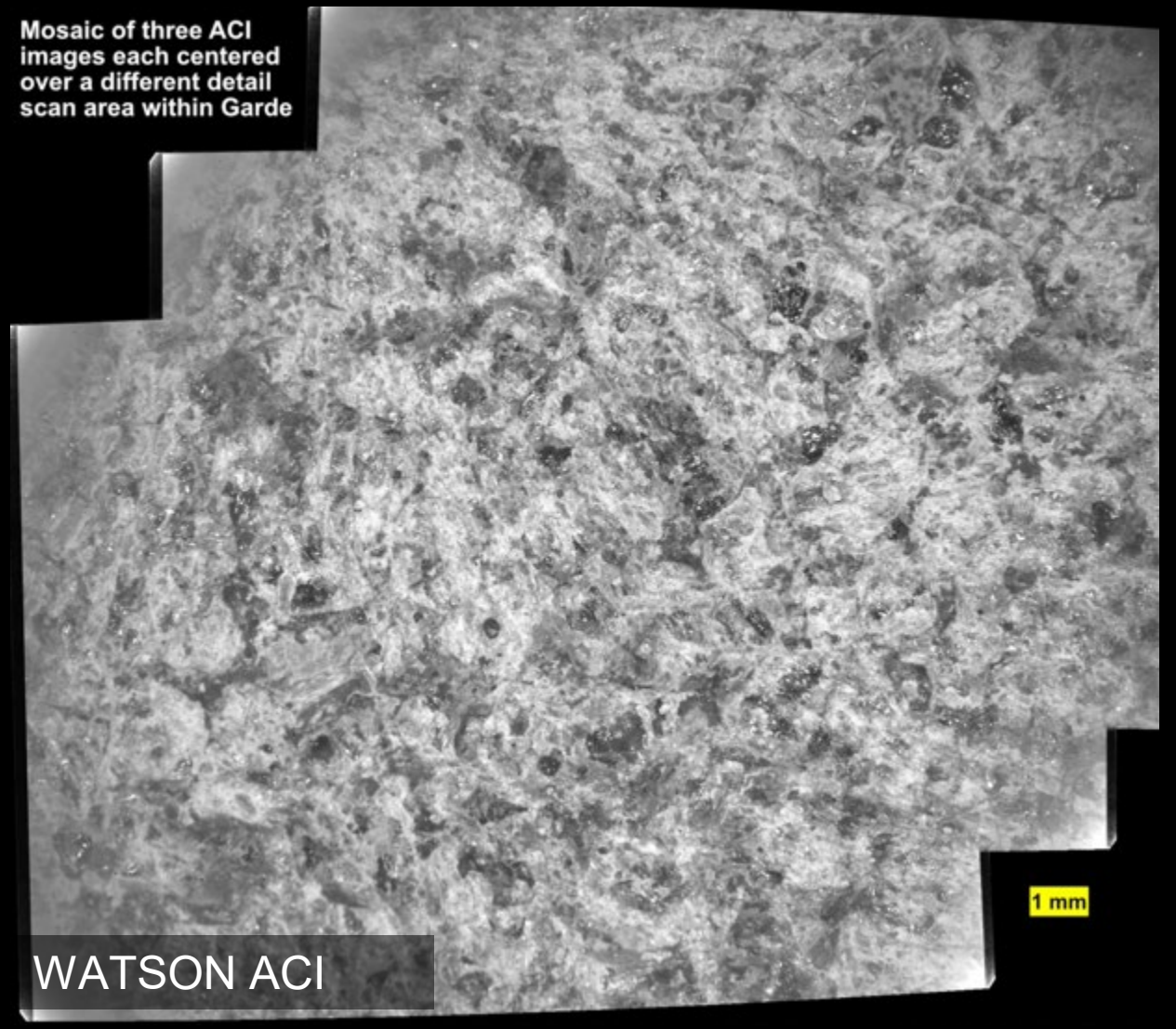



After Hickman-Lewis et al. (2022), *LPSC*

SuperCam RMI

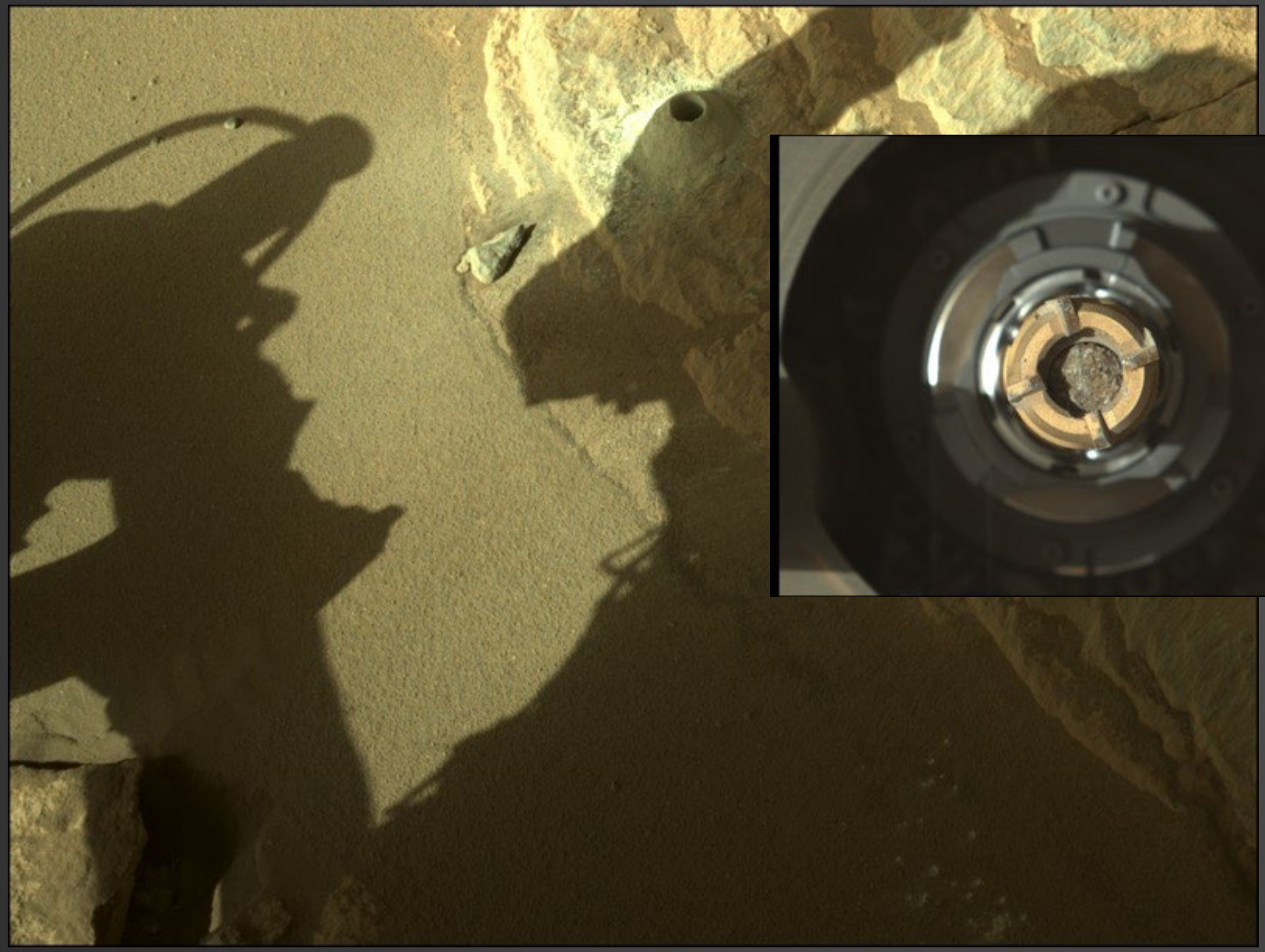

Abundant olivine grains visible in the SuperCam RMIs of relatively fresh surfaces on most Séítah outcrops.




Interlocking crystalline texture with rich mineralogical heterogeneity observed in abraded patches.

After Hickman-Lewis et al. (2022), *LPSC*

# Sample #4: target “Brac”





Sample “Salette”
in the tube!

NASA/JPL-Caltech

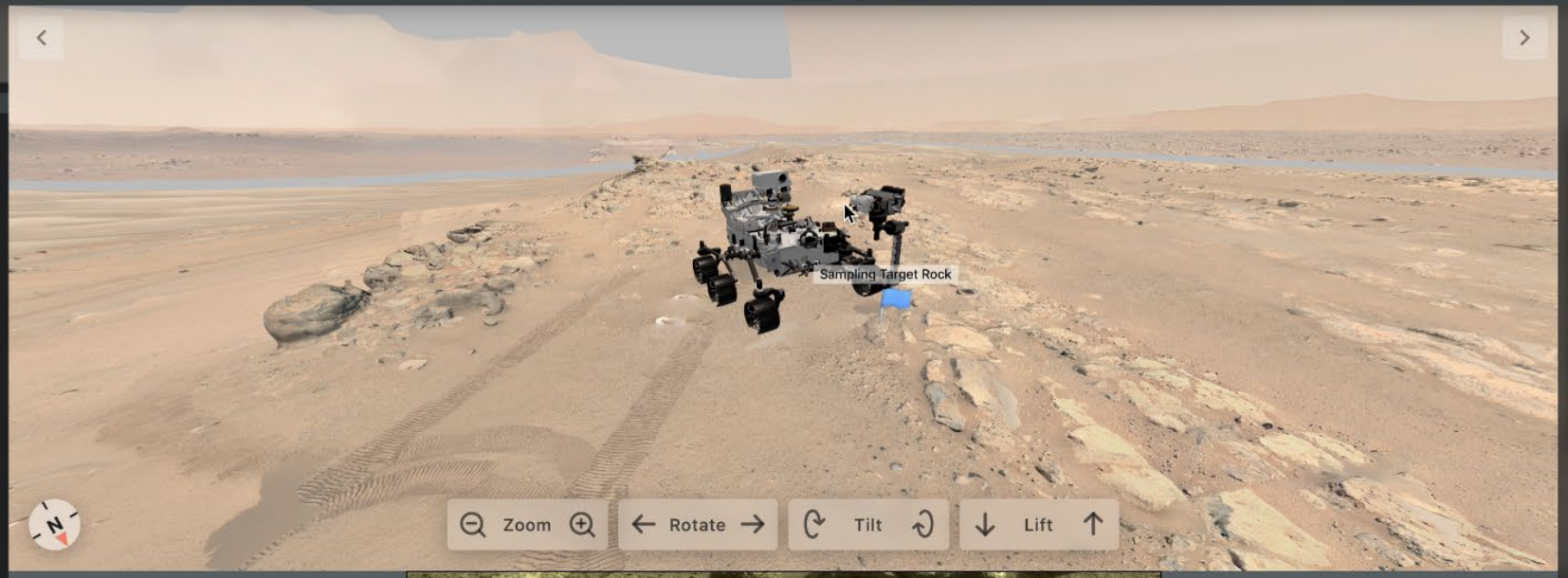
Explore with Perseverance

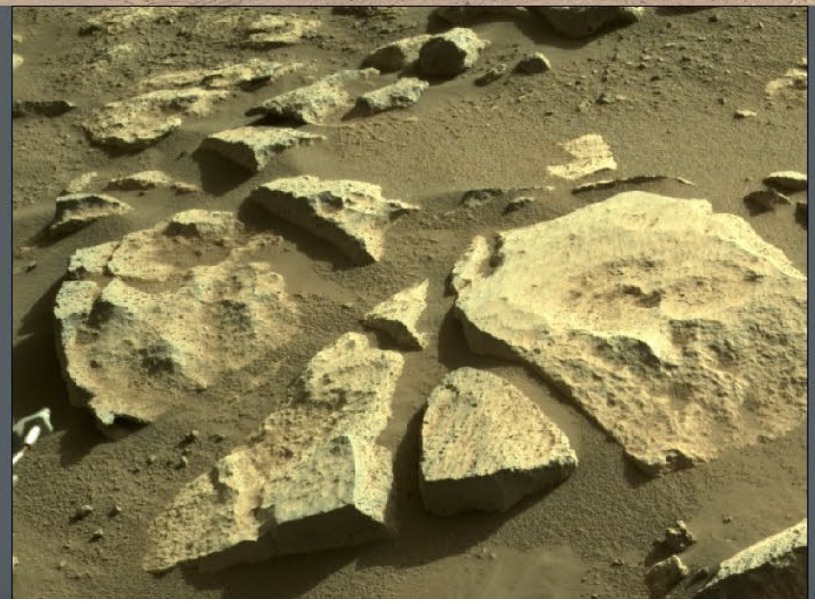
3D Terrain | Images | Split Screen

About | Sols 180 - 196

**Images** 1462

Navigation Camera



L

R

## First and Second Rock Coring Site

Open map view

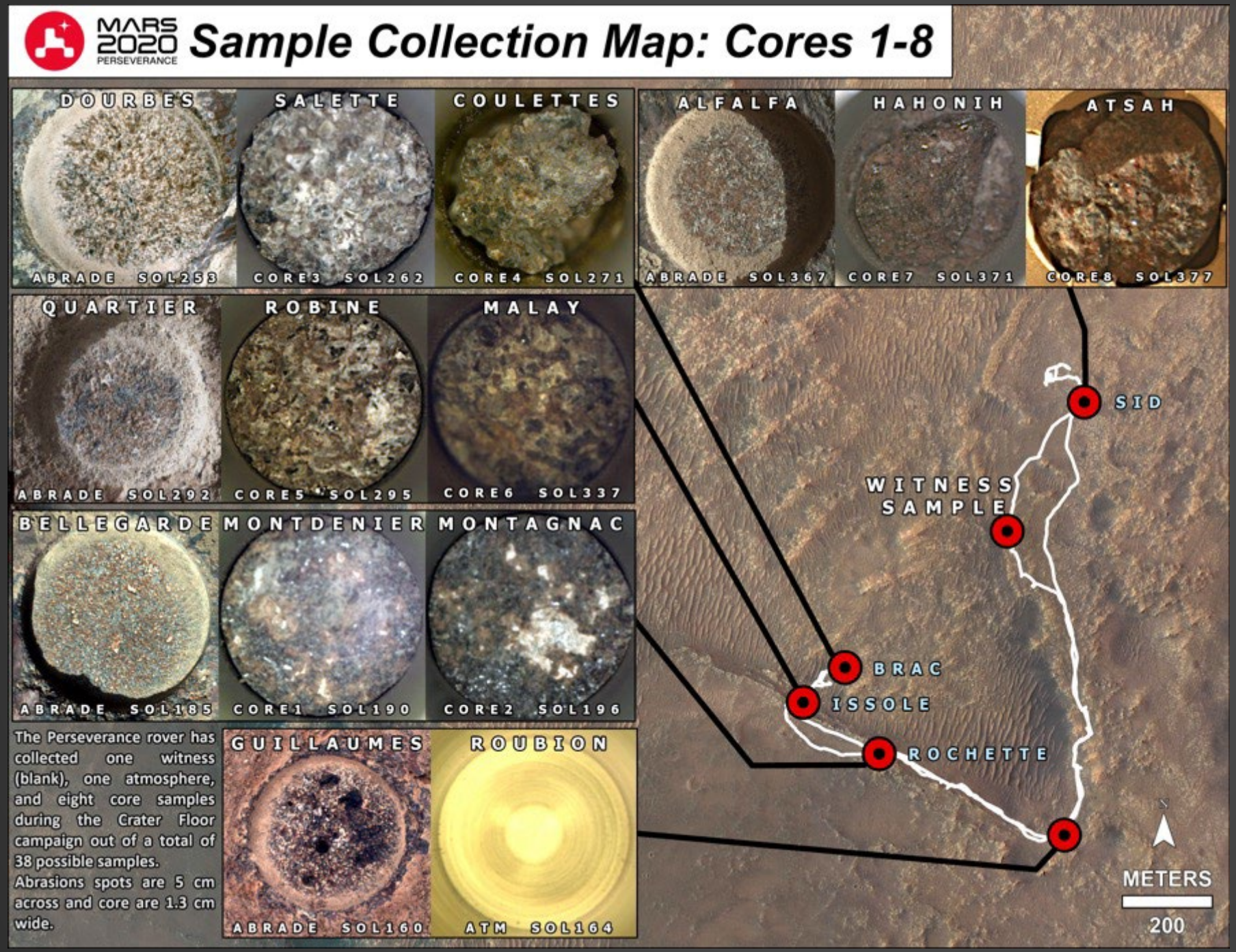
**Points of interest**

- Sampling Target Rock

**About**

History was made at this location, nicknamed "Citadelle." Here Perseverance collected its first two core samples from a rocky ridge overlooking a field of dunes. The rocks at this location were less weathered than at the rover's first drill site, making it possible to collect intact cores.

See other locations




## Máaz samples:

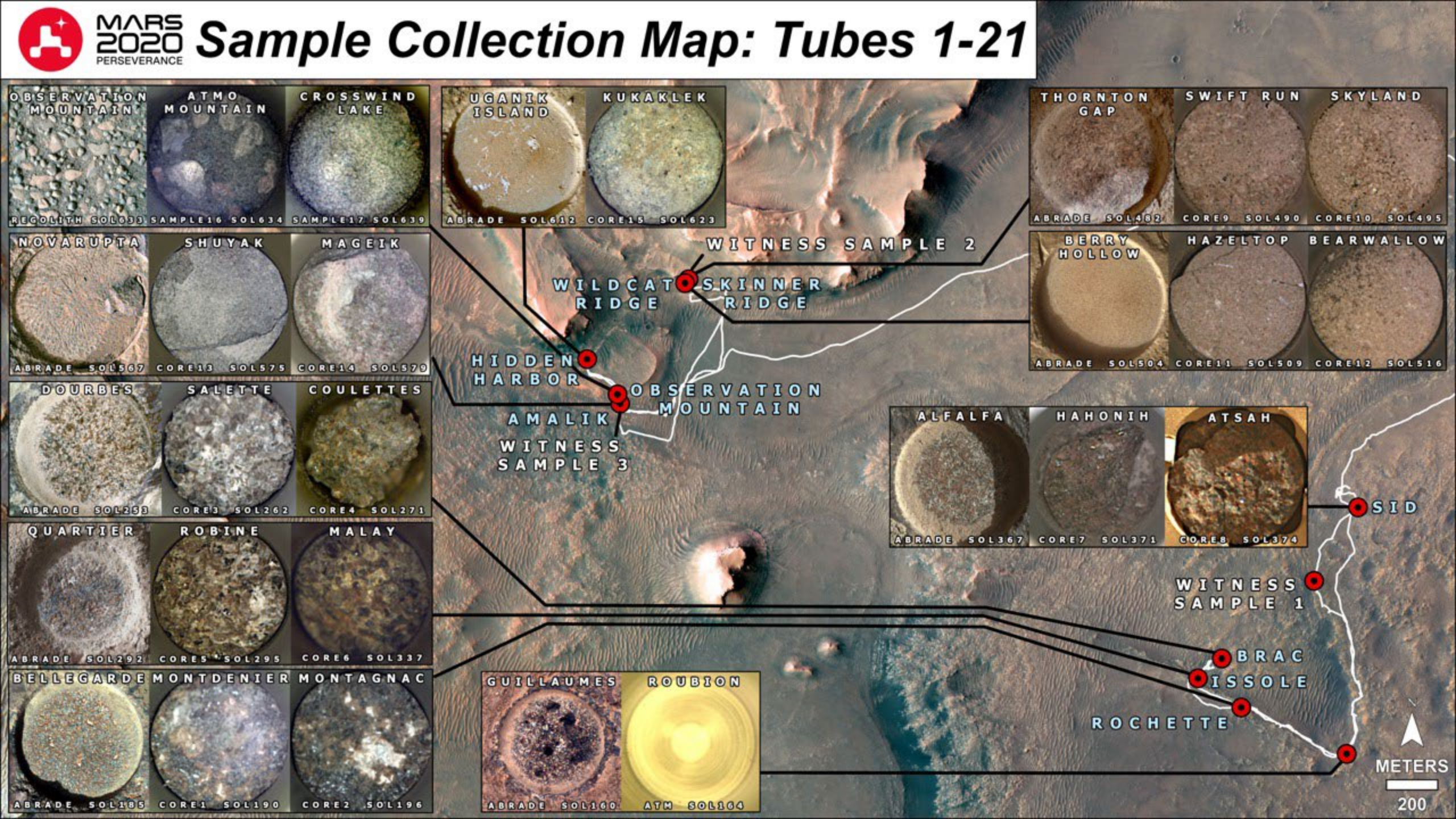
**Igneous**; lava flows with evidence for **alteration by water**

## Séítah samples:

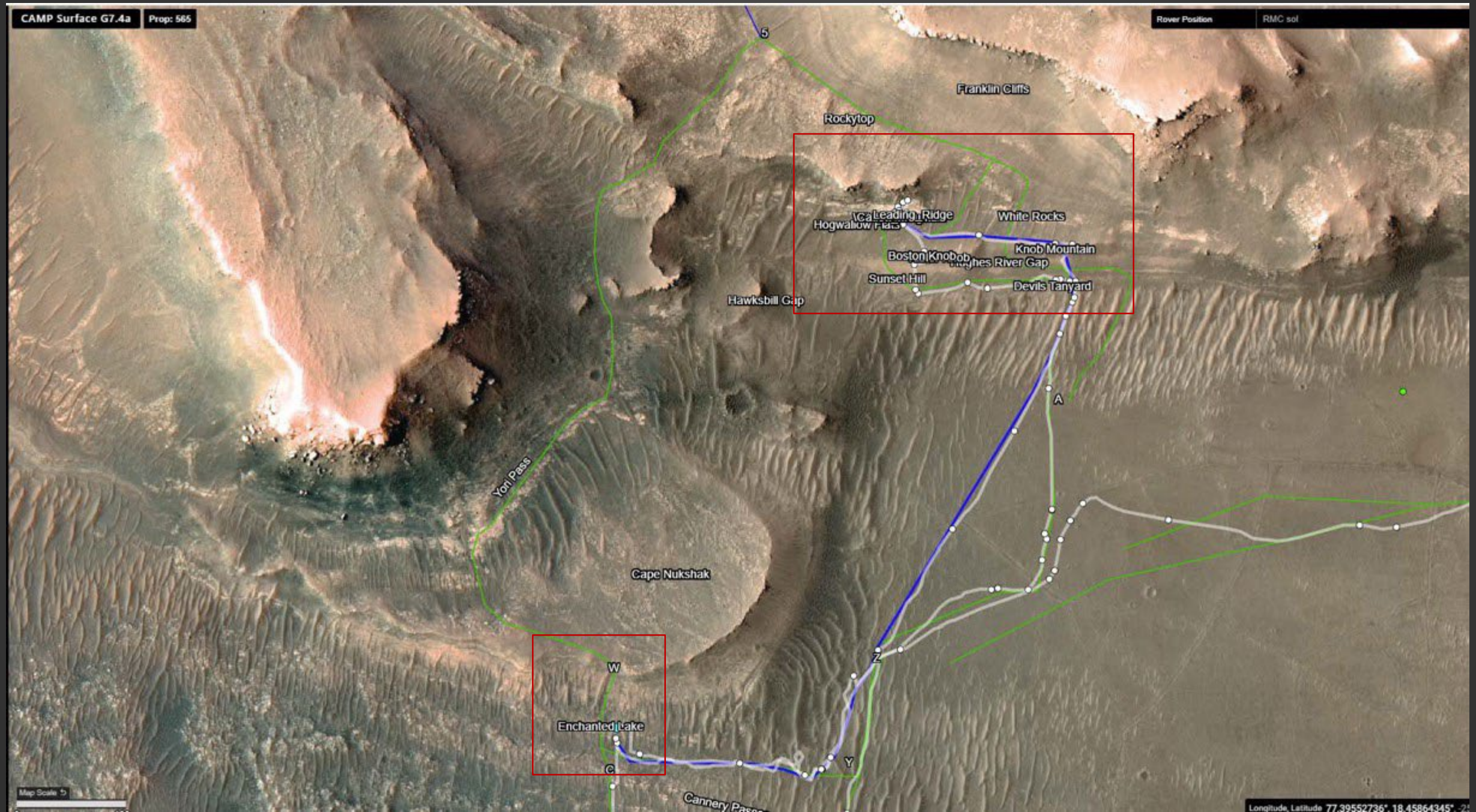
**Igneous**; with evidence for **alteration by water**

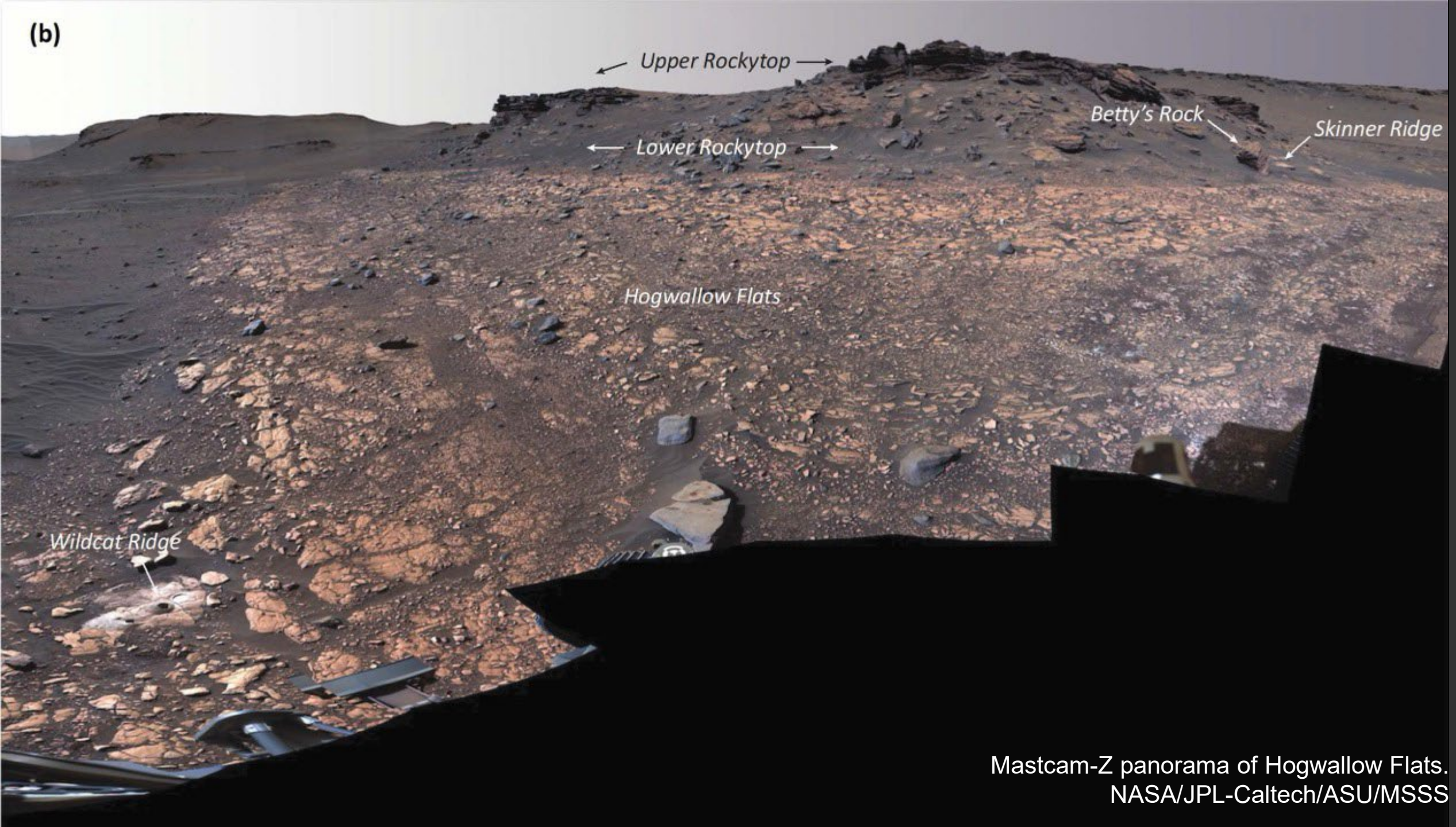
F. Calef/NASA/JPL-Caltech

# MARS 2020 PERSEVERANCE Sample Collection Map: Tubes 1-21



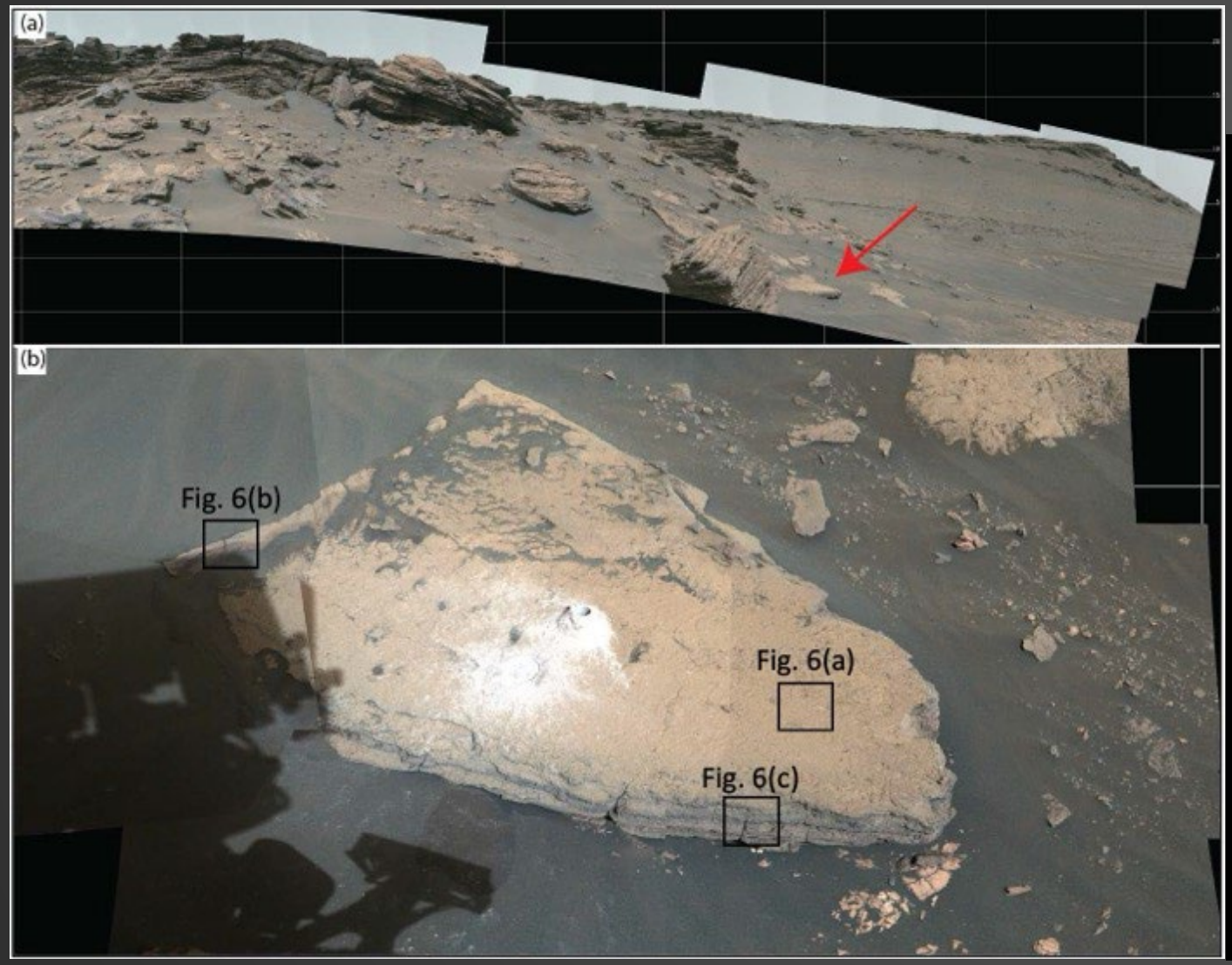
# Delta Front Campaign






Mastcam-Z panorama of Hogwallow Flats.
NASA/JPL-Caltech/ASU/MSSS

# **Skinner Ridge:** Fine/medium-grained, poorly-sorted sandstone

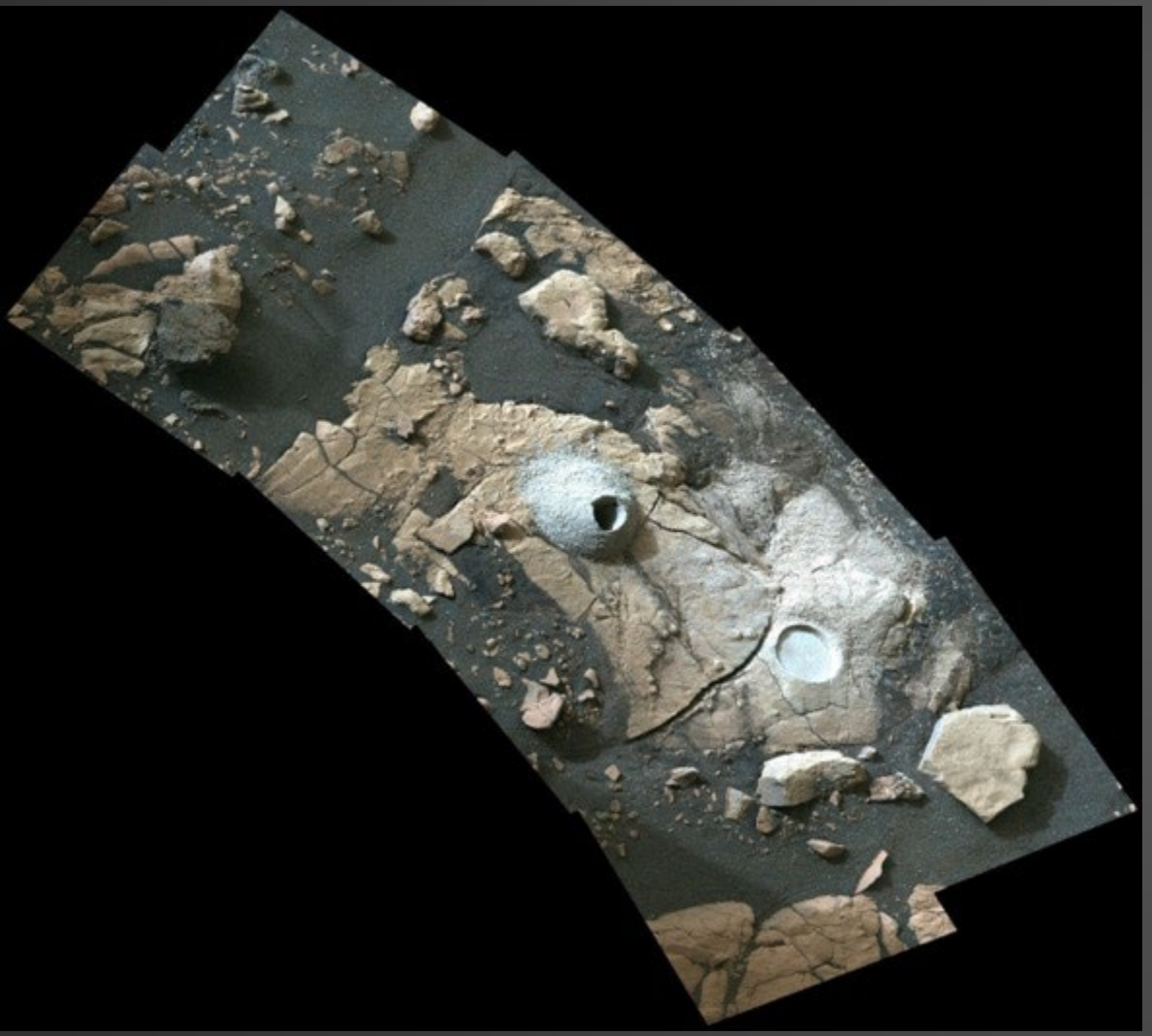



Mastcam-Z images of Rocky Top and Skinner Ridge.
NASA/JPL-Caltech/ASU/MSSS

**Samples:** ***Skyland, Swift Run***

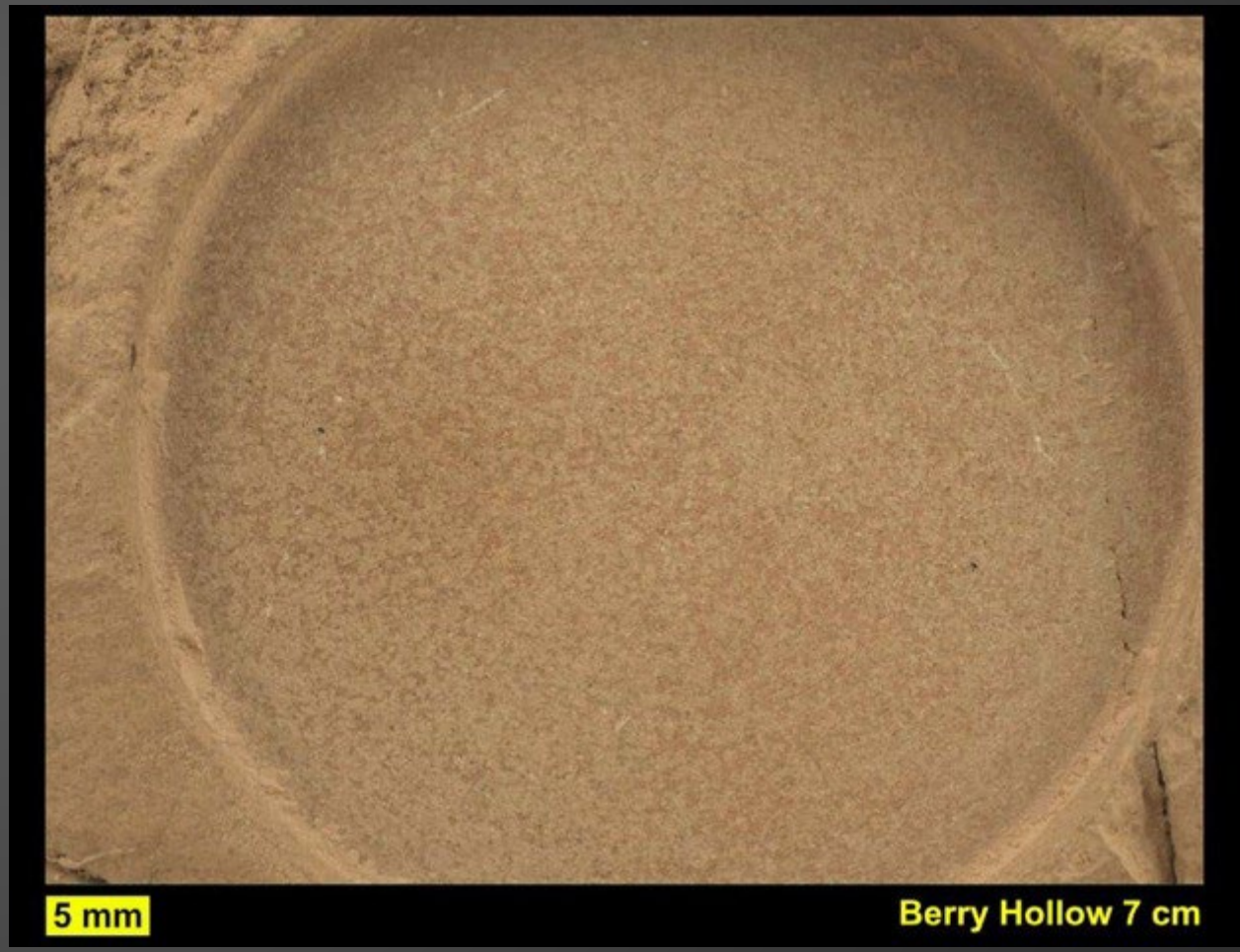

WATSON image of Thornton Gap abrasion.
NASA/JPL-Caltech

## **Wildcat Ridge:** sulfate-rich mudstone



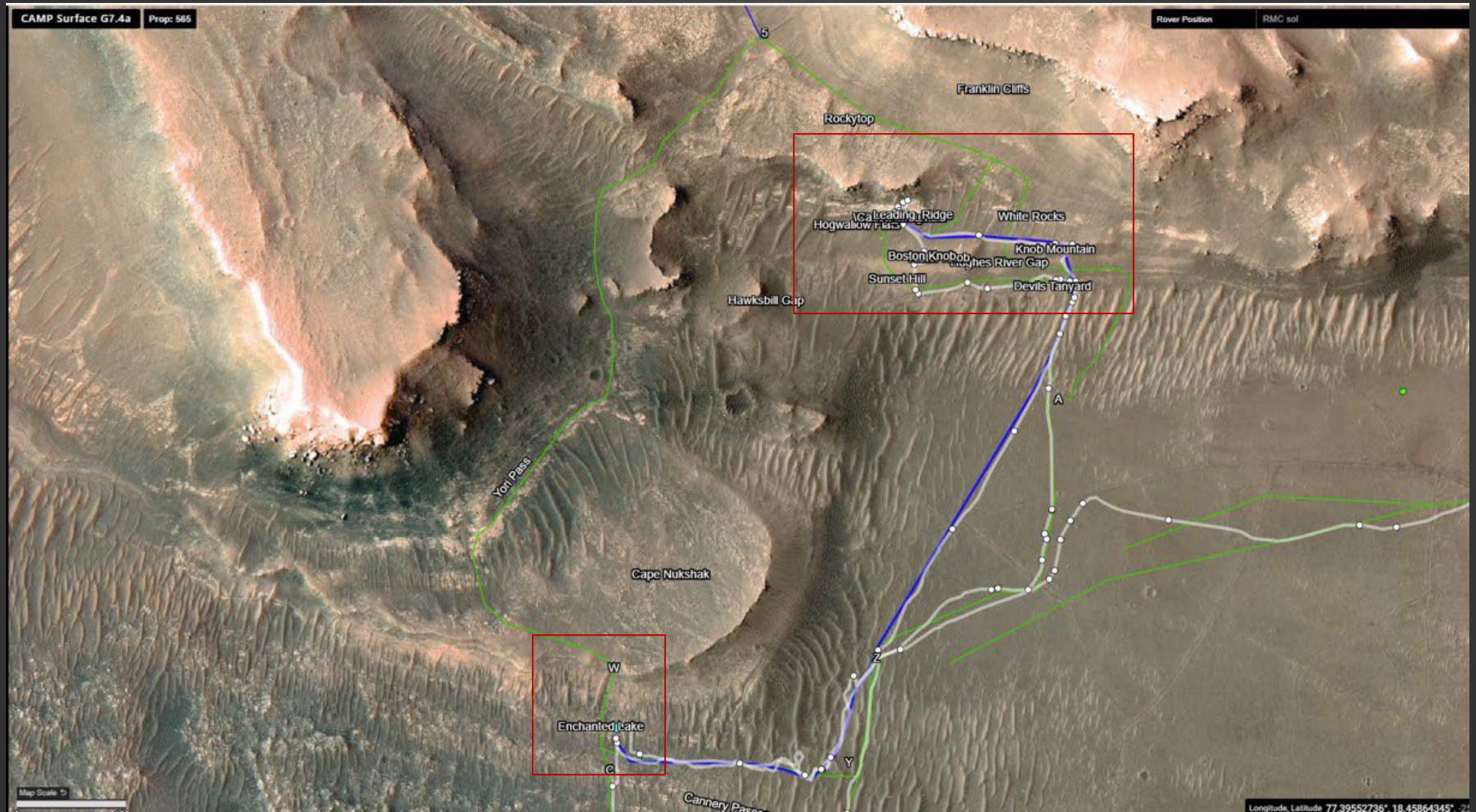
Mastcam-Z image of Wildcat Ridge, with Berry Hollow abrasion and the core hole from the Hazeltop sample. NASA/JPL-Caltech/ASU/MSSS

**Samples: *Hazeltop, Bearwallow***




WATSON image of Berry Hollow abrasion. NASA/JPL-Caltech

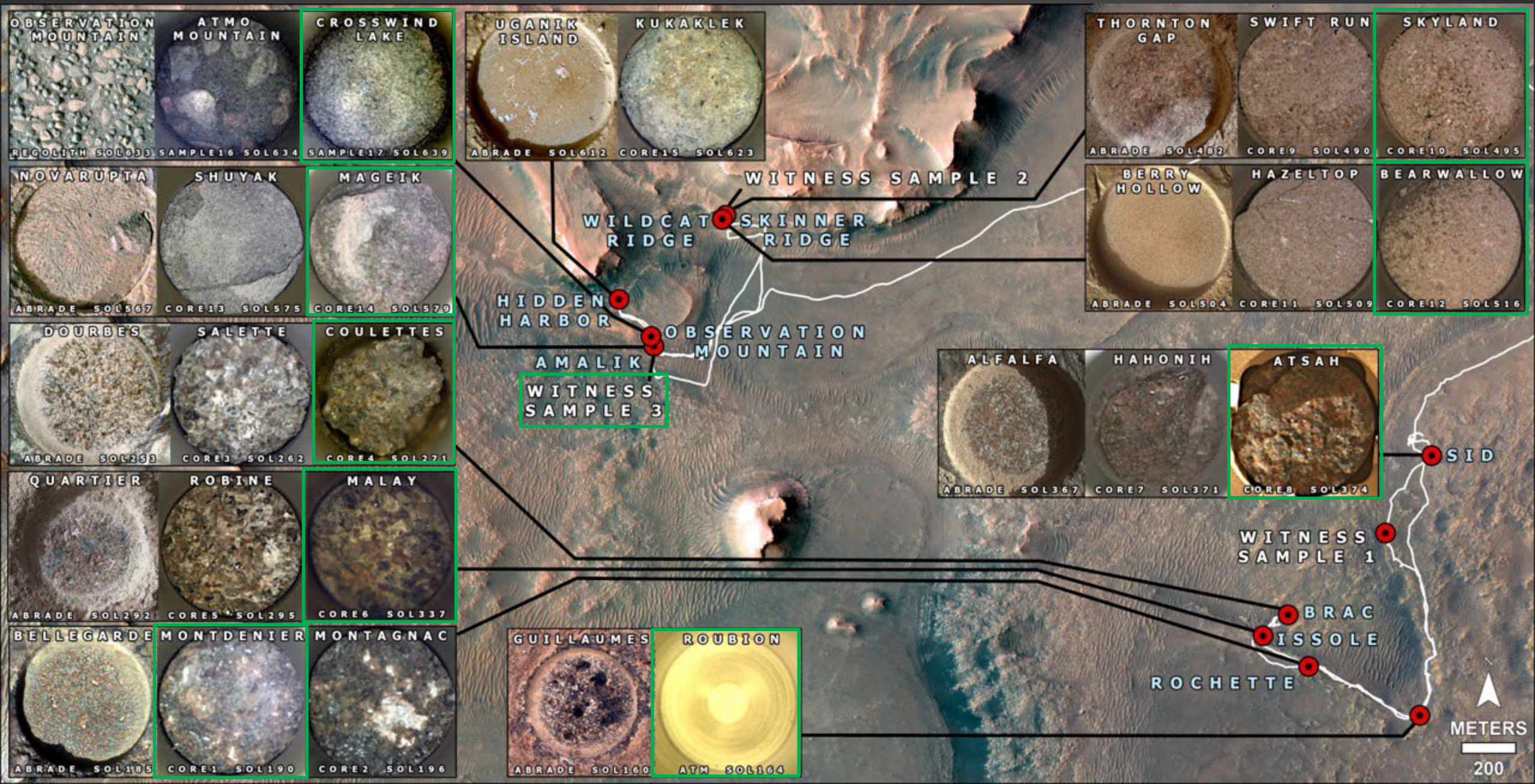
# Delta Front Campaign



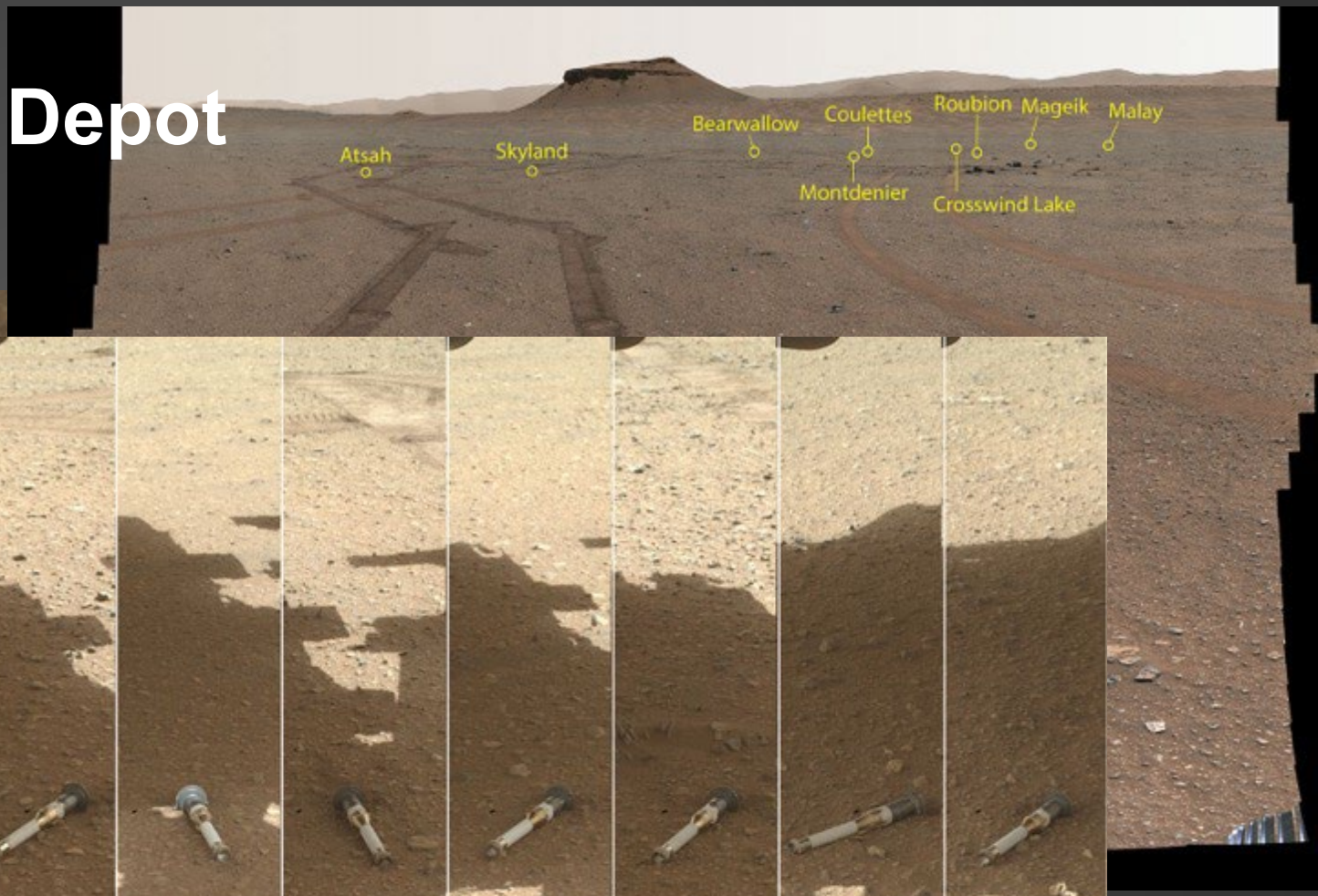
# River Deltas Are Habitable Environments

Alaska runoff, NOAA

# Backup depot construction



# The Three Forks Sample Depot



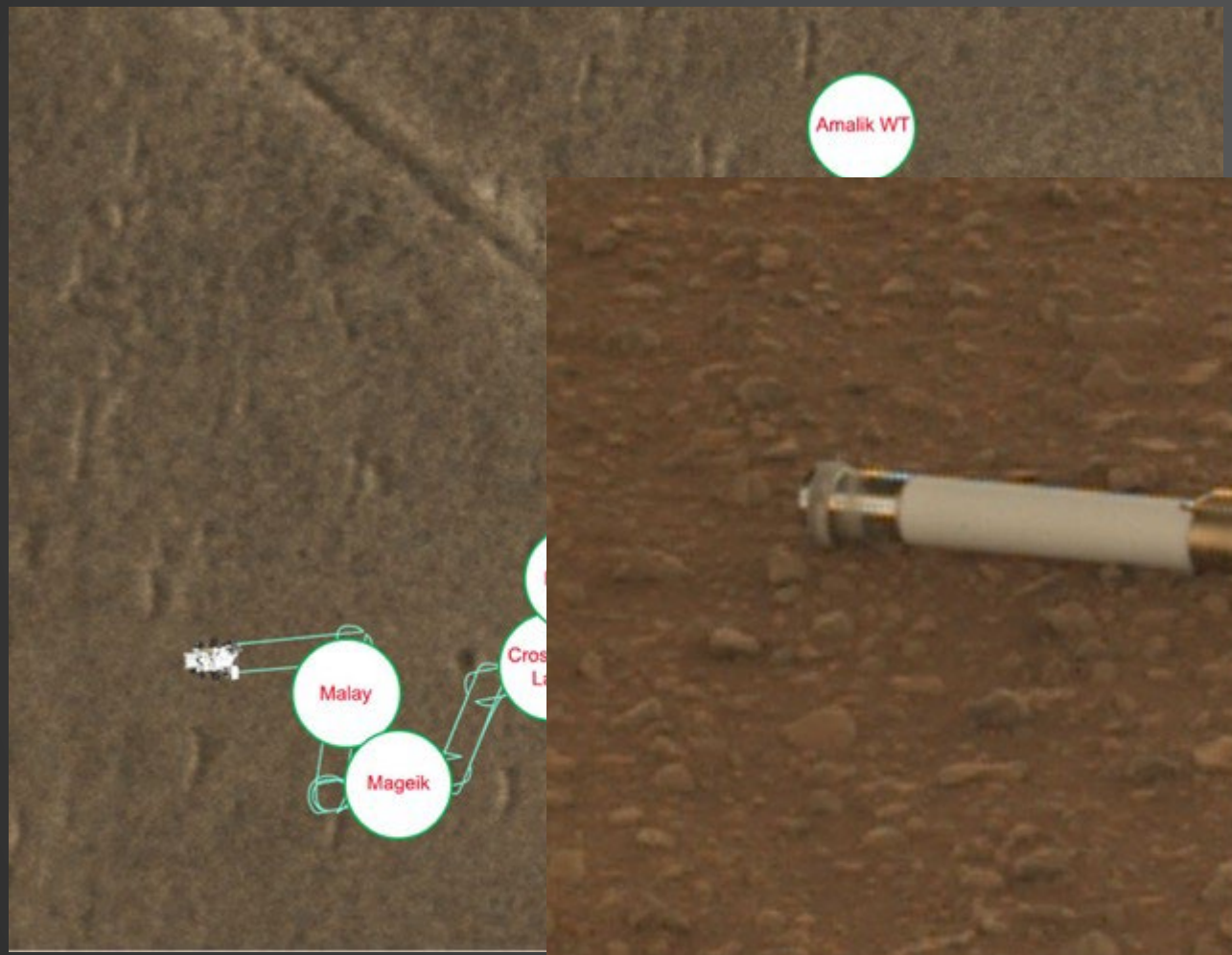


NASA/JPL-Caltech

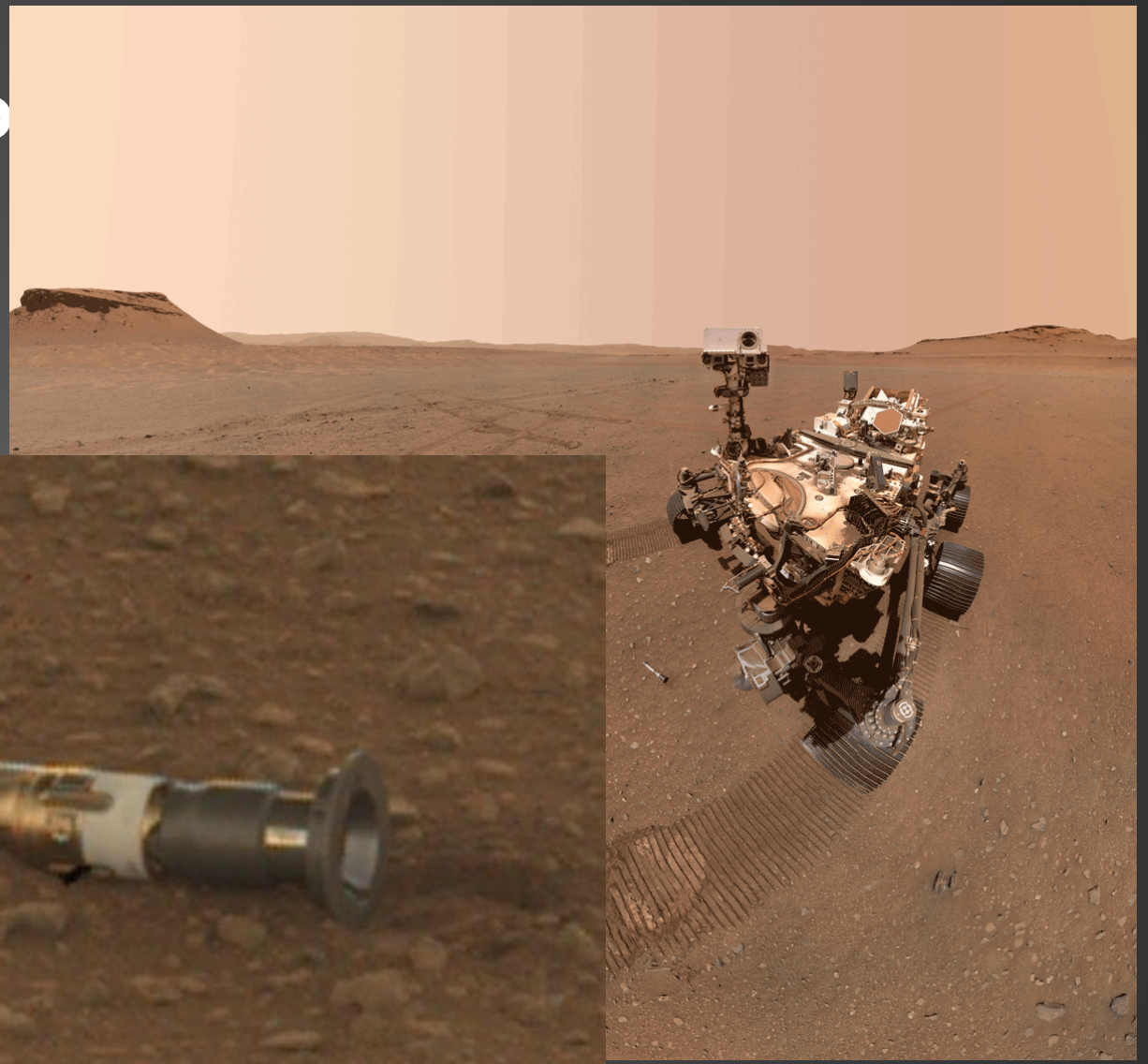


SU/MSSS

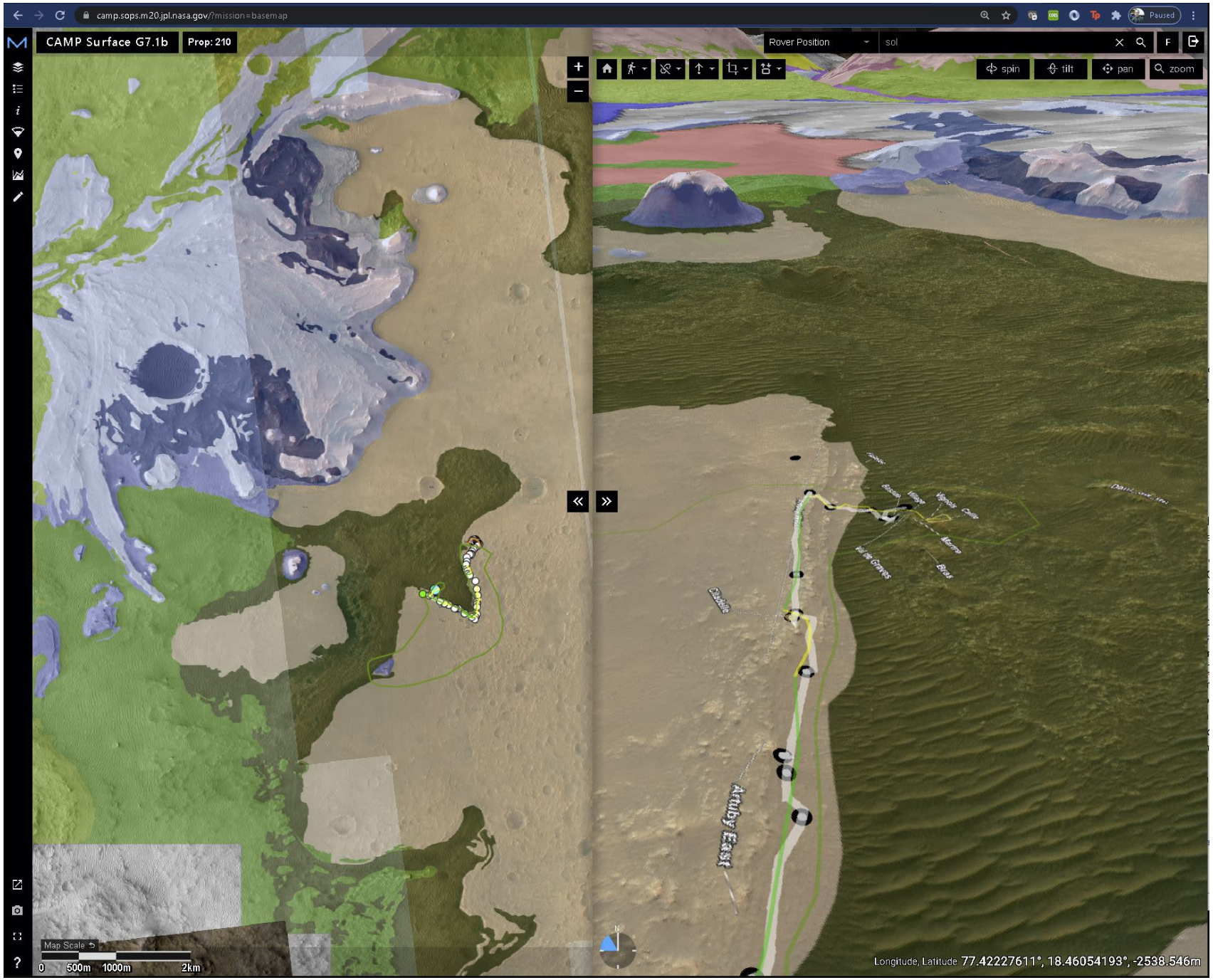
# The Three Forks Sample Depo




NASA/JPL-Caltech

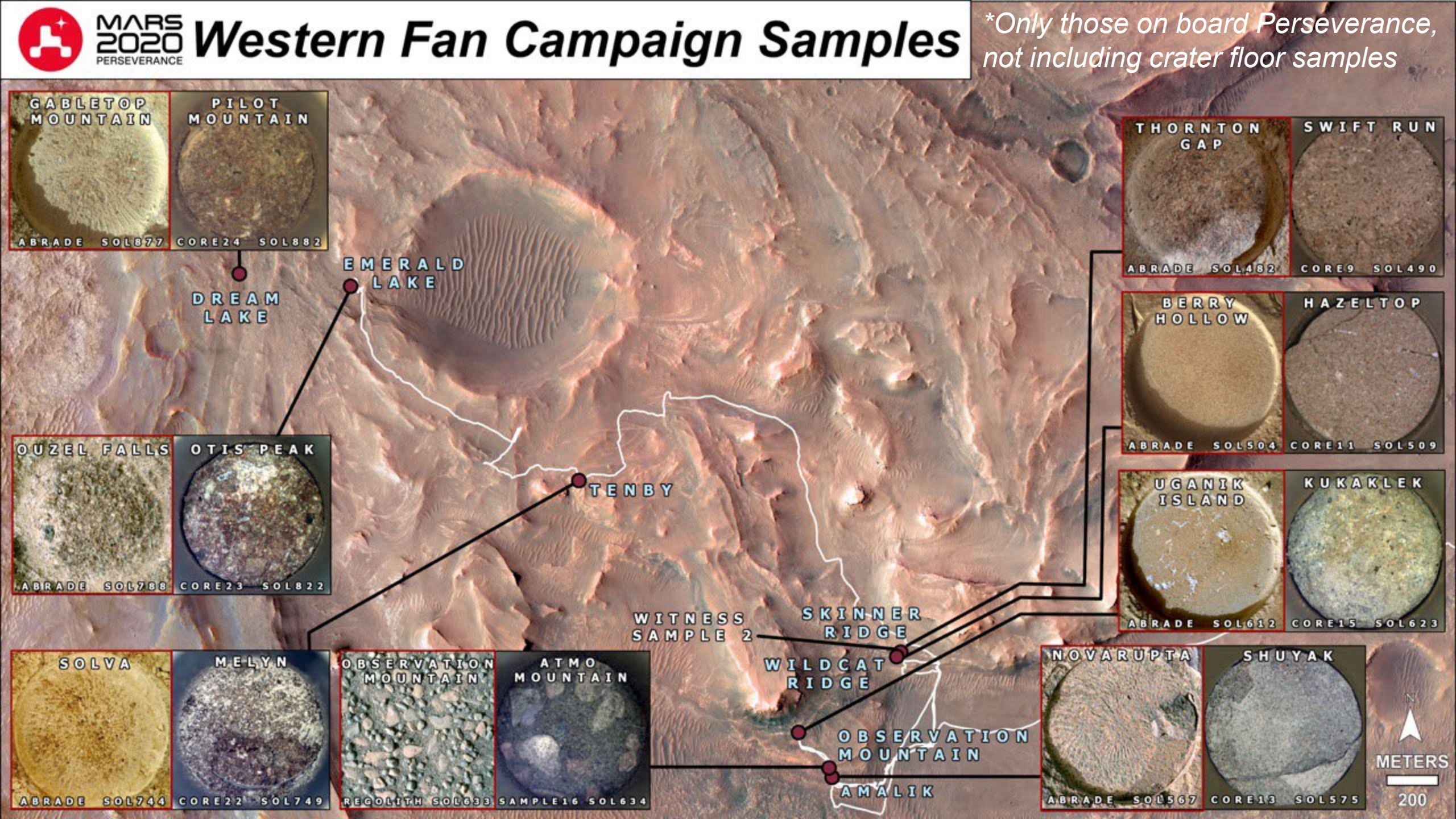


After dropping tube #9.
NASA/JPL-Caltech/MSSS


camp.sops.m20.jpl.nasa.gov/?mission=basemap
Paused
CAMP Surface G7.1b
Prop: 210
Rover Position
sol
F
spin
tilt
pan
zoom
Artuby East
Map Scale
0
500m
1000m
2km
Longitude, Latitude 77.42227611°, 18.46054193°, -2538.546m

# MARS 2020 PERSEVERANCE Western Fan Campaign Samples

*Only those on board Perseverance, not including crater floor samples



# Margin Campaign Samples

| SAMPLES COLLECTED TO DATE | | |
|---|---|---|
| Perseverance | Three Forks | Description |
| | *Roubion* | Atmosphere |
| Montagnac | *Montdenier* | Igneous |
| Salette | *Coulettes* | Igneous |
| Robine | *Malay* | Igneous |
| Hahonih | *Atsah* | Igneous |
| Swift Run | *Skyland* | Sedimentary |
| Hazeltop | *Bearwallow* | Sedimentary |
| Shuyak | *Mageik* | Sedimentary |
| Kukaklek | | Sedimentary |
| Atmo Mountain | *Crosswind Lake* | Regolith |
| Melyn | | Sedimentary |
| Otis Peak | | Sedimentary |
| Pilot Mountain | | Sedimentary |
| Pelican Point | | Sedimentary |
| Lefroy Bay | | Sedimentary |

26 tubes have been filled (including 3 witness tubes)

17 tubes remain (incl 2 witness)

10 tubes were cached at Three Forks Depot (incl 1 witness)

16 sealed tubes are now stored on Perseverance (incl 2 witness)


# Where we are going


From https://mars.nasa.gov/mars2020/mission/where-is-the-rover/ NASA/JPL-Caltech

# Thank you

# Presentation Heritage

This presentation is a consolidation of already released JPL material.

URS: URS307639, CL#22-1092

URS: URS306829, CL#22-1902

URS: URS315549, CL#23-2729