

# The Geology of the ExoMars Rover Landing Site

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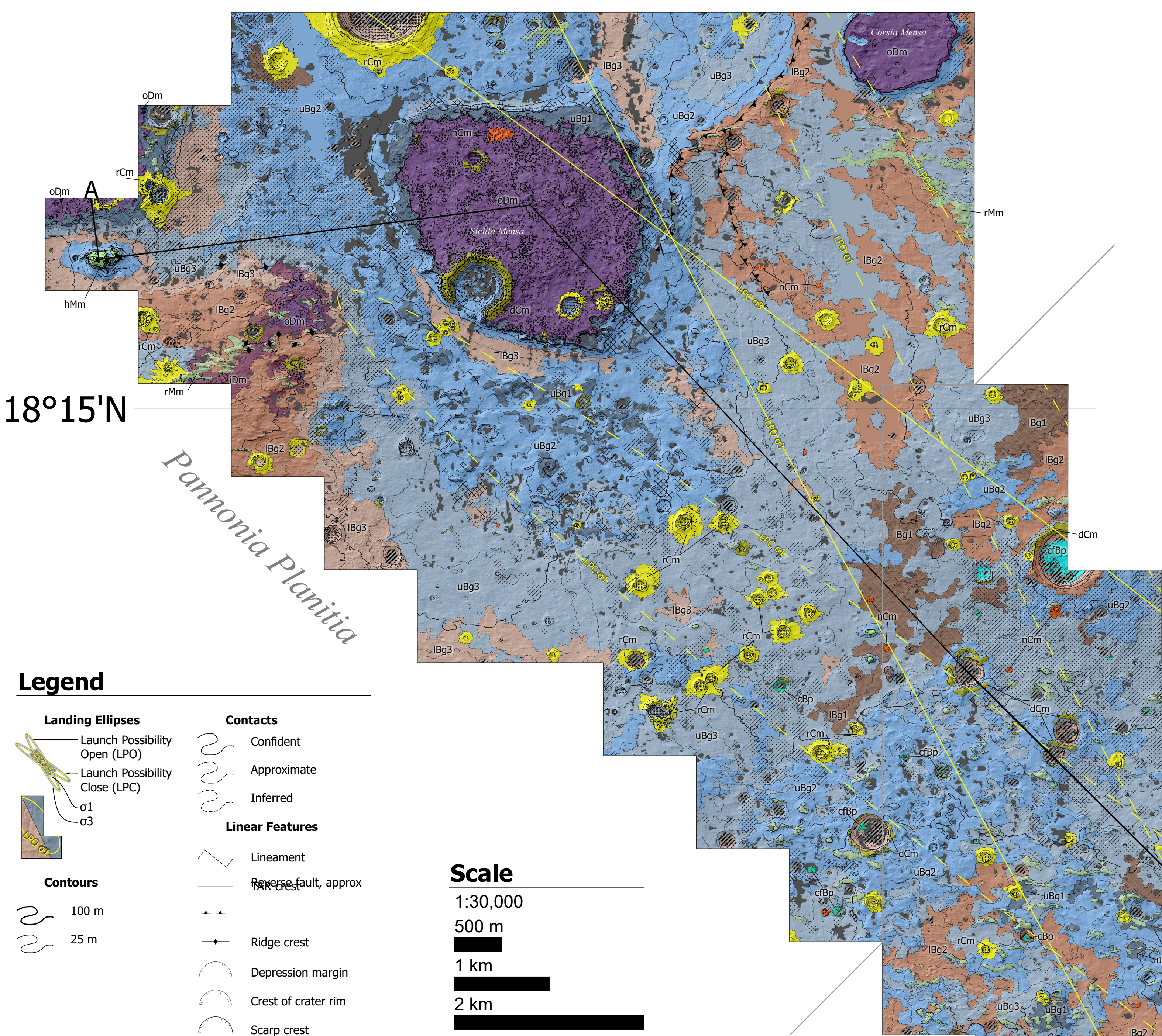
## Map of the landing site

Oxia Planum is the selected landing site for the ExoMars Rosalind Franklin Rover. The goal of the reformulated ExoMars Rosalind Franklin mission, now in planning for launch in 2028, is to search for signs of past and present life and to characterize the water and geochemical environment in the subsurface as a function of depth.

Rosalind Franklin will accomplish this with its 'Pasteur' suite of scientific instruments, and a drilling and sampling subsystem to retrieve samples for analysis from up to 2 m depth.

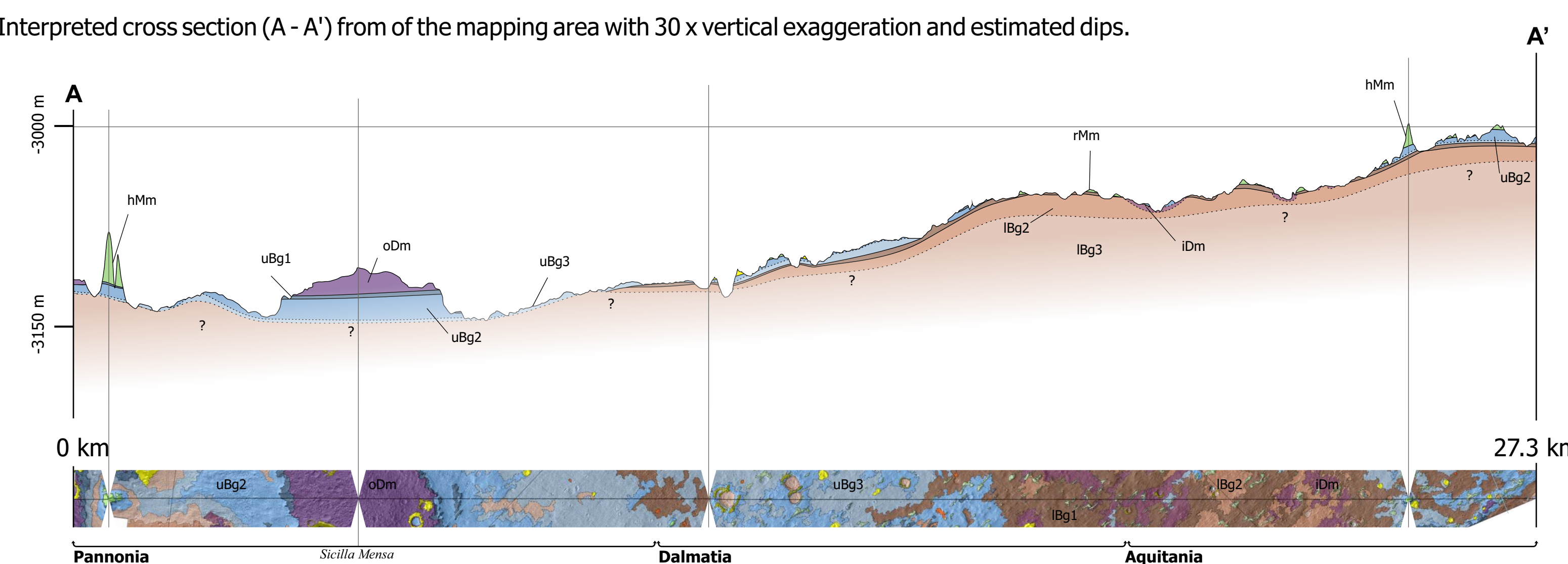
In preparation for the mission, the ExoMars science team undertook a geological mapping exercise of the landing site prioritizing the 1-sigma area of the landing ellipses.

The goal of this map is to develop a thorough understanding prior to rover operations of the OP landing site's geography, stratigraphy, and geological history, and to provide testable hypotheses to facilitate interpretation of results and address the mission's science objectives.



## Cross-section

Interpreted cross section (A - A') from of the mapping area with 30 x vertical exaggeration and estimated dips.

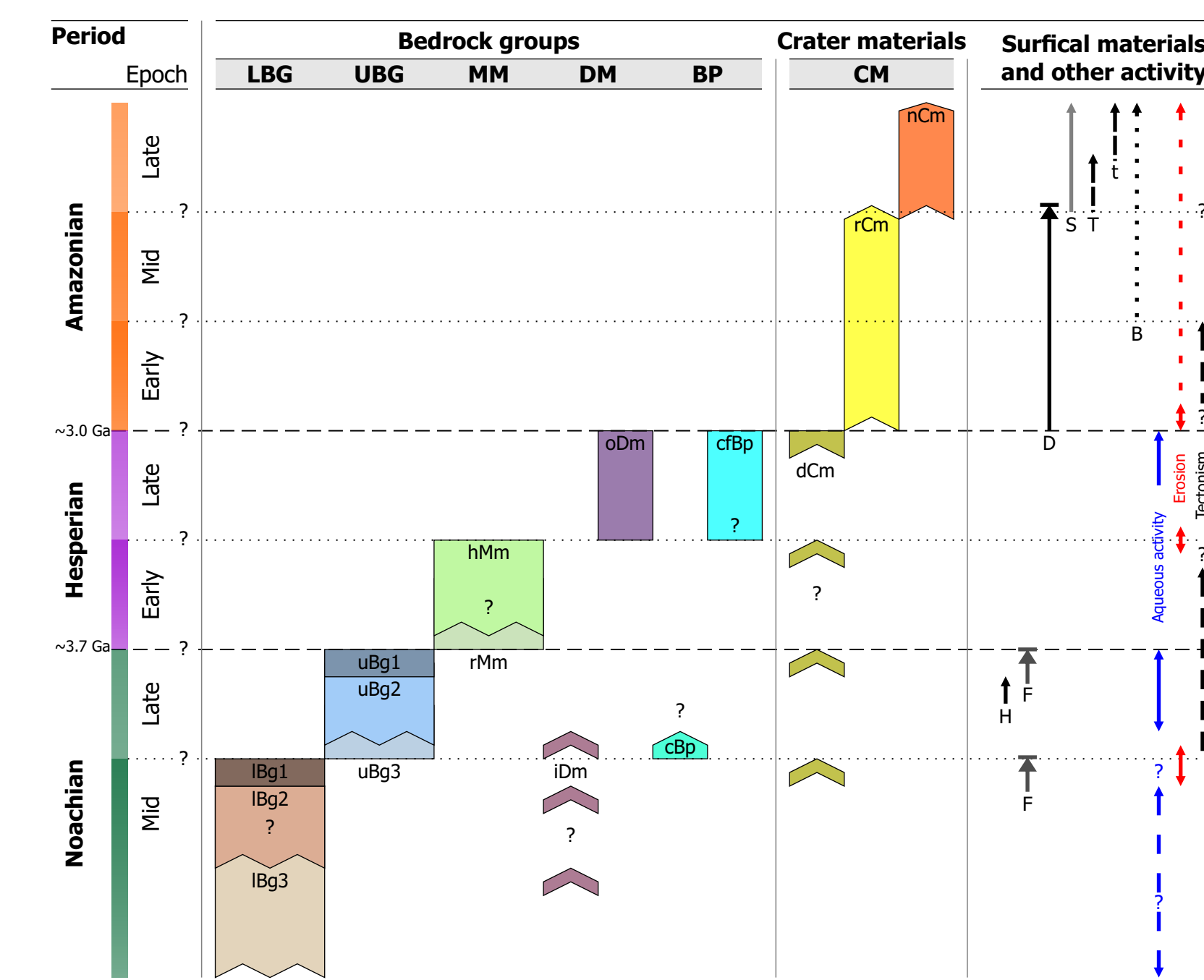


## Correlation of map units

The geological mapping identified 15 bedrock and 7 surficial units. These units are organised into 7 unit groups based on their contextual relationships.

Units in Lower bedrock (LGB), Upper bedrock (UBG) and Mound Material (MM) groups are laterally continuous, having previously completely covered the mapping area. Units in the Dark (DM) and Bright (BM) material groups are laterally discontinuous, representing heterogeneity within a bedrock group or deposition in discreet locations, overlying, or subjacent to, other bedrock units.

Material relating to impact craters (CM) are recorded in three state of degradation and surficial units are represented by textual overlays.



The stratigraphic relationships between the geological units found in the Oxia Planum landing site map and their relationships to various regional processes.

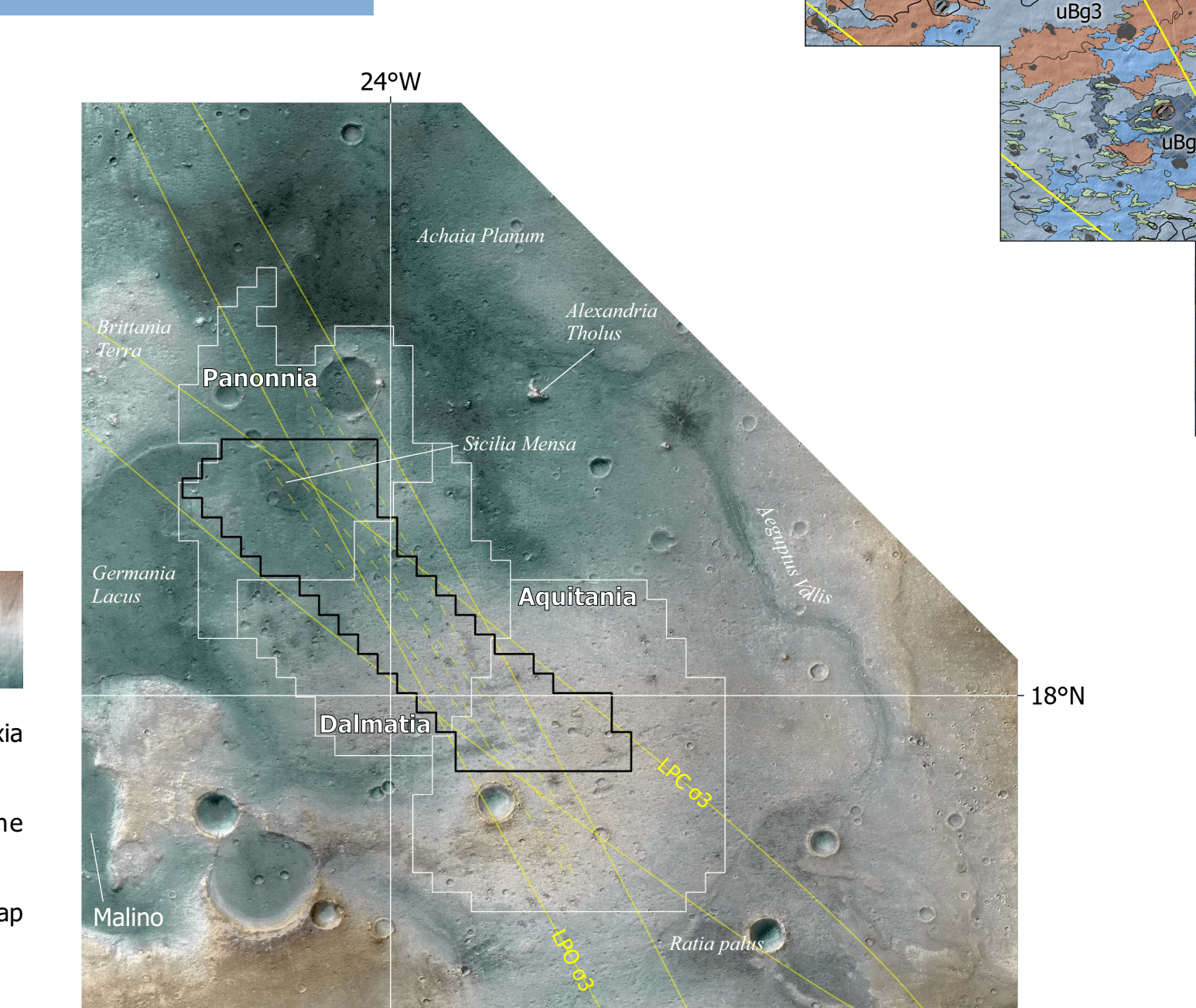
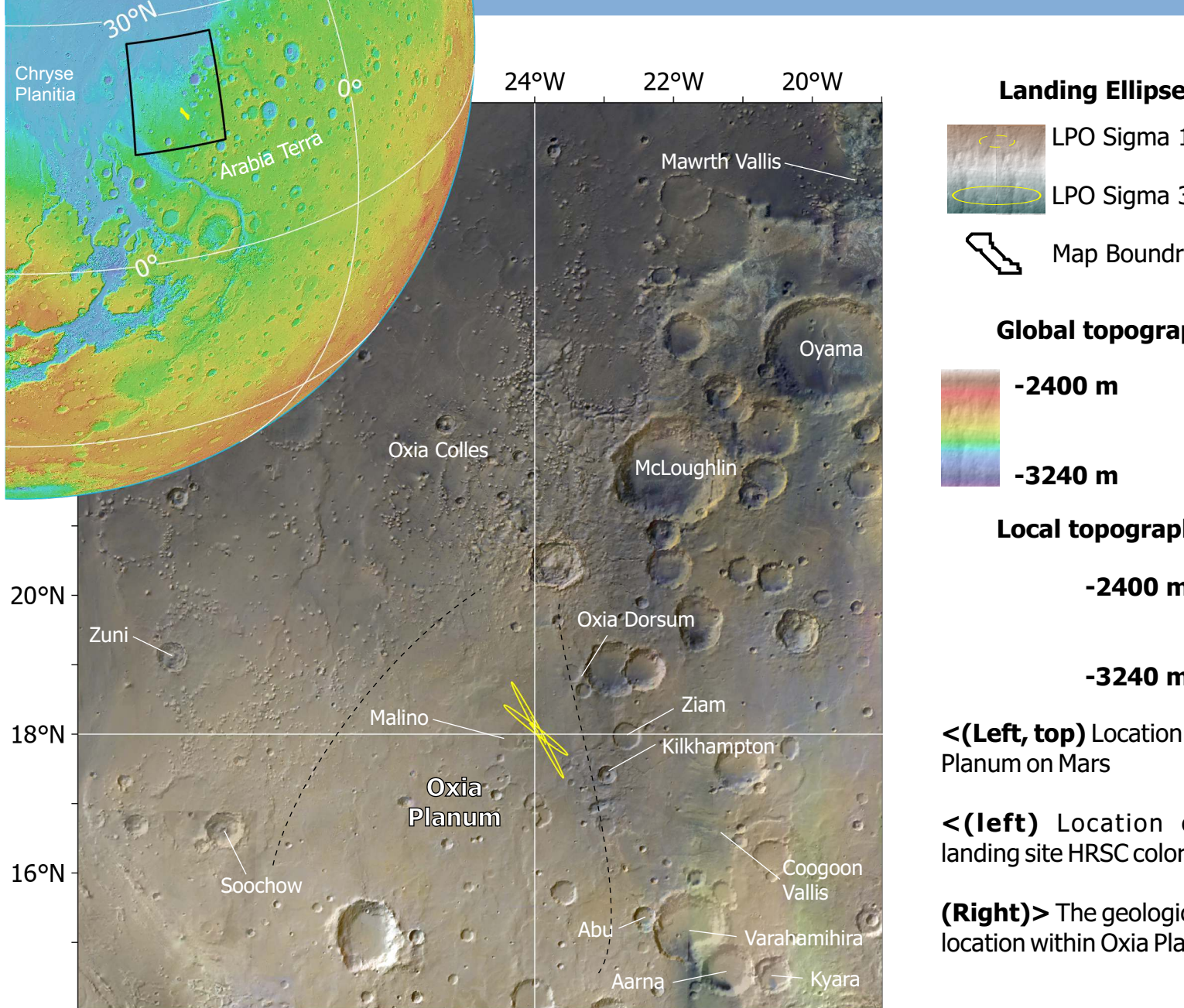
The timing of events is drawn from the contextual geological literature to other events in the region. Coloured bars represent the time in which these events are likely to have occurred they do not reflection their duration.

## Description of map units

Each geological unit is described in terms of its apperany in the HiRISE and CaSSIS data sets. We report notable aspects of their stratigraphic relationships, any compositional information available and their relationship to the geological context of the region.

Unit	Unit name - Description HiRISE & CaSSIS (Near Pan and Blue; NPB)	Additional information and Compositional associations	Stratigraphic relationships and Regional context
<b>Surficial material and texture group (SM)</b>			
B	<b>Boulders</b> - HiRISE: Isolated dark blocks that often cast shadows. Distribution identified by NOAA-H (e.g.; Barrett et al., 2022). CaSSIS: Below resolution.	Associated with oDm, and impact craters (rCm, rMm). There are no resolvable compositional associations.	Overlies all other units. Common throughout the region in similar contexts associated with Dark material and recent impact craters.
t	<b>Small TAR field</b> - HiRISE: Dark toned smooth mantling material with numerous small (<1m) ripples. CaSSIS: Blue tones with low relief.	Numerous small (<5 m wavelength) ripples that make the bedrock identification challenging. Mafic or blank spectral signatures.	Overlies other units and are closely associated with units T and S. Common throughout the region particularly in lower elevations towards Chryse Planitia.
T	<b>Large TARs</b> - Large TARs - HiRISE: Bright faced elongated ridges. CaSSIS: High relief, high albedo ridges with orange tones on illuminated slopes.	Often found in topographic lows (e.g. crater floors) or channels. Ridges are resolvable in DEM data. No clear compositional signature (Berman et al., 2018).	Overlies other units as isolated TARs or grades into smaller continuums, often lower relief. TAR fields (e.g. T). Found in similar contexts throughout the region and strongly associated with sediment fan remnants in Rata Palus.
S	<b>Smooth material</b> - HiRISE: Mid toned, smooth, mantling material. CaSSIS: Blue tones with low relief.	Occasional aeolian ripples superposed. Smooth margins. Often found in recent impact craters or expressed as loose material on scarps. Mafic or spectrally blank signatures.	Overlies other units and closely associated with unit L. Common throughout the regions where loose material accumulates in local topographic lows.
D	<b>Dark patches</b> - HiRISE: Smooth mid to dark toned material. CaSSIS: Dark blue with low relief.	The unit is bounded by small scarps (<1 m high). There is some association with ripples (surface can be "wavy"). No resolvable compositional associations.	Unconformably overlies bedrock units. Located in local topographic lows. Patches are progressively more dissected from SE-NW. Regionally they are found close to recent impact craters.
F	<b>Widely spaced fractures</b> - HiRISE: Polygonal to rectangular troughs ~1-5 m wide with spacings of 10 m - 20 m. CaSSIS: Dark lineations in other units.	No resolvable compositional associations.	Predominantly occur in association with uBg1 and IBg1. Common throughout the region in similar contexts.
H	<b>Honeycomb</b> - HiRISE: Polygonal to rectangular ridges ~2 m wide with spacings of 10 m - 20 m. CaSSIS: Below resolution.	Often highlighted by smooth dark material between the ridges. No resolvable compositional associations.	Predominantly occurs in local topographic highs of uBg2, under uBg1, and around mesas capped with oDm.
<b>Crater material group (CM)</b>			
nCm	<b>New crater material</b> - HiRISE: Very dark halo around small circular pits. CaSSIS: Very dark/black.	Continuous ejecta. ~2-3 crater radii from the crater with diffuse margins that fade into the surrounding units. No resolvable compositional associations.	Overlies all other units and associated with units T and S. Common throughout the region in similar contexts.
rCm	<b>Recent crater material</b> - HiRISE: Smooth mid to dark toned material with moderate relief. Structure is radial to local topographic low (i.e. something confidently identified as an impact crater). CaSSIS: Very dark/black.	Diffuse margin between the ejecta and the surrounding units. No resolvable compositional associations.	Occasionally superposed by surficial group units. Randomly distributed and not related to specific geologic unit.
dCm	<b>Degraded crater material</b> - Degraded crater material - HiRISE: High relief, often with diffuse margins or found on local topographic highs. CaSSIS: Variable, dark blue/orange with yellow toned highlights.	Crater rims removed and little or no ejecta remains. No resolvable compositional associations.	Can be superposed by S, Mm and uBg units. Randomly distributed and not related to specific geologic unit.
oDm	<b>Overlying dark material</b> - HiRISE: Dark-toned, rough, boulder-forming ridges with tops of scarps and it is sufficiently thin (~1m) to contain occasional windows into underlying lighter toned units. CRISM pyroxene signatures (Quantin-Nataf et al., 2021) and possible weak phyllosilicate signatures.	Located on local topographic highs. The unit's margins are recessed from the tops of scarps and it is sufficiently thin (~1m) to contain occasional windows into underlying lighter toned units. CRISM pyroxene signatures (Quantin-Nataf et al., 2021) and possible weak phyllosilicate signatures.	Appears to unconformably overlie F in unit uBg1. Found in regionally topographic lows on local topographic highs, often surrounded by a moat. Often found in continuum with inverted and low relief channels (Fawdon et al., 2022; Davis et al., 2022).
IDm	<b>Interbedded dark material</b> - HiRISE: High relief, bright ~1-3 m diameter rounded knobs picked out by dark infilling material. Occasional bright blocks. CaSSIS: Dark or mottled because the bright knobs are often below the CaSSIS resolution, whereas the unit is lower relief, bright purple-orange tones.	Located in local topographic lows. Appears to crop out in erosional windows within bedrock units. No phyllosilicate signatures observed.	This unit appears to occur sporadically and be interbedded with uBg2. Similar examples of this material are seen occasionally across the region.
BP	<b>Bright material group (BP)</b>		
cbp	<b>Crater fill bright patches</b> - HiRISE: Mid to bright toned, low relief with concentric dark lineation. CaSSIS: Bright/white tones.	Located within degraded impact craters > ~150 m. No observed compositional relationships.	Strongly associated with oCm. Overlain by surficial units. Not seen to be overlain by other units. Common throughout the region in degraded impact craters > 150m in size. It is not seen to be overlain by anything other than surficial units.
cbp	<b>Concentric bright patches</b> - HiRISE: Mid to bright toned, low relief with distinct concentric dark lineation. CaSSIS: Bright/white tones contrasting to subjacent blue tones.	Located in local topographic lows with distinct marginal steps. No observed compositional relationships.	Overlies IBg units. The moat around the edge often hosts aeolian material. Not seen in association with uBg units and occasionally overlain by rMm. Common throughout the region where the orange toned material is exposed. Regional observations suggest cbp is superposed by material from the uBg, and Mm unit groups (McNeil et al., 2022).
hMm	<b>Hill mound material</b> - HiRISE: Smooth, bright, conical mounds ~100 m across and up to 10 m in height. The bright smooth surface has occasional lineations. CaSSIS: Yellow tones in all illumination angles.	hMm forms the tops of larger mounds. Mounds often have a bright layer half way up, scree around their bases and occasionally have small impacts on them. No good CRISM observations are available in Oxia Planum.	Directly overlies uBg1 with uBg2 and uBg3 forming the base of the topographic mound below hMm. hMm never overlies oDm. Mounds with hMm are part of a population extending 100s of km into Chryse Planitia (McNeil et al., 2022). In Oxia Planum hMm must predate oDm. Some mounds are dissected by troughs and have internal ridges.
rMm	<b>Ridge mound material</b> - HiRISE: Bright, upstanding knobby patches and ridges often with a dark unconformity (contact?) seen at base. CaSSIS: High relief, yellow toned.	Bright 'knobbles' often trend into ridges parallel to the trend of periodic bedrock ridges (PBRs). No resolvable compositional associations.	Knobbles and ridges both overlie uBg and IBg group. Similar ridges are frequently seen throughout the wider Oxia Planum region commonly trend into PBRs (Favaro et al., 2021).
<b>Upper bedrock group (UBG)</b>			
uBg1	<b>Upper Bedrock Group 1</b> - HiRISE: Mid to bright toned, low relief, smooth with widely spaced (>5 m) fractures forming a crisply-defined layer ~1 m thick. CaSSIS: Low relief, bright/white/grey tones.	Strongly associated with the top of local topographic highs and scarps. Not strongly associated with phyllosilicate minerals in CRISM.	Overlies uBg2. It is overlain by examples of both the Mm and Dm groups. Similar units appear at the top of scarps and on local topographic highs throughout the region where they are often overlain by Mm and Dm group style units.
uBg2	<b>Upper Bedrock Group 2</b> - HiRISE: High relief, bright, rugged material, forming low hills. CaSSIS: High relief with bright/blue tones.	Forms wide (>100m) upstanding areas in all regions of the map. Strongly associated with the 'honeycomb' texture and scarps in Pannonia. Some association with phyllosilicate minerals and possible mixtures with olivine (Mandini et al., 2022). Dark reolith distribution below the CRISM pixel size may obscure this signal.	Overlies or grades downwards into uBg3, low hills of this unit are often capped with uBg1. Directly underlies uBg1 in mesa walls. Occurs throughout the Oxia Planum region. Crater wall cross-sections show schlieren architecture. Layering often variable in thickness. uBg1 is also strongly associated with inverted/exhumed channels (Davis et al., 2022)
uBg3	<b>Upper Bedrock Group 3</b> - HiRISE: Bright, rough, small-scale (<5 m) fractures. CaSSIS: Dark blue/black with bright speckles.	Small patches of S and D material frequently appear to grade into other surrounding units. Strongly associated with uBg2. Not sampled in any CRISM data.	Occurring as a layer around the bottom of larger mesas of uBg1 and uBg2. Evident in the stumps at the base of rounded buttes capped with hMm where HiRISE coverage permits observation.
<b>Lower bedrock group (LGB)</b>			
IBg1	<b>Lower Bedrock Group 1</b> - HiRISE: Bright, low relief, smooth surface with widely spaced (>10m) spaced fractures picked out by dark material. CaSSIS: Low relief with light orange to cream tones.	The boundary with IBg2 appears gradational but anaglyphs suggest a layered structure. Strong spatial correlation with phyllosilicate spectral signatures.	Directly underlies uBg units and cbp and has a gradational boundary with IBg3. Across the Oxia Planum region, material similar to IBg1 crops out below uBg-style material where it consistently correlates with phyllosilicate spectral signatures. Also spatially correlates with PBRs.
IBg2	<b>Lower Bedrock Group 2</b> - HiRISE: Bright, low relief surface with wide (>10m) spaced fractures and ridges highlighted by dark infill. CaSSIS: Low relief with dark orange/grey and bright white tone.	Often occurs in slightly lower, rougher areas than adjacent IBg1. The more eroded fractures have more dark infill. Below the resolution of CRISM observations.	There is a gradational boundary with IBg1 but a distinct topographic step (~50 cm) between the two where IDm is exposed. Seen throughout the wider Oxia Planum where scarps or windows through IBg allow.
IBg3	<b>Lower Bedrock Group 3</b> - HiRISE: Bright, low relief surface with moderately (~5-10 m) spaced fractures that show fra strong orientation pattern. CaSSIS: Low relief with bright, light orange tone.	Only seen at the lowest elevations of the map (Pannonia and impact craters). The margins can appear to grade into other surrounding units. Very strong spatial correlation with phyllosilicate spectral signatures.	It could underlie or be at the same level as examples of IBg. Elsewhere in the region this unit often occurs in areas with bright orange tone in CaSSIS data, and occur in the lowest parts of the topography.

## Location and context



The global setting of Oxia Planum on the margin between Southern Acidalia Planitia, Chryse Planitia and North-West Arabia Terra and the landing site within Oxia Planum region.

The local setting of the map in norther Oxia Planum. Marked in *italics* are informal names given to the local geography (Fawdon et al., 2021) used to describe the local setting of the map. The landing ellipses and extent the regions containing the map are marked.

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