PSA GUEST STORAGE FACILITY PRODUCT USER GUIDE

The Geography of Oxia Planum

Dataset: *ExoMars2022-RSOWG_Oxia-Planum_Geography-CaSSIS-CTX_V1.0*

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1. INTRODUCTION

The ExoMars Programme is a joint endeavour of the European Space Agency and Roscosmos, comprising two missions, the 2016 Trace Gas Orbiter mission, and the 2022 '*Rosalind Franklin*' Rover and '*Kazachok*' Surface Platform mission. The ExoMars Rover, '*Rosalind Franklin'* has mission objectives focussed on searching for signs of life on Mars (Vago et al., 2017). It will investigate the geochemical environment in the shallow subsurface over a nominal mission of 211 sols. Oxia Planum (OP) was selected as the landing site for the 2022 mission due to a number of scientific and mission safety factors. OP is associated with regional phyllosilicate-bearing terrains (Mandon et al., 2021) – indicative of widespread aqueous processes, Noachian-aged surfaces, and terrain characteristics facilitating a safe landing and low-risk nominal mission (Quantin-Nataf et al., 2021).

We present the geography of Oxia Planum, the landing site for the ExoMars 2022 mission. A collection of three datasets (Fawdon et al., 2021) provide the planetary science community with a framework to investigate this area. This Product User Guide accompanies the dataset hosted on the ESA Planetary Science Archive's Guest Storage Facility, named: '*ExoMars2022-RSOWG_Oxia-Planum_Geography-CaSSIS-CTX_V1.0*', which contains:

(1) **Quad grid and geographic regions:** A grid of quadrangles (quads) grouped into designations of geographic regions to describe Oxia Planum. These regions bridge the scale gap between features observed on large areas (~100s km^2) and the local geography (10s km^2) relevant to the Kazachok surface platform and Rosalind Franklin rover's operations. Specifically,

   a. a grid of 1 x 1 km quads defined to cover the 3-sigma landing ellipse with a logical and accessible alphanumeric naming system designed to be available for quick reference in consideration of long-term planning and science interpretations of local geology, AND on this grid, a set of informally named geographic regions with descriptive terms relating to the main geomorphic features of the landing site. Notable features that are the namesake for regions are also provided as a point shapefile.

(2) **CaSSIS:** A mosaic of synthetic colour data products from the ExoMars Trace Gas Orbiter's Colour and Stereo Surface Imaging System (CaSSIS), registered to the CTX ORI mosaic.

   a. a CaSSIS georeferenced RGB Mosaic, with a spatial resolution of ~4m/pixel.
   b. a set of individual CaSSIS georeferenced RGB rasters with a spatial resolution of ~4m/pixel.
   c. 6 CaSSIS georeferenced CaSSIS data cubes used for the Oxia Planum HiRISE mapping project.
   d. all CaSSIS data cubes in the Oxia Planum region.

(3) **CTX:** A mosaic of Mars Reconnaissance Orbiters' panchromatic Context Camera (CTX) Digital Elevation Models (DEM) and Ortho Rectified Images (ORI) controlled to Mars Express' High Resolution Stereo Camera (HRSC) multi-orbit Digital Elevation Models (DEM).

   a. a set of CTX DEM elevation contours at 100m and 25m spacing.
   b. a CTX orthorectified Mosaic, with a spatial resolution of ~6m/pixel.
   c. a hillshade model of the CTX DEM Mosaic.
   d. a CTX DEM Mosaic, with a spatial resolution of ~20m/pixel.

2. SCIENTIFIC OBJECTIVES

The scientific objectives of these data are:

(1) To provide a common descriptive framework of Oxia Planum to the scientific community, and for use in the ExoMars 2022 mission.

(2) To create the regional geographic context in which to study Oxia Planum.

(3) To characterise the geological context of the ExoMars rover landing site and enable constraint of hypotheses about the paleo-environment prior to landing.

(4) To provide contextual meaning for samples acquired by the Rosalind Franklin rover and analysed by instruments in its Pasteur Payload.

(5) To provide a dataset with spatial resolution that bridges the gap between that of HRSC and HiRISE data, and that is accurately georeferenced with products derived from both.

(6) To a provide a standard georeferencing for Oxia Planum for use during the ExoMars 2022 mission and future research.

3. DATASET GENERATION, CONTENT AND FORMAT

3.1 File types

Data are stored in common geospatial formats that may be identified by their name extensions. Table 1 describes the file formats used in the 3 groups of data that are outlined in section 0, and that are stored across 9 directories (sections 0, 3.3.4, and 0). All data should be compatible with common GIS packages and libraries such as ArcGIS, QGIS, and GDAL.

Table 1: File formats used in this dataset.

Type	File extension	Description of format
Map projection	wkt	Map projection information in 'Well Known Text' syntax compliant with the Open Geospatial Consortium (OGC) standard.
	prj	Map projection information in 'Well Known Text' syntax compliant with the ESRI standard (produced by ESRI ArcMap and ArcPro)
	map	Map projection parameters output by USGS Integrated Software for Imagers and Spectrometers (ISIS).
	cbwx	Worldfile related to USGS Integrated Software for Imagers and Spectrometers (ISIS).
	TFw	Worldfile for a TIF image.
	pgw	Worldfile for a png image.
Shapefile	shp	Shapefile. Contains point, line or polygon geometry.
	sbn	Additional data associated with geometric features in shapefile.
	sbx	Additional data associated with geometric features in shapefile.
	dbf	Additional data associated with geometric features in shapefile.
Image	TIF	'Tagged Image Format'. TIFs in this dataset are 'GeoTIFs', which contain embedded geospatial information.
	png	'Portable Network Graphics' format.
	cub	Image format produced by programs in the USGS Integrated Software for Imagers and Spectrometers (ISIS).
Other	xml	A record of the geoprocessing performed to produce a file.
	txt	ASCII text file containing information about other files in the dataset.

3.2 Quad Grid and Geographic Framework

3.2.1 Summary

This data set provides a grid of quads and projection information to be used for rover operations and the informal geographic naming convention for the regional geography of Oxia Planum. Both subject to update prior to the landed mission. For the results of the sample analysis to be meaningful it is crucial to understand the geological context in which those samples were collected. As such we much understand the geological context of the landing site and a common frame of reference in Oxia Planum is required to communicate about the spatial context of detailed observations and hypotheses. As the first step in this process we present the following common frame of reference for the scientific community a grid of exploration quads to be used in rover operations and an informal set of geographic regions to describe the geography of Oxia Planum.

3.2.2 Coordinate Reference System

Data in this dataset are provided with reference to the IAU IAG Mars 2000 spheroid (equatorial radius = 3396190m and flattening = 169.8944472236118). They are projected in an Equidistant Cylindrical projection centred at 18.20°N, 335.45°. Please see files CRS_PRJ_Equirectangular_OxiaPlanum_Mars2000.[prj/.wkt] for the well known text definitions.

3.2.3 Quad grid

The quad grid was created using the ArcPro 2.7 Grid Index Features Tool . The grid is a 122 × 121 array of 1000 m × 1000 m quads labelled 'A1' in the South West to 'DR121' in the North East. The grid covers the entire CTX mosaic and the lower left corner of quad BN52 coincides with the centre of the ROCC projection system at 335.45°E 18.20°N.

3.2.4 Geographic regions

A common geographical division and naming system for the Oxia Planum region is needed to allow ExoMars team members to communicate efficiently. Identifying and naming geographical locations and zones provides a spatial context for detailed observations, strategic planning and operations, and hypotheses testing.

We group Quads on the grid into 30 contiguous regions across Oxia Planum. This system of regions is a formalisation of the geographic differentiation demanded by discussions since proposal of Oxia Planum as a landing site (e.g. Loizeau et al. 2015).

Each region is defined by a combination of topographic and or albedo changes in the HRSC and CTX data and that encouraged discussion. Regions are smaller closer to the target landing point or where topography and albedo are more variable. This reflects the need to increase the fidelity of discussion where the rover is more likely to land or there are likely to have been more active geomorphic processes. As such, these regions capture features pertaining to hypotheses about the paleo-environments under study by the RSOWG and provide a natural framework to explore Oxia Planum.

The regions are named with three elements: a number, a unique identifier, and a descriptive term. Unique identifiers were drawn from a list of Roman imperial and senatorial provinces at the largest geographic extent of the Roman empire in 117AD. This scheme was chosen because it has geographic and cultural ties throughout Europe and provides an appropriate number and variety of names. The descriptive terms (e.g., *Planum*, *Lacus*, etc) are those used in planetary toponomy (IAU, 1979). Names were selected to reflect the geography of the region (e.g., Caledonia has high elevation terrain in the northwest, Aegyptus has a large channel feature). Geographic locations within regions are also named. These names were drawn from a wider list of Roman towns or other relevant geographic locations with suitable, but process-agnostic, descriptive term (e.g., Alexandria Tholus named after the city in the 'Aegyptus' imperial province). These conventions have the capacity to be expanded as exploration of Oxia Planum continues.

Although IAU recognised features (e.g., Malino crater) have also been included, all other names are informal. Informal naming of local features has been performed by previous Mars Rover mission teams. As has occurred during previous missions, some names may be superseded by future IAU designations.

3.2.5 Files

This data set contains 1 directory containing several groups of files with a common name stem as defined in Table 2.

Table 2: Directories and files comprising the 'quad grid and geographic regions' products in this dataset.

File path	Description	Format

01_a_quad_grid_and_geographic_regions\ CRS_PRJ_Equirectangular_OxiaPlanum_Mars2000. [prj|wkt]	Projection information for all map-projected data layers	'Well Known Text' in ESRI (.prj) and OGC (.wkt) standards.
01_a_quad_grid_and_geographic_regions\ OxiaPlanum_QuadGrid_1km. [shp|cpg|dbf|prj|sbn|sbx|shp.xml|shx]	Quad grid	Polygon shapefile and ancillary GIS files.
01_a_quad_grid_and_geographic_regions\ OxiaPlanum_GeographicRegions_2021_08_26. [shp|cpg|dbf|prj|sbn|sbx|shp.xml|shx]	Geographic regions defined as groups of quads on the grid	Polygon shapefile and ancillary GIS files.
01_a_quad_grid_and_geographic_regions\ OxiaPlanum_GeographicFeatures_2021_08_26. [shp|cpg|dbf|prj|sbn|sbx|shp.xml|shx]	Notable geographic features that often act as a namesake for naming regions	Point shapefile and ancillary GIS files.
01_a_quad_grid_and_geographic_regions\ OxiaPlanum_Origin_clong_335_45E_18_20N. [shp|cpg|dbf|prj|sbn|sbx|shp.xml|shx]	The origin of the local projected coordinate reference system.	Point shapefile and ancillary GIS files.

3.3 CaSSIS RGB

3.3.1 Summary

This data set consists of the CaSSIS RGB data products acquired over the ExoMars Rover landing site in Oxia Planum. It consists of data products acquired by the Colour and Stereo Surface Imaging System (Thomas et al., 2017) at ~4 m/pixel of Oxia Planum, and which we have registered to the CTX ORI mosaic (section 3.4).

These data have been used in the scientific reconciliation stage of the RSOWG Macro Mapping group's HiRISE mapping project (Sefton-Nash et al., 2021).

3.3.2 CaSSIS RGB Data Specificities

A primary science objective of CaSSIS is to study seasonal changes. Consequently, TGO operates in a non-sun synchronous orbit overpassing a point on the surface every 36 days at a range of local times and seasons. Each individual image is invaluable, however for multi-image studies of specific regions the range of view angles, lighting and atmospheric conditions can provide challenges in creation of self-consistent mosaic data sets.

CaSSIS collects data in four filters sensitive to a variety of mineralogy (IR; 950 nm, NIR; 850 nm, PAN; 650 nm and BLUE-GREEN; 475 nm) with a swath width of up to 9 km and the rotation mechanism permits stereo acquisitions. Synthetic RGB products are created as standard by the processing pipelines at the University of Bern and University of Arizona. These data have been georeferenced as such that they are registered to the HRSC controlled mosaic and a CTX mosaic as detailed in Fawdon et al. (2021) to match the base layer to be used in the rover mission.

3.3.3 Observations Used

CaSSIS observations used in this dataset are listed in Table 3.

Table 3: CaSSIS observations used in this dataset

Image ID	Filters	Incidence angle (°)	Local time	Solar longitude (L_s)
MY34_001934_162_0	PAN-RED-NIR-BLU	48.151	08:50:20	167.71
MY34_003806_019_1	PAN-RED-BLU	53.130	09:51:29	260.06
MY34_003806_019_2	PAN-NIR-BLU	53.027	09:52:13	260.06
MY34_003893_018_1	PAN-NIR-BLU	71.037	08:07:36	264.56
MY34_003893_018_2	PAN-RED-BLU	70.803	08:07:55	264.56
MY34_004085_162_1	PAN-RED-BLU	68.856	15:37:41	274.47
MY34_004085_162_2	PAN-NIR-BLU	69.017	15:38:32	274.47
MY34_004172_162_1	PAN-NIR-BLU	51.901	13:54:02	278.91
MY34_004172_162_2	PAN-RED-BLU	52.007	13:54:51	278.91
MY34_004925_019_1	PAN	35.358	12:06:34	315.88
MY34_004925_019_2	PAN-NIR-BLU	35.367	12:07:21	315.88
MY34_005012_018_1	PAN-BLU	40.932	10:25:46	319.95
MY34_005012_018_2	PAN-NIR-BLU	40.814	10:26:26	319.95
MY34_005378_162_1	PAN-RED-BLU	50.339	14:48:19	336.53
MY34_005378_162_2	PAN-NIR-BLU	50.513	14:49:10	336.53
MY34_005664_163_1	PAN-RED-BLU	42.428	09:35:09	348.90
MY34_005664_163_2	PAN-NIR-BLU	42.251	09:36:00	348.90
MY35_006504_018_0	PAN-NIR-BLU	74.907	06:51:39	22.62
MY35_007250_019_0	PAN-RED-NIR-BLU	77.254	17:29:53	50.29
MY35_007337_020_0	PAN-RED-NIR-BLU	56.277	15:59:01	53.44
MY35_007536_021_0	PAN-RED-NIR-BLU	8.678	12:34:18	60.59
MY35_007623_019_0	PAN-RED-NIR-BLU	14.604	11:00:19	63.71
MY35_008275_165_0	PAN-NIR-BLU	16.007	10:56:45	87.07
MY35_008742_019_0	PAN-RED-NIR-BLU	47.860	15:24:50	104.06
MY35_009394_165_0	PAN-NIR-BLU	46.484	15:17:22	128.83
MY35_009481_165_0	PAN-NIR-BLU	24.363	13:42:46	132.27
MY35_012092_163_0	PAN-RED-NIR-BLU	60.915	14:58:52	254.60

3.3.4 Files

CaSSIS data is contained in 4 directories with contents described in Table 4.

Table 4: Directories and files comprising the CaSSIS products in this dataset

File path	Description
02_a_CASSIS_georeferenced_sRGB_mosaic\ CASSIS_OP_sRGB_mosaic_4m_april2021.* [tif|tfw|xml|ovr]	CaSSIS georeferenced RGB Mosaic
02_b_CASSIS_georeferenced_sRGB\ *.[TIF|TFw|xml|ovr]	CaSSIS georeferenced RGB images and ancillary files
02_c_CASSIS_georeferenced_cubes\ MY**_******_***.[cub|cbwx|xml|ovr|map|txt]	6 CaSSIS georeferenced CaSSIS data cubes used for the Oxia Planum HiRISE mapping project. .txt files contain tie points georeferencing each image to the CTX base layer. See Fawdon et al. (2021) for details.
02_d_CASSIS_cubes_all\ MY**_******_***.[cub|xml|ovr|map|png|pgw]	Selected processed CaSSIS data cubes of Oxia Planum

3.4 CTX DEM Mosaic

3.4.1 Summary

This data set is a mosaic of CTX DEM and ortho-rectified images (ORI's) covering the ExoMars rover landing site in Oxia Planum. The data provide a base layer for georeferencing of higher resolution datasets of the rover landing site. It was used to georeference individual CaSSIS and HiRISE data used in the reconciliation phase of the RSOWG mapping project (Sefton-Nash et al., 2021). CTX provides good spatial coverage of Oxia Planum, and bridges the resolution gap between geodetically controlled HRSC mosaics (Gwinner et al., 2016), and higher spatial resolution data products such as CaSSIS and HiRISE that are required for detailed investigation of the landing site.

This data set consists of mosaics of observations by the Context Camera CTX (Malin et al., 2007), Digital Elevation Models (DEM) at 20 m/pix and Orthorectified Images (ORI) at 6 m/pix, plus shapefiles containing contours derived from the DEM. The CTX camera provides data with a swath width of ~20 km. The main map is a mosaic of 6 Orthorectified Images (ORI) and Digital Elevation Models (DEM) created from data where the emission angle and coverage create stereo pairs suitable for the photogrammetric reconstruction of the terrain. This data is controlled to the High Resolution Stereo Camera (Neukum, 1999) 12.5 m/pixel panchromatic mosaic (Gwinner et al., 2016), (please see http://hrscteam.dlr.de/HMC30/ HMC_11W24_co5ps.tif). These data are controlled to a geodetic control network derived from the Mars Orbiter Laser Altimeter (Smith et al., 2001) and provides base layer for registration of other high resolution data sets.

3.4.2 CTX Data Specificities

CTX DEMs were created following the method of Kirk et al. (2008), using public-domain Integrated Software for Images and Spectrometers (ISIS3) software to pre-process the raw Experimental Data Records (EDR). The EDRs were then processed in SocetSet®, a commercially available photogrammetry suite (http://www.socetset.com), with X, Y, and Z co-ordinates of the DEM controlled to MOLA Point Experimental Data Record (PEDR) data. The ORI and DEM were then post-processed in ISIS, mosaicked in the software Environment for Visualising Images (ENVI), before manual georeferencing in ArcGIS software. Finally, the georeferenced image mosaic was blended in Adobe Photoshop to remove seamlines using the Avenza Geographic Imager extension to retain geospatial information in the blended product.

The output from SocetSet® are 18 – 20 m/pix DEM resolving topography of ~50 – 60 m features and 12 orthorectified CTX images at 6 m/pix. The Expected Vertical Precision (EVP) in each CTX DEM can be estimated based on viewing geometry and pixel scale (Kirk et al., 2008, 2003) e.g., EVP = Δp IFOV / (parallax/height). Where: Δp is the RMS stereo matching error in pixel units, assumed to be 0.2 pixels (Cook et al., 1996) and confirmed with matching software for several other planetary image data sets (Howington-Kraus et al., 2002; Kirk et al., 1999). The pixel matching error is influenced by signal-to-noise ratio, scene contrast and differences in illumination between the images. Pattern noise can also be introduced by the automatic terrain extraction algorithm, especially in areas of low correlation. These can be identified as patches of 'triangles' in the hillshade model (e.g., smooth, low contrast slopes and along shadows). IFOV is the instantaneous field of view of the image (pixel size in metres). If the paired images have different IFOV the RMS values is used e.g., IFOV = √(pixel scale image 1 + pixel scale image 2). The parallax/height ratio, calculated from the three-dimensional intersection geometry, reduces to tan(e) for an image with emission angle 'e' paired with a nadir image, e.g., parallax/height = tan(e) where e = |emission angle 1 – emission angle 2|.

Topographic contours were created at 25 m intervals from a version of the CTX DEM down-sampled to 100 m/pix. Contours shorter than 1500 m were removed and the lines smoothed using the PAEK algorithm at a tolerance of 200 m.

3.4.3 Observations Used

CTX observations used in this dataset are listed in Table 5.

Table 5: CTX stereo pairs and the Expected Vertical Precision (EVP) of each DEM.

CTX image pairs (E-W)	Center (Lat, Long)	Emission angle (°)	Pixel size (m)	EVP (m)
J14_050138_1986_XN_18N025W	18.66°N 334.94°E	28.34	7.14	**DEM 1**
K05_055518_1986_XN_18N025W	18.69°N 334.89°E	5.69	5.64	1.71
F21_044178_1988_XN_18N024W	18.83°N 335.12°E	28.08	7.08	**DEM 2**
J05_046723_1985_XN_18N025W	18.57°N 335.08°E	0.09	5.59	1.34
F03_037136_1977_XN_17N023W	17.81°N 336.10°E	14.95	5.95	**DEM 3**
F23_044956_1984_XN_18N024W	18.49°N 335.44°E	3.35	5.59	3.31
J01_045167_1983_XN_18N024W	18.33°N 335.80°E	1.48	5.56	**DEM 4**
J03_045800_1983_XN_18N024W	18.33°N 335.75°E	14.05	5.93	3.04
F03_037070_1980_XN_18N024W	18.09°N 336.09°E	8.63	5.70	**DEM 5**
F03_037136_1977_XN_17N023W	17.81°N 336.10°E	14.95	5.95	6.16
J01_045101_1981_XN_18N023W	18.16°N 336.29°E	11.59	5.78	**DEM 6**
J02_045378_1981_XN_18N023W	18.14°N 336.37°E	0.85	5.57	3.55

3.4.4 Files

CTX products in this dataset are organised in 4 directories. The contents are described in Table 6: Directories and files comprising the CTX products in this datasetTable 6.

Table 6: Directories and files comprising the CTX products in this dataset

File path	Description
03_a_CTX_DEM_contours CTX_OXIA_DEM_cont_100m.[cpg|dbf|prj|sbx|shp|xml|shx] CTX_OXIA_DEM_cont_25m.[cpg|dbf|prj|sbx|shp|xml|shx]	Shapefile and associated ancillary files containing contours spaced at 100m and 25m, derived using the method described in section 3.4.2.
03_b_CTX_ORI CTX_OXIA_ORI_6m.[tfw|tif|xml|ovr]	Orthorectified image in geotiff format, plus ancillary and overview files.
03_c_CTX_DEM_hs CTX_OXIA_DEM_20m_hs.[tfw|tif|xml|ovr]	Hillshade of the CTX DEM in geotiff format, plus ancillary and overview files.
03_d_CTX_DEM CTX_OXIA_DEM_20m.[tfw|tif|xml|ovr]	CTX DEM in geotiff format, plus ancillary and overview files.

4. SOFTWARE

Data in this dataset were generated using ESRI ArcPro 2.7. They should be readable by most mainstream GIS software, including programs in the ArcDesktop 10.x suite, QGIS (https://qgis.org), and the Geospatial Data Abstraction Library (GDAL, https://gdal.org).

5. DATASET CITATION

This dataset is citable with the following DOI:

10.5270/esa-krek4ao

6. ACKNOWLEDGEMENTS

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7. ABBREVIATIONS AND ACRONYMS

CaSSIS	Colour and Stereo Surface Imaging System
CTX	ConTeXt imager (for Mars Reconnaissance Orbiter)
DEM	Digital Elevation Model
DOI	Digital Object Identifier
ENVI	ENvironment for Visualising Images
ESA	European Space Agency
EVP	Expected Vertical Precision
GDAL	Geospatial Data Abstraction Library
GIS	Geographic Information System
HiRISE	High Resolution Science Imaging Experiment
HRSC	High Resolution Stereo Camera
MOLA	Mars Orbital Laser Altimeter
OP	Oxia Planum
ORI	OrthoRectified Image
PSA	Planetary Science Archive
PUG	Product User Guide

QGIS	Quantum Geographic Information System
RGB	Red Green Blue
RSOWG	Rover Science Operations Working Group

8. REFERENCES

Cook, A.C., Oberst, J., Roatsch, T., Jaumann, R., Acton, C., 1996. Clementine imagery: selenographic coverage for cartographic and scientific use. Planet. Space Sci. 44, 1135–1148. https://doi.org/10.1016/S0032-0633(96)00061-X

Fawdon, P., Grindrod, P., Orgel, C., Sefton-Nash, E., Adeli, S., Balme, M., Cremonese, G., Davis, J., Frigeri, A., Hauber, E., Le Deit, L., Loizeau, D., Nass, A., Parks-Bowen, A., Quantin-Nataf, C., Thomas, N., Vago, J.L., Volat, M., 2021. The geography of Oxia Planum. J. Maps 17, 762–778. https://doi.org/10.1080/17445647.2021.1982035

Gwinner, K., Jaumann, R., Hauber, E., Hoffmann, H., Heipke, C., Oberst, J., Neukum, G., Ansan, V., Bostelmann, J., Dumke, A., Elgner, S., Erkeling, G., Fueten, F., Hiesinger, H., Hoekzema, N. ~M., Kersten, E., Loizeau, D., Matz, K.-D., McGuire, P. ~C., Mertens, V., Michael, G., Pasewaldt, A., Pinet, P., Preusker, F., Reiss, D., Roatsch, T., Schmidt, R., Scholten, F., Spiegel, M., Stesky, R., Tirsch, D., van Gasselt, S., Walter, S., Wählisch, M., Willner, K., 2016. The High Resolution Stereo Camera (HRSC) of Mars Express and its approach to science analysis and mapping for Mars and its satellites. Planet. Space Sci. 126, 93–138. https://doi.org/10.1016/j.pss.2016.02.014

Howington-Kraus, E., Kirk, R.L., Soderblom, L.A., Giese, B., Oberst, J., 2002. USGS and DLR topographic mapping of Comet Borrelly.

Kirk, R.L., Howington-Kraus, E., Hare, T., Dorrer, E., Cook, D., Becker, K., Thompson, K., Redding, B., Blue, J., Galuszka, D., Lee, E.M., Gaddis, L.R., Johnson, J.R., Soderblom, L.A., Ward, A.W., Smith, P.H., Britt, D.T., 1999. Digital photogrammetric analysis of the IMP camera images: Mapping the Mars Pathfinder landing site in three dimensions. J. Geophys. Res. Planets 104, 8869–8887. https://doi.org/10.1029/1998JE900012

Kirk, R.L., Howington-Kraus, E., Redding, B., Galuszka, D., Hare, T.M., Archinal, B.A., Soderblom, L.A., Barrett, J.M., 2003. High-resolution topomapping of candidate MER landing sites with Mars Orbiter Camera narrow-angle images. J. Geophys. Res. E Planets 108. https://doi.org/10.1029/2003JE002131

Kirk, R.L., Howington-Kraus, E., Rosiek, M.R., Anderson, J.A., Archinal, B.A., Becker, K.J., Cook, D.A., Galuszka, D.M., Geissler, P.E., Hare, T.M., Holmberg, I.M., Keszthelyi, L.P., Redding, B.L., Delamere, W.A., Gallagher, D., Chapel, J.D., Eliason, E.M., King, R., McEwen, A.S., 2008. Ultrahigh resolution topographic mapping of Mars with MRO HiRISE stereo images: Meter-scale slopes of candidate Phoenix landing sites. J. Geophys. Res. Planets 113, 0–24. https://doi.org/10.1029/2007JE003000

Loizeau, D., Flahaut, J., Vago, J.L., Hauber, E., Bridges, J.C., 2015. ExoMars 2018: the four final candidate Landing Sites. EGU Gen. Assem. 2015, held 12-17 April. 2015 Vienna, Austria. id.5555 17, 5555.

Malin, M.C., Bell, J.F., Cantor, B.A., Caplinger, M.A., Calvin, W.M., Clancy, R.T., Edgett, K.S., Edwards, L., Haberle, R.M., James, P.B., Lee, S.W., Ravine, M.A., Thomas, P.C., Wolff, M.J., 2007. Context camera investigation on board the Mars reconnaissance orbiter. J. Geophys. Res., Planets 112. https://doi.org/10.1029/2006je002808

Mandon, L., Parkes Bowen, A., Quantin-Nataf, C., Bridges, J.C., Carter, J., Pan, L., Beck, P., Dehouck, E., Volat, M., Thomas, N., Cremonese, G., Tornabene, L.L., Thollot, P., 2021. Morphological and Spectral Diversity of the Clay-Bearing Unit at the ExoMars Landing Site Oxia Planum. Astrobiology 21, 464–480. https://doi.org/10.1089/ast.2020.2292

Neukum, G., 1999. The High Resolution Stereo Camera (HRSC) Experiment Onboard the European Mars Express Mission.

Quantin-Nataf, C., Carter, J., Mandon, L., Thollot, P., Balme, M., Volat, M., Pan, L., Loizeau, D., Millot, C., Breton, S., Dehouck, E., Fawdon, P., Gupta, S., Davis, J., Grindrod, P.M., Pacifici, A., Bultel, B., Allemand, P., Ody, A., Lozach, L., Broyer, J., 2021. Oxia Planum: The Landing Site for the ExoMars "Rosalind Franklin" Rover Mission: Geological Context and Prelanding Interpretation. Astrobiology. https://doi.org/10.1089/ast.2019.2191

Sefton-Nash, E., Fawdon, P., Orgel, C., Balme, M., Quantin-Nataf, C., Volat, M., Hauber, E., Adeli, S., Davis, J., Grindrod, P., Frigeri, A., Le Deit, L., Loizeau, D., Nass, A., Ruesch, O., de Witte, S., Vago, J.L., 2021. Team Mapping of Oxia Planum for the ExoMars 2022 Rover-Surface Platform Mission, in: 52nd Lunar and Planetary Science Conference. p. 1947.

Smith, D.E., Zuber, M.T., Frey, H. V., Garvin, J.B., Head, J.W., Muhleman, D.O., Pettengill, G.H., Phillips, R.J., Solomon, S.C., Zwally, H.J., Banerdt, W.B., Duxbury, T.C., Golombek, M.P., Lemoine, F.G., Neumann, G.A., Rowlands, D.D., Aharonson, O., Ford, P.G., Ivanov, A.B., Johnson, C.L., McGovern, P.J., Abshire, J.B., Afzal, R.S., Sun, X., 2001. Mars Orbiter Laser Altimeter: Experiment summary after the first year of global mapping of Mars. J. Geophys. Res. Planets 106, 23689–23722. https://doi.org/10.1029/2000JE001364

Thomas, N., Cremonese, G., Ziethe, R., Gerber, M., Brändli, M., Bruno, G., Erismann, M., Gambicorti, L., Gerber, T., Ghose, K., Gruber, M., Gubler, P., Mischler, H., Jost, J., Piazza, D., Pommerol, A., Rieder, M., Roloff, V., Servonet, A., Trottmann, W., Uthaicharoenpong, T., Zimmermann, C., Vernani, D., Johnson, M., Pelò, E., Weigel, T., Viertl, J., De Roux, N., Lochmatter, P., Sutter, G., Casciello, A., Hausner, T., Ficai Veltroni, I., Da Deppo, V., Orleanski, P., Nowosielski, W., Zawistowski, T., Szalai, S., Sodor, B., Tulyakov, S., Troznai, G., Banaskiewicz, M., Bridges, J.C., Byrne, S., Debei, S., El-Maarry, M.R., Hauber, E., Hansen, C.J., Ivanov, A., Keszthelyi, L., Kirk, R., Kuzmin, R., Mangold, N., Marinangeli, L., Markiewicz, W.J., Massironi, M., McEwen, A.S., Okubo, C., Tornabene, L.L., Wajer, P., Wray, J.J., 2017. The Colour and Stereo Surface Imaging System (CaSSIS) for the ExoMars Trace Gas Orbiter. Space Sci. Rev. 212, 1897–1944. https://doi.org/10.1007/S11214-017-0421-1/FIGURES/29

Vago, J.L., Westall, F., Coates, A.J., Jaumann, R., Korablev, O., Ciarletti, V., Mitrofanov, I., Josset, J.-L., De Sanctis, M.C., Bibring, J.-P., Rull, F., Goesmann, F., Steininger, H., Goetz, W., Brinckerhoff, W., Szopa, C., Raulin, F., Edwards, H.G.M., Whyte, L.G., Fairén, A.G., Bridges, J., Hauber, E., Ori, G.G., Werner, S., Loizeau, D., Kuzmin, R.O., Williams, R.M.E., Flahaut, J., Forget, F., Rodionov, D., Svedhem, H., Sefton-Nash, E., Kminek, G., Lorenzoni, L., Joudrier, L., Mikhailov, V., Zashchirinskiy, A., Alexashkin, S., Calantropio, F., Merlo, A., Poulakis, P., Witasse, O., Bayle, O., Bayón, S., Meierhenrich, U., Carter, J., García-Ruiz, J.M., Baglioni, P., Haldemann, A., Ball, A.J., Debus, A., Lindner, R., Haessig, F., Monteiro, D., Trautner, R., Voland, C., Rebeyre, P., Goulty, D., Didot, F., Durrant, S., Zekri, E., Koschny, D., Toni, A., Visentin, G., Zwick, M., Van Winnendael, M., Azkarate, M., Carreau, C., 2017. Habitability on Early Mars and the Search for Biosignatures with the ExoMars Rover. Astrobiology 17, 471–510. https://doi.org/10.1089/ast.2016.1533