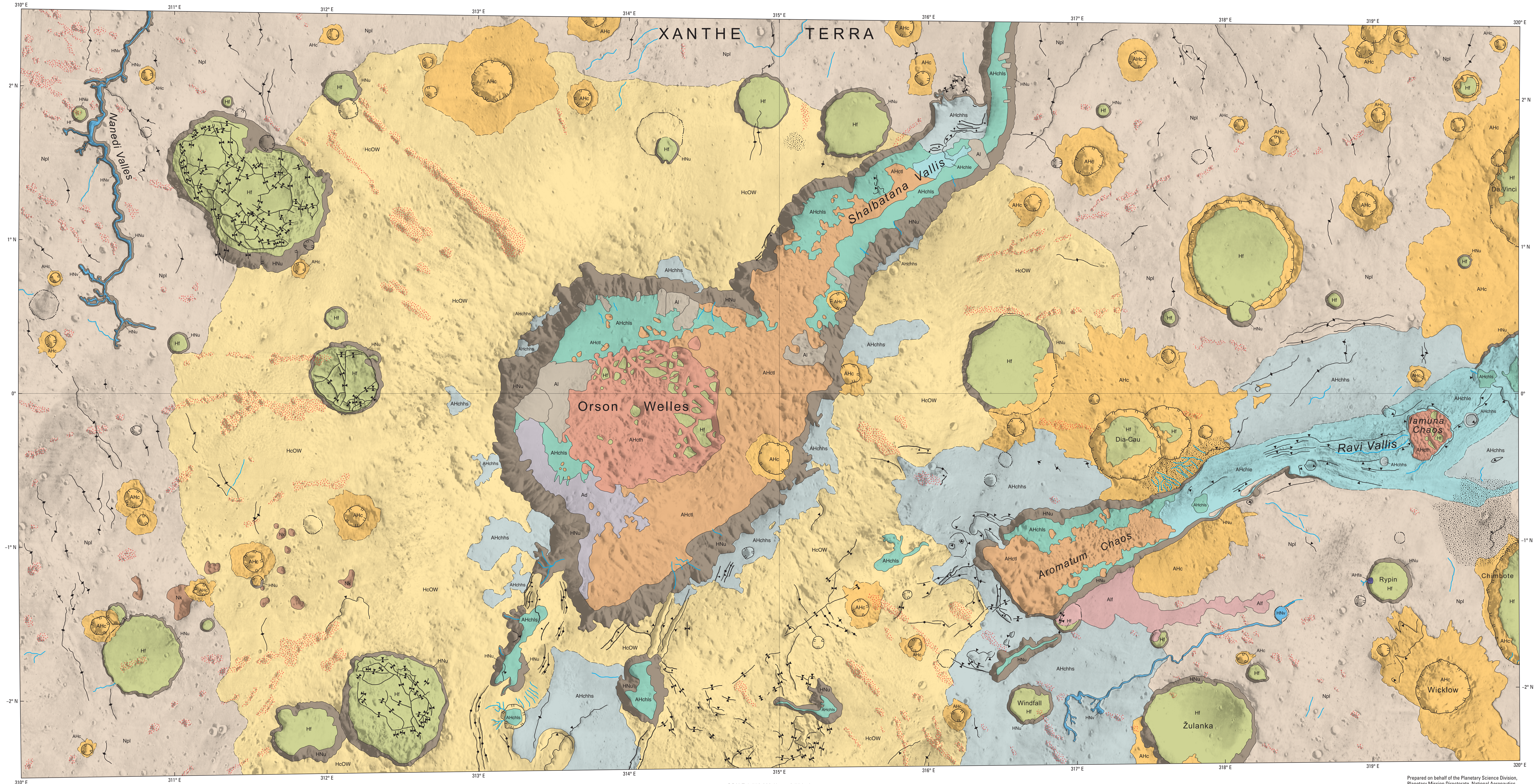


Base from Mars Odyssey Thermal Emission Image System (THEMIS) infrared data

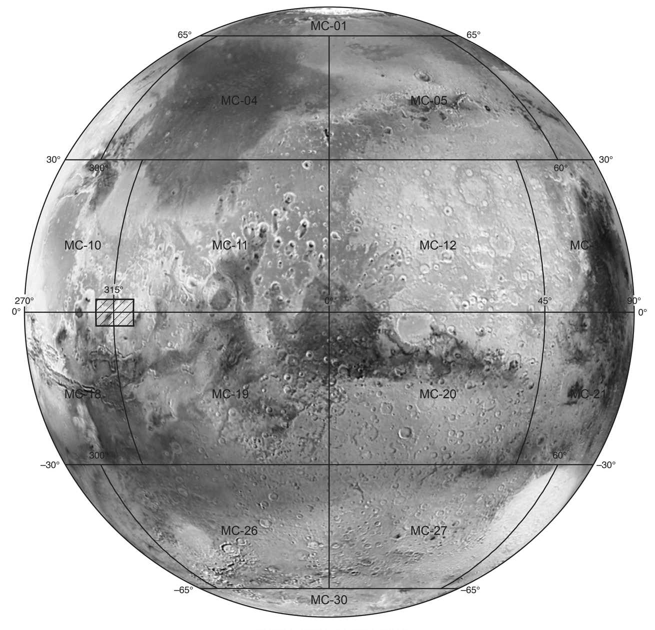
Descriptions of nomenclature used on map are listed at http://planetarynames.wr.usgs.gov

SCALE 1:750 000 (1mm=0.75 km)
TRANSVERSE MERCATOR PROJECTION
10 0 10 20 30 40 50 MILES
10 0 10 20 30 40 50 KILOMETERS
PLANETOCENTRIC LATITUDE AND EAST LONGITUDE COORDINATE SYSTEM

Prepared on behalf of the Planetary Science Division, Planetary Mission Directorate, National Aeronautics and Space Administration

Edited by J.L. Zigler; digital cartographic production by Katie Sullivan

Manuscript approved for publication July 27, 2022



QUADRANGLE LOCATION
Photomosaic showing location of map area (hachured rectangle). An outline of 1:5,000,000-scale Mars Chart quadrangles is provided for reference.

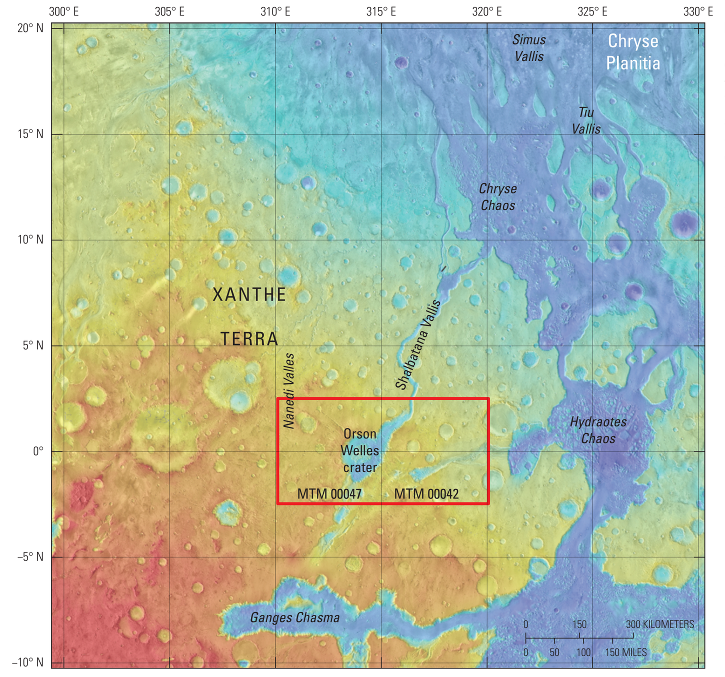


Figure 1. Regional context image showing the map area (red box) and surrounding terrain, including Xanthe Terra, Ganges Chasma to the south, Hydraotes Chaos to the east, and the Chryse basin (Chryse Planitia) to the northeast. Lunae Planum is northwest of this image. Base is 128 pixel per degree Mars Orbiter Laser Altimeter Digital Elevation Model over 100 m/pixel Thermal Emission Imaging System daytime infrared mosaic.

EXPLANATION
Elevation, in meters
High: 4,706
Low: −5,426

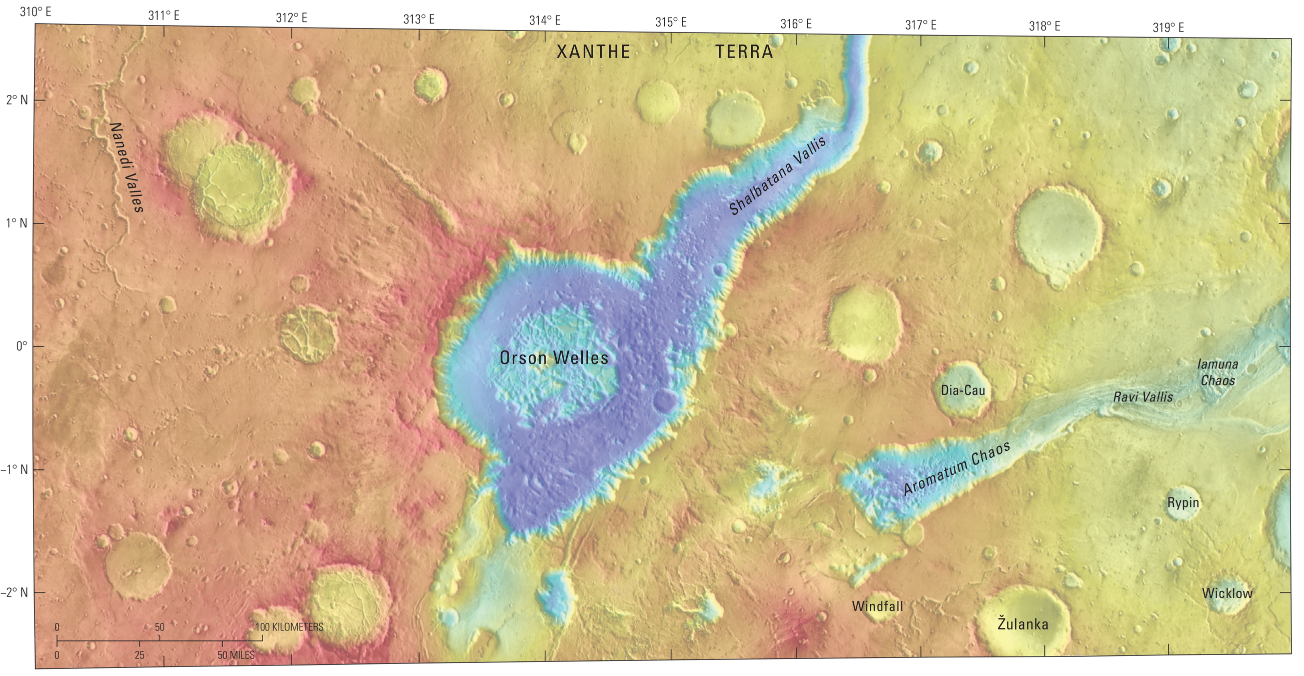


Figure 2. Image showing Mars Orbiter Laser Altimeter 128 pixel per degree elevations for the map area overlying the 100 m/pixel Thermal Emission Imaging System daytime infrared mosaic showing regions of interest.

EXPLANATION
Elevation, in meters
High: 1,780
Low: −4,209

Geologic Map of the Source Region of Shalbatana Vallis, Mars

By

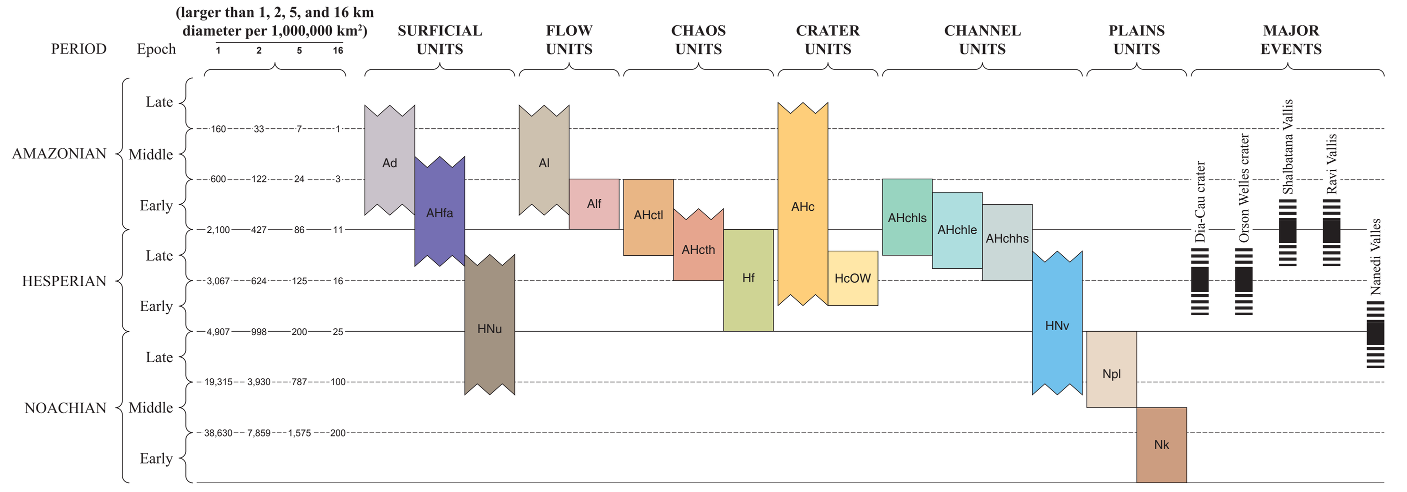
Daniel C. Berman,[1] J. Alexis Palmero Rodriguez,[1] Catherine M. Weitz,[1] and David A. Crown[1]

2023

[1]Planetary Science Institute

CORRELATION OF MAP UNITS, MAJOR EVENTS, AND CRATER COUNTS

[Note: Cumulative crater densities for epoch boundaries at 1, 2, 5, and 16 km diameter are from Werner and Tanaka (2011); see table 1 for model absolute ages. Map unit ages are resolved to nearest epoch unless crater size-frequency distributions and (or) superposition relations allow for greater constraints; sawteeth box edges indicate possible extended durations. The designated ages rely on both stratigraphic relations as documented in the Description of Map Units and crater size-frequency distributions provided in table 1. See Age Determinations section of text for methodology discussion. Determination of ages from crater densities is complicated by the geologic history of the unit of interest, including size-dependent degradation and resurfacing, such that different crater diameter ranges (and the associated N(1), N(2), N(5), and N(16) values) may provide different age estimates for a given geologic unit.]

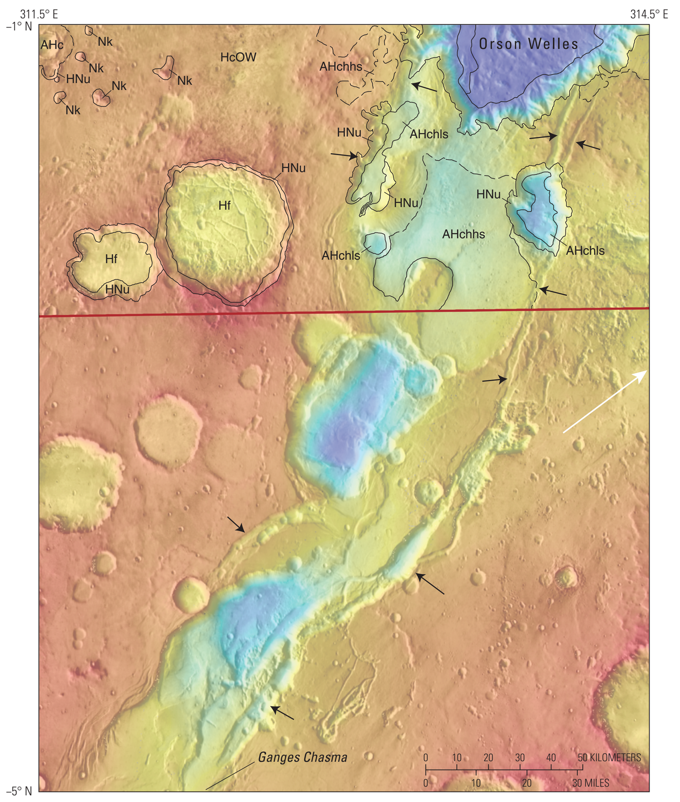


EXPLANATION OF MAP SYMBOLS

- **Dark ejecta**
- **Secondary crater chain**
- **Contact**—Solid where location is certain; dashed where approximately located
- **Normal fault**—Ball and bar on downthrown block
- **Channel**
- **Graben trace**
- **Ridge crest**
- **Trough**
- **Scarp crest**—Barb points upslope
- **Crater rims**
  - **Crest of buried or degraded crater rim**—Topographically subdued rims of infilled craters
  - **Crest of crater rim**—Hachures point toward center of crater

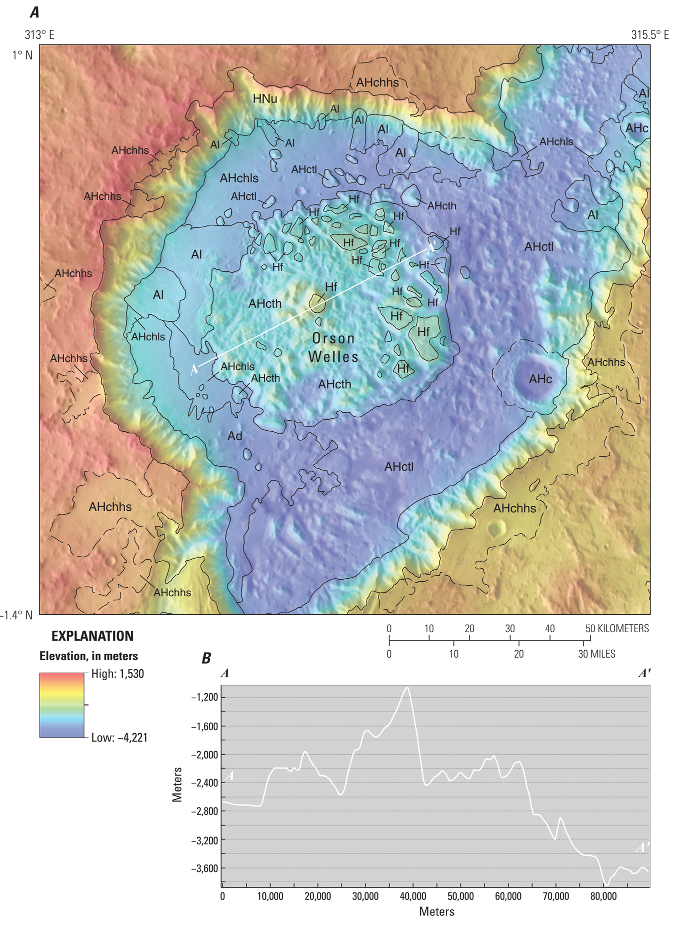
DESCRIPTION OF MAP UNITS

Unit symbol	Unit name and description	Additional characteristics	Interpretation
	SURFICIAL UNITS		
Ad	**Dune material**—Dark, smooth deposits on floor of Orson Welles crater. Superpose units AHchls and AHctl and embay unit AHcth	Large slip faces in center of unit. Barchan shapes around floor margin	Dunes composed of sand-size grains deposited by wind into crater. Dunes around margins of field are barchan shaped
AHfa	**Fan material**—Small (2 km across) fan-shaped deposit on floor of Rypin crater at terminus of channel inlet. Surface contains several impact craters	Stair-step terraces with parallel curvilinear scarps observed in HiRISE image ESP_024135_1785. Hummocky light-toned deposits are found on crater floor just beyond fan. Small dunes are found on upper fan surface	Alluvial fan or delta. Light-toned deposits may represent lower-level extensions of fan
HNu	**Wall material, undivided**—Rocky exposures with superposed smooth surficial deposits on walls of channels and craters	Layering can be observed in some upper walls as shown in CTX image P18_007890_1793_XN_00S045W. Some surficial deposits may be a mixture of Orson Welles ejecta materials and talus. Narrow, sinuous channels are found on walls of Orson Welles crater	Exposures of bedrock from underlying plains units, incised by fluvial activity, subject to ongoing collapse and retreat with talus materials moving downslope
	FLOW UNITS		
Al	**Landslide material**—Lobate deposits with linear ridges in direction of flow emanating from walls (unit HNu) of Shalbatana Vallis and Orson Welles crater and extending to floor, superimposing units AHchls and AHctl	Sets of ridges perpendicular to inferred flow direction are observed where deposits abut chaos material on west side of Orson Welles crater (CTX image P18_008101_1788_XN_01S046W)	Landslides formed by mass wasting along collapsed channel walls. Linear ridges longitudinal to flow direction are common on Martian landslides. Perpendicular ridges formed by compression as landslide material is slowed by chaos materials
Alf	**Lobate flow material**—Flow feature with rugged, lobate margins extending from Aromatum Chaos. Partially fills crater to south	Superposed crater ejecta is rubbly as shown in HiRISE image ESP_046816_1785 and bright in THEMIS nighttime IR data. CTX image J07_047383_1774_XN_02S042W shows a central channel with levees	Lava flow sourced within Aromatum Chaos; source vent is not observed and was likely destroyed or buried by ongoing collapse and retreat of wall materials
	CHAOS UNITS		
AHctl	**Chaotic terrain material, lower**—Small- to medium-sized knobby or sharp-crested blocks or mounds, surrounded by or partially embayed by smooth material, that are contiguous with and sit at a lower elevation than unit AHcth	Small landslides observed on many block walls. Some small-scale fluvial incision on floors. Small exposures of light-toned layered deposits. Smooth material exhibits different degrees of exhumation. Light-toned deposits were observed in several locations within unit AHctl at various levels and generally exhibit fine layers	Unit Hf materials and wall materials that have been highly eroded by collapse and flooding; some may have eroded from unit AHcth materials. Contain little of original materials and likely were subject to an additional flooding event
AHcth	**Chaotic terrain material, higher**—Large knobby or sharp-crested blocks and smooth deposits that surround and embay flat-topped blocks of unit Hf that are surrounded by deep troughs. Unit boundaries represent a plateau of materials that are higher elevation than unit AHctl	Layering is observed below unit Hf exposures (HiRISE image ESP_058750_1800). Original central peak of Orson Welles may be preserved. Troughs and depressions contain small aeolian bedforms	Unit Hf materials in Orson Welles crater and Iamuna Chaos that have undergone collapse and subsidence and subsequently eroded by ponding and (or) flooding
Hf	**Fill material**—Smooth, flat-lying material that almost completely fills large eroded crater floors, including Orson Welles crater and other depressions. Some exposures are marked by deep, wide intersecting troughs that are linear to curvilinear. Most of these floor-fractured craters are near Orson Welles crater. Fill material on the floor of Orson Welles crater is highly fractured and embayed by unit AHcth	May be mottled with degradational pitting as shown in CTX image G16_024557_1807_XN_00N042W. Some exposures in craters have terraces around their margins. Ridges are observed on floor of Dia-Cau crater. Inlet channels are observed debauching into several craters, with one containing a depositional fan (unit AHfa). Some exposures may incorporate ejecta material from Orson Welles; however, stratigraphic relations are not entirely clear	Aeolian or fluvial material eroded from plains materials and filled crater floors. May contain lacustrine sediments as evidenced by fan material. Roda and others (2014, 2017) suggest floor fractures are formed due to collapse of fill material under a sub-ice lake; Sato and others (2010) suggest fractures are formed by collapse over groundwater evacuating from a subsurface cavity
	CRATER UNITS		
AHc	**Crater material**—Fresh to moderately degraded crater-ejecta deposits, raised crater rims, and floor material, superposing cratered plains. Margins of many ejecta deposits approximate as they gradually thin or are buried. Some ejecta blankets highly degraded or completely absent. Superpose units Npl, Nk, and HcOW; some exposures are superposed by units AHctl, AHchls, AHchhs, and Hf	Ejecta of Dia-Cau crater is crosscut by Ravi Vallis	Material excavated from cratered plains and redeposited by impact cratering. Some crater rims and ejecta blankets are partially or completely removed due to degradation and (or) resurfacing
HcOW	**Orson Welles crater material**—Hummocky ejecta deposits that transition gradually into plains. Crater rim is entirely absent. Collapse structures observed to south-southeast	Discontinous ejecta deposits and secondary chains are observed beyond boundaries of unit	Material ejected from impact that formed Orson Welles crater, partially removed or buried by resurfacing. Crater rim destroyed due to ongoing wall collapse and retreat
	CHANNEL UNITS		
AHchls	**Channel material, lower smooth**—Smooth deposits on lower outflow channels with small-scale incision and fans originating from walls, with no observable fluvial bedforms on floor. Includes Shalbatana Vallis and portions of Ravi Vallis lower floor	Northern floor of Orson Welles crater exhibits sinuous ridges. Collapse zone south of Orson Welles exhibits alluvial fans on floor (HiRISE image ESP_048873_1780). Light-toned deposits were observed in several locations at various levels and generally exhibit fine layers	Material deposited primarily by slower flooding events that may have been dominated by debris that buried bedforms (Rodriguez and others, 2006a,b). Sinuous ridges are inverted channels
AHchle	**Channel material, lower etched**—Grooved deposits on lower outflow channel floors with multiple levels that are deeper toward center. Embayed by unit AHchls. Includes narrow section of Ravi Vallis lower floor and part of Shalbatana Vallis	CTX image G03_019533_1809_XN_00N040W shows streamlined bedforms	Fill material that was heavily eroded as floods transitioned to a narrow, more constrained flow
AHchhs	**Channel material, higher smooth**—Smooth, flat-lying deposits marked by scour marks and streamlined forms, found on the floor of upper levels of Ravi Vallis (bound by large ridge to north), as well as covering and embaying Orson Welles and Dia-Cau ejecta and unit Npl exposures around Aromatum Chaos. Boundaries may extend beyond approximate contacts as deposits gradually thin	Some small blocks on floor surrounded by moats can be seen in CTX image J10_048886_1794_XN_00S041W. Bench observed at margin abutting ridge in CTX image P18_007890_1793_XN_00S045W	Material deposited by topographically unconstrained, depositional flood events that spread over intercrater plains, thinning laterally from the main channel segments. Deposits surrounding Orson Welles crater and Aromatum Chaos represent overflow flood deposits. Bench could be a shoreline
HNv	**Valley floor material**—Smooth deposits on floors of Nanedi Valles and an unnamed valley south of Aromatum Chaos	Theater-head channels with U-shaped cross-sectional profiles. Nanedi Valles has a center channel on its floor	Fluvial and mass-wasting deposits on the floor of sapping valleys. Unnamed valley south of Aromatum Chaos may have been refilled by overflow floods from Aromatum Chaos (unit AHchhs)
	PLAINS UNITS		
Npl	**Cratered plains unit**—Smooth to hummocky, heavily cratered plains, characterized by secondary crater chains and wrinkle ridges. Ejecta and rims of some large superposed craters entirely or partly eroded. Generally bright in THEMIS daytime IR, but there is a region that appears darker to the west of unit HcOW. Superposed by all other units except Nk	CTX image G15_024043_1793_XI_00S049W shows small craters range from well-preserved to highly degraded	Undifferentiated combination of highland rocks and sediments, likely to consist of impact breccias, lava flows, and sedimentary deposits that underwent resurfacing sufficient to remove ejecta blankets and rims and smooth topography, possibly by large-scale broad flood events
Nk	**Knobby material**—Small knobs embayed by units Npl and HcOW	CTX image D09_030689_1785_XI_01S048W shows knobs are partially eroded	Remnant highland rocks from ancient terrain



EXPLANATION
Elevation, in meters
High: 1,780
Low: −4,230

Figure 3. Image showing zone of collapsed and subsided terrain from north of Ganges Chasma (south of map area) to the southern edge of Orson Welles crater. Black arrows indicate potential pathways for subsurface water flow from south to north. White arrow indicates the direction of Aromatum Chaos that occurs along this branch of lower-relief collapse relative to the surrounding plateau. Red line indicates southern boundary of map area. Base is 128 pixel per degree Mars Orbiter Laser Altimeter Digital Elevation Model over 100 m/pixel Thermal Emission Imaging System daytime infrared mosaic.



EXPLANATION
Elevation, in meters
High: 1,530
Low: −4,221

Figure 4. *A*. Image showing 128 pixel per degree Mars Orbiter Laser Altimeter Digital Elevation Model over 100 m/pixel Thermal Emission Imaging System daytime infrared mosaic of Orson Welles crater delineating difference in elevation between units AHcth and AHctl. *B*, Elevation profile *A*–*A*' drawn from southwest to northeast.

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Digital files available at https://doi.org/10.3133/sim3492

Suggested citation: Berman, D.C., Rodriguez, J.A.P., Weitz, C.M., and Crown, D.A., 2023, Geologic map of the source region of Shalbatana Vallis, Mars: U.S. Geological Survey Scientific Investigations Map 3492, pamphlet 10 p., scale 1:750,000, https://doi.org/10.3133/sim3492.

Printed on recycled paper

ISSN 2329-1311 (print)
ISSN 2329-132X (online)
https://doi.org/10.3133/sim3492