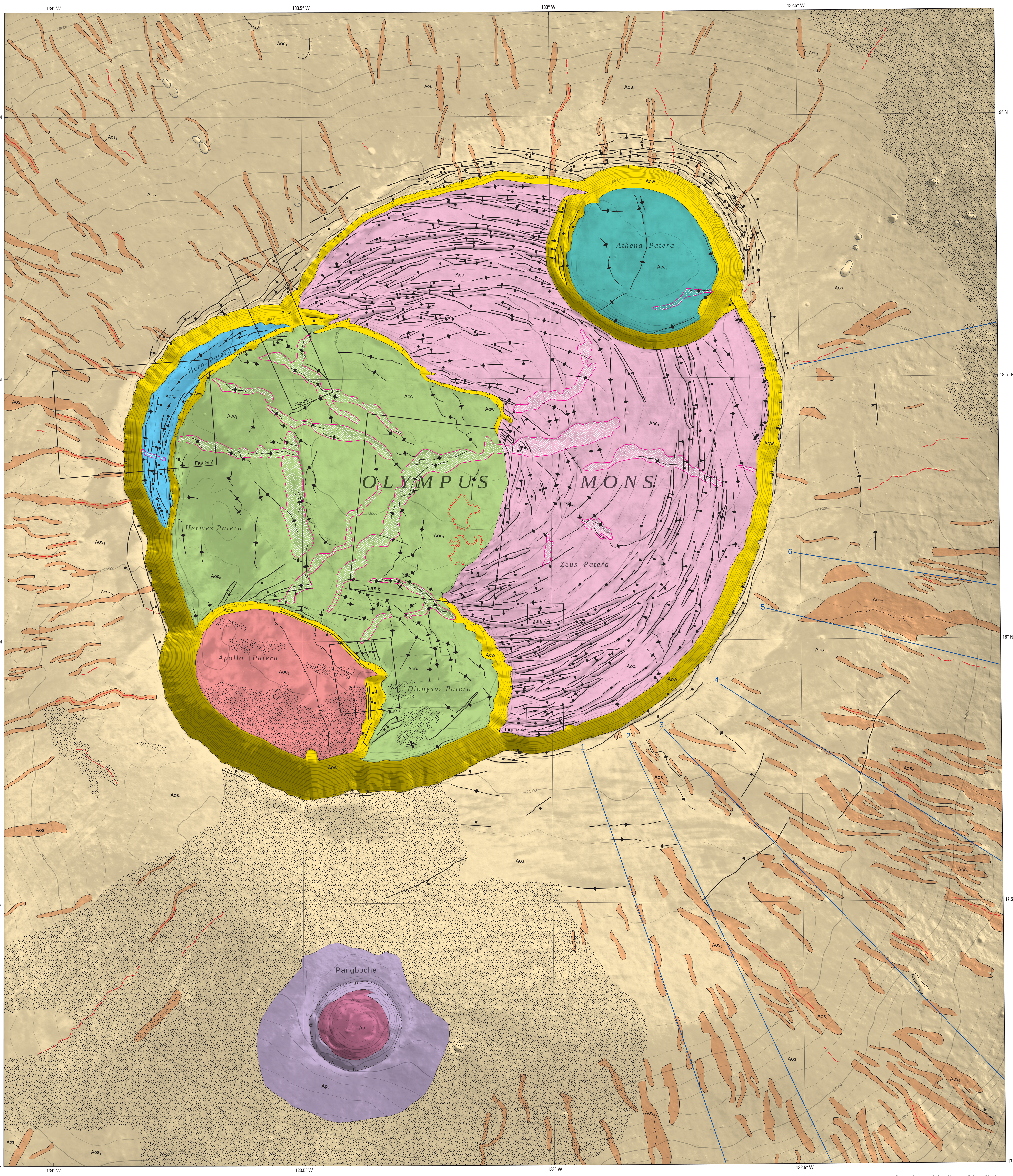
U.S. Department of the Interior
U.S. Geological Survey

Prepared for the
National Aeronautics and Space Administration

Scientific Investigations Map 3470
Pamphlet accompanies map



Planetocentric latitude and east longitude coordinate system
Transverse Mercator projection
Descriptions of nomenclature used on map are listed at https://planetarynames.wr.usgs.gov/

SCALE 1:200 000 AT 134° W. LONGITUDE

Prepared on behalf of the Planetary Science Division, Science Mission Directorate, National Aeronautics and Space Administration
Edited by J.L. Zigler; digital cartographic production by Katie Sullivan
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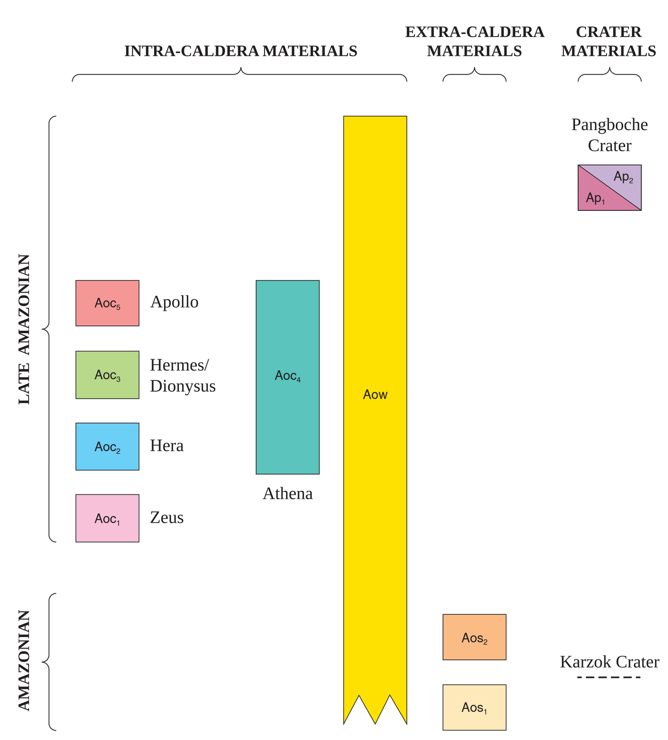
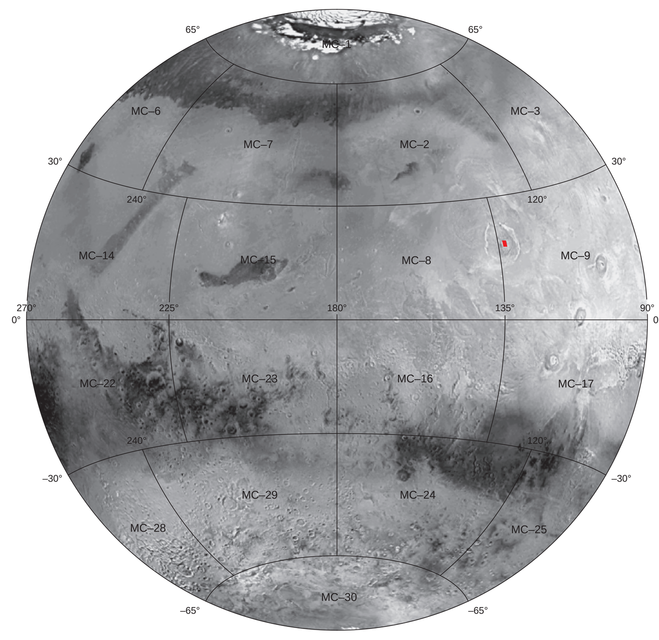
CORRELATION OF MAP UNITS





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

DESCRIPTION OF MAP UNITS

UNIT SYMBOL	UNIT NAME, AGE, AND DESCRIPTION	ADDITIONAL CHARACTERISTICS	INTERPRETATION
	INTRA-CALDERA MATERIALS		
Aoc₅	**Apollo Patera (Late Amazonian)**—Patera, 12 x 16 km, along southwest part of caldera. Topographic rise (~220 m high) along northeast side of patera. Numerous clusters of irregular craters scattered across surface, and lobe of material (at lat 17.47° N., long 226.31° E.) extends northward onto southern floor from wall. Irregular (2.5 x 2.4 km) pit at east margin of patera floor. *Type locality*: lat 17.55° N., long 226.28° E.	HiRISE image PSP_009884_1980 illustrates the landslide material and shows that the raised flow margins can be traced up onto wall material	Most likely youngest collapse event within caldera or comparable in age to Athena Patera. Smooth surface produced by post-collapse resurfacing by either lava erupted from vent on wall adjacent to Dionysus Patera or from a solidified lava lake that once spanned entire floor. Clusters of small craters are part of ejecta materials from Pangboche crater. Topographic bench (fig. 7) may be remnant of a high-stand in level of a former lava lake. Lobe of material at foot of southern wall most likely a landslide, possibly initiated by the formation of Pangboche crater. Lack of secondary craters on landslide suggests that formation post-dated emplacement of ejecta, possibly by seconds to hours
Aoc₄	**Athena Patera (Late Amazonian)**—Near-circular patera 20 x 22 km, at northeast extent of caldera. Several wrinkle ridges on floor. *Type locality*: lat 18.44° N., long 227.12° E.	HiRISE image PSP_001920_1990 shows floor of Athena Patera has numerous eolian dunes, which are absent within Apollo Patera	Lack of superposed impact craters suggests this is second youngest collapse event within caldera, but exact relative age unclear due to lack of superposition relations. Smooth surface produced by post-collapse resurfacing by either lava flow sourced within patera or by a solidified lava lake that once spanned entire floor. Wrinkle ridges formed by contraction of late-stage lavas or subsidence above a shallow magma reservoir
Aoc₃	**Hermes and Dionysus Paterae (Late Amazonian)**—Two connected depressions. Prominent ridges located within Hermes Patera, two of which cross into Zeus Patera. Ridges around perimeter of Hermes Patera are predominately radial to center, while ridges closer to center are mainly concentric to center. Two irregular depressions at east side of Hermes Patera. Numerous faults adjacent to north wall of Apollo Patera occur on southern floor of Hermes Patera and western floor of Dionysus Patera. Clusters of irregular craters on southern floor of Dionysus Patera. *Type locality*: lat 18.14° N., long 226.32° E.	Ridges show multiple episodes of formation in HiRISE image PSP_007524_1985. This suggests that more than one episode of deformation has taken place. HiRISE image PSP_007524_1985 also illustrates a pair of irregular depressions with low, raised rims that are interpreted to be former lava lakes	Hermes Patera most likely a remnant of a patera originally 28 x 37 km. Dionysus Patera may originally have been 21 x 25 km. Faults on southern floor are associated with slump blocks that subsided into the more recent Apollo Patera. Clusters of irregular craters on Dionysus Patera floor are part of the distal ejecta from Pangboche crater
Aoc₂	**Hera Patera (Late Amazonian)**—Crescent-shaped fragment of caldera floor with numerous faults concentric to side of floor. Single radial wrinkle ridge. Eastward trace of rim indicates Hera Patera formed after Zeus Patera. *Type locality*: lat 18.25° N., long 226.13° E.	HiRISE image PSP_004821_1985 reveals that preserved segment of patera floor has wrinkle ridge, in addition to graben comparable to Zeus Patera	A fragment of a once-complete patera measuring ~30 km in diameter that was resurfaced with lava prior to truncation by the formation of Hermes Patera. Circumferential faults most likely the product of slumping following collapse of rim after patera formation
Aoc₁	**Zeus Patera (Late Amazonian)**—Largest patera within caldera, originally measuring ~60 x 65 km before subsequent collapse and burial events removed southwest segment. Striking topographic variation (~1,500 m) from low point in middle to perimeter of patera floor. Northern floor is ~450 m lower than southern floor. Numerous circumferential graben close to caldera wall, and ridges close to patera center, with the transition at ~16 km from patera center. Wide ridges cross boundary into Hermes Patera. *Type locality*: lat 18.15° N., long 227.10° E.	Numerous boulders seen on floors of the graben in HiRISE image PSP_004966_1985, suggesting that these tectonic features have been recently active	Oldest segment of the caldera. Graben and wrinkle ridges produced by downward flexing of patera floor due to magma withdrawal (Zuber and Mouginis-Mark, 1992). North-south elevation disparity of floor may be due to post-collapse inflation of southern rim (Mouginis-Mark and Wilson, 2019)
Aow	**Wall material (Early to Late Amazonian)**—Layered material near rim of patera, frequently covered with high-albedo material near the base. *Type locality*: lat 17.49° N., long 227.00° E.		Layering is a sequence of lava flows or solidified lava lakes associated with pre-collapse phase of volcanic activity. Bright albedo material is fragmented rocks or scree produced by weathering of walls
	EXTRA-CALDERA MATERIALS		
Aos₂	**Summit Flows, differentiated (Amazonian)**—Flows with lobate margins that radiate in all azimuths from the summit caldera. Some flows have central channels. *Type locality*: lat 17.62° N., long 227.32° E.	HiRISE image PSP_005177_1985 provides good high-resolution view of lobate flows	Summit lava flows. Lack of identifiable vents indicates that almost all flows erupted prior to formation of caldera and were beheaded by collapse events. Central channels are lava channels
Aos₁	**Summit Flows, undifferentiated (Amazonian)**—Older flows that have been weathered to remove fine-scale morphology. Lack of prominent morphologic features suggests that these flows are significantly older than unit Aos₂. *Type locality*: lat 17.40° N., long 226.12° E.		Older lava flows that have been weathered to remove fine-scale morphology. Lack of prominent morphologic features suggests that these flows are significantly older than unit Aos₂ and indicate a protracted period of inactivity at the summit
	PANGBOCHE CRATER		
Ap₁	**Floor material (Amazonian)**—Hummocky material with blocks as much as 150 m in diameter embedded in surface. *Type locality*: lat 17.16° N., long 226.36° E. Arcuate ridges approximately concentric to rim of crater. Multiple boulders on surface. Some smooth surfaces on upper swirls show banding that indicates material flowed downslope. *Additional locality*: lat 17.19° N., long 226.38° E.		Ejecta fall-back material and possible impact-melt sheet produced at the time of crater formation. Most likely consist of slump blocks of inner wall material, with blocks preserved from original crater-forming event. Smooth surfaces are flows of impact melt (Mouginis-Mark, 2015)
Ap₂	**Wall and Rim material (Amazonian)**—Upper portions show layers, along with spur and gulley morphology. Lower slopes have bland morphology and appear to partially bury material with a swirl texture. *Type locality*: lat 17.20° N., long 226.35° E. Hummocky material located immediately beyond rim crest of crater. Some large blocks to 70 m wide observed. *Additional locality*: lat 17.18°N., long 226.31°E.	HiRISE image ESP_026024_1975 reveals layers within the wall of Pangboche crater that are continuous for horizontal distances of hundreds of meters, suggesting that this material comprises massive units, most likely material similar to unit Aos₁	Section through target rocks, believed to be a sequence of lava flows from summit (Mouginis-Mark, 2015). Bland material is rock debris that forms scree material derived from eroded lava flows. Exterior part of unit is overturned flap of rim material. Blocks are ejecta formed during impact event

EXPLANATION OF MAP SYMBOLS

- **Discontinuous ejecta**
- **Wrinkle ridges**
- **Contact**—Solid where location certain, dashed where location approximate. Internal contact distinguishes overlapping or adjacent units
- **Normal fault**—Ball and bar on downdropped block
- **Crest of caldera rim**—Hachures point downslope
- **Small endogenic crater rim**
- **Lava lake**—Hachures point away from center
- **Lava channel**
- **Graben trace**—Approximate
- **Wrinkle-ridge margin**
- **Wrinkle-ridge crest**
- **Depression margin**—Hachures point downslope
- **Scarp crest**—Hachures point downslope
- **Scarp base**—Hachures point downslope
- 1 **Topographic profile**

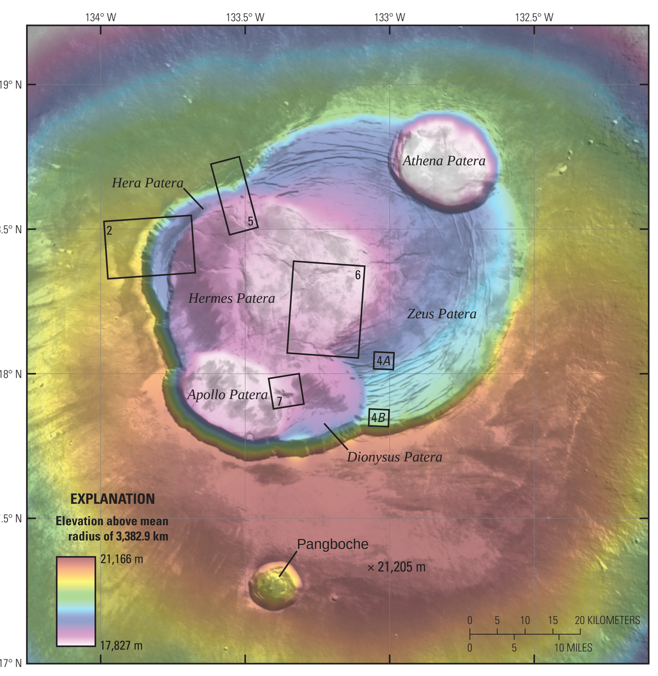


Figure 1. Topography of summit of Olympus Mons map area derived from Mars Orbiter Laser Altimeter (MOLA) data, showing names of paterae within Olympus Mons caldera and highest point on the volcano (21,205 m). Boxes show locations of images in subsequent figures. Base derived from High Resolution Stereo Camera (HRSC) image, with a gradational color scale extending from 17,827 to 21,166 m.

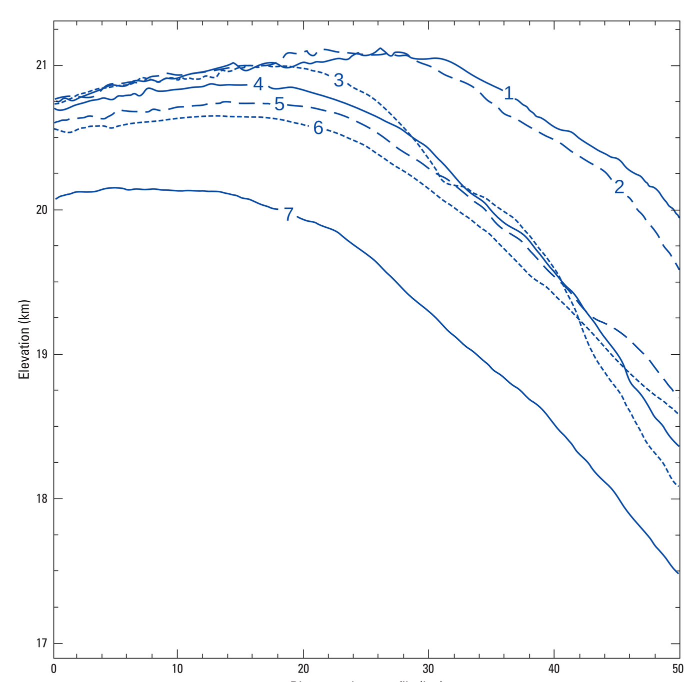


Figure 3. Graph comparing topographic profiles derived from gridded Mars Orbiter Laser Altimeter (MOLA) topography along seven lava flows on the south and east flanks of the caldera. Numbers refer to profile locations on geologic map. This comparison is critical in the recognition that the lobate lava flows (unit Aos₂) appear to first flow uphill before descending down the southeast flanks of the volcano. The most dramatic example is profile 1, which does not reach its maximum elevation until ~28 km from the caldera rim. This relation led Mouginis-Mark and Wilson (2019) to conclude that late-stage summit inflation followed formation of the current rim morphology.

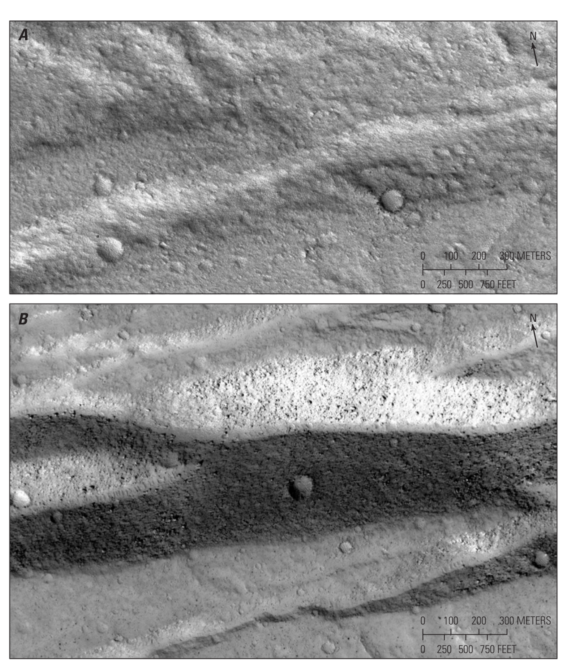


Figure 4. Images of parts of Zeus Patera show differences in the distribution of blocks and mantle materials within the individual graben. Image *A* lies closer to the caldera center than image *B*, where large blocks can be recognized in the walls and floor of the graben. See figure 1 and map for image locations. Images are segments of High Resolution Imaging Experiment (HiRISE) images PSP_004966_1985, and the lighting direction is from the lower left.

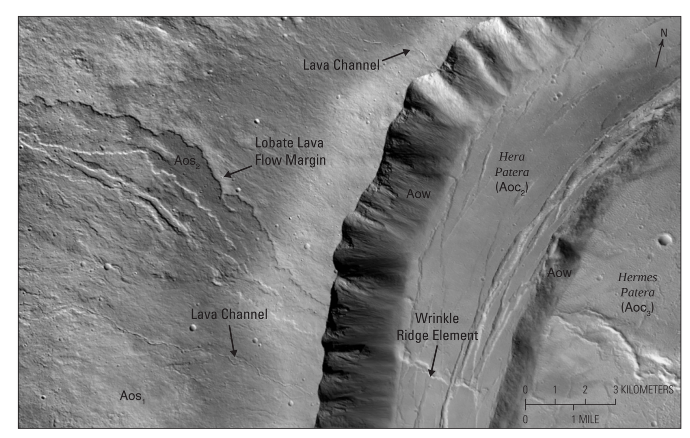


Figure 2. Image of west caldera rim of Olympus Mons caldera, showing that the lobate lava flows (unit Aos₂) and lava channels on the rim do not extend onto the floor of either Hera or Hermes Paterae, which implies that the paterae floors were resurfaced after their formation. Note that the wrinkle ridge within Hera Patera was deformed prior to the formation of Hermes Patera, because it does not extend onto the lower caldera floor in Hermes Patera. Wall material (unit Aow) is labeled. Base is part of Mars Reconnaissance Orbiter Context Camera (CTX) image B11_013919_1984. See figure 1 and map for image location.

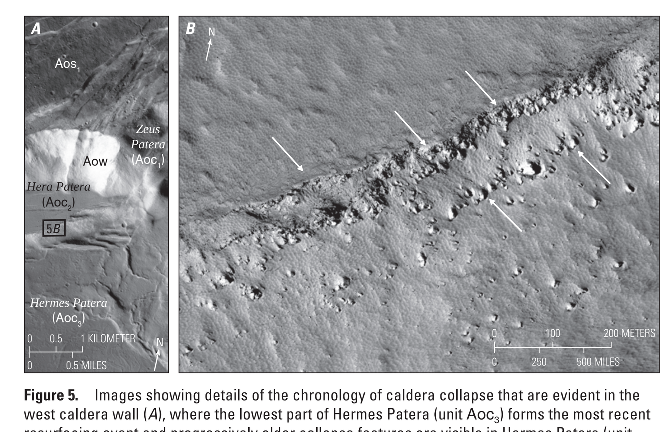


Figure 5. Images showing details of the chronology of caldera collapse that are evident in the west caldera wall (*A*), where the lowest part of Hermes Patera (unit Aoc₃) forms the most recent resurfacing event and progressively older collapse features are visible in Hermes Patera (unit Aoc₂) and Zeus Patera (unit Aoc₁). Extensive wall material (unit Aow) covers the (presumed) lava flows that would otherwise be exposed between Hera Patera and the rim material (unit Aos₁). Box shows location of image *B*. *B*, Layers in the uppermost part of the floor of Hera Patera. Arrows indicate that resurfacing material on the caldera floor is relatively thin. Base from parts of High Resolution Imaging Science Experiment (HiRISE) image ESP_014275_1990. See figure 1 for image location.

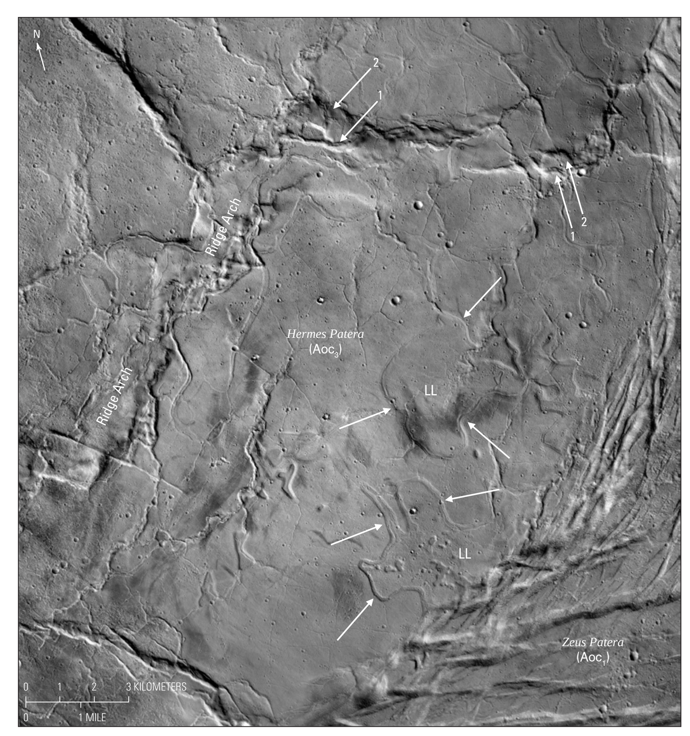


Figure 6. Image showing detailed view of floor of Hermes Patera (unit Aoc₃), showing materials that are interpreted to be deformed surfaces of cooled lava lakes (LL); arrows indicate the extent of these features. The prominent ridge arch just left of center is ~50 m high. Note that linear ridge elements (1) occur on top of the broader ridge arch (2), indicating multiple episodes of deformation. Part of Zeus Patera (unit Aoc₁) is at far right. Illumination from lower left. Part of Mars Reconnaissance Orbiter Context Camera (CTX) image F13_040859_1985. See figure 1 and map for image location.

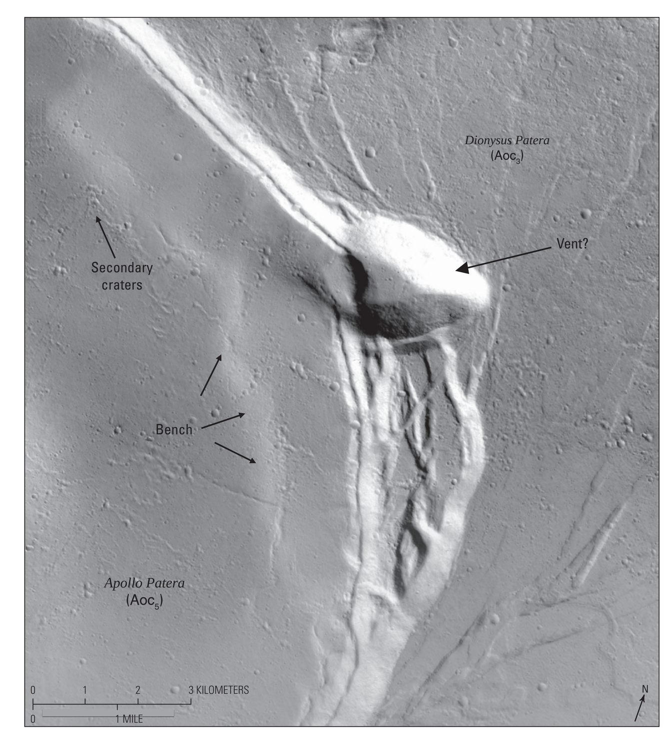


Figure 7. Image showing boundary between Dionysus (unit Aoc₃) and Apollo (unit Aoc₅) Paterae, where a candidate volcanic vent is visible. A bench, ~80 m high, is also identified and may indicate that the original level of the lava lake within Apollo Patera subsequently subsided. Secondary craters from Pangboche crater extend across much of Apollo Patera. Base from part of Mars Reconnaissance Orbiter Context Camera (CTX) image F08_038947_1985. See figure 1 and map for image location.

Geologic Map of Olympus Mons Caldera, Mars

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