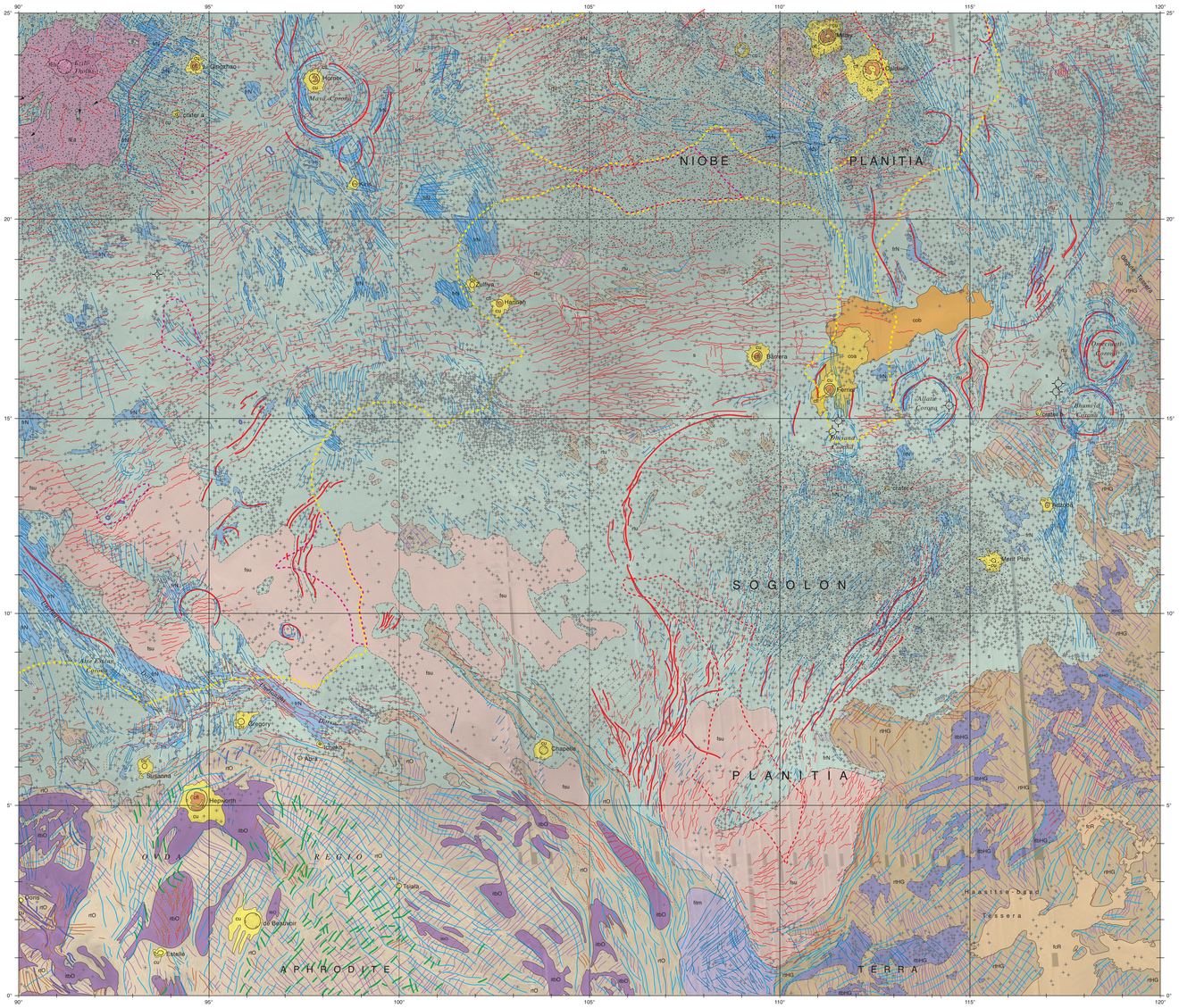
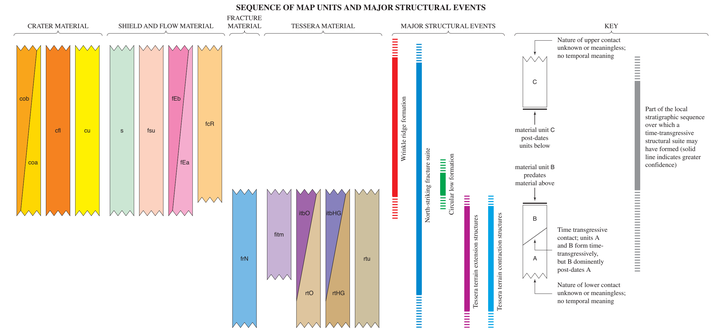
U.S. Department of the Interior
U.S. Geological Survey

Prepared for the
National Aeronautics and Space Administration

Scientific Investigations Map 3025
Atlas of Venus: Niobe Planitia Quadrangle (V–23)
Pamphlet accompanies map



SEQUENCE OF MAP UNITS AND MAJOR STRUCTURAL EVENTS



DESCRIPTION OF MAP UNITS

CRATER MATERIAL

Crater outflow material—*Interpretation*: Materials associated with bolide impact that formed Ferrier crater

ccb **Unit b**—Low backscatter and homogeneous texture

cca **Unit a**—Moderately high backscatter and heterogeneous texture with locally preserved lobate fronts

cfl **Crater fill material**—Undifferentiated; very low backscatter; smooth texture. *Interpretation*: Low viscosity material that locally filled craters following impact crater formation

cu **Crater material, undivided**—High backscatter and blocky texture. *Interpretation*: Materials and structures formed during bolide impact

SHIELD AND FLOW MATERIAL

s **Shield terrain**—Intermediate- to low-backscatter material of heterogeneous texture. Composed of distributed shields that cover much of the map area. *Interpretation*: Composite shield-related volcanic materials

fsu **Smooth flows, undivided**—Generally low backscatter material of mostly homogeneous texture. Locally may include shields, although this might be due to shield forming on unit fsu or to unit fsu locally flowing around shields. Unit fsu generally displays a gradational contact with unit s. *Interpretation*: Low viscosity flow materials

Ezili Tholus flow material—Intermediate- to high-backscatter flows. Comprises numerous individual flows radiating from an unnamed small volcano located at lat 24.7° N., long 91.3° E. Both units display lobate flows that indicate direction of flow. Materials are cut by regional wrinkle ridge suites. *Interpretation*: Volcanic flows related to Ezili Tholus

fEb **Flow b**—Proximal to the volcanic vent

fEa **Flow a**—Distal from the volcanic vent

fclR **Rosmerta Corona flow material**—Intermediate-backscatter flows. Flow indicators mapped on the basis of lobate and digitate flow boundaries. *Interpretation*: Volcanic flows related to Rosmerta Corona

FRACTURE MATERIAL

frN **Niobe Planitia fracture terrain**—Moderate- to low-backscatter, low-regional-relief terrain that sits locally above surrounding regions; typically deformed by fractures. *Interpretation*: Materials of unknown genetic origin deformed by regional and local tectonic structures prior to being locally covered

TESSERA MATERIAL

[Material forming in or associated with tessera terrain]

fbtm **Marginal intratessera flow material**—Moderately low backscatter. Flows seem to originate within crustal plateau margins and locally embay topographic valleys and depressions. Source regions and volcanic structures are typically indiscernible. *Interpretation*: Low viscosity flows emanating from local surfaces filled small and large depressions until magma volume exceeded the depositional center's capacity; excess lava spilled over the edge of the crustal plateau and filled marginal basins and structural lows. Variations in flow thickness may be responsible for the varying degree of preservation of the underlying tessera terrain structures

rtbO **Ovda Regio intratessera basin material**—Low backscatter. Contains local shields. Locally embays ribbons and folds. *Interpretation*: Volcanic flows from localized sources within Ovda Regio (Banks and Hansen, 2000)

rtO **Ovda Regio ribbon-tessera terrain**—High-backscatter, high-relief, terrain deformed by different suites of tectonic structures including various wavelengths of ribbon structures, various wavelengths of folds, and complex graben structures. *Interpretation*: Materials of unknown genetic origin deformed by ribbon and fold tectonic fabric formed during progressive thickening of a thin mechanical layer (Hansen and Willis, 1998; Hansen, 2006)

rtbHG **Haastte-baad and Gegute intratessera basin materials**—Low backscatter. Contain local shields. Locally embays ribbons and folds. *Interpretation*: Volcanic flows from localized sources within Haastte-baad and Gegute Tesserae (Banks and Hansen, 2000)

rtHG **Haastte-baad and Gegute ribbon-tessera terrain**—High-backscatter, moderate- to low-relief terrain deformed by different suites of tectonic structures including various wavelengths of ribbon structures, various wavelengths of folds, and complex graben. *Interpretation*: Material of unknown genetic origin deformed by ribbon and fold tectonic fabric formed during progressive thickening of a thin mechanical layer (Hansen and Willis, 1998; Hansen, 2006)

rtu **Ribbon-tessera terrain, undivided**—High- to moderate-backscatter, moderate relative relief but low regional relief terrain deformed by different suites of tectonic structures including various wavelengths of ribbon structures and folds that occur as inliers or kipukas in the lowland. *Interpretation*: Materials of unknown genetic origin deformed by ribbon and fold tectonic fabric formed during progressive thickening of a thin mechanical layer (Hansen and Willis, 1998; Hansen, 2006)

EXPLANATION

PRIMARY STRUCTURES

Contact—Dashed where gradational or uncertain

Shields

Small shield—Diameter <10 km

Large shield—Diameter >10 km

Channel

Airburst spot

Lava flow direction

Impact crater rim crest

Diameter <20 km

Diameter >20 km

ISOPACH CONTOURS

Isopach contours—Model maximum depth (see text for explanation)

Units frN and rt > 1 km

Units rtHG, rtO, rtu > 1 km

SECONDARY STRUCTURES

Regional fractures

Graben

Wrinkle ridge

Broad ridge crest

Fold crest

Structural trends

Buried lineaments trends

Tessera-terrain trends

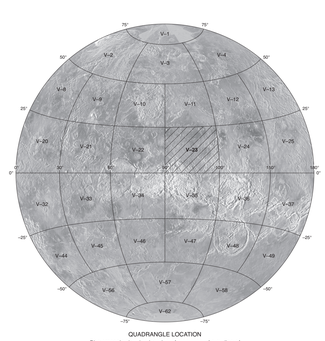
Wide troughs

Fold trends

Tessera trends

Ribbon trends

Pit chains



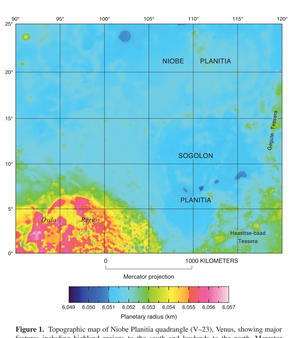


Figure 1. Topographic map of Niobe Planitia quadrangle (V–23), Venus, showing major features including highland regions to the south and lowlands to the north. Mercator projection.

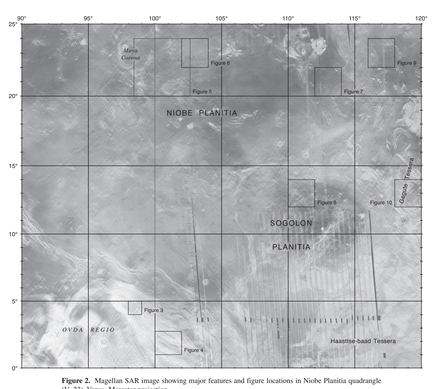


Figure 2. Magellan SAR image showing major features and figure locations in Niobe Planitia quadrangle (V–23), Venus. Mercator projection.

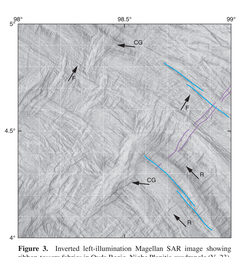


Figure 3. Inverted left-illumination Magellan SAR image showing ribbon-tessera fabrics in Ovda Regio, Niobe Planitia quadrangle (V–23), Venus. These fabrics are representative of ribbon-tessera fabrics across the map area. Ribbons trend northeast (R arrows); two ribbon trends shown in purple. Folds trend northwest: crests of four medium-wavelength folds outlined in cyan; crests of short-wavelength folds indicated by F arrows. Short-wavelength folds >0.3 km long are clearly visible at SAR image resolution (Hansen, 2005). Complex graben structures (CG arrows) trend northeast, generally parallel to ribbon trends. Note that contractional structures trend northwest and have a range of wavelengths; extensional structures trend northeast and also have a range of structural wavelengths.

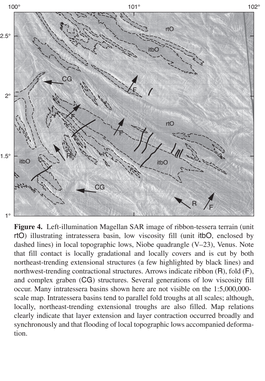


Figure 4. Left-illumination Magellan SAR image of ribbon-tessera terrain (unit rtO) illustrating intratessera basin, low viscosity fill (unit rtbO, enclosed by dashed lines) in local topographic lows, Niobe quadrangle (V–23), Venus. Note that fill contact is locally gradational and locally covers and is cut by both northeast-trending extensional structures (a few highlighted by black lines) and northwest-trending contractional structures. Arrows indicate ribbon (R), fold (F), and complex graben (CG) structures. Several generations of low viscosity fill occur. Many intratessera basins shown here are not visible on the 1:5,000,000-scale map. Intratessera basins tend to parallel fold troughs at all scales; although, locally, northeast-trending extensional troughs are also filled. Map relations clearly indicate that layer extension and layer contraction occurred broadly and synchronously and that flooding of local topographic lows accompanied deformation.

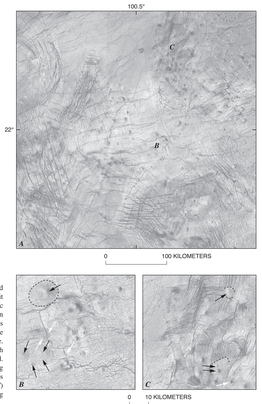


Figure 5 (right). Inverted right-illumination Magellan SAR images cropped from C1- and full-resolution SAR images showing details of shield terrain and tectonic structures in unit frN, Niobe quadrangle (V–23), Venus. ***A***. Image centered at 22° N., 100.5° E.; concentric structures in the upper left are part of Maya Corona that dominantly predates shield-terrain formation; north-northwest-striking fractures and east-northeast-trending wrinkle ridges parallel regionally extensive structural suites. East-striking fractures in the bottom of the image occur within a more localized region. Shields are scattered across the surface. Enlargements ***B*** and ***C*** show a range of shield morphologies and temporal relations with secondary structures. Black arrows point to a few shields that are well to poorly defined. North-striking regional fractures generally predate shield formation, and reactivation along north-striking fractures locally postdates shield emplacement (white arrows). Dashed lines indicate examples of well-defined (upper C) and more poorly defined (***B*** and lower C) limits of shield deposits; local regions of fracture terrain are exposed as kipukas among shield deposits (***C***).

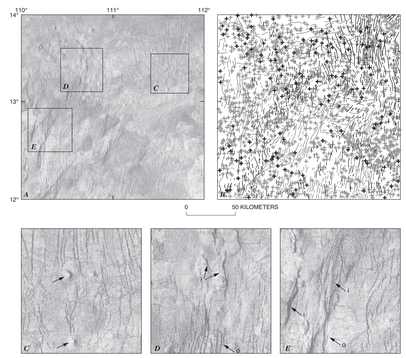


Figure 8. Right-illuminated inverted SAR image (***A***) centered at lat 13° N., long 111° E., showing fracture terrain of Niobe Planitia (unit frN) and locations of enlargements ***C–E***, and mapped geologic structures (***B***), Niobe quadrangle (V–23), Venus. Geologic structures (***B***) show definite shields (black crosses), potential shields (gray crosses), wrinkle ridges (gray lines), and fractures (black lines); white background indicates region of shield terrain shown in image ***A***. Although many shields are cut by reactivated north-striking fractures, other shields clearly postdate fracture reactivation (***C***, arrows). Locally, shield-paint-filled fractures are inverted by later contraction resulting in north-trending inversion structures: folds or wrinkle ridges (gray lines, ***B***; I arrows, ***D***, ***E***) and open fractures (0 arrows, ***D***, ***E***). Open fractures are locally modified along strike, either covered by shield deposits and (or) forming inversion structures (***E***).

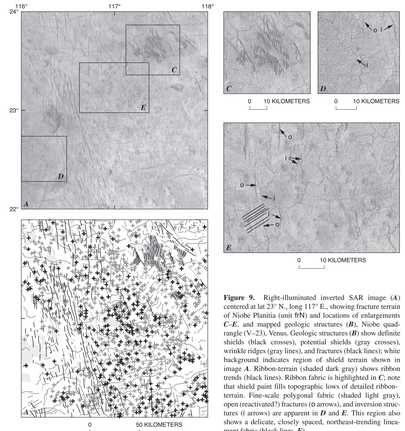


Figure 9. Right-illuminated inverted SAR image (***A***) centered at lat 23° N., long 117° E., showing fracture terrain of Niobe Planitia (unit frN) and locations of enlargements ***C–E***, and mapped geologic structures (***B***), Niobe quadrangle (V–23), Venus. Geologic structures (***B***) show definite shields (black crosses), potential shields (gray crosses), wrinkle ridges (gray lines), and fractures (black lines); white background indicates region of shield terrain shown in image ***A***. Ribbon-terrain (shaded dark gray) shows ribbon trends (black lines). Ribbon fabric is highlighted in ***C***; note that shield paint fills topographic lows of detailed ribbon-terrain. Fine-scale polygonal fabric (shaded light gray), open (reactivated?) fractures (0 arrows), and inversion structures (I arrows) are apparent in ***D*** and ***E***. This region also shows a delicate, closely spaced, northeast-trending lineament fabric (black lines, ***E***).

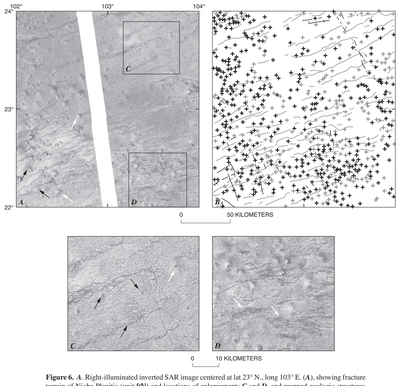


Figure 6. ***A***. Right-illuminated inverted SAR image centered at lat 23° N., long 103° E. (***A***), showing fracture terrain of Niobe Planitia (unit frN) and locations of enlargements ***C*** and ***D***, and mapped geologic structures (***B***), Niobe quadrangle (V–23), Venus. Relative spacing of wrinkle ridges and shields results in inconclusive temporal relations (***A*** and ***C***); although some shields postdate secondary structures (white arrows), in most cases shields are older than wrinkle ridges or fractures (black arrows), indicating wrinkle ridges dominantly postdate shields. Geologic structures (***B***) highlight definite shields (black crosses), potential shields (gray crosses), wrinkle ridges (gray lines), and fractures (black lines); white background indicates region of shield terrain shown in image ***A***. Fine-scale polygonal fabric occurs between wrinkle ridges and is best developed away from shield centers where the unit is likely thin (***C***). Primary shield structures (***D***) locally cover and, therefore, formed after locally preserved basal layer marked by closely spaced, east-trending, anastomosing lineaments (white arrows).

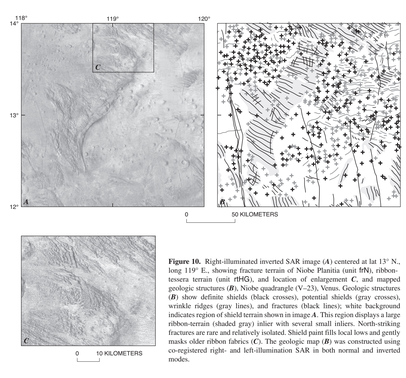


Figure 10. Right-illuminated inverted SAR image (***A***) centered at lat 13° N., long 119° E., showing fracture terrain of Niobe Planitia (unit frN), ribbon-tessera terrain (unit rtHG), and location of enlargement ***C***, and mapped geologic structures (***B***), Niobe quadrangle (V–23), Venus. Geologic structures (***B***) show definite shields (black crosses), potential shields (gray crosses), wrinkle ridges (gray lines), and fractures (black lines); white background indicates region of shield terrain shown in image ***A***. This region displays a large ribbon-terrain (shaded gray) inlier with several small inliers. North-striking fractures are rare and relatively isolated. Shield paint fills local lows and gently masks older ribbon fabrics (***C***). The geologic map (***B***) was constructed using co-registered right- and left-illumination SAR in both normal and inverted modes.

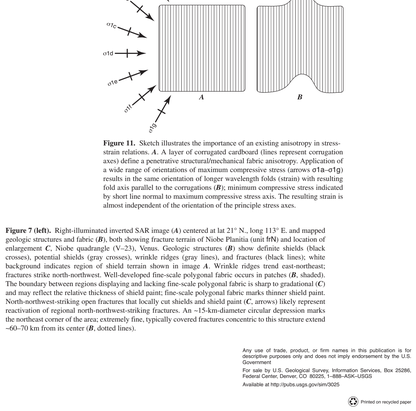


Figure 7 (left). Right-illuminated inverted SAR image (***A***) centered at lat 21° N., long 113° E. and mapped geologic structures and fabric (***B***), both showing fracture terrain of Niobe Planitia (unit frN) and location of enlargement ***C***. Niobe quadrangle (V–23), Venus. Geologic structures (***B***) show definite shields (black crosses), potential shields (gray crosses), wrinkle ridges (gray lines), and fractures (black lines); white background indicates region of shield terrain shown in image ***A***. Wrinkle ridges trend east-northeast; fractures strike north-northwest. Well-developed fine-scale polygonal fabric occurs in patches (***B***, shaded). The boundary between regions displaying and lacking fine-scale polygonal fabric is sharp to gradational (***C***) and may reflect the relative thickness of shield paint; fine-scale polygonal fabric marks thinner shield paint. North-northwest-striking open fractures that locally cut shields and shield paint (***C***, arrows) likely represent reactivation of regional north-northwest-striking fractures. An ~15-km-diameter circular depression marks the northeast corner of the area; extremely fine, typically covered fractures concentric to this structure extend ~60–70 km from its center (***B***, dotted lines).

Figure 11. Sketch illustrates the importance of an existing anisotropy in stress-strain relations. ***A***. A layer of corrugated cardboard (lines represent corrugation axes) define a penetrative structural/mechanical fabric anisotropy. Application of a wide range of orientations of maximum compressive stress (arrows σ1a–σ1g) results in the same orientation of longer wavelength folds (strain) with resulting fold axis parallel to the corrugations (***B***); minimum compressive stress indicated by short line normal to maximum compressive stress axis. The resulting strain is almost independent of the orientation of the principle stress axes.

Geologic Map of the Niobe Planitia Quadrangle (V–23), Venus

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