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GEOLOGIC MAP OF THE BARRYMORE QUADRANGLE (V–59), VENUS

By
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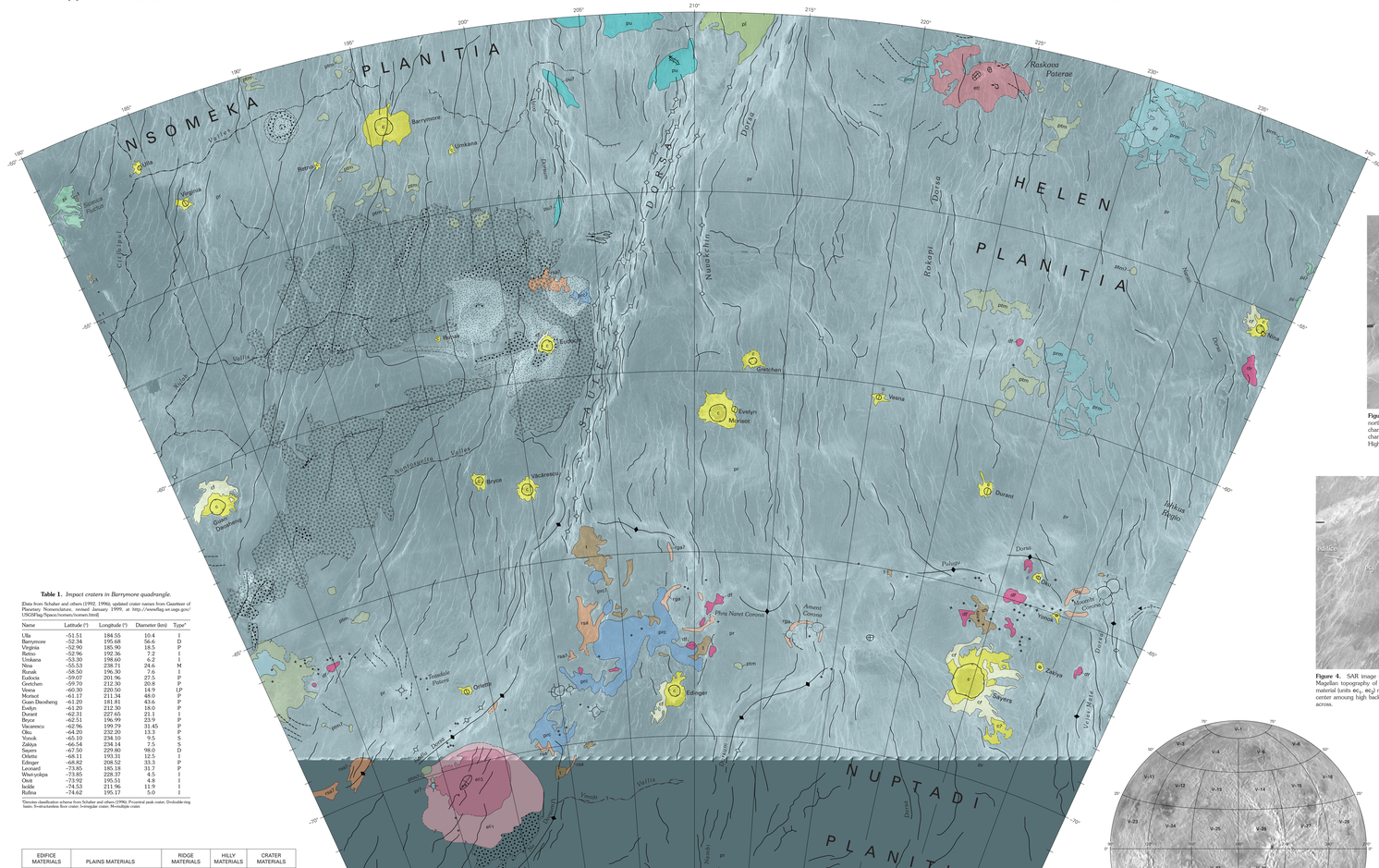

Table 1. *Impact craters in Barrymore quadrangle.*

[Data from Schaber and others (1992, 1996); updated crater names from Gazetteer of Planetary Nomenclature, revised January 1999, at http://wwwflag.wr.usgs.gov/USGSFlag/Space/venus/venus.html]

Name	Latitude (°)	Longitude (°)	Diameter (km)	Type[a]
Ulla	–51.51	184.55	10.4	I
Barrymore	–52.34	195.68	56.6	D
Virginia	–52.90	185.90	18.5	P
Retro	–52.96	192.36	7.2	I
Urokana	–53.30	198.60	6.2	I
Nina	–53.70	238.10	44.4	M
Ulla	–58.50	196.30	7.6	I
Eudocia	–59.07	201.96	27.5	P
Gretchen	–59.70	212.30	20.8	P
Vesna	–60.30	220.50	14.9	LP
Morisot	–61.17	211.34	48.0	P
Guan Daosheng	–61.20	181.81	43.6	P
Evelyn	–61.20	212.30	18.0	P
Durant	–62.31	227.65	21.1	I
Bryce	–62.51	196.99	23.9	P
Vucanescu	–62.96	199.79	31.45	P
Ortia	–64.20	232.20	13.3	P
Yonoh	–65.10	234.10	9.5	S
Zakiya	–66.54	234.14	7.5	S
Sayers	–67.50	229.80	98.0	D
Ortelia	–68.12	228.12	12.1	I
Edinger	–69.48	208.32	33.3	P
Leonard	–73.85	195.18	11.7	P
Wise-yakpa	–73.85	229.37	4.5	I
Ovid	–73.92	195.51	4.8	I
Isolde	–74.53	211.96	11.9	I
Rufina	–74.62	195.17	5.0	I

[a]Denotes classification scheme from Schaber and others (1996): P=central peak crater, D=double-ring basin, S=structureless floor crater, I=irregular crater, M=multiple crater.

DESCRIPTION OF MAP UNITS

[Map units distinguished and interpreted on basis of morphology, texture, stratigraphic position, backscatter properties, and structural associations using cycle 1 and cycle 2 synthetic aperture radar (SAR) images. Most map units distinguished as rock units with structural facies[s] characteristic variations]

EDIFICE MATERIALS

Concentric edifice material—Smooth-textured material extending concentrically around oval-shaped edifice near 71° S., long 192° (fig. 6), material is mantled by small mottling and appears to define boundaries. Western and southern portions more uncertain, with possible embayment by mottled textured plains material (unit **ptm**). May contain moderate density of high backscatter narrow ridges.

Unit 2—Exterior material marked by lower radar backscatter. *Interpretation:* Lava from central caldera structure overlying unit **ec1**.

Unit 1—Exterior material marked by intermediate radar backscatter. *Interpretation:* Lava from central caldera structure underlying unit **ec2**.

Lobate textured edifice material—Series of hummocky to smooth-textured, intermediate backscatter material showing individual lobate margins, most of which radiate outward from central fractural edifices near lat 52° S., long 222–224° (Raskova Paterae) and overlie regional plains material (unit **pr**). Also exhibits high backscatter lineaments spaced 10–50 km apart. *Interpretation:* Overlapping lavas associated with central caldera of Raskova Paterae

PLAINS MATERIALS

Mottled textured plains material—Often semicircular to oval-shaped, intermediate backscatter material overlying regional plains material (unit **pr**). Shows slightly hummocky texture, with margins more diffuse than, for example, mottled ridged plains material (unit **prm**); may exhibit some wrinkle ridges within larger portions and may encompass several small units that are mostly radar-dome fields (unit **df**) at lat 66.5° S., long 203°). *Interpretation:* Probable sites of volcanic (ash-flow?) activity, with hummocky texture possibly arising from many small (below spatial resolution of SAR images) volcanic centers and (or) volcanic ejecta

Lobate plains material—Very high backscatter, digitate to lobate material overlying regional plains material (unit **pr**), usually well defined. Also exhibits high backscatter margins, although more diffuse and interspersed with mottled, lower backscatter splotches or ridges (or both). Stream-lined nature of some portions resembles crater flow material (unit **cf**). Type locality is Scasica Fluctus (lat 52° S., long 181°), which occurs at easternmost extension of fig. 6. *Interpretation:* Material has several low-relief flow lineaments, type locality represents lava flows at terminus of tectonovolcanic region west of map area

Inub plains material—Low to intermediate backscatter plains material apparently emanating from the Inub highland area (unit **ih**) in north-central map area (lat 50°–55° S., long 212.5° and covers regional plains material (unit **pr**). *Interpretation:* Large lava flows originated from Inub Regio, north of map area, and (or) volcanic ejecta from Inub highland, with early-stage lava flow(s) associated with Inub volcano

Regional plains material—Mainly smooth-textured material low to intermediate backscatter[s] exhibiting semilinear or semiparallel high backscatter ridges (or both), most often spaced 10–50 km apart. Stretching, elevated, north-south linear belts in center of map area (Nuptadi Dorsa) show linear to semilinear concentrations of closely spaced (<20 km) high backscatter, positive relief ridges and (or) lineaments. Southeastern part of map area (Nuptadi Planitia) shows a wellike network of semiconcentric to sinuous ridges and troughs in a reticulate fabric. Other areas may show few to no ridges. Overlies corrugated ridged plains material (unit **prc**), mottled ridged plains material (unit **prm**), and wellformed plains material (unit **pp**). *Interpretation:* Plains lavas associated with major, regional volcanic resurfacing event(s), later tectonically warped or deformed by compressional forces, particularly in places to produce ridge development. Smoother areas represent lavas unaffected by wrinkle ridge deformation. Ridge belt areas represent combined compressional (compressional) zones of overlapping wrinkle ridges and smooth ridges with minor fracturing

Undifferentiated plains material—Intermediate backscatter plains material with few patches of low backscatter material (unit **pl**) and numerous radar-dome fields (unit **df**) at lat 51.5°–52.5°, long 209°). Overlain by regional plains material (unit **pr**). *Interpretation:* Older lavas originated from Inub Regio, north of map area, possibly from southern rim of corona at lat 47.5° S., long 208°

Mottled ridged plains material—High to intermediate backscatter plains occurring within regional plains material (unit **pr**). May have low backscatter sinuous to linear channelike forms either confined within the unit or crossing both this unit and unit **pr**; may exhibit semilinear ridges that cross both these units. May occur as lava contacts or as irregular areas or patterns of "splotchy" material with sharp to gradational edges. Superposition relations difficult to discern, but regional plains material (unit **pr**) and (or) ridged plains material (unit **prm**) appear to have embayed this unit. *Interpretation:* Old volcanic deposits, including lava flows, some channelled. Deformed by later ridges; some have superimposed wrinkle ridges of regional plains material

Corrugated ridged plains material—Complicated mixture of narrow high backscatter ridges or curvilinear segments with plains wrinkle ridges. May be embayed or overlain by regional plains material (unit **pr**), arcuate ridge and groove material (unit **rga**), or smooth arcuate ridge material (unit **rsa**). Embays tessera material (unit **t**) in places. Occurs only in center of map area, between southern end of Saule Dorsa and northern end of Chih Nu Dorsum (at 68° S., long 207°; fig. 5). *Interpretation:* Compressionally deformed older plains, such as mottled plains, or possibly the central portion of former corona complex with flooded margins and deformed rims

RIDGE MATERIALS

Arcuate ridge and groove material—Curvilinear to arcuate, semiparallel ridges and grooves elevated relative to surrounding terrain. May be embayed or crosscut by lavas and wrinkle ridges of regional plains material (unit **pr**). At type locality is Phra Naret Corona (lat 60° S., long 208°), which overlies corrugated ridged plains material (unit **prc**). Where not distinguished on basis of prominent features that is, high backscatter ridges/low backscatter grooved, may also be identified by lack of surrounding wrinkle ridges associated with regional plains material (unit **pr**). *Interpretation:* Volcanically flooded corona rims

Smooth arcuate ridge material—Like arcuate ridge and groove material (unit **rga**), but encompasses smaller semiparallel, curvilinear, smooth-topped ridges. May show intervening plains units between ridges. May also show narrow ridges at bases of individual broad ridges. At type locality (at 67° S., long 203°) overlies corrugated ridged plains material (unit **prc**). Broad ridges especially dependent on look direction and may not appear as smooth in cycle 2 as cycle 1 images. *Interpretation:* Ridge belt apices surrounded by volcanically flooded regions; alternatively, corona rim remnants

HILLY MATERIALS

Dome fields—Clusters of small (<20 km diameter) semicircular positive relief materials. Boundary defined where density is too high for consistent use of "small shield" map symbol. May overlap into other unit boundaries. Rarely, lobate material extends radially from small central edifice. *Interpretation:* Fields of volcanic domes, rarely with associated lava flows

Tessera material—High backscatter, relatively high relief small areas showing multiple ridges crosscutting in predominantly one and rarely more than one direction. Intervening plains material grouped within this unit. *Interpretation:* Flooded former corona, tessera, or ridge belt material (or all)

CRATER MATERIALS

Crater floor material—Intermediate to very high backscatter, smooth to hummocky-textured material extending from crater showing lobate edges. May show some mottling and gradational backscatter relations with surrounding terrain of the unit, with slightly hummocky texture nearer crater. Streamlined morphology or high backscatter sinuous streaks or channels for both) may exist. Most material appears to follow topography, and some margins dark low. *Interpretation:* Fluidized ejecta blanket outflow materials with channels, with possible incorporation of minor bedlike ejecta blocks, most often emplaced as a deposit

Crater material—High to intermediate backscatter material with hummocky to speckled textures, radiating from crater with sharp to gradational distal boundaries overlying low backscatter plains material. Material may not surround symmetrically, where crater, and may form individual arms or lobes radiating from crater rim. May form narrow transverse ridges concentrically to crater and gradational contacts with plains or crater flow material (unit **cf**). May include small patches of underlying plains. May include low to intermediate backscatter speckled regions within or at distal ends of hummocky radiating material, gradational with surrounding plains. Also includes crater floor, walls, and rim. May include central, elevated, blocky region, or concentric, usually incomplete elevated rings with symmetric aprons of lower backscatter material at base. *Interpretation:* Impact crater and associated primary and secondary ballistic ejecta with minor fluidization, although in some instances this type of scattering is most important. Small areas of lower backscatter material (unit **c**) may be volcanic flows, usually filling low-relief areas such as crater floor, and (or) lineaments

Table 2a. *Radar property data for geologic units in Barrymore quadrangle (V–59).*

[For each unit, first line is cycle 1 data, second line is cycle 2 data. Backscatter values are given as average σ_o computed from given number of pixels per plot and minus one standard deviation (in parentheses) using the method and software of Campbell (1996). No cycle 1 coverage exists for unit **ec1**.]

Unit	Latitude,Longitude	Pixel	Number scale (m)	Incidence angle of pixels	Backscatter (dB) range (degrees)
ec1	(–70.196,–69.992), (195.060,195.607)	225	8372	18.40–18.33	–8.638 (+9.902,–7.660)
ec1			8536	21.64–21.56	–9.719 (–11.095,–8.679)
ec2					
ec2	(–70.256,–70.115), (194.509,194.839)	225	3015	21.59–21.54	–10.776 (–12.129,–9.745)
ec2	(–54.968,–54.774), (188.360,188.578)	225	5520	21.87–21.82	–13.643 (–14.570,–12.586)
pr			5520	24.74–24.73	–13.936 (–15.244,–12.933)
pr	(–51.359,–51.193), (223.499,223.717)	225	5056	22.89–22.84	–11.969 (–13.891,–10.641)
ec1			5056	24.99–24.98	–12.728 (–14.768,–11.340)
ptm	(–59.602,–59.448), (227.422,227.775)	225	5548	20.82–20.79	–13.957 (–15.197,–12.993)
ptm			5548	24.17–24.16	–9.500 (–12.044,–7.906)
prm	(–51.555,–51.393), (231.767,232.161)	225	12322	22.85–22.78	–11.557 (–15.448,–9.538)
prm			12322	22.85–22.78	–11.557 (–15.448,–9.538)
prc	(–67.593,–67.395), (204.361,204.768)	225	6674	21.42–21.35	–12.980 (–15.181,–10.413)
prc			6674	24.42–24.35	–12.980 (–15.181,–10.413)
pl	(–50.386,–50.246), (212.378,212.516)	225	2345	22.87–22.83	–12.022 (–13.079,–11.173)
pl			2345	24.98–24.97	–13.134 (–13.925,–12.616)
pr	(–50.346,–50.180), (206.515,206.703)	225	4108	23.22–23.16	–9.458 (–11.041,–8.301)
pr			4108	25.05–25.04	–10.038 (–11.917,–8.735)
pl	(–52.206,–52.074), (180.919,181.101)	225	3339	22.62–22.57	–3.933 (–6.262,–2.426)
pl			3339	24.73–24.72	–6.006 (–9.016,–4.271)
rga	(–64.430,–64.159), (211.358,211.995)	225	7436	19.29–19.27	–7.078 (–11.195,–6.171)
rga			7436	21.39–21.37	–9.698 (–11.195,–8.693)
rsa	(–67.117,–66.976), (203.260,203.424)	225	2683	19.35–19.29	–5.953 (–8.141,–3.074)
rsa			2684	22.55–22.49	–8.540 (–12.688,–6.457)
c	(–61.383,–61.275), (181.955,182.332)	225	4472	20.44–20.42	–5.833 (–10.379,–3.622)
c			4472	23.88–23.86	–5.408 (–11.377,–2.985)
cf	(–61.240,–60.992), (180.491,180.580)	225	2478	20.49–20.44	–2.532 (–3.450,–1.771)
cf			2478	23.93–23.89	–4.298 (–5.587,–3.305)
cf	(–67.171,–67.079), (209.490,210.417)	225	14592	19.52–19.46	–7.830 (–10.078,–6.364)
cf			14592	22.76–22.68	–9.517 (–12.527,–7.756)
df	–67.017,–66.781), (206.867,207.165)		6048	19.37–19.31	–5.000 (–11.880,–4.000)
t			6048	22.58–22.51	–9.529 (–13.544,–7.479)
	Stipple Patterns:				
filled	(–57.358,–57.235), (200.426,200.876)	225	6431	21.29–21.27	–11.515 (–14.749,–9.682)
filled		225	6431	24.50–24.48	–13.419 (–18.520,–11.137)
dot	(–56.489,–56.309), (197.866,198.260)	225	7826	21.49–21.45	–5.704 (–6.906,–4.840)
dot		225	7826	24.60–24.58	–14.043 (–15.050,–13.228)
dash	(–63.652,–63.504), (180.885,181.258)	225	5451	21.49–21.44	–8.648 (–10.886,–7.192)
dash		225	5451	23.44–23.41	–9.646 (–11.886,–7.192)
dot	–57.116,–56.899), (197.717,198.027)	225	6695	21.36–21.32	–9.028 (–10.072,–8.187)
dot		225	6695	24.54–24.51	–11.363 (–12.553,–10.430)

Table 2b. *Radar property data for geologic units in Barrymore quadrangle (V–59).*

[Values in parentheses correspond to minimum and maximum values in region. ε_1,ε_2 are dielectric constants estimated from calculations for smooth (s) and rough (r) surfaces using the method of Campbell (1995)]

Unit	Planetary radius (km)	Root-mean-square slope	Reflectivity	Emissivity	ε_1,ε_2
ec1	6051.699 (6051.627,6051.775)	1.74 (1.70,1.90)	0.115 (.105, .129)	0.850 (.850, .851)	4.7,5.1
ec2	6051.549 (6051.500,6051.604)	1.85 (1.80,2.00)	.109 (.105, .115)	.850 (.850, .851)	4.7,5.1
pr	6051.023 (6050.970,6051.062)	3.29 (2.90,4.10)	.178 (.165, .220)	.832 (.830, .834)	5.1,5.7
etf	6050.929 (6050.832,6051.091)	3.33 (2.50,4.50)	.133 (.105, .160)	.848 (.846, .850)	4.5,5.2
ptm	6051.146 (6051.120,6051.195)	4.16 (3.20,5.40)	.198 (.150, .265)	.853 (.852, .854)	4.5,5.0
prm	6051.858 (6051.805,6051.977)	3.29 (2.20,5.70)	.205 (.165, .265)	.845 (.843, .847)	4.6,5.3
prc	6051.537 (6051.497,6051.633)	2.13 (1.70,2.80)	.120 (.105, .140)	.843 (.842, .845)	4.9,5.3
pl	6051.502 (6051.283,6051.598)	2.22 (1.60,4.50)	.096 (.080, .120)	.843 (.842, .845)	4.9,5.3
pr	6051.502 (6051.283,6051.598)	2.22 (1.60,4.50)	.096 (.080, .120)	.843 (.842, .845)	4.9,5.3
rga	6051.167 (6051.053,6051.298)	3.64 (2.50,4.20)	.157 (.120, .175)	.850 (.827, .853)	5.1,5.8
rsa	6051.786 (6051.598,6051.878)	4.81 (2.60,10.10)	.152 (.125, .175)	.849 (.845, .851)	4.5,5.1
c	6051.955 (6051.856,6052.114)	4.62 (3.66,6.40)	.174 (.150, .190)	.849 (.849, .849)	4.7,5.2
cf	6051.172 (6051.101,6051.201)	3.53 (3.20,4.00)	.175 (.145, .215)	.823 (.820, .825)	5.4,6.0
df	6051.082 (6051.052,6051.093)	2.27 (1.80,3.00)	.138 (.115, .165)	.804 (.803, .806)	6.0,6.7
dot	6051.565 (6051.515,6051.640)	4.22 (3.60,5.50)	.148 (.130, .175)	.850 (.849, .851)	4.7,5.1
t	6051.592 (6051.441,6051.762)	3.08 (2.00,4.60)	.149 (.130, .180)	.848 (.848, .849)	4.7,5.2
	Stipple Patterns:				
filled	6051.578 (6051.500,6051.712)	2.73 (2.20,4.20)	.113 (.095, .140)	.839 (.837, .841)	4.9,5.5
open	6051.150 (6051.096,6051.235)	6.46 (4.50,9.80)	.198 (.130, .390)	.837 (.836, .838)	4.9,5.5
dash	6051.257 (6051.214,6051.273)	8.15 (3.00,9.40)	.140 (.120, .180)	.821 (.819, .822)	5.5,6.1
dot	6051.432 (6051.300,6051.546)	5.79 (4.30,8.40)	.241 (.185, .370)	.849 (.844, .854)	4.6,5.2

MAPPING TECHNIQUES

Geologic mapping of Venus surface units using classical photogeologic methods to determine relative ages via embayment and superposition relations (Wilhelms, 1990) must be combined with knowledge of radar image interpretation problems, including foreshortening and layover, geometric distortions effects[s] and augmented by topography, backscatter, and other radar property data. Map units are defined on the basis of the morphology, surface textures, and structures observed in the Magellan SAR images (Tanaka, 1994). Emphasis has been placed on mapping units that represent stratigraphic units, that is, laterally continuous deposits that formed by similar geologic processes over a short period of time. Morphologic and radar units are mainly characterized by structural differences from their surroundings. They do not represent stratigraphically different materials, only differences in the degree of deformation. This map area contains predominantly plains materials that, though exhibiting variable degrees of wrinkle ridge and ridge belt deformation, are grouped into one regional plains unit (unit **pr**). Deformation patterns are schematically designated by symbols rather than through mapping of units. As such, significant structural features such as ridge belts are not mapped as geologic units, but rather as densely deformed structural zones of former plains materials.

Coronae such as Phra Naret Corona are mapped as units, although their rims are distinguished as units (units **rga**, **rsa**). The boundaries of surficial units are mapped by the spatial boundaries of overlapping regional plains material (unit **pr**). Some regions have anomalously high backscatter in cycle 1 backscatter in one cycle compared to another and are distinct from regions in which backscatter differences between cycles are minimal (for example, units **ptm** and **prm**).

Photographic and digital versions of the SAR images from cycles 1 and 2 provide the main tool for geologic mapping. Fullresolution (75 m/pixel) synthetic aperture radar (Bcorr3 (F-MIDR) images sampled to 75 m/pixel) are used where available for detailed study of particular features, whereas compressed images (C1–, C2–, and C3-MIDR) provide regional perspectives, including regions beyond the limit of the map area. Photographic versions of USGS-produced full-resolution images (FMAP's) allow detailed comparisons of closely spaced regions at full Magellan resolution and are a significant aid in locating and determining characteristics of small features such as canali-type channels (Baker and Kargel, 1992). Stereoscopic image pairs (cycle 1–cycle 2) are available in emphasizing topography and backscatter differences (fig. 3). Earth-based radar images (Arecibo, Goldstone) are restricted to the equatorial regions with the use of the Arecibo (Puar and Ocumare, 1992) and are thus unavailable for this area of the planet.

Magellan altimetry has lower spatial resolution than SAR but is nonetheless vital to understanding the present topography of the region. Two products that combine SAR and altimetry data are used here. The first is USGS-produced "synthetic stereo" images that are created from the C1-MIDR and altimetry data and shaded by shining pixels depending on their altitude in a registered Magellan topographic image. Stereo viewing of SAR images having vertical exaggerations of 10× and 20× is useful in the discerning structural and topographic relations between adjacent regions. Placement of structural symbols for ridges and troughs often is based on comparison of the synthetic stereo images with topography for the region. The second product is a synthetic perspective view created by using software developed by Gwinn and Sandwell (1994). Although limited in its control means of readily comparing the distribution of stratigraphic units and structural features with topography. Though both of these products are artifacts resulting from the interpolation of widely spaced altimetry data and altimetric data, the relatively low topographic relief within the Barrymore quadrangle minimizes these effects.

The other radar datasets (emissivity, reflectivity, and root mean square (rms) slope available on the GxDR CD-ROM (Ford and others, 1993) have been compiled and used in the study of Barrymore. Topographic profiles of units that have been mapped using SAR images. Radar property information (table 2) was not used extensively for unit discrimination, although it is important to note that Barrymore has a very small angle of incidence, because natural surfaces generally have few large tilted facets at high angles. The exception is in areas of steep slopes, such as ridges or rift zones, where favorably tilted terrain can produce very bright signatures in the radar image. For most other areas, diffuse echoes from roughness at scales comparable to the radar wavelength are responsible for variations in the SAR return. In this case, the echo strength is also modulated by the reflectivity of the surface material. The density of the upper few wavelengths of the surface can have a significant effect. Low-density surfaces such as ash deposits