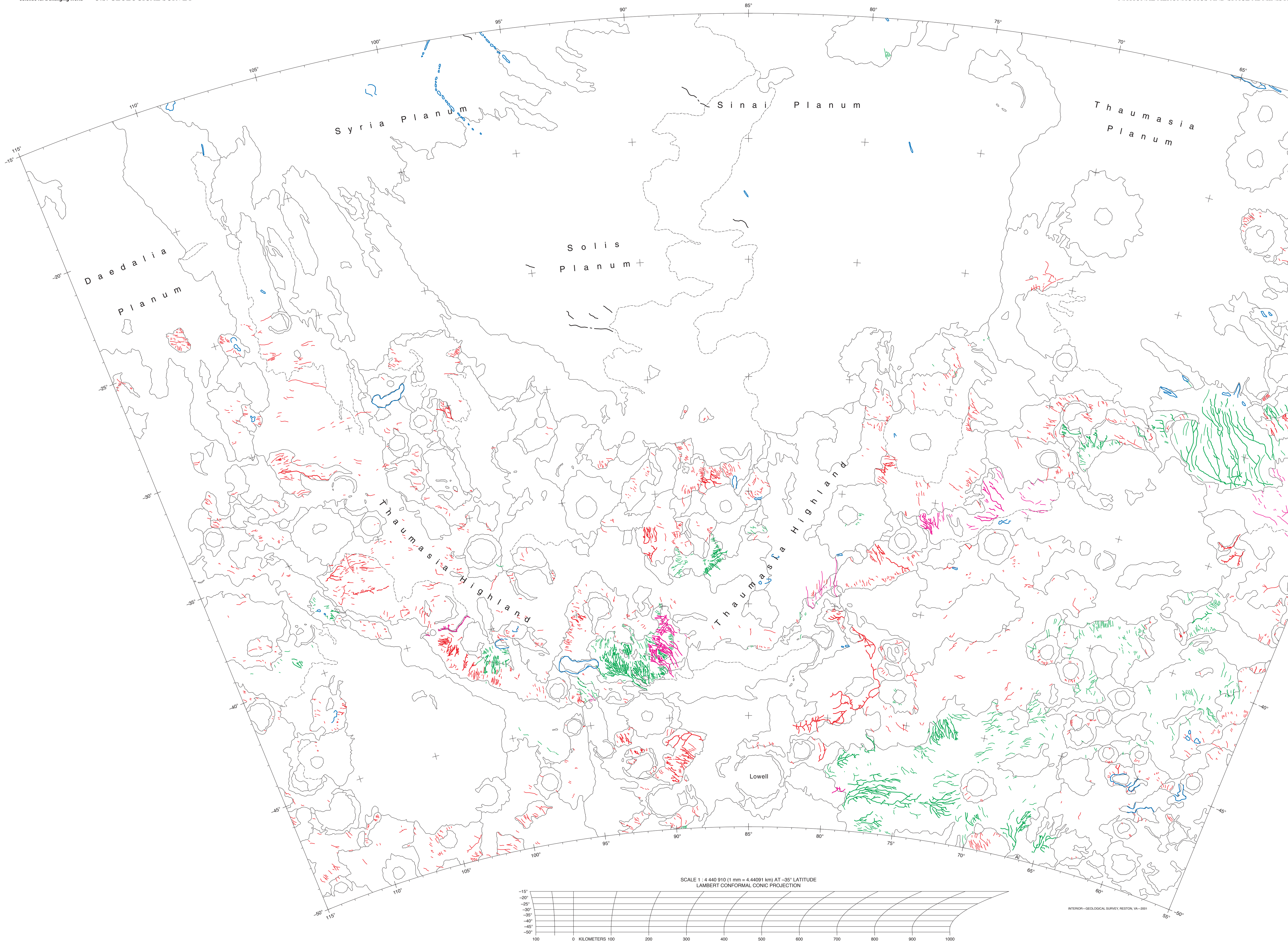

Contact—Dashed where approximately located or gradational

Depression or caldera

Channel—colored according to stage

Furrow—colored according to stage

Channel in lava flow

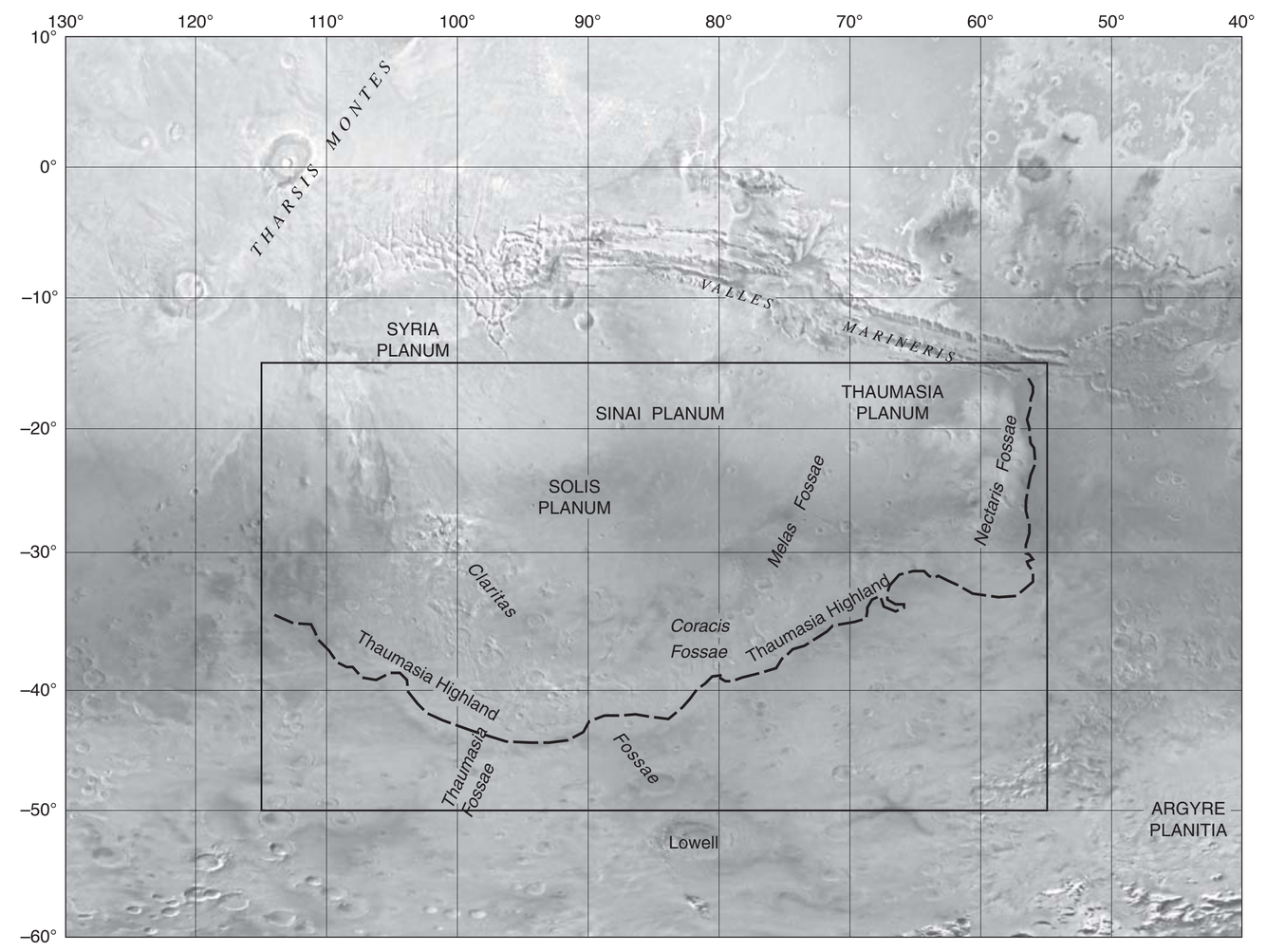

Figure 1. Index map showing Thaumasia region of Mars. Region is dominated by Thaumasia plateau (edge of plateau shown by dashed line), which includes high plains of Syria, Sinai, Solis, and Thaumasia Plana and surrounding Thaumasia highland that is fractured by Thaumasia, Claritas, Coracis, and Nectaris Fossae.

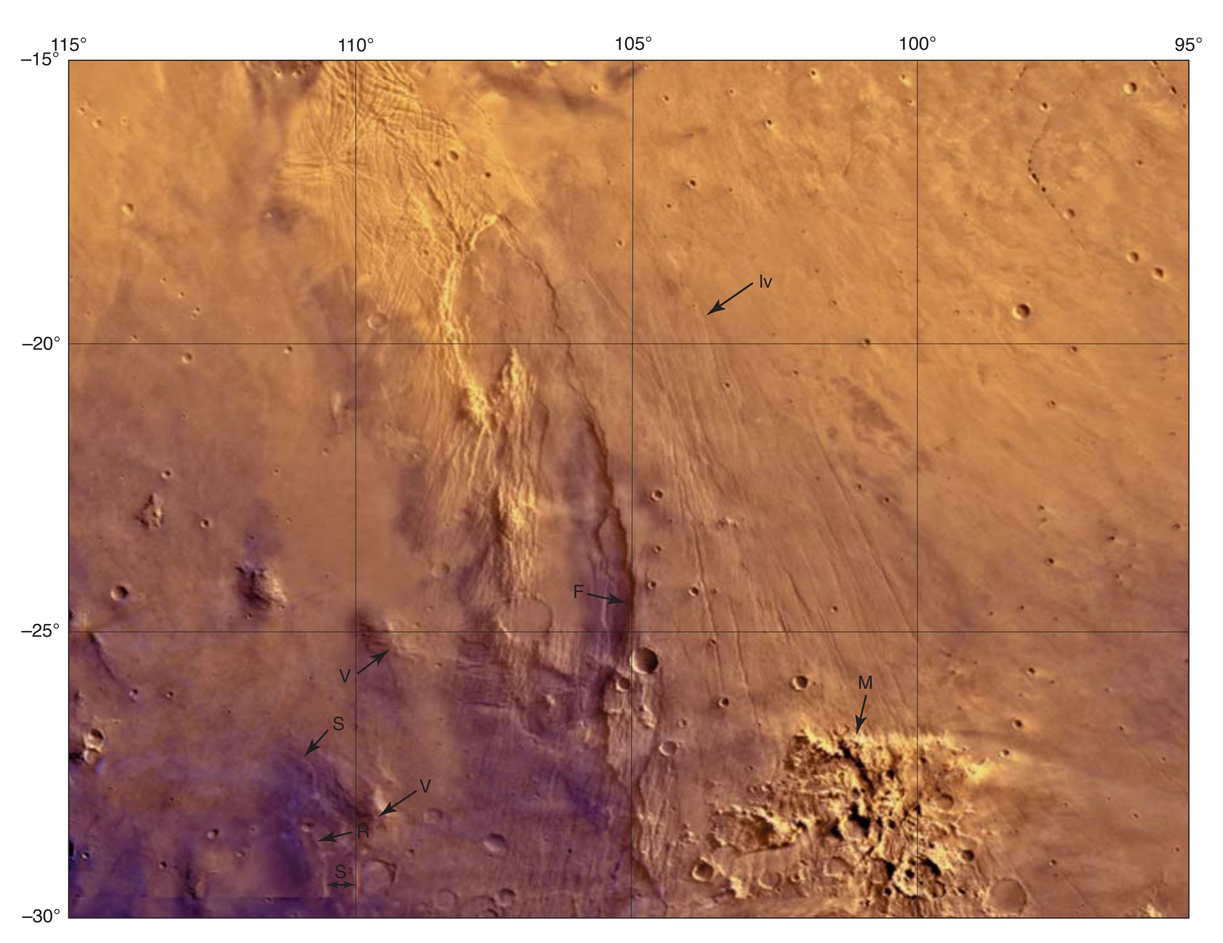

Figure 2. Mars Digital Image Mosaic (MDIM) merged with color of part of MC–17SE (northwest part of Thaumasia region). Arrows indicate large scarps (S), ridges (R), volcanoes (V), lava flows (lv) that bury stage 3 faults of Claritas Fossae, mountains (M), and eastern bounding fault (F) of Thaumasia rift system (Plescia and Saunders, 1982). Scarps and ridges are interpreted to be cuestas and hogbacks formed by tectonic warping and differential erosion of crustal material.

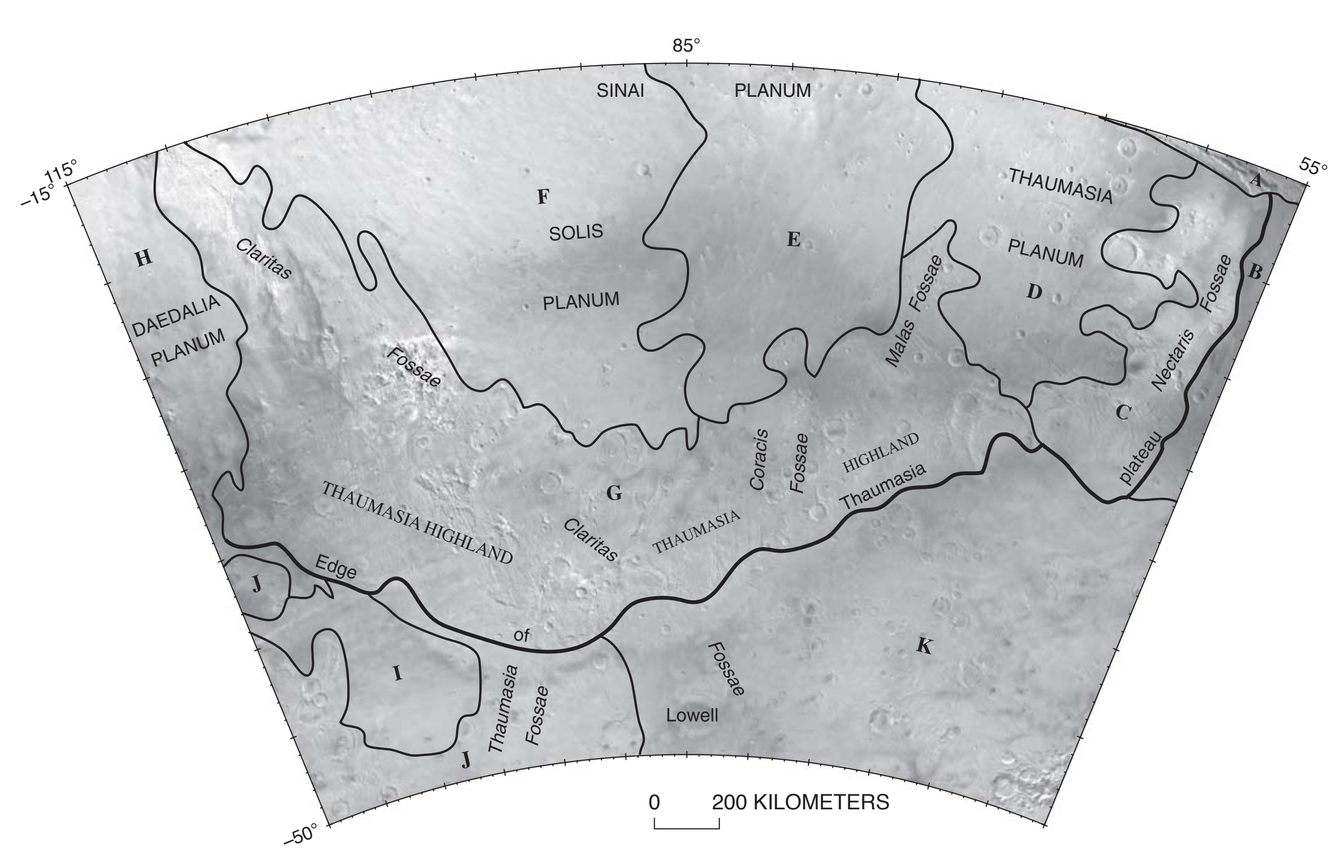

Figure 3. Photomosaic of Thaumasia region showing major physiographic provinces and edge of Thaumasia plateau. Letters correspond to usage in table 2.

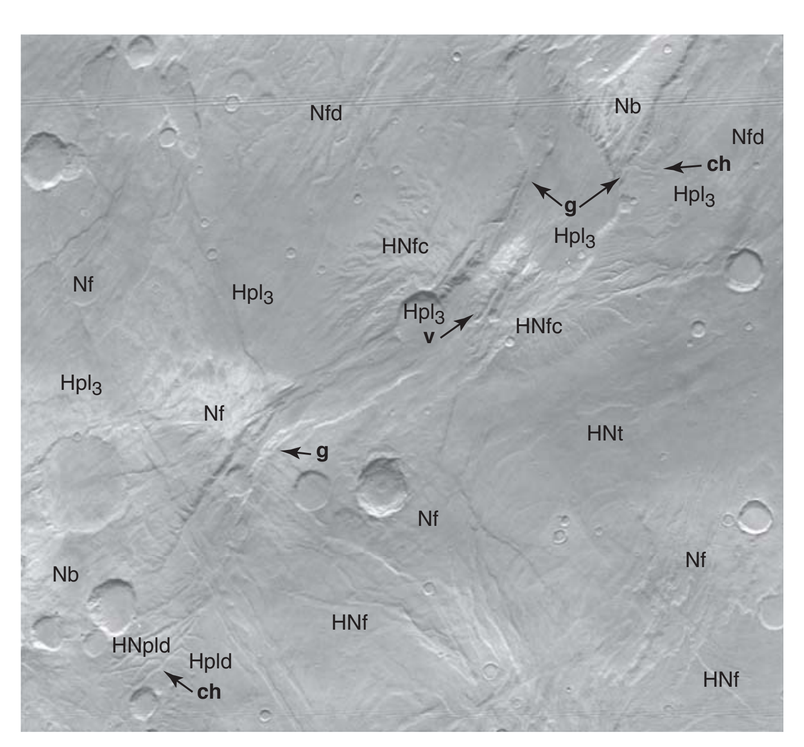

Figure 4. Stage 2 faults and grabens (**g**) of a rift system cut a possible volcano (**v**) that formed during the period of younger (Late Noachian/Early Hesperian) construct-forming activity. Crosscutting relations of stage 2 channels (**ch**) with the rift system, volcano, and surrounding geologic units suggest that channels formed concurrently with volcanotectonic activity. Symbols Nb, Nf, Nfd, HNf, HNt, HNfc, HNpld, Hpl_3 denote basement complex, older fractured material, fractured and dissected material, intermediate fractured material, terraced material, younger flow and construct material, intermediate dissected material, and smooth unit of the plateau sequence, respectively. (Viking image 384S16; resolution 248 m/pixel.)

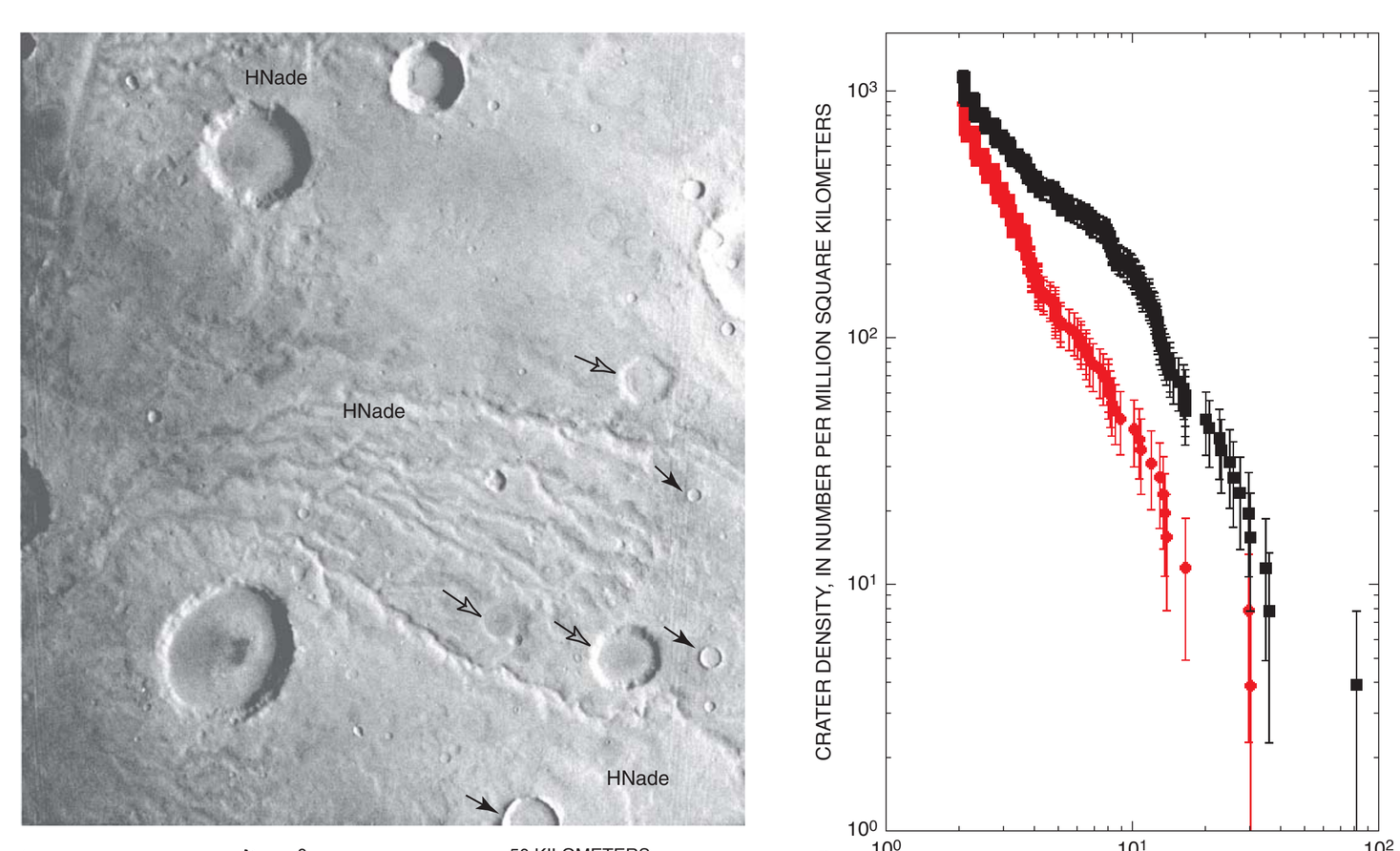

Figure 5. *A*, Hesperian–Noachian surface modified by a well-defined channel system of stage 2 (or younger), dissected and etched unit of the circum-Argyre materials (unit HNade). Superposed craters (solid arrows) and highly eroded craters (open arrows) mark dissected and etched surface. (Viking image 535A25; resolution 154 m/pixel) *B*, Graph showing crater densities of total (partly buried, degraded, and superposed craters; black boxes) and superposed only (red circles) crater populations for all outcrops of dissected and etched unit. Note distinct separation between material (Late Noachian) and resurfacing (Early Hesperian) age at larger diameters.

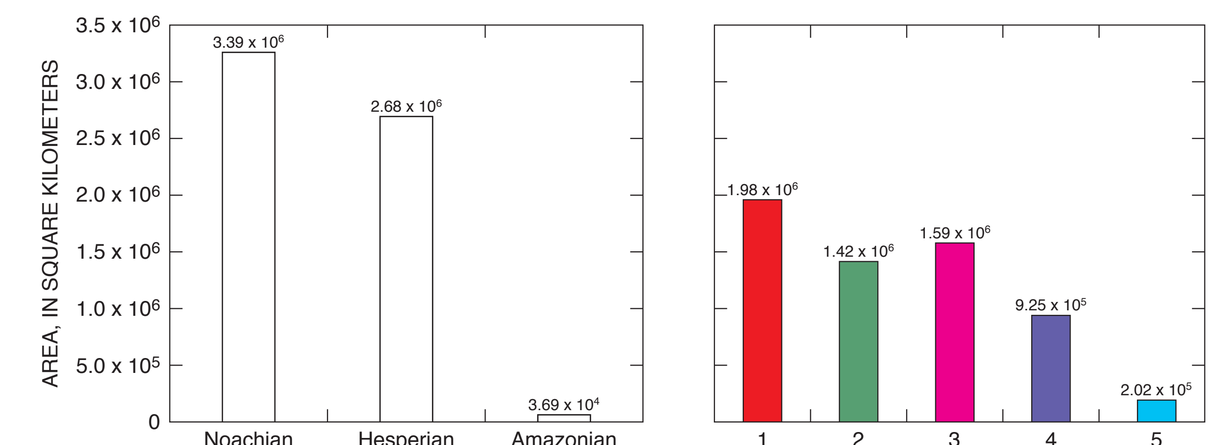

Figure 6. Histograms representing amounts of geologic units per period (*A*) and per stage (*B*).

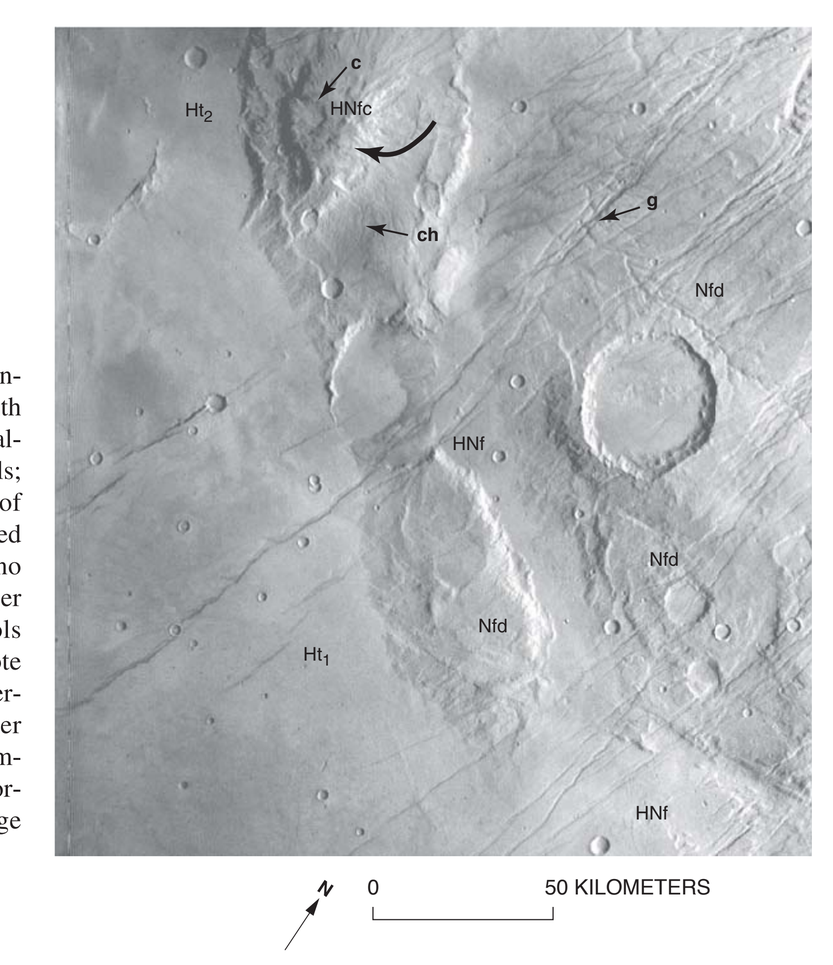

Figure 7 (right). Large mountain (interpreted as volcano; broad arrow) with summit depression (interpreted as caldera; **c**) and dissected flanks (channels; **ch**) occurs along southwest edge of Thaumasia plateau near highly faulted terrain (narrow grabens; **g**). Volcano formed during the period of younger construct-forming activity. Symbols Nfd, HNf, HNfc, Ht_1, and Ht_2 denote fractured and dissected material, intermediate fractured material, younger flow and construct material, and members 1 and 2 of the Tharsis Montes Formation, respectively. (Viking image 567A76; resolution 198 m/pixel.)

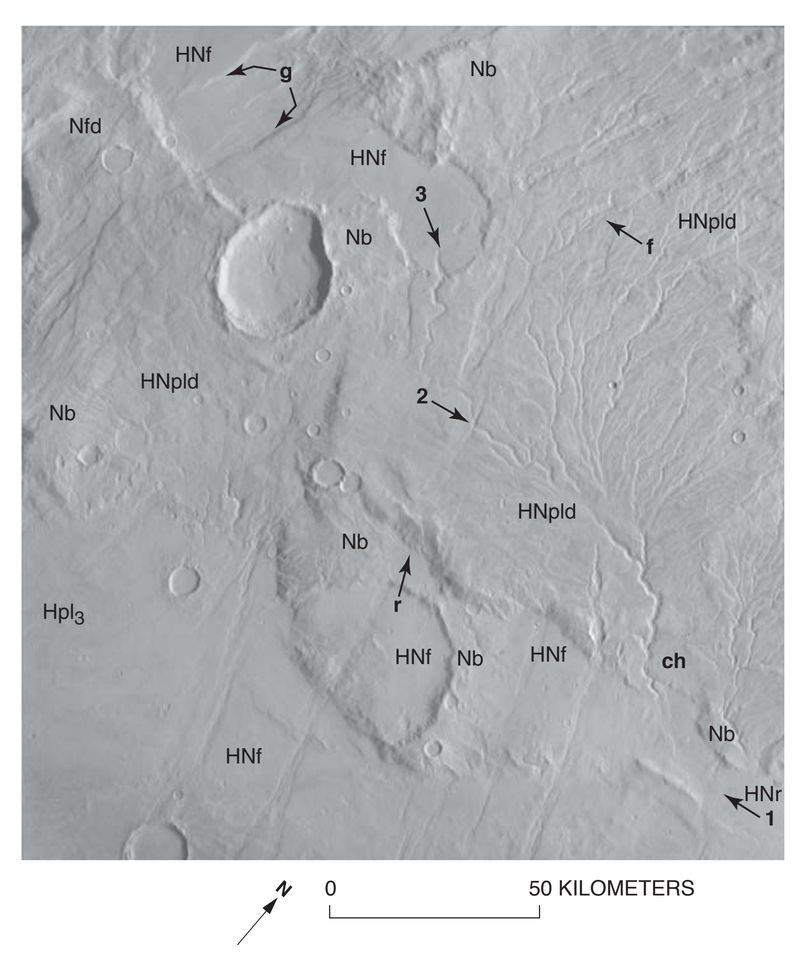

Figure 8*A*. Warrego Valles, a well-defined, stage 2 and 3 channel system of intermediate dissected material (unit HNpld), occurs along south edge of Thaumasia plateau; lower part (1) of main channel (**ch**) transects stage 2, older ridged plains material (unit HNr). Tributary (2) of main drainage system follows and cuts across a stage 2 graben; tributary head (3) and stage 2 graben (**g**) of a rift system also cut stage 2 intermediate fractured material (HNf). Symbols Nb, Nfd, and Hpl_3 denote basement complex, fractured and dissected material, and smooth unit of the plateau sequence, respectively. Fluvial processes highly modified stage 1 materials, including northeast-trending faults (**f**). (Viking image 532A16; resolution 170 m/pixel.)

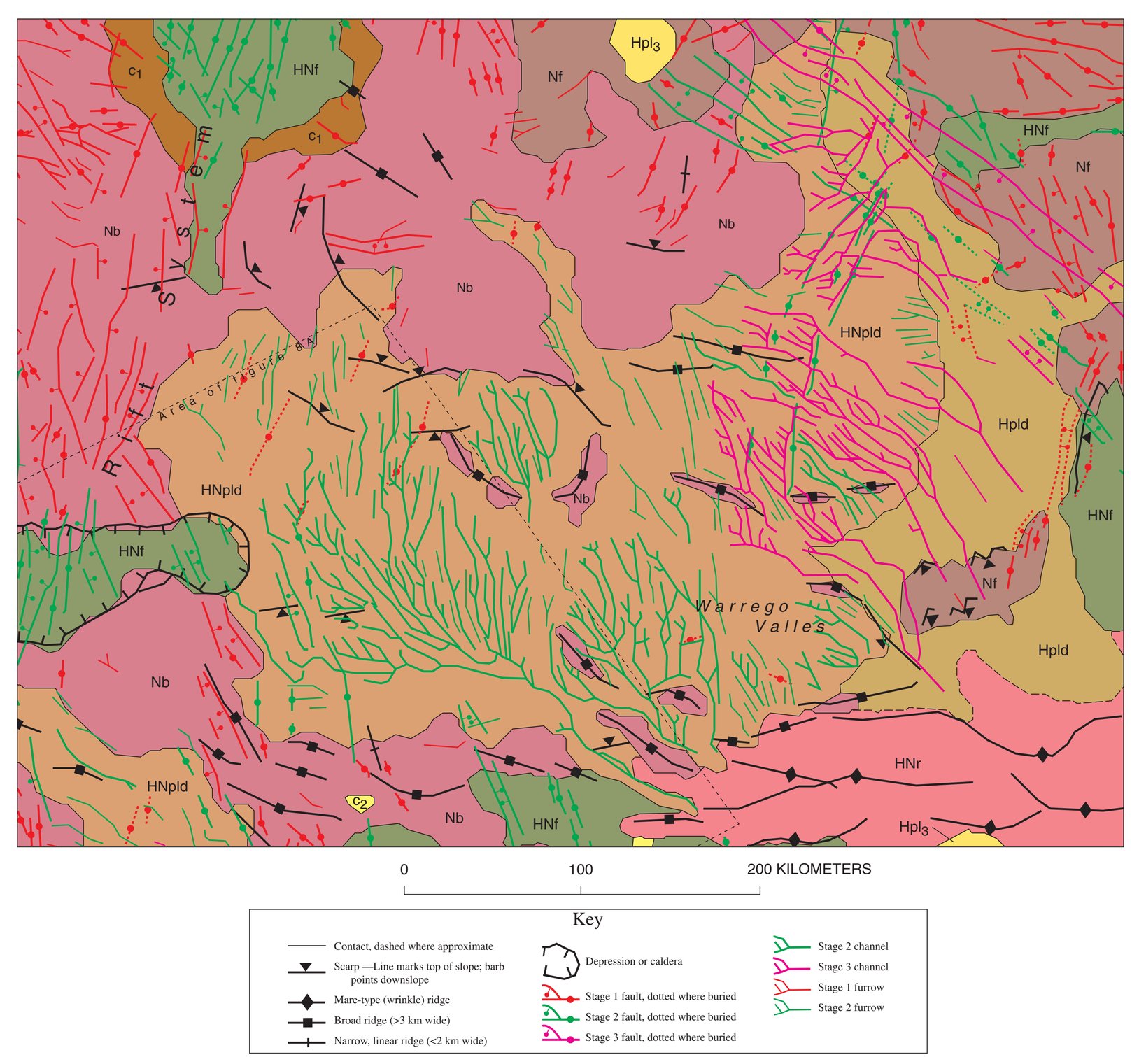

Figure 8*B*. Geologic map of Warrego Valles region showing erosional and tectonic structures. Stages 2 and 3 channel system, Warrego Valles, dissects Noachian/Early Hesperian rock materials and modifies and destroys older fault systems mainly of stage 1. See sheet 1 for descriptions of map units.

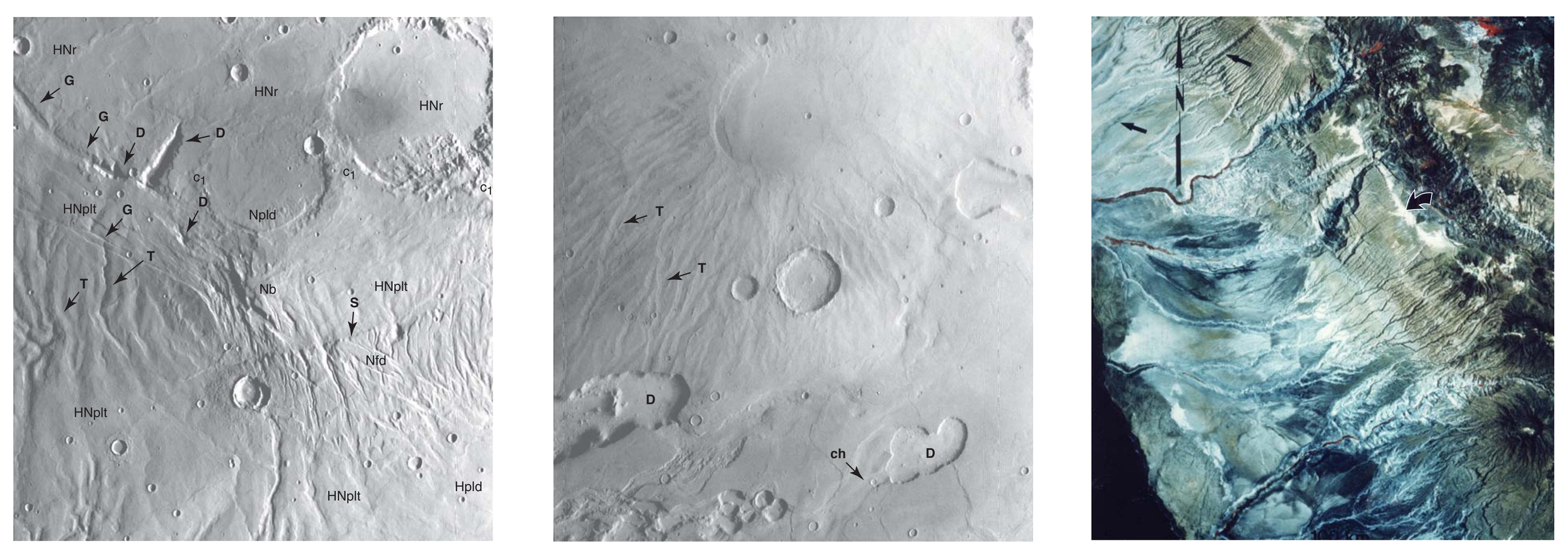

Figure 9. *A*, Stage 2 troughs (**T**) of southern part of Coprates Rise head near large depressions (**D**; interpreted to have formed by collapse) and stage 2 grabens (**G**); large scarp (**S**) probably formed by tectonic activity associated with development of Coprates rise. Symbols Nb, Nf, Nfd, Npld, c_1, HNr, HNplt, and Hpld denote basement complex, older fractured material, fractured and dissected material, older dissected material, material of degraded craters, older ridged plains material, troughed material, and younger dissected material, respectively. (Viking image 610A42; resolution 222 m/pixel.) *B*, Large troughs (**T**) dissect flanks of Hadriaca Patera. Large channels (**ch**) head near large depressions (**D**; interpreted to have formed by collapse). (Viking image 625A18; resolution 235 m/pixel.) *C*, Layers of ignimbrite (large arrow) near Arica, Peru, of the central Andes that were emplaced during the Early Miocene have been tilted by the Andes orogeny, resulting in distinct pattern of parallel troughs (narrow arrows indicate drainages; Alfred McEwen, University of Arizona, oral and written commun., 1996; Landsat TM image).

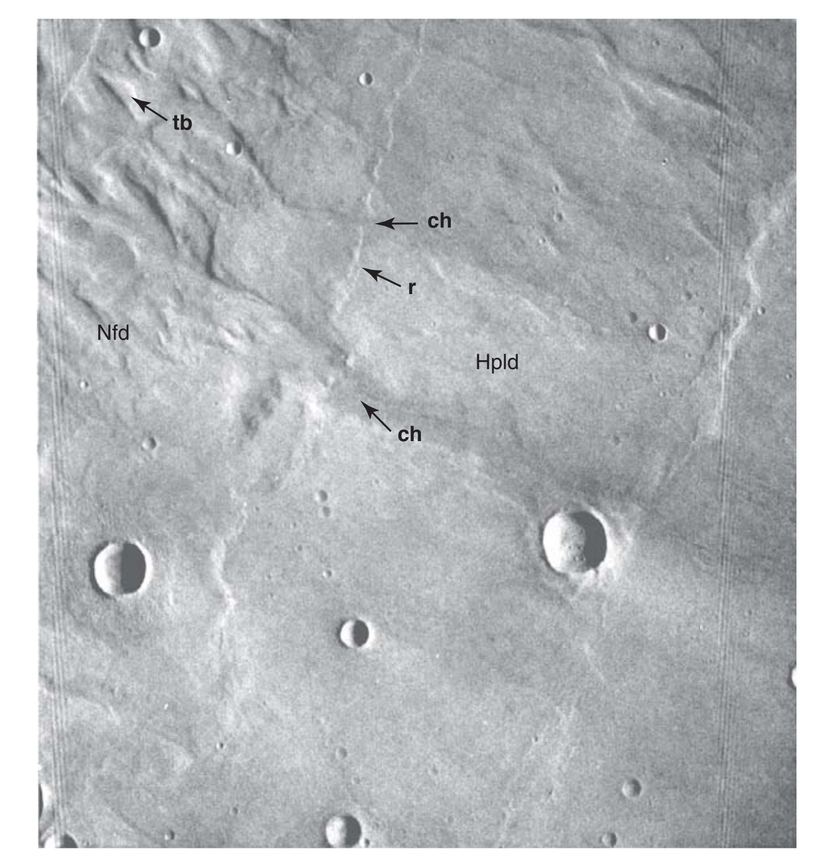

Figure 10. Stage 3 tributary channels of southeast flank of Coprates rise dissect wrinkle ridges (**r**) of younger ridged plains material and join into first-order channels (**ch**) at a break in slope. Triangular faceted bedforms (**tb**; interpreted as cuestas) indicate differential erosion of tilted rock layers. Symbols Nfd and Hpld denote fractured and dissected material and younger dissected material, respectively. (Viking image 465A13; resolution 63 m/pixel.)

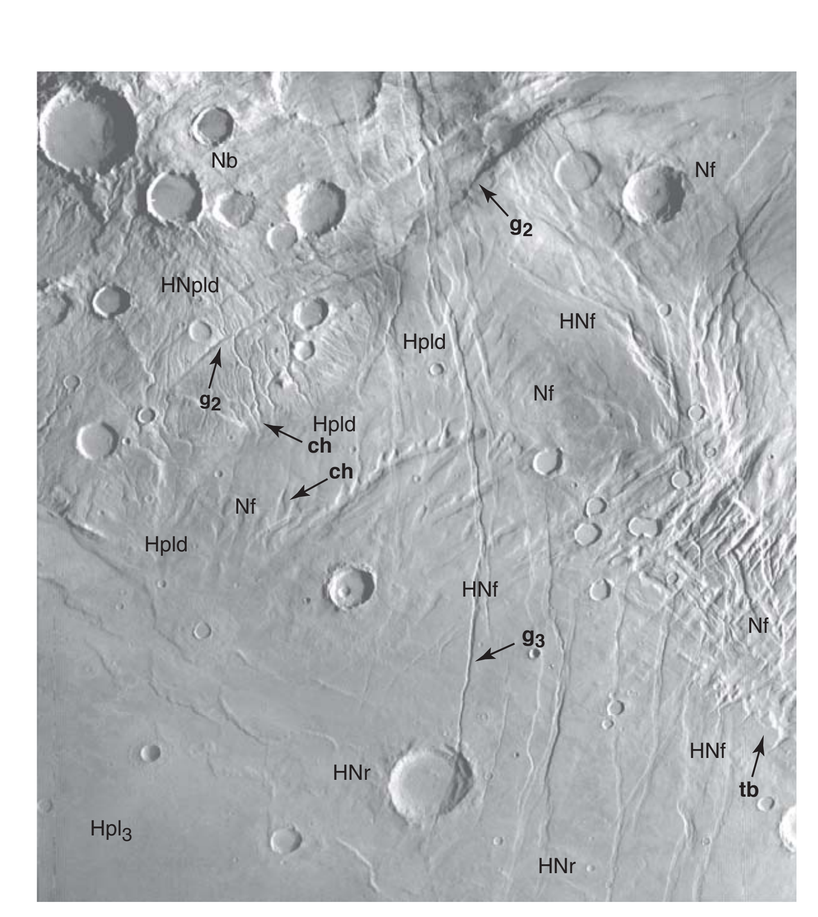

Figure 11. Stage 3 tributary channels (**ch**) of Warrego Valles along south edge of Thaumasia plateau, which dissect stage 2 graben (g_2), join into first-order channels at a break in slope where they dissect Hesperian plains materials. Narrow stage 3 graben (g_3) cuts Noachian and Hesperian materials; tilted beds (**tb**) similar to those of figure 10 are visible. Symbols Nb, Nf, HNpld, HNf, HNr, Hpl_3, and Hpld denote basement complex, older fractured material, intermediate dissected material, intermediate fractured material, older ridged plains material, smooth unit of the plateau sequence, and younger dissected material. (Viking image 606A54; resolution 247 m/pixel.)

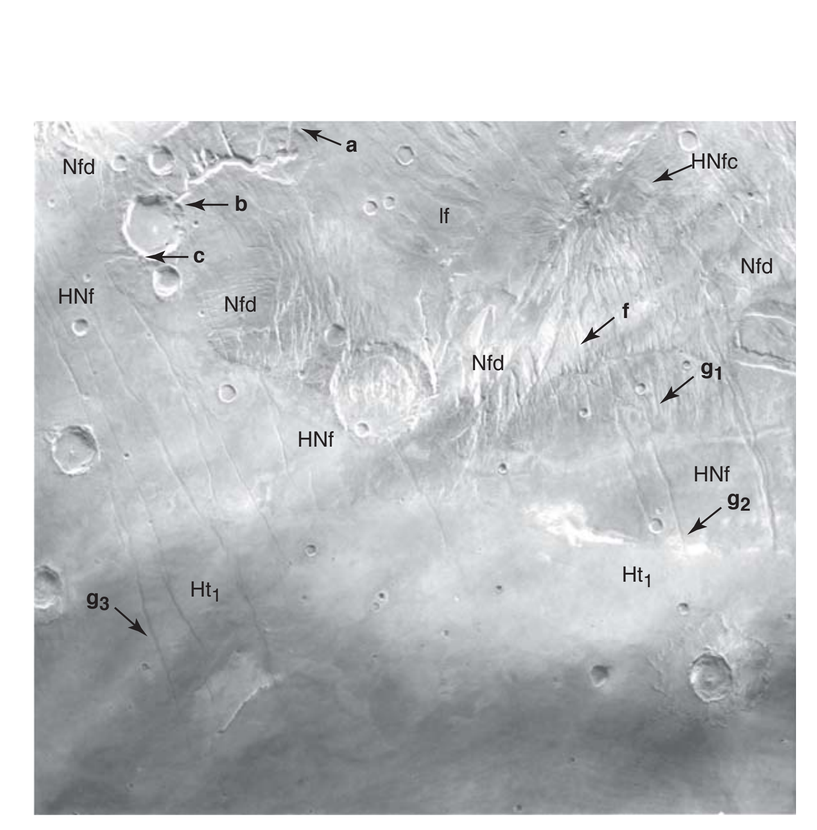

Figure 12. Fresh-appearing, V-shaped channel (**a–c**) in fractured and dissected material (Nfd), which heads near a fault (outside of image area, northeast of **a**), breeches a small impact crater (**b** and **c**) and continues onto intermediate fractured material (HNf). Volcano (HNfc) and its lava flows (**lf**) are mapped as younger flow and construct material (unit HNfc). Small furrows (**f**) downslope from volcano may represent a correlation between channeling and volcanic activity. Stage 1 grabens (g_1) are buried by intermediate fractured material (HNf); Stage 2 grabens (g_2) are buried by member 1 of the Tharsis Montes Formation (Ht_1); Stage 3 grabens (g_3) cut member 1 of the Tharsis Montes Formation. Mottled appearance of image may be due to clouds. (Viking image 57A05; resolution 232 m/pixel)

Figure 13. Part of western Thaumasia Planum province showing younger ridged plains material (unit Hr) burying older ridged plains material (unit HNr; contact between the two ridged plains materials is shown by broad arrows), faults (**f**), and western part of a crater's ejecta blanket (**c**). These relations indicate that extensional tectonism of the Thaumasia province largely ceased during the Early Hesperian, but compressional tectonism may have continued. (Viking image 608A49; resolution 219 m/pixel)

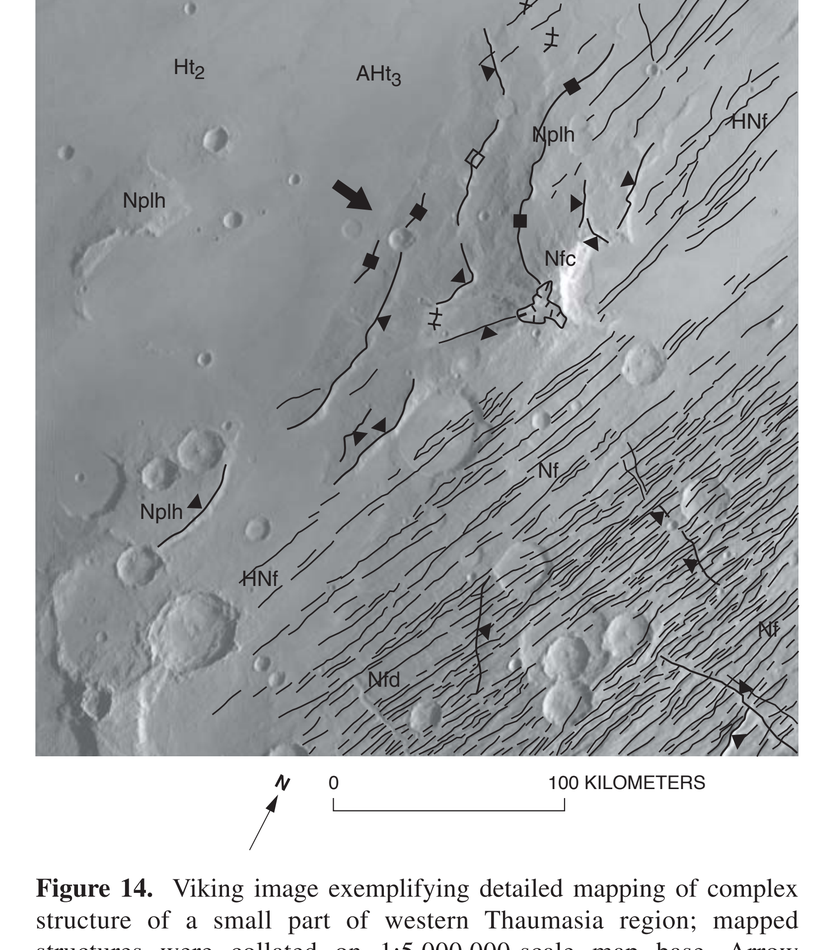

Figure 14. Viking image exemplifying detailed mapping of complex structure of a small part of western Thaumasia region; mapped structures were collated on 1:5,000,000-scale map base. Arrow indicates deformed highland plains (also see fig. 2), which are marked by large scarps, ridges, and a volcano (Nfc) with summit depression. Symbols Nplh, Nfc, Nf, Nfd, HNf, Ht_2, and AHt_3 denote hilly unit, older flow and construct material, older fractured material, fractured and dissected material, intermediate fractured material, and members 2 and 3 of the Tharsis Montes Formation. (Viking image 641A72; resolution 261 m/pixel.)

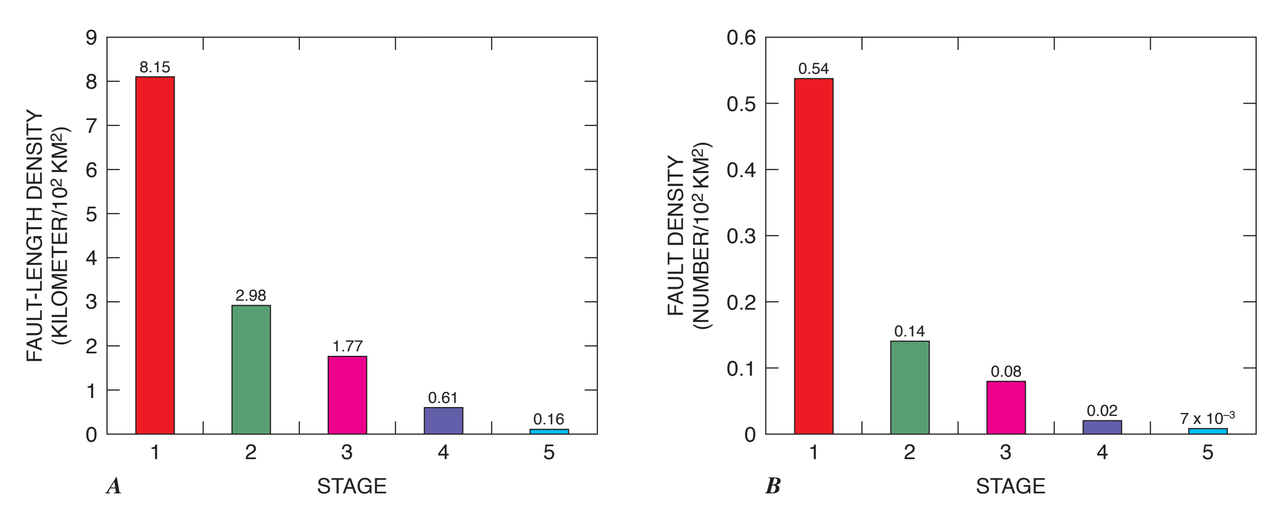

Figure 15. Histograms representing areal density of fault length (*A*) and number of faults (*B*) per stage in Thaumasia region of Mars.

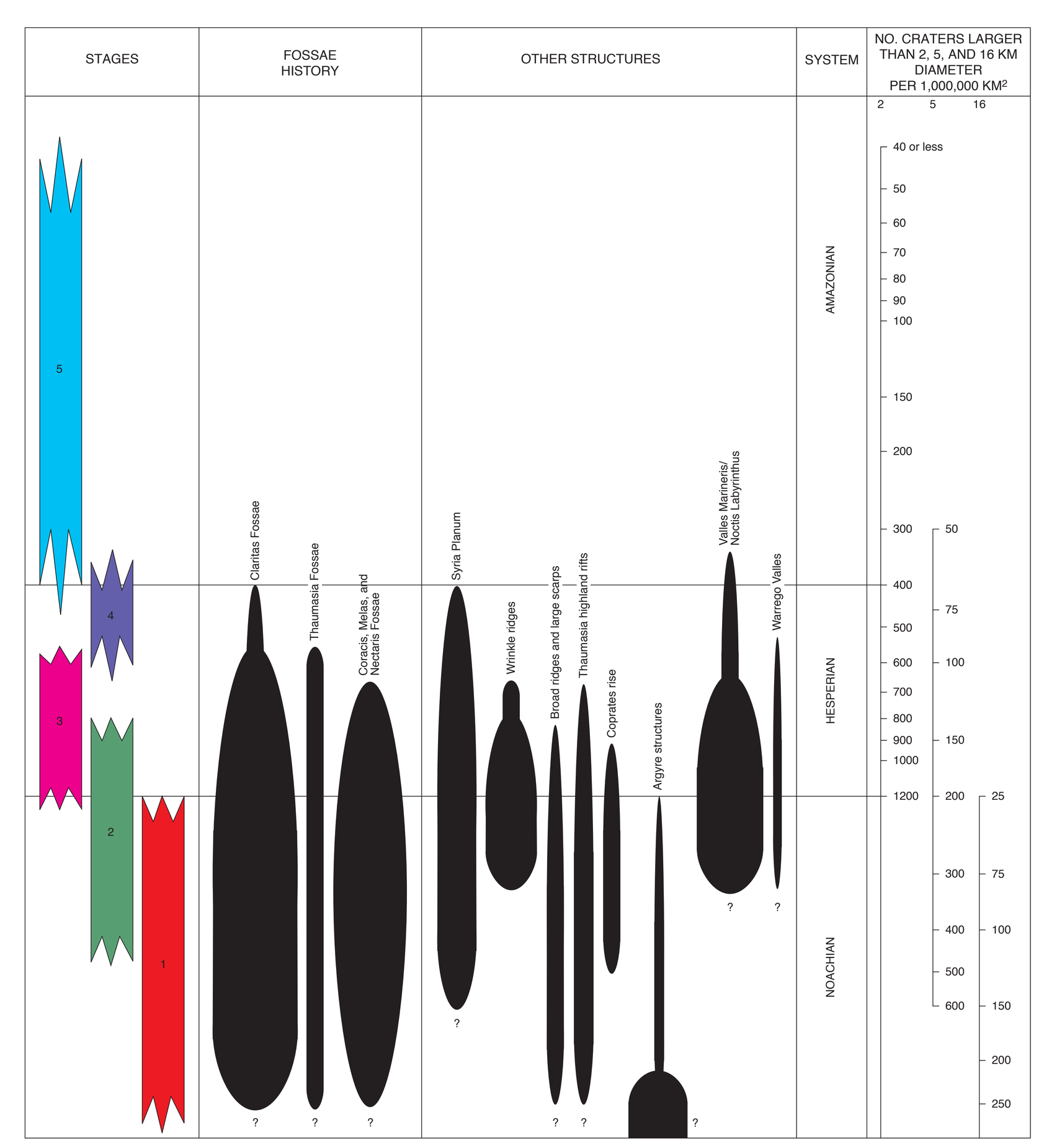

Figure 16. Chart comparing stages of geologic activity in Thaumasia region with significant sets of features (tectonic and erosional). Size of solid areas roughly proportional to degree of exposed deformation; question marks indicate where large uncertainty exists in commencement of structural activity. Crater chronology from Tanaka (1986).

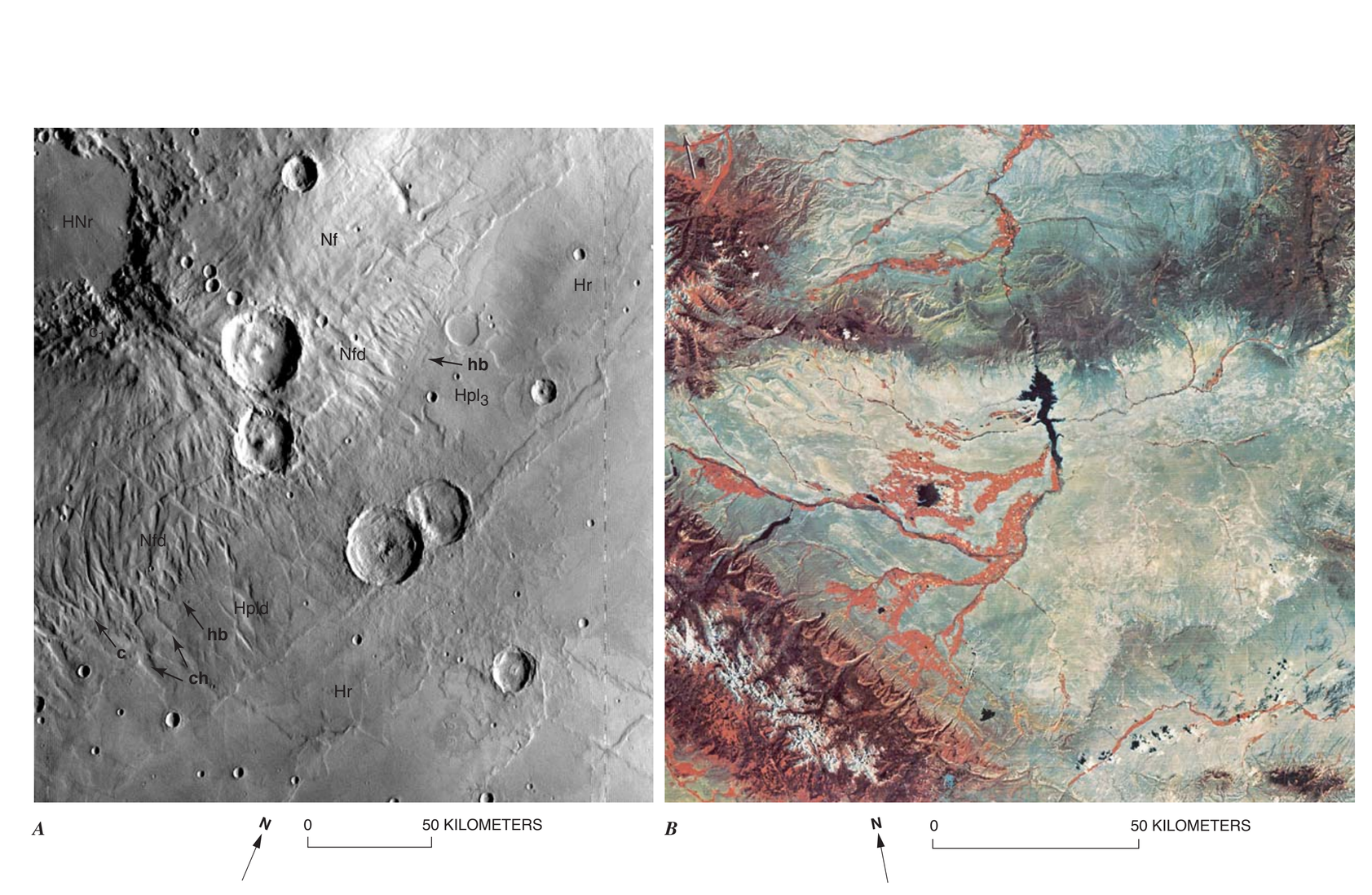

Figure 17. *A*, Cuestas (**c**) and hogbacks (**hb**), which are caused by tectonic tilting and differential erosion, and channels (**ch**) of the southeast part of Coprates Rise. Symbols c_1, Nf, Nfd, Hpl_3, Hr, and Hpld denote material of degraded craters, older fractured material, fractured and dissected material, smooth unit, younger ridged plains material, and younger dissected material. (Viking image 610A44; resolution 224 m/pixel) *B*, Wind River Mountains of Wyoming that display similar morphologic features to Coprates rise. (Landsat TM image; plate 97 of Short and others, 1976).

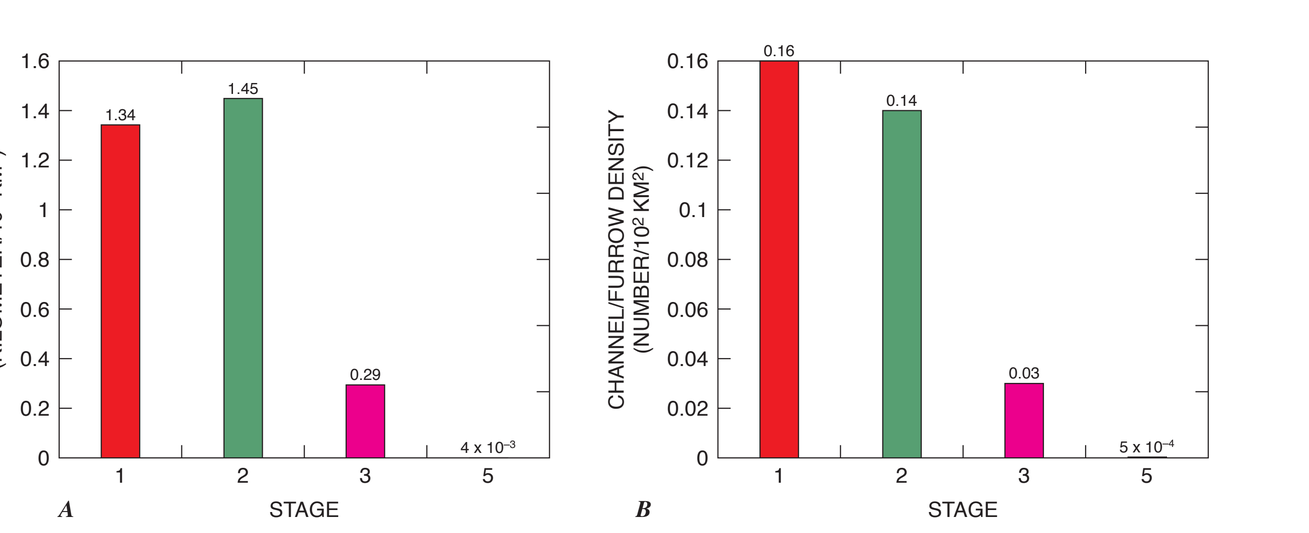

Figure 18. Histograms showing total channel and furrow length density per stage (*A*) and number of channels and furrows per stage (*B*) of Thaumasia region.

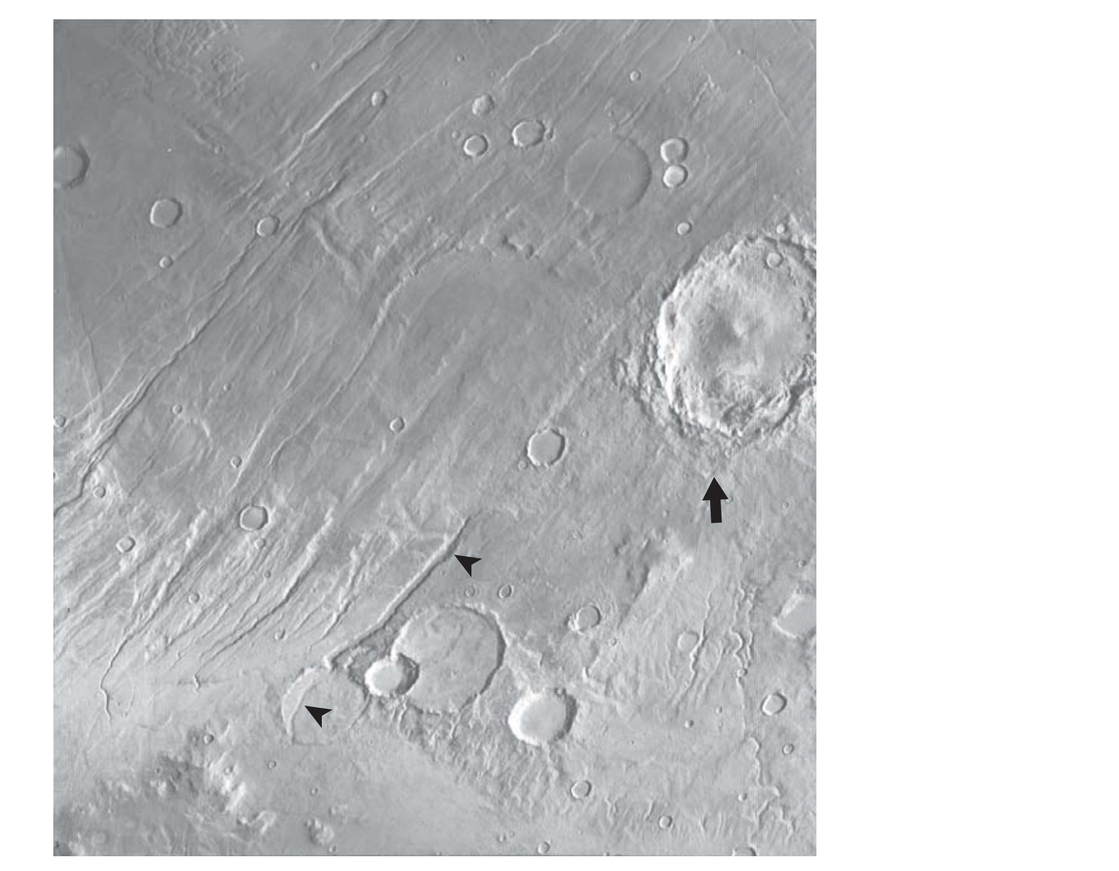

Figure 19. Furrow (arrow heads) which occurs along a preexisting graben downslope of large Hesperian impact crater (broad arrow) that may have formed as a result of the impact event. (Viking image 606A50); resolution 249 m/pixel)

Table 2. *Principal geologic features and their relative ages for major physiographic provinces of the Thaumasia region of Mars.*

Province	Geologic features and their relative ages
A. Valles Marineris	Rifting and collapse structures. Late Noachian–Hesperian
B. Coprates East	Wrinkle ridges. Early Hesperian
C. Coprates	Broad ridges, tilted rock layers (cuestas and hogbacks caused by tectonic tiliting and differential erosion), and wrinkle ridges; small (≤10 km wide) and large grabens and faults and fault and rift systems; depressions; individual valleys and troughs and valley and trough networks; mountains and volcanoes. Noachian–Early Hesperian
D. Thaumasia Planum	Wrinkle ridges; small grabens. Late Noachian–Early Hesperian
E. Sinai	Wrinkle ridges; small grabens only cut older material outcrops. Mostly Early Hesperian
F. Syria-Solis	Lava flows; small grabens. Mostly Late Hesperian
G. Thaumasia highland	Small and large grabens, large faults, and intersecting dense concentrations of grabens; fault and rift systems; broad ridges and tilted rock layers (cuestas and hogbacks) along edge of Thaumasia plateau; mountains, volcanoes, and featureless plains; individual valleys and troughs and valley networks. Noachian–Early Hesperian
H. Daedalia	Lava flows; plateaus and mountains (volcanoes or massifs); small grabens. Mostly Early Hesperian–Amazonian
I. Daedalia southeast	Featureless plains; small grabens; subdued wrinkle ridges. Mostly Early Hesperian
J. Sirenum	Small grabens; large scarps; individual valleys and valley networks; volcanoes. Noachian–Early Hesperian
K. Argyre	Featureless plains within topographic lows; mountains and plateaus; large scarps and faults and small grabens; drainage basins comprising valley networks; large valley forms, irregular depressions, furrows, and highly subdued ridges of all shapes and sizes. Noachian–Hesperian

Table 3. *Map unit information for Thaumasia region.*

Unit name	Number of outcrops	Area (km^2)	Stage
Nb	50	163,520.66	1
Nplh	26	53,490.47	1
Nah	3	44,673.36	1
Nak	6	5,428.28	1
c_1	106	144,935.14	1
Nfc	11	41,666.11	1
dome	9	2,277.65	1
Npl_1	20	356,138.03	1
Nf	23	608,851.60	1
Nple	2	21,553.51	1
Npld	32	119,135.38	1
Nfd	17	208,912.34	1
Npl_2	25	206,419.71	1
HNade	6	254,601.78	2
HNu	7	11,913.14	2
c_2	13	202,011.21	2
HNpld	4	41,925.51	2
HNf	41	281,392.23	2
HNt	13	95,991.25	2
HNr	4	437,188.19	2
HNfc	3	18,890.31	2
HNafs	4	9,826.13	2
HNcht	5	2,691.62	2
HNplt	2	64,196.69	2
Hpl_3	73	492,460.03	3
Hpld	4	75,091.87	3
Hch	3	626.49	3
Hr	3	623,334.36	3
Ht_1	1	183,840.68	3
Ht_2	2	92,782.97	3
Hf	5	122,488.61	3
Hsl_1	5	279,312.62	4
Hsl_2	3	435,357.16	4
Hsu	1	210,500.46	4
AHt_3	1	165,599.36	5
cs	26	27,644.22	5
Avfr	1	1,613.78	5
At_5	1	4,132.81	5
Avfs	6	3,030.68	5
Al	1	451.43	5

Table 4. *Total area of geologic units per period for Thaumasia region.*

Period	Total area (km^2)
Noachian*	3,397,630.40
Hesperian	2,681,394.67
Amazonian	36,872.94

*Includes Noachian-Hesperian units. Includes Hesperian-Amazonian units.

Table 5. *Area, fault, and channel and furrow data per stage for Thaumasia region.*

[Minimum lengths of faults (sheet 2) and channels and furrows (sheet 3) mapped are 1.98 km and 0.96 km, respectively]

Stage	Total area (km^2)	Number of faults	Total length of faults (km)	Number of channels and furrows	Total length of channels and furrows (km)
1	1,977,002.29	10,620	161,045.24	3,105	26,509.48
2	1,420,628.11	2,043	42,320.50	1,928	20,584.65
3	1,590,625.04	1,196	28,153.65	469	4,697.72
4	925,170.26	174	5,670.13	0	0.00
5	202,472.30	14	316.80	1	9.43

Table 1. *Cumulative crater densities and ages of geologic units in Thaumasia region of Mars.*

[Crater statistics were completed for 96.6% of the total map region]

Geologic unit name	Symbol	*Area (km^2)	Type[3]	Average crater density[1] [Crater age[2]] N(2)	N(5)	N(16)	Unit age[2]
Member 3 of Tharsis Montes Formation	AHt_3	166,759	t	408±50 [LH-EA]	84±22 [LH-EA]		LH-EA
			s	366±47 [LH-EA]	42±16 [EA]		
Upper member of Syria Planum Formation	Hsu	210,309	t	585±53 [LH]	95±21 [LH]	5±5 [EH]	LH
			s	580±53 [LH]	90±21 [LH]	5±5 [EH]	
Younger flows of lower member of Syria Planum Formation	Hsl_2	436,307	s	504±34 [LH]	53±11 [EA]	7±4 [EH]	LH
Older flows of lower member of Syria Planum Formation	Hsl_1	281,560	t	583±46 [LH]	114±20 [EH-LH]	11±6 [EH]	LH
			s	579±45 [LH]	110±20 [EH-LH]	11±6 [EH]	
Younger fractured material of PHPA[4]	Hf	115,972	t	543±68 [LH]	95±29 [LH-EA]	9±9 [EH]	LH
			s	543±68 [LH]	95±29 [LH-EA]	9±9 [EH]	
Member 2 of Tharsis Montes Formation	Ht_2	92,680	t	701±87 [EH-LH]	194±46 [LN-EH]	43±22 [LN-EH]	EH
			s	669±85 [EH-LH]	162±42 [LN-LH]	43±22 [LN-EH]	
Member 1 of Tharsis Montes Formation	Ht_1	194,508	t	694±60 [EH-LH]	113±24 [EH-LH]	15±9 [EH]	EH
			s	663±58 [LH]	82±21 [LH-EA]	10±7 [EH]	
Younger dissected material of PHPA[4]	Hpld	74,247	s	1037±118 [EH]	148±45 [EH-LH]		EH
Younger ridged plains material of PHPA[4]	Hr	632,513	t	694±33 [LH]	161±16 [EH]	25±16 [LN-EH]	EH
			s	672±33 [LH]	139±15 [EH-LH]	19±6 [LN-EH]	
Smooth unit of plateau sequence of PHPA[4]	Hpl_3	500,602	t	1125±47 [EH]	210±21 [LN-EH]	22±7 [LN-EH]	EH
			s	1075±46 [EH]	160±18 [EH]	12±5 [EH]	
Troughed material of PHPA[4]	HNplt	64,627	s	851±115 [EH-LH]	139±46 [EH-LH]	16±16 [LN-EH]	LN-EH
Smooth floor unit of circum-Argyre materials	HNafs	9,805	t	1122±338 [N-EH]	306±177 [MN-EH]		LN-EH
			s	1020±323 [N-LH]	204±144 [LN-EA]		
Intermediate dissected material of PHPA[4]	HNpld	45,912	t	1481±180 [N]	305±82 [LN]	22±22 [LN-EH]	LN-EH
			s	1285±167 [N-EH]	109±49 [EH-EA]		
Older ridged plains material of PHPA[4]	HNr	496,792	t	968±44 [EH]	213±21 [LN-EH]	28±8 [LN-EH]	LN-EH
Terraced material of PHPA[4]	HNt	87,864	t	1081±111 [EH]	285±57 [LN]	34±20 [LN-EH]	LN-EH
			s	1059±110 [EH]	262±55 [LN]	34±20 [LN-EH]	
Intermediate fractured material of PHPA[4]	HNf	270,407	t	1010±61 [EH]	266±31 [LN]	48±13 [LN]	LN-EH
			s	958±60 [EH]	215±28 [LN-EH]	33±11 [LN-EH]	
Dissected and etched unit of circum-Argyre materials	HNade	254,890	t	1146±67 [N-EH]	369±38 [MN-LN]	63±16 [LN]	LN-EH
			s	891±59 [EH]	118±22 [EH-LH]	12±7 [EH]	
Younger flow and construct material of WVA[5]	HNfc	18,919	t	1480±280 [N-EH]	317±130 [MN-EH]	53±53 [MN-EH]	LN-EH
			s	1269±259 [N-EH]	106±75 [EH-EA]		
Subdued cratered unit of plateau sequence of PHPA[4]	Npl_2	218,561	t	1606±86 [N]	545±50 [MN]	124±24 [MN-LN]	MN-LN
			s	1299±77 [N]	238±33 [LN]	46±15 [LN]	
Fractured and dissected material of PHPA[4]	Nfd	212,311	t	1437±82 [N]	325±39 [LN]	99±22 [MN-LN]	MN-LN
Older dissected material of PHPA[4]	Npld	112,824	t	1675±122 [N]	541±69 [MN]	124±33 [MN-LN]	MN-LN
			s	1365±110 [N]	239±46 [LN-EH]	18±13 [LN-EH]	
Etched material of PHPA[4]	Nple	22,416	t	1606±268 [N]	491±148 [EN-LN]	178±89 [EN-LN]	MN-LN
			s	1338±244 [N-EH]	223±100 [LN-LH]		
Older fractured material of PHPA[4]	Nf	630,233	t	1453±48 [N]	424±26 [MN-LN]	108±13 [MN-LN]	EN-LN
Older flow and construct material of WVA[5]	Nfc	40,406	t	2203±234 [N]	569±119 [EN-MN]	99±50 [MN-LN]	EN-LN
Cratered unit of plateau sequence of PHPA[4]	Npl_1	430,909	t	1673±62 [N]	610±38 [EN-MN]	202±22 [EN-MN]	EN-MN
Basement complex of PHPA[4]	Nb	168,733	t	2157±113 [N]	581±59 [EN-MN]	190±34 [EN-MN]	EN-MN
Basin-rim unit of circum-Argyre materials	Nah	54,551	t	1027±137 [EH]	568±102 [EN-MN]	202±61 [EN-MN]	EN-MN
Hilly unit of plateau sequence of PHPA[4]	Nplh	59,638	t	2733±214 [N]	989±129 [EN]	335±75 [EN]	EN-MN

[1]Average crater density N(*D*) equals number of craters larger than diameter *D* per million square kilometers.
[2]Relative ages based on time-stratigraphic scale from Tanaka (1986) reflect material ages (see text); N = Noachian, H = Hesperian, A = Amazonian, E = Early, M = Middle, and L = Late. In few instances, crater age varies from unit age because of crater counts of individual unit areas, large crater density error margins, and distinct map relations.
[3]Type of crater count; superposed (s) and total (t), which includes superposed and highly eroded, partly buried impact craters. In most cases, type t reflects material age and in some cases underlying material age, whereas, type s reflects emplacement mainly of relatively thin lava flows, mantling, or resurfacing age.
[4]Plateau and high-plains assemblage of Scott and Tanaka (1986).
[5]Western volcanic assemblage of Scott and Tanaka (1986).
*Values vary slightly with those of table 3 because (1) minor revisions of contacts of preliminary map and (2) some units of this table include areas of crater materials that were separated out in the geologic map (that is, units c_1, c_2, cs).

PALEOEROSIONAL MAP OF THE THAUMASIA REGION, MARS

By
James M. Dohm, Kenneth L. Tanaka, and Trent M. Hare

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