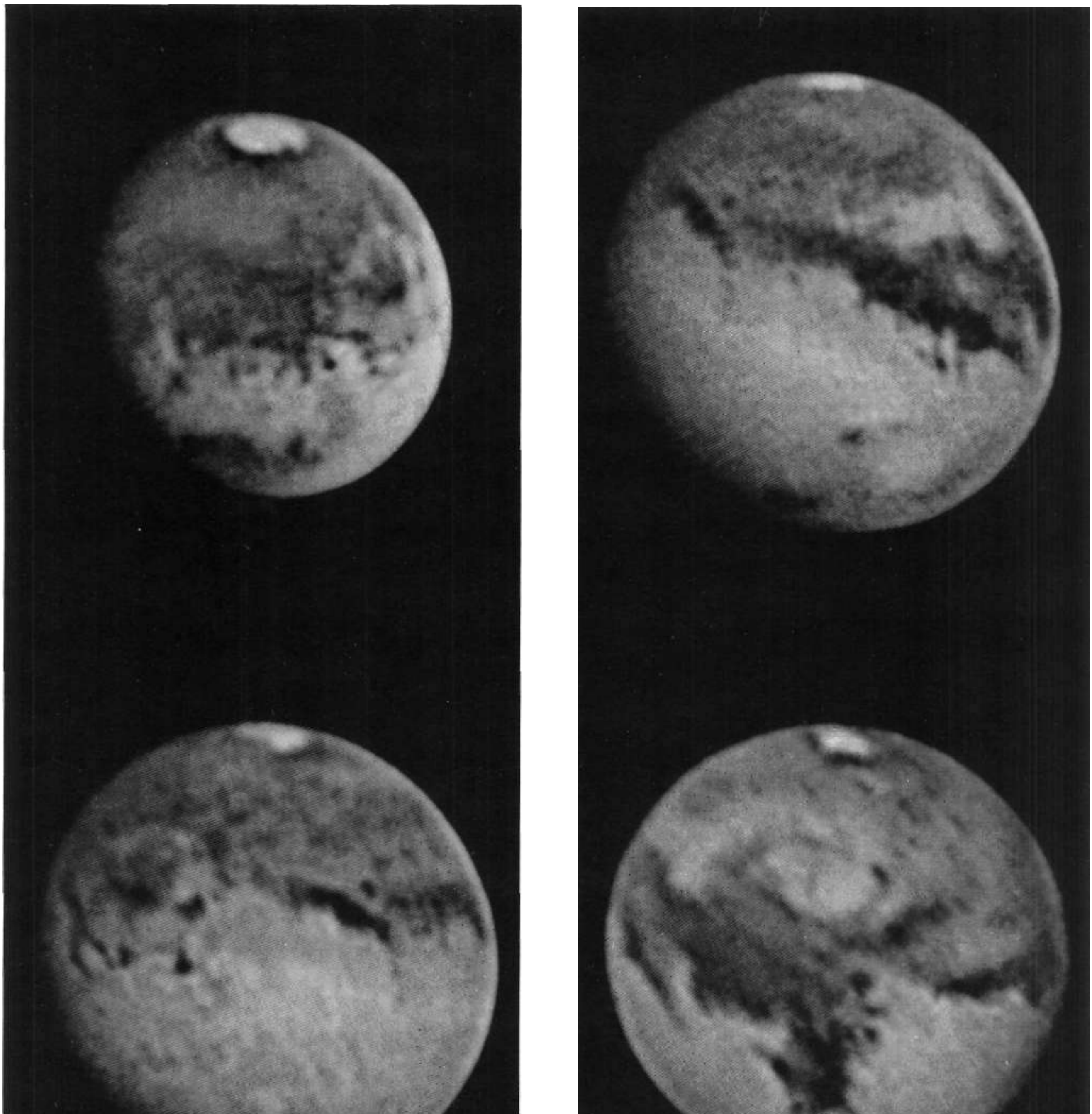
Mars 1988



Red-light CCD images of Mars in 1988 taken by Stephen Larson (Lunar and Planetary Laboratory) and Gary Rosenbaum (Steward Observatory) with the University of Arizona 1.54-metre (61-inch) Catalina reflector. From top left to lower right: August 18.4632 d (ω = 39°); September 9.4439 d (ω = 193°); September 10.2856 d (ω = 128°); October 3.3278 d (ω = 300°). Exposure times were all 0.1 s and the images are reproduced at the same angular scale. The images have undergone digital high-pass filtering with the help of C. Slaughter and W. Schempp (Photometries Ltd.)

The opposition of Mars, 1988

Richard McKim

This report is a discussion of 3,441 observations of the 1988 perihelic opposition covering the period 1987 November to 1989 June. The widespread utilisation of CCD techniques by both amateurs and professionals led to the detection of the finest surface details ever recorded from Earth. Of the albedo features, the *Huygens* crater was still visible as a dark spot in *Iapigia,* while *Nepenthes* continued to be faint or invisible. *Solis Lacus,* as in 1986 was large and complex, with *Phasis* (fading) and *Gallinaria Silva* nearby. The *Acampsis* 'canal' reappeared, and there was a secular darkening of part of the *Memnonia* desert. *Mare Sirenum* was again shortened at its W end, and the *Aetheria* darkening persisted. *Oxia Palus, Achilles Fons* and *Idaeus Fans* were all large and dark. Around opposition the Martian atmosphere was very transparent, with a pronounced Blue Clearing. No global dust storm occurred at perihelion on August 11, but two important local storms were followed. One began in *Hellas* in June, and another started in *Thaumasia* in November. The earlier storm caused a sudden darkening of *Mare Serpentis, Pandorae Fretum* and the E end of *Sinus Sabaeus.* The N limb was marked by the N polar hood for most of the apparition: a N polar cap emerged in 1989. The S polar cap recession was in close accord with Slipher's mean curve, differing slightly but significantly from 1986, when the cap had been slightly smaller than average over the period L_s ~ 210-250°. The fragmentation of the cap was studied in detail.

Report of the Terrestrial Planets Section *Director: R. M. Baum; Mars Coordinator: R. J. McKim*

Introduction

The 1988 apparition was the second in the present series of perihelic approaches, and was the most favourable for N hemisphere observers since 1973.[1] Opposition was on September 28 when Mars was in Cetus with a disk diameter of 23".6. Closest approach to Earth occurred on September 22 *[D* = 23".8] at a distance of only 58.7 million km. In contrast to the 1986 apparition,[2] the planet was well placed at a respectable altitude for UK observers: conditions for most observers were often excellent.

The Martian S hemisphere was again presented to the Earth at opposition, and the regression and fragmentation of the S polar cap was the highlight of the apparition. Physical data for the apparition were as follows:

Latitude of centre of disk at opposition	−21°.5	
Declination at opposition	− 2°	
Winter Solstice of S hemisphere / Summer Solstice of N hemisphere	1987 October 17	(L_s = 90°)
Spring Equinox of S hemisphere / Autumnal Equinox of N hemisphere	1988 April 18	(L_s = 180°)
Mars in perihelion	1988 August 11	(L_s = 250°)
Summer Solstice of S hemisphere / Winter Solstice of N hemisphere	1988 September 12	(L_s = 270°)
Mars in opposition to the Sun	1988 September 28	(L_s = 280°)
Autumnal Equinox of S hemisphere / Spring Equinox of N hemisphere	1989 February 16	(L_s = 0°)

The N hemisphere of Mars was tilted towards Earth until 1988 February 12. After then, the southward tilt of the axis increased to —23°.5 by mid-June, decreased somewhat to —20°.0 by late August, increasing again to —25°.5 by late November. It had decreased to 0° again on 1989 April 22. The Martian date at opposition was January 1.

Useful observations were received from 118 observers or groups in 14 countries: see Table 1. Messrs. Alexescu, Baum, Graham, Haas, Hill, Lenham, Minami, Miyazaki, Moore, Rogers and Sturdy each sent in 50 or more drawings, while Miyazaki, Parker, Shirao and Viscardy sent over 50 high-quality photographs each. Special mention must also be made of Shirao's systematic sets of four-colour filter photographs and colour transparencies. Several observers had the use of large instruments: Dragesco worked with Prof G. de Vaucouleurs with the Lowell refractor while Falorni, Herbert and McKim worked at Meudon with Drs Ebisawa and Dollfus and Parisian members of the Societe Astronomique de France. The writer observed between 1988 July 14 and 1989 April 14, obtaining 105 drawings.

During the apparition many amateur and professional astronomers experimented with CCD or video techniques. Dr Dollfus contributed several CCD images obtained with his 1-metre reflector at Meudon. Cook and Platt in the UK also sent in CCD images, and Kidger obtained some on La Palma. Miyazaki contributed a video recording of his Mars and Jupiter work. Bourgeois also sent some floppy diskettes containing sequences of remarkable static and cinematic images of CCD work at Pic du Midi on Mars and Jupiter; this work was done by J. Lecacheux and F. Colas. I am grateful to Dr S. M. Larson (Catalina Observatory) for permission to reproduce his CCD images (see page 264). Many observers attempted conventional photography of the planet.

Table 1. Observers of the 1988 apparition.

Name	*Location(s)*	*Principal Instrument(s)*
B. Adcock*	View Bank, Victoria, Australia	310 mm refl.
L. Aerts	Heist-op-den-Berg, Belgium	305 mm refl. and 280 mm Schmidt-Cass.
Agrupacion Astronomica de Tenerife (6 observers)	Tenerife and La Palma, Canary Islands	various
M. Alexescu	Bacau, Romania	150 mm Cass, and 200 mm Nasmyth-Cass.
R. W. Arbour*	South Wonston, Hants.	400 mm refl.
G. Bates	Birmingham	152 mm OG
R. M. Baum	Chester	115mmOG
J. D. Beish	Miami, Florida, USA	320 mm Cass.
M. Beveridge	Aberdeen	216 mm refl.
K. W. Blaxall	Colchester, Essex	216 mm refl.
V. Boico	Bucharest, Romania	200 mm refl.
M. Boulton	Redditch, Worcs.	157 mm refl.
J. Bourgeois*	Pic du Midi Observatory, France	1060 mm Cass.
R. D. Bowen	Kenilworth, Warwicks.	300 mm refl.
T. Broadbank	Poole	254 mm refl.
D. G. Buczynski*	Scotforth, Lancaster.	534 mm refl.
F. C. Butler	London	221 mm refl.
R. Buttigieg	Sydney, Australia	203 mm Schmidt-Cass.
N. Cabrol	Meudon Observatory, France	830 mm OG
M. Caffrey	Marlborough College, Wilts.	254 mm OG
G. L. Cameron	Ames, Iowa, USA	320 mm refl.
G. Canonaco	Genk, Belgium	200 mm OG
D. Cardoen*	Puimichel, Alpes de Haute Provence, France	1006 mm refl.
T. R. Cave**	Long Beach, California, USA	320 mm refl.
	Ford Observatory, California	457 mm refl.
R. Cerreta*	Collurania Observatory, Teramo, Italy	400 mm OG
J. Coates	Burnley, Lanes.	305 mm refl.
T. Cook**	Frimley, Surrey	200 mm refl.
D. Crussaire	Meudon Observatory, France	830 mm OG
H. J. Davies	Swansea	150 mm refl.
A. Desai	Bombay, India	203 mm Schmidt-Cass.
P. Devadas	Madras, India	254 mm refl.
A. Diepvens	Balen, Belgium	150mmOG
J. Dijon	Champagnier, France	300 mm refl.
J. Dragesco*	Lowell Observatory, Flagstaff, Arizona, USA	610 mm OG
E. L. Ellis	St. Albans	90 mm OG
G. Falcoianu	Bucharest, Romania	114 mm refl. and 200 mm Dall-Kirkham refl.
M. Falorni	Arcetri Observatory, Florence, Italy	360 mm OG
	Meudon Observatory, France	830 mm OG
D. Fischer	Konigswinter, West Germany	80 mm OG
	Bonn University Observatory	200 mm OG
D. Fisher	Sittingbourne, Kent	215 mm refl.
J. R. Fletcher	Tuffley, Gloucester	250 mm refl.
M. Foulkes	Hatfield, Herts.	254 mm refl. and 203 mm and 355 mm Schmidt-Cass.
M. Giuntoli	Pieve a Nievole, Italy	100 mm OG
T. Gouldstone	St. Keverne, Cornwall	216 mm refl.
D. L. Graham	Brompton-on-Swale, N. Yorks.	152mmOG
	Gilling West, N. Yorks.	406 mm refl.
	Tuffley, Gloucester	250 mm refl.
D. Gray	Spennymoor, Co. Durham	415 mm Dall-Kirkham refl.
H. de Groote*	Vlahertinge, Belgium	300 mm refl.
W. H. Haas	Las Cruces, New Mexico, USA	203 mm and 320 mm refls.
A. W. Heath	Long Eaton, Notts.	300 mm refl.
D. Herbert	Meudon Observatory, France	830 mm OG
	Cambridge University Observatory	203 mm OG
N. D. Hewitt*	Northampton	203 mm Schmidt-Cass.
H. Hill	Wigan	254 mm refl. and 208 mm Schmidt-Cass.
A. J. Hollis	Northwich	300 mm refl.

Name	*Location (s)*	*Principal Instrument(s)*
G. F. Johnstone*	Leamington Spa	254 mm refl.
T. C. Kenyon	Tucson, Arizona, USA	254 mm refl.
M. Kidger**	Teide Observatory, Tenerife	500 mm Cass.
A. P. Lenham	Swindon	203 mm refl.
C. J. R. Lord	Forest Row, E. Sussex	150 mm Mak-Cass.
J. McCue	Norton, Cleveland	254 mm refl.
R. McKay	Havant, Hants.	200 mm refl.
R. J. McKim*	Meudon Observatory, France	600 mm Cass, and 830 mm OG
	Arcetri Observatory, Florence, Italy	360 mm OG
	Cambridge University Observatory	203 mm and 320 mm OGs
	Oundle, Peterborough	216 mm and 300 mm refls.
T. Mahoney	Old Royal Observatory, Greenwich	712mmOG
B. Manning*	Kidderminster	260 mm refl.
R. A. Marriott	Northampton	130 mm OG and 254 mm refl.
K. J. Medway	Southampton	102 mm OG
B. Merrikin	Rugby	210mmOG and 216 mm refl.
M. Minami	Taipei, Taiwan	250 mm OG
	Fukui, Japan	200 mm OG and 200 mm refl.
J. Mitton	Cambridge	203mm Schmidt-Cass.
I. Miyazaki* (with Y. Higa)	Okinawa, Japan	400 mm refl.
M. P. Mobberley*	Bury St. Edmunds	356 mm Cass.
P. A. Moore	Selsey, Sussex	390 mm refl. and 125 mm OG
R. Moseley	Coventry	305 mm refl.
	Scotforth, Lancaster	457 mm refl.
R. Neel	Venissieux, France	310 mm refl.
T. Osawa	Fukuoka, Japan	320 mm refl.
P. W. Parish	Rainham, Kent	222 mm refl.
D. C. Parker*	Miami, Florida, USA	320 mm and 410 mm refls.
R. A. H. Paterson	Thame, Oxon.	320 mm refl.
T. Platt**	Binfield, Berks.	320 mm refl.
G. Quarra Sacco* and D. Sarocchi	Florence, Italy	150 mm OG and 300 mm Cass.
C. Raeburn	Alderney, Channel Islands	150 mm Mak-Cass.
A. J. Read	Yateley, Hants.	215 mm refl.
R. L. Robinson	Morgantown, West Virginia, USA	254 mm refl.
R. Robotham	Port Rowan, Ontario, Canada	150 mm refl.
J. H. Rogers	Linton, Cambs.	254 mm refl.
	Cambridge University Observatory	320 mm OG
M. Salameh*	Meudon Observatory, France	600 mm Cass.
J. Sanford*	Orange, California, USA	350 mm Schmidt-Cass.
R. W. Schmude, Jr.	Tomball, Texas, USA	152 mm and 254mm refls. and 356 mm Schmidt-Cass.
A. Schroyens	Mechelen, Belgium	150 mm refl.
J. D. Shanklin	Cambridge University Observatory	203 mm OG
M. Shirao*	Tokyo,Japan	350 mm refl.
D. Shirreff	Marlborough College, Wilts.	254 mm OG
J. R. Smith	Rudgwick, Horsham	305 mm refl.
D. Strange	Worth Matravers, Dorset	298 mm refl.
K. M. Sturdy	Helmsley, N. Yorks.	216 mm refl.
N. Thompson	Sheffield	254 mm refl.
S. M. Trafford	Towcester	220 mm refl.
D. Troiani	Schaumburg, Illinois, USA	254 mm refl.
Unione Astrofili Italiani (5 observers)	Italy	various
A. van Durs*	Netherlands	250 mm refl.
F. van Loo	Genk, Belgium	250 mm refl. and 200 mm OG

Table 1. (cont.)

Name	*Location(s)*	*Principal Instrument(s)*
E. Verwichte	Genk, Belgium	200 mm OG
D. Vidican	Bucharest, Romania	200 mm reft
G. Viscardy*	St. Martin-de-Peille, France	520 mm Newt-Cass.
T. Wakugawa*	Okinawa, Japan	250 mm refl.
A. W. Wilkinson	Worcester	241 mm refl.
D. C. Wright	Sanderstead, Surrey	133 mm OG
J. Youdale	Billingham, Cleveland	300 mm Cass.

A total of 2,554 drawings and 856 photographs was received, together with 31 CCD images totalling 3,441 observations (an all-time Mars Section record!), covering the period 1987 November 9 (Parker, L_s = 100°) to 1989 June 7 (Haas, L_s = 51°).

Observing prospects for 1988 were described by various individuals.[3,4] Several BAA Interim Reports on 1988 have already been published,[5] as have accounts by the Bund der Sternfreunde (BdS),[6] the Association of Lunar and Planetary Observers (ALPO),[7] Oriental Astronomical Association (OAA), [8-9] Unione Astrofili Italiani (UAI),[10] Groupement International d'Observateurs de Surfaces Planetaires (GIOSP)[11] and others.[12-17] The Section collaborated with all these groups and with the Planetary Society (USA) via Parker, the Societe Astronomique de France (SAF) via Dr Dollfus and D. Crussaire and the Vereniging voor Sterrenkunde (VvS) via Aerts in Belgium.

Clark[18] has drawn an albedo map from videotapes. Colas," de Vaucouleurs,[15] Larson[20] and O'Meara[21] have all reproduced CCD images. In another article featuring CCD images, Hartmann[22] discusses the difficult question of the true colours of the *maria* and the application of reflection spectroscopy to determine the mineral composition of the Martian surface rocks. Iwasaki *et alP* continued their work on the regression of the SPC. Since the publication of our last report[2] the Lowell Observatory has published a 1986 photographic albedo map;[24] it agrees well with the BAA chart. Further, the ALPO has published its final results for the 1984 apparition.[25]

The present report is arranged in the usual way, and Figures 1-11 illustrate aspects of the apparition. Unfortunately it is impossible to reproduce more than a fraction of the observations sent in, but *all* work received has been consulted in preparing the Report, and the writer extends his thanks to each contributor. The study of Mars can only be effective through a collaborative effort.

Surface features

Note: nomenclature is after Ebisawa;[26] E and W are used areographically *(E=p;* W=/). Selected apparent visual colours are given wherever there was reasonable accord between observers.

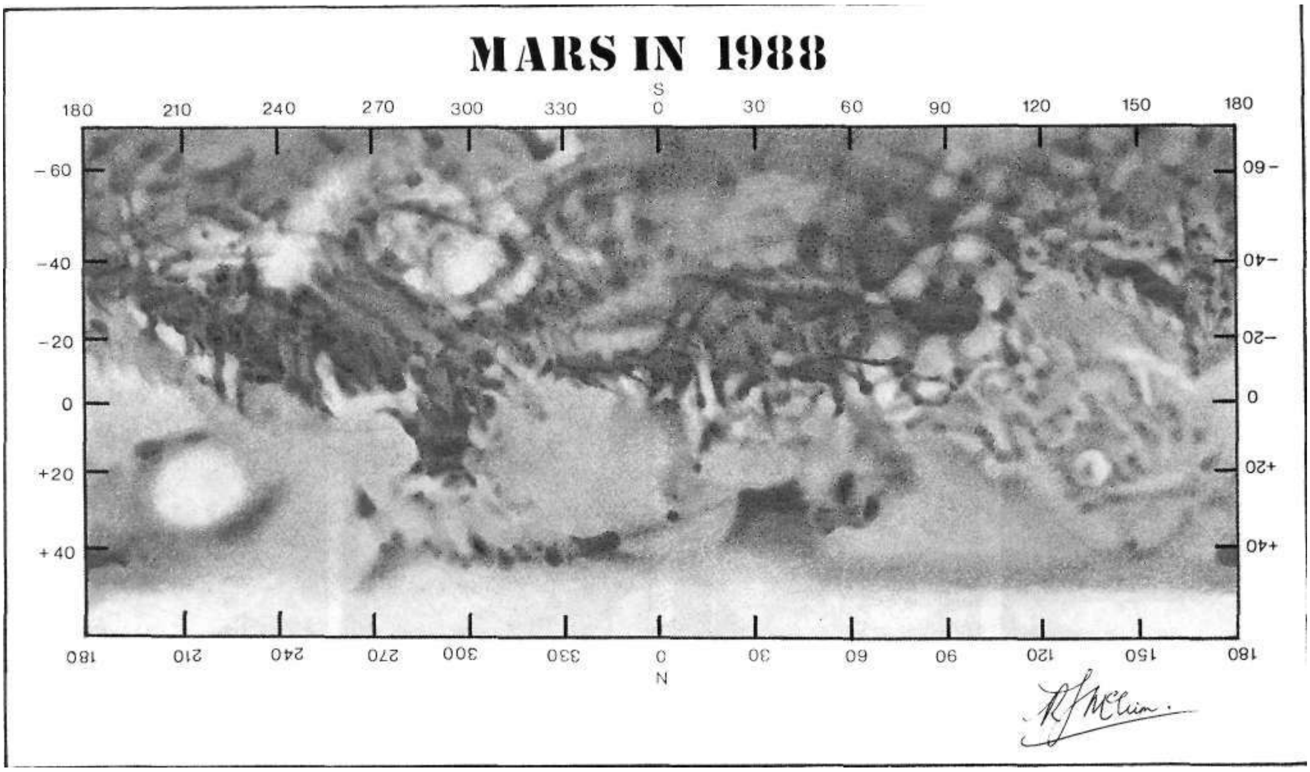


Figure 1. General map of the planet compiled from the best CCD images from mid-August through early October. The SPC is not visible but the NPH south edge is shown for the time of opposition. *R. J. McKim.*

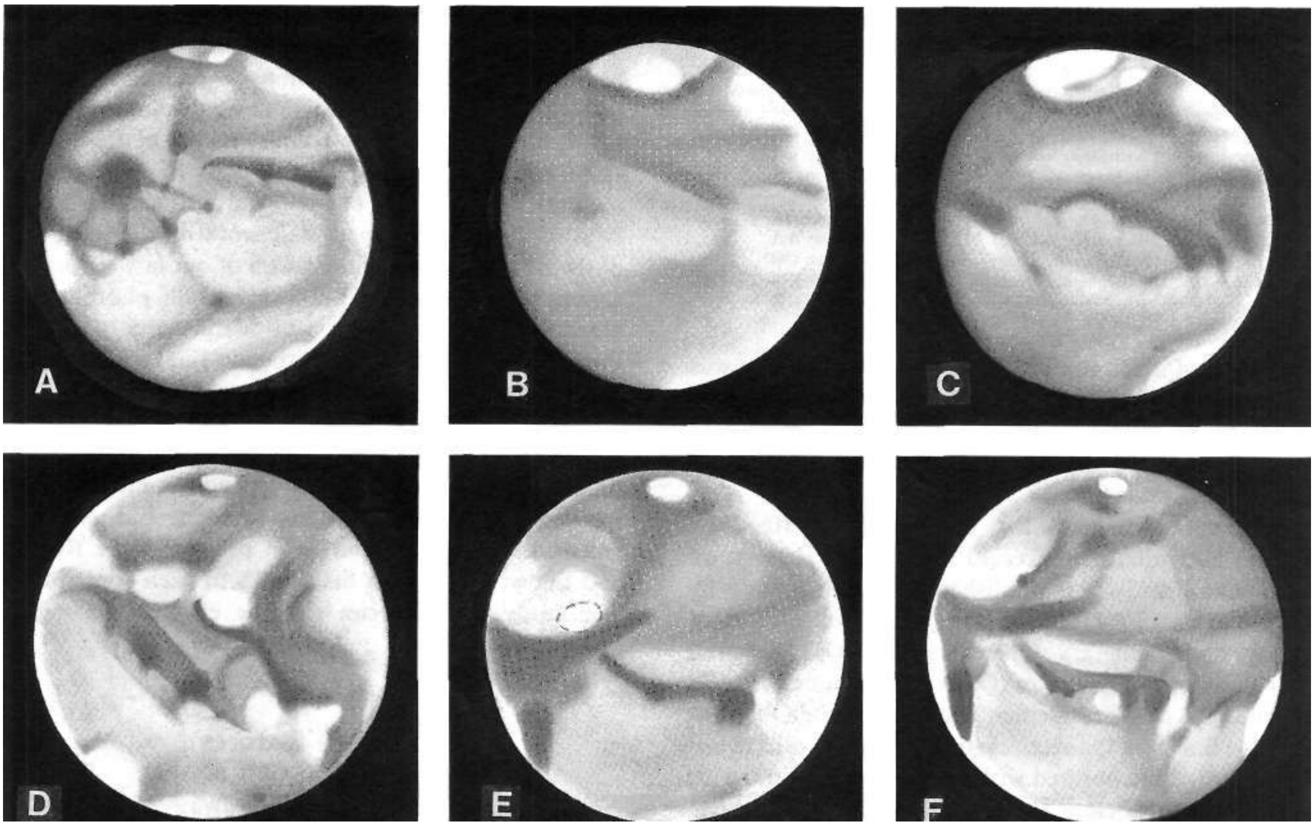


Figure 2. Drawings by R. J. McKim. Seeing (S) is given on the Antoniadi scale. (A) August 27d 21h 40m, ω = 110°, 360 mm OG, x 270, x 450, INT, W15, W25, SII-III, moments of I. Complex *Solis Lacus* 'canal' pattern; *Memnonia* darkening. (B) July 26d 03h 08m, ω = 137°, 830 mm OG, x 320, INT, W15, W25, SIII. Low contrast of *Solis Lacus* area and albedo features generally; *Memnonia* darkening. (C) July 19d OOh 55m, ω = 171°, 830 mm OG, x 540, INT, W15, W25, SII-III. SPC rift, dark spot and bright patch; *Elysium* morning cloud. (D) October 27d 18h 45m, ω = 244°, 830 mm OG, x 320, INT, W15, W25, SIII. Many bright areas, including morning haze over *Hellas-Iapigia-Syrtis Major.* (E) September 12d 22h 20m, ω = 334°, 216 mm refl., x 232, x 464, INT, W15, W25, SII-III. Bright patch in NW *Hellas; Margaritifer Sinus* obscured by morning haze. (F) October 26d OOh 45m, ω = 350°, 830 mm OG, x 320, x 400, INT, W15, W25, SH-IV.

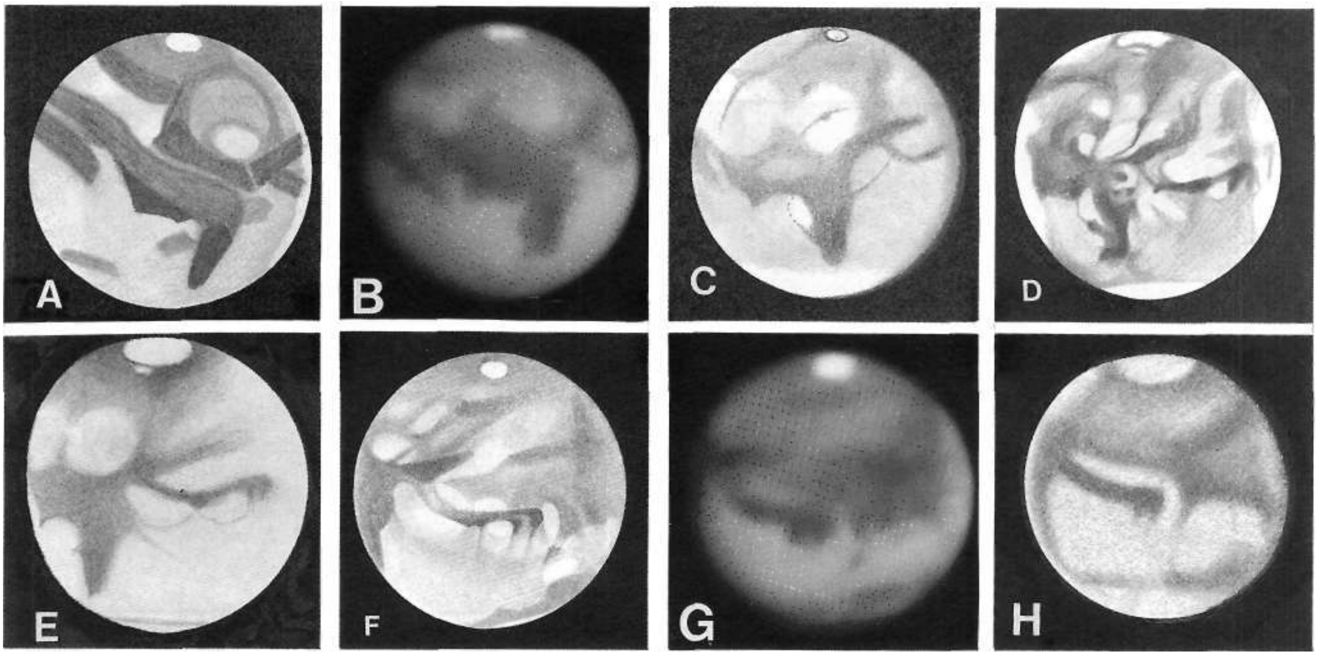


Figure 3. Drawings and photographs of *Region I by* different observers, ω = 250-010°, (A) September 19d 21h 50m, ω = 267°, 203 mm Schmidt-Cass., x 220-440, *Foulkes.* (B) September 11d 17h 16m, ω = 271°, 400 mm refl., f/175, TP 2415 film, 2 sec, *Miyazaki. Novus Mons* detached in (B), (D), (E). (C) October 24d 20h 15m, ω = 293°, 457 mm refl., x 245, *Moseley.* (D) September 8d 18h00m, ω = 309°, 250 mm OG, x 540, *Minami.* (E) August 16d 04h 05m, ω = 314°, x 268, x 343, *Hill.* (F) October 21d 22h 00m, ω = 346°, INT, W15, 830mm OG, x460, *Falorni.* (G) September 21d 05h 07m, ω = 4°, 410 mm refl., f/165, TP 2415 film, 3 sec, *Parker.* (H) *1989* March 15d 19h 45m, ω = 5°, x 475, INT, W25, *Gray.* SPH and NPC visible.

Apparition map

Figure 1 represents the result of the writer's attempts to chart all the detail visible in the best CCD images of Mars from mid-August to early October. The red-light CCD images by Larson (front cover) were used, together with images published by de Vaucouleurs[15] and Colas.[19] Coordinates of the markings were read from orthographic graticules, and are probably correct to the nearest degree near the equator. Visual observations with large instruments showed a similar degree of fine detail, but it could not be drawn accurately. Figure 1 is the most detailed map ever published by the Section; unlike our previous maps of 1980-86, which were drawn by reference to the IAU chart, the 1988 map was drawn entirely from the measured CCD images.

Region I: ω = 250 - 010°

Region I is best illustrated in Figure 3. *Syrtis Major:* broad, dark and blunted to the N, much as in 1986. It had a distinct bluish-grey tint, especially from September, though this colour had been reported as early as June. In August however, both Falorni and Lord independently found the *Syrtis* to be grey-brown. *Syrtis Major* looked complex to McKim from Meudon and to others with large apertures; CCD work confirms this. *Moeris Lacus* was a dark round spot with a little of the extreme S tip of *Nepenthes* running into it, but *Nepenthes* was otherwise invisible. De Vaucouleurs[15] found it to be absent with the 155-cm US Naval Observatory reflector, but it is shown faintly on some drawings, particularly by Minami and Miyazaki, in September. *Nilosyrtis* was scarcely visible in 1988, but it may have darkened later in the apparition, when Hill drew attention to it on November 2. *Astusapes* was also faint. The *f* side of *Syrtis Major* was the darkest and most complex side, containing several small bays and projections. Indications of this structure have been discernible in several high-resolution observations since 1982; indeed the overall shape of the marking seems to have varied little since then, indicating a continued long-lived secular variation by reference to the IAU and Ebisawa maps, affecting mostly the W side. As in 1986, *Deltoton Sinus* was visible in part. It was quite prominent, but remained smaller than shown on the reference maps. Some of the small features in and around the *Syrtis* may be compared with Ebisawa's chart,[26] and a small dark spot near its NW corner corresponds to the *Antoniadi* crater.

Nodus Alcyonius continued to be an isolated dark spot, near the north limb at opposition, remaining a little SW of its place on Ebisawa's map (Figures 2D, 3B). Its measured position this year (+29°, 265°) was the same as in 1982. The S tip of *Casius* was seen above the north polar hood (NPH) at opposition. It was darker and more prominent at the end of the apparition as the N hemisphere became more visible, as shown particularly by the later drawings of Gray and Moore (Figure 6H) who observed well into 1989. Within the irregularly shaded *Iapigia* region (which showed a less distinct blue-grey tint) the *Huygens* crater was again located by a very dark spot (Figures 3B, D, 4). Visually it was joined to *Iapigia* at the E side by a filament. The CCD images show fine structure in the immediate surroundings of the crater.

Hellas was generally dull on the central meridian (CM). Its S part was dusky from August onwards so that the N half was brighter than the rest (Figures 3A, 6F). Falorni described it as pink in September, as did Hill for the S half in October. It's NW corner often brightened up further in the Martian afternoon (Figure 2E). The whole basin was prone to morning mist at opposition and later (Figure 2D). *Peneus, Alpheus* and *Zea Lacus* were well seen, apparently darkening through the Martian Summer. The writer's Meudon map (Figure 4) shows these features well. *Mare Hadriacum* was dark blue-grey or green-grey, curling to the W at its S tip into *Peneus.* At the W side of *Hellas, Yaonis Fretum* formed a dusky border which from September contained the dark spot *Nerei Depressio. Yaonis Regio* was a lighter channel. *Hellespontus* was dusky throughout 1988. It was obscured by the June dust storm (see later), and appeared darker afterwards. It was very complex at high resolution, being broken down into a few darker spots in the CCD images. *Depressiones Hellesponticae,* visible from May, was particularly well seen from September as an intensely dark spot separated from the SPC north edge (Figures 2E, F, 5B, C). *Mare Australe* and *Chersonesus* were dusky and normal. *Ausonia* was often bright in the N in the Martian afternoon and evening and showed similar diurnal behaviour to *Hellas* (Figure 6F); it also appeared pink to Falorni and Hill in September.

Mare Serpentis was another very dark feature, and from July onwards it was seen to be once again joined to the ρ end of *Sinus Sabaeus,* as it had been before 1980. *Mare Serpentis* was also seen to have darkened suddenly in late June, after being covered by a dust storm which had commenced in *Hellas. Mare Serpentis*

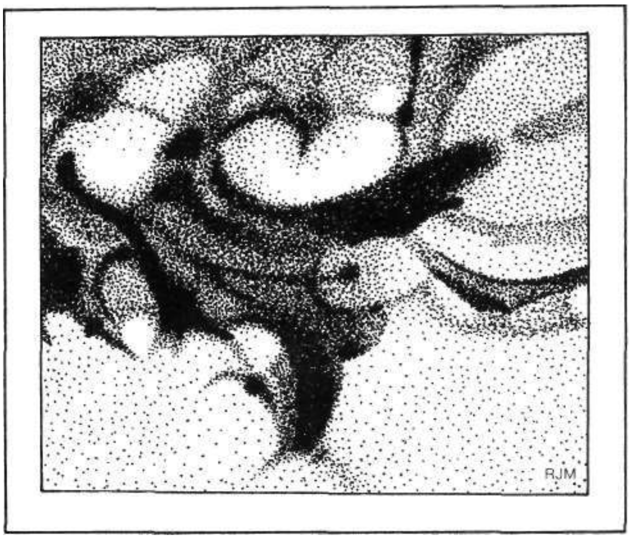


Figure 4. Chart of the *Syrtis Major* region from observations with the 830 mm OG at Meudon, x 540, 1988 October 22-27, *McKim.*

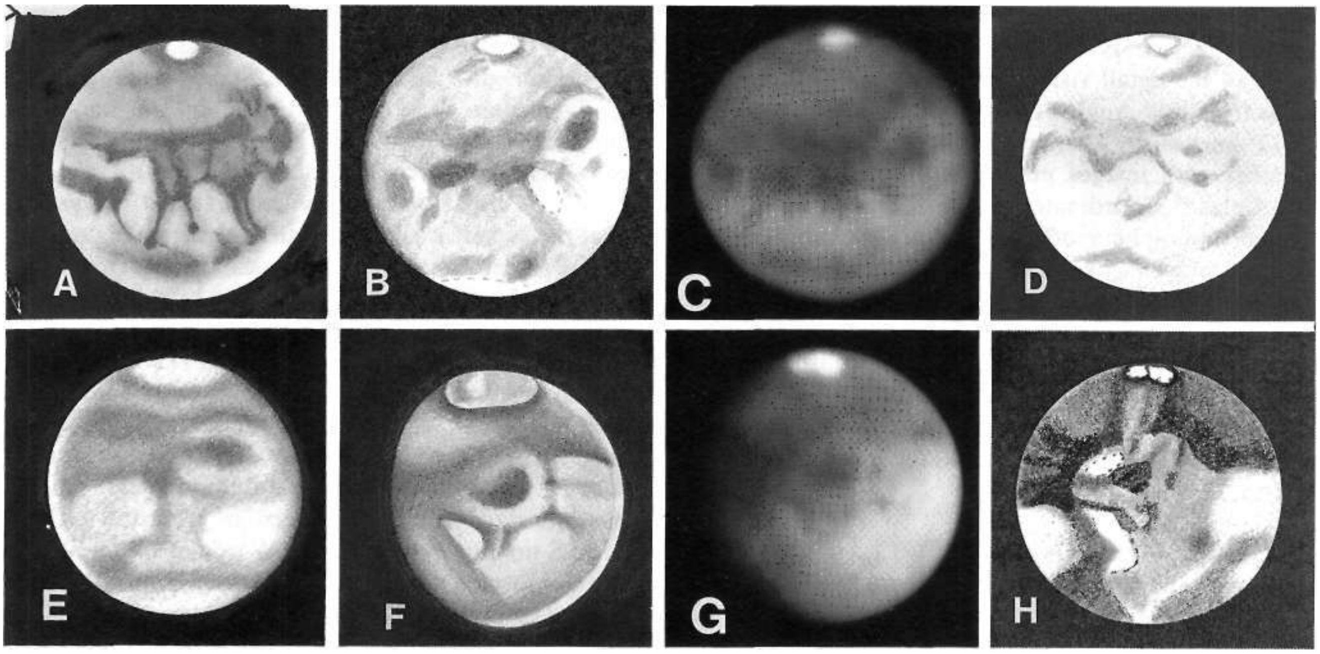


Figure 5. Drawings and photographs of *Region //* by different observers, m = 010-130°, (A) September 9d 23h 40m, ω = 23°, W25, 250 mm refl., x 398, *Graham.* (B) September 6d 23h 25m, ω = 46°, 200 mm OG, x 224, *Rogers.* (C) October 2d 14h 47m, ω = 49°, 400 mm refl., f/175, TP 2415 film, 2 sec, *Miyazaki.* (D) October 12d 21h 30m, ω = 59°, 390 mm refl., x 450, *Moore.* (E) *1989* March 7d 18h 40m, ω = 67°, x 333-540, W25, *Gray.* SPH and NPC visible. (F) July 15d 16h 00m, ω = 70°, 200 mm refl., x 395, *Miyazaki.* SPC details. Narrow dark streak W *oiGallinaria Silva* crossing *Memnonia.* (G) August 24d I7h 39m, ω = 79°, 400 mm refl., f/175, TP 2415 film, 2 sec, *Miyazaki.* (H) September 7d 02h 00m, ω = 84°, 305 mm refl., x 271, x 348, *Aerts.* Note SPC rift.

had a dark bluish-grey colour and extended into *Noachis* as located on Ebisawa's map. It was wider and more conspicuous than in 1986, but in 1988 it did not extend as far as the E end of *Mare Erythraeum.* It was resolved into a complex pattern of dark spots. *Noachis* was rarely bright, appearing salmon-yellow or orange to Baum.

Sinus Sabaeus appeared brownish to Falorni and McKim at Arcetri in August, and to Minami from June to September; it appeared grey or green-grey to some others. The *p* end of *Sinus Sabaeus,* beginning east of *Portus Sigeus,* and weakly linked to *Mare Serpent is* was never as dark as on the IAU map, but during 1980-86 had been even fainter. The *Edom* crater appeared as a lighter spot. A small 'bridge' cut diagonally across *Edom* linking *Meridiani Sinus* to *Sinus Sabaeus,* and this feature can also be traced on 1969 *Mariner 7* imagery.[15] *Aram* exhibited variability due to white cloud over *Thymiamata* and *Deucalionis Regio.* The W end of *Deucalionis Regio* was bridged by complex shading and the 'canals' *Neudrus I* and *II* extending south to a pair of dark spots at the E end of *Pandorae Fretum,* as in 1986.

Pandorae Fretum was invisible up till June, but after the *Hellas* dust storm it suddenly darkened, and remained visible throughout the apparition (Figures 2E, F, 3D-G). Gray could still see it in 1989 March (Figure 3H). Its *p* end was narrower and fainter than its /end, giving it a 'tipped' appearance (Ebisawa), never quite joining up with *Mare Serpentis.* Although conspicuous from late June, it was never as broad and as dark as it can sometimes be. *Pandorae Fretum* appeared blue-grey to Hill (July-August). *Meridiani Sinus* was much as in 1986 as our chart (Figure 1) will show. The E fork was again accompanied by a narrow, additional component *(Brangaena).*

Boreosyrtis - Coloe Palus - Protonilus - Ismenius Lacus - Deuteronilus were glimpsed near the N limb at opposition, and are best shown on the red-light CCD images which penetrated the N polar hood. *Gehon* was a dusky curving sweep of halftone shading, joining up with *Deuteronilus* near a small *Siloe Eons* but there was no sign *oı Euphrates* to most observers.

Region II: ω = 010-130°

Refer to Figure 5 for views specifically of this Region. *Mare Erythraeum* was dark. The area enclosed by it and the *Margaritifer Sinus* and *Aurorae Sinus* to the north was exceptionally complex. As in 1986 *Margaritifer Sinus* was not especially dark at its centre but had dark NE and NW edges. Hill, who found it to be blue-grey saw it truncated to the N in July; from August it was more tapering. *Oxia Palus* was exceptionally large, with a hook-like extension to the NE (Figures 3F, G). *Bosporus Gemmatus* and the S borders of *Thaumasia* were dark. *Chrysokeras* was well-seen in August-October (and surrounded by dark spots) though it seemed less obvious later. *Aurorae Sinus* was dark, complex and blue-grey. *Juventae Fons* (Figure 5C) appeared as in 1986 and was very dark.

The general appearance of the *Solis Lacus* region was as in 1986 with a few notable exceptions: *Phasis* was fainter and *Acampsis* had revived. The writer and others had rather Schiaparellian views of the *Solis Lacus* surrounded by broad dusky 'canals' (Figures 2A, 3), but their objective reality is confirmed by the CCD

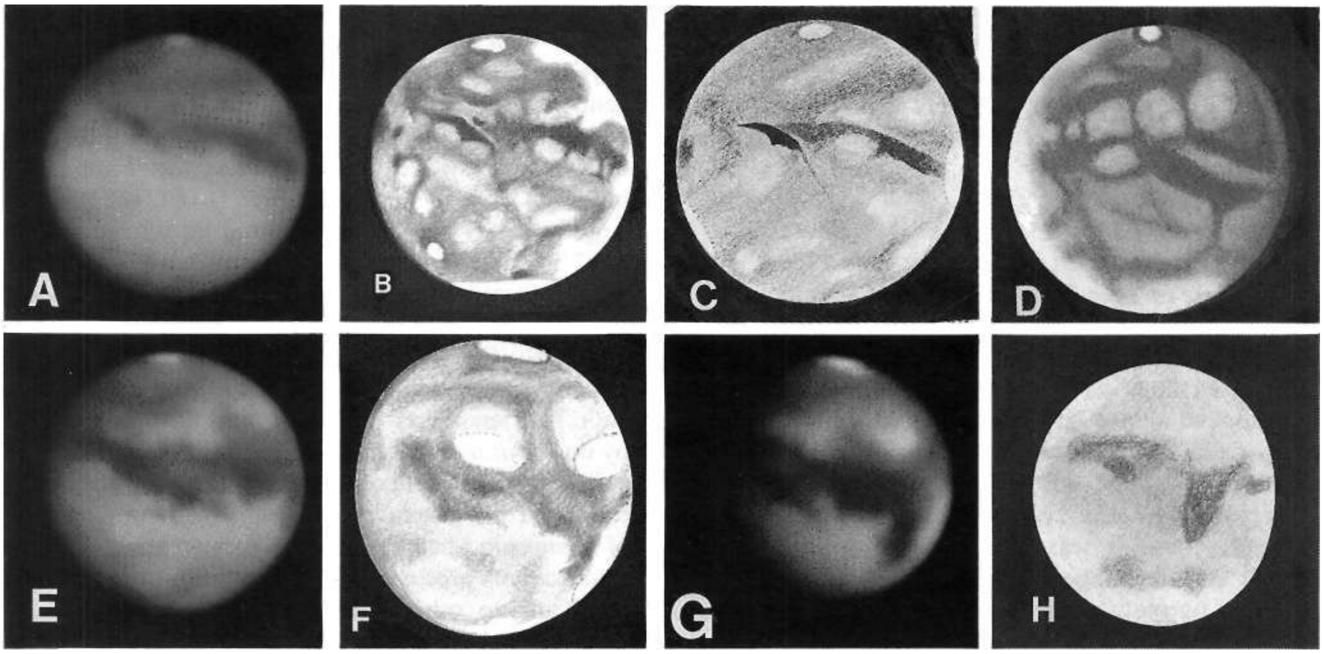


Figure 6. Drawings and photographs of *Region III* by different observers, ω = 130-250°. (A) September 21d 16h 18m, ω = 169°, 400 mm refl., f/175, TP 2415 film, 2 sec, *Miyazaki. Nix Olympica* at *p* limb in (A)-(C). (B) September 23d 17h 30m ω = 169°, 250 mm OG, x 540, *Minami.* (C) September 29d 21h 15m, ω = 170°, x 340, 360 mm OG, *Falorni.* (D) November 2d 20h 35m, ω = 216°, W15, W25, 152 mm OG, x 286, *Graham.* (E) September 15d 16h 37m, ω = 226°, 400 mm refl., f/175, TP 2415 film, 2 sec, *Miyazaki.* (F) August 21d 02h 30m, ω = 242°, 200 mm Nasmyth-Cass., x 353, red filter, *Alexescu.* Bright areas in N *Ausonia* and *Hellas.* (G) August 19d 0lh 35m, ω = 247°, red filter, f/69, TP 2415 film, 1 sec, *Viscardy. Novus Mons* detached. (H) *1989* March 27d 19h 30m, ω = 247°, 390mm refl., x 360, *Moore.* Note *Casius-Utopia* and the NPC.

images. *Solis Lacus* (which was generally seen to be blue-grey or green-grey) again showed the two little spots on its S edge but they were apparently not visible before August, showing only as protrusions in Ebisawa's July drawings from Meudon. *Solis Lacus* was very similar in size and shape to 1986, being large and dark. It was joined to the greyish *Mare Erythraeum* by a dark and broad *Nectar. Nectaris Fons* and the 'canal' *Nia* were visible (also shown in the 1986 data). *Coprates* and the entire *Tithonius Lacus* area were very similar to 1986 and will not be described here.

Aonius Sinus was pointed to the N: a change since 1986. *Hyscus* was a lighter half-tone (it had been as intense as, and continuous with *Mare Sirenum* in 1986). *Phasis* was fainter, being first seen in May as soon as Mars was close enough, and was followed until December. It seemed to slowly fade after August. The spot at its N end - *Gallinaria Silva* - was large and dark as in 1986, but it was more circular. The canals *Esophorus* and *Acampsis* were well seen, neither being well visible in 1986. *Acampsis* connected *Gallinaria Silva* to the tiny spot *Arctii* or *Sirii Fons.* Figures 2A and 5G show the foregoing features well. *Ambrosia, Bathys, Calydon* and *Geryon* appeared as in 1986. *Thaumasia* was very dusky in July but lightened later. *Phoenicis Lacus* was another dark feature. In July - early September it underwent a curious temporary transformation: it became extended to the NW and was resolved into three separate components by Falorni and Miyazaki. No visible yellow cloud activity can be linked to this change, and *Phoenicis Lacus* again became a normal, circular spot later (Figures 2A, 5D, F, G). As in 1986 the N border of *Pyrrhae Regio (Aurorae Fretum)* was complex and contained several northward projections or detached Oases'. *Eos* could be recognised but it was not prominent.

Mare Acidalium was too far north to be observed except towards the end of the apparition (Figure 5E). However, *Niliacus Lacus* formed a dark streak near the N limb, appearing bluish to Minami and Miyazaki. The features *Ganges, Lunae Lacus, Nilokeras, Clytaemnestrae Lucus, Achilles Fons* and *Idaeus Fons* appeared exactly as in 1986. *Ganges* was red-brown to Miyazaki in July, though grey to Hill in August. In August Minami saw *Nilokeras* bluish and *Lunae Lacus* brownish. The *Thar sis* volcanoes were not often prominent as albedo features but their orographic clouds were seen at times. Thus *Nix Olympica* was well seen in September and October (Figures 6A-C, 7F). *Ascraeus Lacus (Mons)* was linked to *Arsia Mons* and *Pavonis Lacus* by a dusky band. *Olympus Mons* was another vague spot. The volcanoes seem to appear as darker albedo features during the N hemisphere Summer (such as in the 1982 and 1984 apparitions) than during the southern Summer. No features in their vicinity were well-defined; thus *Uranius* and other streaks were imperfectly seen. Of interest is Larson's September 10 CCD image (front cover) which shows *Olympus Mons* near the CM: it is evident thereon that the evening side of the volcano is more shaded than the other, and the feature is surrounded by a lighter ring, reminiscent of far-encounter spaceprobe images! The whole of the desert areas of this region were covered with tiny details on the CCD images.

Argyre I was a light region, ochre-grey or ochre-yellow. It was often brighter at the evening limb or terminator. As de Vaucouleurs notes,[15] it no longer showed its classical shape. It was affected by dust activity, particularly in June-July and November-December. *Dia* and *Argyre II* were lighter areas, bordered by a complex pattern of spots in the grey-brown *Mare Australe* area.

Region III: ω = 130 - 250°

Region III is illustrated in Figure 6. As in 1986, the W end of *Mare Sirenum* had faded. It ends near longitude 165° on our chart, rather than at the customary 175° (Ebisawa). From Meudon in July McKim did not see any bluish colour in *Mare Sirenum* or *Mare Cimmerium* (they looked reddish-grey then), but with smaller telescopes from August onwards he noted a bluish-grey colour in both, and this was the prevalent opinion of others. Hill saw *Mare Sirenum* as brown in July and November, but it was blue-green to him in June, August and September. The E end of *Mare Sirenum* appeared normal (being blunted rather than pointed), running into the half-tone shading of *Hyscus.* There was a bulge on its N edge at *Gorgonum Sinus* (—28°, 150°). The new W end was near *Gigantum Sinus (—24°,* 162°), from which an unnamed 'canal' ran NW and ended in a small faint spot at —9°, 167° near *Medusae Fons* (Ebisawa). (See Figures 2C, 6B, C). *Tartarus* was a broad streak separating *Amazonis* from *Zephyria.* A good summary of the changes in this area, with historical comparisons, has been given by Dijon" *(Pulsar,* No. 670, 24-25).

S of *Mare Sirenum* was *Caralis Fons,* to whose reappearance Schmude drew attention. Our chart shows it a few degrees W of Ebisawa's position. This rarely seen dark spot is shown on several drawings and photographs from September onwards and seems to be identifiable with the crater *Newton* (Figures 6A, B). The region between *Mare Sirenum* and *Mare Cimmerium,* and the interior of *Mare Cimmerium* itself was complex and broadly similar to 1986. *Laestrygonum S., Atlantidum S.* and *Sinus Gomer* - the latter having two conspicuous northward projections (Figures 2D, 6B, E) - were all prominent. *Cerberi Sinus* was visible as a complex swelling of *Mare Cimmerium,* and from it the *Mare* tapered into a long, pointed *Tritonis Sinus* which had a small dark spot near its N end. McKim saw this tiny feature *(Cyllenius Lacus)* from Meudon easily but it was not otherwise visible except on the best CCD images. Running SW from *Cerberi S.* was *Cerberus III,* cutting across *Hesperia. Cerberus III was* fainter than in 1986. *Hesperia* was rather dusky, especially in its S and E parts, but was lighter W of longitude ≈ 250°.

Some attention was given to a darkening in the *Memnonia* desert. When first seen in early July by Miyazaki (Figure 5F) and Parker this was a *narrow* dark band a little detached from but parallel to *Mare Sirenum,* running W from *Gallinaria Silva.* O'Meara traced it "as far [west] as *Cerberus IIГ'* in August *(IAUC* 4645), implying an extension through the deserts west of *Memnonia.* (His drawing is reproduced by Parker *et al.,*[6] page 35.) However, there can be no doubt that only the darkening of *Memnonia* was new, as the dusky shadings in *Zephyria-Aeolis-Aethiopis* were already present. When Ebisawa and McKim independently observed the shading in *Memnonia* from Meudon in late July (Figure 2B) it had become a *diffuse* dusky band. It was easily visible in August (Figure 2A), but CCD work by Lecacheux *et al. (IA UC* 4654) in late August / early September "showed no significant feature" at these longitudes. In September it was hardly visible except to the east (Figure 6B), but Parker thought it recovered somewhat in November. Shadings in this position are shown on Ebisawa's general map, but they are normally very faint *(Erinnys, Arimanes,* etc.). This temporary darkening must have been caused by dust storm activity, but its inception is unclear. An early drawing by Hill on June 19 is highly suggestive: he found the disk generally yellowish, except for the region of *Memnonia* which had a warm (orange) tint. Was this evidence of precursor dust activity? Unfortunately there are no other clues, but as *Solis L.* was also relatively pale from May through July it is likely that dust activity in this neighbouring region may also be associated with the development of *Acampsis* (running parallel to the *Memnonia* development), the fading of *Phasis* nearby, and the temporary alteration in shape of *Phoenicis Lacus* (see *Region II). Memnonia* appeared rosy-pink to Moseley in July. From Meudon in July McKim found the desert areas of southern *Zephyria-Aeolis* (including *Symplegades Insulae)* to be very red compared with the other desert areas to the north. The CCD images show the *Amazonis* and *Arcadia* deserts to be covered with fine details; *Olympus Mons* has already been mentioned in *Region II.*

The deserts of *Phaethontis* and *Electris* were generally shaded, especially the former which was normally indistinguishable from *Simois. Eridania* was brighter late in the apparition at the morning terminator. *Scamander* was not seen in July but was wide, dark and double from August onwards, as the deserts on either side became lighter with the progress of the Martian seasons. *Palinuri F. - Mare Chronium - Tiphys Fretum* formed a complex dark band to the south. It bordered the retreating cap in July but was well separated from it in August. This band was always reddish or brownish (Butler, Falorni, McKim, Moseley and others) compared to the bluish-grey *Mare Cimmerium* and *Mare Tyrrhenum. Thyle I* and *//* were areas of differing brightness within the cap in July (Figures 2B, C), separated by *Ulyxis Fretum.* Later they appeared to the N of the cap edge as featureless halftones.

The *Trivium Charon tis - Phlegra - Cerberus (I) - Cyclops* region was much as in 1986. *Cerberus* was bluish to Miyazaki in July. *Elysium* was sometimes brighter than the surrounding deserts but generally not. *Nubis Lacus, Thoana Palus* and *Nodus Laocoontis* were all quite invisible. The eastern part of *Aetheria* was still shaded (Figures 2D, 6E) but the whole region was too near the N limb to be seen in detail. This secular development dating from 1978 is well shown in one of the new US Geological Survey topographic-albedo

Mars 1988

Table 2. Martian intensity estimates.

	Observer														
Feature	Cerreta	Foulkes	Graham	Heath	Hewitt	Lenham	Lord	McKim	Merrikin	Moseley	Rogers	Sturdy	Ave.	s.d. (±)	No.
Acampsis	–	–	–	–	–	–	–	4.0	–	–	–	–	4.0	(–)	3
Achillis F.	–	–	–	–	–	–	–	6.5	–	–	4.5	–	5.5	(1.0)	2
Aeolis	3.0	–	–	–	–	1.9	2.0	2.4	–	1.8	–	–	2.2	0.5	37
Aeria	–	2.2	2.0	0.9	1.7	1.6	2.0	1.9	–	1.9	1.1	–	1.7	0.4	65
Aetheria	–	–	–	–	–	2.6	–	2.9	–	–	–	–	2.8	(0.2)	15
Aethiopis	3.0	2.2	–	–	1.2	2.3	1.8	2.2	–	–	1.2	–	2.0	0.6	55
Agathodaemon	–	–	–	–	–	4.5	–	5.8	–	3.9	–	–	4.7	1.0	10
Alpheus	–	–	–	–	–	–	–	3.5	–	–	–	–	3.5	(–)	2
Amazonis	–	2.3	2.3	1.0	1.1	2.2	–	2.3	1.7	2.0	1.4	–	1.8	0.5	79
Ambrosia	–	–	–	–	–	–	–	3.8	–	–	–	–	3.8	(–)	2
Amenthes	–	–	–	–	–	1.8	–	1.9	–	–	–	–	1.8	(0.1)	14
Amphitrites. M.	–	–	–	–	–	–	3.8	4.0	–	–	–	–	3.9	(0.1)	6
Aonius S.	–	6.1	–	5.0	–	4.9	–	5.0	–	4.4	4.0	–	4.9	0.7	33
Arabia	–	2.2	–	1.0	–	2.0	2.0	2.0	–	1.8	1.2	–	1.7	0.5	49
Araxes	–	–	–	–	–	–	–	4.0	–	2.6	–	–	3.3	(0.7)	8
Arcadia	–	–	–	–	–	3.4	–	2.4	–	–	–	–	2.9	(0.5)	31
Argyre (I)	3.3	2.8	1.5	1.0	–	1.8	2.4	2.0	1.5	1.9	1.9	–	2.0	0.7	63
Ascraeus L.	–	–	–	–	–	–	–	4.0	–	–	–	–	4.0	(–)	1
Atlantidum S.	–	–	–	–	–	–	2.5	4.3	–	–	–	–	3.4	(0.9)	7
Aurorae S.	5.5	6.2	5.3	5.1	–	6.0	–	5.8	4.6	4.3	4.8	9.5	5.7	1.5	72
Ausonia	3.3	2.1	1.8	1.0	1.1	1.8	2.1	1.7	1.0	1.8	1.1	–	1.7	0.7	105
Australe, M.	4.7	3.8	3.5	3.8	2.9	5.1	3.2	3.8	2.6	3.0	2.9	–	3.6	0.7	102
Bathys	–	4.5	–	–	–	–	–	3.9	–	–	–	–	4.2	(0.3)	6
Bosporus Gemmatus	5.3	5.1	–	–	3.8	–	–	5.2	4.2	–	3.8	–	4.6	0.7	48
Calydon	–	–	–	–	–	–	–	4.0	–	–	–	–	4.0	(–)	4
Candor	–	–	–	–	–	1.8	–	1.4	–	1.1	–	–	1.4	0.4	15
Cerberi S.	–	7.3	–	6.0	–	–	–	6.0	–	–	–	–	6.4	0.8	27
Cerberus (I)	3.5	4.0	–	–	–	–	–	3.8	–	2.5	–	–	3.4	0.7	19
Cerberus (III)	–	–	–	–	–	–	–	5.4	–	–	–	–	5.4	(–)	5
Chalce	–	–	–	–	–	2.0	2.1	3.8	–	–	–	–	2.6	1.0	14
Chersonesus	4.5	–	–	–	–	–	–	5.3	–	–	–	–	4.9	(0.4)	5
Chronium, M.	5.5	5.8	4.5	4.2	3.2	5.4	3.0	4.5	3.8	3.9	3.7	5.9	4.4	1.0	132
Chryse	–	2.1	–	–	–	1.8	2.0	1.7	2.0	2.0	1.2	–	1.8	0.3	39
Chrysokeras	–	–	–	3.7	–	–	–	3.4	–	3.5	–	–	3.5	0.2	16
Cimmerium, M.	6.5	6.5	6.2	5.1	4.6	5.7	4.0	5.6	4.6	4.5	5.8	7.7	5.6	1.1	146
Claritas	–	–	–	–	–	1.8	–	2.8	–	2.1	–	–	2.2	0.5	27
Daedalia	–	–	–	–	–	–	–	2.9	–	–	–	–	2.9	(–)	15
Deltoton S.	–	4.2	–	–	–	2.3	3.3	4.7	–	–	–	–	3.6	1.0	20
Deucalionis R.	4.0	2.5	–	2.0	–	1.9	1.9	2.1	–	1.5	1.6	–	2.2	0.8	50
Deuteronilus	–	–	–	–	–	–	–	3.0	–	–	–	–	3.0	(–)	1
Dia	–	–	–	–	–	–	–	3.3	–	–	–	–	3.3	(–)	7
Eden	–	2.1	–	–	–	–	2.5	2.0	–	–	1.3	–	2.0	0.5	23
Edom	–	–	–	–	–	1.6	1.8	1.6	–	–	0.8	–	1.4	0.4	29
Electris	–	3.6	1.8	2.0	1.1	2.2	2.8	2.7	–	1.8	–	–	2.2	0.8	56
Elysium	–	2.2	–	–	–	2.3	1.9	1.5	–	2.0	0.9	–	1.8	0.5	45
Eos	–	–	–	–	–	–	2.8	4.3	–	–	–	–	3.6	(0.8)	8
Eridania	3.3	2.1	1.8	1.1	1.3	2.0	2.4	2.0	–	2.4	1.2	–	2.0	0.7	77
Erythraeum, M.	5.8	5.2	4.8	4.2	–	5.7	3.8	5.2	3.8	3.9	4.2	7.0	4.9	1.0	81
*Gallinaria Silva**	–	–	–	–	–	–	–	5.0	–	–	–	–	5.0	(–)	2
Ganges	–	4.3	4.7	–	–	–	–	4.4	–	3.5	3.0	–	4.0	0.7	29
Gehon	–	–	–	–	–	–	–	3.0	–	–	–	–	3.0	(–)	3
Geryon	–	–	–	–	–	–	–	3.8	–	–	–	–	3.8	(–)	5
*Gomer S.***	4.0	–	–	–	–	–	4.0	3.8	–	5.3	–	–	4.3	0.7	19
Hadriacum, M.	5.0	5.7	5.4	3.9	5.0	4.8	–	5.2	3.5	3.5	3.7	6.0	4.7	0.9	70
Hellas	3.3	2.2	2.0	1.5	1.2	1.5	1.7	1.6	0.9	1.6	1.2	–	1.7	0.6	135
Hellesponticae, D.	5.0	5.2	–	–	–	5.8	3.4	5.8	–	3.2	4.5	7.5	5.0	1.3	26
Hellespontus	–	5.0	–	–	–	4.2	3.3	4.9	–	3.3	3.2	7.0	4.4	1.4	44
Hesperia	4.9	3.2	2.5	2.3	–	2.6	2.0	3.4	–	2.0	3.5	–	2.9	0.9	63
Hyscus	–	4.5	–	–	–	–	–	3.8	–	–	–	–	4.2	(0.4)	12
Iapigia	6.5	5.8	5.9	5.0	4.6	4.6	3.6	4.8	3.5	4.2	4.5	–	4.8	0.9	74
Icaria	–	–	–	–	–	–	–	3.8	–	–	–	–	3.8	(–)	11
Idaeus F.	–	–	–	–	–	–	–	6.5	–	–	4.5	–	5.5	(1.0)	2
Indus	–	–	–	–	–	–	–	3.5	–	3.0	–	–	3.2	(0.2)	5
Isidis R.	3.0	2.3	–	–	1.4	1.5	1.5	1.6	–	1.8	1.1	–	1.8	0.6	46
Ismenius L.	–	–	–	–	–	4.2	2.8	3.5	–	–	–	–	3.5	0.7	4
Laestrygonum, S.	6.5	–	–	–	–	–	2.5	5.2	–	–	–	–	4.7	2.0	8
Libya	–	2.2	–	–	1.3	2.0	2.0	1.4	–	1.5	0.8	–	1.6	0.5	47
Lunae L.	4.0	4.8	–	–	–	3.8	–	5.4	–	3.3	3.0	–	4.0	0.9	17
Margaritifer S.	6.0	4.9	5.5	4.1	–	4.3	3.7	4.8	4.1	4.2	4.4	–	4.6	0.7	68
Melas L.	–	–	–	–	–	–	–	6.5	–	–	–	–	6.5	(–)	3

Table 2. (cont.)

	Observer														
Feature	Cerreta	Foulkes	Graham	Heath	Hewitt	Lenham	Lord	McKim	Merrikin	Moseley	Rogers	Sturdy	Ave.	s.d. (±)	No.
Memnonia	–	2.2	2.0	–	1.1	1.4	2.0	2.5	1.7	1.6	1.2	–	1.7	0.5	68
Meridiani S.	7.0	5.5	6.8	5.5	–	6.3	4.5	6.2	5.0	5.3	6.1	9.2	6.1	1.3	79
Meroe	–	2.3	–	–	–	–	–	1.8	–	–	–	–	2.0	(0.2)	16
Moab	–	2.1	–	–	–	1.9	2.1	2.0	–	–	1.2	–	1.9	0.4	32
Moeris L.	3.5	–	–	–	–	–	–	6.0	–	–	–	–	4.8	(1.2)	4
Nectar	5.5	4.2	–	–	–	5.8	–	4.8	–	3.3	–	–	4.7	1.0	20
Neith R.	–	2.3	–	–	1.4	1.7	–	1.9	–	–	1.2	–	1.7	0.4	31
Nereidum F.	–	–	–	–	–	–	–	4.0	–	–	–	–	4.0	(–)	8
Niliacus L.	5.0	4.8	4.0	2.8	–	4.6	–	4.7	3.0	4.0	4.0	–	4.1	0.8	34
Nilokeras	–	–	–	–	–	–	–	4.5	–	3.5	–	–	4.0	(0.5)	13
Noachis	–	3.0	–	1.9	–	1.9	2.1	2.9	2.9	2.6	2.6	–	2.5	0.4	59
Noctis L.	–	–	–	–	–	–	–	5.2	–	–	–	–	5.2	(–)	4
Nodus Alcyonius	–	–	–	–	–	–	–	4.2	–	–	–	–	4.2	(–)	3
Ogygis R.	–	–	–	–	–	–	–	3.0	–	–	–	–	3.0	(–)	7
Olympus Mons	–	–	–	–	–	–	–	4.5	–	–	–	–	4.5	(–)	3
Ophir	–	–	–	–	–	2.0	–	1.2	–	–	0.8	–	1.3	0.6	13
Oxia P.	5.8	–	7.0	–	–	4.5	–	4.0	–	–	3.5	–	5.0	1.4	5
Palinuri F.	–	–	–	–	–	–	–	4.0	–	–	3.0	–	3.5	(0.5)	20
Pandorae F.	4.5	4.8	4.5	3.8	–	3.9	3.0	4.2	3.8	3.3	3.0	–	3.9	0.6	60
Peneus	–	4.0	–	–	–	–	–	4.2	–	–	–	–	4.1	(0.1)	9
Phaethontis	–	3.8	–	2.0	–	2.4	2.8	3.2		2.1	–	–	2.7	0.7	47
Phasis	–	–	–	–	–	–	–	4.0	–	2.5	–	–	3.2	(0.8)	8
Phlegra	–	–	–	–	–	–	–	3.9	–	–	–	–	3.9	(–)	4
Phoenicis L.	–	–	–	–	–	–	–	4.6	–	3.4	–	–	4.0	(0.6)	13
Phrixi R.	–	–	–	–	–	4.9	–	4.5	–	4.0	–	–	4.5	0.4	9
Portus Sigeus	–	6.0	–	–	–	–	–	6.3	–	–	6.5	–	6.3	0.2	11
Protei R.	–	–	–	–	–	–	3.0	4.6	–	–	–	–	3.8	(0.8)	9
Protonilus	–	–	–	–	–	–	–	3.0	–	–	–	–	3.0	(–)	1
Pyrrhae R.	–	4.8	–	–	–	–	2.8	3.9	3.2	–	3.5	–	3.6	0.8	22
Sabaeus S.	6.0	5.4	6.2	5.7	4.5	5.6	4.2	5.7	4.0	4.7	5.8	6.5	5.4	0.8	89
Scamander	4.5	–	3.5	–	–	–	2.5	3.8	–	–	–	–	3.6	0.8	9
Serpentis, M.	6.2	6.2	4.5	5.3	4.8	5.5	3.8	6.1	3.9	4.5	5.2	7.0	5.2	1.2	78
Simois	–	–	–	–	–	–	–	3.2	–	–	–	–	3.2	(–)	6
Sirenum, M.	7.0	6.1	5.7	5.6	5.2	6.2	4.8	5.4	4.3	4.8	4.5	7.5	5.6	1.0	108
Solis L.	6.0	6.3	7.1	5.1	6.3	5.3	4.0	5.5	4.8	5.2	5.1	8.8	5.8	1.2	88
Symplegades Insulae	–	–	–	–	–	–	2.8	2.8	–	–	–	–	2.8	(0.0)	16
Syrtis Major	7.0	6.5	6.5	5.6	4.9	6.4	4.4	6.3	4.6	5.2	6.4	8.0	6.0	1.1	106
Syrtis Minor	6.5	7.2	–	6.0	5.8	–	4.5	5.9	5.0	5.0	6.0	9.0	6.1	1.2	51
Tartarus	–	–	–	–	–	–	–	3.8	–	–	–	–	3.8	(–)	16
Tempe	–	–	–	–	–	–	–	2.0	–	–	–	–	2.0	(–)	10
Tharsis	–	2.2	–	–	–	–	2.0	2.0	2.3	–	1.0	–	1.9	0.5	27
Thaumasia	3.3	2.5	–	–	–	1.8	–	2.8	–	2.6	1.5	–	2.4	0.7	47
Thyle (I)	–	3.6	–	–	2.3	–	3.2	1.6	2.0	2.5	–	–	2.5	0.7	37
Thyle (II)	4.5	3.6	–	–	2.4	–	3.5	2.4	2.4	2.5	–	–	3.0	0.8	48
Thymiamata	–	–	–	–	–	1.5	1.9	1.6	–	–	1.0	–	1.5	0.4	11
Tiphys F.	–	–	–	–	–	–	2.5	4.4	–	–	–	–	3.4	(1.0)	10
Tithonius L.	4.0	4.8	–	3.0	–	4.4	–	4.0	3.2	3.4	–	–	3.8	0.6	30
Tritonis S.	–	4.2	–	–	–	–	–	5.2	–	4.0	–	–	4.5	0.6	14
Trivium Charontis	3.2	4.3	–	–	–	4.8	2.8	4.4	–	2.7	–	–	3.7	0.9	24
Tyrrhenum, M.	6.2	6.4	5.5	5.0	4.9	5.6	3.4	5.8	3.9	4.5	5.8	6.8	5.3	1.0	123
Ulyxis F.	–	–	–	–	–	–	–	3.4	–	–	–	–	3.4	(–)	9
Vulcani Pelagus	–	–	–	–	–	4.3	2.8	4.0	–	–	–	–	3.7	0.8	15
Xanthe	–	2.1	–	–	–	–	2.3	1.9	–	0.9	1.2	–	1.7	0.6	28
Yaonis F.	5.0	–	–	–	–	–	4.0	4.8	–	–	–	–	4.6	0.5	9
Yaonis R.	–	–	4.5	3.0	–	4.6	3.6	4.5	–	–	–	–	4.0	0.6	20
Zea L.	4.3	–	–	–	–	–	–	3.8	–	–	–	–	4.0	(0.2)	3
Zephyria	–	2.2	2.0	–	1.1	2.3	2.0	2.0	–	1.4	1.4	–	1.8	0.4	68
No. of useful estimates:	107	625	201	237	147	480	113	1239	126	562	182	62	Total		3910
Period of observation	Sep 9– Oct 29	Jun 3– Nov 23	Aug 7– Dec 16	Aug 17– Dec 16	Sep 18– Nov 18	Aug 17– Dec 12	Jul 31– Aug 28	Jul 14– Nov 23	Aug 7– Oct 31	Jun 5– Nov 16	Jul 3– Oct 31	Aug 7– Dec 13			

* This feature was estimated at intensity 6.0 in 1986 by the writer [not tabulated in that Report]. ** *Gomer S.* was listed as *Cyclopia* in the 1986 table.

photomosaics published recently.[27] *Propontis I* was dark (Figures 6A, B, G) and showed some structure.

Intensity Estimates

White light intensity data are given in Table 2. There were 28 contributors: only 12 worked systematically.

The martian atmosphere

White clouds

General

Areas which frequently whitened at the limb, terminator or on mid-disk are hereinafter referred to as 'white clouds' and are listed on a monthly basis; such regions are often best seen in green, blue or blue-violet light. Little white cloud activity was noted before August. The orographic *Tharsis* clouds were most prominent in September (appearing sporadically before then). Northern *Ausonia, Candor-Ophir, Edom,* NW *Hellas, Libya-Isidis Regio* and *Thymiamata* were often seen as bright areas around opposition. Observations from 1988 May to 1989 January inclusive are complete in longitudinal coverage.

1987 November to 1988 April

Observations mostly by Minami and Parker: *Argyre I* and *Hellas* were generally light in late December-early January, and *Elysium* was bright at the morning limb. Parker saw evening orographic clouds over *Olympus Mons {Nix Olympica)* and *Phoenicis Lacus* on December 27, and found *Elysium* bright at the evening terminator on January 25.

February: *Hellas* was light, invaded by the S polar hood. A.m. limb: *Elysium, Zephyria;* p.m. terminator: *Chryse, Elysium, Tempe.*

March: *Hellas* was dull. A.m. limb: *Zephyria;* p.m. terminator: *Candor-Ophir, Elysium* (slight), *Tharsis.*

April: A.m. limb: *Amazonis, Arcadia, Thaumasia;* p.m. terminator: *Tharsis* (not very bright), *Xanthe.*

1988 May

A.m. limb: *Elysium;* p.m. terminator: *Hellas.*

1988 June

A.m. limb: *Candor-Ophir, Chryse, Eridania;* p.m. terminator: *Amazonis, Electris, Elysium, Phaethontis, Tharsis, Xanthe.*

White cloud activity was still very low, but extensive *yellow* clouds were seen in June-July.

1988 July

Hellas was generally dull on mid-disk, but some parts (especially N) were brighter at times. Cave saw *Nix Olympica* bright on July 4 and 6.

A.m. limb: *Aeolis, Argyre I, Ausonia, Electris, Elysium, Eridania, Hellas* (after dust storms subsided), *Hellespontus, Libya;* p.m. terminator: *Aeria, Argyre I, Libya, Tharsis, Thaumasia, Zephyria.* Some of these areas were also lighter near the CM, as were *Edom, Thymiamata.*

1988 August

White cloud frequency increased; *Nix Olympica* was now seen more often. A.m. limb: *Aeolis, Aeria, Arabia, Ausonia, Candor-Ophir,* E *Deucalionis Regio, Edom, Elysium, Eridania,* N *Hellas, Libya, Noachis, Phaethontis, Thaumasia, Zephyria;* p.m. terminator: *Argyre I, Candor-Ophir, Hellas, Libya, Noachis, Solis Lacus* (Hill, August 29), *Syrtis Major* (Cave, August 16 and 18), *Tharsis, Xanthe.* Again, some of these clouds persisted throughout the day; other bright areas on mid-disk were seen in *Arcadia, Chryse, Laestrygonum Sinus* (small), *Memnonia, Thyle* /and //(ground frost?), *Thymiamata.*

1988 September

Nix Olympica was well seen throughout the Martian day: see Figures 6A-C. From September 3 Parker photographed other orographic evening clouds over *Phoenicis Lacus* and *Arsia Mons.* On September 30 at 1439 and 1442 UT, Miyazaki (CML = 65°) photographed a dusky spot near —9°, 130°, just off the morning terminator. The spot, similar in size and darkness to *Phoenicis Lacus* lay a little W of the unseen *Arsia Mons.* Images around 1705 UT no longer show it (nor does Figure 1). Miyazaki suggests that the temporary dark spot could have been the morning shadow cast by *Arsia Mons.* He observed it again on October 2.

Hellas was covered by morning haze (often also obscuring *Iapigia-Syrtis Major),* clearing as it moved onto mid-disk. Near local noon a brighter patch formed in its NW corner, becoming very bright in the evening. Some observers mistook this diurnal white cloud for dust storm activity. Further, white cloud also formed in N *Ausonia* in a similar way, A.m. limb: *Aeolis,* N *Argyre I, Argyre II, Candor-Ophir, Chryse, Edom, Electris, Elysium, Eridania, Libya-Isidis Regio,* N *Margaritifer Sinus, Tharsis, Thaumasia* (irradiating to Baum, September 8), *Thymiamata;* p.m. limb: *Aeolis, Aeria, Amazonis, Arcadia, Argyre I, Candor-Ophir,* E *Deucalionis Regio, Edom, Libya-Isidis Regio, Memnonia, Tharsis, Thaumasia, Thyle II, Thymiamata, Xanthe.* Many areas were also brightened on mid-disk, together with *Aethiopis,* N *Hesperia, Symplegades Insulae.* Minami saw a complex group of small clouds over *Thyle* /and //, September 12-15.

1988 October

Nix Olympica appeared as in September, but was less obvious. Parker and Shirao photographed the 'W' cloud at the evening limb from October 11th (Figure 7F). *Ausonia* and *Hellas* showed the same diurnal

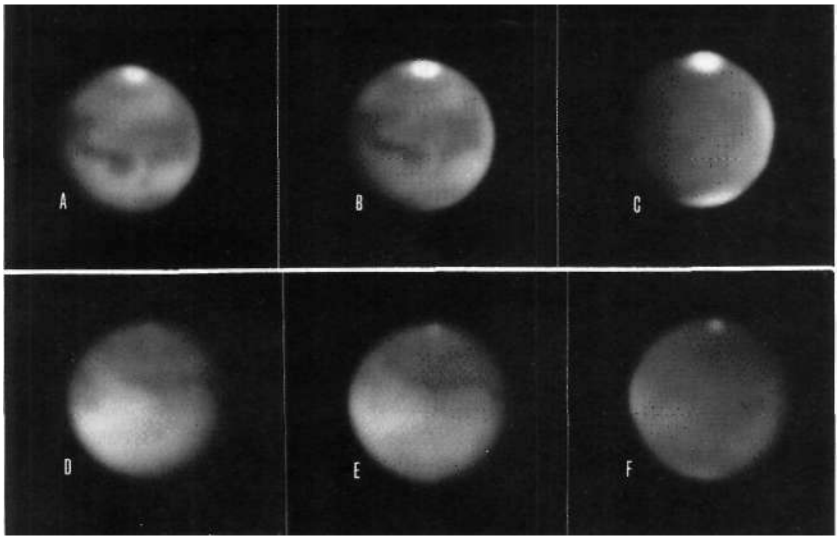


Figure 7. Comparative photographs in red (R-60 filter), green (G-540) and blue-violet (B-390) light, 350 mm refl., f/151-226, hydrogen-hypered TP 2415 film, 2-4 sec, 6-15 sec. and 15-20 sec., respectively, *Shirao.* (A)-(C) August 29d 15h 12m, ω = 357°; (D)-(F) October 26d 1 lh 59m, ω = 154°. Note the 'W cloud at the *p* limb in (F) and the weak blue clearing and bright N polar hood in (C).

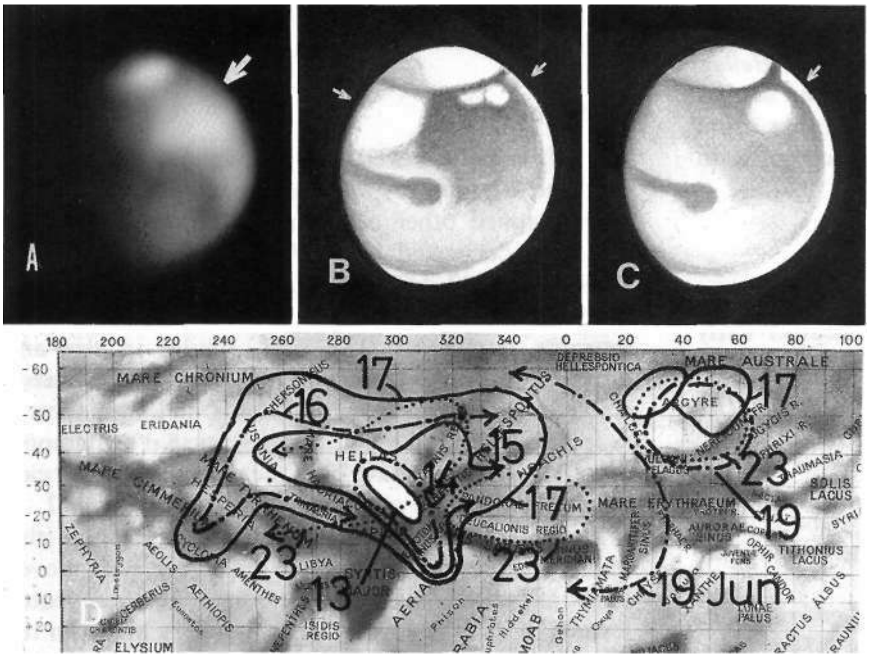


Figure 8. The 1988 June-July dust storm. Yellow clouds are arrowed. (A) June 16d 09h 42m, ω = 257°, 410 mm refl., f/165, TP 2415 film, 3.5 sec, *Parker.* Yellow cloud covers *Hellas* and is crossing *Hesperia.* (B) June 17d 17h00m,co = 355°, 200 mm refl., x 395,W15, *Miyazaki.* (B) and (C) show the W side of the storm, with separate activity in *Noachis-Deucalionis Regio* etc., and in *Argyre I.* (C) June 19d 18h 30m, ω = 358°, 200 mm refl., x 395, *Miyazaki.* (D) Chart of the storm's progress on an IAU basemap from June 13-23. The E part of the chart is based on results published elsewhere;[7] the general W limit of June 19 is approximate only. Open curves indicate that only part of the storm is shown for that date.

behaviour to September. A.m. terminator: *Aeolis, Aeria, Claritas, Edom, Elysium, Eridania, Libya-Isidis Regio, Meroe, Noachis, Phaethontis, Thaumasia, Thymiamata, Xanthe;* p.m. limb: *Argyre I, Candor-Ophir, Edom, Elysium, Libya-Isidis Regio, Memnonia, Symplegades Insulae, Tharsis, Thymiamata, Xanthe.* Additional bright areas on mid-disk: *Aethiopis, Amenthes, Dia, Eos, Icaria, Thyle II.* There were also indications of a white cloud near where *Novus Mons* had recently disappeared.

1988 November

Ausonia and *Hellas* behaved as in October. *Nix Olympica* was still visible to Parker. A.m. terminator: *Aeolis, Amazonis, Argyre I, Candor-Ophir* (including the Y-shaped region of *Tractus Albus), Elysium, Eridania, Libya-Isidis Regio, Phaethontis, Thaumasia, Thymiamata, Xanthe;* p.m. limb: *Aeria, Amazonis, Argyre I* and *II, Candor—Ophir, Eden, Edom, Daedalia, Libya-Isidis Regio, Memnonia, Nox Lux* (the orographic cloud near *Phoenicis Lacus), Tharsis, Thaumasia, Xanthe.* A long white cloud stretching from the CM to the terminator was often seen in *Daedalia-Memnonia. Symplegades Insulae, Edom* and *Deucalionis Regio* sometimes each contained a bright patch on mid-disk.

Dust activity in late November-December complicates the analysis.

1988 December

Hellas behaved as in September-November. A.m. terminator: *Arcadia, Ausonia, Eridania, Libya;* p.m. limb: *Candor-Ophir* (and *Tractus Albus),* W *Deucalionis Regio, Edom, Tharsis, Thymiamata, Xanthe.*

1989 January

A.m. terminator: *Eridania, Hellas, Libya-Isidis Regio;* p.m. limb: *Hellas, Libya-Isidis Regio, Memnonia. Hellas* was dull at the CM.

1989 February onwards

February: *Libya-Isidis Regio* and *Xanthe* were bright in the morning. NW *Hellas* was still bright in the evening, as were *Isidis Regio-Neith Regio* and *Zephyria. Hellas* was not bright on mid-disk.
March: *Hellas* was still light at the evening limb, dull near the CM.
April: Evening clouds seen over *Argyre I* and *Chryse. Hellas* was dull (but few observations to hand).
May: *Hellas* was sometimes seen to be light (p.m. limb, CM).

Blue clearings

Photographs in blue-violet light were taken by Dragesco (September 9 - October 14, Wratten 47 filter), Parker (September 4 - October 16, colourslides rephotographed through Wratten 47 filter) and Shirao (July 6 - December 11, B-390 filter). Many observers made visual observations with the W47 filter. Shirao's photographs were calibrated by a Kodak step tablet, making his long series particularly valuable. His B-390 filter, with· peak transmission near 400 nm, seems to be very similar to the W47.

The Blue Clearing (BC) was quite strong from around mid-September, through opposition, and sometimes very obvious; it continued to be reported into mid-October at most longitudes. It was not distinct in July, and the visual observations with the W47 filter before then do not reveal it. It was weakly seen sometimes in August and from mid-October into November. It was not seen thereafter, and in 1989 the planet was too distant for such work. As usual there is evidence for daily variability. The filter photographs in Figure 7 give examples of the BC.

Several photographs by Shirao in October-November show the *Daedalia* and part of the *Memnonia* deserts to be particularly dark in blue-violet light. Does this represent dust storm activity, invisible in white light? Parker also photographed an unusual dark spot in *Mesogaea* on October 16 with the W47 filter.

Yellow clouds (Dust storms)

General

The only significant activity of the apparition occurred in June-July and November-December. Both dust storms occupied a considerable area, but they were of a local character only. There was no global storm in 1988, although such an event had been widely expected.

1988 May-July

The ALPO reported a yellow cloud in *Hellas* during May 5-7, which expanded to the NW.[6] Throughout May and June several observers reported that *Solis Lacus* and its surroundings were faint and apparently veiled. *Solis Lacus* had been drawn as a dark feature by Parker earlier in the apparition. However, no discrete yellow cloud was detected there.

On June 3 SAF observer G. Teichert in France saw a yellow cloud in *Hellas.*[6.1] Drawings by Quarra Sacco and Sarocchi on June 3 also show two bright areas in *Hellas-Ausonia,* visible in green (W58) and red (W25) light but not in blue-violet (W47), independently confirming Teichert. The *Hellas* cloud had expanded by June 13 into *Yaonis* according to K. Rhea *(IAUC*4617) and was seen by Beish and Parker next day (Figure 8A). Confirmatory observations came from Aerts, Haas, Kidger, Schmude and van Loo. Parker and Wakugawa photographed the storm, and its maximum extent was reached during June 17-21. After then, it declined. Figure 8D charts its progress. At its maximum, the storm spread into *Iapigia* and *Aeria,* across *Ausonia-Eridania, Hesperia* and *Mare Tyrrhenum* to the E, and as far as eastern *Mare Erythraeum* to the W. The expansion velocity of the storm was about 33 km h^{-1} to the east and about 29 km h^{-1} to the west at latitude — 33°, between June 13 and 17.

On June 17 Miyazaki found the storm to be obscuring part of the N edge of the SPC, as did Haas and Kidger on June 19-24. The *Noachis* cloud was not definitely seen on June 22 or later, so activity had already ceased there. However, there was some dust remaining in *Deucalionis Regio,* and yellow clouds sometimes also obscured *Meridiani Sinus* and its environs to Minami, Miyazaki and Neel during June 17-30. There was still dust in *Hellas-Ausonia* on June 23 according to drawings by the Japanese observers, and Parker's June 27 photo shows residual dust in *Eridania.* The *Hellas* event led to a sudden darkening of *Mare Serpentis, Pandorae Fretum* and *ρ* the end of *Sinus Sabaeus* (see also *Region I* under 'Surface Features'). This seems to have been noticed first by Ebisawa[16] and Minami on June 22.

Further activity was now also occurring to the west, apparently independently of the *Hellas* outbreak; Minami and Miyazaki detected two small yellow clouds in *Argyre I* on June 17 which merged on the 18th, but activity declined after June 19 (Figures 8B, C). European observers followed the dying stages of the storm, with *Argyre I* appearing bright on June 23-July 3 to Hewitt, Rogers and Shirreff; the same feature was still slightly lighter and yellowish to Miyazaki on July 25 (the final record of dust here). Hill found *Hellas* to be still yellowish on July 3, and *Noachis* was " 'subdued' in tone as though partially veiled". He found the/» half of *Hellas* to be white on July 9, the / part being ochre-yellow. On the 11th *Hellas* was warm orange and cloud-free. Probably the end of the storm in *Hellas* was reached about July 9.

In late July from Meudon McKim thought that the details of the *Solis Lacus* region were still difficult to observe, though this may have been partly due to the duskiness of *Thaumasia* at this time. Falorni and Hill recorded the same impressions (late July-early August). To the west, temporary darkening of part of the *Memnonia* desert was recognised independently by Parker and Miyazaki in early July and later that month by Ebisawa and McKim at Meudon. This darkening took the form of an E-W dusky band, which became more diffuse with time. Dust activity must have accounted for this change, but its progress could not be observed: see 'Surface Features' *{Region III).* Probably this dust activity was also responsible for the reappearance of *Acampsis* and for a temporary change in shape of *Phoenicus Lacus* (see 'Surface Features', *Region II).* In summary, it appears that dust was quite widespread around the planet in June and into July, but discrete yellow clouds were only observed within a restricted longitude range.

1988 August-October

From August to October there was no further major outbreak of dust activity. However, it should be noted that the N or NW part of *Hellas* was quite often bright and sometimes yellowish from August onwards, but it was primarily affected by diurnal *white* cloud, with the region being especially bright in the evening. The same phenomenon occurred in N *Ausonia. Hellas* was bright in yellow and red light, but its brightness was not enhanced in these wavebands. Occasional brightness was seen in *Argyre I* but it was probably not yellow cloud. As Mars reached perihelion on August 11, it is likely that never before had so much attention been paid to the red planet by both amateurs and professionals. But all were to be disappointed: there was to be no global storm. A possible minor dust storm was noted by Hill on August 2 when a small yellow spot was visible in N *Argyre I.* Ebisawa's polarisation data[16] showed that there was residual atmospheric dust affecting the storm regions of June-July for several months afterwards.

During mid-October Minami wrote that the fine details of the *Mare Hadriacum-Ausonia (Borealis)* region seemed to show small changes in visibility from night to night, suggesting dust movement. McKim had a similar experience with the *Solis Lacus* region during October. The only other yellow cloud reported during July-November was witnessed by the OAA on October *\-l·,* who described *Solis Lacus* and *Thaumasia* as being covered by yellow-green 'morning mist' (dust?) when observed near the sunrise terminator. Obscuration was not apparent later in the Martian day. Though clearly only a thin yellow veil, whose optical density was probably enhanced by oblique illumination, it may have accounted for the small albedo changes noted above. There can be no doubt that around the time of opposition the Martian atmosphere was extremely clear and transparent, coinciding with a long period of Blue Clearing (see later).

1988 November-December

On November 23, another important storm began in southern *Thaumasia,* being discovered by two US observers, Robinson (at OOh 10m) and Troiani (at 01h48m; Figure 9A).[7] Both drew a small yellow cloud south of *Solis Lacus* extending over *Bosporus Gemmatus.* On November 27 there were two clouds according to Beish: one over E *Solis Lacus* and *Nectar,* with another stretching from SE *Thaumasia* across *Bosporus Gemmatus* into *Argyre I.* He also observed yellow cloud from W *Mare Erythraeum-Protei Regio* through *Ophir-Candor.* Parker photographed the storm on the 28th (Figures 9B, C). From the UK, Baum (Figure 9D) and Hill caught the E end of the dust storm at the morning terminator on November 28. Both independently drew a bright yellow irradiating cloud over W *Noachis* and *Argyre I.* Crussaire had had a similar view on November 25. At the height of the storm Kenyon (November 29, CML~ 73°) and Beish and Parker (December 1, CML^ 10°) also saw other parts of the yellow cloud projecting beyond the morning terminator.

On November 29 the circular yellow cloud over E *Solis Lacus* had disappeared, leaving the whole *Thaumasia* region somewhat darkened and lacking in contrast, with *Solis Lacus* itself faint or invisible. The main storm to the south expanded till December 1 when Parker found that the cloud had moved further E into *Noachis* and southern *Hellespontus* (Figure 9E). There was still dust over W *Mare Erythraeum-Protei Regio-Ophir—Candor.* Measurements of Parker's photos show that the cloud moved some 1600 km eastwards from *Argyre I* into *Noachis* in 74 hours between November 28 and December 1 at latitude —50°: a rate of some 22 km h'. During the storm, from November 28 onwards, Cave, Haas and Parker noted a temporary darkening of *Mare Australe* which lay to the south of the storm's track. Another pertinent observation was by Parker, who found the N polar hood temporarily considerably weakened on November 30/ December 1. During late November, UK observers found the hemisphere of *Hellas-Syrtis Major* to be dust-free.

Soon, other observers were studying the western parts of the storm. Alerted by telephone by Parker on November 29, the writer requested UK and European observers to watch as these regions became visible at the E limb (BAA *Circular* No. 682). Miyazaki quickly informed the writer that he had observed and photographed the storm at the evening limb from Japan on November 29; it looked yellowish-white. Ebisawa[16] also followed it from November 25. Over the next few days the storm's W boundary coincided with the W edge of *Daedalia* (longitude ~ 130°), the storm appearing as a belt of cloud which also covered *Claritas, Icaria, Aonius Sinus* and S *Thaumasia* (Figure 9F). The storm reached its maximum extent on December 1, the W end later becoming indistinct. On December 2, *Icaria, Aonius Sinus* and *Daedalia* were free from cloud. *Solis Lacus,* though faint and obscured to the south, was visible. When Minami saw the region on the CM on December 3, *Solis Lacus* and its immediate surroundings had returned nearly to normal, although *Thaumasia* was still shaded and there was still some dust to the SE. There remained a general lack of contrast in the region throughout December.

By early December observers in Europe also saw the storm's W side at the evening limb. But by that time

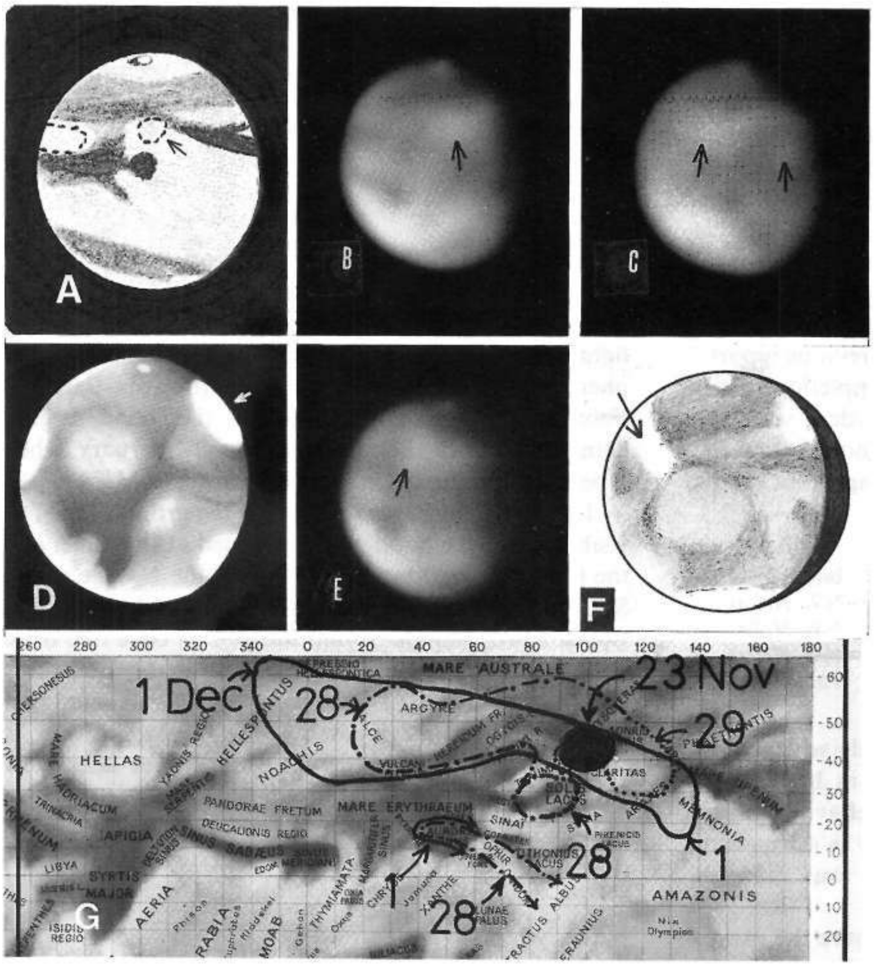


Figure 9. The 1988 November-December dust storm. Yellow clouds are arrowed. (A) November 23d 01h 48m, ω = 102°, 254 mm refl., x 284, W8 (yellow), *Troiani.* Shows the initial yellow cloud. (B) November 28d 00h 04m, ω = 32°, 410 mm refl., f/165, hydrogen-hypered TP 2415 film, 1 sec, *Parker.* (B) and (C) show clouds over *Solis Lacus* and *Argyre I,* etc. (C) November 28d 02h 19m, ω = 65°, 410 mm refl., f/165, Fujichrome 100 film, 2.5 sec, *Parker.* (D) November 28d 19h 30-40m, ω = 319°, x 186, *Baum.* E end of storm on morning terminator. (E) December 1d 02h 01m, ω = 32°, 410 mm refl., f/165, hydrogen-hypered TP 2415 film, 2 sec, *Parker.* Comparison with (B) reveals the eastward motion of the storm and the darkening of *Mare Australe.* (F) November 29d 09h 10m, ω = 156°, 250 mm OG, x 420, *Minami.* The W end of the storm is indicated. (G) Map of the storm's progress, like Figure 8D, for November 23-December 1. Figures 9A-C, E-F formed the basis of the map, together with additional drawings by Parker (November 28 - December 1) and Minami (December 1, 10h 20m, from which the W storm limit on that date was defined). Only selected dates were mapped, and the initial November 23 cloud is represented by the black oval.

there was little left of the storm to see, and it was easy to confuse evening white cloud with the dust storm. However, with *Solis Lacus* near the CM, it was now apparent to McKim, Minami and Miyazaki that the region of *Aonius Sinus* and the S border of *Thaumasia* had darkened. On December 4/5 Beish saw yellow haze over the S limb at CML~ 309°, and the SPC was 'hardly visible'. Beish and Parker now saw a bright yellow spot in N *Hellas* and another in *Libya;* there was still the dust over *Noachis* and *Hellespontus* but the storm appeared to have stopped spreading east. By December 5/6 the dust storm was essentially over, but some features had not yet returned to their normal intensities and traces of dust remained over some regions. Parker still detected the *Libya* and *Hellas* yellow clouds, but the SPC was once again brighter and the dust elsewhere appeared to be dispersing. Features to the north of the SPC such as *Mare Australe* were light and below normal intensity. In mid-December *Thaumasia* remained somewhat dusky on unpublished CCD images by Dollfus and to McKim visually. Ebisawa[16] considered that some dust had dispersed to the north, so that the *Tempe-Arcadia* region had been affected. An image in polarised light by Dollfus[28] on January 22, obtained with the new video polarimeter at Meudon revealed residual dust in *Arcadia* by the locally reduced polarisation of that region. However, there was no evidence for residual dust in *Thaumasia* by this date. No further activity was seen in an international collaborative watch continuing into 1989 June. Figure 9G illustrates the behaviour of this storm. (See also reference 6, page 431 for a chart by Troiani.)

Discussion

The dust storms of 1988 took place in the usual favoured sites. Their motions also followed historical precedents. It is interesting to note the relationship between yellow cloud activity and the darkening of adjacent surface features. Several examples of this have been given: for example, *Mare Australe* in November-December due to the yellow cloud in *Argyre I,* the appearance of dark shading in *Thaumasia* at the same time, and so on. These events were transitory, as was the darkening of part of *Memnonia* earlier in the apparition. Some other observations may be given here. During the November storm, Minami and Parker often noted that the W edge of the storm was well-defined, and sometimes it seemed to have a darker border. Probably this represented a temporary darkening of the Martian surface near the edge of the cloud. On June 16-17 Parker found that there was an odd N-S dark streak marking the E edge of the *Hellas-Ausonia* dust storm. He attributed this to the shadow of the yellow cloud: a temporary excavation of fine surface dust by the storm, leaving the underlying ground darker than before, would also explain the observations. The latter explanation is preferred by the writer. It is also tempting to suggest that the reported visibility in November-December of white cloud in the Y-shaped region of *Candor-Ophir-Tractus Albus* was related to the dust activity, with some dust dispersing into the northern hemisphere and causing a local cooling effect or providing nuclei for the formation of white clouds.

In both 1986 and 1988 two important though local dust storms were seen rather than the anticipated global events. A brief comparison between the 1986 storms and historical events was made in our previous report.[2] Further discussion is deferred until completion of the BAA Dust Storm Project, which will deal with the period from 1892 to date. We simply note below the planetocentric longitudes of the most important events of the last two years:

Commencement date	L_s	Initial location
1986 May 28	178°	NW *Hellas*
1988 June 3	207°	NW *Hellas*
1986 November 8	278°	NW *Hellas*
1988 November 23	314°	*Thaumasia*

Clearly the storms were more seasonally advanced in 1986, and by about a Martian month in both cases. There seems to be a link here with the behaviour of the SPC. In 1986, its regression was broadly in advance of the seasonal average, while in 1988 it was more in accord with the historical norm.

The global storms of 1971 and 1973 were the exception rather than the rule, and gave false expectations for 1986 and 1988. While the accumulation of observations points increasingly to a link between atmospheric dust and cap regression behaviour, we are still unable to predict the outbreaks of dust storms in anything other than a general way.

North Polar Region

Whiteness was seen over the N limb from late 1987, this being the north polar *hood.* It was frequently in evidence for the rest of the apparition but visibility depended on the CML, and the tilt of the axis. Thus at opposition it was greatly foreshortened; the hood generally had a bluish-white tint.

In late 1988 November through 1989 April the southward tilt decreased to zero, and the transition to the surface cap was seen. Parker on February 7 (L_s = 355°) thought he was now observing the ground *cap.* Moore had a similar experience on January 18 and 21. On January 21 (L_s = 346°, CML 119°, 390-mm reflector, x 400) he writes: 'I can see clear traces of N whiteness - and there is an impression of a thin, darker border'. Later observations by Moore and others confirmed the presence of the cap, but the new cap was sometimes still covered by polar hood and its edge was not well defined. Gray saw the cap especially well in March - April in generally very good conditions. Refer to Figures 3H, 5E, 6H. It was visible at least until the final observations in June, but no accurate measures could be made. In 1986,[2] the NPC seemed to be constantly visible from L_s = 350°, in accord with the 1988 results.

South Polar Region

Early observations in late 1987 frequently showed a light polar *hood* bordering the S limb. As the S hemisphere of Mars began to be tilted towards Earth in February, the disappearance of the hood began. Minami found the hood dull until mid-February, when it began to brighten. On March 8 Parker (CML 170°, L_s = 158°) thought he was observing the ground *cap.* The visibility of both hood and cap varied at this time, and the OAA during March 8-10 found the N edge of the SPC still obscured by haze in the longitude of *Hellas.* But in April, Minami found the SPC N edge free from haze at all longitudes; the cap was probably hood-free from L_s = 172°, *Depressiones Hellesponticae* first appeared as a sombre patch at the N edge in May. It was a more prominent isolated dark spot later. The irregular dark border to the cap was bluish or greenish to Cave, Hill, Lord, Raeburn and others during June-August. *Magna Depressio* was a dark spot near longitude 270° (see McKim's October 24 drawing in the *Journal,* 99, 2 (1989)).

Although the SPC was now well-defined, it was seen to have some dull shading within it towards the S limb, perhaps indicating a remnant of SPH. The US observers first noted this effect on April 3, and it was seen often in May and June, rarely in July and not at all later.

By late June *Novissima Thyle* was bright on the morning side of the cap, but appeared dull at the p.m. terminator. Beish and Parker[8] observed the *Rima Australis* rift for the first time on June 3, and the rift grew across the cap as time progressed. It was Miyazaki who first saw it completely separating *Novissima Thyle* (called *Novus Mons* when detached) from the cap on July 25 (L_s = 239°; compare 1986,[2] when separation was complete near L_s = 240°); see Figures 3B, D, E, 6G. On August 7 and later Ebisawa at Meudon saw *Novus Mons* indented on its N edge. Falorni and Minami also saw *Novus Mons* narrowed in the centre, and Cave saw it split in two on August 19.

On August 25 Cave saw a bright star-like flash from *Novus Mons* (the 'Mountains of Mitchell') (0810 UT, CML 274°, D_e = -20°.2, L_s = 255°). This is quite a rare event, and Lowell[29] has related some similar, earlier observations, which probably result from sunlight striking part of the cap at a favourable angle. *Novus Mons* continued to be seen until September 11 (Minami and Miyazaki, L_s = 270°). Next day, in excellent conditions, McKim could see no sign of it. *Argenteus Mons* was seen as a bright patch within the cap from July and remained visible until September (see

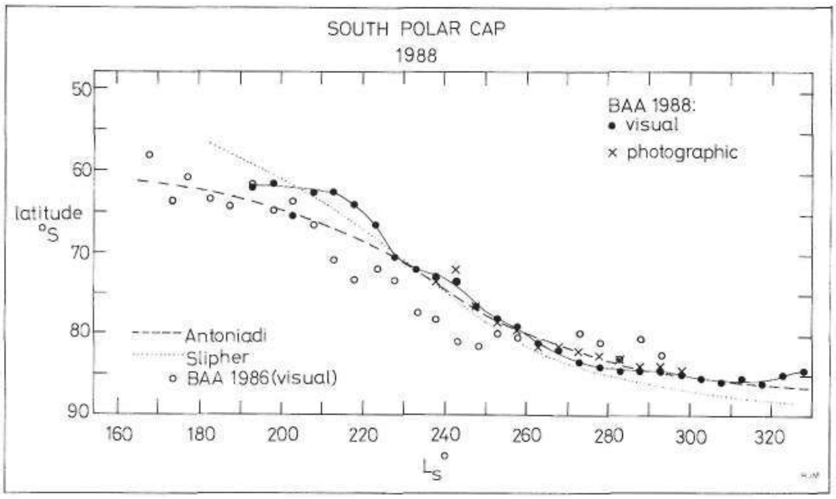


Figure 10. SPC regression curves. The latitude of the N edge of the cap was measured from drawings (solid curve) and from photographs (with a few CCD and micrometer measures; crosses). Points represent 5° means in L. Average regression curves by Antoniadi (1856-1929) and Slipher (1798-1924), and BAA data for 1986 are added for comparison. See text and Table 3 for more details.

Journal 98(6) front cover, and 98, 337 for August 7 drawings by McKim and Hill respectively). The rift *Rima Augusta* was also seen.

In July, bright areas located in the positions of *Thyle* /and //were seen in the cap (Figures 2B, C). In August *Thyles Mons* appeared, first as a bright projection, then as a detached portion. *Thyles Mons* was sometimes accompanied by a bright, following cloud. A bright area in the region was still visible in September (Figure 6B). *Ulyxis Fretum* was most prominent as a broad rift ending in a dark spot near longitude 160° in July (Figure 2C). In August through October a broad rift entered the cap near longitude 60° (Figures 5G, H), departing near longitude 320°, thus splitting it into two unequal portions. The remnant cap varied in brightness in parts. Between September 8-16 Minami and Miyazaki observed a tiny detached part near longitude 270°. Little detail could be seen after October, but the cap was seen to remain non-circular.

Some haze was seen over the regressing SPC from time to time: Akutsu, Hewitt, Miyazaki, Moseley and Osawa agreed that the side near longitude 210° was most affected; the N edge of the cap seemed ill-defined on a few occasions in August and September, and it is notable that this was the side of the cap which evaporated most rapidly. The tiny SPC Summer remnant became hard to see from December onwards with telescopes of 200 mm aperture or less, and could no longer be seen at every CML because of its asymmetry. (From August onwards it had clearly no longer been centred on the areographical pole: see McKim's 'Fournier polar spiral' in *Journal* 99, 53.) Observers having both good seeing and large apertures kept the cap in view till 1989 March 2 (Parker, with x 600 on 320 mm reflector), when L_s had reached 6°. This is a later seasonal date than in 1986,[2] when the SPH formed near L_s = 329°; however, observational conditions in 1988 favoured the detection of the cap remnant long into the Martian Summer. From January on there was often a diffusely lighter region surrounding the pole. This haze (the S polar hood) sometimes merged with similar haze in *Hellas* when the latter feature was also on the disk. Figures 3H and 5E show the SPH.

The regression of the cap was studied by using measurements of its E-W diameter from drawings. The procedure from 1986[2] was followed. (Note that the measured cap diameter excludes any obviously detached parts.) Figure 10 shows the regression curve based on measures from 1868 drawings by 62 observers over the interval L_s = 191 - 330° (May 7 - Dec 22). Measurements were made on the (109) very best photographs and CCD images, and combined with a few (11) filar micrometer measurements from Butler, Sacco and Sarocchi to produce a second regression curve illustrated in Figure 10. The mean regression data after Slipher[30] and Antoniadi[31] are also shown. In addition,

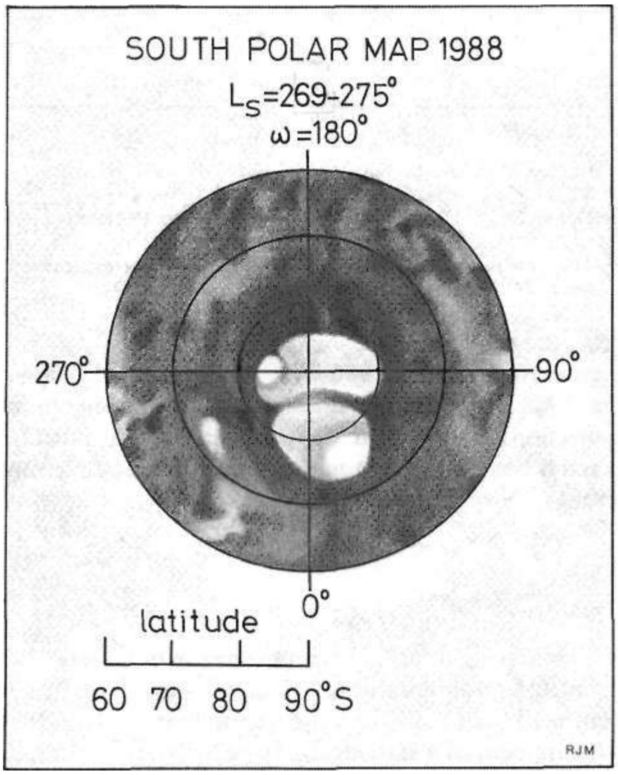


Figure 11. The South Polar Region near opposition. Cap outline: from CCD images by Larson, September 10-20 (L, = 269-275°); *Novus Mons* (near —72°, 310°): Minami and Miyazaki drawings and photographs September 4-11; interior cap details: drawings September 4-20; surroundings: CCD images as for Figure 1.

Table 3. SPC diameter measurements, 1986 and 1988.

Mean L_s°	1986			1988				
	*T.D.**range*	*Diameter of cap (°)*	*No. of measures*	*T.D. ** range*	*Diameter of cap (°)*		*No. of measures*	
		D_d†	N_d		D_d†	D_p†	N_d	N_p
168*	May 7–15	64	4	–	–	–	–	–
173	May 16–24	52	10	–	–	–	–	–
178	May 25–Jun 2	58	18	–	–	–	–	–
183	Jun 3–11	53	14	–	–	–	–	–
188	Jun 12–19	51	20	–	–	–	–	–
193	Jun 20–28	57	21	May 7–15	56	–	8	–
198	Jun 29–Jul 6	50	29	May 16–23	57	–	11	–
203	Jul 7–15	53	39	May 24–Jun 1	49	–	5	–
208	Jul 16–23	47	42	Jun 2–9	55	–	9	–
213	Jul 24–31	38	30	Jun 10–17	55	–	25	–
218	Aug 1–8	33	31	Jun 18–25	52	–	41	–
223	Aug 9–16	36	35	Jun 26–Jul 3	47	–	47	–
228	Aug 17–24	33	15	Jul 4–11	39	–	50	–
233	Aug 25–Sep 1	25	16	Jul 12–19	36	–	46	–
238	Sep 2–9	23	17	Jul 20–27	34	33	56	6
243	Sep 10–17	18	11	Jul 28–Aug 4	33	36	62	3
248	Sep 18–25	17	15	Aug 5–12	27	27	78	9
253	Sep 26–Oct 3	20	20	Aug 13–20	24	23	141	7
258	Oct 4–11	19	16	Aug 21–27	22	21	82	14
263	Oct 12–18	18	13	Aug 28–Sep 4	18	17	111	5
268	Oct 19–26	16	3	Sep 5–12	16	17	177	14
273	Oct 27–Nov 3	20	4	Sep 13–20	13	16	120	11
278	Nov 4–11	18	12	Sep 21–28	12	15	115	9
283	Nov 12–19	14	7	Sep 29–Oct 6	11	14	136	7
288	Nov 20–28	19	2	Oct 7–15	11	12	99	3
293	Nov 29–Dec 6	15	10	Oct 16–23	11	12	66	4
298	Dec 7–14	10	6	Oct 24–31	10	11	129	3
303	–	–	–	Nov 1–9	9	9	73	4
308	–	–	–	Nov 10–17	8	8	42	3
313	–	–	–	Nov 18–26	9	–	38	–
318	–	–	–	Nov 27–Dec 5	8	–	67	–
323	–	–	–	Dec 6–13	10	–	14	–
328	–	–	–	Dec 14–22	11	–	5	–
		Totals††	460				1853	102

* Corresponding to L_s 'bins' of 166-170°, 171-175°, etc.
** T.D. = Terrestrial Date.
t D_d and D_p are the cap diameters from drawings and from photographs, CCD images and micrometer measurements, respectively; N_d and N are the corresponding numbers of measurements.
tt These are the totals of *useful* measurements, which exclude data for inadequately observed epochs. The actual numbers of measurements made were 474, 1868 and 120, respectively.

Figure 10 compares 1986 with 1988. Figure 11 shows the 1988 cap at opposition in stereographic polar projection. Details near the pole are hard to position exactly, but the present map seems an acceptable representation of the cap at L = 269-275°.

Discussion

It is reassuring to note the close agreement between the visual and photographic cap diameter measurements in Figure 10; this tends to validate the writer's view that measurement of a statistically large sample of drawings can yield scientifically useful data.

In 1986 the SPC had appeared slightly but significantly smaller than the seasonal mean over $L_s \approx$ 210 - 250°. In 1988 it followed Slipher's mean curve[30] very exactly until $L_s \approx$ 280°, after which it appears to have been a little larger than normal. The maximum regression rates for 1986 and 1988 are similar. Comparison may also be made with Antoniadi's mean curve[31] in Figure 10. In 1988 the SPC conformed even more closely to the historical means; our graph shows somewhat better accord with Antoniadi. Comparison with 1986 shows an obvious and significant difference. In 1986 the cap began to shrink at an earlier seasonal date than in 1988, and was consequently smaller than in 1988 over the interval $L_s \approx$ 210 - 250°. This disparity is in accord with our last report in which it was noted that differences between successive S hemisphere Summers are most apparent at $L_s \approx$ 240 - 250°. The discord between the two Martian S Summers is even better illustrated by the diameter measurements for these years which are given in Table 3.

The martian satellites

Deimos was photographed by Manning, with his 260-mm reflector on October 28, on hydrogen-hypered TP 2415 film at F/10.4, exposure 200 seconds. *Sky and Telescope*[32] contained an interesting account of the satellites' visibility with different apertures. Falorni saw both satellites from Arcetri, even in strong moonlight.

Errata in 1986 report

In Table 2,[2] for *Cyclopia* read *Gomer Sinus.* In Figure 3(C), for *Sp,* read *Sf.* Minami writes that, contrary to the observations described in the yellow cloud section, which suggested veiling of the *Meridiani Sinus* area on June 9/10 and 20, he observed that region to be normal near the CM on June 9/10. The observations described by the writer[2] were made with the latter region near the morning limb, so it would appear that the yellow haze implied was at most a thin veil, enhanced by oblique illumination.

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