The opposition of Mars, 1986

Richard McKim

The BAA observations of the 1986 perihelic apparition are described and illustrated by a summary map, photographs and drawings. The seasonal behaviour of the south polar cap was studied in detail, with several rifts and bright portions being recorded. The regression curve did not differ greatly from the historical results of Antoniadi and Slipher. The north polar hood displayed daily variations in brightness and extent. Several local dust storms occurred, but in 1986 there was no global event. A number of albedo changes on the Martian surface were detected, the most important of these involving *Hesperia, Noachis, Solis Locus, Phasis* and *Mare Sirenum.* The *Aetheria* darkening was still present, while *Nepenthes* and the E end of *Sinus Sabaeus* remained faint.

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

Introduction

For UK observers, in spite of the large disk size, the 1986 apparition was the least favourable in the 15- or 17-year cycle of oppositions. At opposition on July 10 the Martian disk subtended 22.1 arc sec, and the planet was closest to Earth on July 16 *[D* = 23.2 arc sec], but the great southerly declination at opposition gave it a meridian altitude of only some 10° for observers in southern England. Consequently, seeing conditions were very poor for most UK observers until late in the apparition when Mars was again in high northern declination. Fortunately, many overseas members were able to take full advantage of the large angular disk diameter of the planet.

The Martian S pole was tilted towards the Earth at opposition, the apparition being the first in a new series of perihelic approaches. Observations covered winter, spring and summer in Mars' S hemisphere. Physical characteristics of the apparition were as follows:

Latitude of centre of disk at opposition	− 5°.9	
Declination at opposition	− 27°	
Winter Solstice of S hemisphere / Summer Solstice of N hemisphere	1985 November 30	(L_s = 90°)
Spring Equinox of S hemisphere / Autumnal Equinox of N hemisphere	1986 June 1	(L_s = 180°)
Mars in opposition to the Sun	1986 July 10	(L_s = 202°)
Mars in perihelion	1986 September 24	(L_s = 250°)
Summer Solstice of S hemisphere / Winter Solstice of N hemisphere	1986 October 26	(L_s = 270°)

The tilt of the Martian axis towards Earth varied from + 10° in 1986 late January through 0° in mid-March to -10°.4 in late May. It then fell to -3°.1 in early August, increasing again to —26°.2 by late December. It had decreased to 0° again by 1987 mid-May. The Martian date at opposition, as defined by the ALPO

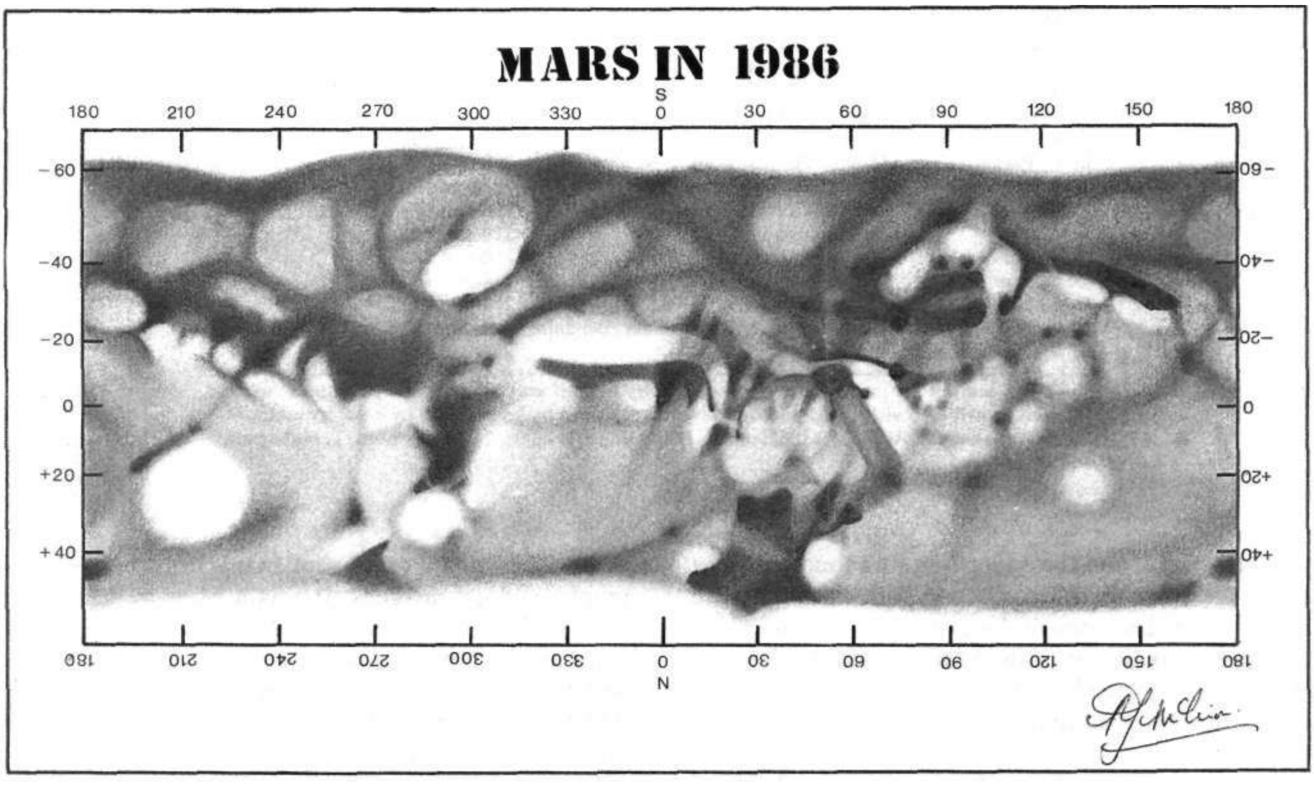

Figure 1. Albedo map of Mars in 1986, showing the outlines of the SPC and NPH at opposition, *R. J. McKim.*

Table 1. Observers of the 1986 apparition

Observer	*Location*	*Instrument(s)*
G. L. Adamoli	Padua and Verona, Italy	250-mm refl. and 110-mm OG
B. Adcock	View Bank, Victoria, Australia	310-mm refl.
L. Aerts	Heist-op-den-Berg, Belgium	150-mmOG
T. Akutsu*	Tochigi-ken, Japan	250-mm refl.
M. Alexescu	Bacâu, Romania	150-mm Cass.
T. Asada	Munakata, Japan	125-mm OG
R. M. Baum	Chester	115-mmOG
J. D. Beish	Miami, Florida, USA	320-mm Cass.
M. Beveridge	Aberdeen	150-mm refl.
T. Broadbank	Poole, Dorset	203-mm Schmidt-Cass.
F. C. Butler	London	221-mm refl.
T. R. Cave	Long Beach, California, USA	320-mm refl.
L-H. Chang	Taipei, Taiwan	250-mm OG
J. Dragesco	Butare, Rwanda, Central Africa	355-mm Schmidt-Cass.
	Pic du Midi Observatory	1060-mm Cass.
M. Falorni	Arcetri Observatory	360-mm OG
	Florence, Italy	205-mm refl.
J. R. Fletcher	Tuffley, Gloucester	216-mm refl.
M. Foulkes	Hatfield, Herts.	203-mm Schmidt-Cass.
M. V. Gavin	Worcester Park, Surrey	203-mm Schmidt-Cass.
M. Giuntoli	Pieve a Nievole, Italy	200-mm refl.
D. L. Graham	Brompton-on-Swale, Yorks.	152-mmOG
W. H. Haas	Las Cruces, NM, USA	320-mm refl.
A. W. Heath	Long Eaton, Notts.	300-mm refl.
N. D. Hewitt	Northampton	203-mm Schmidt-Cass.
A. J. Hollis	Northwich	300-mm refl.
T. Ishibashi	Kanagawa-ken, Japan	210-mm refl.
T. Iwasaki	Kitakyushu, Japan	125-mm OG
R. J. McKim	Cambridge University Observatory	200-mm OG
	Colchester	216-mm refl.
	Oundle	100-mm OG
	Pic du Midi Observatory	1060-mm Cass.
R. A. Marriot	Northampton	216-mm refl.
K. P. Marshall	Medellin, Colombia, S. America	305-mm and 465-mm refls.
M. Mattel	Massachusetts, USA	152-mm OG
N. Matsumoto	Sasebo, Japan	310-mm refl.
M. Minami*	Taipei, Taiwan	250-mm OG
I. Miyazaki	Okinawa, Japan	204-mm refl.
M. Mobberly	Bury St. Edmunds	152-mm OG and 356-mm Cass.
P. A. Moore	Selsey, Sussex	125-mm OG and 390-mm refl.
	Yerkes Observatory	1000-mm OG
R. Moseley	Coventry	150-mm refl.
T. Nakagami	Tochigi-ken, Japan	290-mm refl.
R. Néel	Vénissieux, France	310-mm refl.
P. O'Neill	Newtonabbey, N. Ireland	200-mm Schmidt-Cass.
T. Osawa	Fukuoka, Japan	320-mm refl.
P. W. Parish	Gillingham, Kent	222-mm refl.
D.C. Parker	Miami, Florida, USA	300-mm refl.
J. H. Rogers	Cambridge University Observatory	200-mm OG
R. W. Schmude, Jr.	Tomball, Texas, USA	105-mm OG
M. Shirao	Tokyo, Japan	210-mm refl.
D. Shireff	Marlborough College, Wilts.	250-mm OG
D. Strange	Worth Matravers, Dorset	210-mm OG
R. de Terwangne	Antwerp, Belgium	200-mm Cass.
A. van der Jeugt	Gent University Observatory, Belgium	203-mm OG
A. W. Wilkinson	Worcester	229-mm refl.

* Akutsu sent an album of Mars photographs by himself and his Japanese colleagues, while Minami contributed visual and photographic observations by himself and by other members of the OAA namely T. Asada, L-H. Chang, T. Ishibashi, T. Iwasaki, N. Matsumoto, T. Nakagami and M. Shirao.

was October 16, and the apparition was comparable in seasonal aspects to 1971.[1] Starting with this report we use L_s, the planetocentric longitude of the Sun, as a more precise indicator of the Martian seasons than the heliocentric longitude (η) used formerly. ($L_s = 0°$ defines the vernal equinox of the N hemisphere; $L \approx \eta - 85°$).

Useful work came from 50 observers: see Table 1. Falorni sent a good series of drawings made at Arcetri, while Beish and Parker sent many drawings, photographs and colourslides. It was a pleasure to receive observations from Cave and Haas after an interval of many years. Contact was also established with the Mars Section of the Oriental Astronomical Association (OAA), and their Secretary M. Minami contributed drawings by himself and other Japanese observers.

From Butare, Dragesco wrote of continual poor seeing, but together with the writer was able to make

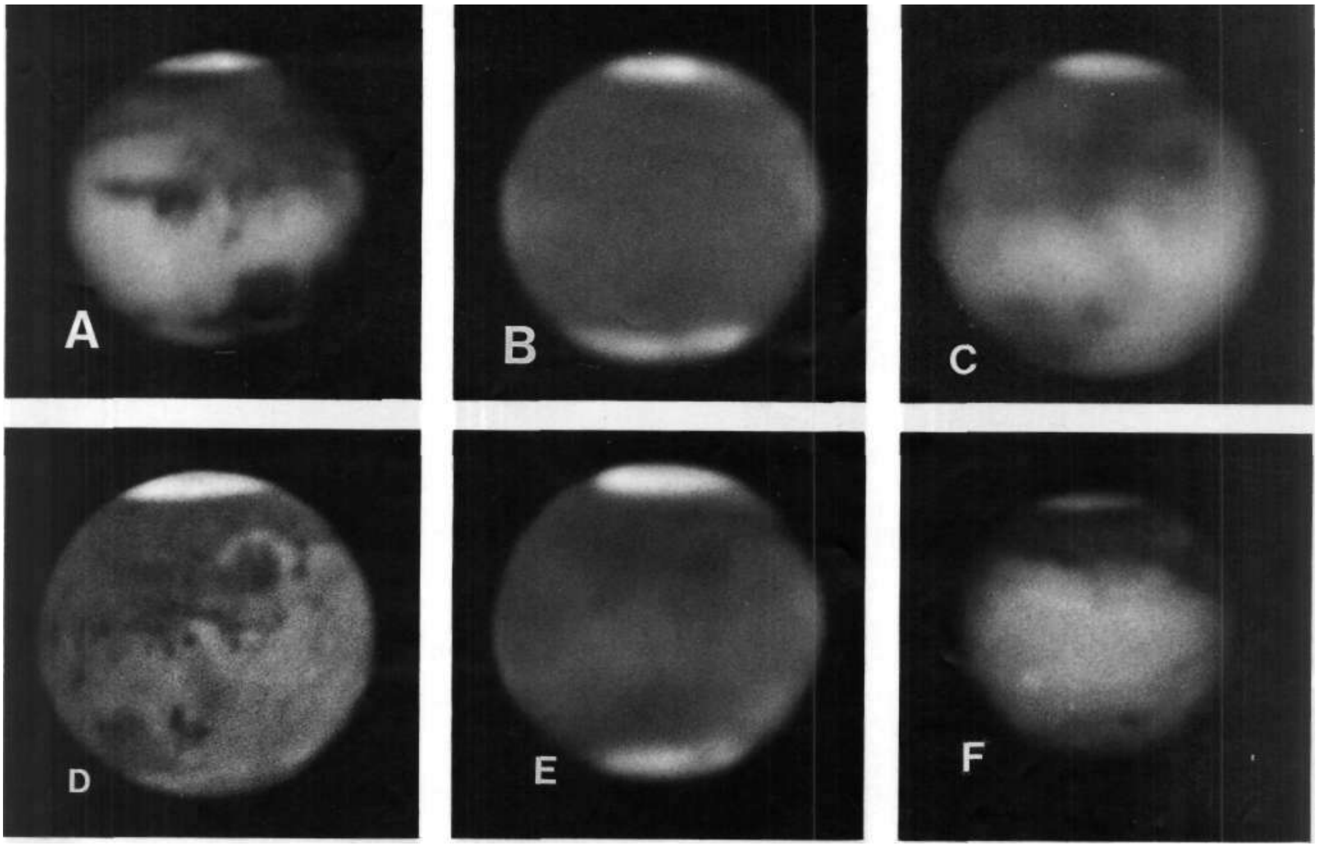

Figure 2. Photographs of Mars in 1986 from the Pic du Midi Observatory with 1060-mm Cass., Kodak TP 2415 b/w film by J. Dragesco (A, B, D-F; f/52) and R. J. McKim (C; f/30). D is the best image, obtained in perfect seeing, and the print here was enhanced by unsharp masking. (A) July 20d 22h 18m, ω = 11°, W29 filter, ¼ sec. (B) July 20d 22h 23m, ω = 12°, W49 filter, 8 sec. (C) July 17d 23h 44m, ω = 59°, W29 filter, ½ sec. (D) July 15d 23h 07m, ω = 68°, W29 filter, ¼ sec. (E) July 15d 23h 09m, ω = 68°, W49 filter, 8 sec. (F) July 9d Olh 26m, ω - 164°, ½ sec.

some detailed observations at the Pic du Midi observatory during the opposition month. A general account of the results has already appeared,[2] as have several preliminary reports on the 1986 opposition.[3-7] McKim obtained a few early views in April from Tenerife, where he had taken his 216-mm reflector to view Halley's Comet.

A total of 939 drawings and 299 photographs was received, covering the period 1986 January 26 (Graham, L_s = 105°) to 1987 June 22 (Haas, L_s = 38°). The further increase in the photographic work is encouraging. Several previews of the apparition appeared,[8] while the writer issued new-style observing forms together with the usual pre-apparition Circular to all active observers in 1985 December. Figures 1-12 present a selection of the observations received. Since the publication of the 1984 report,[9] other accounts of the last apparition have been published in the literature.[10-12]

Surface features

Note: nomenclature is after Ebisawa;[13] E and W are used areographically (E = *p;* W = *f).*

Region I: ω = 250 - 010°

Syrtis Major was quite broad and dark; it was darkest to the north and showed some internal detail. The *Syrtis* had a green tint to the OAA observers but others simply described it as grey. Its pointed *Np* tip *(Nili L.)* was cut off by *Nili Pons,* and continued northward into the faint *Nilosyrtis-Boreosyrtis. Nepenthes* was still virtually invisible, but *Nodus Alcyonius* was well seen, as in 1984 (Figures 3K, 6G, 7G). The southern tip of *Casius* was visible to the south of the NPH, and was dark, apparently unchanged in form since 1982. *Antigones F.* was present at the NW corner of *Syrtis Major* with the pale *Astaboras* leading to *Astaborae F.* and *Coloe P. Iapigia* was normal, but Beish, Cave, Minami and Miyazaki detected a distinct dark spot within it, apparently located inside the large *Huygens* crater! (Figures 3K, 6G, H, 7G). *Hellas* was almost habitually dull during June and July; Falorni described it as dull orange-grey on June 20. In May, and from August onwards it was affected by both white and yellow clouds, especially in its NW corner (see later). *Peneus, Zea Lacus* and other details were noted as being visible within the basin from late May (Figures 6G, 8A). *Mare Hadriacum* formed a dark border to the E of *Hellas,* as did *Yaonis Fretum* to the W. *Mare Tyrrhenum* was dark and conspicuous, as usual, but its shape had been modified since 1984 as our chart shows; Falorni found it to be brown. *Libya* was normal. *Moeris Lacus* was small, dark and oriented *Sp* to N*f* at the E edge of *Syrtis Major.*

Hellespontus was dark throughout the apparition, running N*p* to S*f* and terminating in a conspicuous dark spot (on the N edge of the SPC at opposition): *Depressiones Hellesponticae.* A thin, dark, tapering

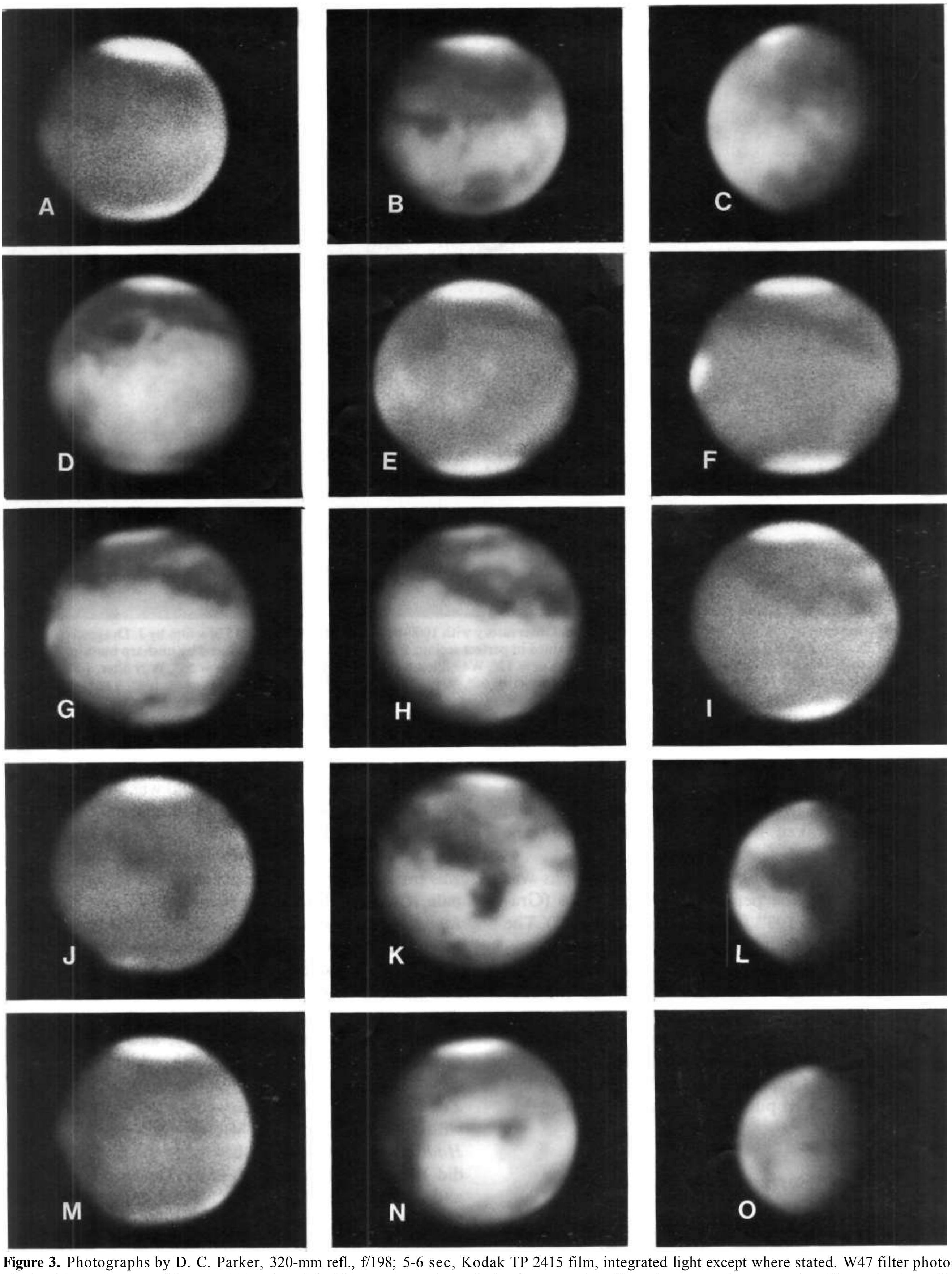

Figure 3. Photographs by D. C. Parker, 320-mm refl., f/198; 5-6 sec, Kodak TP 2415 film, integrated light except where stated. W47 filter photos obtained by rephotographing ED-200 colourslide film exposures through the filter onto b/w film. Photos mostly arranged as filter pairs here. (A) June 24d 06h 45m, ω = 14°, W47 filter (weak BC only). (B) June 24d 07h 05m, ω = 19°. (C) August 30d 02h 00m, ω = 62° (obscuration of S/ maria). (D) July 20d 04h 12m, ω = 105°. (E) July 20d 04h 43m, ω = 112°, W47 filter *(Tharsis* W-cloud). (F) July 12d 04h 42m, ω = 183°, W47 filter *(Arsia Mons* evening cloud). (G) July 12d 04h 52m, co= 186°. (H) July 9d 05h 16m, ω = 219°. (I) July 9d 05h 40m, ω= 225°, W47 filter. (J) July 4d 05h 58m, ω = 273°, W47 filter (partial NPH only). (K) July 4d 06h 24m, ω = 279°. (L) September 12d Olh 19m, ω = 290° (yellow cloud in *Hellas).* (M) June 28d 06h 03m, ω = 328°, W47 filter. (N) June 28d 06h 37m, ω = 336°. (O) October 13d OOh 08m, ω = 336° (yellow cloud in *Hellas).*

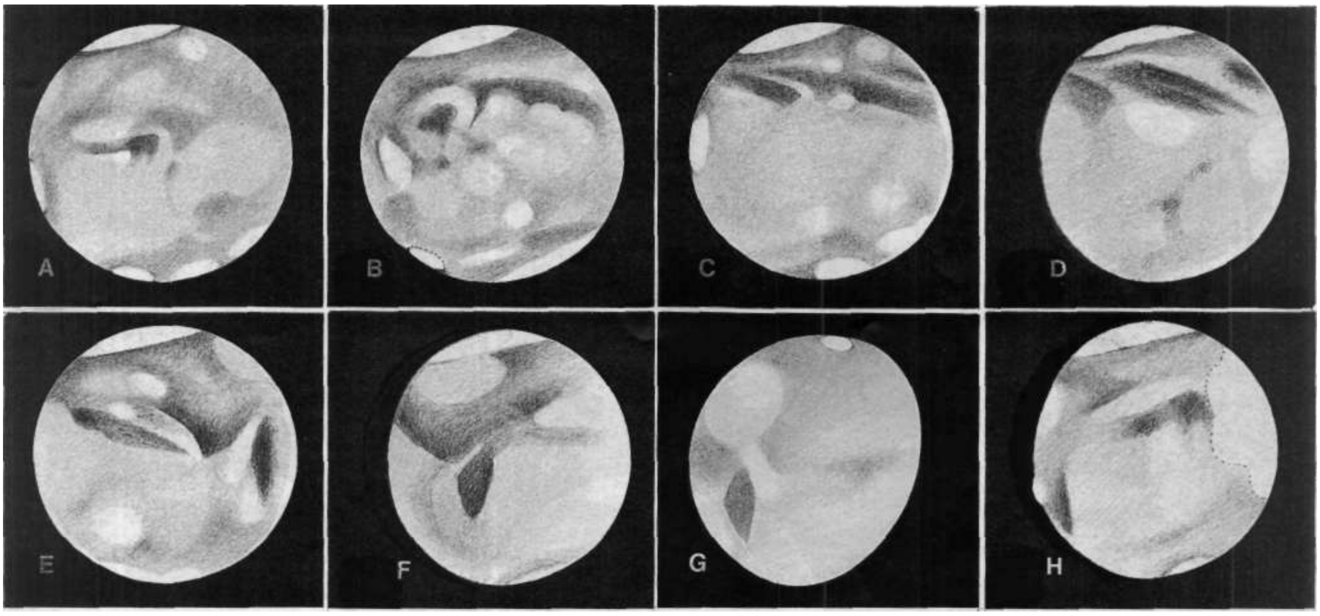

Figure 4. Drawings by M. Falorni with 360-mm OG, χ 270-450. (A) July 22d 23h 15m, ω = 7°. (B) July 10d 23h 10m, ω = 113°. (C) July 6d 00h 40m, ω = 179° *(Trivium Charontis* veiled? Compare (D)). (D) May 28d 02h 40m, ω = 202°. (E) June 26d 23h 20m, ω = 239°. (F) May 19d 03h 20m, ω = 295 ·. (G) November 8d 17h 00m, ω = 330° (dust storm from *Hellas* to *Aeria).* (H) May 14d 02h 40m, ω = 331° (extensive dust storm off morning limb).

streak ran *Np* to S*f* diagonally across *Noachis,* and then due W into *Mare Erythraeum.* It was less broad and intense than the *Noachis* dark streak of 1928-29[14] (Figures 2A, 3N, 4A, 5A, F, 6H, 7A, H, I). Some observers mistook it for *Pandorae Prelum,* which lay further north. For most of the apparition *Pandorae Fretum* was invisible or no darker than the *Noachis* desert, as would be expected for the time in the season. It began to be visible in October according to the OAA; Beish drew it on November 16 and Falorni saw that it had darkened in December, when it had perhaps been affected by the dust storm which originated in *Hellas* on November 8 (see later). *Noachis* itself was rather dusky.

Sinus Sabaeus was dark, but it was incomplete at its *p* end (as in 1980-84). *Mare Serpentis* was visible in part, forming the N part of the *Noachis* streak. Nearby, *Deltoton Sinus* was visible only in its E (or NE) part, as in 1984. *Sinus Sabaeus, Mare Serpentis* and *Meridiani Sinus* were brownish-red to the OAA observers. *Meridiani Sinus* was double, the E fork being the longer and darker, with a narrow third fork *(Brangaend)* also seen, spanning the end of *Deucalionis Regio.* The latter channel was also bridged at the point where it curved northwards into *Thymiamata* by the dusky streaks of *Neudrus I* and *II* (these running south to the dark spot, *Sextantis D.). Protonilus* was hard to see, lying so close to the NPH at opposition, but *Ismenius Lacus* was dusky, and joined to *Mare Acidalium* by a wide and obvious *Deuteronilus. Gehon* was occasionally seen as a faint diffuse band.

To the south of Region I, *Ausonia* was blue-green to Falorni on September 3. Like *Noachis* it was dusky for most of the apparition, but later on it was affected by cloud (see later). *Mare Australe* was a dusky shading bordering the retreating SPC.

Region II: ω = 010 - 130°

Mare Erythraeum exhibited much complex detail in the Pic du Midi observations. *Margaritifer Sinus* was normal, though its central parts were sometimes faint. It darkened as it tapered to the north. It showed a bluish tint to Minami, and was separated at its N end from a large, dark, wedge-shaped *Oxia Palus* (Figures 2A, 3B, 4A, 5A, 6A, H, 7A). The *Sp-Sf* border of *Thaumasia* was very dark, extending round to *Aonius Sinus,* with a small break for the lighter *Chrysokeras* (Figures 5C, 6B). *Aurorae Sinus* was complex and intensely dark, as were *Baetis, Juventae Pons, Agathodaemon (Coprates)* and *Melas Lacus.* The intense darkness of *Juventae Fons* was noted by several observers; the feature was larger and darker than in 1984 (Figures 5C, 6B).

Melas Lacus, a little larger than *Juventae Fons,* was the largest of at least five spots forming *Tithonius Lacus.* Phoenicus Lacus* was very distinct. *Nectar* was dark and extremely wide, and continued into *Mare Erythraeum,* connecting the latter feature to a complex, dark and very large *Solis Lacus. Solis Lacus* measured about 16° in latitude and 21° in longitude on Dragesco's best photograph of July 15. Figures 2C, D, 3D, 4B, 5C, D, 6B, C, 7B-D show this region well.

Solis Lacus was surrounded by the dusky lineaments *Ambrosia, Bathys, Calydon* and *Geryon.* It was divided into two main parts by a shaded E-W channel. The S component had two tiny, rarely-seen condensations on or just detached from its S edge. Minami and Miyazaki imperfectly resolved these two spots as southward projections from *Solis Lacus.* The N component was darkest at the *f* side. According to the writer's July Pic du Midi observations, the colours of the markings in

* The Pic du Midi reflector easily revealed much minute detail, such as the fine structure in and around *Solis Lacus.* In perfect moments, particularly when studying this region of Mars, the writer could easily see that the whole disk was permeated with minute, irregular details. However, craters could *not* be distinguished upon the surface.

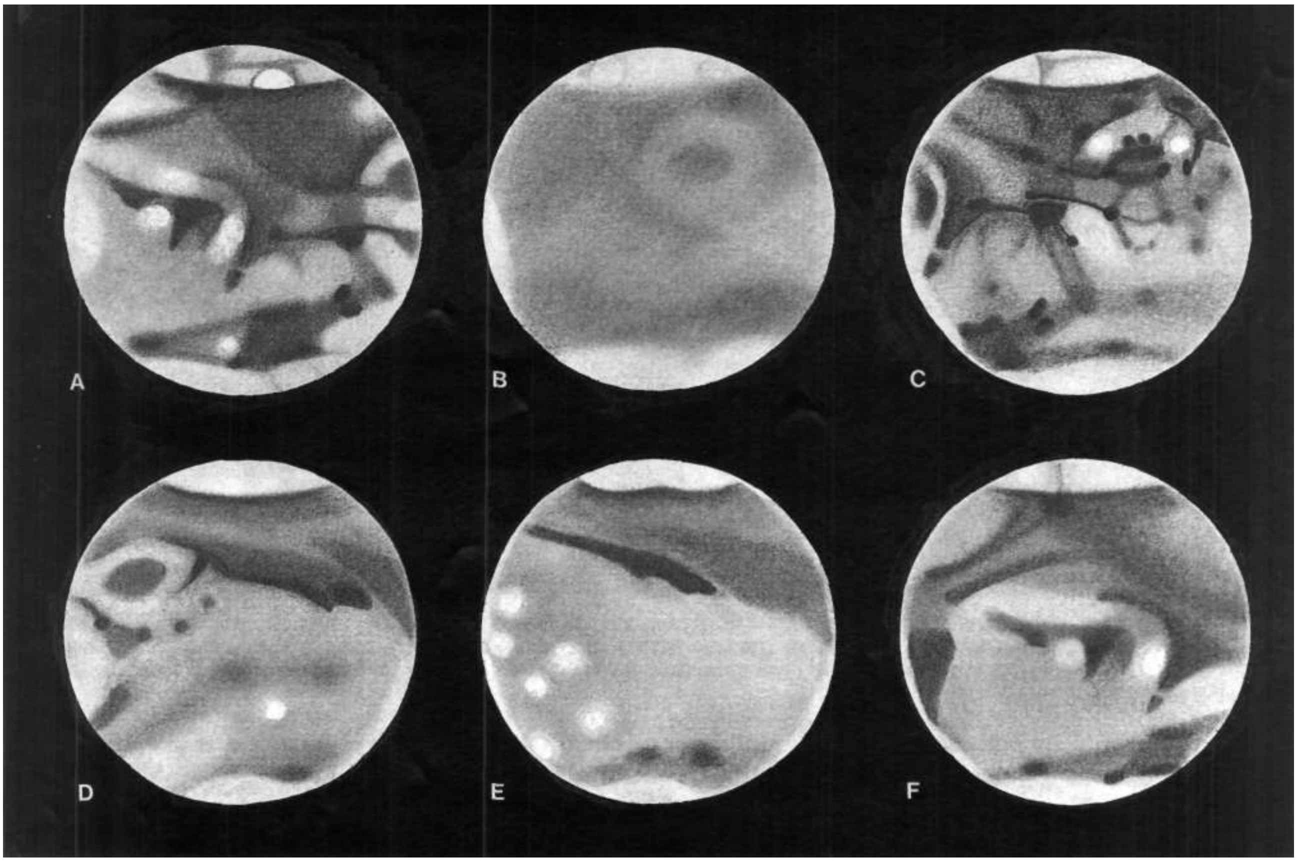

Figure 5. Drawings by R. J. McKim with 1060-mm Cass., x 213-533. Seeing (S) is given on the Antoniadi scale. (A) July 20d 22h 55m, ω = 20°, INT + W29, SII-III (SPC details). (B) July 15d 22h 40m, ω = 61°, W49, SI (rough sketch to show BC). (C) July 18d 00h 02m, ω = 63°, INT + W29, SI-II *(Solis Lacus* fine details). (D) July 10d 23h 45m, co= 121°, INT + W29, SIII *(Tharsis* orographics). (E) July 11d 02h 00m, ω = 153°, INT only, SIV (ditto, (D)). (F) July 20d 21h 00m, ω = 352°, INT + W29, SIII.

the desert areas of Region II varied from the usual *pinky-orange* to a rather more intense *red* colour in the somewhat darker northern part of *Thaumasia.* In August, the southern half of *Thaumasia* also seems to have darkened so that the whole region was then uniformly dusky.

Phasis, the streak from *Aonius Sinus* to *Phoenicus Lacus* which was seen in 1984 to have replaced the *Claritas-Daedalia* secular darkening of 1973-1982, changed its shape further during the 1986 apparition. In 1986 it was darker, shorter, and curved to the E, terminating in a small, dark 'oasis', which appeared slightly elongated N-S. The latter oasis was probably *Gallinaria Silva. Phasis* was easily photographed by Dragesco, McKim and Parker. Figure 9 portrays the *Solis Lacus* region at each opposition of the 15-year cycle from 1971 to the present, with 1877 for comparison. Although *Phasis* has been drawn at several of the intervening apparitions between 1877 and the present, only in 1986 did it regain the prominence it had shown in 1877-79. *Phasis* continued to be visible throughout the 1988 apparition. *Icaria* and *Hyscus* were deeply shaded and almost indistinguishable from the ρ end of *Mare Sirenum,* thus continuing into Region III. The N border of *Mare Erythraeum - Pyrrhae Regio* appeared very irregular, with several fine northward protrusions such as *Hydapsis Sinus, Iamunae Sinus* and *Orestes:* see Figures 2D, 3B, 5C.

Mare Acidalium was dark (although foreshortened) throughout the apparition. *Niliacus Lacus* was seen as a darker, undetached S component, while the part of *Mare Acidalium* next to the NPH was darker than the centre. *Nilokeras* was also dark and unusually wide. *Idaeus Fons* and *Achillis Pons* were two intense elliptical *dark brown* spots on the dusky *Nilokeras** (Figures 2D, 3B, 5C, 6B). *Lunae Lacus* was large, but scarcely darker than *Nilokeras.* The OAA found a brown colouration in both *Lunae Lacus* and *Ganges. Ganges* was well seen as a wide dusky streak. Visually, the writer found it had darker, irregular edges. This double aspect (i.e., the visibility of both *Ganges* and *Ister)* was confirmed on some photographs and by the drawings of Cave, Marshall, Minami and Miyazaki (Figures 5C, 6B). *Clytaemnestrae Lucus* was an inconspicuous small smudge. The Martian volcanoes in *Tharsis* were readily seen as small dusky spots. Around the time of opposition, the white

* Although the Pic du Midi is some 10° further S than England, atmospheric dispersion was still noticeable on the Martian disk when viewed without filters. We habitually employed powers up to χ 500 on the 1.06-metre reflector, but not beyond, for this reason. However, no more was usually desired, and any trace of atmospheric dispersion could be dispelled with a W29 deep-red filter. In white light, McKim did not usually notice any very striking colours in the dark markings between longitudes 150° westward through 300°. However, in excellent seeing he noticed a striking *dark brown* tint in *Idaeus Fons* and *Achillis Fons.* These two spots lie within the region which Antoniadi called the 'lune of brown spots' in the BAA Mars *Memoir* for 1911-1912.

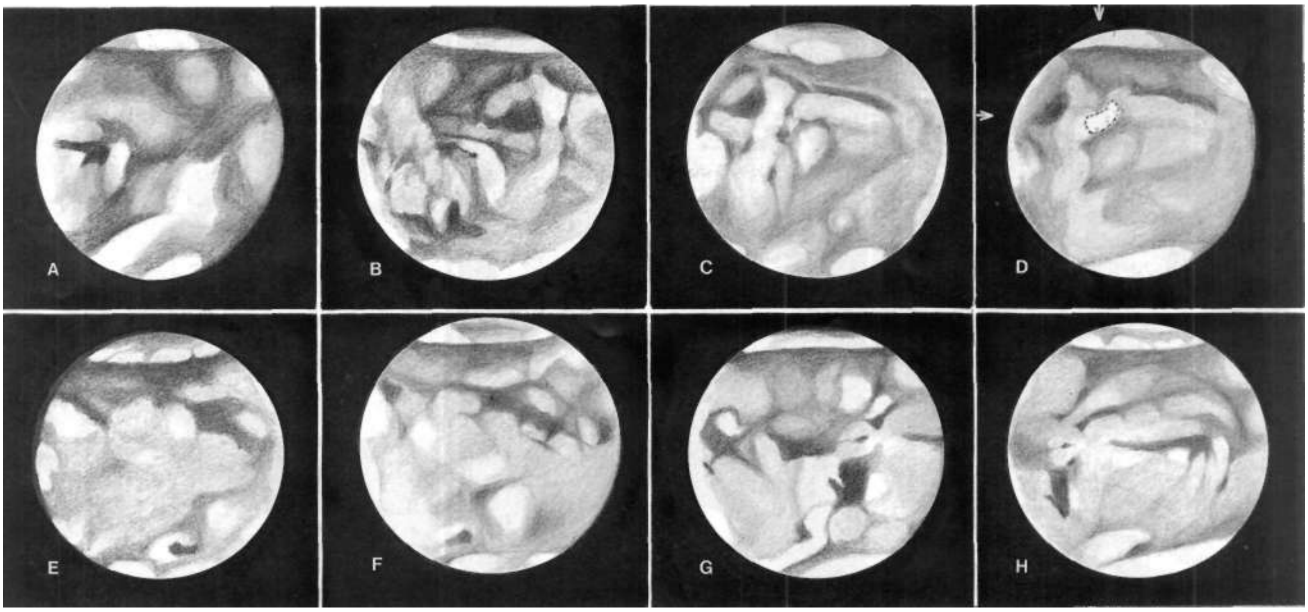

Figure 6. Drawings by M. Minami with 250 mm OG, χ 417-536. (A) August 15d 15h 10m, ω = 33° (dust storm over *Mare Acidalium, Chryse,* etc.). (B) July 7d 18h 10m, ω = 66°. (C) July Id 18h 10m, ω = 119°. (D) August 3d 14h 30m, ω= 132° (dust storm obscuring N part of *Phasis,* indicated by the arrows). (E) June 22d 16h 30m, ω = 175°. (F) July 25d 14h 00m, ω = 205°. (G) July 21d 16h 20m, ω = 275°. (H) July 13d 15h 20m, ω = 331°.

orographic afternoon clouds associated with these were well seen, especially in violet light (see Figures 2F, 3E, F, 4B, C, 5D, E, 6E, 7E). To the S of Region II, *Argyre* /was occasionally light (Figure 4A) but usually shaded, while *Mare Australe* was dark.

Region III: ω = 130-250°

Unfortunately most of this region could not be studied in detail from the Pic, but Falorni's and Minami's drawings show it particularly well. *Mare Sirenum* was dark, but was rather narrower in a N-S sense than in 1984 (see Figures 2F, 5D, E, 6C-E, 7D, E); also, *Sirenum Sinus* (the 'beak') was not well marked. Most importantly, the W (/) end of *Mare Sirenum* had faded, with the result that it appeared shorter in longitude, ending at ω ≈ 160° instead of at ≈ 170°. The OAA described *Mare Sirenum* as being maroon in June, but later, near L_S = 260° it was described as bluish. *Tartarus* was a faint streak running N*f* from the W end of *Mare Sirenum.*

Mare Cimmerium was well-marked and complex. *Cerberus III* marked the W edge of *Mare Cimmerium;* this is a rarely seen feature but in 1986 it was quite dark, running N-S across the dusky *Hesperia,* giving the region an unusual appearance (Figures 3H, 6F, G, 7G). *Gomer Sinus* was normal, visible in good seeing (Figures 3G, H, 6E, F, 7E), while *Atlantidum Sinus, Cerberi Sinus, Laestrygonum Sinus* and *Tritonis Sinus* were well-marked.

The southern deserts of this Region, *Phaethontis, Electris* and *Eridania* were rather more intensely shaded than their equatorial counterparts. However, in September and later they were lighter, with some dust activity noted there (see later). *Mare Chronium, Palinuri Fretum, Scamander, Simois, Tiphys Fretum* and *Xanthus* were dusky shadings. *Cerberus I* and *Trivium Charontis* (small) were generally dark, but *Phlegra* was very faint (Figures 2F, 3G, H, 4D, 6E, F). *Propontis I* was dark and lozenge-shaped as in 1984, with *Castorius Lacus* nearby (Figure 5E). *Propontis II* was lost in the NPH. *Elysium* was occasionally brighter than its surroundings but was more often dull. The *Aetheria* shading was still present, as in 1984, though it was not very intense (Figures 3H, 4E, 6F, 7F). BAA observers again failed to detect either *Nodus Laocoontis* or *Thoana Palus* but Dr Ebisawa tells me in a letter that he was able to see them as small faint spots with his 490 mm reflector at Kyoto. Many low-contrast features were observed in the equatorial deserts of Region III.

Apparition map

The chart reproduced here (Figure 1) was drawn from the best observations in June-July to represent the appearance of Mars at opposition. Almost all the details were shown in the photographs. The outlines of the SPC and NPH at opposition are also indicated.

Intensity estimates

The work of 6 of the 12 contributing observers was suitable for analysis, these observers contributing 2392 white-light intensity estimates. Of this total, 2052 estimates were analysed, and the results are presented in Table 2.

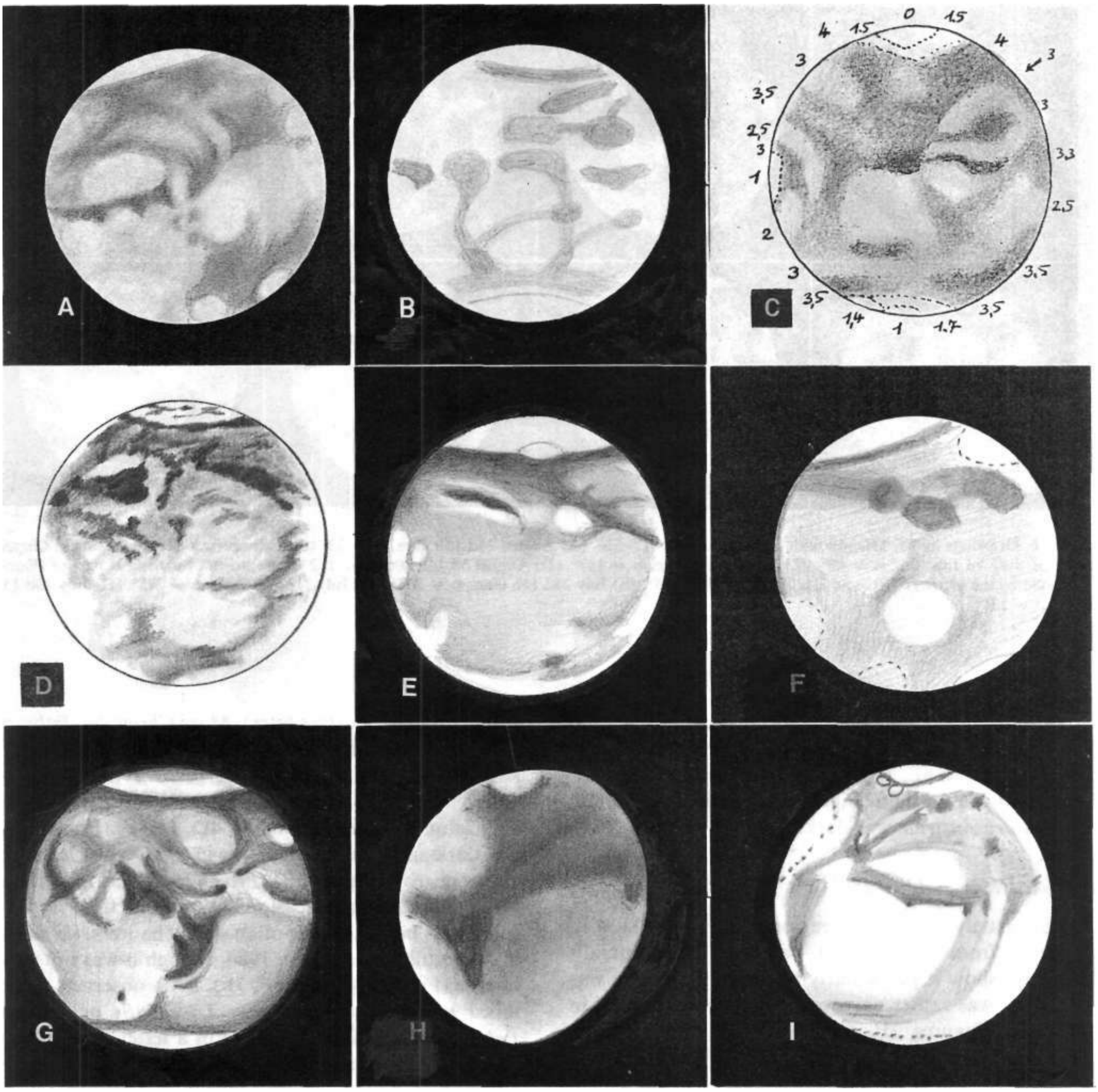

Figure 7. Drawings by various observers. (A) July 21d 23h 15m, ω = 16°, 310-mm refl., x 310, *R. Néel.* (B) July 27d 05h 04m, ω = 57°, 320-mm refl., x 321, *W. H. Haas.* (C) August 20d 20h 06m, ω = 59°, 203-mm Cass., χ 250, *R. de Terwangne (Mare Acidalium* veiled). (D) July 18d 03h 30m, ω = 114°, 320-mm Cass., x 430, *J. D. Beish (SolisLacus, Tharsis* details). (E) June 21d 15h 26m, ω= 169°, 204-mmrefl., x 136, */. Miyazaki (Tharsis* evening clouds). (F) July 2d 00h 55m, ω = 218°, 200-mm OG, χ 170, *J. H. Rogers.* (G) July 18d 14h 40m, ω = 277°, 204-mm refl., x 136, *I. Miyazaki.* (H) October 4d 18h 20m, ω = 329°, 152-mm OG, x 222, *D. L. Graham.* (I) September 8d 03h 15m, m = 349°, 320-mm refl., x 320-410, *T. R. Cave (Novus Mons).*

The Martian atmosphere

White Clouds

General

We list in this section the bright areas visible at the limb, terminator or CM that were *prominent* in white or blue light. Some of these areas were only seen bright once or twice in that month, while others were more or less permanently so. Some attempt has been made to identify those areas which were less frequently brightened. During May through November the observations are complete in their longitudinal coverage; outside this period there were too few observations for a complete longitudinal survey. The *Tharsis* orographic afternoon clouds were well-seen from May to August. The OAA thought them less prominent than during the 1982 opposition. *Elysium* was only occasionally brighter during 1986, with *Argyre I* and *Hellas* displaying greater activity.

1985 November through 1986 April

The OAA found *Hellas* bright up until late February (L_s = 130°). When they next observed it at L_s = 146° it was dull, brightening only near the ρ terminator. On

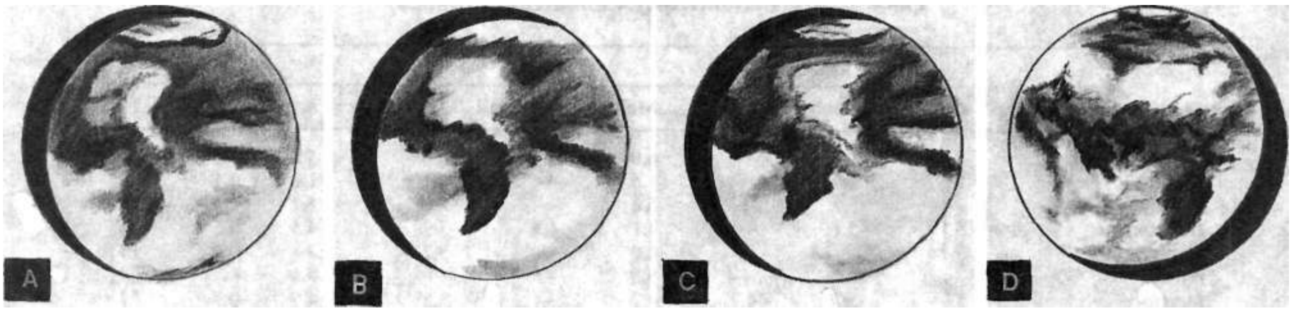

Figure 8. Drawings by J. D. Beish with 320-mm Cass., χ 430, to show dust storm activity. (A) May 28d 09h 25m, ω = 299° *{Hellas* yellow cloud). (B) May 29d 09h 50m, ω = 296° (ditto (A); SPC N edge hazy). (C) May 30d 09h 55m, ω = 288° (ditto (A)). (D) September 13d 01h 10m, ω = 278° (dust in *Hellas-Ausonia-Eridania).*

Table 2. Martian intensity estimates

	Observer								
Feature	Adamoli	Foulkes	Heath	McKim	Marshall	Terwangne	Ave.	s.d. (±)	No.
Achilles F.				7.8			7.8	(—)	2
Acidalium, M.	4.1	5.0	3.3	5.2	4.0	4.3	4.3	0.7	24
Aeolis	—	—	—	—	—	2.2	2.2	(-)	15
Aeria	1.8	2.2	—	2.0	2.0	2.3	2.1	0.2	27
Aetheria	—	—	—	—	—	3.0	3.0	(-)	15
Aethiopis	—	—	—	2.0	—	2.7	2.4	(0.4)	21
Agathodaemon	—	—	—	5.4	—	4.0	4.7	(0.7)	22
Amazonis	2.0	2.5	—	2.1	—	2.9	2.4	0.4	29
Amenthes	—	—	—	—	—	2.7	2.7	(-)	17
Aonius S.	—	—		5.8	—	4.3	5.0	(0.8)	17
Arabia	—	2.0		2.0	2.0	2.4	2.1	0.2	17
Araxes	—	—		—	—	3.3	3.3	(-)	13
Arcadia	—	2.0		2.0	—	3.0	2.3	0.6	19
Argyre I	—	—		3.8	2.5	2.9	3.1	0.7	20
Ascraeus L.	—	—		3.2	—	—	3.2	(-)	2
Aurorae S.	5.7	6.0	5.3	5.6	4.0	4.3	5.2	0.8	36
Ausonia	2.4	2.5	—	2.9	—	2.6	2.6	0.2	27
Australe, M.	4.9	—	—	4.8	—	4.2	4.6	0.4	22
Baetis	—	—	—	6.0	—	—	6.0	(-)	2
Baltia	—	—	—	—	—	3.5	3.5	(-)	13
Boreum, M.	—	3.5	2.5	3.1	—	3.6	3.2	0.5	21
Bosphorus Gemmatus	5.2	—	—	5.4	—	—	5.3	(0.1)	6
Candor	—	—	—	1.5	—	2.5	2.0	(0.5)	23
Casius	—	—	—	—	—	3.7	3.7	(-)	15
Cebrenia	—	—	—	3.3	—	3.2	3.2	(0.1)	12
Cecropia	—	—	—	—	—	3.7	3.7	(-)	5
Cerberus I	—	—	—	3.8	—	3.1	3.4	(0.4)	16
Choice	—	—	—	—	—	4.1	4.1	(-)	15
Chronium, M.	—	—	—	4.9	—	3.8	4.4	(0.6)	8
Chryse	2.0	—	1.0	2.0	—	2.5	1.9	0.6	26
Chrysokeras	—	—	—	3.5	—	3.8	3.6	(0.2)	13
Cimmerium, M.	5.5	6.3	5.2	5.3	4.0	4.4	5.1	0.8	47
Claritas	—	—	—	1.9	—	3.2	2.6	(0.6)	17
Cyclopia	—	—	—	—	—	3.5	3.5	(-)	16
Cydonia	—	—	—	3.0	—	2.9	3.0	(0.1)	17
Daedalia	—	—	—	2.0	—	—	2.0	(-)	5
Deltoton S.	—	—	—	—	—	4.4	4.4	(-)	9
Deucalionis R.	2.6	2.5	—	2.2	—	3.1	2.6	0.4	25
Deuteronilus	—	—	—	3.8	—	3.3	3.6	(0.2)	13
Diacria	—	—	—	—	—	3.2	3.2	(-)	9
Dioscuria	—	—	—	—	—	3.8	3.8	(-)	6
Eden	2.0	2.1	—	2.0	—	—	2.0	0.1	14
Edom	—	—	—	0.8	—	2.3	1.6	(0.8)	15
Electris	—	—	—	3.8	—	3.0	3.4	(0.4)	10
Elysium	1.8	2.2	—	1.9	—	2.4	2.1	0.3	28
Eridania	—	2.2	—	3.4	—	2.8	2.8	0.6	15
Erythraeum, M.	5.3	4.9	5.0	5.2	3.8	4.1	4.7	0.6	45
Ganges	5.0	4.0	—	3.5	3.2	—	3.9	0.8	8
Gehon	3.5	—	—	3.0	—	3.2	3.2	0.2	21

(Table continued on next page)

Table 2. Martian intensity estimates (continued)

	Observer								
Feature	Adamoli	Foulkes	Heath	McKim	Marshall	Terwangne	Ave.	s.d. (±)	No.
Hadriacum, M.	5.5			6.0		4.0	5.2	1.0	15
Hellas	1.3	2.4	—	1.5	—	2.1	1.8	0.5	25
Hellesponticae D.	—	5.5	—	5.8	—	3.9	5.1	1.0	15
Hellespontus	5.1	5.1	—	4.1	4.6	3.9	4.5	0.6	28
Hesperia	3.7	—	—	4.0	—	3.7	3.8	0.2	19
Hyscus	—	—	—	5.8	—	—	5.8	(-)	4
Iapigia	5.0	5.7	4.7	4.2	—	3.8	4.7	0.7	24
Icaria	—	—	—	5.2	—	3.5	4.4	(0.8)	18
Idaeus F.	—	—	—	7.8	—	—	7.8	(-)	2
Isidis R.	1.3	2.1	—	1.8	—	2.3	1.9	0.4	28
hmenius L.	—	—	—	5.0	—	3.4	4.2	(0.8)	9
Juventae F.	—	—	—	6.0	—	—	6.0	(—)	2
Libya	—	—	1.0	0.9	—	2.9	1.6	1.1	20
Lunae L.	4.5	—	—	4.4	—	3.4	4.1	0.6	21
Margaritifer S.	—	4.6	4.7	5.3	4.5	4.0	4.6	0.5	34
Mêlas L.	—	—	—	5.4	—	—	5.4	(—)	4
Memnonia	—	—	—	2.0	—	2.3	2.2	(0.2)	20
Meridiani S.	5.1	5.6	5.1	5.2	3.8	4.5	4.9	0.6	44
Meroe	—	—	—	—	—	2.8	2.8	(-)	10
Moab	—	—	—	2.0	—	2.3	2.2	(0.2)	14
Moeris L.	—	—	—	—	—	3.4	3.4	(—J	16
Nectar	—	—	—	5.5	—	—	5.5	(-)	2
Neith R.	—	—	—	1.8	—	2.4	2.1	(0.3)	21
Nepenthes	—	—	—	—	—	3.3	3.3	(—)	14
Nereidum Fr.	—	—	—	5.1	—	4.1	4.6	(0.5)	25
Niliacus L.	—	—	—	5.8	—	3.5	4.6	(1.2)	16
Nilokeras	4.0	6.5	3.0	4.0	3.0	3.5	4.0	1.3	27
Nilosyrtis	—	—	—	—	—	3.1	3.1	(-)	13
Noachis (desert)	3.4	3.6	—	3.6	—	3.2	3.4	0.2	30
Noachis (dark band)	—	—	—	5.0	—	—	5.0	(—)	2
Noctis L.	—	—	—	4.3	—	—	4.3	(—)	3
Nodus Alcyonius	—	—	—	—	—	3.4	3.4	(—)	15
Ogygis R.	—	—	—	3.0	—	4.1	3.6	(0.6)	18
Ophir	—	—	—	1.5	—	—	1.5	(—)	2
Ortygia	—	—	—	—	—	3.4	3.4	(-)	12
Oxia P.	—	—	—	6.0	—	—	6.0	(—)	5
Panchaïa	2.8	3.3	3.0	3.3	—'	3.1	3.1	0.2	18
Pandorae Fr.	—	—	—	—	—	3.5	3.5	(—)	14
Phaethontis	—	—	—	3.6	—	3.0	3.3	(0.3)	13
Phasis	—	—	—	5.0	—	—	5.0	(-)	3
Phlegra	—	—	—	3.2	—	3.1	3.2	(0.1)	11
Phoenicus L.	6.0	—	—	4.0	—	2.9	4.3	1.6	16
Phrixi R.	—	—	—	5.1	—	4.2	4.6	(0.4)	22
Propontis 1	5.0	—	—	4.0	—	3.1	4.0	1.0	9
Protêt R.	—	—	—	4.2	—	—	4.2	(—)	3
Protonilus	—	—	—	4.0	—	3.4	3.7	(0.3)	10
Pyrrhae R.	—	—	3.0	3.9	3.0	3.7	3.4	0.5	23
Sabaeus S.	5.0	4.6	4.3	4.9	3.2	4.1	4.4	0.7	44
Scandia	3.0	3.2	3.0	3.1	—	3.2	3.1	0.1	20
Serpentis, M.	—	—	—	4.5	—	4.0	4.2	(0.2)	11
Sirenum, M.	5.8	5.6	5.1	5.8	—	4.2	5.3	0.7	41
Soils L.	6.0	6.6	5.2	5.4	4.0	3.8	5.2	1.1	39
Styx	—	—	—	—	—	3.0	3.0	(~)	10
Syrtis Major	6.0	6.8	5.8	5.0	4.2	5.2	5.5	0.9	37
Tanais	—	—	—	—	—	3.7	3.7	(—)	14
Tempe	—	—	—	1.9	—	2.7	2.3	(0.4)	26
Tharsis	2.0	2.3	—	2.0	—	2.4	2.2	0.2	36
Thaumasia	—	—	—	2.4	—	3.2	2.8	(0.4)	26
Tithonius L.	—	—	—	3.9	—	4.0	4.0	(0.1)	25
Trivium Charontis	—	—	—	—	2.7	3.1	2.9	(0.2)	13
Tyrrhenum, M.	5.9	6.5	5.1	5.3	—	4.8	5.5	0.7	47
Umbra	—	—	—	—	—	3.8	3.8	(—)	9
Utopia	4.2	—	3.0	3.0	—	3.6	3.4	0.6	15
Vulcanl Pelagus	—	—	—	—	—	4.0	4.0	(—)	17
Xanthe	2.0	2.0	—	2.0	—	2.7	2.2	0.4	31
Yaonls Fr.	—	—	—	4.1	—	—	4.1	(—)	4
Yaonis R.	—	—	—	—	—	3.5	3.5	(—)	7
Zephyria	—	2.0	—	2.0	—	2.4	2.1	0.2	19
No. of useful estimates:	134	152	79	369	26	1292		Total	2052
Period of observation	Jun 27-Oct 1	Jun 28-Oct 9	Jun 12-Jan 8	Apr 6-Oct 15	Mar 9-Jul 24	Jul 3-Nov 15			

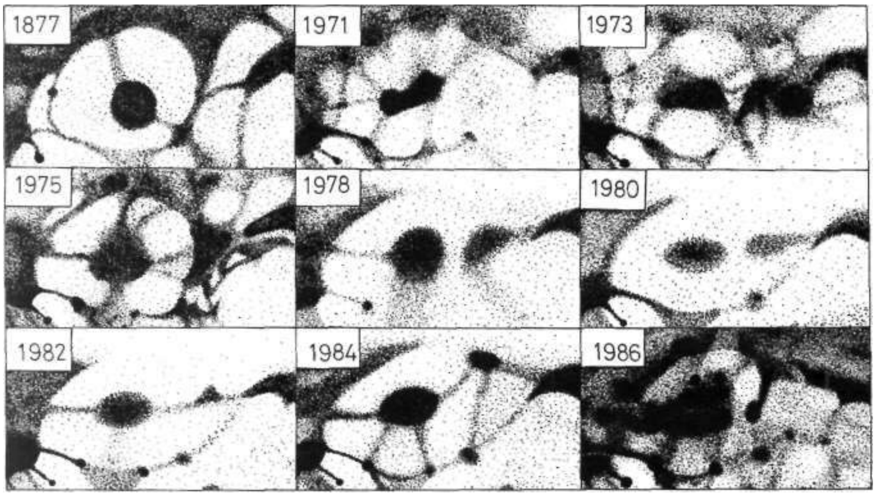

Figure 9. Drawings of *Solis Lacus* and environs showing the *Claritas-Daedalia* development of 1973-82, and the *Phasis* streak in 1877 and 1984-86. 1971 is added as a 'normal' year for comparison. Drawn by the writer from the following sources: (A) 1877, Schiaparelli; (B)-(C) 1971-73, Lowell Observatory Map Series (photographic); (D) 1975, BAA observations by Dragesco; (E) 1978, BAA observations by Capen, Dragesco, Grant, Heath, Rogers and Sturdy; (F)-(I) 1980-86, from the BAA Mars Reports. The region was very difficult to study in 1978-82 due to unfavourable tilt and the smallness of the Martian disk at opposition.

March 18 Falorni saw a large bright evening cloud over *Amazonis,* but there was as yet no sign of the *Tharsis* orographic clouds. In April evening cloud was seen over *Amazonis* and *Arcadia,* and bright areas at the morning limb were seen in *Tempe, Thaumasia* and *Zephyria.*

1986 May

Hellas was described as dull and whitish by the OAA ($L_s \approx 165°$); Beish found it brighter at the ρ terminator. A bright orographic cloud over *Arsia Mons* was first detected on May 8 by Parker (confirmed by the OAA in late May). The other *Tharsis* orographic clouds were not visible this month.

Other bright areas were seen as follows: ρ terminator: *Arabia, Arcadia, Deucalionis Regio, Eden, Edom, Isidis Regio* (Falorni saw a bright irradiating cloud over *Libya* and SE *Syrtis Major* on May 14, see Figure 4H), *Xanthe;* mid-disk: *Aeolis, Aeria, Chryse, Deucalionis Regio, Edom,* around *Ganges* (i.e., *Candor, Ophir, Xanthe), Libya,* NW *Noachis* (Beish 20d*), *Tempe, Thymiamata; f limb: Aeolis, Aethiopis, Amazonis, Azania, Candor, Chryse, Deucalionis Regio, Eden, Edom, Elysium* (Beish 2d only), *Moab* (Parker 28d, W47 filter); *Ophir, Tempe, Zephyria.* In addition to the above, a possible equatorial cloud band from *Arabia* to *Chryse* was recorded by Parker on May 19 (CML 19°, W47).

1986 June

The OAA found *Argyre I* to be slightly bright, and *triangular* in shape (frost?). This unusual aspect had disappeared by July. *Hellas* was habitually dull during June, although the W side was a little brighter sometimes. The *Tharsis* orographics were prominent, with *Nix Olympica* and the clouds over *Ascraeus Mons* and *Pavonis Mons* now also visible, and with the *Arsia Mons* cloud the most prominent (Figures 6E, 7E). The W-cloud was partly visible on Parker's W47 photographs from June 13.

* i.e., on May 20, etc. ...

The other bright areas were as follows: ρ terminator: *Aeolis, Aethiopis, Alba, Candor, Daedalia, Eridania, Libya, Ophir, Xanthe, Zephyria;* mid-disk: *Candor, Deucalionis Regio, Eridania, Hesperia* (Beish 11d; Falorni 26d, Figure 4E), *Isidis Regio, Libya, Ophir,* surrounding *Propontis I* (Minami 22d, Figure 6E), *Thaumasia, Thymiamata, Zephyria; f* limb: *Arcadia, Isidis Regio, Libya, Neith Regio, Noachis, Ophir, Tempe* (brilliant to Parker 28 d, merging with NPH).

1986 July

Argyre I was seen on a few occasions by Falorni as a small bright circular patch, but was rarely brightened by atmospheric activity. *Hellas* was usually dull, with occasional brightenings in the W. *Elysium* showed sporadic brightenings (Figures 3G, H). The *Tharsis* orographics showed up well, especially when east of the CM. Falorni and McKim saw *Nix Olympica* bright *west* of the CM on July 10 and this behaviour was confirmed by others: see Figures 4B, 5D. Parker photographed the W-cloud on several dates, and McKim saw it well on July 10 (Figures 3E, 5E). The *Arsia Mons* cloud remained the largest of the orographic clouds (Figures 3F, G).

Other bright areas: ρ limb: NE *Mare Acidalium, Aeria, Amazonis, Candor, Mare Cimmerium-Electris, Daedalia, Deucalionis Regio, Diacria, Edom, Isidis Regio, Moab, Libya, Neith Regio, Ophir, Tempe* (including *Nix Tanaica,* Figure 4B), *Xanthe, Zephyria;* mid-disk: *Candor, Claritas, Nix Cydonia* (Figure 5A), *Deucalionis Regio, Edom, Electris* (small white patch to Falorni 6 d, Figure 4C), *Libya, Ophir, Thaumasia* (various small bright spots changing position from night to night; Figure 5C), *Thymiamata;*/'limb: *Aethiopis, Alba, Amazonis, Arcadia, Ausonia, Azania, Cebrenia, Deucalionis Regio, Dia, Eridania,* a tiny bright spot in W Noachis (Miyazaki 18d, Figure 7G), *Ophir, Nix Tanaica, Tharsis, Thaumasia.* Parker's W47 photograph of July 21 (CML 90°) shows a light band of cloud extending across *Xanthe* and *Candor* into *Tharsis.*

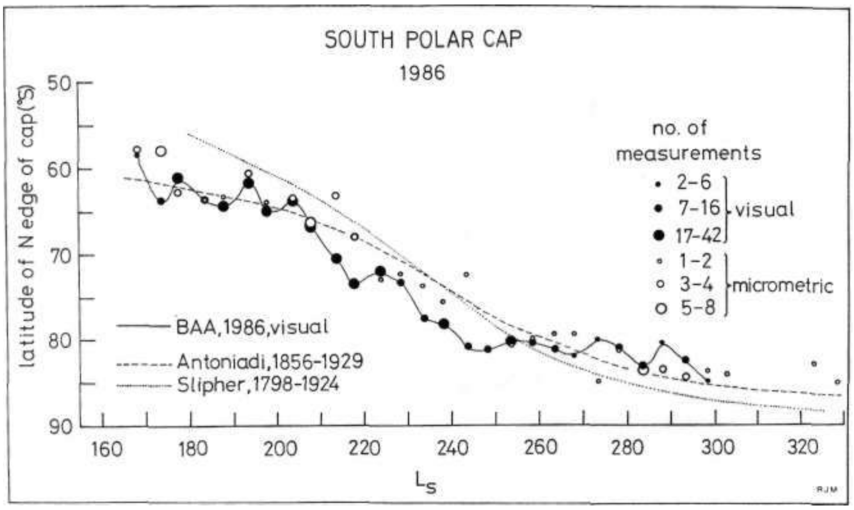

Figure 10. Curve showing the shrinkage of the SPC in 1986. Latitudes were calculated from measures of the E-W diameter of the cap, and averaged in intervals of 5° in L_s.

1986 August
The ALPO commented that white cloud activity this month was less than in June-July. The *Tharsis* orographics were sometimes still visible. *Hellas* was brighter once more, but an increasing amount of yellow cloud here complicates the analysis. The basin was brighter to the W, but the E part also brightened at the evening limb. *Argyre I* was sometimes visible but not very bright. *Elysium* was sometimes bright, but usually dull.

The other regions were as follows: ρ limb: *Aeolis, Arcadia, Ausonia, Chryse, Eden, Edom, Isidis Regio, Libya, Memnonia, Meroe, Moab, Neith Regio, Phaethontis, Syrtis Major* (Beish 3 d), *Tharsis, Thaumasia, Thymiamata, Umbra;* mid-disk: *Candor, Nix Cydonia, Deucalionis Regio, Ophir, Tharsis, Thymiamata; f* terminator: *Aeria, Aethiopis, Ausonia, Azania, Daedalia, Electris, Libya, Noachis, Ophir, Tharsis.*

1986 September
Orographic clouds in the *Tharsis* region were seen over *Olympus Mons* and *Asia Mons* by Haas, on September 26 only. *Hellas* was often rather bright, and both white and yellow clouds were seen there. There were bright areas in *Ausonia* and *Eridania,* but these were probably due to yellow cloud (see next Section). *Argyre I* was again occasionally bright.

Other whitened areas: ρ limb: *Mare Acidalim, Amazonis, Ausonia, Chryse, Cydonia, Isidis Regio, Libya, Memnonia, Moab, Noachis* (Foulkes 26d), *Nix Tanaica, Tempe, Xanthe, Zephyria;* mid-disk: *Nix Cydonia, Edom, Eridania* (a small *white* cloud seen by Beish 17d), *Libya, Isidis Regio, Memnonia, Neith Regio, Thymiamata; f* terminator: *Aeria, Arcadia, Daedalia, Libya, Meroe, Tharsis, Xanthe.*

1986 October
Hellas showed similar activity to September. Other brightened areas were: ρ limb: *Aethiopis, Ausonia, Chryse, Eridania, Isidis Regio, Libya, Memnonia, Tempe;* mid-disk: *Aeria, Deucalionis Regio, Isidis Regio, Libya*; *f* terminator: *Aeria, Amazonis, Arcadia, Argyre I* (Haas, October 14 only), *Claritas, Daedalia, Deucalionis Regio, Libya, Tharsis.*

1986 November
In November, the *Hellas* basin was affected largely by yellow cloud, but its observed brightening at the ρ limb may have been due to white cloud. It was dull for the rest of the Martian day. Other bright areas: ρ limb: *Ausonia, Isidis Regio, Libya, Memnonia, Meroe, Tharsis;* mid-disk: *Aeria, Libya, Yaonis Regio* (Beish 17 *d);f* terminator: *Tempe.*

1986 December through 1987 June
In December, the incomplete observations show that *Hellas* was bright, probably due to white cloud, on the CM and morning terminator. *Argyre I* was also brighter occasionally. Other bright areas: ρ limb: *Aeolis, Isidis Regio, Libya, Memnonia, Xanthe, Zephyria;* mid-disk: *Isidis Regio, Libya; f* terminator: *Chryse, Tempe, Zephyria.*

In January, *Hellas* was brighter only at the evening limb. *Argyre I* showed up bright occasionally, while *Amazonis, Electris, Memnonia* and *Thaumasia* were bright at the evening limb. Haas' later observations reveal that *Hellas* was sometimes brighter at the evening limb from February to April.

Yellow Clouds (Dust Storms)

Yellow clouds were often seen during May, August (pre-perihelion) and from September (perihelion) onwards. In May, August and November the obscurations were notable, but at no time does there appear to have been a *global* storm. Some observers, such as Falorni and Moore, thought the surface features generally a little less contrasty than usual for several months around opposition, but it is difficult to be more quantitative about this.

1986 May through September
On May 8 van der Jeugt (CML 32°) found *Mare Acidalium* unusually weak near the CM and *Meridiani Sinus* invisible, but the rest of the S hemisphere was fairly well defined. Next day, Rogers (CML 22°) recorded a somewhat similar view. On May 14 Falorni

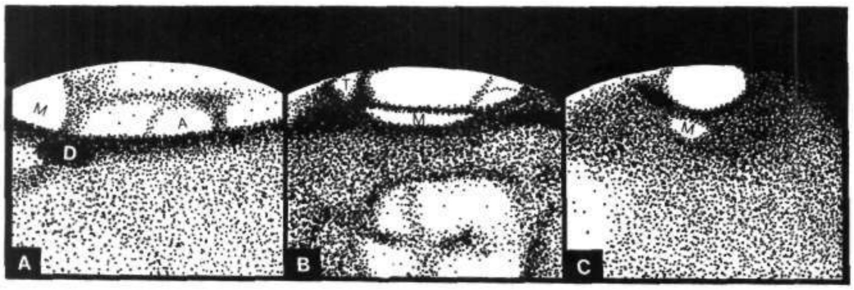

Figure 11. The recession of the SPC, after drawings by (A) McKim, July 20, ω = 20°, φ (tilt) = -5°; (B) Beish, September 12, ω = 300°, φ = -7°; (C) Miyazaki, October 26, ω = 350°, φ = - 17°. Some features are identified thus: A = *Argenteus Mons,* D = *Depressiones Hellesponticae,* M = Mountains of Mitchell *(Novus Mons),* T = *Thyle II.*

(CML 331°) detected a bright yellow dust storm reaching half-way from the morning limb to the CM, and from 40°N to 40°S, covering *Margaritifer Sinus,* the S part of *Mare Acidalium* and just touching *Meridiani Sinus* (Figure 4H). On May 19 (CML 295°) he found 'only traces of *Meridiani Sinus'* near the morning limb (Figure 4F). From the USA, Beish was able to observe these regions backing onto the disk: on May 18 (CML 26°) he found an 'unusual dull haze or dusty region obscuring SE limb features', including *Meridiani Sinus,* and he had a similar view next day. On May 20 the region was normal. Beish saw *Mare Acidalium* well during this time from May 15 onwards. The storm appears to have been centred on *Chryse,* and may have arisen either here or perhaps in *Noachis. Deucalionis Regio* was also bright during this period, but was probably affected only by white cloud.

Beish recorded a bright yellow cloud in western *Hellas* on May 28 (L_s = 178°). According to Beish, Parker and ALPO the cloud moved slowly into *Aeria* by May 30 (Figures 8A-C); it does not appear to have spread further. At this time the edge of the SPC had been free of the SPH since mid-month in the longitude of *Hellas.* The cap had shown a sharp edge to Beish on May 28 and 30, but on May 29 he shows it as diffuse again. Could this be evidence of some connection with the *Hellas* dust? On June 9 (CML 57°) *Meridiani Sinus* was again weak to Falorni, and the general contrast of the planet low. The next day, Osawa also found that *Meridiani Sinus* was not clearly defined, while on June 10 and 20 Falorni felt *Meridiani Sinus* and *Sinus Sabaeus* to be weak. Parker's photos from June 24 show these regions to be normal. Activity may also have occurred in the *Tharsis* region for on June 6 Fletcher found a wide area devoid of detail in good seeing, and on June 12 Broadbank (CML 49°) reported that the yellow colour of *Tharsis* was most striking when seen with an orange filter. There was also some yellow cloud activity in *Ausonia,* for the region was bright yellow to Rogers on the morning limb on July 2 (Figure 7F), and Parker's June 21 photograph gives a similar impression. No further outbreaks were seen in June; the occurrence of pre-perihelic dust storm activity is quite normal. In the opposition month of July, Falorni found *Trivium Charontis* weak on the 5th (Figure 4C).

Up until August, there had been no evidence of dust activity in the *Thaumasia* region, but on August 3 Minami and Chang (OAA) saw a cloud with a bright yellow core at about 10-25°S, longitude 100-110°, covering the N end of *Phasis* (Figure 6D). The cloud was not visible on the neighbouring dates. The OAA followed the outbreak of a further dust storm in the *northern* hemisphere of Mars in mid-August, details of which were also sent by Minami. The regions of *Niliacus Lacus* and *Mare Acidalium* were visible as usual up until August 14. But on August 15 they appeared to be veiled by cloud emanating from the north polar hood (Figure 6A). On the 16th, the veil, yellowish in tone, had expanded up to the equator near *Eos,* but *Niliacus L.* had recovered its intensity. *Chryse* appeared bright and yellowish on August **17-18.** Veiling of *Oxia P., Margaritifer S.* and *Nilokeras* was also observed. After August 19 these regions were lost to the Far East observers. On August 19 McKim (CML 84°, 100-mm OG)) could see *Ganges* and *Nilokeras* at the/7 limb, with evening cloud over *Chryse.* The storm region was seen nearer to the CM by Néel on August 20 (CML 62°). He seems to have observed dust clouds over *Mare Acidalium, Chryse* and *Xanthe.* McKim, observing on the 27th in poor seeing (CML 349°) suspected obscuration of *Meridiani Sinus-Margaritifer Sinus-Mare Erythraeum.* The activity was also confirmed by Parker's photos. On August 27 (CML 90°) most albedo features are well-contrasted, but the ρ limb showed up bright, possibly representing the continuing storm covering the regions E of *Thaumasia {Mare Erythraeum-Eos,* etc.). Of most significance is the August 30 image (CML 62°): see Figure 3C. *Mare Acidalium* and its environs are clearly marked, but *Margaritifer Sinus, Oxia Palus* and *Meridiani Sinus* appear washed-out and very pale; indeed, all the S hemisphere details E of the dusky E border of *Thaumasia* are faint. The dust storm is also confirmed by some of Terwangne's drawings of August 16-23. Some show *Niliacus L.* still dark, but *Mare Acidalium* is generally faint, and was noted as 'veiled' on the 20th (Figure 7C). Details in the *Mare Erythraeum* area were generally faint. Cave's early September drawings show the region normal. It seems that the storm was confined to the *Margaritifer Sinus-Mare Acidalium-Chryse* region and did not spread W of *Ganges-Nilokeras.* Minami thought the dust storm was precipitated by the southward expansion of the NPH, but was separated from the hood after August 15 and centred on *Chryse.*

In early August ALPO again noted a yellow cloud in *Hellas,* but it does not appear to have developed. The OAA noted a possible one-day storm in W *Hellas* on August 28. During July 30-August 1 Terwangne (CML 245-263°) further noted a general yellow tint over the S hemisphere deserts bordering the SPC. Activity was further reported during September by ALPO and the OAA, confined to the NW corner of the *Hellas* basin

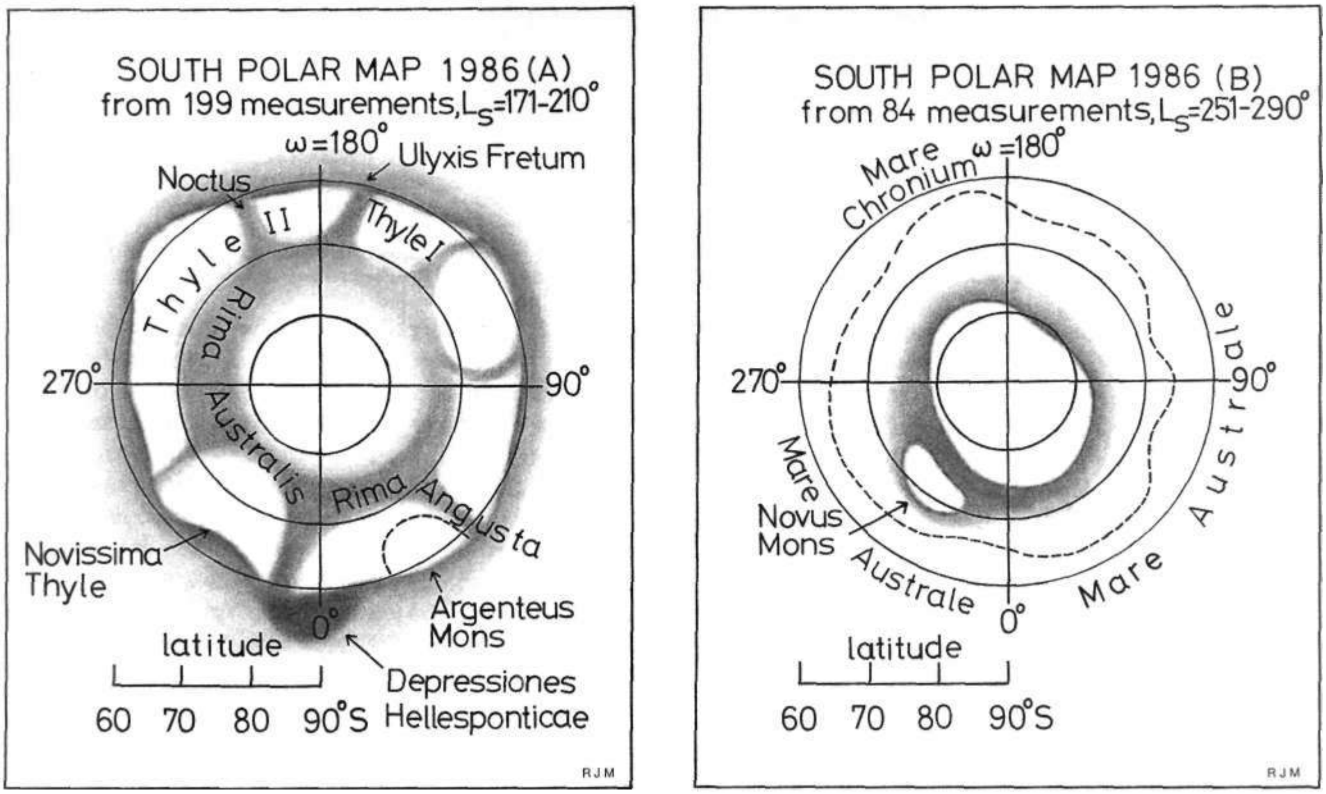

Figure 12. (A) Map of the SPC at L_S = 171-210° on polar projection. (B) Map of the SPC at L_S = 251-290° on polar projection. The interior line thus:———denotes the contour of the cap for L_S = 211-250°.

(Figure 3L). Terwangne again found a yellow tint over the light S deserts generally during September 5-7 (CML 250-269°), and Beish, Haas and Parker found dust in *Ausonia* and *Eridania* during September 12-21 (Figure 8D). Ebisawa, in a report on the 1986 apparition,[11] confirmed local dust activity in *Hellas-Ausonia* on September 22 and afterwards.

1986 October through 1987 June

Mars reached perihelion in September, and the S hemisphere summer solstice occurred in October. At such times it is usual for a major dust storm to develop in one of the favoured germination sites in the S hemisphere, and to spread westward round the planet. Often, as in 1909, 1924, 1956, 1971, 1973 and in the years of the *Viking* Project the storms have been global in extent. In all these years there was also evidence of yellow haze dimming the markings prior to perihelion. Germination sites have been low-lying desert areas with strong local topographic contrast *{Hellas, Noachis, Thaumasia).*

On October 1, Terwangne noted a possible obscuration of parts of *Gehon, Mare Acidalium* and *Nilokeras* by a bright E-W band (dust?), and the OAA found dust in *Eridania* and S *Ausonia* during October to December. Ebisawa[11] confirms this activity, which continued from September. Beish and Parker both saw a yellow cloud N of *Mare Sirenum* on December 9-10. However, the most significant activity from October onwards was confined to *Hellas* and its environs. With *Hellas* lying near the ρ limb on October 2, Falorni found the basin to contain a bright yellow patch in its NW corner. The writer found *Hellas* to have a yellow tint on October 4. When Falorni next observed, on November 6, the same region was on view near the ρ limb, but now the entire basin had become bright yellow. ALPO and OAA members also noted that the region had contained a bright yellow area in October (Figure 30). On November 8 an exciting development occurred, as Falorni reported: 'A bar-like yellow feature extended itself from *Hellas* to *Aeria,* obliterating the underlying regions of *lapigia* and *Deltoton* Sr. Boattini, observing with Falorni, confirmed his drawing in every detail. Falorni's discovery drawing is reproduced as Figure 4G.

Fortunately Falorni was able to follow developments with the Arcetri refractor and he has described his observations in a recent paper in the *Journal.*[15] He found that the cloud rapidly lost its initial sharpness and intensity. There followed widespread but partial obscuration of the markings, the storm apparently spreading round the planet in a westerly direction from *Hellas* in the S hemisphere. A key observation is Falorni's drawing of November 19 (CML 213°), which shows the E half of the disk dusty and the W part clear (see Figure 1F of reference 15). While this type of yellow cloud motion is likely, it must be appreciated that the situation is complicated by the fact that dust activity was also being observed elsewhere at the same time; as already noted, yellow cloud activity was often seen in *Ausonia* and *Eridania* through September to December. It is likely that the storm did not spread far into the N hemisphere for Falorni noted that the N part of the *Syrtis Major* remained unaffected. The affected features such as *Sinus Sabaeus* were by no means obliterated, rather reduced somewhat in intensity.

Falorni rapidly reported his observation of November 8 to the writer, and a BAA *Circular* was issued. As it was nearly the end of the 'Mars Season', most observers had ceased work. However, on November 6 Rogers (200-mm OG, CML 25°) noted in good seeing: 'Contrast seems to be genuinely low'. Rogers and McKim were also observing with the 200-mm OG on November 8, but conditions for them were mediocre. However, on this occasion *Hellas* looked bright in both integrated and yellow light, and in the days following the outbreak McKim had the impression that Mars appeared rather washed-out, with a distinct yellowish tint in the S hemisphere rather than the usual orange tint which was still evident to the north. The outbreak of the storm could not be seen from the USA or Japan, but the OAA could observe the relevant longitudes until November 7, showing that the outbreak did not take place before November 8. Both the ALPO and OAA confirmed the dustiness of *Hellas* in November-December, but did not notice any consistent loss of contrast due to dust elsewhere. On November 16 the outbreak region began to be visible at the evening limb from the USA. Beish drew *Hellas* containing yellow-white cloud on the 16th-19th, with a short W extension over *Hellespontus* on the 16th. On November 23, Beish saw only white cloud in *Hellas.* Quoting Falorni:[15] 'On December 12 ... Mars again showed the regions where the event started. With the exception of the most northerly part of *Syrtis M.,* the whole disk appeared partially and irregularly discoloured; the initial core in *Hellas* was still active and hints of activity were present in *Aeria.* The *Deucalionis-Sabaeus* complex showed the typical belted appearance that characterizes the seasonal change following such dust storm activity' (see Figure 1J of reference 15). Ebisawa," in his 1986 report, noted the obscuration of the southern deserts by dust late in the apparition.

In poor seeing the writer found the markings more distinct from December 20 onwards. More significantly, observations in December to February by Moore, Rogers, and Wilkinson showed all the major surface features well-defined. Thus, in superb seeing on January 29 Moore (CML 248°) wrote: 'There is no sign of dust storm activity anywhere. The main dark areas are much more prominent than they have been over much of the apparition, even with a disk of less than 6 arc sec diameter'.

There was one final *Hellas* outbreak. On 1987 January 31-February 1 Beish (CML ~ 340°) found a yellow cloud in SE *Hellas* extending to the E limb. On February 2 Beish and Parker thought the *Hellas* cloud had moved across *Iapigia* into *Moab.*

A close watch for a global storm was maintained until 1987 June, when the disk diameter fell below 5 arc sec. The principal albedo features could still be detected, and no further dust activity was reported.

Discussion

Falorni advises caution in the interpretation of observations made on the small Martian disk, but he has the advantage of long experience and the use of a large aperture. The storm was not global in extent, and may therefore be classified, as Falorni suggests, as being intermediate in nature between a local dust storm and a planet-encircling event. Its emergence, on 1986 November 8 (L_s = 278°), was somewhat after perihelion, but its development closely followed that of previous storms originating in the *Hellas* basin, such as that of 1971.' The date of emergence compares closely with that of the second global storm witnessed by the *Viking* cameras during 1976-77 (L_S = 275°), and falls midway in season between the commencement dates for the global storms beginning on 1971 September 21 (L_S = 259°) and 1973 October 12 (L_S = 299°). A detailed statistical study of Martian atmospheric phenomena has recently been published by the ALPO, which includes a survey of yellow clouds.[16]

Addition to the 1984 report

In the 1984 BAA report[9] the writer noted that for the period at the end of the apparition, i.e., between 1984 August and 1985 March, the sporadic later observations gave no clear evidence of a major dust storm. Since publication of this report, Dr Ebisawa has kindly sent his report of that apparition,[11] in which he noted that there was a dust storm in the southern hemisphere of the planet only, during October-December, comparable in its evolution with that of 1956. Ebisawa had the advantage of good conditions and a large aperture. It is perhaps notable that neither Ebisawa's 1984 storm nor the 1986 November event were global in extent. Checking again the 1984 BAA data the writer found slight confirmatory evidence that some features were less conspicuous during Ebisawa's storm, but this could not have been deduced from our data alone. The importance of continual, international coverage of Mars is again demonstrated.

Blue Clearings

A strong-to-moderate BC (order 2-3) was seen before and at opposition. Parker submitted a number of prints made by re-photographing his colourslides through a W47 filter; these photos, conforming closely with the telescopic appearance of Mars with this filter, provide evidence for BC phenomena throughout the opposition, at least from April through September. His technique[17] is a promising one, for colourslides can be obtained with short exposure times (3—4 seconds), but W47 photos require exposure times at least eight times longer than this-not very practicable with amateur-sized telescopes. Adcock also obtained useful blue-violet filter photographs using this method.

Complete longitudinal coverage for BC work covers May through October only. BC (of order 1-2) were seen at all longitudes in May, June, July and August, though not all the time (Figures 2, 3, 5B). This applies for the S hemisphere features; only *Mare Acidalium* was available as a large N hemisphere feature for BC detection, but this was also seen in blue-violet light sometimes (from the Pic in July, the writer habitually found it less prominent than the S hemisphere features; the *Tempe* and *Arcadia* deserts were dark in blue-violet light; Figure 5B). Daily variability is well seen in Beish's systematic observations from 1986 April to 1987 February; other useful W47 drawings were made by Marshall and Parker. In September and October the BC seemed less frequent and penetrating. Fragmentary observations to the end of the apparition showed occasional BC continuing, sometimes of order 3.

Clearings of order 3 (when the features in blue-violet light are virtually as intense as in white light) were rare, but several such instances are on record between May and November.

North Polar Region

Very early work by the ALPO beginning 1985 October showed a 'normal' north polar cap (NPC) regression as far as could be seen; the planet was then too distant for fine detail to be detected. Detailed BAA records began in March, by which time the NPH had formed. The NPC was still sporadically visible in April, and a drawing by the late C. F. Capen[8] on April 17 (ω = 330°, L_S = 155°) shows the summer NPC remnant apparently flanked by white clouds.

A bright, variable NPH was seen during most of the apparition, from March through to about October, after which the tilt of the Martian S pole towards Earth was temporarily so high that only a small part of the hood could be seen. When visible, the NPH was bright, often brilliant in blue and violet light, with brighter patches within it. It was invisible in red light. Its size and shape were variable on a daily basis. At opposition, the S edge of the Hood extended nearly up to *Propontis I* on one side of the planet, and up to *Ismenius Lacus* on the other; i.e., up to c. + 40° at opposition.

During July, Dragesco and the writer observed and photographed a brighter area within the NPH just following the longitude of *Mare Acidalium.* There was a concave indentation in the S edge of the NPH just p this bright region; a common phenomenon which has been seen in past apparitions (Figures 2B, E, 5A-C). Sometimes the NPH S edge was displaced toward the equator near the morning limb. In August a temporary southward expansion of the NPH seemed to precipitate dust storm activity in the *Mare Acidalium-Chryse* region (see earlier).

In 1987 the southward tilt of the axis towards the Earth decreased, and the NPR was again shown by the sporadic later observations. A late series of drawings by Haas (till June) shows a large, bright NPR. Haas found this area to be the easiest feature on the tiny (~ 4 arc sec diameter) disk. In December and January it was of variable size and brightness, thus representing the N polar *hood.* Haas considered that he first detected the surface *cap* on February 11, but the NPC was only constantly visible from March 13 (L_S = 350°). For example, on April 5 Haas described the NPC as 'moderately brilliant'.

South Polar Region

Drawings up until early 1986 April show a large, variable south polar hood (SPH) at the south limb. The SPC probably began to show through the hood in April; at this stage, before regression began, no details were seen in the cap. Observing from Tenerife on April 6 McKim (CML 24°, L_S = 150°) found the SPC to be large and bright, and apparently not surrounded by haze. However, the cap was not free from haze at all longitudes for some time; Minami found the cap already clear of haze on the ω = 180° side from L_S = 151°, but the part near *Hellas* was misty up until L_S = 170°, i.e., until mid-May. Ebisawa[12] found the SPH still present on May 4 at CML 285° (L_S = 164°). Beish and Parker also found haze along the N edge of the cap in May, which on some occasions was confined to the morning limb at the cap edge. A general faint shading over the southern half of the SPC was drawn by Minami and Miyazaki in June and July; some authorities consider that this can be interpreted as a remnant of the dull SPH overlying parts of the cap and dissipating southwards. Beish shows a number of dull streaks and patches within the cap in May (Figures 7A, C). Possibly these were also connected with the SPH, for rifts in the cap do not appear until later in the season. On May 29 Beish shows the N edge of the SPC temporarily obscured during yellow cloud activity in *Hellas* (see earlier).

The regression of the SPC has been well observed, and 474 *drawings* submitted by 37 observers were measured. Blue-light drawings were, as usual, excluded. Unlike the NPC, which is always centred on the north aereographical pole, the summer remnant of the south polar cap is located near longitude 40°, latitude 83°. Thus it is not appropriate to construct a regression curve from measurements of the latitude of the N edge of the cap on the CM, as was done with the NPC data for 1980 and 1982. It is more convenient to measure the diameter of the cap in an E-W sense from the drawings, and this has been the procedure in this report. Allowance was made for the fraction of the cap unilluminated on account of phase, in the early part of the apparition. As in previous years, the observations were combined in intervals of 5° in planetocentric longitude, from L_S = 166-300° (1986 May 7-December 14): refer to Figure 10. A total of 49 micrometer measurements of the E-W diameter of the cap was made at the telescope by Beish and Parker, while 28 visual estimates of the cap width by means of an eyepiece reticule were made by H. Cralle of ALPO and communicated by Parker. These data were averaged in 5° intervals in L_S and added to Figure 10. The agreement with the measures from the drawings is excellent, allowing for the slight asymmetry of the cap.

The behaviour of the SPC during 1986 has been compared with the average results obtained by Antoniadi[14] (visual data) and Slipher[18] (visual, micrometric and photographic). It will be seen that the behaviour of the cap in 1988 did not differ greatly from these authorities. The slightly irregular recession shown in the figure is only partly accounted for by the scatter in the measurements of the various observers' drawings. It was very difficult to observe the small residual summer cap after the end of 1986. The cap probably shrank further, but the disk then became too small for detailed observation. Parker was the last to see a definite *cap* on January 30. On February 2 Beish (ω = 297°, L_S = 329°) found the SPR hazy, indicating the beginning of the formation of the SPH. Haas shows a variable white area here in March-June. Earlier, on some occasions in 1986 September-December the SPC N edge did not appear quite sharp, indicating occasional haze or possibly dust obscuration (i.e., Beish, September 22, October 12, November 16-18; Hewitt October 11).

As the cap receded, its dark border became less intense, although darker parts remained. Areas of differing brightness, together with several rifts, developed in the retreating cap. Several indentations appeared in the cap outline from June onwards, and some brighter patches were seen within the cap (such as *Argyre II* on Parker's June 19 photo). *Depressiones Hellesponticae* and one end of the *Rima Australis* rift were well seen by the writer on July 20 *(L_S* = 208°) (Figures 5A, F). It must be remembered that the tilt of Mars' SPR towards Earth at this time was only marginally favourable for the observation of fine SPC details, but conditions improved after early August. *Ulyxis Fretum* entering the cap and several other details are shown by Minami on June 22 (Figure 6E). By July 20 *Novissima Thyle* had become a bright patch inside the cap at its N edge. Cave on September 8 *(L_S* = 240°) was first to notice the beginning of the detachment of this feature, it being separated from the rest of the cap by the dark *Rima Australis.* See Figures 71 and 11. (After separation it is customarily known as the Mountains of Mitchell or *Novus Mons).* Beish was the last to see a small remnant of this bright patch on November 17 (L_S = 284°).

Rima Angus ta was seen at the Pic on July 15 and later (Figures 5A, C). From July 18 the writer noted that *Argenteus Mons* was now a bright area within the cap alongside *Rima Augusta* (Figure 5A). On August 30 Beish showed *Argenteus Mons* projecting from the N edge of the retreating cap, and on September 12 he observed it isolated (Figure 11B). On this occasion he also saw *Thyle II* detached, and *Magna Depressio* as a dark patch lying at the edge of the cap. (The latter feature is usually the first dark patch to be seen in the regressing cap, but as it is situated at high S latitude its apparent absence earlier in 1986 may be due to the unfavourable presentation at the critical season). At the same CML on October 14 Beish found that of these peripheral bright areas, only *Novus Mons* remained.

Combination of the observations by longitude rather than by time, together with additional measurements with graticules resulted in the polar plots shown here (Figure 12). For this work, it was necessary to measure the latitude of the N edge of the cap on the CM of each drawing. These latitude data were combined in 'bins' of 20° or more in CM longitude, using drawings made within a restricted time interval. The period L_S = 171-210° (May 16-July 23) represents an almost static cap (Figure 12A). To obtain enough datapoints to cover all longitudes one needs a moderate time interval; for a static cap this presents no difficulty, but with the regressing cap the results are less satisfactory due to latitude variations during the L_S interval. Figure 12B also shows the *outline only* of the cap during L_S = 211-250° (July 24-September 25), together with a polar map for L_S = 251-290° (September 26-November 28). 199, 178 and 84 observations, respectively, were used for these plots. They show tolerably well the various features observed, and the asymmetry of the summer cap. Those interested should compare them with the historical results of Antoniadi,[14] Dollfus (1956),[19] Fournier,[20] and others. The 1988 apparition will give the best opportunity in the present cycle of perihelic oppositions for studying the summer SPC.

Discussion

Compared with average regression curves[14,18] in the literature, the SPC behaved normally in 1986, although it is notable that the agreement is closer to Antoniadi than to Slipher, and that the visual curve is systematically *slightly* below each average curve from *c.* L_S 210 to 250°. There has been much discussion in the literature about the differences between successive seasonal cycles of the Martian polar caps. The writer found no evidence for change in the behaviour of the *north* cap from BAA data for 1980 and 82 on comparison with the work of Dollfus for 1946-52. However, there is increasing evidence for change in the behaviour of the SPC. In making comparisons with the literature one must be careful only to compare observations which have been reduced in the same manner, which therefore have similar systematic errors. That is, a number of photographic regression curves may be confidently compared with each other, but less certainly with micrometric or visual data.

Slipher found no evidence that the SPC regression in one apparition differed measurably from any other from an analysis of a limited number of apparitions between 1798 and 1924. Antoniadi[14] found differences between successive apparitions which he thought correlated with the solar cycle. The OAA[21] and de Vaucouleurs[22] have also considered the question of variability. Evidence for *small* changes in the seasonal cycles comes from *Viking* data. As James *et al.* note,[23] spacecraft data for 1971 and 1977 at the same season show small differences in SPC boundaries. They have shown that observable differences in the regression may occur during the rapid phase of evaporation, and stress that in the case of the asymmetric south cap it is important to compare regression data for different apparitions with careful reference to the CM longitude. Thus Iwasaki *et al.* have recently published their 1986 photographic SPC data in a series of polar stereographic projections.[24] These confirm that differences between successive Martian years are most apparent at about L_S = 240-250°. The short, relatively hot southern Martian summer, suggests James *et al.,* may be a better indicator of climatic variations than that of the northern hemisphere.

Conclusions

The main features of the 1986 apparition were:

1. *Nepenthes* and the E part of *Sinus Sabaeus* continued to be faint; *Deltoton Sinus* was only partly visible. There was a dark streak across the *Noachis* desert from *Mare Serpentis* to *Mare Erythraeum. Pandorae Fretum* was seasonally faint for most of the apparition.
2. *Solis Lacus* was unusually large and dark, while *Phasis* was very prominent after years of obscurity. *Nilokeras, Ganges, Achillis Fans* and *Idaeus Fons* were also dark and prominent.
3. The visibility of *Cerberus III* altered the appearance of *Hesperia.* The *Aetheria* darkening continued to be visible on the NW border of *Elysium.* The W end of *Mare Sirenum* had faded.
4. White cloud seasonal activity was normal.
5. An extensive though not constant Blue Clearing was observed.
6. Pre-perihelic *local* dust storm activity commenced in May, and *Hellas* was dusty in May (from L_S = 178°) and from August onwards. There was no *global* storm, but the initiation of a storm intermediate between a local and a global event was observed in November (L_{Svvv} = 278°) in NW *Hellas.*
8. The clearance of the SPH commenced at about L_s = 150°. The seasonal behaviour of the SPC was quite normal; several rifts and detached bright portions were observed, with the SPH reforming at about L_s = 329°.
9. The NPH was very variable in appearance, and the NPC was invisible for most of the apparition.

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Address: 5 Ashton Road, Oundle, Peterborough PE8 4BY.

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Photographing the occultation, continued from page 214

the star clearly but short enough to avoid the image of Saturn spreading over that of the star. It was decided that 5-second exposures at 30-second intervals might do the trick.

Having aligned the telescope and astrograph on Saturn, two difficulties were at once revealed. A Forsythia bush had, while I was not looking, surreptitiously grown at least a metre in height, and Saturn was only fitfully visible through its fronds. A brisk sortie with the secateurs soon settled that problem. The other trouble was that, because of the low altitude, the shutter knob of the astrograph was eight feet above the floor, making it necessary for me to perch precariously on a stool during the entire operation.

First, the instrument was set, using a ground glass screen, so that the image of Saturn was at the edge of the field - taking care that it was not the wrong edge. Then the drive was switched on, the film-holder loaded and all was ready in a few seconds before the planned time of 22:30. The sequence was to open the shutter for 5 seconds, close it, switch off the drive for about 20 seconds, switch it on again and, on the minute or half-minute, make the next exposure. This was repeated 41 times until 22:50. Two factors were responsible for imperfections in the final result. First, the undriven intervals were not precisely equal, causing slight variations in the spacing of the pairs of images, of no great consequence. More seriously, Spode (alias Murphy) was at large and, after 15 exposures, the shutter, which is a manually operated leaf in front of the focal plane, developed rheumatism and became so stiff to move that doing so disturbed the astrograph slightly with corresponding distortion of the images. Happily, after four further exposures and some verbal encouragement, the trouble righted itself and the remaining and more important exposures were passably good.

On the negative, faint remanent images of Titan are visible, but they have been suppressed by the deep printing adopted to give high contrast and sharp definition.

H. B. Ridley