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Red and reddened stars in the region of Cygnus OB2 (VI Cygni) association*

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Abstract. — From an ultra-low dispersion spectroscopic survey of the Cyg OB2 association several red and reddened stars are detected. Most of these stars appear to be reddened early-type stars belonging to the Cygnus OB2 association. The distance moduli $V_0 - M_v = 11.2$ and minimum reddening $E(B-V) = 1.2$ suggests that some of the red stars in the magnitude range 15 to 17 are most likely reddened late B and early A main sequence stars of the Cyg OB2 association.

Key words: stars: classification — associations: Cyg OB2 — dust, extinction

1. Introduction

The Cygnus OB2 association (Cygnus II, VI Cygni) was found by Münch & Morgan (1953). This association contains a group of very luminous and highly reddened ($A_v \sim$ 4−10 mag) stars. It is very young, with members of spectral type as early as O3 (Walborn 1973). Initially eleven OB stars were found by Münch & Morgan (1953). A further seven fainter OB stars were found by Morgan et al. (1954) using the technique of spectral classification by very low dispersion objective prism spectra. This technique was again applied to detect the OB stars in this region by Schulte (1956a, b & 1958) who found ten more early type stars and a total of 88 suspected OB stars. Reddish et al. (1967) made *UBV* photographic photometry of about 1600 stars in the region of Cygnus OB2 association. They found more than 300 OB stars which are likely members of the association. They also estimate that there are 900 stars brighter than $m_{\rm pg} = 21$ and 3000 brighter than $m_r = 20$.

Recently Torres-Dodgen et al. (1991) obtained *uvby* and *JHK* photometry of 80 stars . They found the ratio of total to selective extinction to be $R_v = 3.04$ and true distance modulus of $V_0 - M_v = 11.2$ corresponding to a distance $d = 1.7$ kpc. More recently Massey & Thompson (1991) studied this association using CCD, *UBV* photometry and spectroscopy. They conclude that the star formation in Cyg OB2 association is not strictly coeval and the initial mass function (IMF) is considerably flatter (IMF slope of $\tau = -1.0$) than that previously found for massive stars in the Galaxy. Recently from an analysis of IRAS data Parthasarathy, Jain & Bhatt (1992) detected several possible young stellar objects (YSOs) in the region of Cygnus OB2 association.

This association is very young. Its age is estimated to be 3 million years (Torres-Dodgen et al. 1991). Detection of fainter red and reddened stars in OB associations is of considerable importance for proper understanding of their initial mass function (IMF), stellar luminosity function (SLF) and star formation history etc. Morgan et al. (1954) showed that very faint reddened early-type stars and red stars could be detected on 103aF plates at a dispersion of the order of 30,000 Å mm $^{-1}$. Subsequent work by Schulte (1956a, b) identified several reddened O-B stars of Cyg OB2 association from very low dispersion (10,000 Å mm^{-1}) objective prism spectra. This technique requires construction of prisms of very small angle (Bidelman 1972). This ultra low dispersion or micro spectra technique was developed at the Kavalur observatory and was successfully employed to detect red and blue stars and to carry out approximate spectral classification (Bappu & Parthasarathy 1977; Parthasarathy 1978). Bappu & Parthasarathy (1977) and Bappu, Parthasarathy & Scaria (1977, 1978, 1985) used this ultra-low dispersion technique and detected several very red stars (M supergiants and carbon stars) in the Large Magellanic Cloud (LMC).

In this paper we report the detection of several red and reddened stars in the Cyg OB2 association region using the ultra-low dispersion spectra.

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*Table 1 is also available electronically at the CDS via anonymous ftp 130.79.128.5

[†] Deceased on 17th November 1994

2. The technique and observations

The instrument (Bappu & Parthasarathy 1977) used is an $f/2$ slitless spectrograph with a three degree quartz prism and a Schmidt camera at the Cassegrain focus of the 1-meter Ritchey-Chretien reflector at the Vainu Bappu Observatory (VBO), Kavalur. The field is 40′ in diameter. Spectra covering the wavelength range 3500 Å to 6600 Å were obtained on Kodak 103 (a-E) emulsion. The dispersion is 10,000 Å mm^{-1}. The spectra are unwidened and are about 250 μ in length along the dispersion (Bappu & Parthasarathy 1977). With this setup ultra-low dispersion spectra of all the stars within the 40′ field can be recorded in one exposure.

3. Classification

The principal criterion for classification is the shape of the stellar spectrum and also the density in different portions of the image. The ultra- low dispersion spectra of B, A, F, G, K, M stars are shown in Fig. 1. The ultra- low dispersion spectrum of an O type star is not shown in Fig. 1. Unreddened O -type stars are rare and the O - type stars in the region of Cyg OB2 are all significantly reddened. The least reddened OB stars in Cyg OB2 show $E(B-V)=1.2$ (Torres-Dodgen et al. 1991; Massey & Thompson 1991). The method of classification was described by Bappu & Parthasarathy (1977), and Parthasarathy (1978). From Fig. 1 it is clear that one can easily distinguish O-B stars and very red stars. The discontinuity in the spectrum is due to the dip in the sensitivity of the 103 a-E emulsion in the green region which serves as a wavelength reference to distinguish the blue region of the spectrum from the red region. For example notice the differences in the spectra of B star and K or M star shown in Fig. 1. But by far the easiest application of the ultra-low dispersion technique is in the detection of faint red stars and faint blue stars, both of which are of much interest. The Cyg OB2 association is one of the most heavily reddened regions with a minimum reddening of $E(B-V)>1.2$ (Massey & Thompson 1991; Torres - Dodgen et al. 1991). The ultra low dispersion spectra of the most heavily reddened stars in Cyg OB2 association shows no extension of the spectrum shortward of the green region.

4. Results

We have used the spectral types and colours of Cyg OB2 stars determined earlier by Schulte (1956a, b), Reddish et al. (1967), Leitherer et al. (1982), Torres-Dodgen et al. (1991), Massey & Thompson (1991) to compare and calibrate our classification. We have detected a number of new red and reddened stars in Cyg OB2 association. These are shown in Figs. 2 to 7 and are listed in Table 1. In Table 1 the first column is our identification number, the second column is the number of the star in the paper of Reddish et al. (1967). The number in the parenthesis in the second column gives the field number in the paper of Reddish et al. (1967). If the second column is "NI" it indicates that it is a new identification and the star is not listed in the catalogue of Reddish et al. (1967). Reddish et al. (1967) have obtained UBV photometry of several stars brighter than 16.5 magnitude. Stars which are cross identified with Reddish et al. numbers, their V and $B-V$ values are given in Cols. 3 and 4 respectively (Table 1). Using Reddish et al. photometry & Palomar Sky Survey Charts we have estimated the magnitudes of newly identified stars ("NI" Col. 2 of Table 1). The upper limit of uncertainty in the estimated magnitudes is of the order of ± $0\overset{\mathrm{m}}{.}5$. The location of the stars in Figs. 2 to 7 is indicated in the 5 th column of Table 1. A few of the stars listed in Table 1 are also in the list of Massey & Thompson (1991). We have cross identified with Massey & Thompson (1991) numbers and they are given in the last column of Table 1.

The observed ultra-low dispersion spectra of the stars (Figs. 2 to 7) suggest that most of the stars are reddened early-type stars belonging to the Cyg OB2 association. (see Reddish et al. 1967; Torres-Dodgen et al. 1990; Massey & Thompson 1991).

The ultra-low dispersion spectroscopy very easily permits detection of early-type stars and very late-type stars as most of the flux in the former case is in the blue region and in the latter case it is in the red region. In the tadpole like appearance of the ultra-low dispersion spectrum the tail portion (blue region) is relatively longer and prominent in the case of hot stars, and in the case of cool stars the head portion (the red region) is prominent and the tail length is relatively shorter. However there is some amount of uncertainty in the separation of reddened early-type stars from G-type giants and K-type dwarfs. In the Cyg OB2 region we have identified many red or reddened stars down to 16.5 magnitude (Table 1, Figs. 2 to 7).

Figures 2 to 7 indicate the presence of several fainter red stars (fainter than 16.5 magnitude) which we have not listed in Table 1. Some of these stars may be low-luminosity and /or lower main sequence members of the Cyg OB2 association or heavily reddened early-type stars.

We find several red stars in the magnitude range 15 to 17. Using the distance moduli $V_0-M_v=11.2$ and minimum reddening $E(B-V)=1.2$ we find that the 15 to 17 magnitude stars in the Cyg OB2 have M_v in the range 0.2 to 2.2 indicating that they are most likely reddened late B and early A main- sequence stars. Reddish et al. (1967) found a major concentration of points at $V=15.7$ and $B-V=0.9$ and $U-B=0.6$. They have argued that these are reddened late B and early A stars belonging to the association. Our survey also indicates the presence of many fainter red stars in the region of Cyg OB2. Reddish et al. (1967) estimated that there are 900 stars brighter than $m_{\mathrm{pg}}=21$ and 3000 brighter than $m_r=20$. They find

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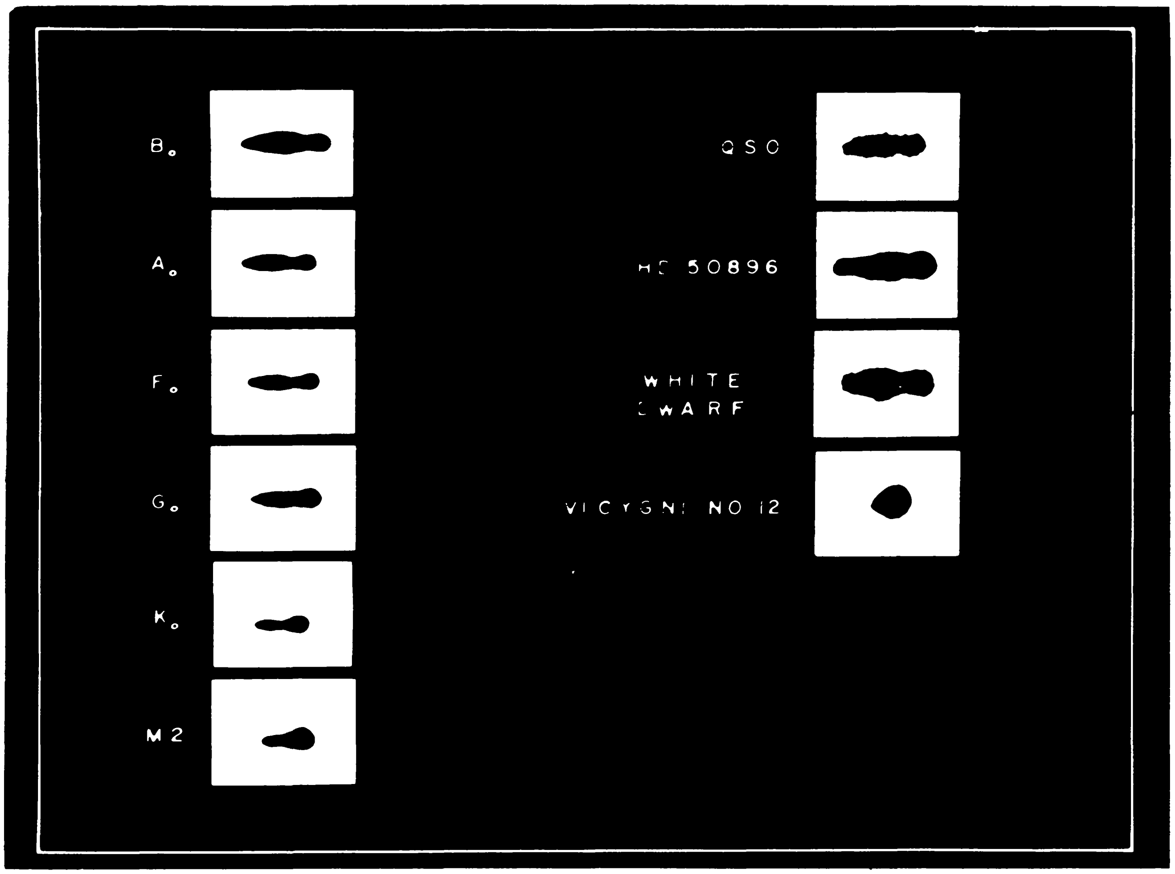


Fig. 1. The ultra-low dispersion (10,000 Å/mm) spectra of stars of different spectral types. The longer wavelength is to the right. The discontinuity in the spectrum is due to the dip in the sensitivity of the 103a-E emulsion in the green region

that the association stands out markedly from the field star fluctuations for all magnitudes fainter than $m = 13$. They also find the ratio of red stars to blue stars to be 3.43 indicating that the association contains more than the average number of stars with large colour indices. If we use the minimum reddening $E(B-V)$ =1.2 and the distance moduli $V_0 - M_v = 11.2$ the fainter red stars ($m_{\rm pg} = 21$ or $m_r = 20$) are found to have M_v around +6.2 indicating that they may be K type dwarfs. However it is not possible to conclude with any certainty whether the large number of fainter stars are late type main sequence stars or highly reddened OB stars or they may be pre-main sequence stars with large positive $B-V$ values $(B-V) \approx 3$. The CCD *UBVRI* photometry down to 22nd magnitude may further enable us to understand the nature of these stars.

5. Conclusions

We have detected many red and reddened stars in the Cyg OB2 association using the ultra-low dispersion spectra. Since Cyg OB2 association stars show moderate to heavy reddening, $E(B-V)$ ranging from 1 to 3.25 (Torres-dodgen et al. 1991; Massey & Thompson 1991), we conclude that several of the red stars that we find in our survey (Figs. 2 to 7, Table 1) are most likely reddened early-type stars and some of the fainter red stars may be late type pre-main-sequence stars or heavily reddened early-type stars of the Cyg OB2 association.

References

Bappu M.K.V., Parthasarathy M. 1977, Kodaikanal Obs. Bull. 2, 1
Bappu M.K.V., Parthasarathy M., Scaria K.K. 1977, Kodaikanal Obs. Bull. 2, 85
Bappu M.K.V., Parthasarathy M., Scaria K.K. 1978, Kodaikanal Obs. Bull. 2, 184
Bappu M.K.V., Parthasarathy M., Scaria K.K. 1985, Kodaikanal Obs. Bull. 5, 1
Bidelman W.P. 1972, in "The role of Schmidt telescopes in astronomy" ed. U. Haug (ESO, SRC) p. 53
Leitherer C., Hefele H., Stahl O., Wolf B. 1982, A&A 108, 102
Massey P., Thompson A.B. 1991, AJ 101, 1408
Munch L., Morgan W.W. 1953, ApJ 118, 161
Morgan W.W., Meinel A.B., Johnson H.M. 1954, ApJ 120, 506
Parthasarathy M. 1978, in "The HR Diagram" IAU Symp. 80 (D. Reidel) 25

Parthasarathy M., Jain S.K. 1989, in "Interstellar Dust" IAU Symp.135, Contributed papers, NASA Conf. Pub. 3036, p. 211
Parthasarathy M., Jain, S.K., Bhatt H.C. 1992, A&A 266, 202
Reddish V.C., Lawrence L.C., Pratt N.M. 1967, Publ. Roy. Obs. Edinburgh 5, 111
Schulte D.H. 1956a, ApJ 123, 250
Schulte D.H. 1956b, ApJ 124, 530
Schulte D.H. 1958, ApJ 128, 41
Torres-Dodgen A.V., Tapia M., Carroll M. 1991, MNRAS 249, 1

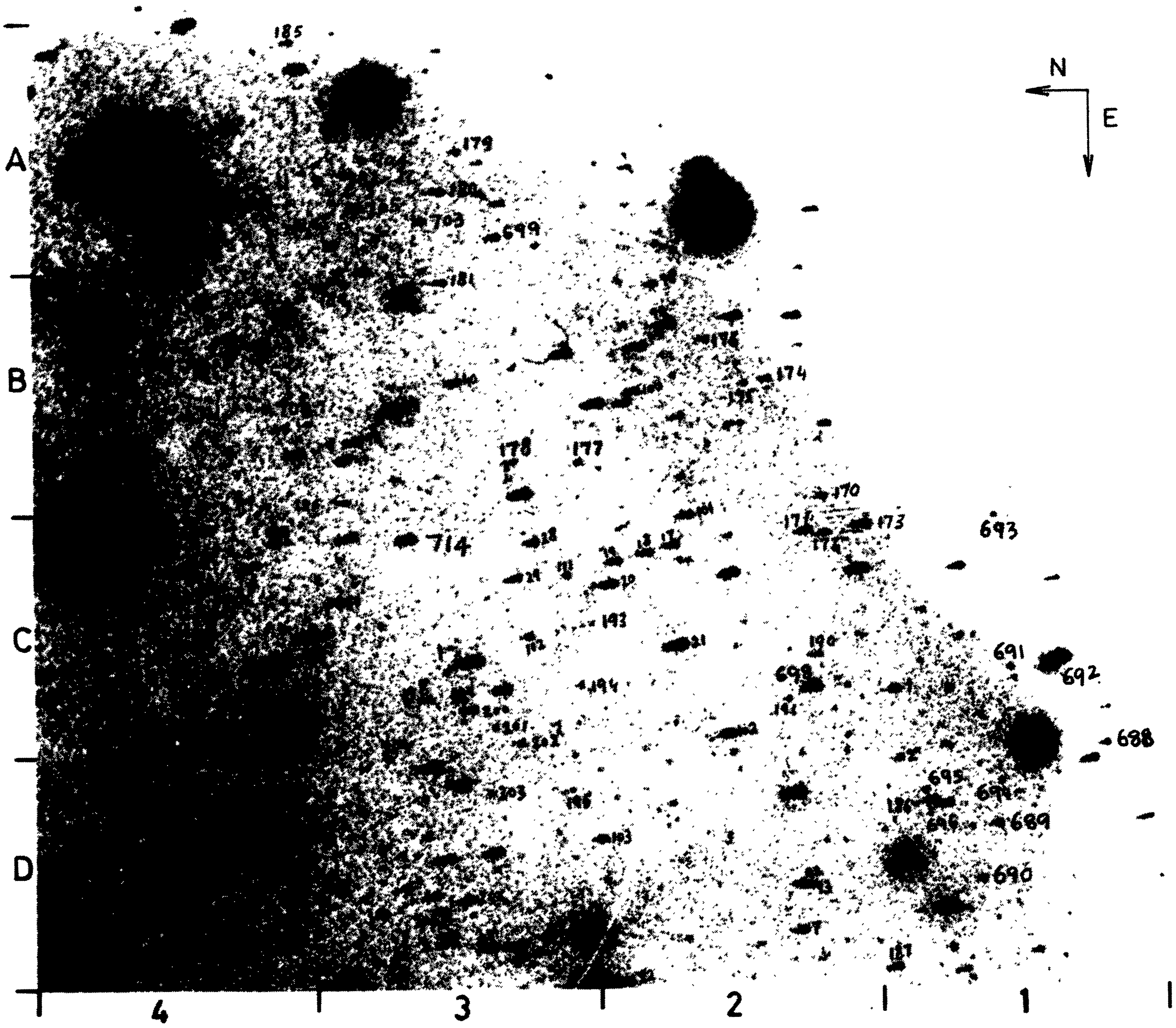


Fig. 2. The ultra-low dispersion spectra of stars in the region of Cygnus OB2 (VI Cygni) association. North is towards left and east is down. The scale is 6.″8/mm. The reddened and red stars are listed in Table 1

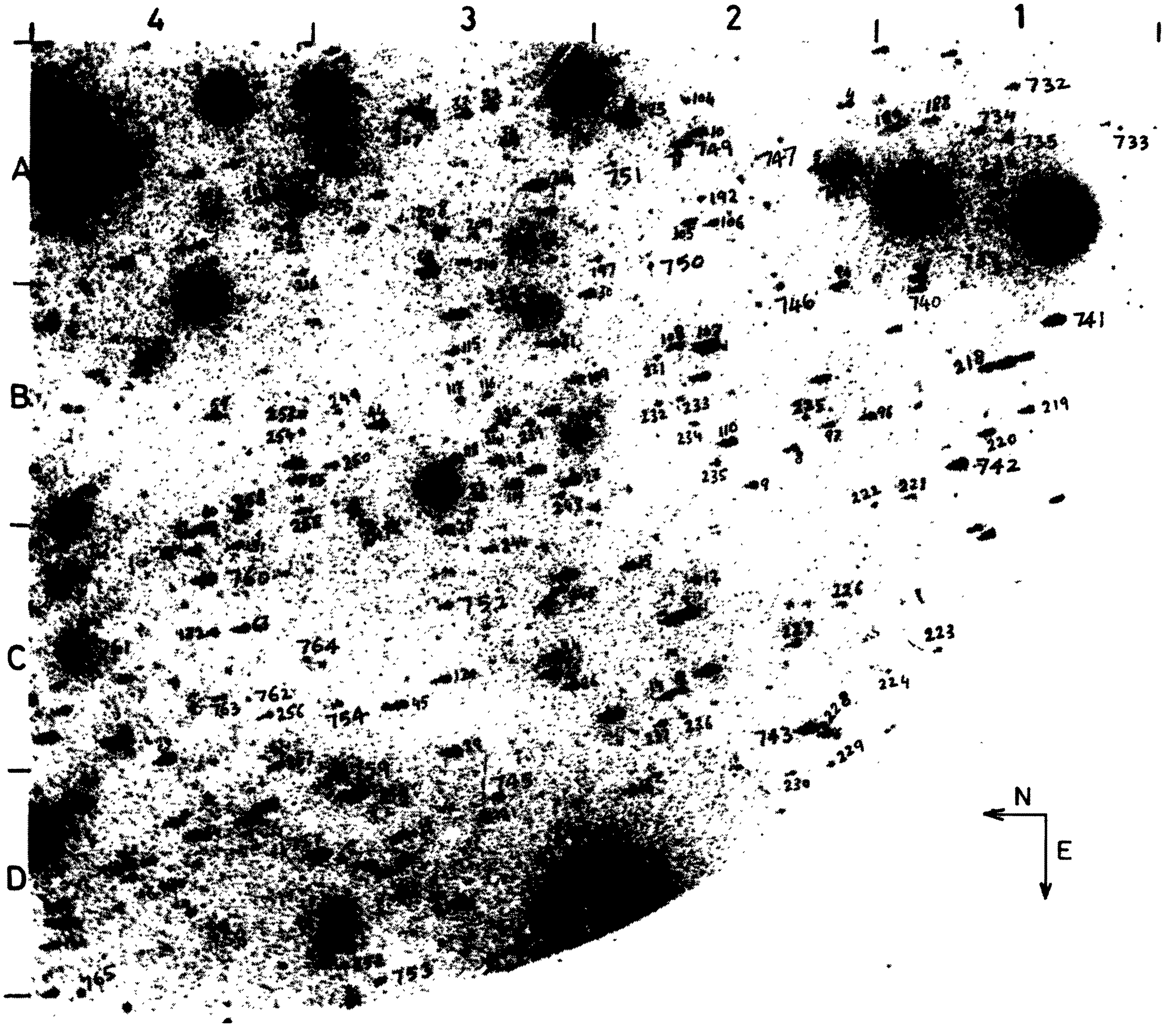
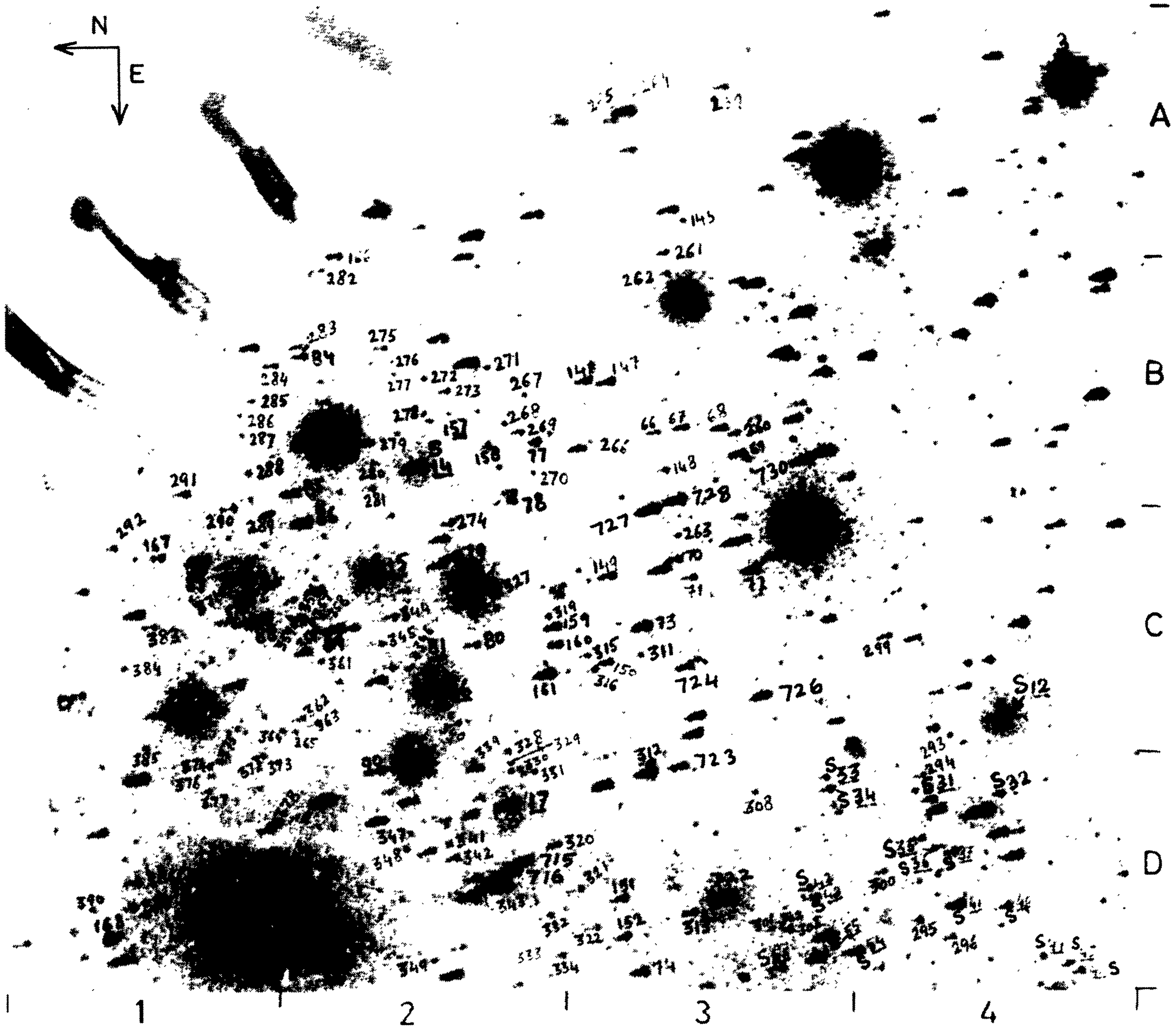


Fig. 3. Same as Fig. 2 caption



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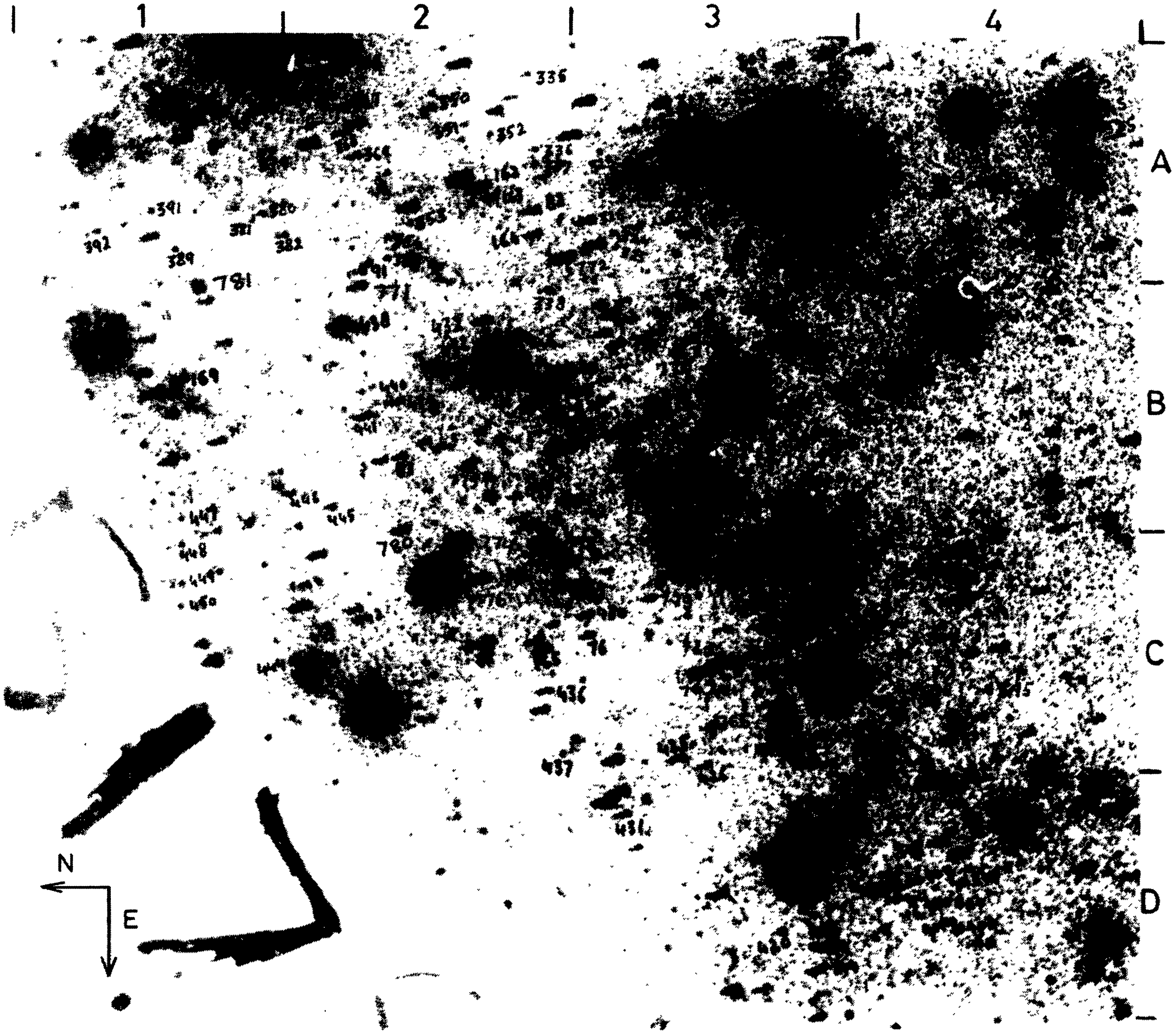

Fig. 5. Same as Fig. 2 caption

Fig. 6. Same as Fig. 2 caption

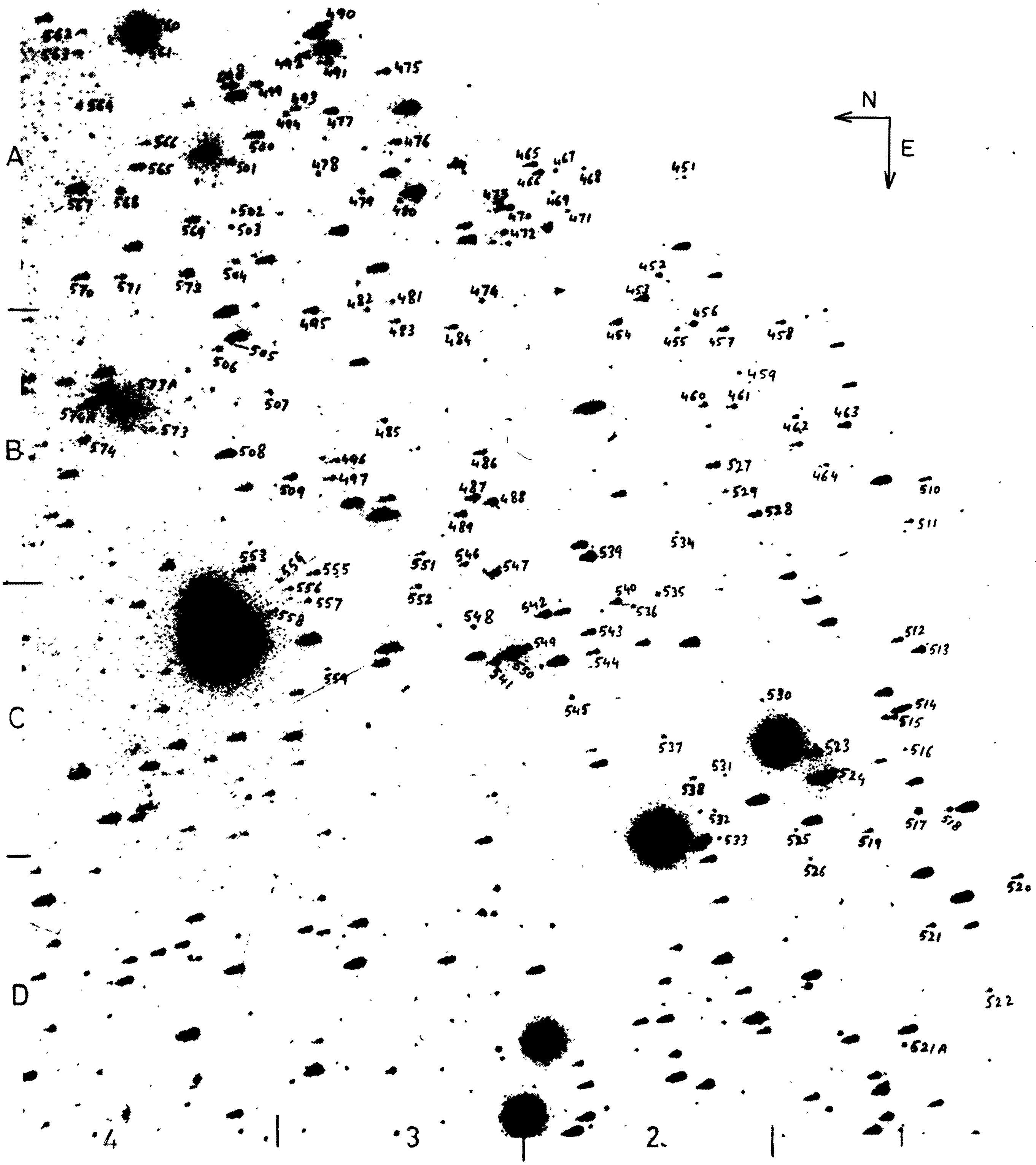

Fig. 7. Same as Fig. 2 caption

Table 1. Red and reddened stars in the region of Cygnus OB2 (VI Cygni) association

S.No	Reddish et al. (1967)	m	B-V	Grid Id Fig.no./grid	Massey and Thompson (1991)
1	987 (9)	15.33	1.17	II.C.1	
2	NI	16		II.D.1	
3	NI	14		II.D.1	
4	1013 (9)	15.36	1.03	III.A.2	
5	1014 (9)	15.47	1.03	III.A.2	
6	1071 (8)	15.21	1.22	III.C.2	
7	994 (9)	15.04	1.46	II.D.2	
8	1049 (9)	15.49	0.97	III.B.2	
9	1048 (9)	15.55	1.05	III.B.2	
10	1016 (9)	14.66	0.95	III.A.2	439
11	1017 (9)	15.65	0.95	III.A.2	
12	1073 (8)	15.56	1.04	III.C.2	
13	NI	16		III.C.2	
14	1077 (8)	15.38	1.12	III.C.2	
15	816 (9)	15.17	1.32	III.C.2	
16	1079 (8)	15.22	1.28	III.D.2	
17	895 (9)	15.40	0.89	II.C.2	
18	896 (9)	15.40	1.00	II.C.2	
19	897 (9)	15.51	0.98	II.C.2	
20	898 (9)	14.83	0.69	II.C.2	
21	893 (9)	12.73	1.03	II.C.2	
22	869 (9)	15.39	0.94	II.D.2	
23	NI	16		III.A.2	
24	815 (8)	13.71	1.76	III.C.3	712
25	814 (8)	13.46	2.00	III.C.3	720
26	813 (8)	15.15	1.35	III.C.3	
27	832 (9)	13.92	1.53	III.B.3	635
28	905 (9)	15.39	1.21	II.C.3	
29	904 (9)	15.46	1.04	II.C.3	
30	837 (9)	15.02	1.58	III.B.3	
31	836 (9)	14.87	1.63	III.B.3	568
32	864 (9)	15.32	1.28	III.A.3	
33	863 (9)	14.71	1.79	III.A.3	435
34	865 (9)	15.48	0.91	III.A.3	
35	844 (9)	13.26	0.86	III.A.3	479
36	841 (9)	11.88	2.11	III.A.3	516
37	829 (9)	15.53	1.07	III.B.3	
38	820 (9)	15.04	0.86	II.D.4	659
39	809 (8)	15.01	0.86	III.C.3	
40	NI	15.5		II.B.3	
41	861 (9)	15.65	0.75	III.A.3	
42	862 (9)	15.00	0.78	III.A.3	
43	840 (9)	12.98	1.88	III.A.3	534
44	826 (9)	13.92	1.63	III.B.3	620
45	810 (8)	14.94	1.10	III.C.3	
46	915 (10)	15.10	1.05	II.B.3	
47	916 (10)	12.70	0.83	II.B.3	
48	917 (10)	15.44	0.90	II.B.3	
49	918 (10)	15.47	1.03	II.B.3	
50	901 (9)	15.22	1.11	II.C.3	
51	887 (9)	13.02	2.28	II.C.3	267
52	886 (9)	15.23	1.27	II.C.4	282
53	652 (9)	15.48	1.12	II.C.4	
54	850 (9)	14.47	1.86	III.A.3	477
55	823 (9)	14.65	1.73	III.B.4	645
56	800 (8)	15.41	0.78	III.D.3	
57	NI	15		II.C.4	
58	670 (9)	15.56	0.78	II.C.4	
59	742 (9)	15.03	1.37	III.B.4	621
60	743 (9)	13.55	0.76	III.C.4	663
61	744 (9)	15.43	1.07	III.C.4	
62	745 (9)	15.35	1.25	III.C.4	
63	821 (9)	15.41	0.97	III.C.4	
64	763 (8)	15.37	1.05	III.D.4	
65	NI	16		V.A.3	
66	621 (7)	15.58	0.92	IV.B.3	515
67	622 (7)	15.41	0.90	IV.B.3	
68	623 (7)	15.43	0.89	IV.B.3	
69	624 (7)	14.9	1.39	IV.B.3	222
70	635 (6)	15.52	0.98	IV.C.3	
71	634 (6)	15.65	0.85	IV.C.3	
72	631 (6)	14.24	1.37	IV.C.3	252
73	637 (6)	13.21	1.58	IV.C.3	270
74	677 (6)	14.35	1.57	IV.D.3	428
75	722 (6)	14.90	1.36	V.B.3	576
76	777 (5)	15.61	0.89	V.C.3	
77	521 (7)	15.40	1.08	IV.B.2	
78	519 (6)	15.21		IV.B.2	
79	516 (6)	13.40	1.18	IV.C.2	248
80	513 (6)	15.47	1.03	IV.C.2	
81	493 (6)	15.53	0.93	IV.C.2	
82	435 (6)	15.24	1.24	V.A.2	
83	421 (6)	15.41	1.09	V.B.2	
84	542 (7)	14.93	1.15	IV.B.2	
85	528 (7)	15.01	0.65	IV.B.2	232
86	530 (7)	13.88	0.70	IV.B.2	241
87	499 (6)	15.48	1.01	IV.C.1	
88	503 (6)	12.40	0.59	IV.C.1	269
89	507 (6)	13.54	0.96	IV.C.2	275
90	474 (6)	14.37	1.37	IV.D.2	
91	440 (6)	15.44	1.06	V.A.2	
92	992 (9)	15.62	0.88	II.D.2	
93	993 (9)	15.55	1.05	II.D.2	
94	1044 (9)	15.28	1.06	III.A.2	
95	1043 (9)	14.51	1.97	III.A.1	
96	1051 (9)	15.36	1.06	III.B.2	
97	1050 (9)	15.59	0.91	III.B.2	
98	960 (10)	15.39	1.21	II.B.2	
99	961 (10)	14.15	1.90	II.B.2	
100	910 (10)	15.40	0.96	II.B.2	
101	894 (9)	15.18	0.90	II.C.2	
102	990 (9)	14.53	1.39	II.C.2	
103	892 (9)	15.28	1.32	II.D.2	
104	NI	16		III.A.2	
105	1018 (9)	15.48	1.02	III.A.2	
106	1019 (9)	15.67	0.93	III.A.2	
107	1022 (9)	12.40	1.36	III.B.2	563
108	1020 (9)	15.52	0.93	III.B.2	
109	835 (9)	15.28	1.20	III.B.3	
110	1047 (9)	14.91	1.00	III.B.2	
111	NI	15.5		II.C.3	
112	NI	15		II.C.3	
113	875 (9)	15.01	0.96	II.D.3	
114	873 (9)	15.52	1.08	II.D.3	
115	NI	15.5		III.B.3	

Table 1. continued

S.No	Reddish et al. (1967)	m	B-V	Grid Id Fig.no./grid	Massey and Thompson (1991)
116	NI	16.5		III.B.3	
117	NI	16		III.B.3	
118	828 (9)	15.48	1.12	III.B.3	
119	830 (9)	14.44	1.58	III.B.3	639
120	811 (8)	15.46	1.04	III.C.3	
121	808 (8)	15.47	1.13	III.D.3	
122	807 (8)	14.96	0.86	III.D.3	
123	599 (10)	15.32	1.10	II.A.4	
124	NI	13		II.B.4	
125	600 (10)	13.97	2.02	II.B.4	
126	NI	15.5		II.C.4	
127	881 (9)	15.63	0.87	II.D.4	
128	853 (9)	13.68	2.11	III.A.3	448
129	852 (9)	12.95	1.72	III.A.3	
130	702 (9)	12.77	2.39	III.A.4	512
131	822 (9)	15.68	0.92	III.C.4	
132	747 (9)	15.49	1.11	III.C.4	
133	606 (7)	12.70	1.46	II.B.4	
134	605 (7)	15.53	0.96	II.B.4	
135	603 (7)	14.02	1.93	II.B.4	
136	651 (9)	14.97	0.88	II.C.4	
137	NI (9)	15		II.D.4	
138	665 (9)	14.19	1.48	V.A.3	
139	710 (6)	12.74	1.49	III.A.4	
140	709 (6)	13.36	1.02	III.A.4	
141	751 (6)	12.23	1.12	V.C.3	674
142	749 (6)	12.02		V.C.3	
143	755 (6)	15.69	0.91	V.C.3	708
144	790 (5)	15.53	0.96	III.D.4	
145	612 (7)	15.67	0.83	IV.A.3	
146	616 (7)	14.69	1.41	IV.B.3	
147	615 (7)	14.46	1.35	IV.B.3	202
148	620 (7)	15.65	0.95	IV.B.3	
149	638 (6)	14.82	1.38	IV.C.3	255
150	641 (6)	15.50	1.00	IV.C.3	
151	673 (6)	15.47	1.13	IV.D.3	
152	676 (6)	15.14	1.34	IV.D.3	409
153	682 (6)	13.78	1.41	V.A.3	517
154	721 (6)	14.56	1.24	V.B.3	554
155	719 (6)	13.97	1.50	V.B.3	573
156	734 (6)	15.48	0.84	V.B.3	
157	524 (7)	15.28	1.03	IV.B.2	
158	523 (7)	15.62	0.98	IV.B.2	
159	639 (6)	14.68	1.49	IV.C.2	271
160	640 (6)	15.47	1.03	IV.C.2	
161	492 (6)	13.14	1.55	IV.C.2	292
162	437 (6)	14.31	0.85	V.A.2	
163	436 (6)	15.38	0.94	V.A.2	
164	434 (6)	15.11	1.10	V.A.2	
165	398 (6)	15.42	0.89	V.C.2	
166	554 (7)	13.92	1.07	IV.A.2	166
167	498 (6)	15.69	0.91	IV.C.1	
168	269 (6)	14.97	1.63	IV.D.1	
169	416 (6)	13.99	1.54	V.B.1	
170	NI	16		II.B.2	
171	NI	15.5		II.C.2	
172	971 (10)	15.44	0.84	II.C.2	
173	970 (10)	14.24	1.14	II.C.2	
174	NI	16		II.B.2	
175	NI	16		II.B.2	
176	962 (10)	15.67		II.B.2	
177	NI	16		II.B.3	
178	907 (10)	15.69	0.91	II.B.3	
179	NI	16		II.A.3	
180	NI	15.5		II.A.3	
181	NI	16		II.B.3	
182	NI	14.5		II.A.3	
183	NI	15		II.A.3	
184	NI	15		II.B.3	
185	NI	15.5		II.A.4	
186	NI	16.5		II.D.1	
187	1012 (9)	15.54	0.92	II.D.1	
188	1025 (9)	15.55	0.95	III.A.1	
189	1024 (9)	15.61	0.89	III.A.1	
190	988 (9)	15.66		II.C.2	
191	NI	16		II.C.2	
192	NI	15.5		III.A.2	
193	NI	17		II.C.3	
194	NI	16.5		II.C.3	
195	NI	16.5		II.D.3	
196	866 (9)	15.38	1.03	III.A.3	
197	837 (9)	15.02	1.58	III.A.2	
198	NI	16		II.C.3	
199	NI	16		II.C.3	
200	NI	16		II.C.3	
201	NI	16		II.C.3	
202	NI	16		II.C.3	
203	NI	16		II.D.3	
204	NI	16.5		II.D.3	
205	NI	16		II.D.3	
206	877 (9)	15.55	0.90	II.D.3	
207	860 (9)	15.30	1.03	III.A.3	
208	NI	16		III.A.3	
209	NI	16		III.A.3	
210	NI	16		III.A.3	
211	659 (9)	15.56	1.04	II.C.4	
212	NI	16		II.D.3	
213	NI	16.5		II.D.4	
214	NI	15.5		III.A.4	
215	848 (9)	15.55	0.93	III.A.4	
216	NI	16		III.A.4	
217	662 (9)	15.60	1.00	II.D.4	
218	1041 (9)	15.54	0.96	III.B.1	
219	1054 (9)	14.76	1.30	III.B.1	
220	1053 (9)	15.16	0.91	III.B.1	
221	NI	16		III.B.1	
222	NI	16		III.B.1	
223	NI	16		III.C.1	
224	NI	16		III.C.1	
225	NI	16		III.B.2	
226	NI	16.5		III.C.2	
227	NI	15.5		III.C.2	
228	NI	15.5		III.C.2	
229	1070 (8)	15.69	0.91	III.C.2	
230	NI	16		III.D.2	

Table 1. continued

S.No	Reddish et al. (1967)	m	B−V	Grid Id Fig.no./grid	Massey and Thompson (1991)
231	NI	16		III.B.2	
232	NI	14.87	0.82	III.B.2	85
233	NI	16		III.B.2	
234	NI	16		III.B.2	
235	NI	16		III.B.2	
236	NI	16		III.C.2	
237	1078 (8)	15.53	1.07	III.C.2	
238	NI	16		III.B.3	
239	NI	15.5		III.B.3	
240	NI	15.5		III.B.3	
241	NI	13.41	1.13	III.B.3	86
242	NI	16		III.B.3	
243	NI	15.5		III.B.3	
244	819 (9)	15.51	0.98	III.C.3	
245	818 (9)	15.67	0.83	III.C.3	
246	NI	16		III.D.3	
247	NI	15.5		III.B.3	
248	NI	16		III.D.3	
249	NI	15.5		III.B.3	
250	825 (9)	15.67	0.83	III.B.3	
251	798 (8)	15.44	1.16	III.D.3	
252	NI	15.5		III.D.3	
253	NI	15.5		III.B.4	
254	NI	15.5		III.B.4	
255	NI	16		III.B.4	
256	NI	15.5		III.C.4	
257	804 (8)	15.63	0.97	III.C.4	
258	NI	15.5		III.B.4	
259	591 (7)	14.43	1.16	IV.A.3	118
260	NI	16		IV.B.3	
261	611 (7)	15.47	0.94	IV.A.3	
262	610 (7)	15.63	0.87	IV.B.3	
263	NI	16		IV.C.3	
264	NI	15.5		IV.A.3	
265	NI	16		IV.A.3	
266	617 (7)	14.5	1.39	IV.B.3	
267	NI	16		IV.B.2	
268	NI	16		IV.B.2	
269	NI	15.5		IV.B.2	
270	NI	16		IV.B.2	
271	NI	15.5		IV.B.2	
272	NI	15.5		IV.B.2	
273	546 (7)	15.63	0.87	IV.B.2	
274	NI	15.5		IV.C.2	
275	544 (7)	15.69	0.91	IV.B.2	
276	NI	16		IV.B.2	
277	NI	16		IV.B.2	
278	NI	16		IV.B.2	
279	526 (7)	15.5	0.85	IV.B.2	
280	NI	16		IV.B.2	
281	525 (7)	15.69	0.90	IV.B.2	
282	555 (7)	15.5	0.92	IV.A.2	
283	543 (7)	14.90	1.00	IV.B.2	
284	541 (7)	15.58	0.89	IV.B.2	
285	NI	16		IV.B.1	
286	NI	16		IV.B.1	
287	NI	16.5		IV.B.1	
288	NI	16.5		IV.B.1	
289	531 (7)	15.62	0.98	IV.B.1	
290	NI	16		IV.B.1	
291	532 (7)	15.4	1.10	IV.B.1	
292	250 (6)	15.64	0.96	IV.C.1	
293	655 (9)	15.56	1.04	IV.C.4	
294	NI	16		IV.D.4	
295	663 (9)	15.62	0.98	IV.D.4	
296	662 (9)	15.60	1.00	IV.D.4	
297	NI	16		V.A.4	
298	NI	16		V.B.4	
299	650 (9)	15.67	0.83	IV.C.4	
300	NI	16		IV.D.4	
301	NI	15.5		IV.D.3	
302	NI	15.5		IV.D.3	
303	NI	16		IV.D.3	
304	NI	15.5		V.A.3	
305	NI	15.5		V.A.3	
306	NI	16		V.A.3	
307	NI	16		V.A.3	
308	NI	16		IV.D.3	
309	693 (6)	13.87	2.73	V.A.3	
310	686 (6)	15.59	0.85	V.A.3	
311	NI	16		IV.C.3	
312	NI	15.5		IV.D.3	
313	672 (6)	15.57	0.93	IV.D.3	
314	681 (6)	15.53	1.07	V.A.3	
315	NI	15.5		IV.C.2	
316	NI	15.5		IV.C.2	
317	684 (6)	14.12	1.69	V.A.3	
318	NI	16		V.A.3	
319	NI	15.5		IV.C.2	
320	NI	15.5		IV.D.3	
321	NI	15.5		IV.D.3	
322	675 (6)	15.63	0.97	IV.D.3	
323	NI	16		V.A.3	
324	NI	16		V.A.3	
325	NI	16		V.A.3	
326	727 (6)	14.33	1.46	V.A.3	513
327	514 (6)	15.21	0.83	IV.C.2	
328	NI	15.5		IV.C.2	
329	NI	15.5		IV.D.2	
330	NI	15.5		IV.D.2	
331	486 (6)	15.66	0.94	IV.D.2	
332	NI	16		IV.D.2	
333	NI	15.5		IV.D.2	
334	674 (6)	15.69	0.91	IV.D.2	
335	463 (6)	15.69	0.91	V.A.2	
336	NI	15.5		V.A.2	
337	NI	16		V.A.2	
338	NI	15.5		V.B.2	
339	NI	15.5		IV.D.2	
340	NI	15.5		IV.C.2	
341	NI	15.5		IV.D.2	
342	NI	15.5		IV.D.2	
343	NI	15.5		IV.D.2	
344	511 (6)	15.65	0.85	IV.C.2	

Table 1. continued

S.No	Reddish et al. (1967)	m	B-V	Grid Id Fig.no./grid	Massey and Thompson (1991)
345	510 (6)	15.69	0.91	IV.C.2	
346	NI	15.5		IV.C.2	
347	NI	16		IV.D.2	
348	NI	16		IV.D.2	
349	NI	16		IV.D.2	
350	459 (6)	15.62	0.84	V.A.2	
351	NI	16		V.A.2	
352	NI	16		V.A.2	
353	NI	16		V.A.2	
354	NI	16		V.A.2	
355	NI	16		V.A.2	
356	504 (6)	15.61	0.89	IV.C.2	
357	506 (6)	15.67	0.93	IV.C.2	
358	NI	15.5		IV.C.2	
359	NI	15.5		IV.C.2	
360	NI	15.5		IV.C.2	
361	505 (6)	15.41	0.76	IV.C.2	
362	NI	16		IV.C.2	
363	NI	16		IV.C.2	
364	NI	16		IV.C.2	
365	NI	16		IV.C.2	
366	454 (6)	15.53	0.94	V.A.2	
367	455 (6)	15.66	0.84	V.A.2	
368	456 (6)	15.40	1.20	V.A.2	
369	457 (6)	15.64	0.96	V.A.2	
370	NI	15.5		IV.C.1	
371	NI	16		IV.C.1	
372	NI	16		IV.D.1	
373	NI	16		IV.D.1	
374	NI	15.5		IV.D.1	
375	NI	15.5		IV.D.1	
376	NI	15.5		IV.D.1	
377	NI	16		IV.D.1	
378	NI	15		IV.D.1	
379	NI	16		V.A.1	
380	NI	16		V.A.1	
381	NI	16		V.A.1	
382	444 (6)	15.66	0.84	V.A.2	
383	496 (6)	15.69	0.91	IV.C.1	
384	NI	15.5		IV.C.1	
385	NI	15.5		IV.C.1	
386	479 (6)	15.63	0.87	IV.D.1	
387	NI	15.5		IV.D.1	
388	NI	15.5		V.A.1	
389	NI	15.5		V.A.1	
390	NI	15.5		IV.D.1	
391	NI	16		V.A.1	
392	272 (6)	15.66	0.94	V.A.1	
393	705 (9)	15.51	0.99	V.B.4	
394	NI	16		V.C.4	
395	NI	16		V.C.4	
396	NI	15.5		V.C.4	
397	NI	16		V.C.4	
398	764 (8)	15.59	0.91	V.D.4	
399	NI	16		V.D.4	
400	NI	16		V.D.4	
401	NI	16		V.D.4	
402	NI	16		V.D.4	
403	NI	15.5		V.B.3	
404	NI	15.5		V.B.3	
405	NI	15.5		V.B.3	
406	NI	16		V.C.3	
407	759 (5)	15.6	0.90	V.C.3	
408	NI	15.5		V.D.4	
409	NI	15.5		V.D.4	
410	765 (8)	15.38	1.09	V.D.4	
411	NI	15.5		V.D.4	
412	NI	15.5		V.B.3	
413	715 (6)	15.65	0.76	V.B.3	
414	NI	16		V.B.3	
415	NI	16		V.B.3	
416	740 (6)	15.46	1.04	V.B.3	
417	750 (6)	15.62	0.88	V.C.3	
418	NI	16		V.C.3	
419	NI	15.5		V.D.3	
420	NI	15.5		V.D.3	
421	735 (6)	15.56	1.04	V.B.3	
422	739 (6)	15.64	0.96	V.B.3	
423	753 (6)	15.30	1.01	V.C.3	
424	NI	15.5		V.C.3	
425	770 (5)	15.20	1.04	V.C.3	
426	769 (5)	15.69	0.91	V.C.3	
427	NI	15.5		V.B.2	
428	NI	15.5		V.B.2	605
429	775 (5)	15.67	0.82	V.C.3	
430	776 (5)	15.56	0.87	V.C.3	
431	771 (5)	15.67	0.83	V.D.3	
432	433 (6)	15.46	0.70	V.B.2	
433	432 (6)	15.60	0.90	V.B.2	
434	NI	14		V.B.2	
435	NI	15.5		V.B.2	
436	NI	15		V.C.3	
437	NI	16		V.C.3	
438	442 (6)	15.64	0.96	V.B.2	
439	420 (6)	15.60	0.87	V.B.2	
440	NI	15.5		V.B.2	
441	419 (6)	15.64	0.86	V.B.2	
442	404 (6)	15.67	0.93	V.C.2	
443	NI	16		V.C.2	
444	393 (5)	15.62	0.98	V.C.2	
445	NI	15.5		V.B.2	
446	NI	15.5		V.B.2	
447	NI	16		V.B.1	
448	NI	16		V.C.1	
449	NI	15.5		V.C.1	
450	NI	15.5		V.C.1	
451	NI	15.5		VII.A.2	
452	NI	15.5		VII.A.2	
453	NI	15		VII.A.2	
454	NI	15.5		VII.B.2	
455	NI	16		VII.B.2	
456	NI	15.5		VII.B.2	
457	NI	15.5		VII.B.2	
458	NI	15.5		VII.B.2	

Table 1. continued

S.No	Reddish et al. (1967)	m	B-V	Grid Id Fig.no./grid	Massey and Thompson (1991)
459	NI	16		VII.B.2	
460	NI	15.5		VII.B.2	
461	NI	16		VII.B.2	
462	NI	16		VII.B.1	
463	NI	14.5		VII.B.1	
464	NI	16		VII.B.1	
465	NI	15.5		VII.A.3	
466	NI	15.5		VII.A.3	
467	NI	15.5		VII.A.2	
468	NI	15.5		VII.A.2	
469	NI	16		VII.A.2	
470	NI	15.5		VII.A.3	
471	NI	16		VII.A.2	
472	NI	15.5		VII.A.3	
473	NI	15.5		VII.A.3	
474	NI	15.5		VII.A.3	
475	NI	15		VII.A.3	
476	NI	15.5		VII.A.3	
477	NI	16		VII.A.3	
478	NI	16		VII.A.3	
479	NI	16		VII.A.3	
480	NI	15.5		VII.A.3	
481	NI	16		VII.A.3	
482	NI	16		VII.B.3	
483	NI	16		VII.B.3	
484	NI	16		VII.B.3	
485	NI	16		VII.B.3	
486	NI	16		VII.B.3	
487	NI	15		VII.B.3	
488	NI	15		VII.B.3	
489	NI	15		VII.B.3	
490	NI	15		VII.A.3	
491	NI	12.5		VII.A.3	
492	NI	15.5		VII.A.3	
493	NI	16		VII.A.3	
494	NI	16		VII.A.3	
495	NI	15		VII.B.3	
496	947 (10)	15.69	0.91	VII.B.3	
497	948 (10)	15.63	0.97	VII.B.3	
498	NI	14.5		VII.A.4	
499	NI	15.5		VII.A.4	
500	NI	14.4		VII.A.4	
501	NI	16		VII.A.4	
502	NI	16		VII.A.4	
503	NI	16		VII.A.4	
504	NI	15.5		VII.A.4	
505	NI	16		VII.B.4	
506	NI	15.5		VII.B.4	
507	NI	16		VII.B.4	
508	944 (10)	14.43	0.81	VII.B.4	
509	946 (10)	15.54	0.96	VII.B.3	
510	NI	15.5		VII.B.1	
511	NI	16		VII.B.1	
512	NI	15.5		VII.C.1	
513	NI	14.5		VII.C.1	
514	NI	15.5		VII.C.1	
515	NI	15.5		VII.C.1	
516	NI	16		VII.C.1	
517	NI	15.5		VII.C.1	
518	NI	15.5		VII.C.1	
519	NI	15.5		VII.C.1	
520	NI	15.5		VII.D.1	
521	NI	15.5		VII.D.1	
522	NI	15.5		VII.D.1	
523	NI	14.5		VII.C.1	
524	NI	16		VII.C.1	
525	NI	16		VII.C.1	
526	NI	16		VII.C.1	
527	NI	15.5		VII.B.2	
528	NI	15.5		VII.B.2	
529	NI	16		VII.B.2	
530	NI	16		VII.C.2	
531	NI	16		VII.C.2	
532	NI	16		VII.C.2	
533	NI	16		VII.C.2	
534	NI	16		VII.B.2	
535	NI	16		VII.C.2	
536	NI	16		VII.C.2	
537	NI	16		VII.C.2	
538	NI	16		VII.C.2	
539	NI	13.5		VII.B.2	
540	NI	14.5		VII.C.2	
541	NI	15		VII.C.3	
542	NI	14.5		VII.C.2	
543	NI	15		VII.C.2	
544	NI	15.5		VII.C.2	
545	NI	16		VII.C.2	
546	NI	16		VII.C.3	
547	NI	15.5		VII.C.3	
548	NI	16		VII.C.3	
549	NI	15.5		VII.C.2	
550	NI	12.5		VII.C.3	
551	NI	16		VII.B.3	
552	NI	16		VII.C.3	
553	NI	16		VII.C.4	
554	NI	16		VII.C.3	
555	NI	15.5		VII.C.3	
556	NI	15.5		VII.C.3	
557	NI	15.5		VII.C.3	
558	NI	16		VII.C.3	
559	NI	16		VII.C.3	
560	NI	11		VII.A.4	
561	NI	15.5		VII.A.4	
562	NI	16		VII.A.4	
563	NI	16		VII.A.4	
564	NI	16		VII.A.4	
565	NI	16		VII.A.4	
566	NI	16		VII.A.4	
567	NI	13		VII.A.4	
568	NI	15.5		VII.A.4	
569	NI	15.5		VII.A.4	
570	928 (10)	15.55	0.94	VII.A.4	
571	NI	16		VII.A.4	
572	NI	15.5		VII.A.4	

Table 1. continued

S.No	Reddish et al. (1967)	m	B-V	Grid Id Fig.no./grid	Massey and Thompson (1991)
573	NI	16		VII.B.4	
574	NI	16		VII.B.4	
575	NI	15		VI.A.3	
576	1599 (10)	15.53	0.97	VI.A.3	
577	NI	16		VI.A.3	
578	NI	16		VI.A.3	
579	1609 (10)	14.94	1.17	VI.A.3	
580	NI	16		VI.A.3	
581	NI	16		VI.A.3	
582	NI	16		VI.A.3	
583	1607 (10)	15.55	1.05	VI.B.3	
584	NI	15.5		VI.B.3	
585	1606 (10)	15.39	1.21	VI.B.3	
586	NI	15.5		VI.B.3	
587	NI	16		VI.B.3	
588	NI	15.5		VI.B.3	
589	927 (10)	15.69	0.91	VI.B.3	
590	926 (10)	15.65	0.95	VI.B.3	
591	925 (10)	15.65	0.85	VI.B.3	
592	NI	16		VI.B.3	
593	NI	16		VI.B.3	
594	NI	16		VI.B.3	
595	NI	16		VI.B.3	
596	NI	15.4		VI.B.3	
597	937 (10)	15.57	1.03	VI.B.3	
598	938 (10)	15.38	1.12	VI.B.3	
599	921 (10)	15.12	0.86	VI.B.3	
600	1598 (10)	15.61	0.99	VI.A.3	
601	NI	16		VI.A.3	
602	1602 (10)	15.57	0.93	VI.A.3	
603	NI	16		VI.A.3	
604	NI	16		VI.A.3	
605	NI	15.5		VI.A.3	
606	1597 (10)	15.19	1.13	VI.B.2	
607	NI	15.5		VI.B.3	
608	1605 (10)	14.71	1.75	VI.B.3	
609	596 (10)	15.01	1.37	VI.B.2	
610	NI	16		VI.B.2	
611	597 (10)	14.49	1.96	VI.B.2	
612	1603 (10)	15.68	0.92	VI.B.2	
613	NI	16		VI.B.3	
614	NI	16		VI.B.3	
615	NI	16		VI.B.3	
616	NI	15.5		VI.B.2	
617	NI	15.5		VI.B.2	
618	589 (7)	15.69	0.91	VI.B.1	
619	588 (7)	15.60	1.00	VI.B.1	
620	NI	16		VI.B.1	
621	NI	15.5		VI.B.1	
622	NI	15.5		VI.B.1	
623	NI	15.5		VI.B.1	
624	NI	16		VI.B.1	
625	NI	16		VI.B.1	
626	NI	15.5		VI.B.4	
627	943 (10)	15.51	0.99	VI.B.4	
628				VI.B.4	
629				VI.B.4	
630				VI.B.4	

S.No	Reddish et al. (1967)	m	B-V	Grid Id Fig.no./grid	Massey and Thompson (1991)
631	NI	16		VI.C.4	
632	941 (10)	15.5	1.10	VI.C.4	
633	NI	15.5		VI.C.3	
634	NI	16		VI.C.3	
635	NI	15.5		VI.C.3	
636	NI	16		VI.C.3	
637	NI	15.5		VI.C.3	
638	NI	15.5		VI.B.3	
639	NI	16		VI.C.3	
640	NI	15.5		VI.C.3	
641	NI	16		VI.C.3	
642	NI	16		VI.C.3	
643	NI	16		VI.C.3	
644	NI	16		VI.C.3	
645	599 (10)	15.32	1.10	VI.C.2	
646	593 (7)	12.25	1.80	VI.C.2	
647	NI	16		VI.C.2	
648	NI	16		VI.C.2	
649	NI	16		VI.C.2	
650	NI	16		VI.C.2	
651	NI	16		VI.C.2	
652	NI	16		VI.C.2	
653	NI	16		VI.C.2	
654	605 (7)	15.53	0.96	VI.C.2	
655	NI	15.5		VI.C.1	
656	NI	16		VI.C.1	
657	NI	16		VI.C.1	
658	612 (7)	15.67	0.83	VI.C.1	
659	NI	16		VI.C.1	
660	611 (7)	15.47	0.94	VI.C.1	
661	NI	16		VI.C.1	
662	NI	16		VI.C.1	
663	NI	15.5		VI.C.1	
664	NI	15.5		VI.C.1	
665	NI	16		VI.C.1	
666	NI	16		VI.C.1	
667	NI	16		VI.C.1	
668	NI	16		VI.C.1	
669	NI	15.5		VI.C.1	
670	NI	15.5		VI.C.1	
671	546 (7)	15.63	0.87	VI.C.1	
672	NI	16		VI.C.1	
673	NI	15.5		VI.C.1	
674	NI	15.5		VI.C.1	
675	NI	15.5		VI.C.1	
676	524 (7)	15.28	1.03	VI.C.1	
677	NI	15.5		VI.C.1	
678	NI	15.5		VI.C.1	
679	523 (7)	15.62	0.98	VI.C.1	
680	521 (7)	15.40	1.08	VI.C.1	
681	NI	16		VI.C.1	
682	NI	16		VI.D.1	
683	NI	15.5		VI.D.1	
684	519 (6)	15.21		VI.D.1	
685	NI	15.2		VI.D.1	
686	518 (6)	15.15	0.72	VI.D.1	
687	513 (6)	15.47		VI.D.1	
688	NI	15		II.D.1	

Table 1. continued

S.No	Reddish et al. (1967)	m	B-V	Grid Id Fig.no./grid	Massey and Thompson (1991)
689	NI	15.5		II.D.1	
690	NI	16		II.D.1	
691	NI	16		II.C.1	
692	NI			II.C.1	
693	NI	16		II.C.1	
694	NI	16.5		II.D.1	
695	NI	16.5		II.D.1	
696	NI	15		II.D.1	
697	NI	16		II.C.1	
698	NI			II.C.2	
699	NI	15.5		II.A.3	
700	NI	16.5		II.A.3	
701	NI			II.B.4	
702	NI	16.5		II.B.4	
703	NI	16.5		II.B.3	
704	NI	16		II.A.3	
705	NI	16		II.A.3	
706	NI			II.B.4	
707	NI			II.C.4	
708	NI	16.5		II.B.4	
709	NI	17		II.B.4	
710	NI	17		II.B.4	
711	NI	17		II.B.4	
712	NI	17		II.C.4	
713	NI	17		II.C.4	
714	NI	14		II.C.3	
715	NI			IV.D.2	
716	NI			IV.D.2	
717	NI	16.5		II.A.4	
718	NI	16		II.B.4	
719	NI	13.5		II.B.4	
720	NI	17		II.B.4	
721	NI	15		II.D.4	
722	NI			IV.D.3	
723	NI	14.5		IV.D.3	
724	NI	14.5		IV.C.3	
725	NI	16.5		II.D.4	
726		14.06		IV.C.3	301
727		12.75		IV.B.3	236
728	NI	13.5		IV.B.3	
729	NI			II.B.4	
730	NI	12.5		IV.B.3	
731	NI	16.5		II.D.1	
732	NI	16.5		III.A.1	
733	NI	16.5		III.A.1	
734	NI	15.5		III.A.1	
735	NI	15		III.A.1	
736	NI	14		III.A.1	
737	NI	16		III.A.1	
738	NI	16		III.A.1	
739	NI	16.5		III.A.1	
740	NI	15		III.B.1	
741	NI	13.5		III.B.1	
742	NI	14		III.B.1	
743	NI	14		III.C.2	
744	NI	15.5		III.D.2	
745	NI	17		III.D.3	
746	NI	16		III.B.2	
747	NI	16		III.A.2	
748	NI			III.A.2	
749	NI	14.5		III.A.2	
750	NI	16.5		III.A.2	
751	NI	16.5		III.A.2	
752	NI	16		III.C.3	
753	NI	16.5		III.D.3	
754	NI	16.5		III.C.3	
755	NI	16		III.A.4	
756	NI	16.5		III.D.4	
757	NI	15		III.D.3	
758	NI	13		III.D.3	
759	NI	15		III.D.3	
760	NI	13.5		III.C.4	
761	NI	12.5		III.C.4	
762	NI	17		III.C.4	
763	NI	17		III.C.4	
764	NI	17		III.C.4	
765	NI	16		III.D.4	
766	NI	16		V.C.3	
767	NI	16.5		V.C.3	
768	NI	17		V.B.3	
769	NI	15		V.A.3	
770	NI	16		V.B.3	
771	NI	16		V.A.2	
772	NI	14		V.A.2	
773	NI	16.5		V.A.3	
774	NI			V.B.2	
775	NI	16		V.B.2	
776	NI	14		V.C.2	
777	NI	16		V.C.2	
778	NI	14		V.C.2	
779	NI	16.5		V.C.2	
780	NI	15		V.C.2	
781	NI			V.B.1	