ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **123,** 507-528 (1997)

A photometric study of the Bright Cloud B in Sagittarius

VIII. 1061 new variable stars⋆,⋆⋆,⋆⋆⋆

A. Terzan[1], **A. Bernard**[1], **and J. Guibert**[2,3]

[1] Observatoire Astronomique de Lyon (CRAL), F-69561 Saint Genis Laval Cedex, France
[2] Centre d'Analyse des Images CNRS/INSU/MAMA, Observatoire de Paris, France
[3] Observatoire de Paris (DEMIRM)/URA 336 du CNRS, 77 Avenue Denfert-Rochereau, F-75014 Paris, France

Received August 8; accepted October 18, 1996

Abstract. We present a catalogue of positions and photographic R magnitudes at observed maximum and minimum brightness for 1061 variable stars newly detected in the direction of the Bright Cloud B in Sagittarius. The limiting R magnitude of the survey is about 18. Most of these stars are long period variables. Taking into account the previously published lists (Terzan et al. 1982, 1988, 1991), the total number of new variable objects discovered in the surveyed 100 square degree field amounts to 4430.

Key words: the Galaxy: structure; center — stars: variables; AGN, post-AGN

1. Introduction

A systematic photographic survey initiated in 1959 by A. Terzan (A. T.) in the direction of the Bright Cloud B in Sagittarius has been going on since 1976 at the ESO 1 m Schmidt telescope (Chile). A large number of peculiar objects have already been recognized, e.g. variable stars, galactic open clusters, galactic globular clusters, diffuse objects, planetary nebulae and proper motion stars (Terzan 1990 and references therein; Terzan & Gosset 1991; Acker et al. 1992; Cuisinier et al. 1993, 1994).

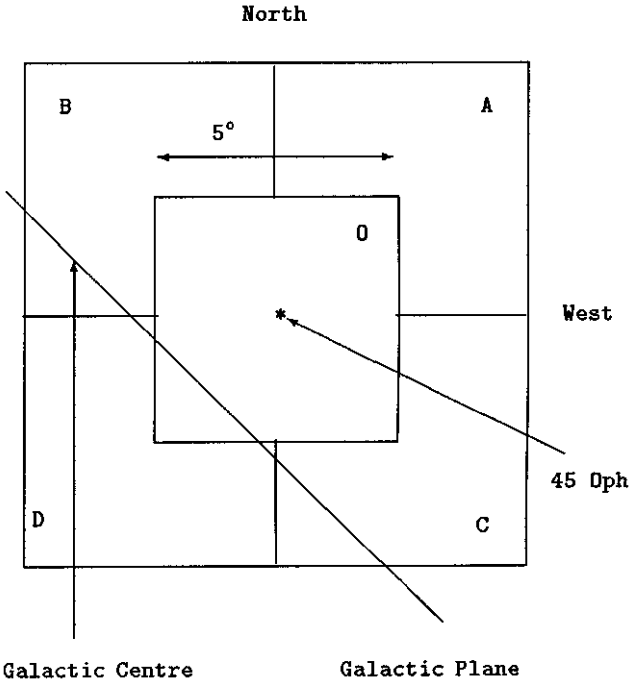

Fig. 1. Location of the $10^\circ \times 10^\circ$ area covered by fields A, B, C and D. Coordinates of star 45 Oph can be found in the text

The $10^\circ \times 10^\circ$ programme field is centred on the star 45 Oph (α = 17h 27m 21.2s; $\delta = -29^\circ\ 52'\ 01''$, equinox 2000.0).

We present now the results of the search for long period variable stars in the last part of the programme field. The investigated region is a $5.5^\circ \times 5.5^\circ$ area, situated south-west the star 45 Oph, and defined by: 17h 04m $\lesssim \alpha \lesssim$ 17h 27m and $-35^\circ\ 05' \lesssim \delta \lesssim -29^\circ\ 52'$. It corresponds to part C of the programme field (see Fig. 1, Table 1, and Fig. 2). A catalogue of positions and photographic R magnitudes at observed maximum and minimum brightness is given for 1061 newly detected variables. The limiting

Send offprint requests to: A. Terzan

⋆ Plate scanning done with MAMA. MAMA is developed and operated by INSU (Institut National des Sciences de l'Univers).

⋆⋆ Based on observations made at the Palomar and European Southern Observatories.

⋆⋆⋆ The whole of Table 3, as well as the full catalogue of 4430 variables are only available in electronic form at CDS via anonymous ftp cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

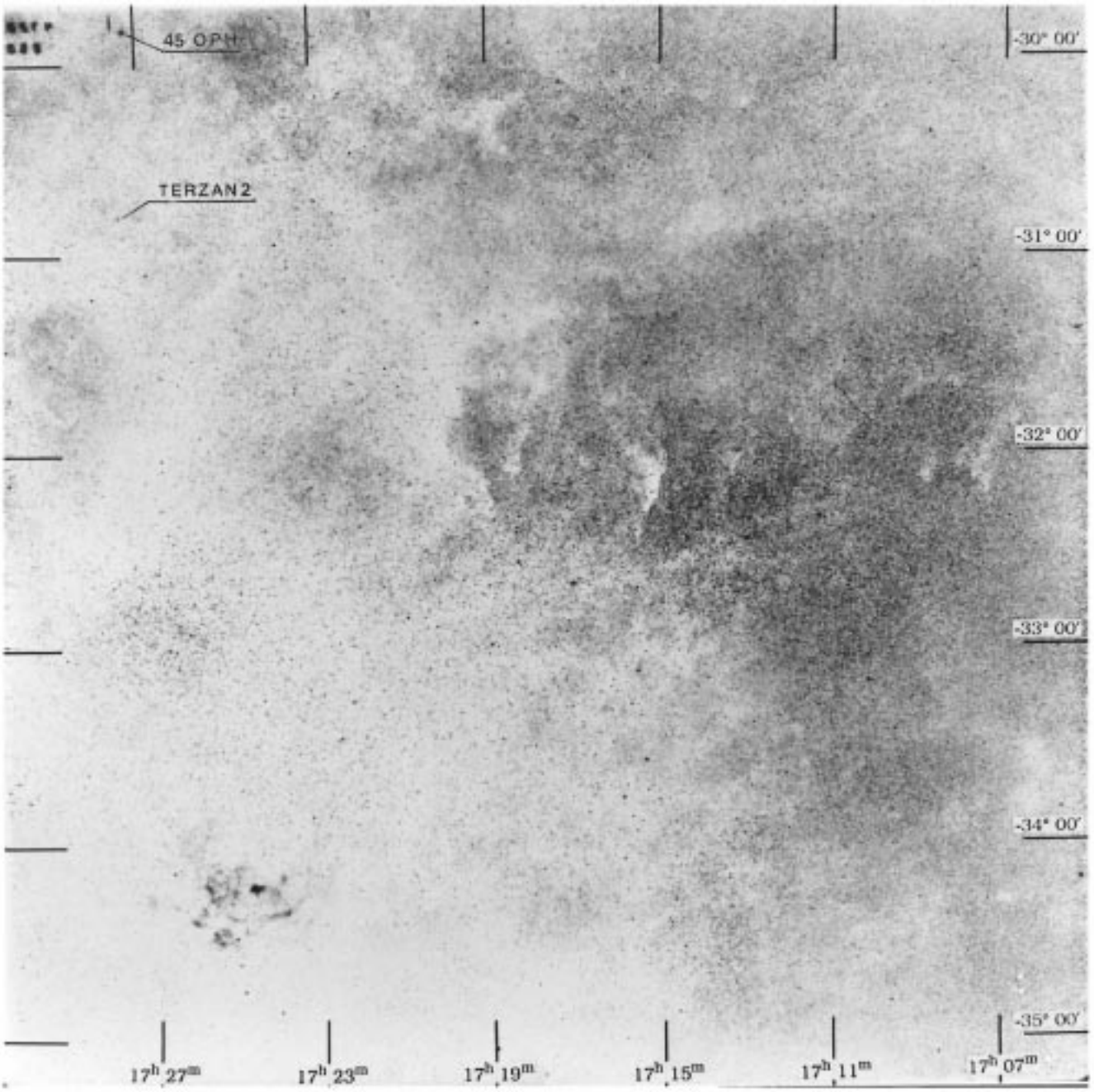

Fig. 2. Chart of Field C, south-west the star 45 Oph

magnitude of the detection is about 18. If we take into account the 3369 similar objects previoulsy discovered by Terzan et al. (1982, 1988, 1991), the total number of new variable stars discovered in our 100 square degree field amounts to 4430. The global catalogue will be available in electronic form at CDS via anonymous ftp cdsarc.u-strasbg.fr or 130.79.128.5

2. Observations and data reduction

Our programme is based on photographic observations made in 1968 (june and july) at the 48″ Schmidt telescope of Mount Palomar Observatory (f/2.44, 67.1 arcsec mm^{-1}; B, V, R, $10'' \times 10''$ plates) by A.T. continued, after 1976, at the 1 m Schmidt telescope (f/3, 67.5 arcsec mm^{-1}; U, B, V, R, $12'' \times 12''$ plates) of ESO (Chile) by local staff observers.

For the present survey thirteen R photographic plates have been retained for their photometric quality, at

Table 1. Location of the investigated areas and number of detected variable stars

Field	Limits (Eq. 2000)	known variables (a)	detected variables (b)	new variables (c)
A	17h 04m $\lesssim$ alpha $\lesssim$ 17h 27m -29° 52′ $\lesssim$ delta $\lesssim -24^\circ$ 42′	97	1235	1178 (d, e)
B	17h 27m $\lesssim$ alpha $\lesssim$ 17h 52m -29° 52′ $\lesssim$ delta $\lesssim -24^\circ$ 42′	56	1383	1383 (d, f)
C	17h 04m $\lesssim$ alpha $\lesssim$ 17h 27m -35° 05′ $\lesssim$ delta $\lesssim -29^\circ$ 52′	46	1204	1061 (g) + 130 (d)
D	17h 27m $\lesssim$ alpha $\lesssim$ 17h 52m -35° 05′ $\lesssim$ delta $\lesssim -29^\circ$ 52′	53	686	678 (d, e)
Total		252	4508	4430

(a) GCVS (Kholopov et al. 1985, 1987);
(b) in the course of our programme;
(c) some low amplitude and/or blue objects of the Kukarkin's catalogue escaped the blink detection;
(d) Terzan et al. (1982);
(e) Terzan & Ounnas (1988);
(f) Terzan & Gosset (1991);
(g) this paper.

Table 2. Characteristics of the plates

	Plate number	Date	Emulsion	Filter	Exposure	Seeing	Observatory
1	3809	1968-06-29	103a-E	RG1	20 mn	2″	Palomar
2	3818	1968-06-30	103a-E	RG1	20 mn	1″	Palomar
3	3879	1968-07-26	103a-E	RG1	20 mn	2″	Palomar
4	3899	1968-07-29	103a-E	RG1	20 mn	2″	Palomar
5	4810	1982-05-20	098-04	RG630	30 mn	2″	ESO
6	7608	1988-10-02	098-04	RG630	30 mn	1″	ESO
7	8005	1989-04-12	098-04	RG630	30 mn	1.2″	ESO
8	8030	1989-05-09	098-04	RG630	30 mn	1.5″	ESO
9	8081	1989-06-06	098-04	RG630	30 mn	1.5″	ESO
10	9227	1991-04-19	098-04	RG630	30 mn	1.5″	ESO
11	9234	1991-04-21	098-04	RG630	30 mn	1″	ESO
12	9354	1991-07-10	098-04	RG630	30 mn	1.5″	ESO
13	10636	1993-06-20	098-04	RG630	30 mn	1.5″	ESO

observational time intervals suitable for the detection of long-period variable stars. The characteristics of the plates (plate number, date of the observation, emulsion, filter, exposure, and seeing conditions) are given in Table 2. The comparison of photographic plates was done by one of us (A. T.) using the blink microscope of the Observatoire de Lyon, an instrument allowing stellar variations as small as 0.2 magnitude to be estimated on plates obtained in good seeing conditions ($\lesssim$ 1 arcsec) (Terzan et al. 1978). We found 1061 new variable stars in field C, in addition to the 130 variables already detected in the area common to fields O and C (Terzan et al. 1982). Magnitudes have been estimated by scaling the photographic densities of variables to a sequence of densities corresponding to standard stars with R magnitudes between 9 and 17.5 (Terzan & Bernard 1981). Under these conditions, the uncertainty on R is about 0.3 magnitude in the range $9 \lesssim R \lesssim 14$, and then increases up to 0.5 as R approaches 18, the magnitude limit of the estimations. The determination of the rectangular coordinates X and Y of the stars was made partly at ESO Garching with the microdensitometer S 3000- Optronics, partly with MAMA (Machine Automatique à Mesurer pour l'Astronomie). The astrometric reductions were performed using the PPM catalogue (Röser et al. 1991, 1993), with an internal accuracy of $\approx$ 0.2 arcsec (see e.g. Robichon et al. 1996).

Table 3. The first 16 new variable stars discovered in Field C

star number	α (2000)	δ (2000)	$l^{\rm II}$	$b^{\rm II}$	R[Max]	E	R[Min]	E	R[Min] − R[Max]	Remarks
3380	17 04 39.21	−34 05 02.6	350.8	+04.3	11.9	13	18.0	7	6.1	
3381	17 04 44.01	−33 47 47.1	351.1	+04.5	15.8	7	$\gtrsim$18	13		
3382	17 04 48.71	−33 34 32.5	351.3	+04.6	11.0	8	15.3	13	4.3	
3383	17 04 49.05	−34 14 23.1	350.7	+04.2	11.0	8	15.8	13	4.8	
3384	17 04 55.37	−33 06 06.3	351.7	+04.9	14.2	13	18.0	6	3.8	
3385	17 05 01.04	−32 59 14.7	351.8	+04.9	14.2	8	17.6	6	3.4	
3386	17 05 04.96	−33 12 39.6	351.6	+04.8	13.0	6	18.0	7	5.0	
3387	17 05 07.97	−31 28 41.4	353.0	+05.8	10.2	8	15.8	12	5.6	
3388	17 05 17.04	−33 05 26.6	351.7	+04.8	13.0	7	17.6	8	4.6	
3389	17 05 17.16	−34 12 23.7	350.8	+04.2	14.2	12	16.6	11	2.4	
3390	17 05 19.92	−32 11 07.2	352.4	+05.4	13.0	8	16.6	6	3.6	
3391	17 05 21.00	−33 26 36.0	351.4	+04.6	14.2	6	18.0	7	3.8	
3392	17 05 21.43	−33 24 55.3	351.5	+04.6	11.0	10	15.8	7	4.8	
3393	17 05 23.40	−34 03 04.4	351.0	+04.2	15.0	8	18.0	11	3.0	
3394	17 05 23.87	−30 28 00.2	353.8	+06.4	10.2	7	14.2	5	4.0	
3395	17 05 25.83	−32 15 53.4	352.4	+05.3	15.8	6	$\gtrsim$18	7		

The whole of Table 3, as well as the full catalogue of the 4430 variables discovered in the $10^\circ \times 10^\circ$ programme field are available in electronic form at CDS via anonymous ftp cdsarc.u-strasbg.fr or 130.79.128.5

3. The catalogue

Astrometric and photometric results for the 1061 variables are catalogued in a table which is available in electronic form at CDS, and part of which is displayed for illustration as Table 3 in the printed version of this paper. This table also includes 13 variables belonging to the GCVS, but for which we provide identification charts as well as more accurate positions and Red magnitudes at observed maximum and minimum. The content of the successive columns is as follows:

Column 1: Star number. The numbering starts at 3380 for continuation of a previous list of already published variable stars (Terzan et al. 1982, 1988, 1991). The stars are classified according to increasing right ascension.

Columns 2 and 3: Equatorial coordinates referred to the equinox 2000.0.

Columns 4 and 5: Galactic coordinates $l^{\rm II}$ and $b^{\rm II}$.

Columns 6 and 8: R[Max] and R[Min], the R magnitudes of the star at the observed maximum and minimum brightness.

Columns 7 and 9: E: Identification number of the plate corresponding to the epoch of observation of R[Max] and R[Min] (Table 2).

Column 10: A: Observed amplitude, R[Min] − R[Max].

Column 11: Identification of the star in the GCVS catalogue (Kholopov et al. 1985, 1987). For IRxxx stars, see Terzan (1965) and references therein.

Finding charts for all the stars (from R plates) are grouped on plates 1 to 17. North is up and east is to the left, and scales are identical for all charts.

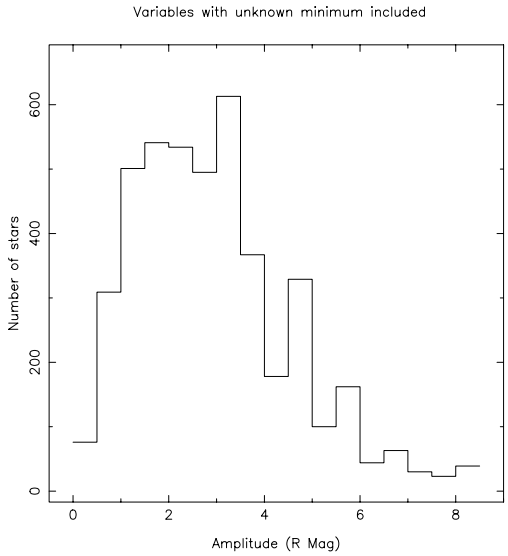

Fig. 3. Histogram of the observed amplitudes A, binned in steps of 0.5 magnitude, for the 2432 variables with definite R amplitude

4. Discussion

An histogram of the number N of variable stars as a function of the binned observed amplitude A, in steps of 0.5 magnitude, and for all stars with definite amplitude is represented in Fig. 3. For 50% of the stars, the amplitudes range between 1.0 and 3.0, with a maximum for $1.5 \lesssim A \lesssim 2.0$. Ascribing magnitude 19 at brightness minimum to the stars with R[Min] $\gtrsim$ 18, one can build the corresponding histogram for almost all the catalogued

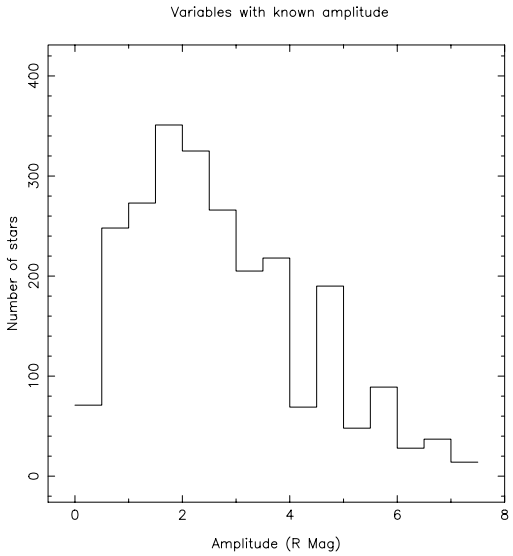

Fig. 4. Histogram of the amplitudes A, binned in steps of 0.5 magnitude, for the 4430 variables. Here, stars without known amplitude at minimum light are included in the statistics, with Rmin taken equal to 19 (see text)

stars (Fig. 4). This approximation is believed to be realistic for long period variables (most of the present stars) since:

(i) the magnitude limit achieved on a 30 mn exposure R plate is about 19.5;

(ii) the thirteen R magnitudes determined for each star are well distributed over a complete cycle when phased together for typical periods of the detected variables (between 70 and 500 days).

The distributions displayed by Figs. 3 and 4 (in the latter, 50% of the stars have amplitudes between 1.5 and 3.5), are quite similar (the 0.5 magnitude shift observed between the two histograms is not significant). The (ii) statement is supported by a recent study of field O (Alard et al. 1996) showing that 122 of the 150 variables selected for their large amplitude variations ($A \gtrsim 2$ mag) are Mira type stars, most of them with periods between 150 and 500 days. The analogy shown by the distributions N/A (Fig. 4) and N/Period (Alard et al. 1996) corresponds to the period-amplitude relation existing for this class of stars. We plan to characterize Mira type stars in other parts of the $10^\circ \times 10^\circ$ field of our programme. These high luminosity objects show a definite period-luminosity relation and thus are good distance indicators. Infrared J and K photometry of these stars would then be worthwhile in order to evaluate the variation of the interstellar extinction with the distance modulus in the direction of the galactic centre.

Acknowledgements. We would like to thank all the members of the MAMA team for assistance during the scanning of the photographic material. We are indepted to Gerard Marichy and Daniel Robert for their technical help.

References

Acker A., Cuisinier F., Stenholm B., Terzan A., 1992, A&A 264, 217
Alard C., Terzan A., Guibert J., 1996, A&AS 120, 275
Cuisinier F., Terzan A., Acker A., 1993, A&A 277, 203
Cuisinier F., Terzan A., Acker A., 1994, A&A 287, 227
Kholopov P.N., et al., 1985, 1987, General Catalogue of Variable Stars, Nauka, Moscow, Vols. II and III (GCVS)
Robichon N., Turon C., Makarov V., et al., 1995, A&A 304, 132
Röser S., Bastian U., 1991, PPM Star Catalogue, Vol. III, Publications A.R.I., Spektrum
Röser S., Bastian U., 1993, PPM Star Catalogue, Vol. IV, Publications A.R.I., Spektrum
Terzan A., 1965, C. R. Acad. Sc. Paris 291, 3974
Terzan A., 1990, The Messenger 59, 41
Terzan A., Bernard A., 1981, A&AS 46, 49
Terzan A., Bijaoui A., Ju K.H., Ounnas C., 1982, A&AS 49, 715
Terzan A., Chatagnat M., Dubet D., 1978, J. Opt. 9, 121
Terzan A., Gosset E., 1991, A&AS 90, 451
Terzan A., Ounnas C., 1988, A&AS 76, 205

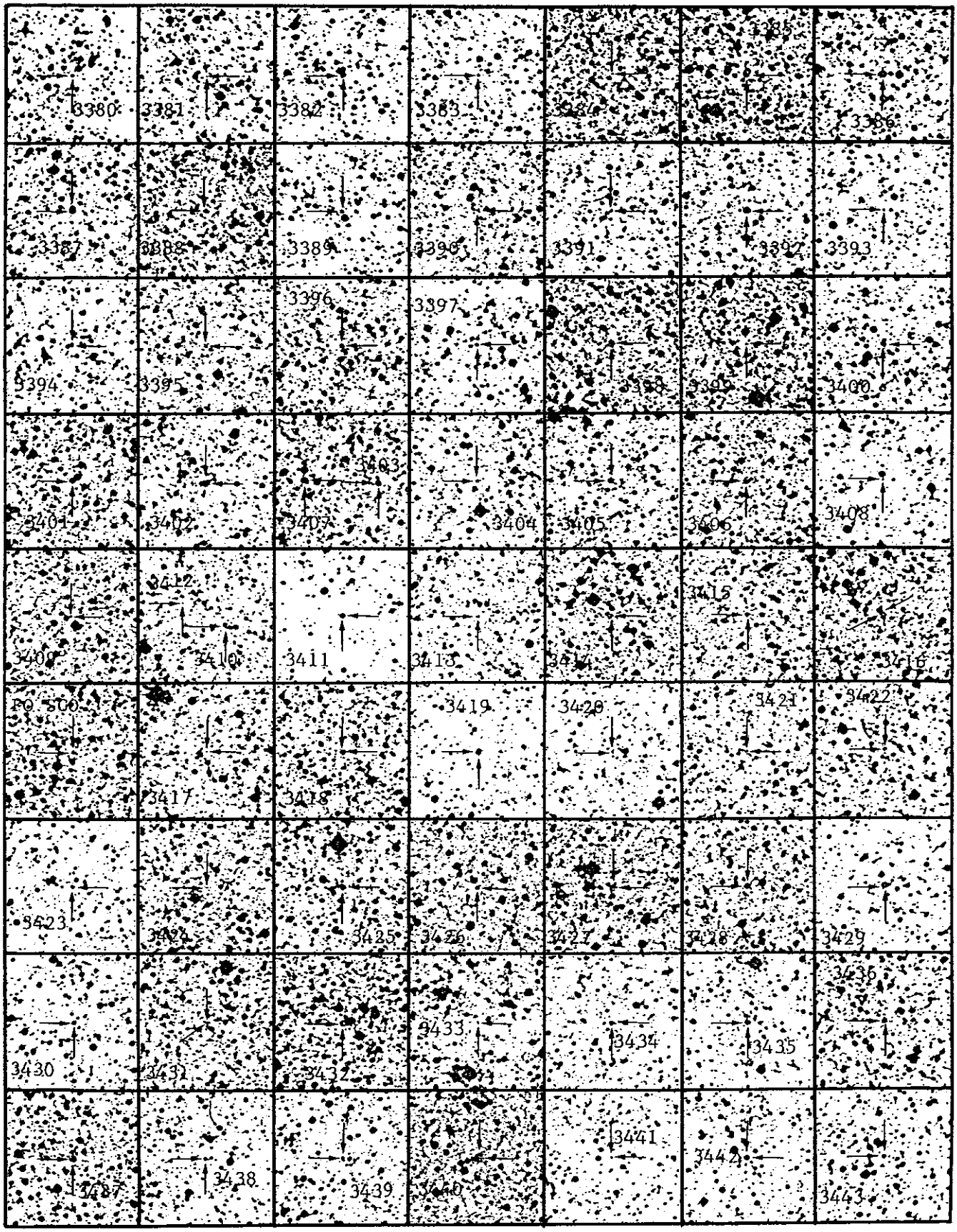
3380
3381
3382
3383
3386
3387
3388
3389
3390
3391
3392
3393
3394
3395
3396
3397
3400
3401
3402
3403
3404
3405
3406
3408
3409
3410
3411
3413
3415
3416
3417
3418
3419
3420
3421
3422
3423
3425
3426
3427
3428
3429
3430
3431
3432
3433
3434
3435
3436
3437
3438
3439
3440
3441
3442
3443

Plate 1

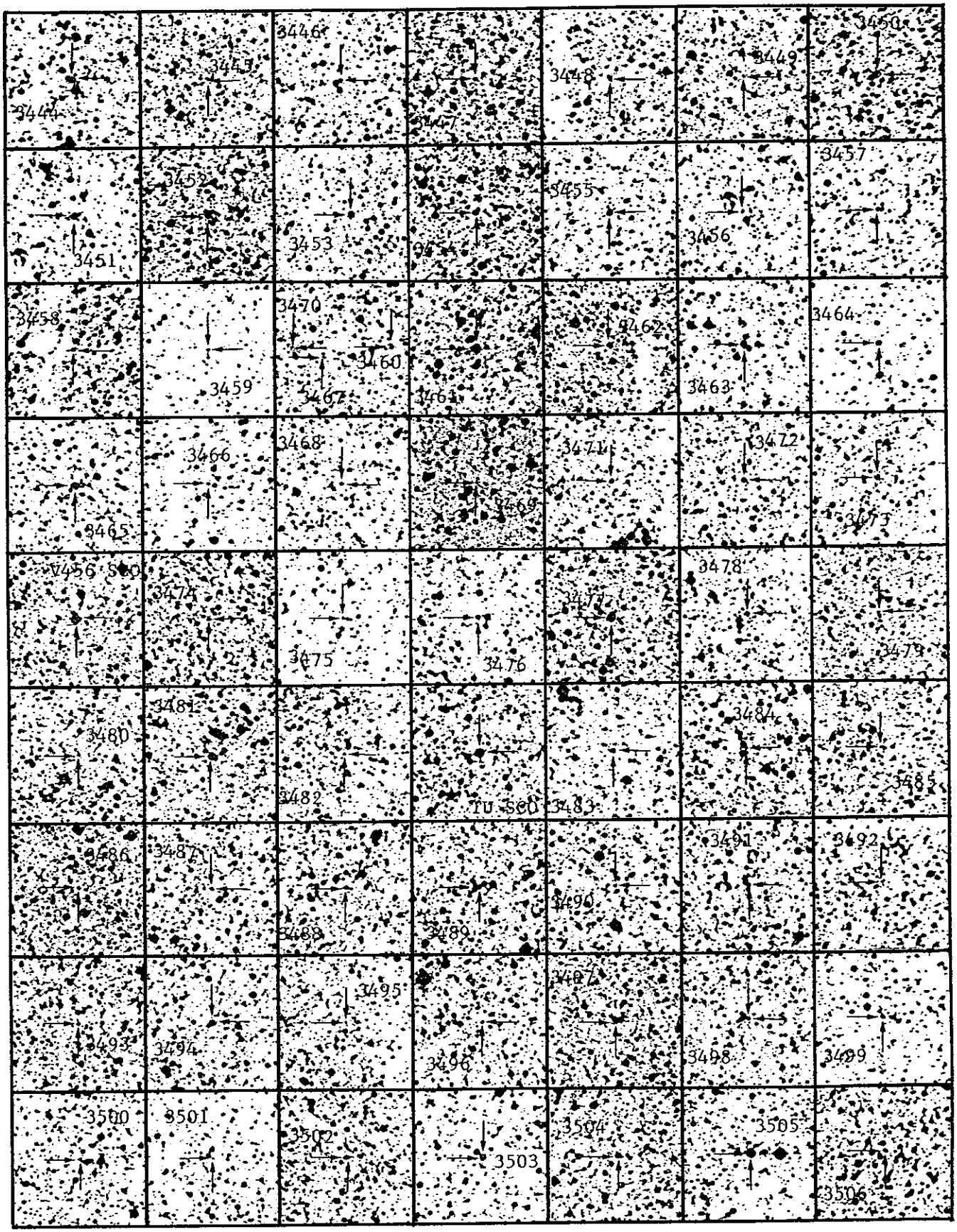
3446
3447
3448
3449
3450
3451
3452
3453
3455
3456
3457
3458
3459
3460
3461
3462
3463
3464
3465
3466
3468
3469
3471
3472
3473
V456 Sco
3474
3475
3476
3477
3478
3479
3480
3481
3482
Tu Sco
3483
3484
3485
3486
3487
3488
3489
3490
3491
3492
3493
3494
3495
3496
3497
3498
3499
3500
3501
3502
3503
3504
3505
3506

Plate 2

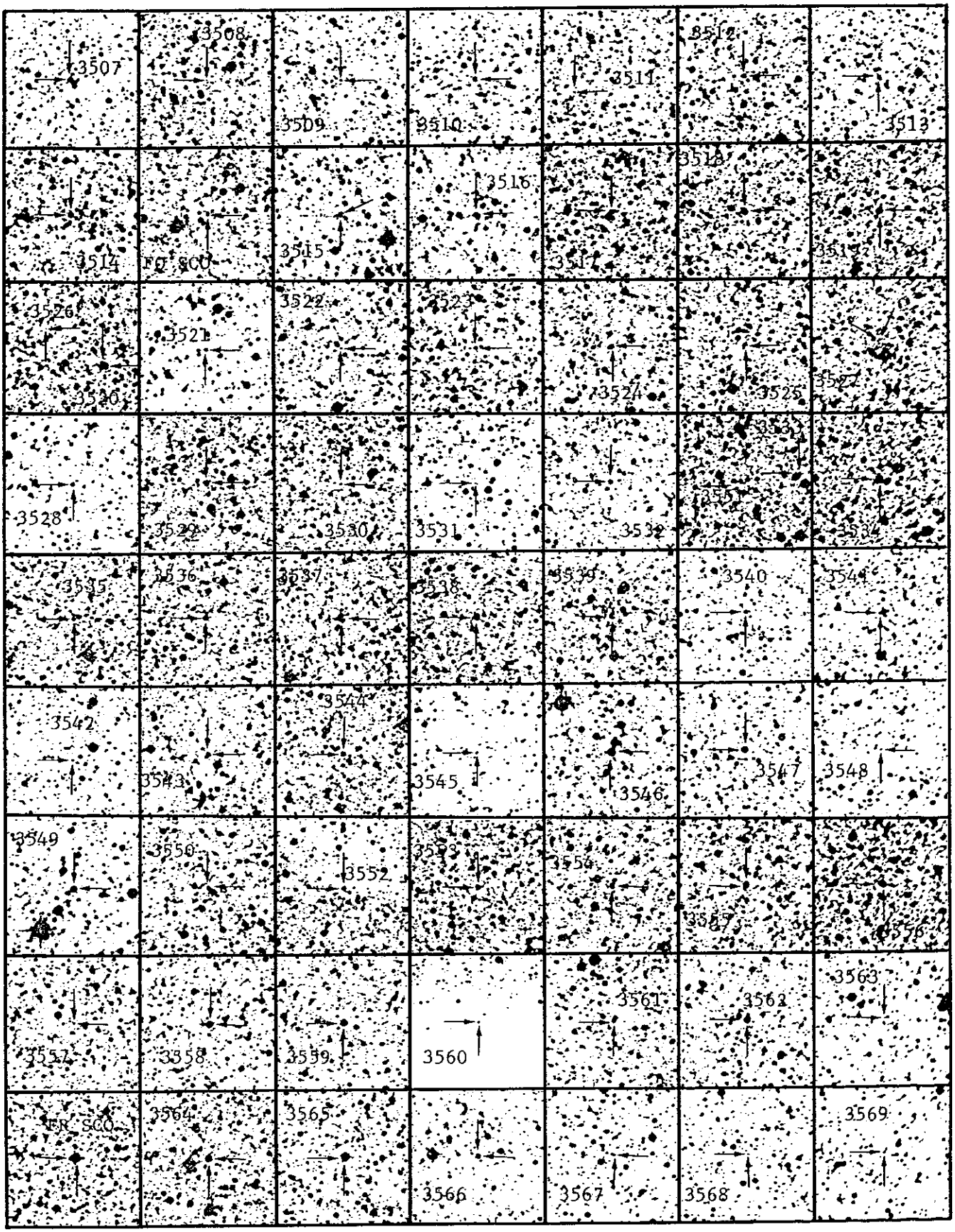
3507
3508
3509
3510
3511
3512
3513
3514
FG SCO
3515
3516
3517
3518
3519
3520
3521
3522
3523
3524
3525
3526
3527
3528
3529
3530
3531
3532
3533
3534
3535
3536
3537
3538
3539
3540
3541
3542
3543
3544
3545
3546
3547
3548
3549
3550
3552
3554
3556
3557
3558
3559
3560
3561
3562
3563
ER SCO
3564
3565
3566
3567
3568
3569

Plate 3

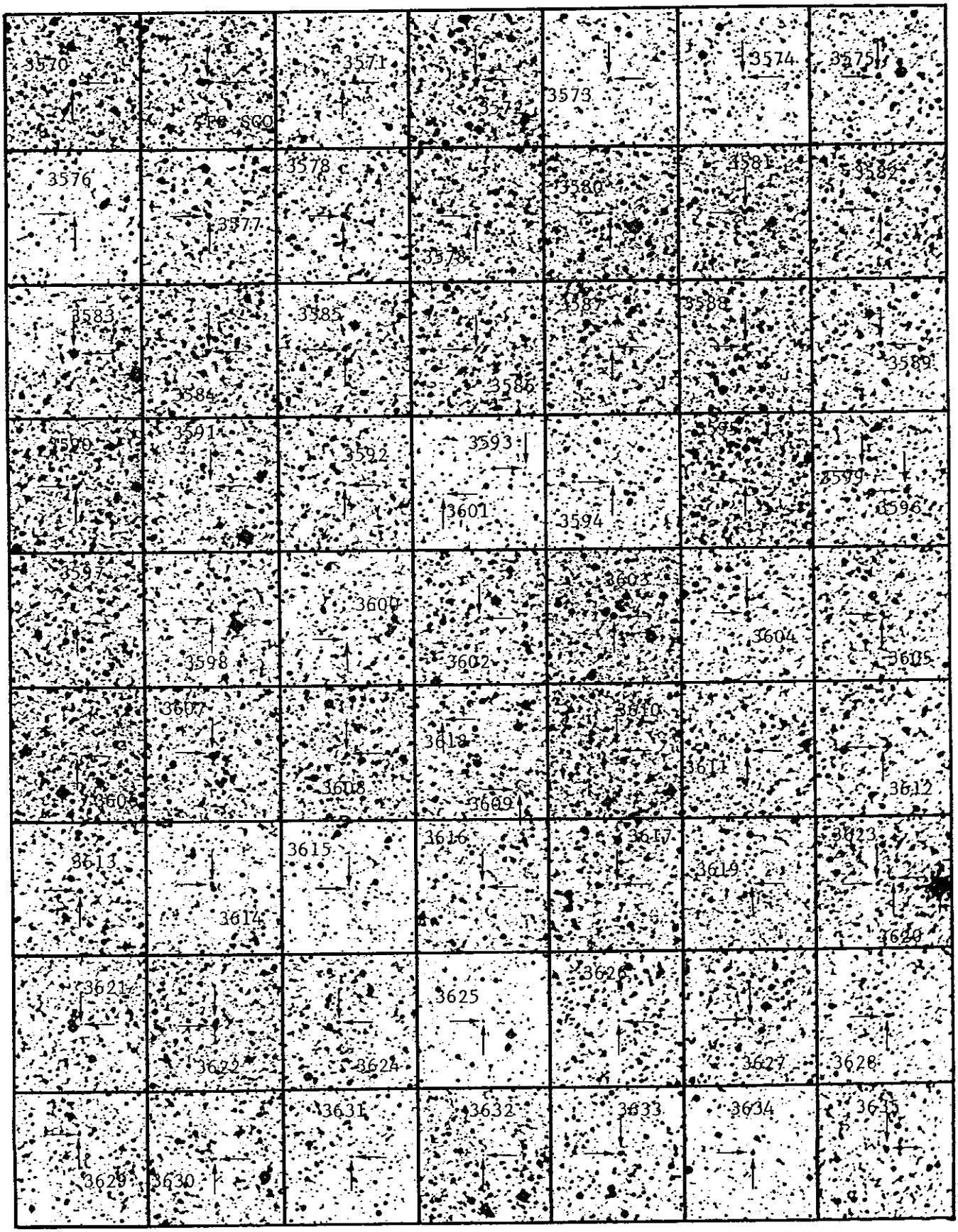
3570
3571
3572
3573
3574
3575
3576
3577
3578
3579
3580
3581
3582
3583
3584
3585
3586
3587
3588
3589
3590
3591
3592
3593
3594
3595
3596
3597
3598
3599
3600
3601
3602
3603
3604
3605
3606
3607
3608
3609
3610
3611
3612
3613
3614
3615
3616
3617
3618
3619
3620
3621
3622
3623
3624
3625
3626
3627
3628
3629
3630
3631
3632
3633
3634
3635

Plate 4

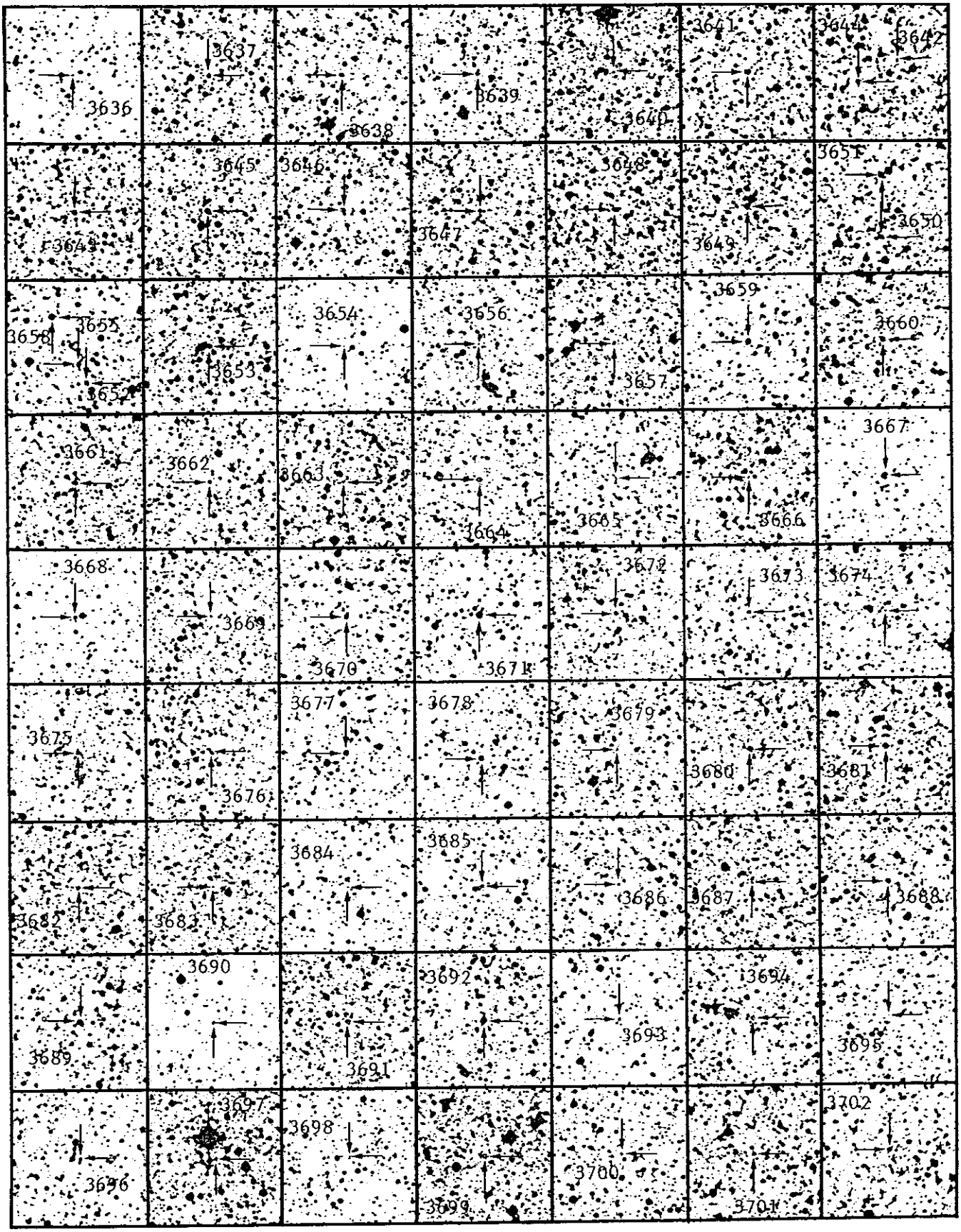
3636
3637
3638
3639
3640
3641
3642
3643
3645
3646
3647
3648
3649
3650
3651
3652
3653
3654
3655
3656
3657
3659
3660
3661
3662
3663
3664
3665
3666
3667
3668
3669
3670
3671
3672
3673
3674
3675
3676
3677
3678
3679
3680
3681
3682
3683
3684
3685
3686
3687
3688
3689
3690
3691
3692
3693
3694
3695
3696
3697
3698
3699
3700
3701
3702

Plate 5

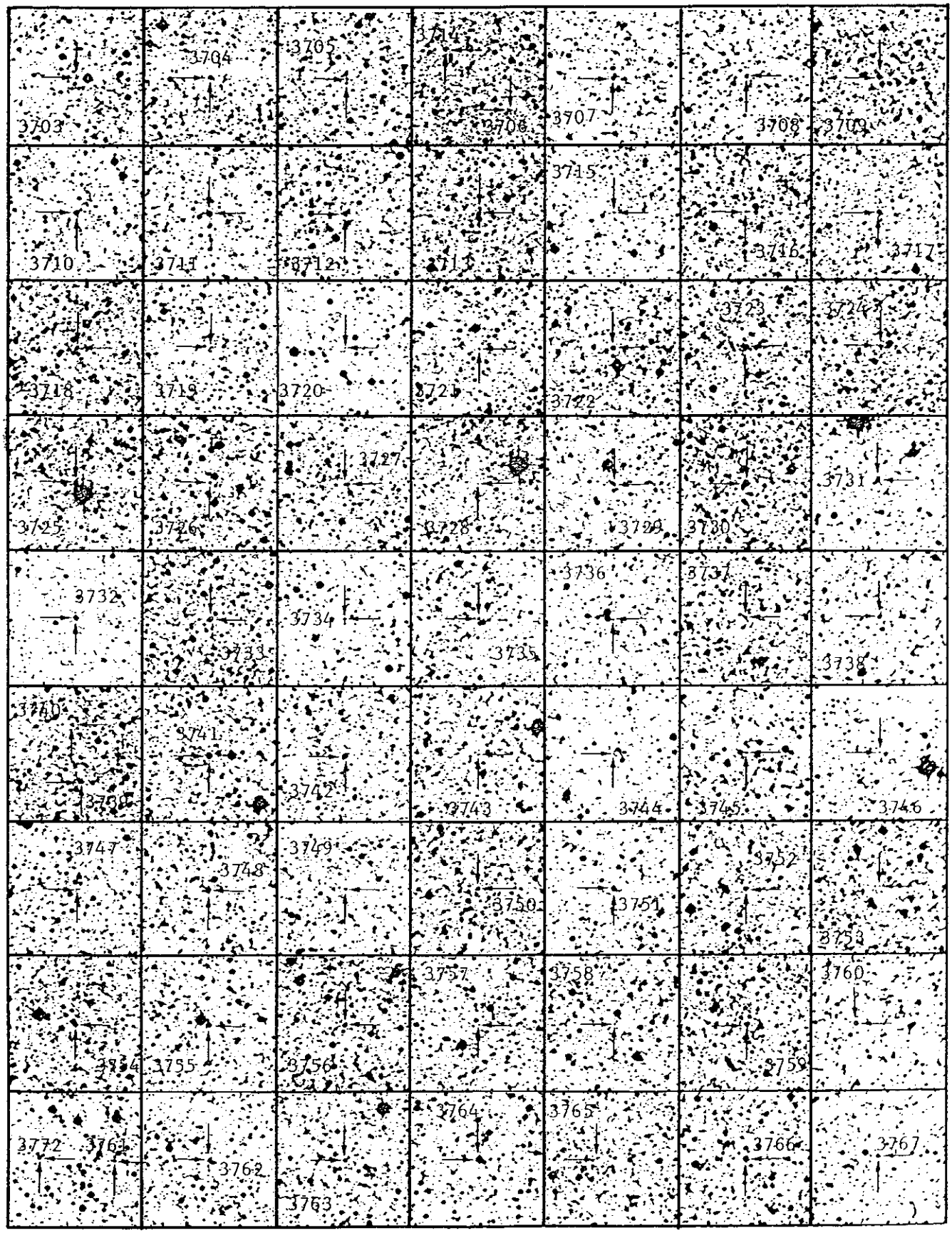
3703
3704
3705
3706
3707
3708
3709
3710
3711
3712
3715
3716
3717
3718
3719
3720
3722
3723
3724
3725
3726
3727
3728
3729
3730
3731
3732
3733
3734
3735
3736
3737
3738
3740
3741
3742
3743
3744
3745
3746
3747
3748
3749
3750
3751
3752
3753
3754
3755
3756
3757
3758
3759
3760
3762
3763
3764
3765
3766
3767

Plate 6

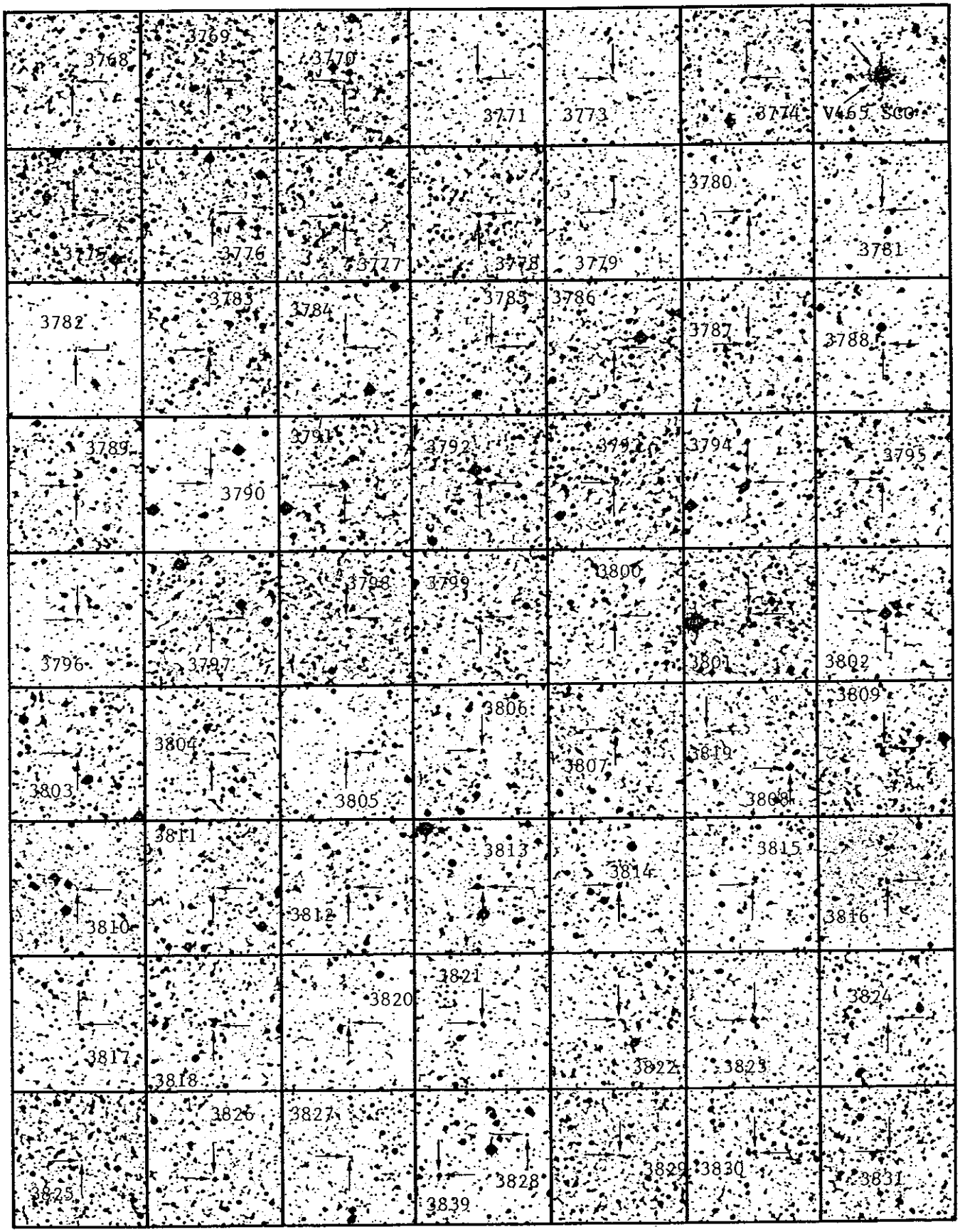
3768
3769
3770
3771
3773
3774
V465 Sco
3775
3776
3777
3778
3779
3780
3781
3782
3783
3784
3785
3786
3787
3788
3789
3790
3791
3792
3793
3794
3795
3796
3797
3798
3799
3800
3801
3802
3803
3804
3805
3806
3807
3809
3810
3811
3812
3813
3814
3815
3816
3817
3818
3820
3821
3822
3823
3824
3825
3826
3827
3828
3829
3830
3831
3839

Plate 7

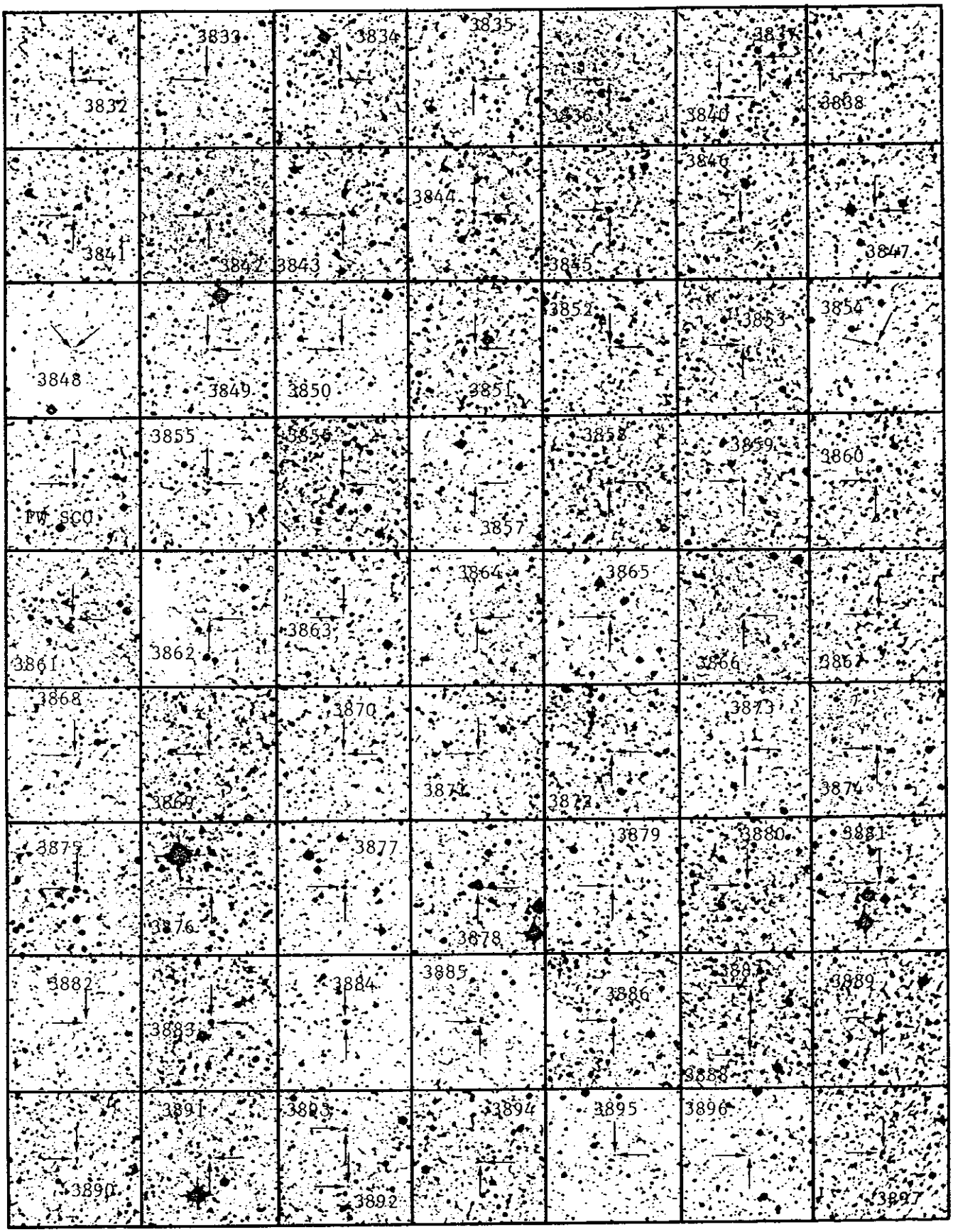
3832
3833
3834
3835
3836
3837
3838
3840
3841
3842
3843
3844
3845
3846
3847
3848
3849
3850
3851
3852
3853
3854
PW SCO
3855
3856
3857
3858
3859
3860
3861
3862
3863
3864
3865
3866
3867
3868
3869
3870
3871
3872
3873
3874
3875
3876
3877
3878
3879
3880
3881
3882
3883
3884
3885
3886
3887
3888
3889
3890
3891
3892
3893
3894
3895
3896
3897

Plate 8

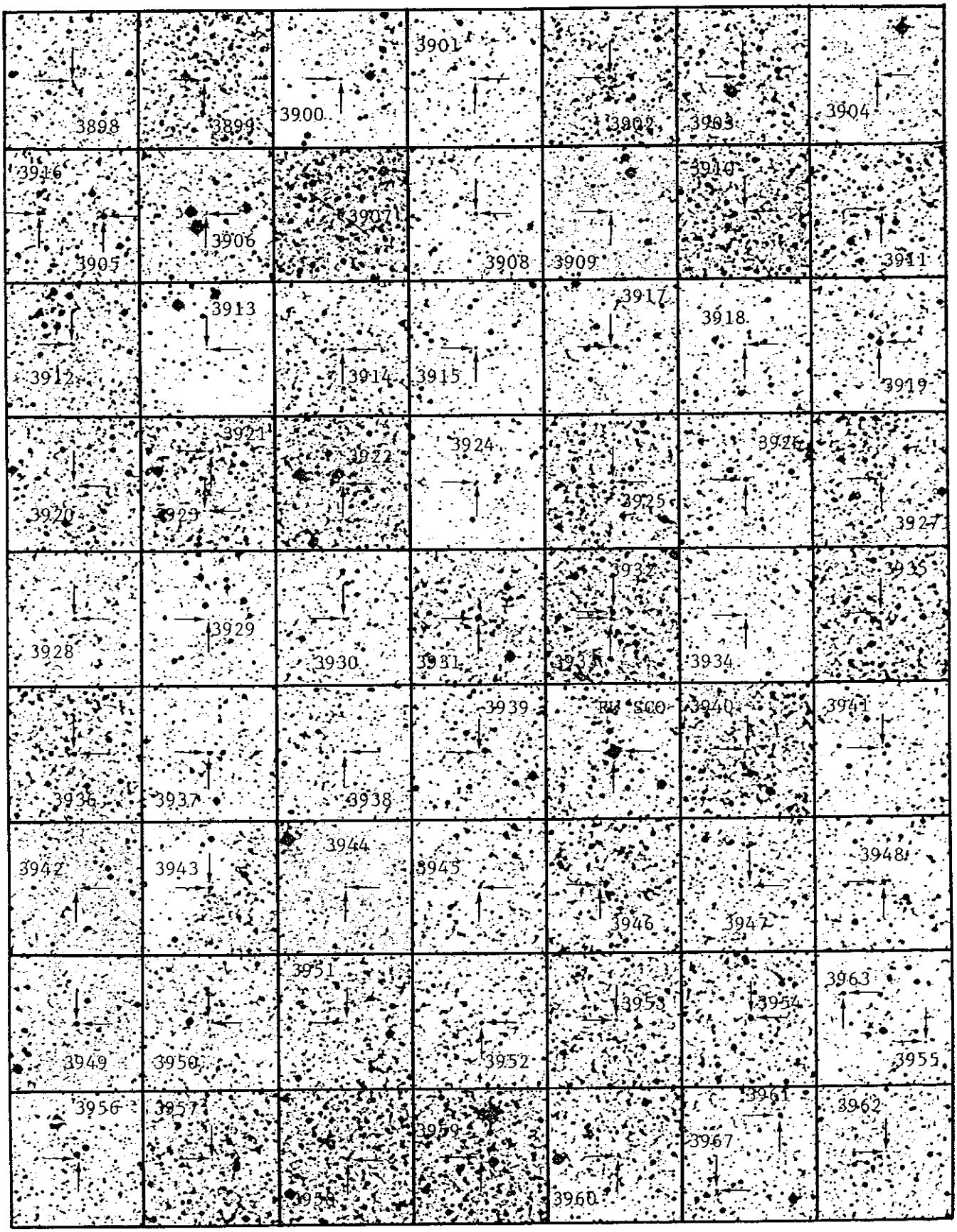
3898
3899
3900
3901
3902
3903
3904
3916
3905
3906
3907
3908
3909
3910
3911
3912
3913
3914
3915
3917
3918
3919
3920
3921
3922
3924
3925
3926
3927
3928
3929
3930
3931
3933
3934
3935
3936
3937
3938
3939
RU SCO
3940
3941
3942
3943
3944
3945
3946
3947
3948
3949
3950
3951
3952
3953
3954
3963
3955
3956
3957
3958
3959
3960
3961
3967
3962

Plate 9

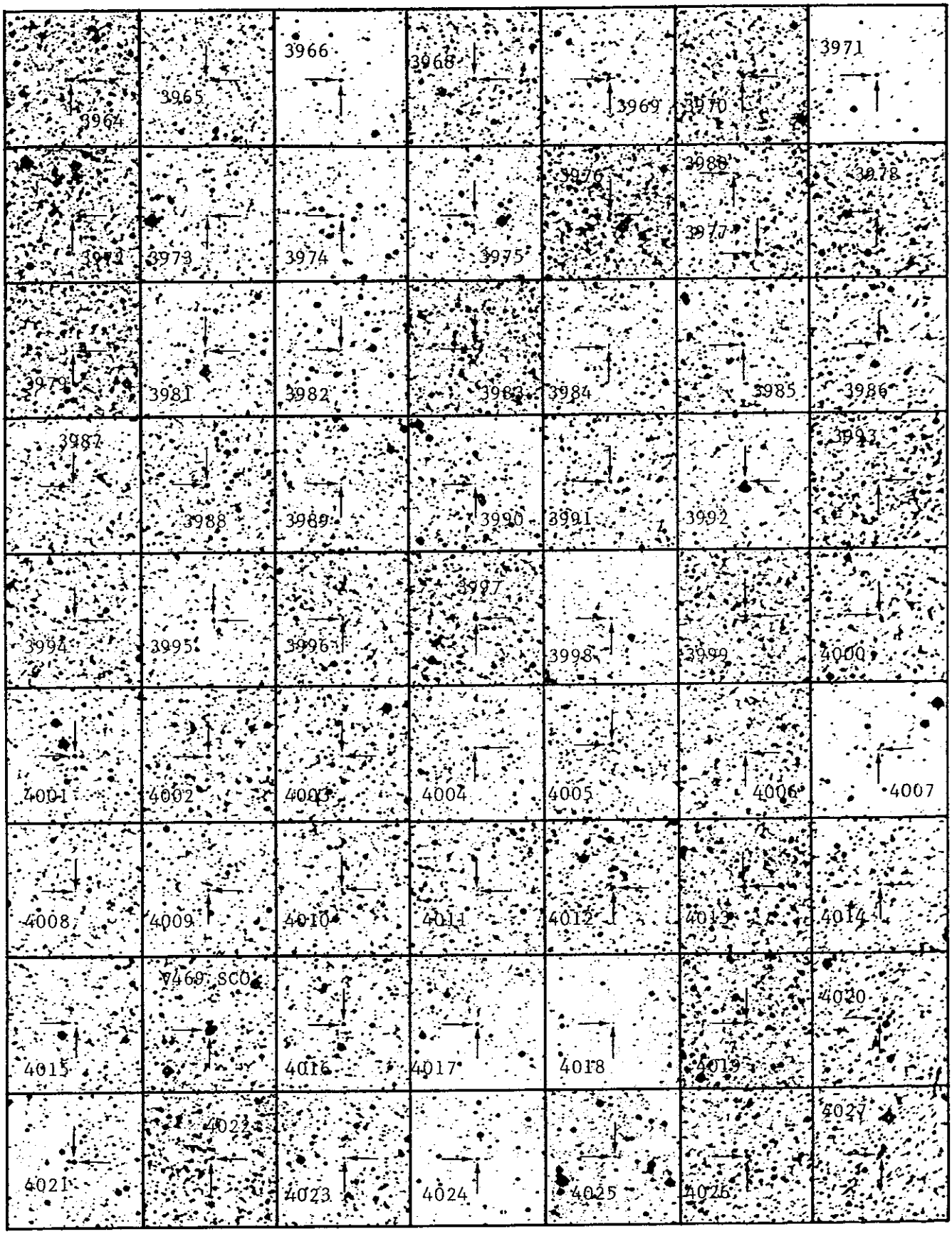
3964
3965
3966
3968
3969
3970
3971
3972
3973
3974
3975
3976
3977
3978
3979
3981
3982
3983
3984
3985
3986
3987
3988
3989
3990
3991
3992
3993
3994
3995
3996
3997
3998
3999
4000
4001
4002
4003
4004
4005
4006
4007
4008
4009
4010
4011
4012
4013
4014
V469 SCO
4015
4016
4017
4018
4019
4020
4021
4022
4023
4024
4025
4026
4027

Plate 10

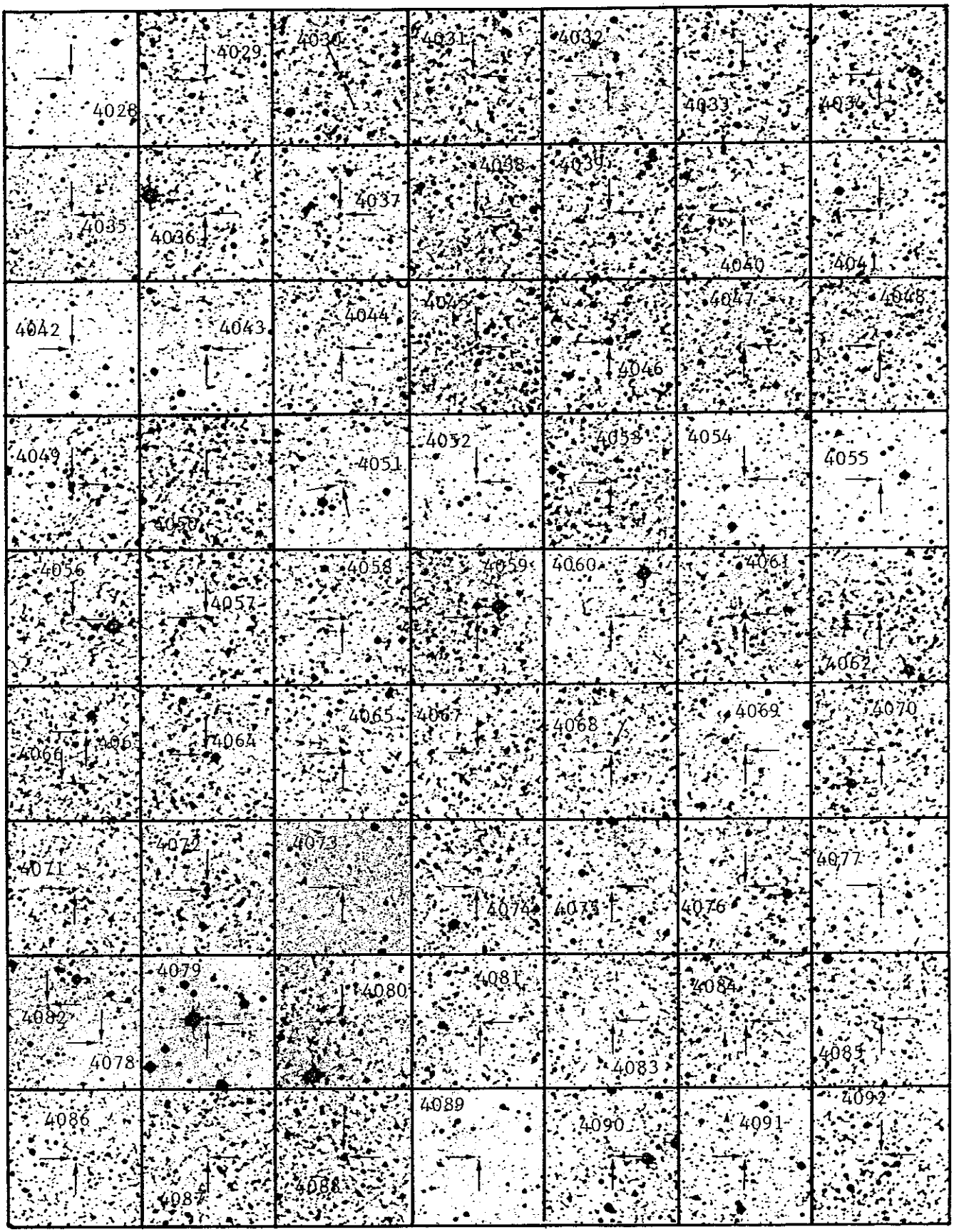
4028
4029
4030
4031
4032
4033
4034
4035
4036
4037
4038
4039
4040
4041
4042
4043
4044
4045
4046
4047
4048
4049
4050
4051
4052
4053
4054
4055
4056
4057
4058
4059
4060
4061
4062
4063
4064
4065
4067
4068
4069
4070
4071
4072
4073
4074
4075
4076
4077
4078
4079
4080
4081
4082
4083
4084
4085
4086
4087
4088
4089
4090
4091
4092

Plate 11

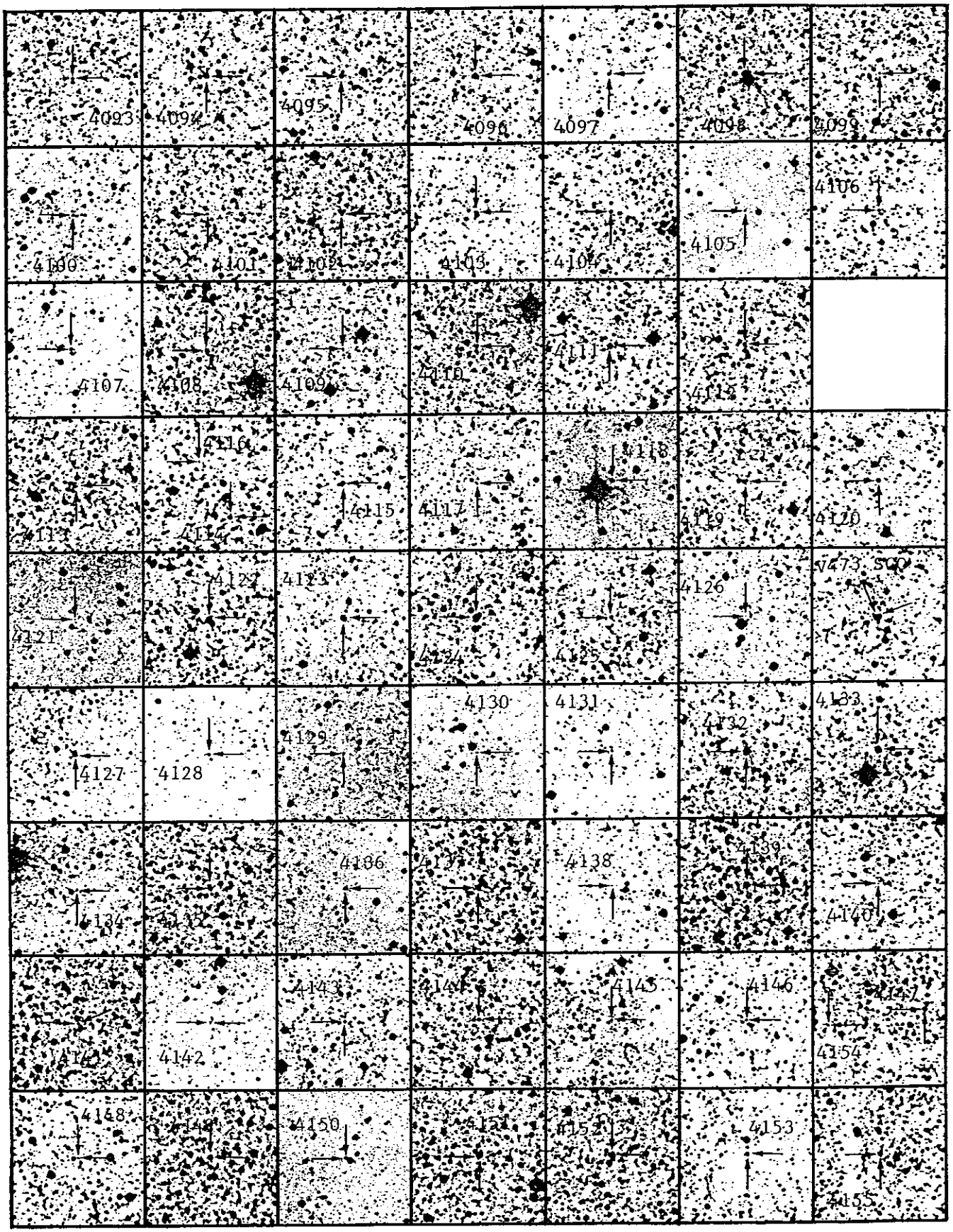
4093
4094
4095
4096
4097
4098
4099
4100
4101
4102
4103
4104
4105
4106
4107
4108
4109
4110
4111
4112
4113
4114
4115
4116
4117
4118
4119
4120
4121
4122
4123
4124
4125
4126
4127
4128
4129
4130
4131
4132
4133
4134
4135
4136
4137
4138
4139
4140
4141
4142
4143
4144
4145
4146
4147
4148
4149
4150
4151
4152
4153
4154
4155

Plate 12

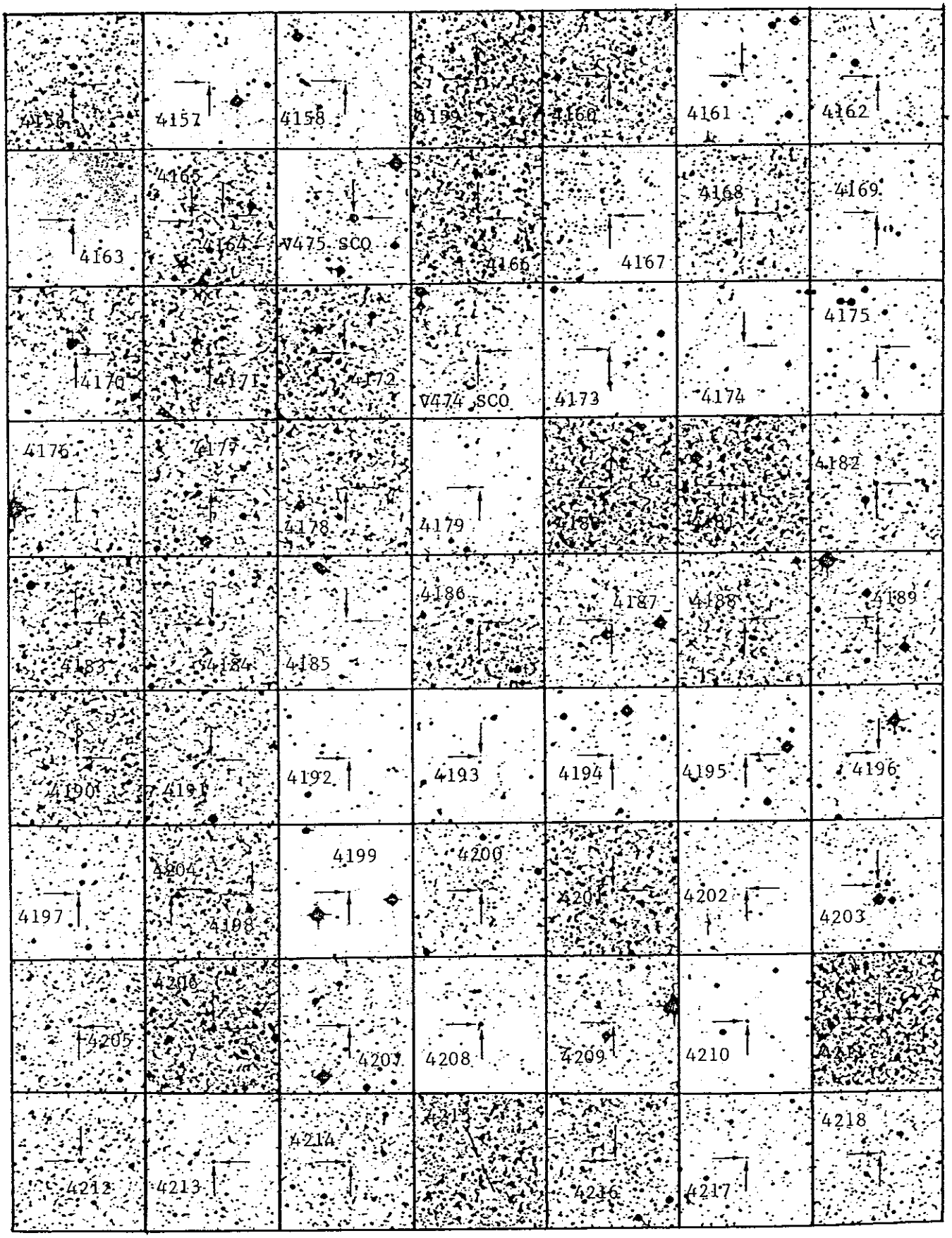
4156
4157
4158
4159
4160
4161
4162
4163
4164
4165
V475 SCO
4166
4167
4168
4169
4170
4171
4172
V474 SCO
4173
4174
4175
4176
4177
4178
4179
4182
4183
4184
4185
4186
4187
4188
4189
4190
4191
4192
4193
4194
4195
4196
4197
4198
4199
4200
4202
4203
4205
4206
4207
4208
4209
4210
4212
4213
4214
4216
4217
4218

Plate 13

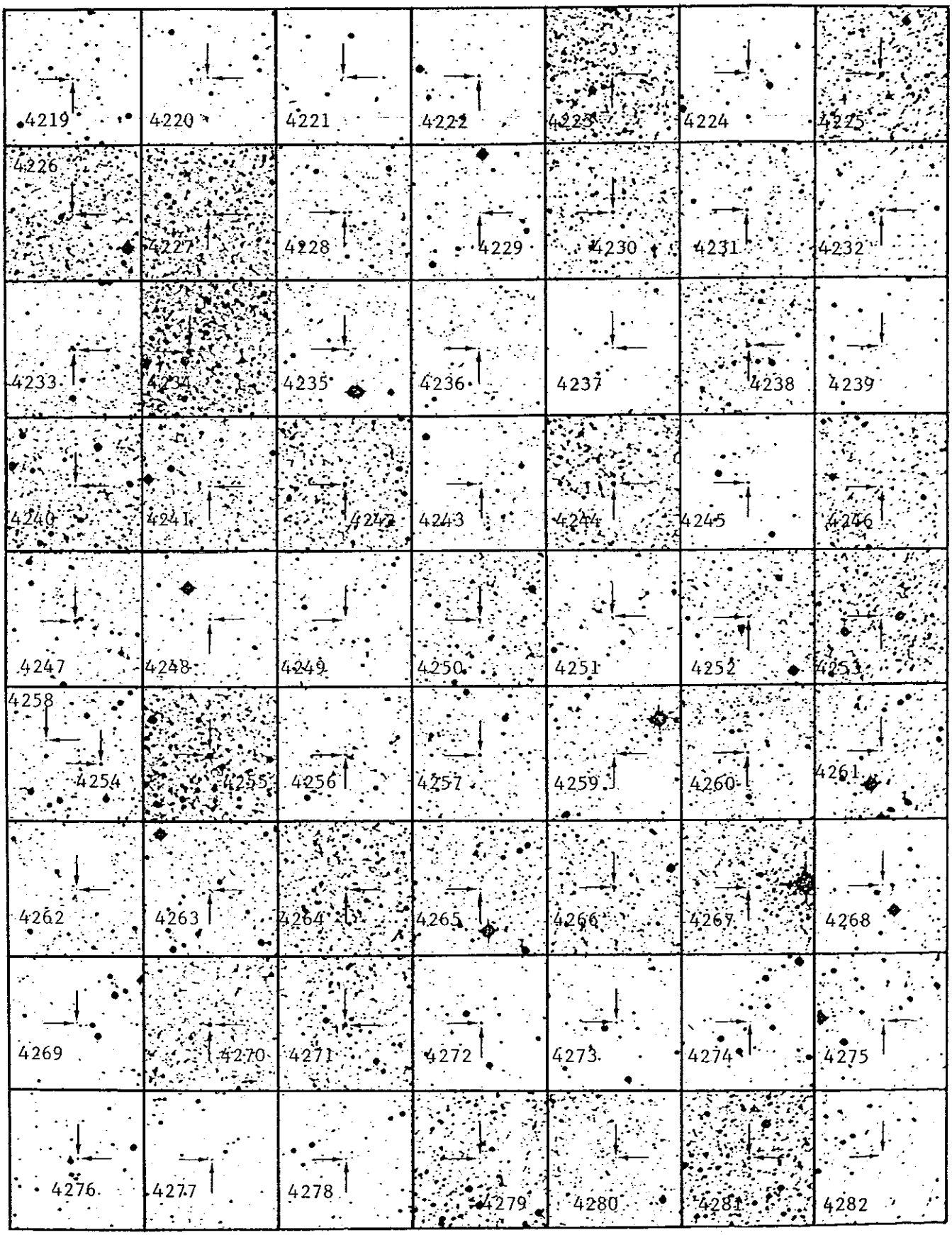
4219
4220
4221
4222
4223
4224
4225
4226
4227
4228
4229
4230
4231
4232
4233
4234
4235
4236
4237
4238
4239
4240
4241
4242
4243
4244
4245
4246
4247
4248
4249
4250
4251
4252
4253
4258
4254
4255
4256
4257
4259
4260
4261
4262
4263
4264
4265
4266
4267
4268
4269
4270
4271
4272
4273
4274
4275
4276
4277
4278
4279
4280
4281
4282

Plate 14

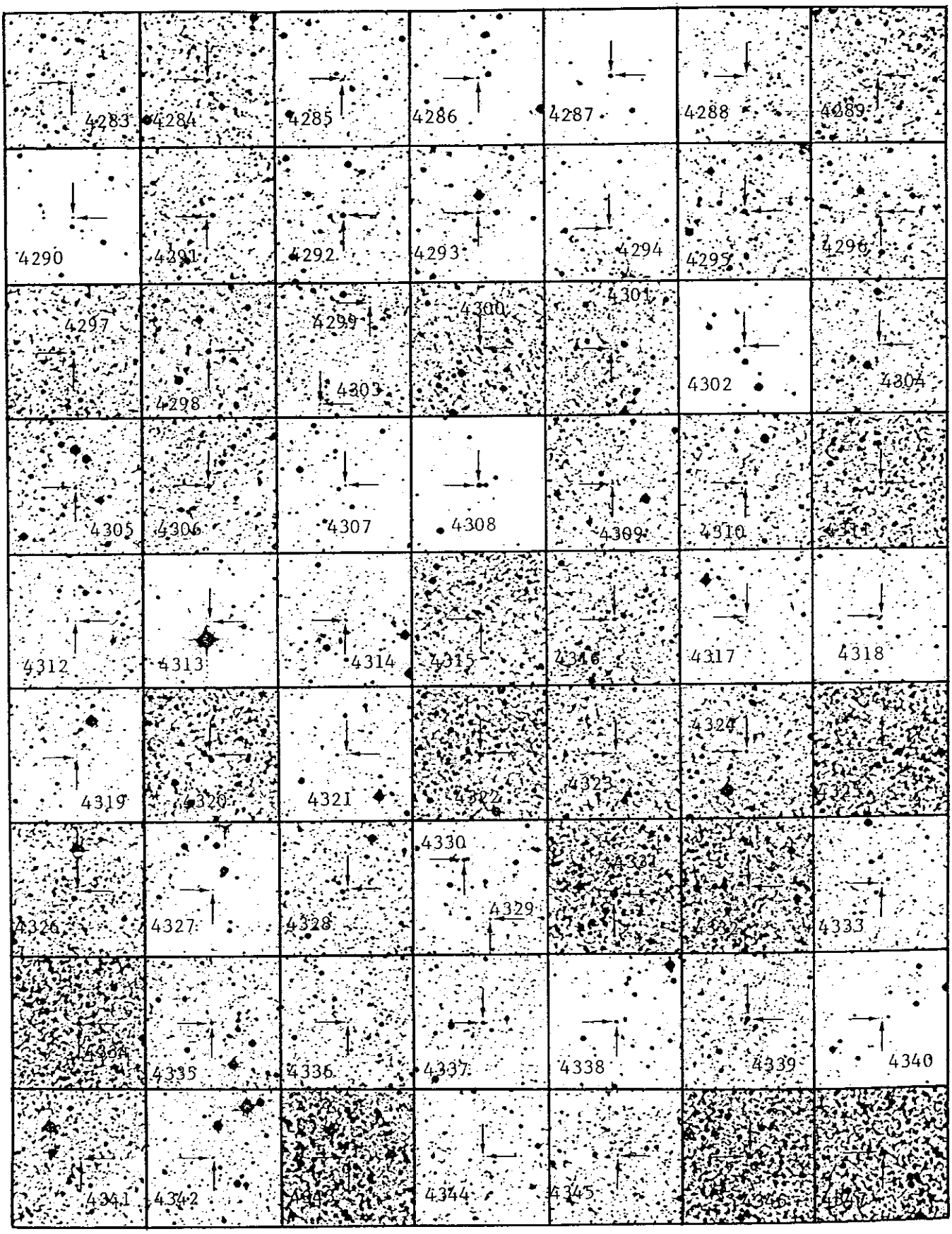
4283
4284
4285
4286
4287
4288
4289
4290
4291
4292
4293
4294
4295
4296
4297
4298
4299
4300
4301
4302
4303
4304
4305
4306
4307
4308
4309
4310
4312
4313
4314
4315
4316
4317
4318
4319
4320
4321
4322
4323
4324
4326
4327
4328
4329
4330
4333
4335
4336
4337
4338
4339
4340
4341
4342
4344
4345

Plate 15

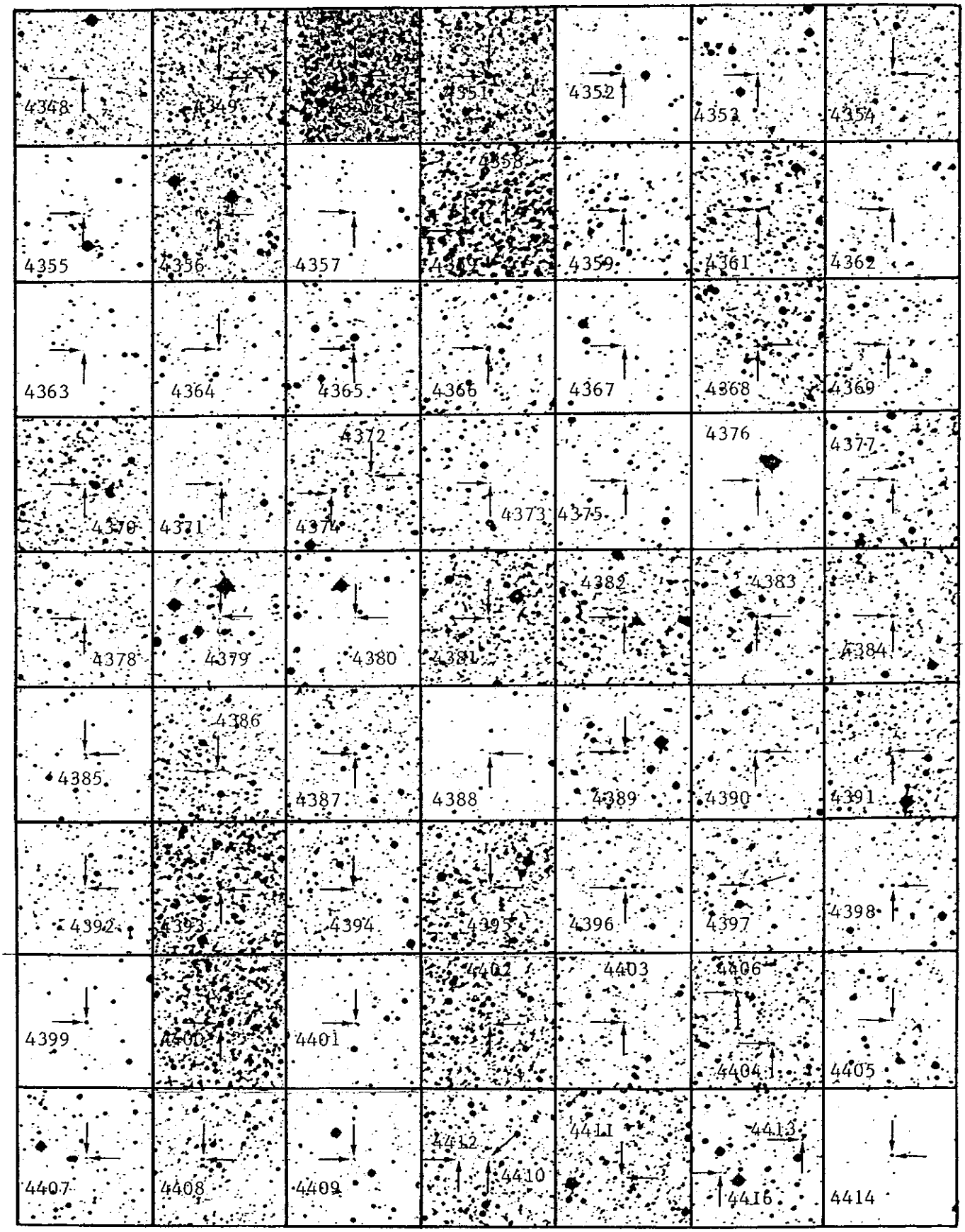
4348
4349
4351
4352
4353
4354
4355
4356
4357
4358
4359
4361
4362
4363
4364
4365
4366
4367
4368
4369
4370
4371
4372
4373
4375
4376
4377
4378
4379
4380
4381
4382
4383
4384
4385
4386
4387
4388
4389
4390
4391
4392
4393
4394
4395
4396
4397
4398
4399
4400
4401
4402
4403
4404
4405
4407
4408
4409
4410
4411
4413
4414
4416

Plate 16

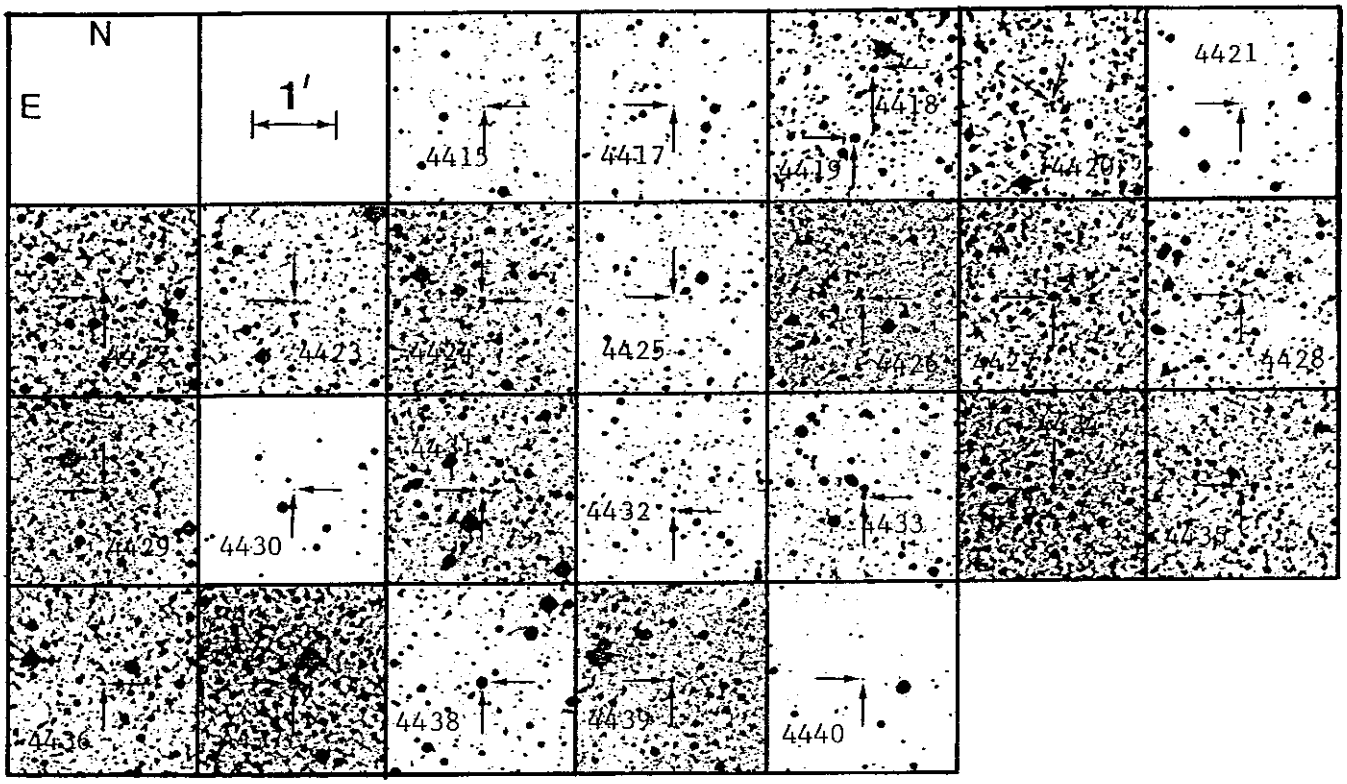
N
E
1′
4415
4417
4418
4419
4420
4421
4423
4425
4426
4428
4429
4430
4432
4433
4436
4438
4439
4440

Plate 17