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A NOTE ON THE OBSERVATIONS OF SUNSPOTS RECORDED AT KODAIKANAL FROM 1903 TO 1950.

BY

R ANANTHAKRISHNAN

ABSTRACT

A statistical study of the sunspots observed at Kodaikanal during the period 1903-50 has been made. It is pointed out that the scheme of sunspot classification suggested by Prof Waldmeier in 1947 is more suitable than Cortie's classification which has been followed at Kodaikanal since 1903

1. *Introduction.*

The records of the Kodaikanal Observatory show that regular solar observations were commenced at this station from 1901, March 14. One of the routine items of work was "daily examination of the sun's surface for spots". For over two years this examination appears to have been confined mostly to visual observations on a solar image of 8 inches diameter projected by the six-inch Cooke telescope of this observatory mounted in the "South Dome" which at present houses the prominence spectroscope. Beginning from 1903, August 22, photoheliograms were taken on a scale of 8 inches to the sun's diameter with a 4-inch Dallmeyer photoheliograph which was housed in what is at present known as the "iron shed". The old reports indicate that the mounting of this instrument was not quite satisfactory, and that it was somewhat shaky especially during high winds. This instrument was in use upto 1912, July 31. From that date the Lerebours and Secretan equatorial remounted by Grubb which is installed in the "North Dome" of the observatory has been in use for taking sun photographs. The 6-inch lens of this instrument was replaced by a Cooke photo-visual lens of the same aperture and the instrument was adapted for direct solar photography A guide telescope of 2¾ inches aperture was used for projecting a solar image of 8 inches diameter on a screen rigidly attached to the instrument for visual observations and sketching of sunspots and faculae.

Upto 1908 April 30, the charts on which sunspots and faculae were sketched were blank discs of 8 inches diameter on which only the N-S and E-W lines were marked. Beginning from 1908 May 1, the sun charts in use have solar latitude and longitude lines at 5° intervals printed on them. These charts are prepared from the original large drawings made by Father R. de Beaurepaire.

2. *Classification of Sunspots.*

From the early days of sunspot observations at Kodaikanal the scheme of sunspot classification originally proposed by Rev Father A L Cortie, S.J., has been followed at this observatory (1). This classification which is based essentially on the appearance of the spotgroups is according to the scheme stated below :—

Type	I	A group of one or more small scattered spots.
Type	II	The two spot formation.
	IIa	In which the leader is the principal spot.
	IIb	In which the following spot is the principal spot.
	IIc	In which both spots are more or less equal.

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Type III A train of spots.
- IIIa With well-defined principal spots.
- IIIb Without well-defined spots, but consisting mostly of penumbral patches with shattered irregular umbra.

Type IV Single spots.
- IVa A single spot of round and regular outline.
- IVb A single spot of round and regular outline with small companions.
- IVc A single spot of irregular outline.
- IVd A single spot of irregular outline with a train of smaller companions.
- IVe A single spot of irregular outline with small companions not in a train.

Type V An irregular group of larger spots

Fig. 1 illustrates the various types.

According to Cortie, the scheme of classification outlined above represents approximately the ordinary process of spot formation and the life history of spotgroups. A new spotgroup first makes its appearance as one or more small scattered dots surrounded by bright faculae. These dots next coalesce into two principal spots—the type II stage During the next phase of evolution a train of small spots appears between the two spots, the group thus passing over to Type III. The small spots between the two principal spots then disappear and this is followed in most cases by the breaking up of the following spot During this stage which is represented by Type IV the group generally consists of a single predominant spot The last stage in the life history of a spotgroup is represented by a recurrence of Type I. Irregular groups of larger spots which do not fit into this scheme are listed under Type V.

At Kodaikanal, the spotgroups observed daily are assigned the appropriate type numbers by the observer who sketches them on the sun charts, and they are subsequently listed in the sun-spot register These records are available without interruption—except for breaks due to unfavourable weather conditions—for the period commencing from 1903 August 1 to date.

3. *Analysis of Data.*

From the original sunspot registers monthly and yearly frequency tables were prepared classifying the observed spotgroups into the various types listed in Cortie's classification. Table A gives the annual frequencies of the different sunspot types for the period 1904-1950. The total number of spotgroups observed on the sun in each year, the total number of days of observation and the mean daily number of sunspot groups are also given in the table.

TABLE A

Year	Type of Sunspot					Total No of Spots (N)	No of days of Obsn (D)	N/D=G	Spotless days (d)	100d/D	Observed Rel. Sunspot No. (R)	R/G
	I	II	III	IV	V							
1904	457	134	238	408	10	1247	343	3 64	0	0	42 0	11·5
05	652	158	207	482	14	1513	346	4 37	0	0	63 5	14·5
06	700	121	163	444	22	1450	339	4 27	2	0 6	53·8	12·6
07	784	56	145	499	36	1520	353	4 30	0	0	62·0	14·4
08	694	50	93	438	19	1294	344	3 76	4	1·2	48 5	12 9
09	622	45	82	440	6	1195	347	3 44	3	0·9	43 9	12·7
10	399	27	13	177	14	630	353	1·78	57	16·2	18·6	10·4

TABLE A—*contd.*

Year	Type of Sunspot I	II	III	IV	V	Total No. of Spots (N)	No. of days of Obsn. (D)	N/D = G	Spotless days (d)	100d/D	observed Rel Sunspot No (R)	R/G
1911	128	3	7	96	5	239	337	0 709	160	47 5	5 7	8 1
12	53	9	6	26	0	94	330	0 285	239	72 5	3 6	12 6
13	44	0	3	7	0	54	339	0·16	289	84 3	1 4	8 76
14	189	30	13	58	0	290	347	0·835	156	45 0	9 6	11·5
15	592	40	85	291	22	1030	335	3 08	12	3 6	47 4	15·4
1916	823	44	48	275	6	1196	336	3·56	6	1 8	55 4	15 5
17	1284	102	177	540	17	2120	331	6·40	0	0	103 9	16·2
18	1174	57	136	384	6	1757	343	5·12	0	0	80 6	15 7
19	754	64	72	447	11	1348	341	3·95	0	0	63 6	16·1
20	532	15	51	260	2	860	328	2·62	9	2 8	37 6	14 4
1921	361	10	28	210	0	609	340	1·79	47	13·8	26 1	14·6
22	217	8	26	95	1	347	328	1·06	120	36 6	14 2	13·4
23	116	2	7	41	0	166	317	0 52	175	55 2	5 8	11 2
24	258	6	13	124	0	401	334	1·20	114	33 2	16 7	13 9
25	737	7	137	139	11	1031	332	3·11	31	9 4	44 3	14·2
1926	1032	14	166	289	15	1516	354	4·28	3	0 9	63 9	14 9
27	1003	7	158	393	17	1578	335	4·70	0	0	69 0	14·7
28	938	9	266	373	65	1651	335	4·83	0	0	77 8	16·1
29	871	10	140	374	59	1454	344	4·23	0	0	65 0	15·2
30	613	2	99	238	0	952	329	2·89	7	2 1	35 7	12 3
1931	386	9	45	109	0	549	328	1·67	52	15 9	21 2	12 7
32	166	10	29	110	3	318	339	0·94	126	37 3	11 1	11 8
33	72	11	19	37	0	139	328	0·424	232	69·7	5 7	13·4
34	143	5	12	66	0	226	317	0·712	154	48 5	8 7	12·2
35	538	3	67	225	1	834	318	2 62	18	5 7	36 1	13 3
1936	1040	15	98	389	32	1574	318	4·95	0	0	80 4	16 2
37	1363	36	150	559	74	2182	326	6·71	0	0	114·4	17·0
38	1081	14	215	486	48	1844	324	5 69	0	0	109 6	19 3
39	1040	12	200	625	22	1899	329	5·77	0	0	88·8	15 4
40	822	12	137	444	9	1424	331	4 30	0	0	67 8	15 8
1941	529	11	111	355	11	1017	311	3 27	1	0 3	47·5	14 5
42	352	6	109	231	2	700	323	2·17	24	7 4	30 6	14 1
43	177	10	25	158	2	372	313	1·19	58	18 5	16 3	13 7
44	178	10	3	15	0	206	297	0·695	161	54 3	9 6	13·8
45	498	55	14	31	2	600	308	1·95	35	11 4	33 2	17·0
1946	744	264	58	475	26	1567	283	5·54	0	0	92·6	16·7
47	887	541	71	584	146	2229	288	7·24	0	0	151·6	20·9
48	881	503	60	477	138	2059	306	6·73	2	0 6	136·3	20.2
49	633	700	163	703	50	2249	314	7·16	0	0	135·9	19·0
50	378	355	73	445	61	1312	276	4·76	3	1·1	83 3	17·5

Sunspot maxima are indicated in bold type and minima in italics. The table also gives the observed numbers of spot-free days and the Zurich relative sunspot numbers for the respective years (2). Fig. 2 gives a graphical representation of sunspot activity during the period in question based on the data given in Table A

The percentage frequencies of the various types for the individual years have been worked out and are given in Table B. Fig. 3 gives a dot diagram based on these frequencies.

TABLE B

Percentage Frequencies

Year	Type of Sunspot					Year	Type of Sunspot				
	I	II	III	IV	V		I	II	III	IV	V
1904	36 6	10 7	19 1	32·8	0·8	1931	70 4	1·6	8·2	19·7	0
05	43 0	10 4	13 7	31 8	0 9	32	52·2	3·1	9·1	34·6	0 9
1906	48 3	8 4	11 2	30 6	1 5	33	51 8	7 9	13·7	26·6	0
07	51 6	3 7	9 5	32 8	2 4	34	63·3	2 2	5 3	29·2	0
08	53 6	3 9	7 2	33 8	1 5	35	64·6	0 4	8 0	27 0	0·1
09	52 0	3 8	6 9	36 8	0 5	1936	66·1	0·9	6 2	24·7	2·0
10	63 5	4 3	2 1	28 0	2 2	37	62 4	1·6	6 9	25·6	3·4
1911	53 6	1 3	2 9	40 0	2 1	38	58·6	0·8	11·7	26·4	2·6
12	56 4	9 6	6 4	27 6	0	39	54·8	0·6	10·5	33·0	1·2
13	81 5	0	5·5	13 0	0	40	57·7	0·8	9·6	31·2	0·6
14	65 2	10 3	4 5	20 0	0						
15	57 5	3 9	8 2	28 2	2 1	1941	52 0	1·1	10·9	34·9	1·1
1916	68 8	3 7	4 0	23 0	0·5	42	50 2	0·8	15·6	33·0	0·3
17	60 6	4 8	8 4	25 5	0·8	43	47 7	2 7	6·7	42·5	0 5
18	66 8	3 3	7 7	21 8	0 3	44	86·5	4 9	1 5	7·3	0
19	56 0	4 7	5 4	33 2	0·8	45	83·0	9 2	2 3	5·2	0·3
20	61 8	1 7	5·9	30 2	0·2	1946	47 5	16 8	3·7	30·3	1·6
1921	59 4	1 6	4 6	34 5	0	47	39 8	24 3	3 2	26·2	6·5
22	62 6	2 3	7 5	27 4	0 3	48	42 8	24·5	2 9	23·2	6·7
23	70 0	1 2	4 2	25 0	0	49	28·2	31·1	7·3	31·2	2·2
24	64 3	1 5	3 2	31·0	0	50	28 8	27·1	5 6	33·9	4·7
25	71 4	0 7	13 3	13 5	1 1						
1926	68 1	0 9	11 0	19 1	1·0						
27	63 6	0 4	10 0	24 9	1·1						
28	56 7	0 5	16 1	22 6	3·9						
29	60 0	0 7	9 6	25·8	4 0						
30	64·5	0 2	10·4	25·0	0						

4. *Discussion.*

Cortie's scheme of classification is based on the visual impression which the observer gets from the appearance of the spotgroups. Spotgroups present such a diversity in their structure that it is sometimes possible to assign more than one type number to the same group. The "personal equation" of the observer, therefore, enters in some measure in the classification. This fact has to be borne in mind when we consider the data in Tables A and B above.

The most striking fact brought out by tables A and B and by Fig. 3 is that generally about 60% of the spotgroups fall under Type I. The next in order of frequency is Type IV, which comprises about 30% of the total. Types III, II and V then follow in the order of decreasing frequency. The period 1946-50, however, shows a departure from the above trend. It will be seen that during this period there has been a systematic fall in the percentage frequency of Type I and a corresponding rise in the case of Type II. During 1949 and 1950 these two types which together comprise nearly 60% of the total number of observed spotgroups, are found to have occurred with almost equal frequencies This feature is in striking contrast with the observations of the past 40 years.

To seek on explanation for this, the sunspot registers in which the type numbers of the spotgroups observed daily are entered have been compared with the sun charts in which the spotgroups have been sketched by projection. It is seen that the "personal equation" of the observer has been largely responsible for the observed discrepancy. There has been a distinct bias on the part of recent observers in favour of the bipolar spotgroup—type II of Cortie's classification. The bias of the previous observers would appear to have been to avoid type II as much as possible. Several spotgroups with the recent observers have classified as type II would have been grouped by the previous observers under one or other of the types I, III or IV.

If all sunspot groups follow the life history contemplated in Cortie's scheme, we might expect to find all types occurring with comparable frequencies. The predominance of type I indicates that the majority of sunspots die out before they pass through all the stages of evolution.

Examination of the last five columns of Table A and also of Fig.2 shows that during the period under consideration sunspot activity has passed through four cycles with maxima during the years 1905, 1917, 1928, 1937 and 1947 and minima during the years 1913, 1923, 1933 and 1944. It is well known that the sunspot maximum of 1947 is the highest on record in recent times. From the table of relative sunspot numbers published by the Zurich Observatory for the period commencing from 1749 to date it is seen that the latest sunspot maximum has been exceeded only once—by the sunspot maximum of 1778. It may be of interest to note that the sunspot minimum of 1913 is one of the lowest on record, being surpassed only by the minimum of 1810.

The dotted curve at the top of Fig. 2 shows the percentage of spot-free days in each year during the period under consideration. The sunspot minima stand out conspicuously. The other two curves in Fig. 2 bring out the close parallelism between the mean daily number of sunspot groups observed at Kodaikanal and the Zürich relative sunspot numbers. In a recent paper from the United States Naval Observatory, Markowitz(3) has examined the relation between sunspot areas measured at Washington and Zürich relative sunspot numbers, and found a high degree of correlation between these quantities.

Examination of Fig. 3 suggests that the percentage frequencies of sunspot types III and IV fluctuate in such a way that type III is more frequent near the maximum epoch while type IV is more frequent near the minimum epoch.

The last column of Table A gives the ratio between the relative sunspot numbers and the mean daily numbers of sunspot groups for the various years. It is seen that these figures also show a variation more or less parallel with the trend of sunspot activity. According to the convention adopted by Wolf, the relative sunspot number (r) is obtained from the formula :

$$r = k\ (10g + f)$$

where g is the total number of groups of spots visible on the sun's disc and f is the individual number of spots that can be counted in all these groups k is a coefficient depending upon the instrument used and the observer. This was taken as unity by Wolf for his observations at Zurich with a telescope of 10 cms aperture and a power of 64 We then have :

$$r/g = 10 + f/g$$

f/g is the average number of individual spots in a group. The sequence of the figures in the last column of Table A therefore indicates that during maximum periods the spot groups contain more individual spots than during the minimum periods. It is easily seen that the minimum possible value of r/g is 11. The fact that in one or two cases this value is less than 11 in the last column of Table A is because the relative sunspot numbers and the mean daily number of sunspots are not based on the same observational data. It is interesting to note that the value of r/g is highest for the latest sunspot maximum.

5. *Waldmeier's Scheme of Classification of Sunspot-groups.*

In the quarterly Bulletin on Solar Activity for 1947 Waldmeier ([4]) has given a scheme of classification of sunspot groups which is more objective than Cortie's scheme. Nine separate classes are recognised which represent the "normal stages of evolution of a large sunspot group". These are .

A. An isolated spot or group of spots without penumbra or bipolar structure.

B. Group of spots in bipolar configuration, penumbra lacking.

C Bipolar spotgroup, only one of the principal spots (the P- or the F-spot) being surrounded by penumbra.

D. Bipolar spotgroup, both groups showing penumbrae ; at least one of the spots should possess a simple structure. Length usually $<10°$.

E. Large bipolar sunspot group, both principal spots having penumbrae, usually of complicated structure. Intermediate region occupied by small sunspots. Total length of the group at least 10°.

F. Very large bipolar or complex sunspot group, length at least 15°.

G. Large bipolar group without intermediate spots. Length at least 10°.

H. Unipolar sunspot surrounded by a penumbra. Diameter$>2°\cdot5$.

J. Unipolar sunspot surrounded by a penumbra. Diameter $<2°\cdot5$.

Fig. 4 gives a diagramatic representation of Waldmeier's classification.

Comparison of Waldmeier's scheme with Cortie's shows that :

(*i*) A and B correspond to type I.

(*ii*) D, E, G correspond to type II.

(*iii*) F corresponds to type III.

(*iv*) C, H, J correspond to type IV.

(*v*) Some cases of F correspond to type V

6. *Conclusions.*

Waldmeier's classification recognises the bipolar configuration in one or other of its various manifestations as the most prevalent type of sunspot. This is in conformity with the large mass of observational data which has been collected since the discovery of sunspot magnetism by Prof. Hale in 1908. Although Cortie's classification was formulated before this date, he has also drawn attention to the importance of the bipolar type in the following remark : "The chief type, however, of which the above mentioned are in most, possibly in all, cases but phases is the double spot formation, with a train of smaller spots between the two principal spots of the group, the whole drifting into more or less parallelism with the solar equator". What is then the reason for the small percentages of the "two spot formation" (type II) during the years 1904 to 1945? This is partly due to the fact that the line of demarcation between the various types is not unambiguous. Examination of the original records shows that when the individual spots are small, the general practice has been to classify the group as type I even when there is clear indication of a bipolar structure. Again, it is seen that some spotgroups which have been classified under one or other of the types III and IV could also have been classified under type II. The spotgroups which illustrate Cortie's paper do not furnish an adequate reference chart for an unambiguous classification of the spot groups observed day by day. In the circumstances, the "judgement" of the observer plays a large part. This is clearly illustrated by the change in trend since 1945 to which reference has already been made. All this would emphasise the necessity for the adoption of a scheme of classification of sunspotgroups which is more objective than Cortie's scheme.

According to the Mount Wilson classification which is based on magnetic polarity, spots are divided into three main categories, viz., (i) unipolar spots (α), (ii) bipolar spots (β) and (iii) multipolar spots (γ). The results of the classification show that over 60% of the observed spotgroups are bipolar, about 38% are unipolar while the rest are multipolar. ([5]).

In the absence of the necessary arrangements for routine daily observations of the magnetic polarity of sunspots, we have to adopt a scheme of visual classification which covers all the types met with in day to day observations, which conforms to the usually observed life cycle of the majority of sunspot groups and which can be used as far as possible unambiguously in daily work. The author is of opinion that Waldmeier's classification satisfies these requirements better than Cortie's classification.

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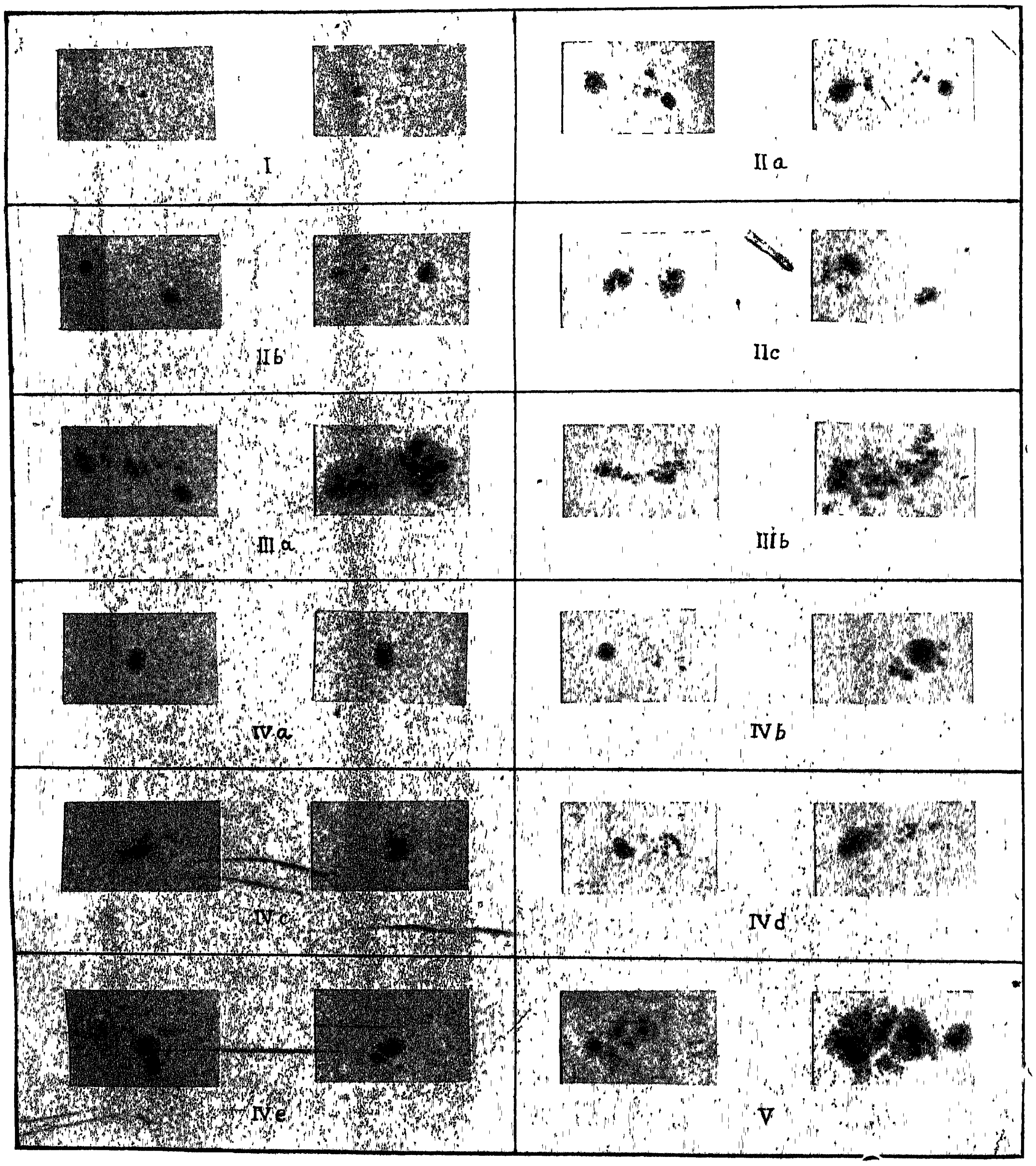

FIG. 1.
TYPES OF SUNSPOTS

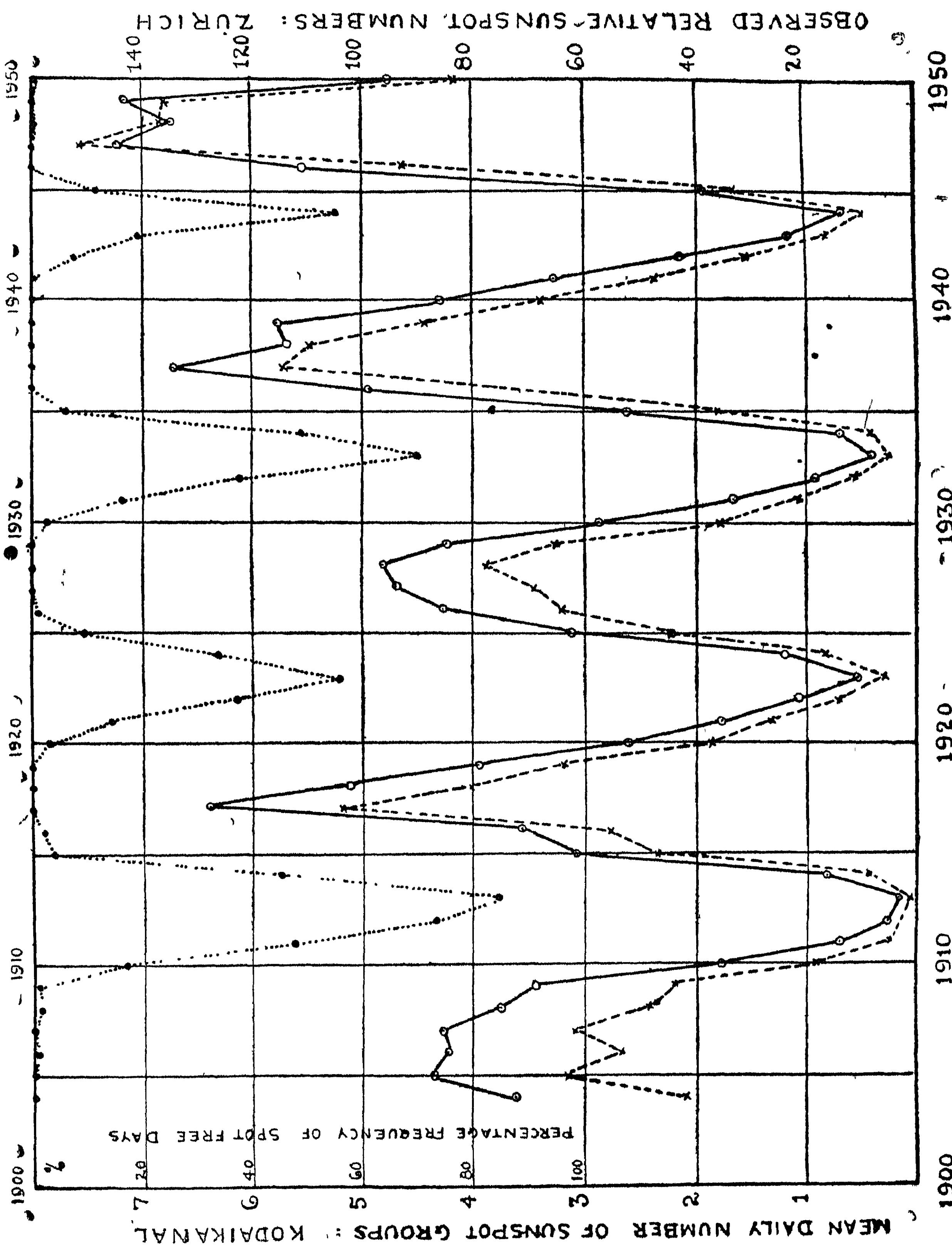
OBSERVED RELATIVE SUNSPOT NUMBERS: ZÜRICH
MEAN DAILY NUMBER OF SUNSPOT GROUPS: KODAIKANAL
PERCENTAGE FREQUENCY OF SPOT FREE DAYS
KODAIKANAL
ZÜRICH
1900
1910
1920
1930
1940
1950

Fig. 2

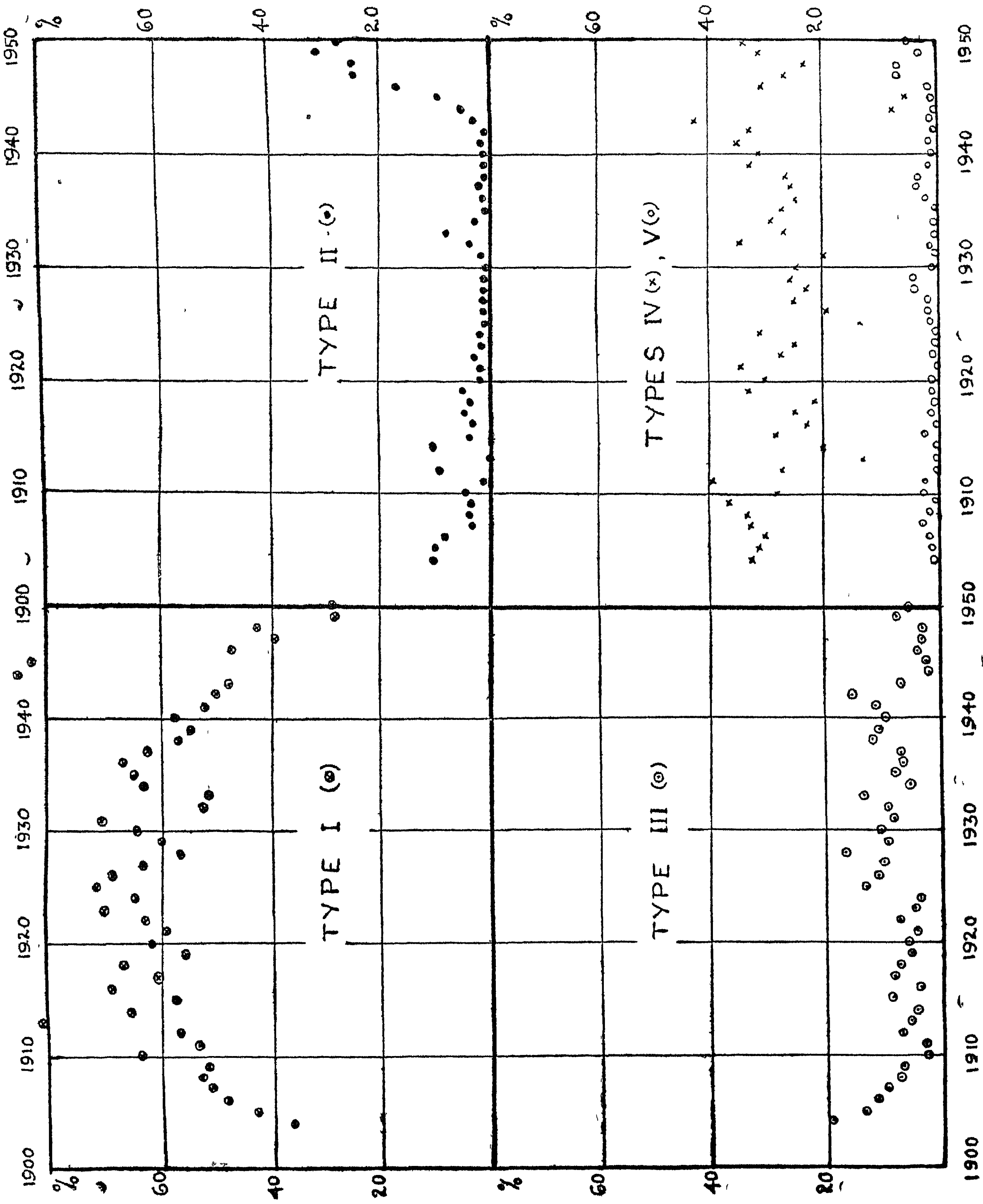

FIG. 3

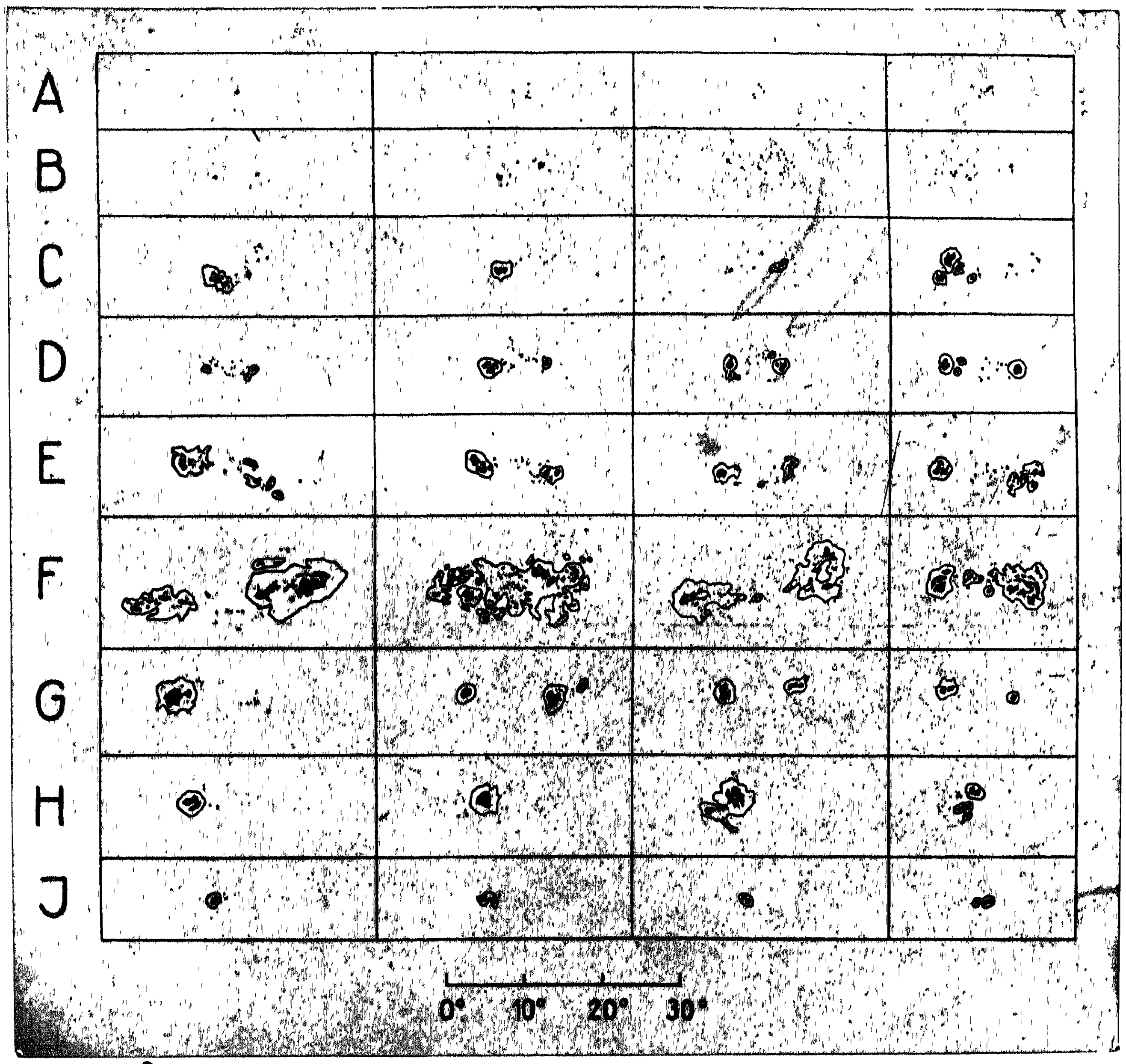

FIG. 4

CLASSIFICATION OF SUNSPOTS GROUPS
(AFTER WALDMEIER).

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