

UNCLASSIFIED

AD

402 858

*Reproduced
by the*

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA



UNCLASSIFIED

Solar Prominence Activity, 1944-1954

By

DONALD H. MENZEL AND F. SHIRLEY JONES

Solar Department of Harvard College Observatory
Harvard University
Cambridge 38, Massachusetts

Contract No. AF19(604)-4962
Project No. 7649
Task No. 76490

SCIENTIFIC REPORT No. 15

December, 1962

Prepared for
**GEOPHYSICS RESEARCH DIRECTORATE
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS**

(18) (19)
AFCRL 62-1062

(5) 393200
(7) NA
(9) NA

(6) Solar Prominence Activity, 1944 - 1954

(10) by

Donald H. Mensel and F. Shirley Jones

393200
Solar Department of Harvard College Observatory
Harvard University
Cambridge 38, Massachusetts

(15) Contract No. AF19(604)-4962^{6K}
(16) Project No. 7649
(17) Task No. 76490

(14) SCIENTIFIC REPORT No. 15

(11) December 1962

(12) 10 P.
(13) NA

(20) 2W
(21) See page 193

Prepared for

GEOPHYSICS RESEARCH DIRECTORATE
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS

Yol

**Requests for additional copies by agencies of the
Department of Defense, their contractors, and other
Government agencies should be directed to the:**

**ARMED SERVICES TECHNICAL INFORMATION
AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**

**Department of Defense contractors must be established for
ASTIA services or have their 'need to know' certified by the
cognizant military agency of their project or contract.**

All other persons and organizations should apply to the:

**U. S. DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
WASHINGTON 25, D. C.**

SOLAR PROMINENCE ACTIVITY, 1944-1954

BY DONALD H. MENZEL AND F. SHIRLEY JONES

Harvard College Observatory, Cambridge, Mass.

ABSTRACT

Solar prominences appearing on surveys made at the High Altitude Observatory, Climax, Colorado, and at the Sacramento Peak Observatory, Sunspot, New Mexico, were measured for size and position and each prominence was classified according to the Menzel-Evans (1953) scheme of classification. We compare prominence activity to spot activity, and study the distribution of the various classes with respect to solar latitude.

During this period 93 per cent of the areas were in A-type prominences and 20 per cent were in S types. The hedgerow (AN) family of prominences is much the largest class; the spicules (BNs), the smallest. The activity of all classes except the spicules was greatest near spot maximum in 1947 and lowest almost two years before spot minimum in 1954. Up to and including 1947, southern areas predominated, and northern areas thereafter.

Introduction. An earlier article in this JOURNAL (Jones 1958) outlined the history of the classification of solar prominences and described in detail the Menzel-Jones classification project. Classifications have now been completed for prominences of solar cycle number 18 which, as defined by the daily mean spotted areas at Greenwich (1955), began in 1944 and ended in 1954, with maximum activity occurring in 1947 (figures 1 and 2). We present here the major results for that period; a more detailed account of the research appears elsewhere (Menzel and Jones 1956-1961).

We studied the prominences on the surveys made with an H α Lyot filter and 6-inch coronagraph at the High Altitude Observatory, Climax, Colorado (1944-1950), and at the Sacramento Peak Observatory, Sunspot, New Mexico (1951-1954). For each prominence the solar latitude and area were determined and each was classified according to the Menzel-Evans (1953) scheme of classification, as follows:

A. Prominences originating from above, in coronal space:

S. Spot prominences

- l. loops
- f. funnels

N. Non-spot prominences

- a. coronal arcs
- b. tree trunks
- c. trees
- d. hedgerows
- e. suspended clouds (not included in the original classification)
- m. mounds

B. Prominences originating from below, in the chromosphere:

S. Spot prominences

s. surges

p. puffs

N. Non-spot prominences

s. spicules

Prominence Activity of all Classes of Prominences Combined. Figures 1 and 2 show the average number of prominence units a day of all classes of prominences for the northern and southern solar hemispheres together and separately, for each one-third year, and the spotted areas for each year. For the prominences, the unit of area is the international prominence unit which is a "rectangle", one heliocentric degree long and one geocentric degree high. The unit of spot area is 10^{-6} of the sun's visible hemisphere.

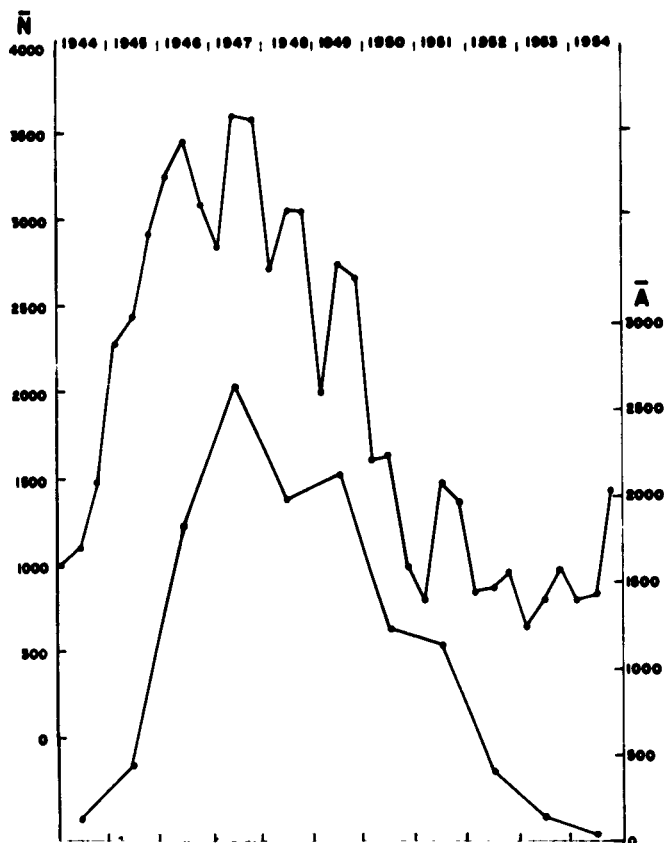


FIG. 1—Daily mean areas for all classes and all latitudes, both prominences and sunspots. *Top*: average number of prominence units per day ($\bar{N}$), both hemispheres. *Bottom*: mean annual spotted area ($\bar{A}$), both hemispheres (Greenwich 1955).

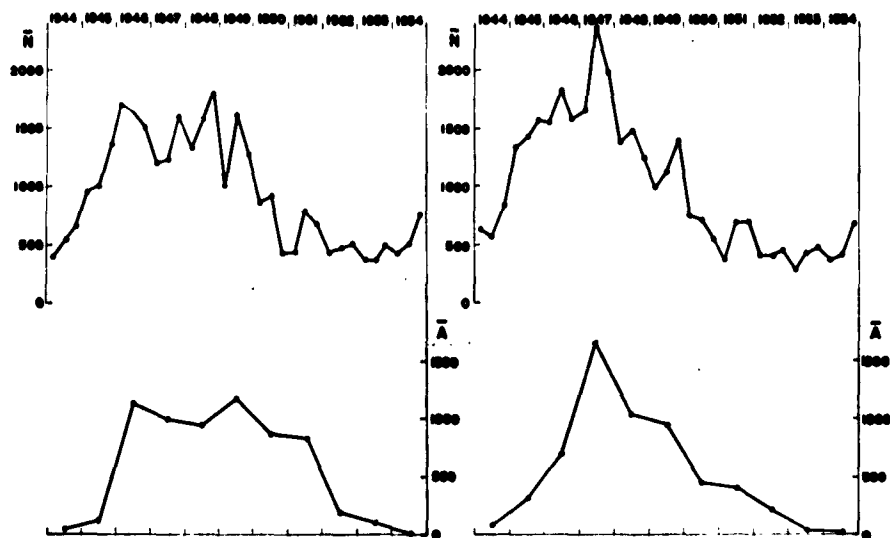


FIG. 2—Daily mean areas for all classes of prominence and of sun-spots, by hemisphere. *Left:* northern hemisphere; *right:* southern hemisphere. *Top:* average number of prominence units per day ($\bar{N}$) in the hemisphere; *bottom:* the mean annual spotted area ($\bar{A}$) for the same hemisphere.

In general the prominences followed a pattern of activity similar to that of the spots. For both, the maximum activity for the whole sun occurred in 1947, mainly because the high peak of activity in the southern hemisphere took place that year. In the northern hemisphere a peak of activity occurred in 1946 for both spots and prominences. A second peak for the prominences occurred in 1948 and a second peak for the spots in 1949.

The minimum for the prominences, however, occurred earlier than that for the spots by more than a year. The periods of fast increase and decrease in total area occurred earlier for the prominences, as well.

The distribution of all classes of prominences with latitude for each year appears in figure 3. Every year, except 1947, 1948, and 1949, had one major peak of activity in each hemisphere. These peaks moved poleward from 1944 to 1948. In 1947, 1948, and 1949 additional peaks closer to the equator emerged and started a new cycle. The principal features of these curves agree with those found by observers at Zurich (Brunner 1945, and Waldmeier 1946-1955).

Figure 4 corresponds to the "butterfly" diagrams plotted by sun-spot observers. M. and L. d'Azambuja (1948) plotted such a diagram for the solar filaments. Ananthakrishnan and Nayar (1953) give a somewhat similar diagram showing only the peaks of prominence activity in each latitude zone. The most conspicuous difference between figure 4 and

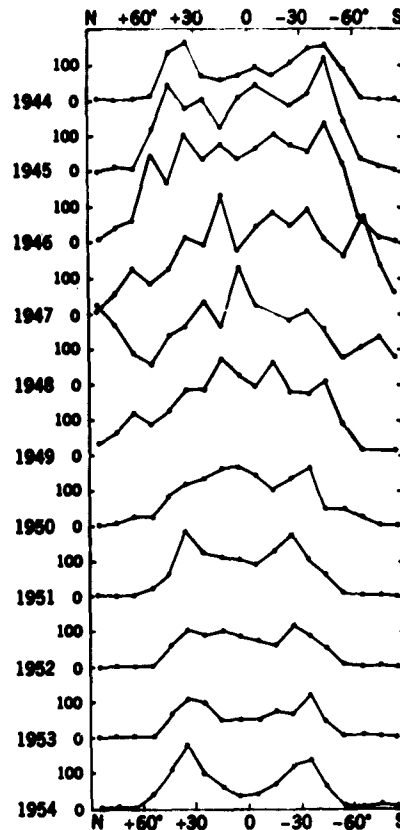


FIG. 3—Distribution in latitude, for each year, of the daily mean areas of all prominences.

similar plots of sun-spots is the high-latitude extension of the "wing" of the butterfly. These high-latitude prominences are present in the Meudon and Kodaikanal diagrams mentioned above and were also noted by Menzel and Bell (1953).

Activity of AS, BS, AN, and BN Prominences. During solar cycle number 18 the A-type prominences, those in which material moves downward toward the photosphere, accounted for 93.1 per cent of all the prominences. Of these, the loops and funnels (AS) contributed 14.1 per cent and the tree trunks, trees, hedgerows, etc. (AN), 79.0 per cent. Surges and puffs (BS), 5.6 per cent, and spicules (BNs), 1.3 per cent, make up the remaining 6.9 per cent.

Combining the areas for the loops, surges, puffs, and funnels, we find that 19.7 per cent of the prominences were of the S type, characteristic of spot regions.

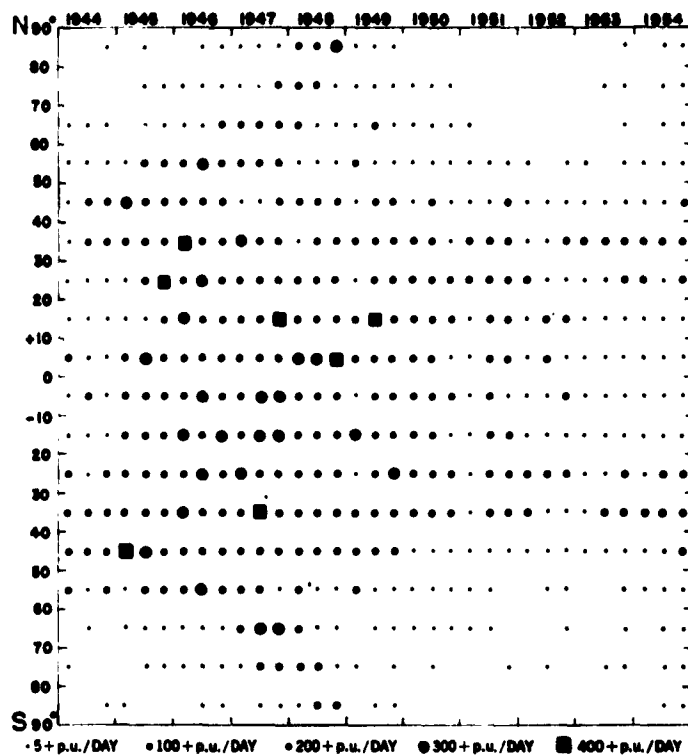


FIG. 4—"Butterfly" diagram for all prominences.

Figure 5 shows the yearly distribution in solar latitude of the four main classes, *AS*, *BS*, *AN*, and *BN*. The *AS* and *BS* prominences generally had a peak of activity in each hemisphere. These peaks approached the equator in a somewhat irregular manner. From a latitude of about $\pm 30^\circ$ in 1944, they moved to about $\pm 15^\circ$ in 1952, becoming less dominant in the process. In 1952 the loops and funnels and the surges were definitely at minimum. The 1953 curves indicate an increase in activity with the suggestion of new peaks at about $\pm 30^\circ$.

The equatorward trend of the spot prominences paralleled the activity of the spots themselves. However, the minimum occurred two years earlier for the prominences.

Frequency curves for the coronal rays $\lambda 5303$ and $\lambda 6374$ (Waldmeier 1950a; also Bell, unpubl.) also show major peaks in each hemisphere that approach the equator throughout the cycle. For $\lambda 5303$ these peaks are conspicuous in 1944 and continue until 1953. The new cycle has become apparent by 1951 (Bell, unpubl.).

The curves for the hedgerow family of prominences (*AN*) also exhibit

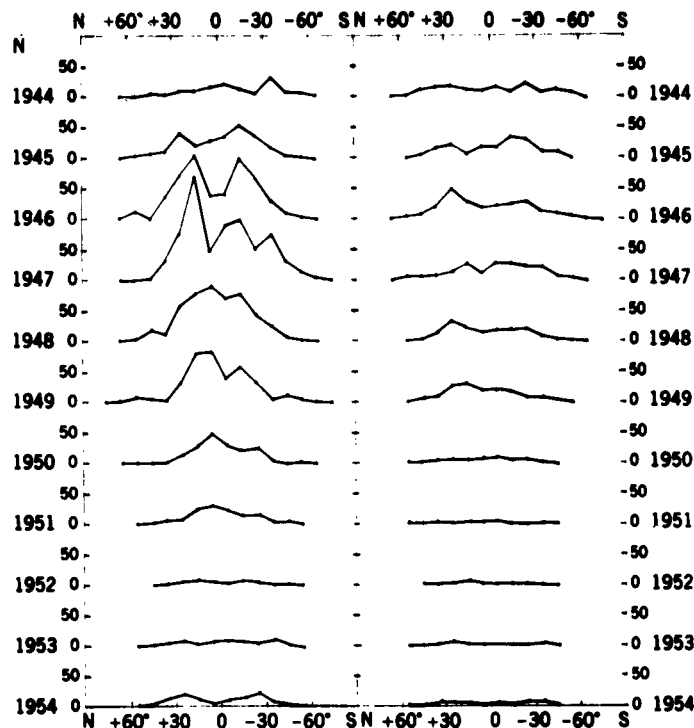


FIG. 5a—Distribution in latitude of the daily mean areas ($\bar{N}$). Left: AS prominences (loops and funnels); right: BS prominences (surges and puffs).

two main peaks of activity, one in each hemisphere (figure 6c). These moved poleward from 1944 to 1948. The coronal line $\lambda 5303$ also had peaks of activity in the high-latitude regions that moved poleward from 1944 to 1949. By 1951 there were again two prominent peaks, one at $+35^\circ$, the other at -25° . The northern peak stayed at about $+35^\circ$ from 1951 to 1954. The southern peak moved southward to -35° in 1953 and was still there in 1954. These prominence peaks, which lie somewhat equatorward of the new cycle peaks in $\lambda 5303$, may occur near the latitude of minimal frequency of coronal rays (Bell, unpubl.).

North-South Asymmetries of Areas of Various Types of Prominences. The total area for all classes of prominences during this cycle was greater for the southern hemisphere ($\Sigma \bar{N} = 10861$) than for the northern ($\Sigma \bar{N} = 10275$), while the areas of the spots were greater in the northern hemisphere ($\Sigma \bar{A} = 6211$) than in the southern ($\Sigma \bar{A} = 5846$). To discover which class of prominence was responsible for this southern excess, yearly values of the ratio $N/(N + S)$ (area in northern hemisphere over total

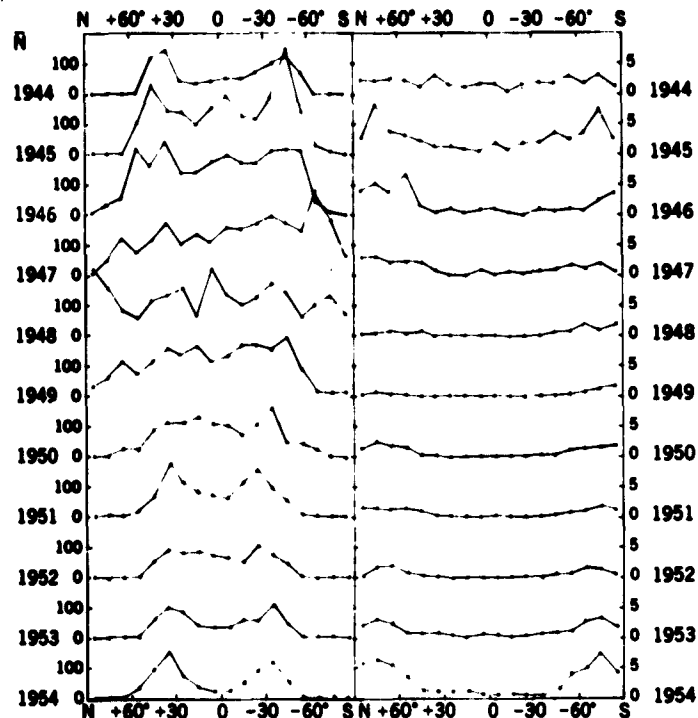


FIG. 5b—Distribution in latitude of the daily mean areas ($\bar{N}$). Left: AN prominences (hedgerow family); right: BN prominences (spicules).

area) were computed for all the prominences, those from the sun-spot areas alone, prominences of both high and low latitude, the A and B prominences, the S and N prominences, the AS and BS prominences, and the AN and BN prominences.

Figure 6 indicates that every type of prominence, except the spicules, and also the sun-spot areas showed a southern excess up to and including 1947, the year of spot maximum, and a northern excess thereafter.

The high-latitude prominences which are mainly of the AN type have the $N/(N+S)$ ratio farthest from 0.5 both before and after spot maximum. The overall southern excess refers chiefly to AN prominences, especially to those in the higher latitudes.

Ratio of Prominence Areas to Spot Areas. Figure 7 shows the variation of the prominence areas in relation to the spot areas throughout the cycle. For all the prominence types together and for each separately we see that this ratio decreased rapidly from 1944 to 1946 and then more slowly in 1947. The year 1948 showed a small increase for the surges (BS) and

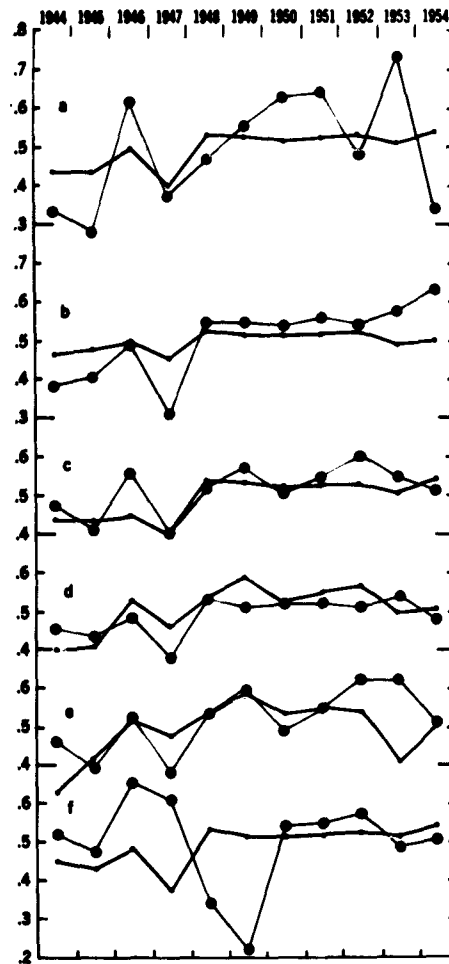


FIG. 6—North-south asymmetries, $N/(N+S)$, plotted against date. (a) Dots, prominences of all types; circles, sun-spot areas. (b) Dots, prominences of all types, lat. 0° – 40° ; circles, prominences of all types, lat. 40° – 90° . (c) Dots, all A prominences; circles, all B prominences. (d) Dots, all S prominences; circles, all N prominences. (e) Dots, all AS prominences; circles, all BS prominences. (f) Dots, all AN prominences; circles, all BN prominences.

the hedgerow family (AN), but otherwise the ratio was practically constant from 1946 to 1951 except for a small steady overall decrease during this period.

The ratio slowly began to increase in 1952, augmenting rapidly in 1953 and 1954, and becoming very conspicuous in the curves for the hedgerow family (AN) in the northern hemisphere (figure 7f and 7a).

Thus, although the prominences were at a minimum in 1952, the ratio

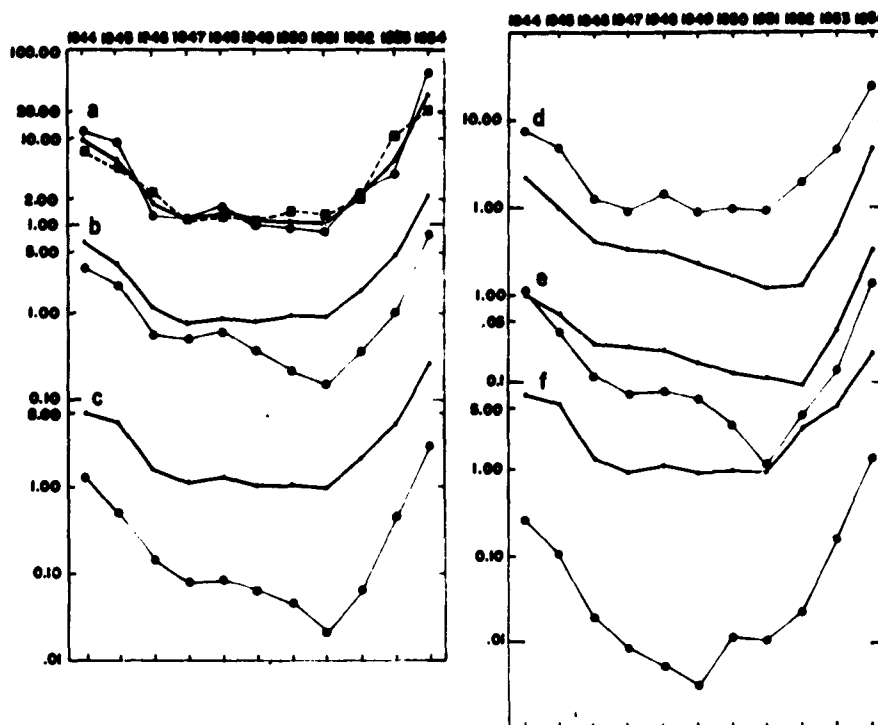


FIG. 7—Prominence area plotted against spot area ratios. (a) *Dots*, all prominences, all latitudes; *circles*, all prominences, N. latitudes; *squares*, all prominences, S. latitudes. (b) *Dots*, all prominences, lat. 0°-40°; *circles*, all prominences, lat. 40°-90°. (c) *Dots*, all A prominences; *circles*, all B prominences. (d) *Dots*, all S prominences; *circles*, all N prominences. (e) *Dots*, all AS prominences; *circles*, all BS prominences. (f) *Dots*, all AN prominences; *circles*, all BN prominences.

of prominence area to spot area had already begun to increase, giving every indication of a more active prominence cycle to follow.

Acknowledgments. We wish to thank Dr. Walter O. Roberts, former Director of the High Altitude Observatory at Climax, Colorado, and presently Director of the National Center for Atmospheric Research at Boulder, Colorado, and Dr. John W. Evans, Director of the Sacramento Peak Observatory, Sunspot, New Mexico, for supplying us with the original survey films. We are also especially grateful to Dr. Barbara Bell for reading the paper and contributing many helpful comments.

The research reported in this paper has been sponsored in part by the Geophysics Research Directorate of the Air Force Cambridge Research Laboratories, Office of Aerospace Research, under Contract AF19(604)-4962.

REFERENCES

- Ananthakrishnan, R. and Nayar, P. M. 1953, *Kodaikanal Obs. Bul.*, no. 137.
 d'Azambuja, M. and d'Azambuja, L. 1948, *Aus. Obs. Paris, Maudon*, vol. 6, fasc. VII.
 Brunner, W. 1945, *Astr. Mitt.*, Zurich, no. 144.
 Greenwich, Royal Observatory. 1955, *Sunspots and Geomagnetic Storm Data, 1874-1954*.
 Jones, F. S. 1955, *R.A.S.C. Jour.*, vol. 52, p. 149.
 Menzel, D. H. and Bell, B. 1953, *Accad. Naz. dei Lincei, "Convegno Volta"*, Roma, 14-19 Sett. 1952.
 Menzel, D. H. and Evans, J. W. 1953, *Accad. Naz. dei Lincei, "Convegno Volta"*, Roma, 14-19 Sett. 1952.
 Menzel, D. H. and Jones, F. S. 1956, *Sci. Rep.*, no. 42, AF19(804)-146; 1957, *ibid.*, nos. 3, 4, 5, AF19(804)-1394; 1958, *ibid.*, nos. 9, 11, 12, AF19(804)-1394; 1959, *ibid.*, no. 3, AF19(804)-4982; 1960, *ibid.*, no. 5, AF19(804)-4982; 1961, *ibid.*, nos. 7, 9, 12, AF19(804)-4982.
 Waldmeier, M. 1946, *Astr. Mitt.*, Zurich, no. 148; 1947, *ibid.*, no. 150; 1949, *ibid.*, nos. 156, 161; 1950a, *ibid.*, no. 171 = *Zs. f. Ap.*, vol. 27, p. 237; 1950b, *ibid.*, no. 172; 1951, *ibid.*, no. 176; 1952, *ibid.*, no. 180; 1953, *ibid.*, no. 184; 1954, *ibid.*, no. 186; 1955, *ibid.*, no. 193.