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MAJOR FLARES AND GEOMAGNETIC ACTIVITY

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Major Flares and Geomagnetic Activity

By Barbara Bell [1]

Since Hale (1931) and Newton (1930, 1943) pointed out the striking tendency of great solar flares to be followed by more or less severe disturbance of the earth's magnetic field, it has become generally accepted that nonrecurrent, sudden-commencement (sc) geomagnetic storms result from clouds of ionized gases (corpuscles) ejected by the flaring solar region and interacting with the field of the earth. However, there exists no one-to-one correlation between major flares and geomagnetic storms. A discouragingly high percentage of even bright and optically impressive flares are not followed by any significant disturbance of the earth's magnetic field.

Recent work has been concentrated largely on a search for one or more properties of flares that will permit forecasters to distinguish storm-producing from non-disturbing flares. Radio-noise studies have to date provided the most useful criteria for this purpose, and substantial progress has been made by Dodson and Hedeman (1958), Simon (1956, 1959), Maxwell, Thompson and Garmire (1959), and others. It is only reasonable that radio outbursts should provide the most reliable criteria, since these radiations arise at higher levels in the solar atmosphere than do the optical flares; if a flare cannot disturb the outer solar atmosphere, it would not seem to have much chance to disturb the earth.

Significant and useful as the radio noise properties of a flare are, however, a radio outburst would appear more in the nature of evidence of corpuscular emission rather than a cause of it. Casual factors more probably reside in the details of the magnetic field and the hydromagnetic forces that produce the flare itself. Unfortunately, we cannot yet study these forces observationally in anything like the necessary detail. The only data available are the Mount Wilson Observatory's classification of the magnetic-field types of sunspot groups, a classification that has been carried out systematically since 1917.

Bell and Glazer (1958) used these Mount Wilson data to investigate the geomagnetic consequences of the central meridian passage (CMP) of large sunspot groups. They found the magnetic-field type to be the most useful optical criterion we yet have for separating geomagnetically disturbing spots from others of equally large area. In the present paper, the geomagnetic consequences of major flares will be discussed, with emphasis on the magnetic class of the flaring spot group. Location of the flare on the solar disc will also be considered, and evidence presented that a flare in the northern solar hemisphere has a substantially greater probability of producing a great magnetic storm than does a southern flare.

Data

For the purposes of this investigation, a major flare is one rated importance 3 or 3+ by at least one observatory, or 2+ by two or more observatories. The IAU Quarterly Bulletin of Solar Activity yielded 580 major flares in the 23 years, 1937–1959, each associated with a specified active region. By matching active regions with spot groups, I was able to link most major flares with a particular Mount Wilson sunspot. About two percent of the flares (12 flares), however, occurred in the absence of any identifiable sunspot, while another two percent (11 flares) occurred in the region of an unborn or an extinct sunspot. Most of the flares occurred in association with sizable sunspots, but about five percent (32

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flares) were associated with either no spot or a small spot of maximum observed field strength less than 1000 gauss.

The Mount Wilson classification of sunspots according to their magnetic properties (Hale and Nicholson, 1938) recognizes four basic categories of sunspot groups: unipolar (α), bipolar (β), semicomplex ($\beta\gamma$), and complex (γ). Unipolar (α) groups are single spots or groups of spots having the same magnetic polarity. Bipolar (β) groups in their simplest form consist of two spots of opposite polarity; often, however, a bipolar group is a stream of spots, those in the preceding and those in the following parts of the group having opposite polarities. Complex or multipolar (γ) groups are those having polarities so irregularly distributed that they cannot be classified as bipolar; sharply bounded regions of opposite polarities sometimes exist within the same penumbra. Semicomplex ($\beta\gamma$) groups show bipolar characteristics but lack a clearly marked dividing line between the regions of opposite polarities; this category includes groups whose preceding or following members are accompanied by small spots having an opposite polarity.

Through 1958 the average magnetic classification for each spot group was published by the Mount Wilson Observatory in Publications of the Astronomical Society of the Pacific. For the present study, however, the magnetic type on the flare day was needed, since the magnetic type of many groups changes during the 14 days of a disc passage. With the cooperation of Mount Wilson, J. G. Wolbach obtained for me the daily classifications of the relevant sunspots. Because of gaps in the observations, no reasonable estimate could be obtained for the flare-day magnetic type for about 12 percent of the flares. About 15 percent had a flare-day type significantly different from the average classification of the associated spot.

Each flare was assigned to one of four categories of geomagnetic "success," according to the behavior of the Kp and Ap magnetic indices in the three days following the flare: (1) no storm ($Ap<25$ on all three days following the flare); (2) small storm (Ap and Kp both $\geq$ 25 on at least one day); (3) moderate storm (one or more $Ap \geq 50$ and/or a 3-hr $Kp \geq 7^+$); and (4) great storm (one $Ap \geq 100$ and/or one 3-hr $Kp \geq 9^-$). While the daily Kp is used below in the superposed epoch analyses, Ap has been given the greater weight in classifying the magnetic storms. Ap, having a linear scale, is a more sensitive indicator of differences in the magnitudes of the storms; however, because it departs radically from a normal distribution, one or two large storms could distort a superposed epoch curve. Kp, a logarithmic measure of disturbance, also lacks a normal distribution but does come much closer to it than does Ap; thus Kp seems to me preferable for use in superposed epoch analyses. Most flares could be assigned to a geomagnetic-success category without difficulty; the few borderline cases should not significantly distort the results.

If a given day had two or more major flares, this day entered two or more times into the analysis.

Figure 1*a* shows a superposed epoch diagram of Kp where the flares have been sorted solely on the basis of their geomagnetic success. Day zero is the flare day. Figure 1*a* illustrates the differences between the geomagnetic classes and may be useful in interpreting other superposed epoch curves in this and other papers. Figure 1*b* shows only the great storms, subdivided into great (4) and extra great (4^+), the latter having at least two 3-hr $Kp \geq 9^-$ or one $Kp=9^0$. Note that this 4^+ curve has its maximum one day after the flare; the class 3 and 4 curves have their maxima on day +2, and the class 2 curves on day +3. This progression would suggest that the more violent the storm, the shorter the time lag. Note also the two strong subsidiary peaks in the 4^+ curve. A spot having one flare vigorous enough to give rise to a 4^+ magnetic storm seems particularly likely to have other storm-producing flares during its disc passage. Spots having central meridian passage (CMP) on 18 January 1938, 26 March 1940, 27 March 1946, 19 September 1946, 23 January 1949, and 14 July 1959, each produced two or more great storms, and several other spots produced one great and one or more lesser storms. This tendency accounts for the lack of sharpness in most of the superposed epoch curves in this paper.

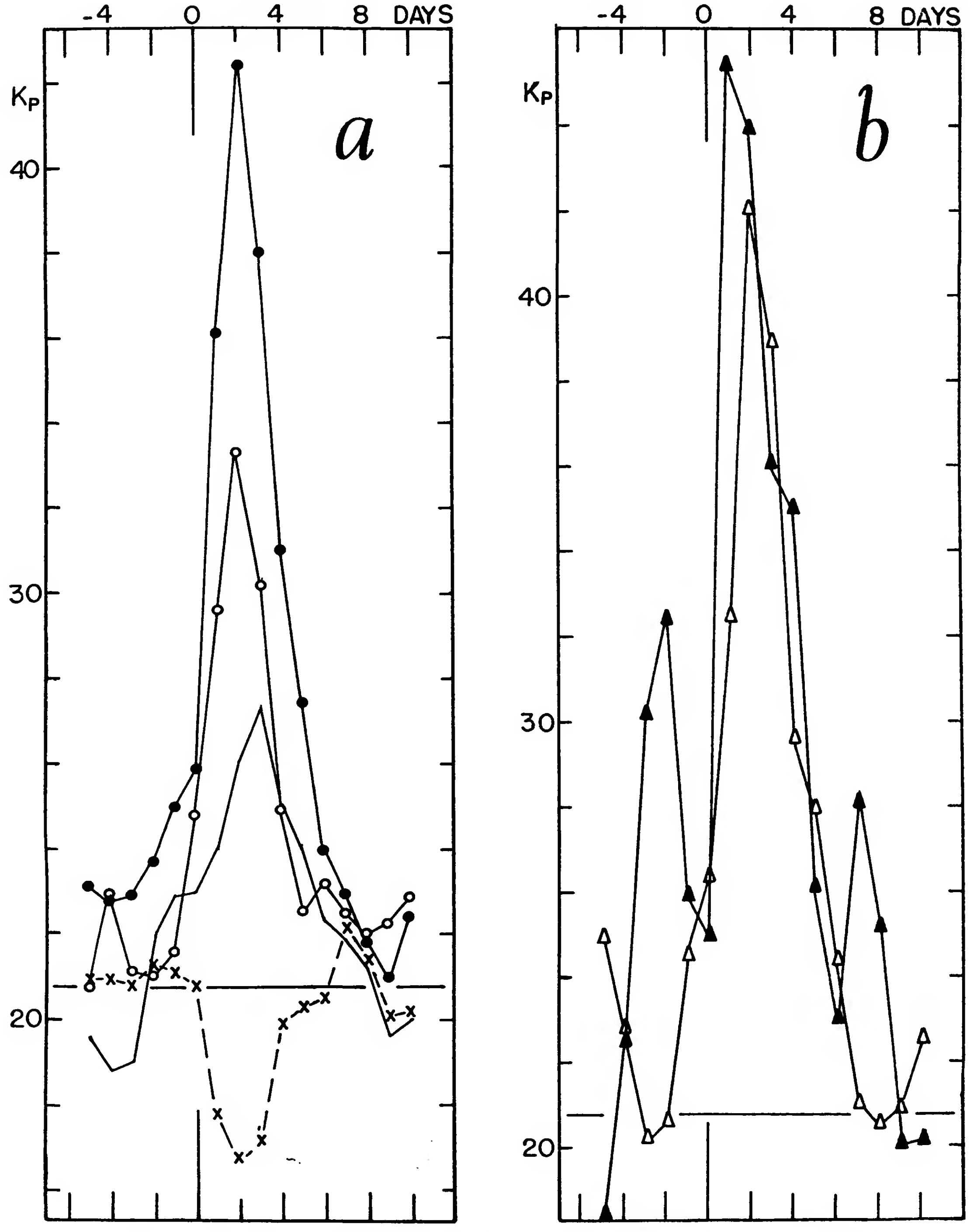

Figure 1.—Average geomagnetic conditions (Kp) after major flares followed within three days by (in *a*) a great geomagnetic storm (●—●), a moderate storm (○—○), a small storm (——), no storm (×——×), and (in *b*) by a great storm (△—△) and an extra-great storm (▲—▲).

Location of Flares

Newton (1943) and several subsequent writers have pointed out that those flares that are followed by great storms generally occur within about 45° of the solar central meridian (CM). Figure 2*a* shows the distribution of the present 580 major flares with solar central meridian distance. The shadings correspond to the four categories of geomagnetic success. Figure 2*b* shows the longitude distribution in terms of the ratio of successes to the total number in the particular longitude interval.

The longitude distribution shows no east-west asymmetry. Indeed, exactly half (290) of the flares occurred east of the CM, and half of them west of it. Nor do great-storm flares show any significant asymmetry, 37 of them being west of the CM, and 36 east of it; of small-storm flares, we find 75 east and 77 west. A marked excess west of the CM appears, however, in moderate-storm flares, with 46 west and only 28 east of the CM. A compensating excess east of the CM occurs among the failures, with 130 west and 151 east of the CM. According to the normal distribution law, the probability that an asymmetry as large as that shown by moderate-storm flares should arise by chance is about 10^{-3}.

It is beyond the scope of this paper to theorize on possible causes of the anomalous distribution in moderate-storm flares. It is perhaps relevant to note, however, that Hartz and

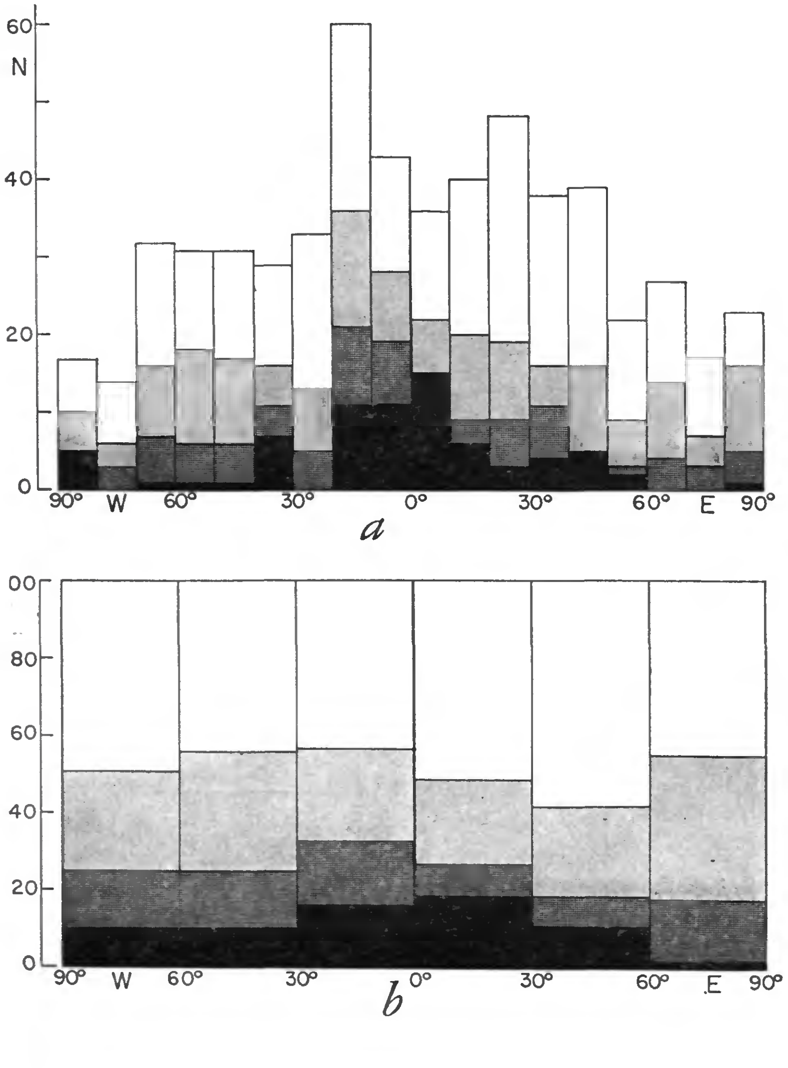

FIGURE 2.—Distribution of 580 major solar flares with central meridian (CM) distance. *a*, Number of flares; *b*, percent in the given latitude interval. Shadings indicate flares followed within 3 days by a great storm (black), by a moderate storm (dark gray), by a small storm (light gray), and by no storm (white).

McAlpine (1960) found a very pronounced western excess in number of flares followed by polar cap absorption and a *weak* Forbush decrease in cosmic ray intensity, but no western excess among flares followed by polar cap absorption and a *strong* Forbush decrease. Their interpretation of this difference in terms of the fields in interplanetary space might be applied also to the differing distributions of great- and moderate-storm flares; the possibility at least deserves further study.

Figure 3*a* shows the longitude variation when flares in the eastern and western hemispheres are combined and the data smoothed by running means over 30° intervals (20° at each end). Figures 3*b* and 3*c* show the smoothed distributions in terms of percents of successes. Previous workers (Behr and Siedentopf, 1952; Waldmeier and Bachmann, 1959) found the visibility function to the limb of flares to be roughly proportional to the cosine of the longitude from the CM. However, the distribution of the major flares plotted in figure 3*a* does not fit a cosine law, and indeed appears perhaps best represented by a straight line. Both east and west show fewer flares in the 0–9° zone than in the adjacent zones. This dip can be only partially explained by the fact that 9°E to 9°W contains one degree less than the 10–19° zones; however, its signifiance is doubtful since Waldmeier and Bachmann (1959) report a contrary excess of flares of importance 2 and 3 in the central zone as compared to the 11–20° zone for the years 1945–1954.

Figures 2*a* and 3*a* confirm the previously reported tendency for great-storm flares to be

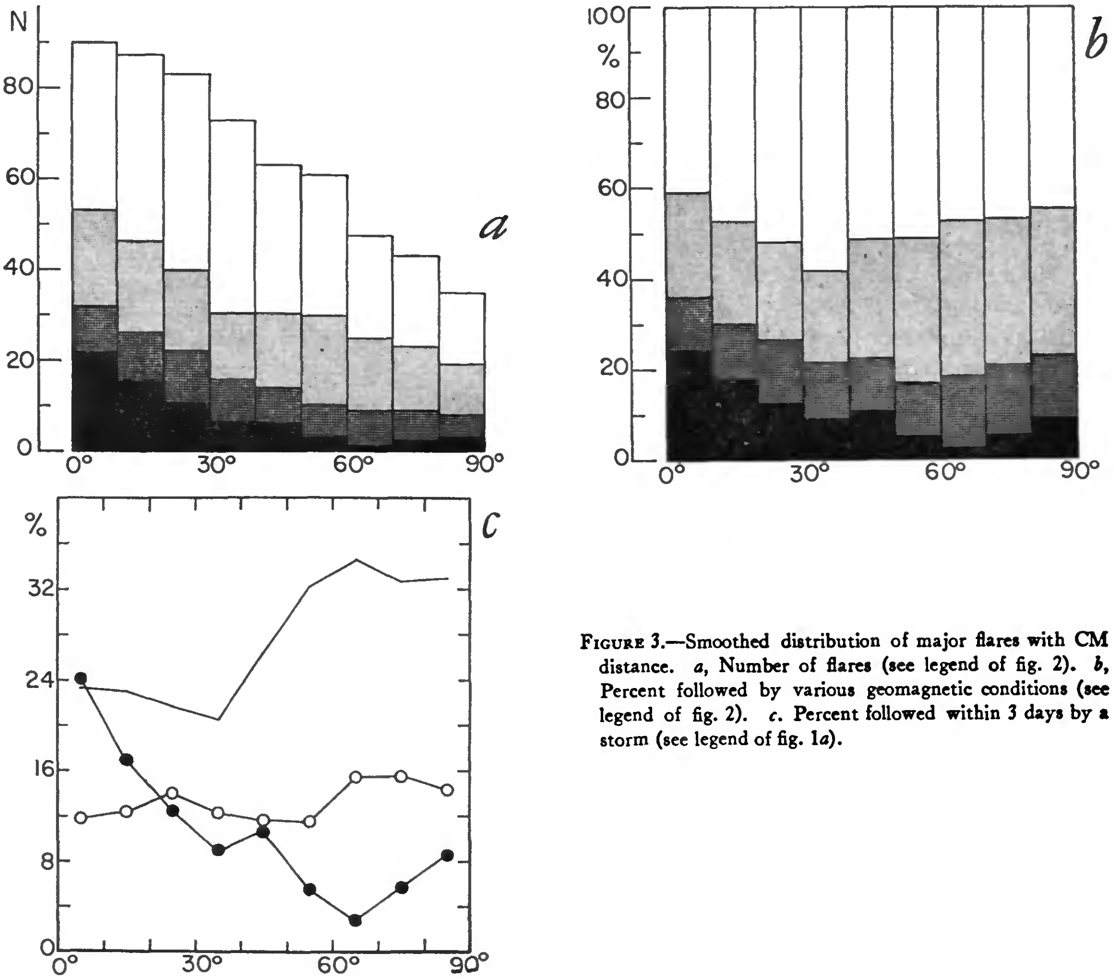

FIGURE 3.—Smoothed distribution of major flares with CM distance. *a*, Number of flares (see legend of fig. 2). *b*, Percent followed by various geomagnetic conditions (see legend of fig. 2). *c*. Percent followed within 3 days by a storm (see legend of fig. 1*a*).

concentrated toward the CM. The center-to-limb decrease in the number of great-storm flares fits neither a cosine nor a linear distribution law. At first, the frequency decreases rapidly with increasing distance but then levels off around 50° and shows a slight rise at the limb. If we consider the ratio of storm flares to all major flares in the given longitude range, we see (fig. 3*c*) that the probability of a great storm reaches a minimum for a flare in the 60–69° interval. The probability of a moderate storm shows no significant dependence on the distance from the CM, while the probability of a small storm actually increases toward the limb. (Some of these small-storm flares would probably give rise to great storms if they were located closer to the CM.) The probability of failure (no storm) appears to be greatest for flares around 35° (unshaded section of figure 3*b*).

Figure 4*a* maps the location of all major flares that were followed by great magnetic storms within three days. Figure 4*b* similarly shows the location of all major flares that were followed by moderate storms. The symbols here indicate the magnetic type of the flaring spot, the actual flare-day type being used whenever known. I originally plotted this figure to look for differences in longitude distribution between the magnetic types. Its striking and unexpected feature, however, is the strong preference of great-storm flares for the northern solar hemisphere over the southern hemisphere. Further data on latitude distribution and the north-south asymmetry are shown in figures 5–7 and in table 1.

In the 23 years studied, about 56 percent of all observed flares, regardless of importance, occurred in the northern solar hemisphere. Of the 580 major flares in this study, 62 percent occurred in the north (see table 1). Northern spot groups, however, produced 86 percent of the 74 major flares that were followed by a great storm (64 north and 10 south), and 64 percent of the 70 that were followed by moderate storms, but only 52 percent of the 153 that were followed by small storms and 60 percent of the 284 failures. Thus 64 percent of the flares that were followed by at least a small storm occurred in the north. The north dominance increases strongly with increasing magnitude of the geomagnetic disturbance. The

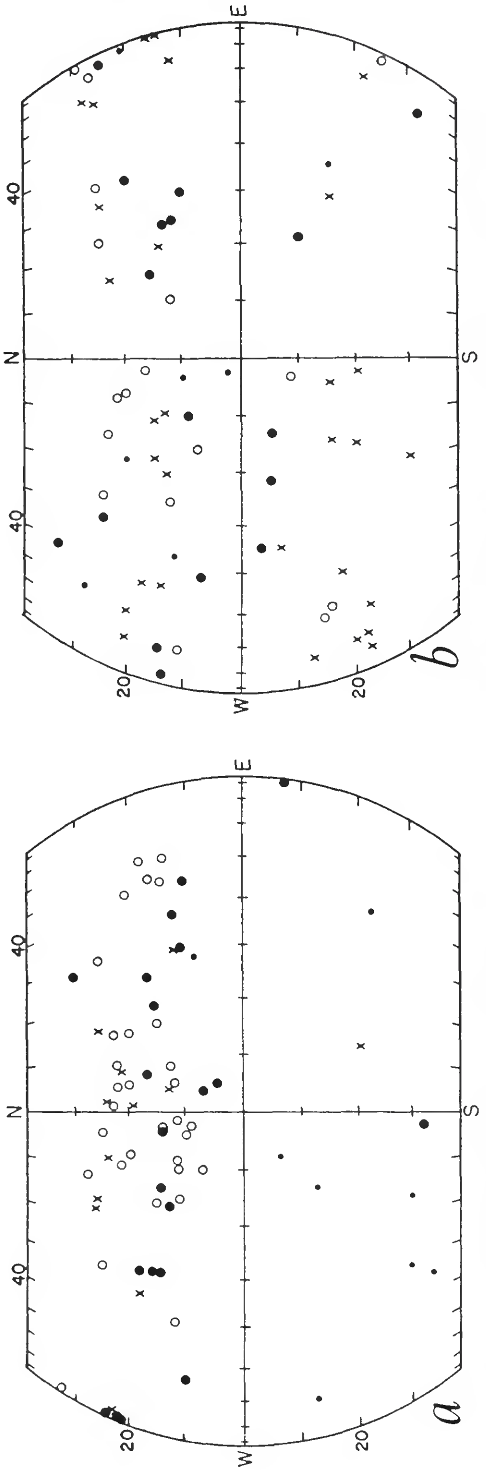

FIGURE 4.—Plot of the location of all major flares followed within 3 days by: *a*, a great magnetic storm; *b*, a moderate magnetic storm. Symbols indicate the magnetic class of the associated spot group: ●, γ; ○, $\beta\gamma$; ×, β; and •, α.

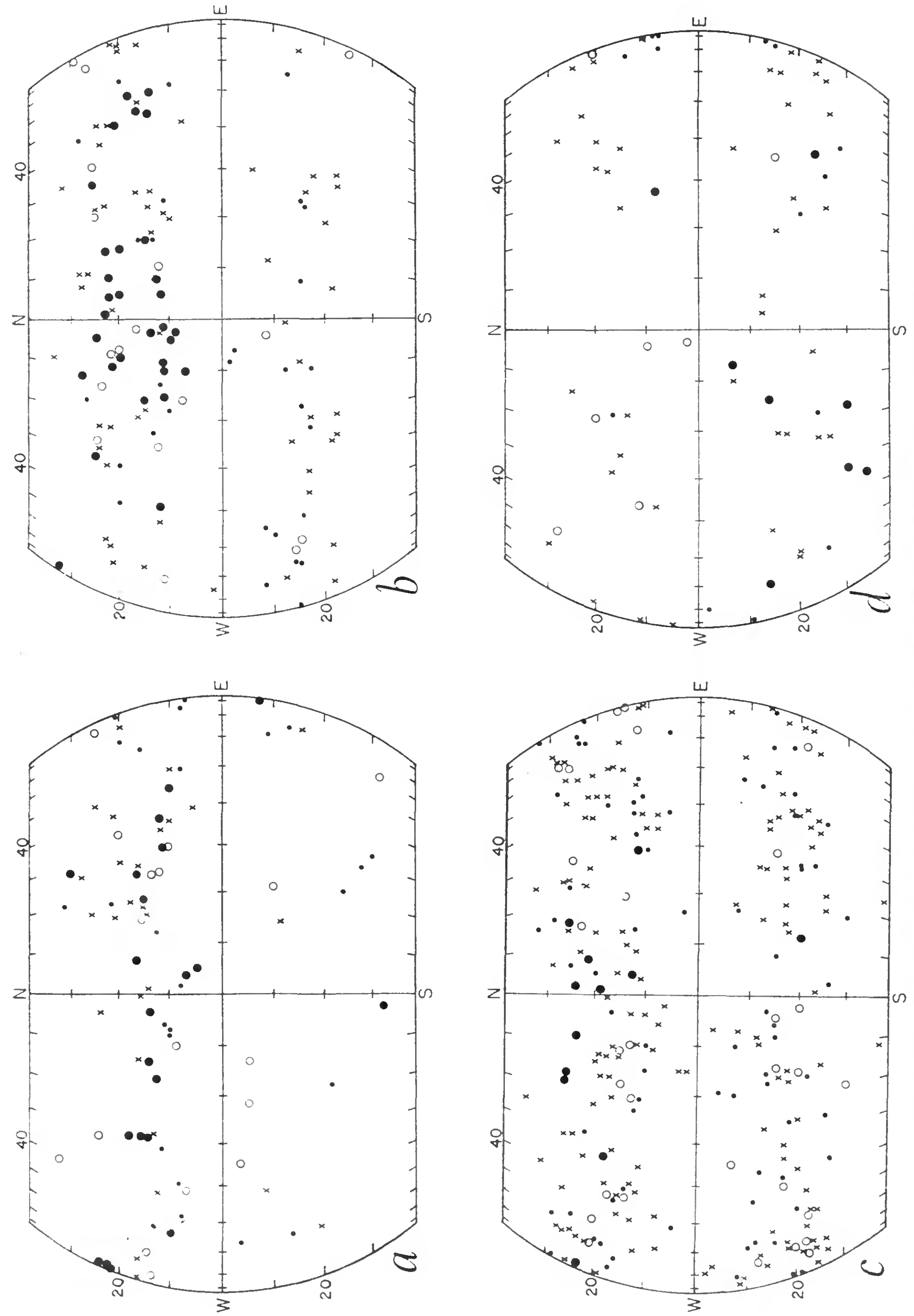

FIGURE 5.—Plot of location of all major flares associated with: *a*, γ spots; *b*, βγ spots; *c*, β spots; *d*, α spots. Symbols indicate flares followed by great storm (●), moderate storm (○), small storm (•), and no storm (×).

probability of a great storm after a northern major flare is 0.176, contrasted with only 0.045 after a southern major flare. The probability of so large an asymmetry occurring by chance is less than 10^{-3}.

If we consider storms instead of flares, we find 46 great storms in the data, of which 37 were preceded by northern, 6 by southern, and 3 (on 2 and 4 September 1957, and 15 July 1959) by both northern and southern major flares. The data include 53 moderate storms, 32 of them preceded by northern, 14 by southern flares, and 7 by both a northern and a southern flare. As figure 7 shows, this astonishing dominance of the northern solar hemisphere is present in all three sunspot maxima that were studied and shows no apparent relation to the 22-year cycle observed in the magnetic polarities of sunspot. Evidence for a longer cycle will be explored in a subsequent paper.

Magnetic type of flaring spot

Figure 8 shows the number of major flares observed in association with spot groups of the four basic magnetic types, and the probability of geomagnetic success of each type of major

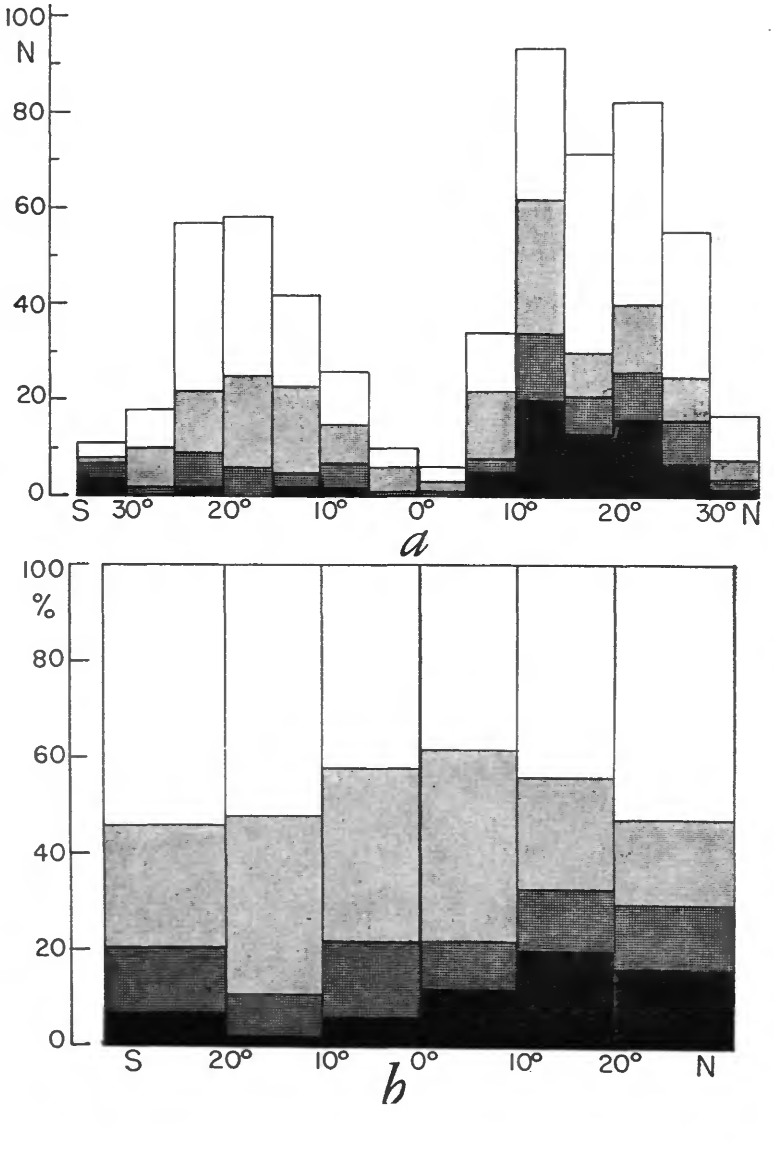

FIGURE 6.—Distribution of major flares with solar latitude (see legend of fig. 2). *a*, Number of flares. *b*, Percentage in the given latitude interval followed by each geomagnetic condition.

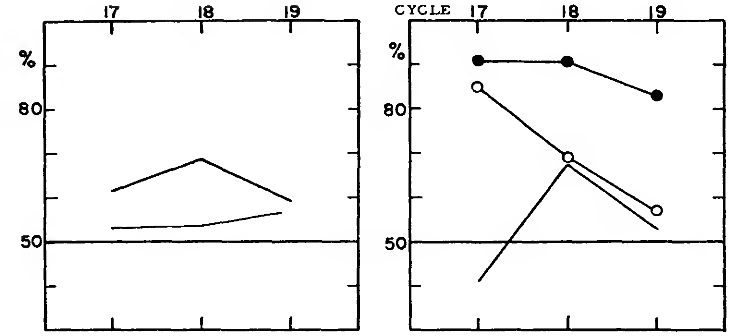

FIGURE 7.—Percentage of observed major flares in each spot cycle (Nos. 17–19) occurring in the northern solar hemisphere. Left: Heavy line indicates major flares; thin line, all flares. Right: See legend of figure 1*a*.

flare. Bipolar spot groups are much more numerous than complex ones, although the latter on the average produce more flares per group (Hale and Nicholson, 1938; Giovanelli, 1939; Bell and Glazer, 1959). The distribution in figure 8*a* arises from a combination of these two factors. Figure 8*b* illustrates the much larger probability of a great or moderate geomagnetic disturbance following a flare associated with a complex group, as compared with a bipolar group.

Superposed epoch curves appear in figure 9, with the flares grouped according to (a) average magnetic type, and (b) flare-day magnetic type of the associated spot group. Flares of all CM distances are included here. The mean value of *Kp* is 20.75, derived from the annual mean values of *Kp*, with each year weighted according to the number of major flares observed in that year. For each magnetic type, the peak value of *Kp* is higher when the flare-day type is used, presumably because in this case those flares whose flare-day type could not be estimated with reasonable confidence were omitted. Most of the differences between figure 9*a* and 9*b*, however, are minor. The only conspicuous difference appears in the unipolar or α curve, where the flare-day α's have better geomagnetic success than those whose average type is α.

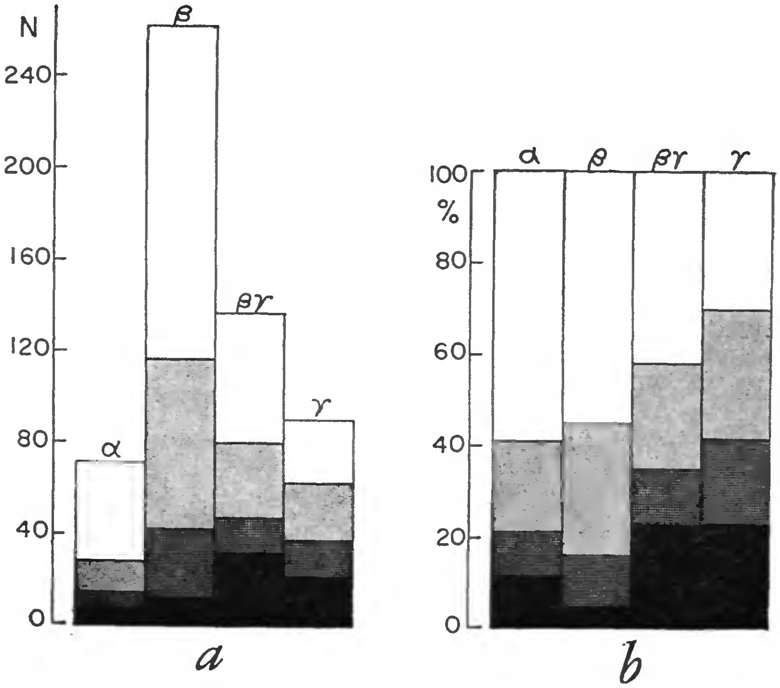

FIGURE 8.—Magnetic type of sunspot groups associated with major flares. *a*, Number of flares associated with (left to right) α, β, βγ, and γ spots. *b*, Percentage of each type of flare followed within 3 days by a great storm (black), moderate storm (dark gray), small storm (light gray), and no storm (white).

Figure 9 may be compared with figure 1 of Bell and Glazer (1958), which shows the geomagnetic conditions associated with the CMP of large sunspot groups of each magnetic type. While the differences between these two figures are not striking, the higher level of geomagnetic disturbance is obtained from each magnetic type when the dates of major flares, rather than the CMP dates of large sunspot groups, define the zero day. In the γ case the difference between flare and spot curves is small; but for the $\beta\gamma$, β, and α types the flares give substantially more disturbance. The systematic direction of the difference between flare and spot curves supports the now prevalent opinion that the emission of a corpuscular stream from the sun is associated with the occurrence of a major flare rather than with the CMP of the sunspot region. The small difference between the γ curves from flares and from spots suggests that a given γ spot is more likely than any other type to produce one or more major, and geoactive, flares.

The double maximum in the γ-flare curves probably arises from the tendency of an active γ spot to produce more than one disturbing flare during its disc passage (cf. figure 1*b*). I have no explanation for the strange form of the α-flare curves, with their major peak two days before the flare day.

The influence of the disc position of the flare on superposed epoch curves appears in figures 10 and 11. The former shows that the effect of separating the flares of figure 9*b* according to CM distance is minor. The greater probability of a small storm from a flare at CM distance beyond 45° in large measure compensates for the reduced probability of a great storm from a flare in these noncentral regions (fig. 3*c*). The curves in figure 11 were computed at a different time from those of figure 10 and include some additional flares of unknown flare-day type that were assigned on the basis of the average type of the spot. Note that in figure 11 the geomagnetic difference between northern and southern flares is particularly striking for $\beta\gamma$ and β flares, and negligible for α and γ flares. In this connection it may be of interest that T. Cragg (private communication via J. Wolbach) remarked that when an α spot becomes complex it tends to become a γ, but when a β becomes complex, it more commonly becomes $\beta\gamma$.

To investigate further the north-south asymmetry, I used the large sunspots previously studied (Bell and Glazer, 1958), separated the north and the south spots of each magnetic type, and obtained the results shown in figure 12 and table 2. In essential agreement with the flare results, northern γ and $\beta\gamma$ spot groups appear conspicuously more disturbing than southern ones. (Note that the spot data cover 1937–1953 and do not include the current maximum.)

Denisse (1952) and Simon (1956) have demonstrated that radio noise at meter wavelengths is a valuable criterion for picking out geomagnetically disturbing spots (see also Bell and Glazer, 1958). It is of interest to look for north-south asymmetries in radio-noisy (R) and radio-quiet (Q) spot groups. Using Simon's list of R and Q spots, but including only those of area greater than 500 millionths of a solar hemisphere, I find that the distribution of R and Q spots shows no marked north-south asymmetry. However, as table 3 shows, the geomagnetic difference between R and Q spots is very much clearer for northern than for southern spots. The Q spots act, geomagnetically, about the same in the north and in the south. Southern R spots are on the average geomagnetically inactive, while the northern R spots are quite disturbing.

One may well ask whether northern active centers seem to possess a greater disturbing power because complex spots and associated flares are relatively more numerous in the north,

Table 1.—*Percentage of major flares in the northern solar hemisphere*

Magnetic class	Followed within 3 days by				Avg.
	Great storm	Moderate storm	Small storm	No storm	
γ	90%	71%	68%	85%	78%
$\beta\gamma$	100	76	47	63	69
β	92	53	51	56	55
α	12	86	36	45	44
unclassified					61
Average	86	64	53	60	62

or because, regardless of magnetic type, northern active centers are simply more vigorous ejectors of corpuscles. The γ regions decisively favor the north in the years under study, with 14 northern and 6 southern large spots; γ spots contribute 21.5 percent of the northern major flares and 8.7 percent of the southern. The $\beta\gamma$ spots, on the other hand, are somewhat more numerous in the south, although $\beta\gamma$ spots contribute 28 percent of the northern but only 20.2 percent of the southern flares. Southern $\beta\gamma$ spots and flares, on the average, are geomagnetic failures, while northern ones rival the γ's in storm-producing power. Thus a greater proportion of the northern flares do arise in magnetically complex regions; but β and $\beta\gamma$ data clearly suggest that northern flares of a given type are far more likely to produce significant geomagnetic disturbance than are corresponding southern flares. For all types except the α, north dominance increases with increasing storm intensity. The probability that a given flare region will eject enough corpuscles to produce at least a minor storm is only slightly greater for northern flares than for southern; but the probability of an ejection vigorous enough to produce a great storm is much greater for a northern flare.

These facts suggest that northern centers, when they do eject corpuscles, may do so at higher velocities than southern centers. Or, insofar as one believes that storm magnitude is determined by the number rather than by the velocity of the corpuscles, one would conclude that a northern flare region ejects on the average a larger number of corpuscles than does a southern region.

Another solar-geomagnetic relation might be mentioned in connection with this north-south asymmetry. Bell and Glazer (1957) found that in the declining years of cycle 18, geomagnetic activity showed a negative correlation with the brightness of the green λ5303 coronal line in the solar hemisphere on the same side of the solar equator as the earth, the so-called favorable hemisphere. They also briefly considered north and south coronal intensities simultaneously. In the autumn, with the northern solar hemisphere favorable (Nf), the correlations appeared not to be influenced by southern coronal intensities. In the spring, when the earth was south of the solar equator, the data were more am-

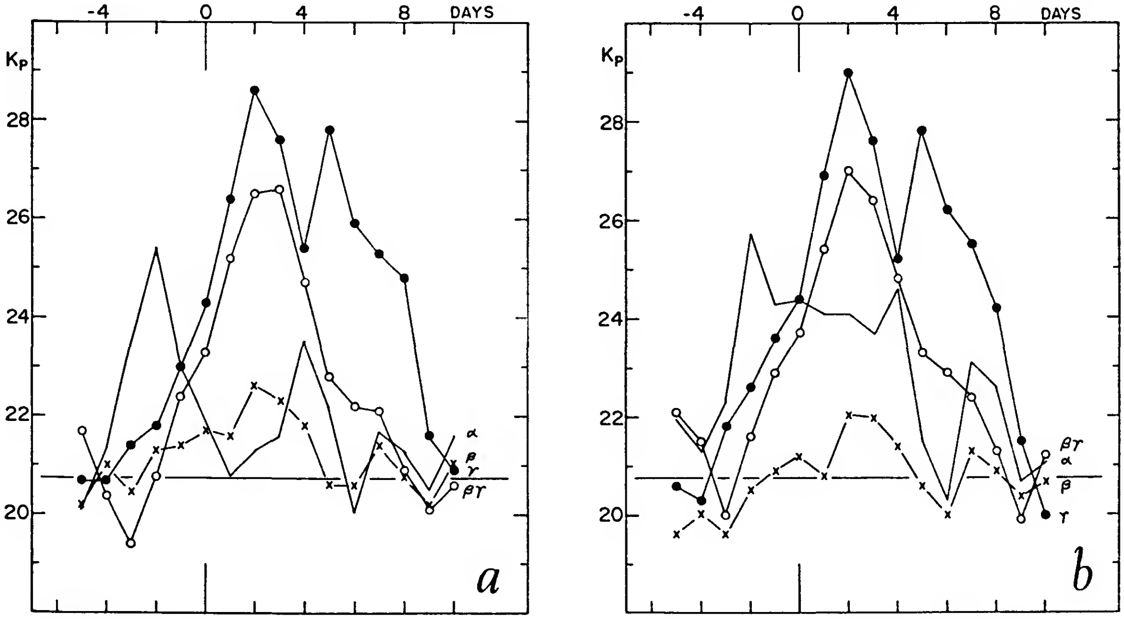

Figure 9.—Average geomagnetic conditions (*Kp*) on days around the occurrence of a major flare. Day zero is the flare day. Flares are divided according to average magnetic type (*a*) and flare-day magnetic type (*b*) of the associated spot group.

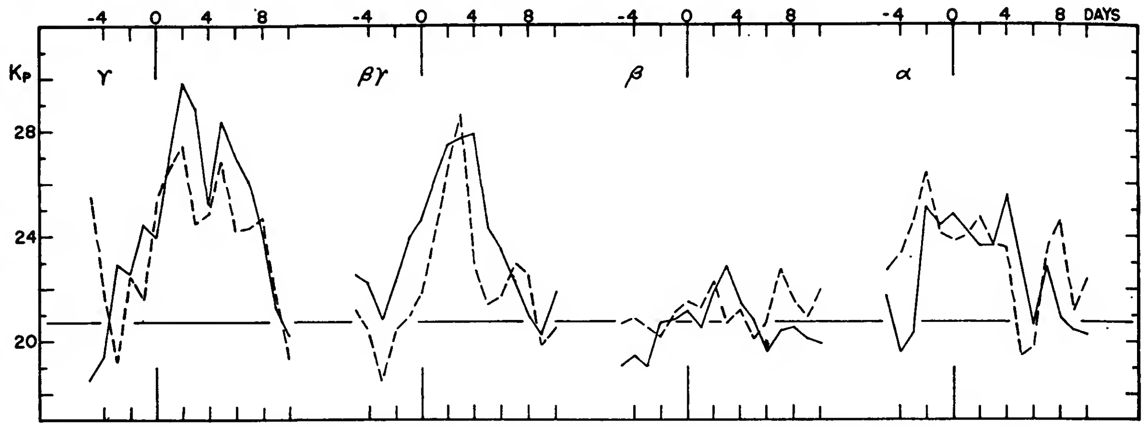

FIGURE 10.—Average geomagnetic conditions (Kp) on days around the occurrence of a major flare, subdivided by flare-day magnetic type of the associated spot. Solid line indicates flares within 45° of the CM; broken line, flares more than 45° from CM.

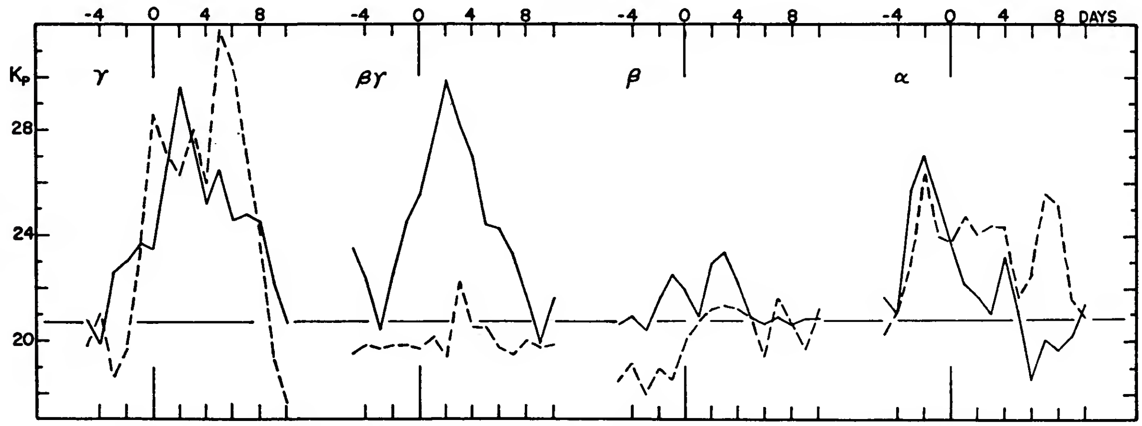

FIGURE 11.—Average geomagnetic conditions (Kp) on days around the occurrence of a major flare, subdivided by flare-day magnetic type of the associated spot. Solid line indicates flares in the northern solar hemisphere; broken line, flares in the southern solar hemisphere.

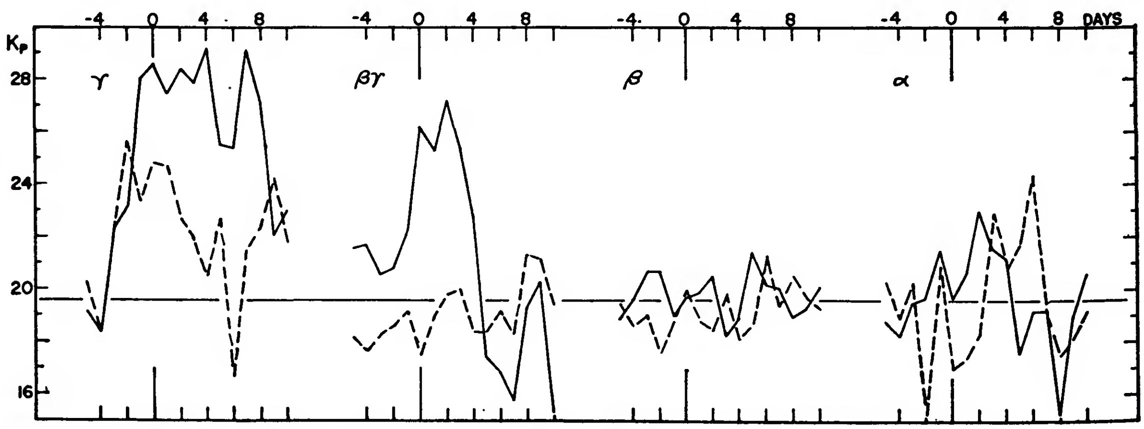

FIGURE 12.—Average geomagnetic conditions (Kp) on days around central meridian passage (0=CMP day) of large (A ≥500 millionths) sunspot groups of the four magnetic types. Solid line indicates northern spots; broken line, southern spots.

biguous; the authors found "some indication that Sf is more effective in giving the 'expected' *Kp* results when paired with a similar Nu. The data appear to suggest that the northern solar hemisphere may have a more powerful 'control' over *Kp* conditions than the southern; but in view of the short time covered, we would not propose that such an inherently unlikely suggestion to be taken too seriously" (Bell and Glazer. 1957, p. 75 and fig. 18).

Other results

The 580 major flares were sorted by month, with the results as shown in table 4 and figure 13. The well-known seasonal variation in geomagnetic activity appears most clearly in the variation in probability of a failure (top, unshaded portions of figure 13) and much less clearly in the probability of a great storm where an October–December minimum is the most conspicuous feature. The apparent seasonal variation in the probability of a great storm in figure 13 is distorted by observational selection, as can be seen from the final column of table 4, which gives the total number of great storms without regard for whether the storm was preceded by an observed major flare. (The definition of great storm remains the same as that used elsewhere in this paper.)

The flares of each magnetic type were next grouped according to whether they were on the same (favorable) or opposite (unfavorable) side of the solar equator as the earth. In agreement with the results that Bell and Glazer (1958) determined from spot groups, no significant geomagnetic difference was found between the favorable and the unfavorable flares of any given type. Thus it seems clear that the axial hypothesis is not an adequate explanation for the seasonal variation in frequency of great and other lesser nonrecurrent storms.

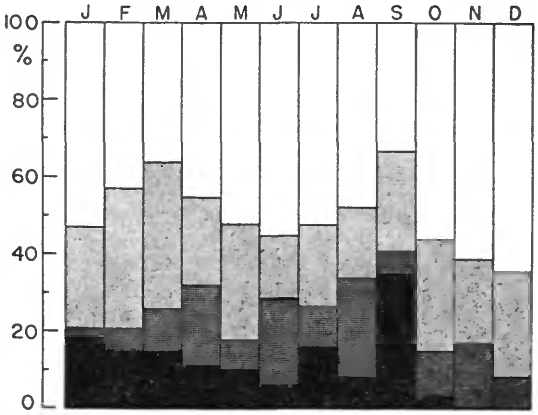

FIGURE 13.—Percentage of observed major flares in each month followed by a great storm (black), moderate storm (dark gray), small storm (light gray), and no storm (white).

TABLE 2.—*North-south asymmetry in geomagnetic conditions associated with major flares (1937–1959) and with CMP of large sunspot groups (1937–1953)*

Magnetic class	Hemisphere	Major flares		Large sunspots		
		No.	*Kp* (max)*	No.	*Kp* (max)*	*Kp* (0, +4)†
γ	N	72	29. 6(2)	14	29. 4(4)	28. 3
	S	18	28. 0(3)	6	24. 8(0)	23. 0
γ	N	94	29. 9(2)	21	27. 2(2)	25. 4
	S	42	22. 2(3)	25	20. 0(3)	18. 9
β	N	140	23. 3(3)	51	20. 5(2)	19. 3
	S	113	21. 3(3)	62	19. 9(0)	18. 7
α	N	26	23. 1(4)	19	23. 0(2)	21. 2
	S	35	24. 7(1)	10	22. 9(3)	19. 6

*Highest average value of the *Kp* index in the 5-day interval (0, +4), with day of occurrence in parentheses.

†*Kp* index of geomagnetic activity averaged over the five days (0) through (+4), around CMP of spot groups.

McIntosh (1959) has found evidence for a component in the diurnal variation of disturbance which seems clearly related to the obliquity of the earth's magnetic axis relative to the earth-sun line, along which the solar corpuscles are presumed to travel. He revives a long-neglected suggestion of Bartels to argue that the semiannual variation in disturbance also most probably arises from the seasonal

TABLE 3.—*North-south asymmetry in geomagnetic conditions associated with CMP of large radio-noisy (R) and radio-quite (Q) sunspots*

Location	Radio noise	No. spots with *Kp*(0,+4)			Total No.	*Kp*(0,+4)
		≥25.0	20.0–24.9	<20.0		
North	R	19	8	1	28	27. 8
	Q	1	5	14	20	17. 8
South	R	7	10	13	30	20. 4
	Q	2	3	10	15	17. 8

variation in the angle between the earth's magnetic axis and the earth-sun line. In view of the difficulties encountered by the equinoctial and the axial hypotheses [2] McIntosh's suggestion would appear to deserve serious consideration.

TABLE 4.—*Seasonal distribution of observed major flares and their geomagnetic consequences, 1937–1959*

Month	No. flares followed within 3 days by				Total major flares	Total great mag. storms
	Great storm	Moderate storm	Small storm	No storm		
Jan	7	1	10	20	38	5
Feb	7	3	17	20	47	4
Mar	7	5	18	17	47	12
Apr	5	10	11	21	47	6
May	5	4	15	26	50	4
Jun	3	11	8	27	49	3
Jul	10	7	13	33	63	5
Aug	5	15	11	28	59	5
Sep	24	4	18	23	69	13
Oct	1	5	11	22	39	2
Nov	0	6	8	22	36	0
Dec	0	3	10	23	36	0

TABLE 5.—*Geomagnetic conditions following major flares, subdivided by area (in heliographic square degrees)*

Area of flare	No. flares	Avg. CM distance	*Kp*(max)	Percent north	Percent followed by	
					Great storm	Moderate storm
<10	33	34°	27.9(1)	70%	6%	15%
10–19	140	34	24.4(2)	60	11	13
20–29	94	40	24.6(3)	55	14	13
30–39	33	41	23.9(2)	64	6	12
40–49	14	45	27.0(2)	50	14	0
≥50	14	40	34.2(2)	64	36	21

For many of the flares observed since 1949, the IAU Quarterly Bulletin gives data on the intensity of Hα in units of the neighboring continuum intensity, and on the area in heliographic square degrees. The largest reported value was recorded for each flare. The flares were sorted by area and by intensity, and the geomagnetic superposed epoch curves computed, with the results summarized in tables 5 and 6. For the years 1949–1959 the weighted mean of *Kp* is 21.8. The data give little evidence for any systematic increase in geomagnetic effectiveness with either flare area or intensity. However, flares of area greater than 50 square degrees, or Hα intensity exceeding 200 percent of the neighboring continuum, do appear to be substantially more disturbing than smaller and/or weaker flares. There is no clear-cut relation between flare area or intensity and the north-south asymmetry.

TABLE 6.—*Geomagnetic conditions following major flares, subdivided by intensity of Hα (in units of the neighboring continuum intensity)*

Intensity of Hα	No. flares	Avg. CM distance	*Kp*(max)	Percent north	Percent followed by	
					Great storm	Moderate storm
<100	52	41°	24.3(1)	60%	13%	12%
100–149	73	43	24.2(1)	48	8	15
150–199	34	37	25.0(2)	56	15	9
200–299	35	33	30.1(2)	74	20	14
≥300	11	34	31.9(1)	64	27	9

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[2] For statements of these hypotheses, consult Bartels (1932) or Bell and Glazer (1957, 1958).

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Abstract

Relations between geomagnetic activity and major (importance $\geq 2^+$) solar flares are studied, with primary attention to magnetic type and location of the flaring sunspot group. The data cover the years 1937–1959 and include 580 observed major flares. It is found that a major flare occurring in association with a magnetically complex (γ or $\beta\gamma$) sunspot group is much more likely to be followed by a major geomagnetic storm than is a similar flare in a unipolar (α) or bipolar (β) group. Great-storm flares show the expected concentration toward the central regions of the solar disc, and also an unexpected concentration in the northern solar hemisphere. In the 23 years studied, northern spot groups produced 62 percent of all observed major flares, and 86 percent of those followed within 3 days by a great geomagnetic storm. This north predominance of great-storm flares appears about equally in each of the three sunspot maxima covered and is apparently not related to the 11-year or 12-year solar cycles.

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