Variations of Geomagnetic Activity With Lunar Phase

Harold L. Stolov

The City College of the City University of New York
and
Goddard Institute for Space Studies
National Aeronautics and Space Administration
New York, New York

and

A.G.W. Cameron

Goddard Institute for Space Studies
National Aeronautics and Space Administration
New York, New York

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Abstract

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An analysis of 31 years of K_p data suggests a genuine variation of geomagnetic disturbance with lunar phase. A broad increase in geomagnetic activity of about 4% begins half a day after full moon and lasts for seven days. A broad decrease in geomagnetic activity of about 4% is found for the seven days preceding full moon. The results are verified by a study of random data and by an examination of quiet and disturbed periods. The effect is not found during periods of greatest disturbance.

AUTHOR

Introduction

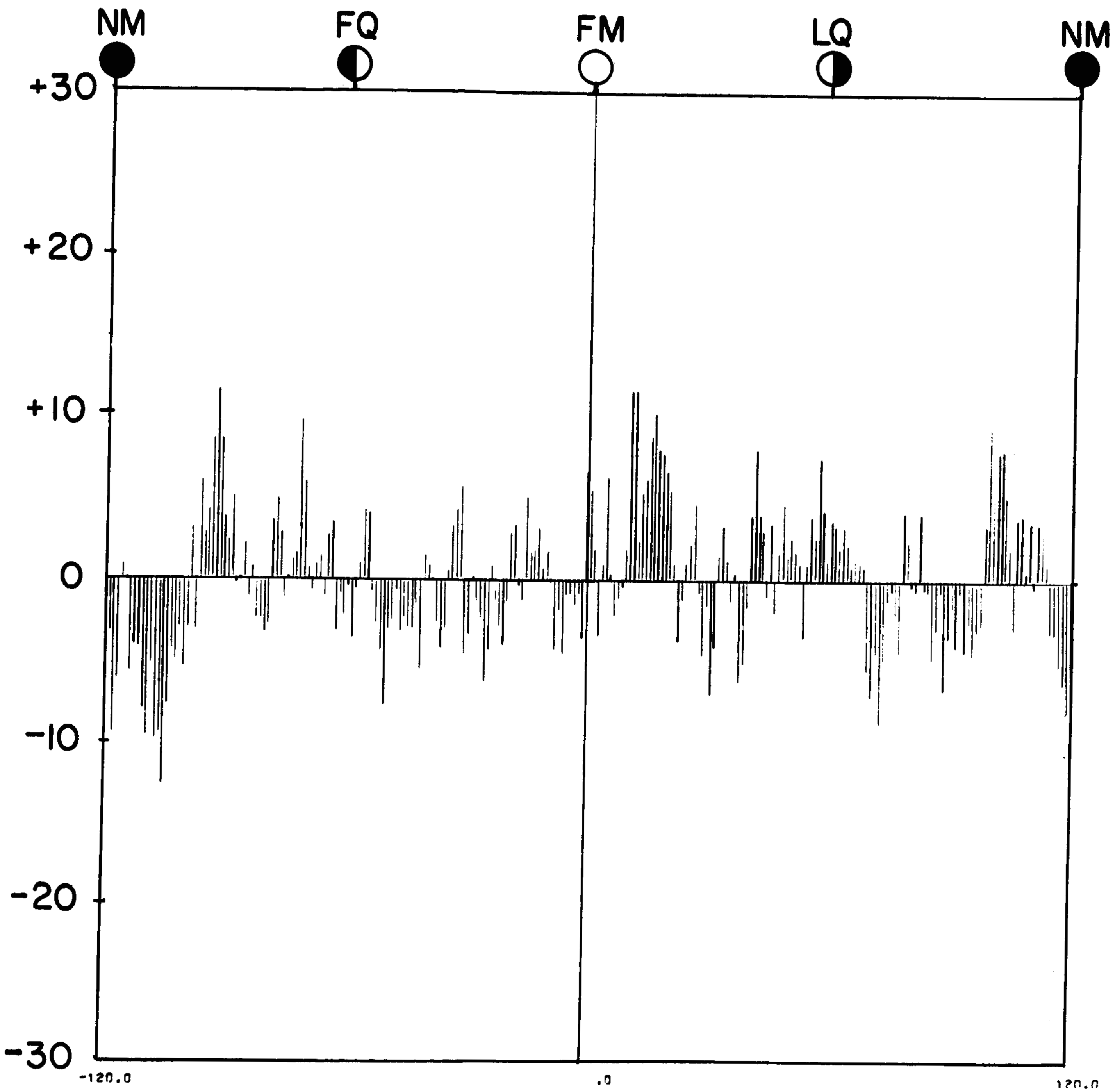
Reports of lunar influence on a number of geophysical variables have appeared in the literature. Bradley _et al_ (1962) and Adderley and Bowen (1962) claim to find a lunar influence on rainfall. Bigg (1963a) presents evidence for a lunar modulation of freezing nucleus concentrations measured in the lower atmosphere. Bowen (1963) reports variations in the incoming meteor rate with lunar phase, and Adderley (1963) claims a lunar effect on the amount of atmospheric ozone. Dorman and Shatashvili (1961) present evidence for a lunar diurnal variation in the intensity of the neutron component of cosmic radiation dependent on lunar phase. Acceptable physical mechanisms for the various lunar modulation effects are not easy to find.

The search for a better understanding of these surprising lunar influences led Bigg (1963b, c) to re-examine the earlier work of Sucksdorff (1956) on the influence of the moon on geomagnetic disturbances. Several confusing and contradictory claims have been made in previous lunar-geomagnetic activity studies:

1. That there is a distinct decrease of geomagnetic activity, averaging 12% during new moon, and a less marked decrease of 7% during full moon. Geomagnetic activity is 7% higher than average during first quarter (Sucksdorff 1956).
2. That there is a minimum of geomagnetic disturbance at new moon, 20% lower than any other minimum on the curve, and a broad maximum of geomagnetic activity shortly after full moon (Bigg 1963b).
3. That there is a decrease in the frequency of magnetic storms at new moon and a tendency for magnetic storms to occur preferentially near first and third quarters (Bigg 1963b).
4. That the decrease in the frequency of magnetic storms at new moon applies only to the gradual-commencement type of storm. The sudden-commencement storms show an increased frequency at new moon (Bigg 1963c).

Bartels (1963) shows that the conclusions stated in (3) above are questionable, since randomizing the data yields variations of size comparable to those in the lunar data.

It is the purpose of this paper to clarify the current



MEAN OF PERCENT DEVIATION OF KP VS TIME IN 3 HOUR PERIODS

Fig. 9

confusion and to determine whether genuine influences of the moon on geomagnetic activity are present. It is established herein that correlations with lunar phase do exist; they may prove valuable in understanding the solar wind - magnetosphere interactions.

Procedure

There is now available more than 31 years of K_p indices, consisting of more than 90,000 well-determined values of standard quality. They represent a detailed history (8 values per day) of the disturbance variations of the geomagnetic field over nearly three sunspot cycles. The scientific community is indebted to the late Professor J. Bartels and his collaborators for their dedicated efforts in the compilation of this series. The K_p index is a worldwide measure of geomagnetic activity expressed on a quasi-logarithmic scale and based on the measurements at a fixed group of 12 observatories in upper middle geomagnetic latitudes. The K_p index is traditionally taken to be a measure of the velocity of the solar corpuscular stream. The Mariner 2 measurements of Snyder et al (1963) establish with a considerable degree of certainty, that the classical view is well taken. No support in the data is found for the alternate view of Dessler and Fejer (1963), which attributes K_p variations to the time rate of change of solar wind plus magnetic pressure and predicts that a strong constant solar wind blowing past the magnetosphere will result in a low K_p. The data indicate the opposite to be the case.

The search for a lunar influence on K_p began with the establishment of a suitable reference level with which to compare the magnetic activity at individual times during the lunar cycle. The mean value of K_p for each lunar synodic period was taken; this is called $\bar{K}_p$. The difference between each K_p value during the lunar month and $\bar{K}_p$ was found. This difference, divided by $\bar{K}_p$ and multiplied by 100, is the % departure of magnetic disturbance from the reference level.

$$\% \text{ departure} = \frac{100\ (K_p - \bar{K}_p)}{\bar{K}_p}$$

This was done for all the lunar synodic periods contained in the 31 years of K_p data. Mean values of the % departures (eight per day) were taken during the course of the lunar cycle and are shown in Figure 1. Figure 1 is the output of a plotter where each vertical marker represents one of the mean values of % departure. Figure 1 indicates the following important features:

a) A broad maximum of geomagnetic activity ($\approx$ 4%) begins a half day after full moon and lasts nearly seven days.

b) A broad minimum of geomagnetic activity ($\approx$ 4%) exists for about seven days preceding full moon.

c) There is nothing at new moon but random statistical fluctuations (verified below).

These results are generally unexpected, in view of the emphasis given to the new moon position by previous investigators, where some type of "shadowing" mechanism at new moon has usually been expected.

Several additional studies were performed to test the above conclusions.

1. To test the significance of the departures observed before and after full moon, and to determine if they might have originated in random fluctuations, a series of artificial lunar periods of 25, 26, 27, 28, 29, 30, 31 and 32 days were run through the same computer

program using all the 31 years of K_p data in each case. In all these random data there were five cases where essentially clean departures of about 4% existed for periods of about three days, and three cases when departures of about 3% existed for periods of about four days. All other departures were for lesser periods. As examples of the random data, Figures 2 and 3 are presented for the 27 day and 29 day runs respectively. It will be noted that Figures 2 and 3 show more than one random negative departure comparable to the meaningless departure at new moon in Figure 1. Many more were found in the runs that have not been reproduced. There is nothing like the seven day clear departures of Figure 1 in any of the random data.

2. As a further test of the physical reality of the observed effects before and after full moon, two separate runs of % departures were made each for eight years of data only. The first was for the eight years of quiet sun consisting of K_p indices

from 1932, 1933, 1934, 1942 (last half only), 1943, 1944, 1953, 1954 and 1955 (first half only). The second was for the eight years of disturbed sun consisting of K_p indices from 1937, 1938, 1939 (first half only), 1947, 1948, 1949, 1957, 1958 and 1959 (first half only). Figures 4 and 5 represent the results of this study. It is seen for the quiet sun, where random fluctuations of K_p are expected to be small, that the previously observed effects persist as in Figure 1. It is seen for the disturbed sun, where random fluctuations of K_p are expected to be large, that the effects about full moon have weakened considerably if present at all. With only eight years of quiet sun K_p data, the previously observed effects are clearly visible.

3. Instead of using the Zurich relative sunspot numbers to distinguish those periods of strong solar plasma flow from the quieter periods, the $\bar{K}_p$ values themselves might be used. In this study the 382 lunar periods were divided into four groups on the basis of different levels of $\bar{K}_p$. All four groups were run

through the same % departure analysis. The results for the lowest to the highest $\bar{K}_p$ groups are shown in Figures 6, 7, 8 and 9 respectively. In Figure 6 the random fluctuations of K_p are expected to be small, and the observed lunar effects of Figure 1 are indeed seen to be present. In Figure 9 the random fluctuations of K_p are expected to be large, and the effects at full moon are not evident. The figures for the two intermediate groups represent a gradation between Figures 6 and 9. The lunar periods assembled to form Figure 6 are not necessarily those of Figure 4, nor are those of Figure 9 the same as the lunar periods of Figure 5. In fact, they are not the same in more than half the cases. This is not surprising when one contemplates the occurrence of disturbed periods in low sunspot years or quiet periods in high sunspot years.

Conclusions

It has been shown that the earth's magnetic field is on the average $\approx$ 4% quieter for the period beginning after lunar first quarter and lasting until just after full moon and is then on the average $\approx$ 4% more disturbed from just after full moon until last quarter. Any physical mechanism to account for the variations of geomagnetic activity about full moon must be sought in the interactions between the moon and the tail of the geomagnetic cavity formed by the magnetosphere embedded in the flow of the solar wind.

Acknowledgments

It is a pleasure to acknowledge the able assistance of Mr. Bernard Goldstein, who programmed and carried out the numerical computations on the IBM 7094 computer and S-C 4020 plotter.

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Figure Captions

Figure 1 - Mean values of the % departure of K_p as a function of lunar phase. (31 years of K_p data)

Figure 2 - Mean values of the % departure of K_p for 27 day periods. (31 years of K_p data)

Figure 3 - Mean values of the % departure of K_p for 29 day periods. (31 years of K_p data)

Figure 4 - Mean values of the % departure of K_p as a function of lunar phase. (8 quiet sun years only)

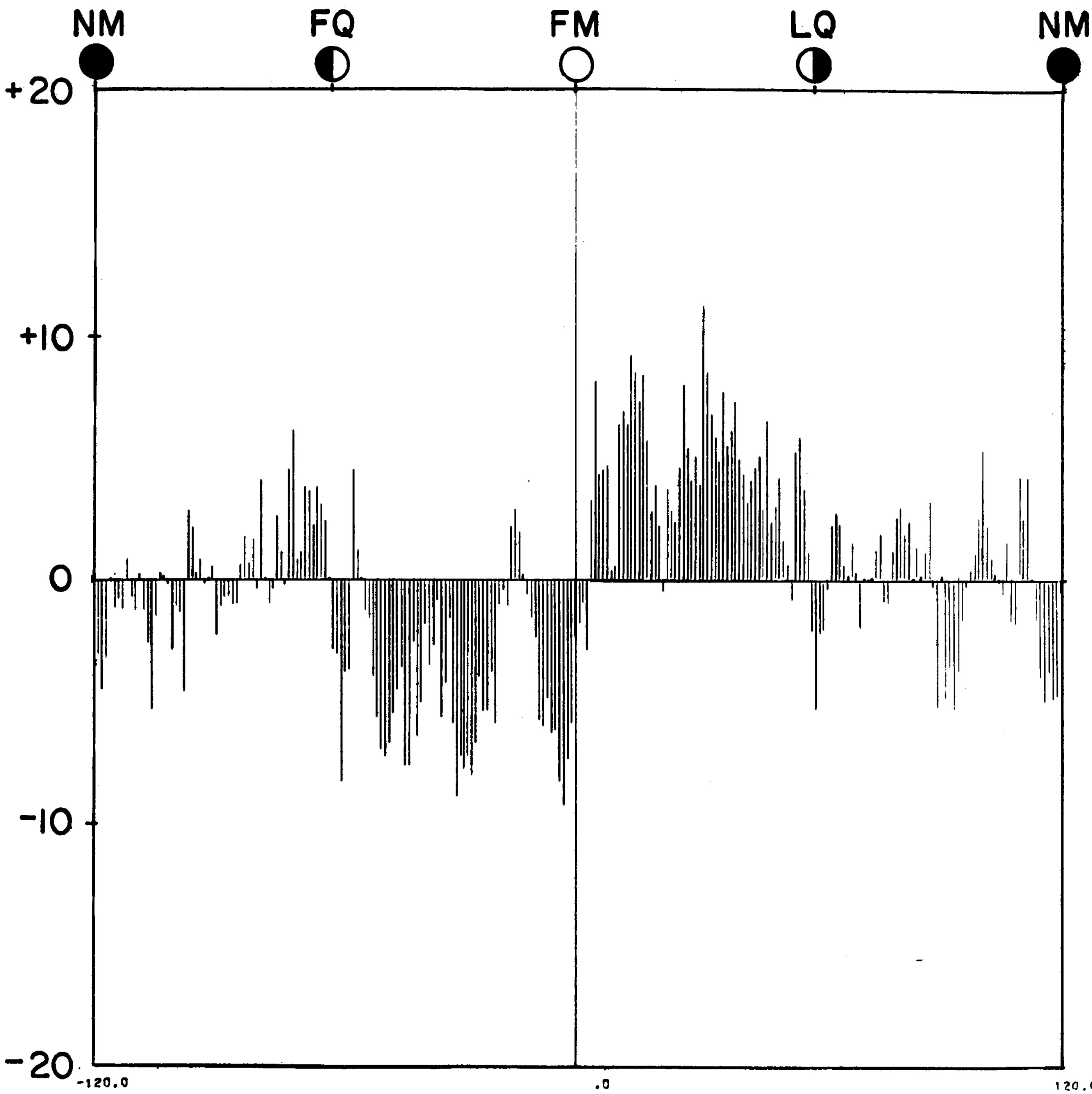
Figure 5 - Mean values of the % departure of K_p as a function of lunar phase. (8 disturbed sun years only)

Figure 6 - Mean values of the % departure of K_p as a function of lunar phase. ($\bar{K}_p$ values of the lowest quarter only)

Figure 7 - Same as Figure 6. ($\bar{K}_p$ values of the next to the lowest quarter only)

Figure 8 - Same as Figure 6. ($\bar{K}_p$ values of the next to the highest quarter only)

Figure 9 - Same as Figure 6. ($\bar{K}_p$ values of the highest quarter only)



MEAN OF PERCENT DEVIATION OF KP VS TIME IN 3 HOUR PERIODS

Fig. 1

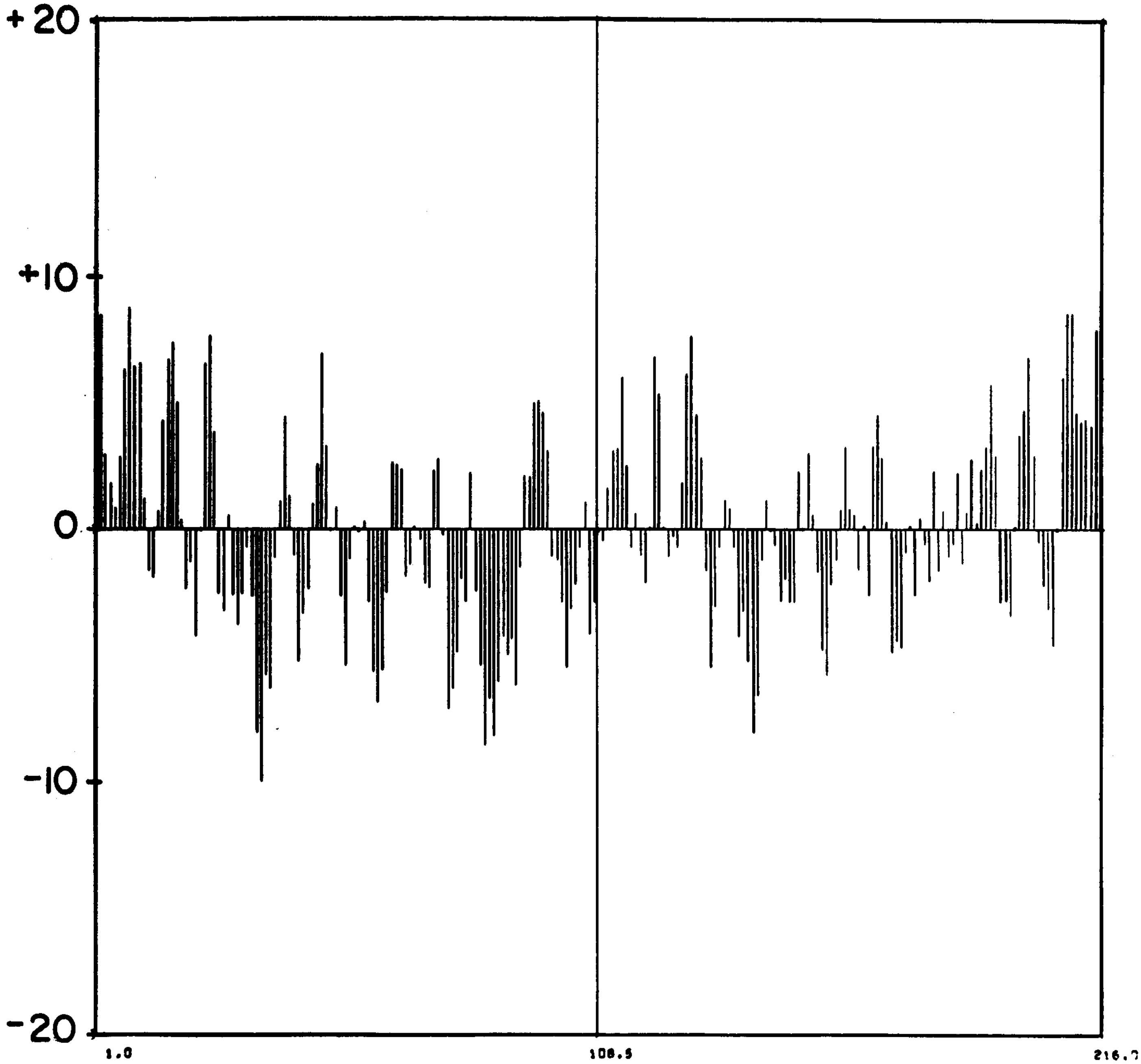


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Fig. 2

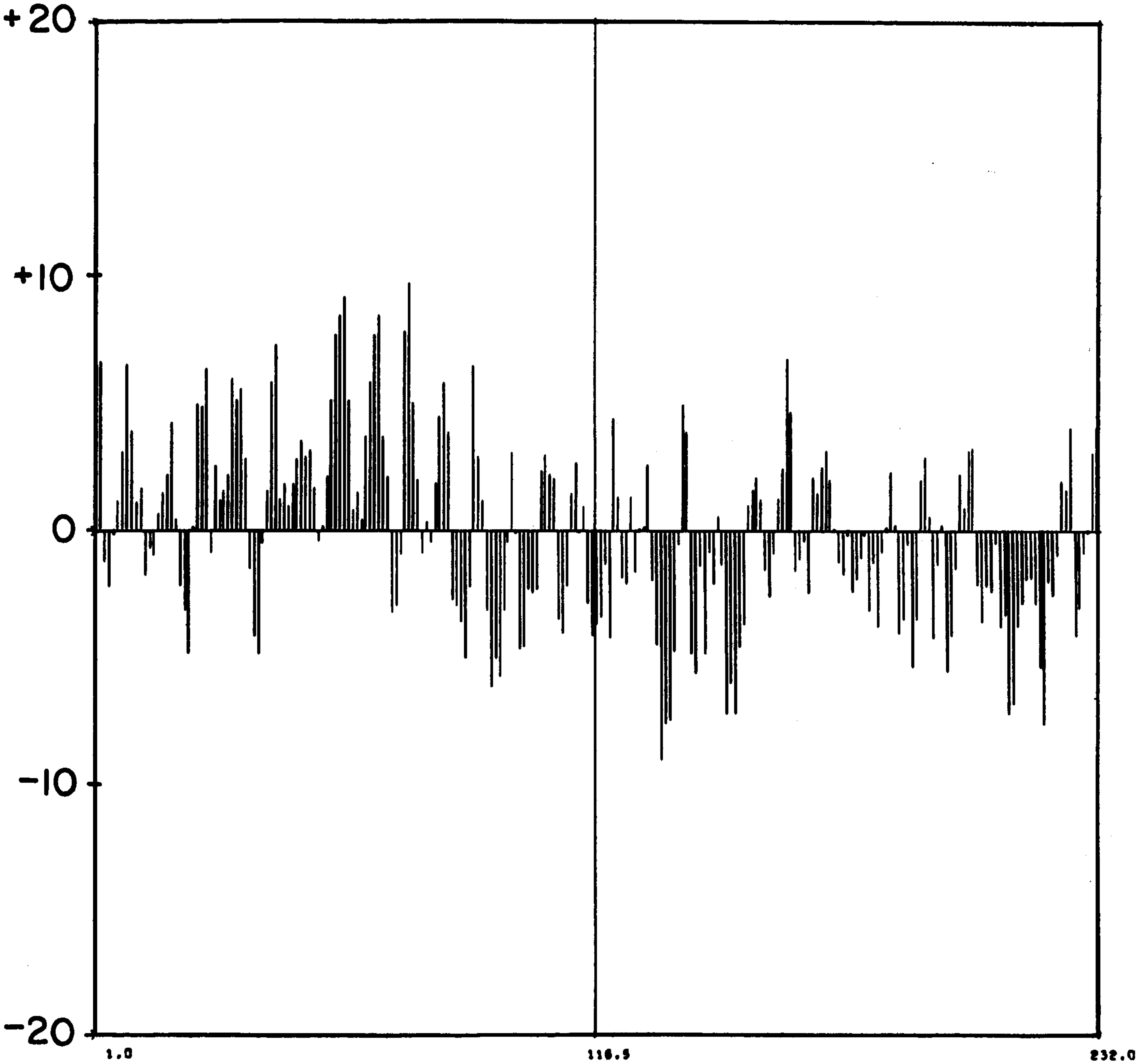

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Fig. 3

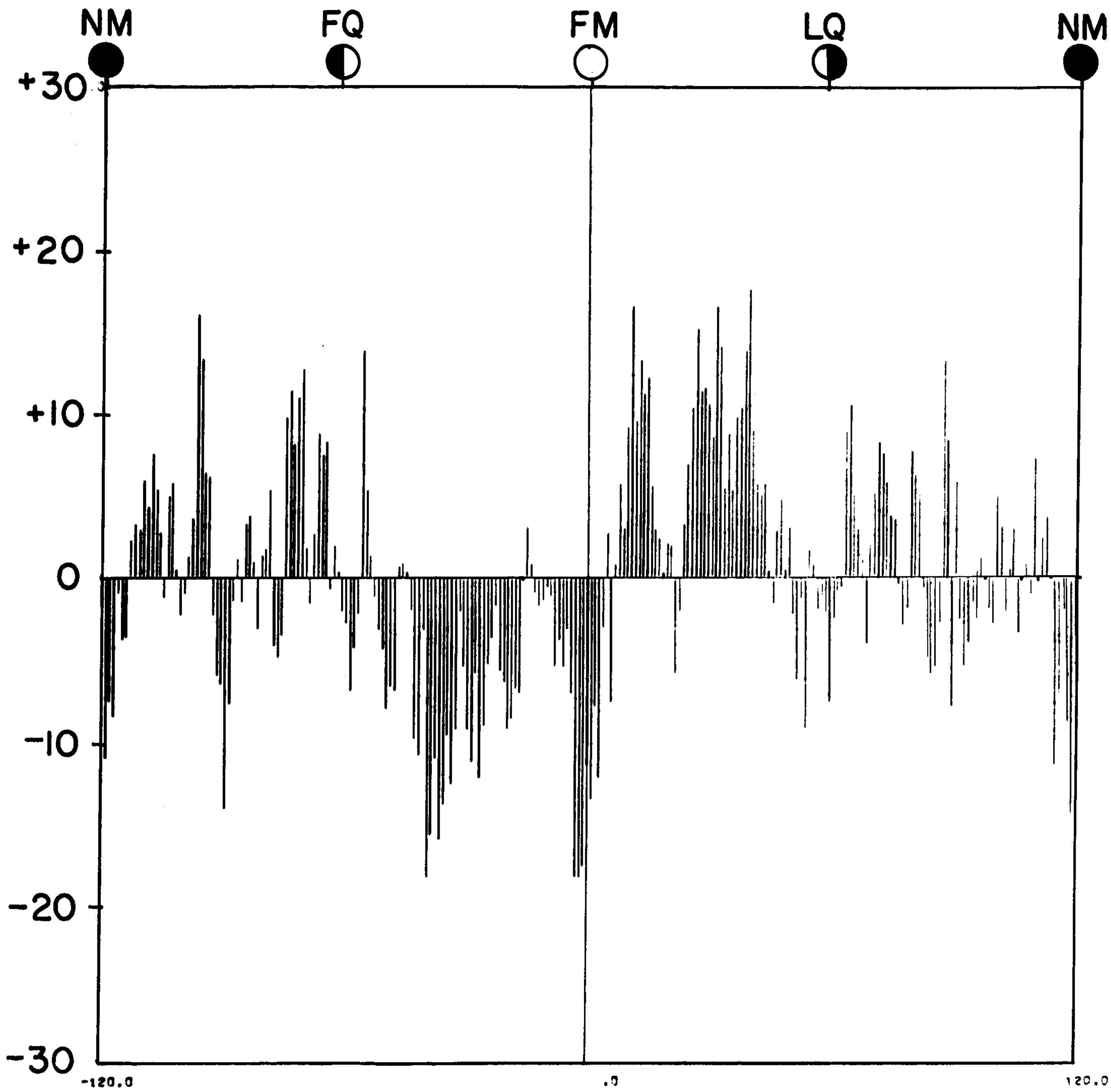

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Fig. 4

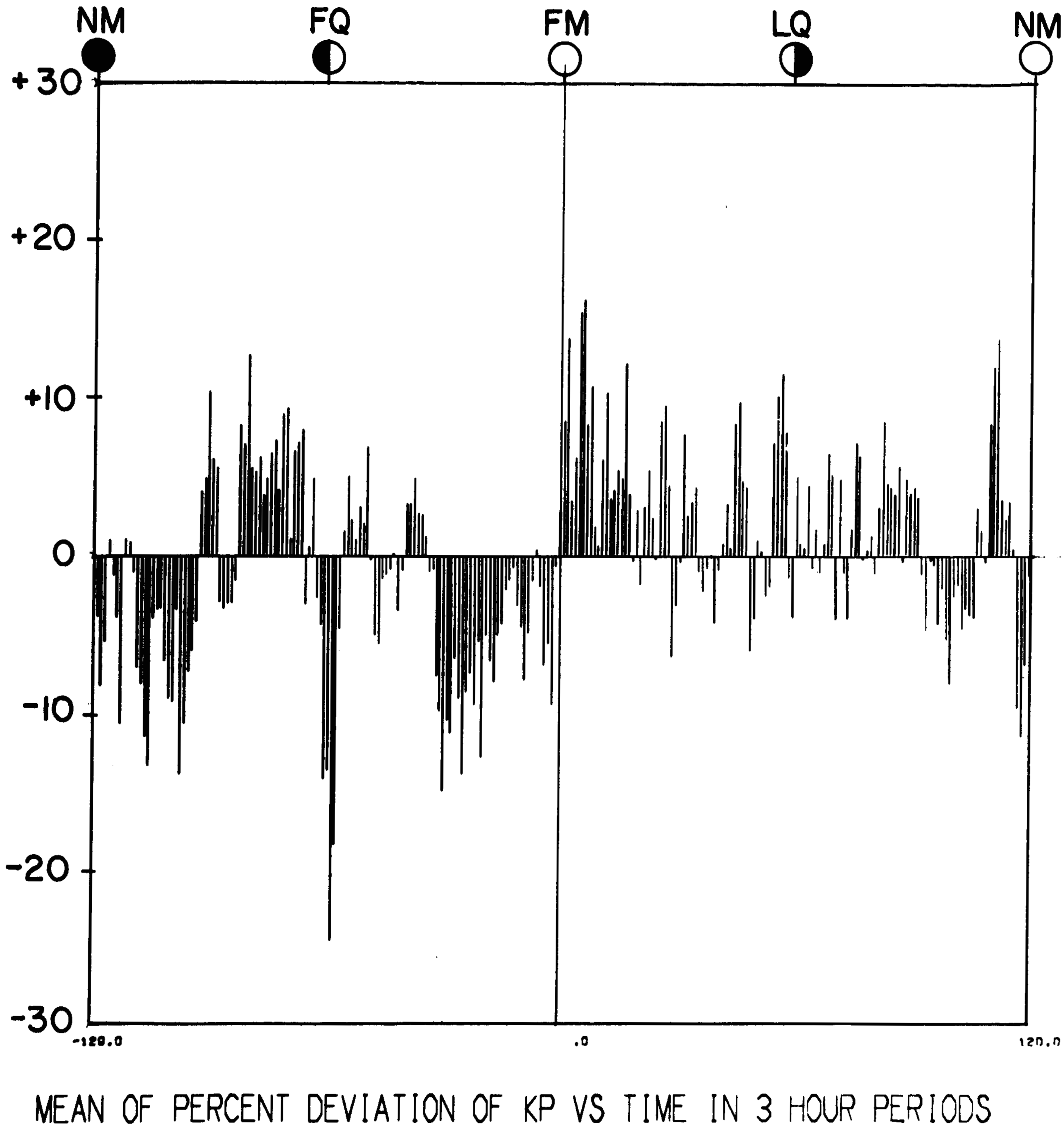
NM
FQ
FM
LQ
NM
+30
+20
+10
0
-10
-20
-30
-120.0
.0
120.0
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Fig. 5

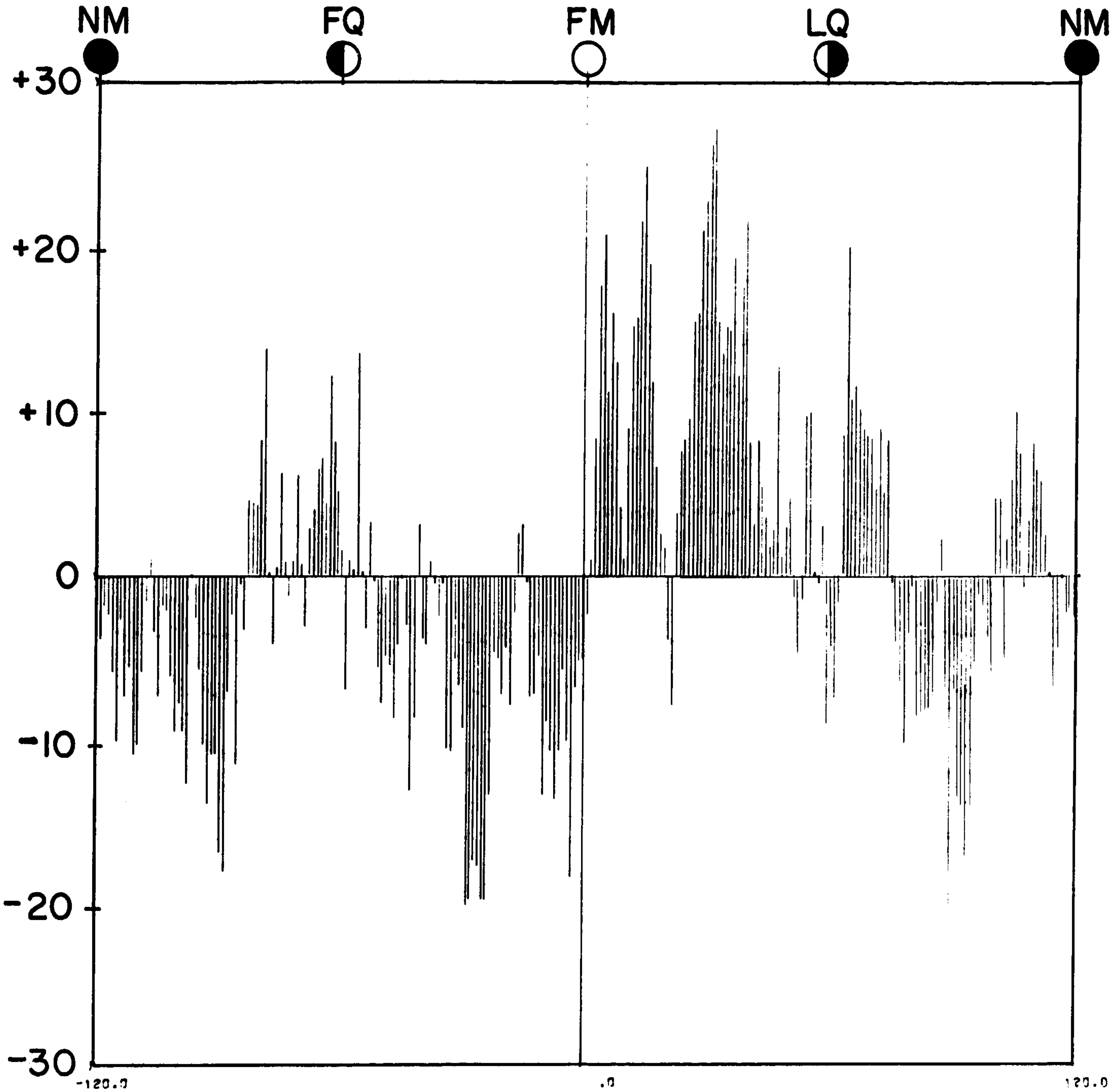

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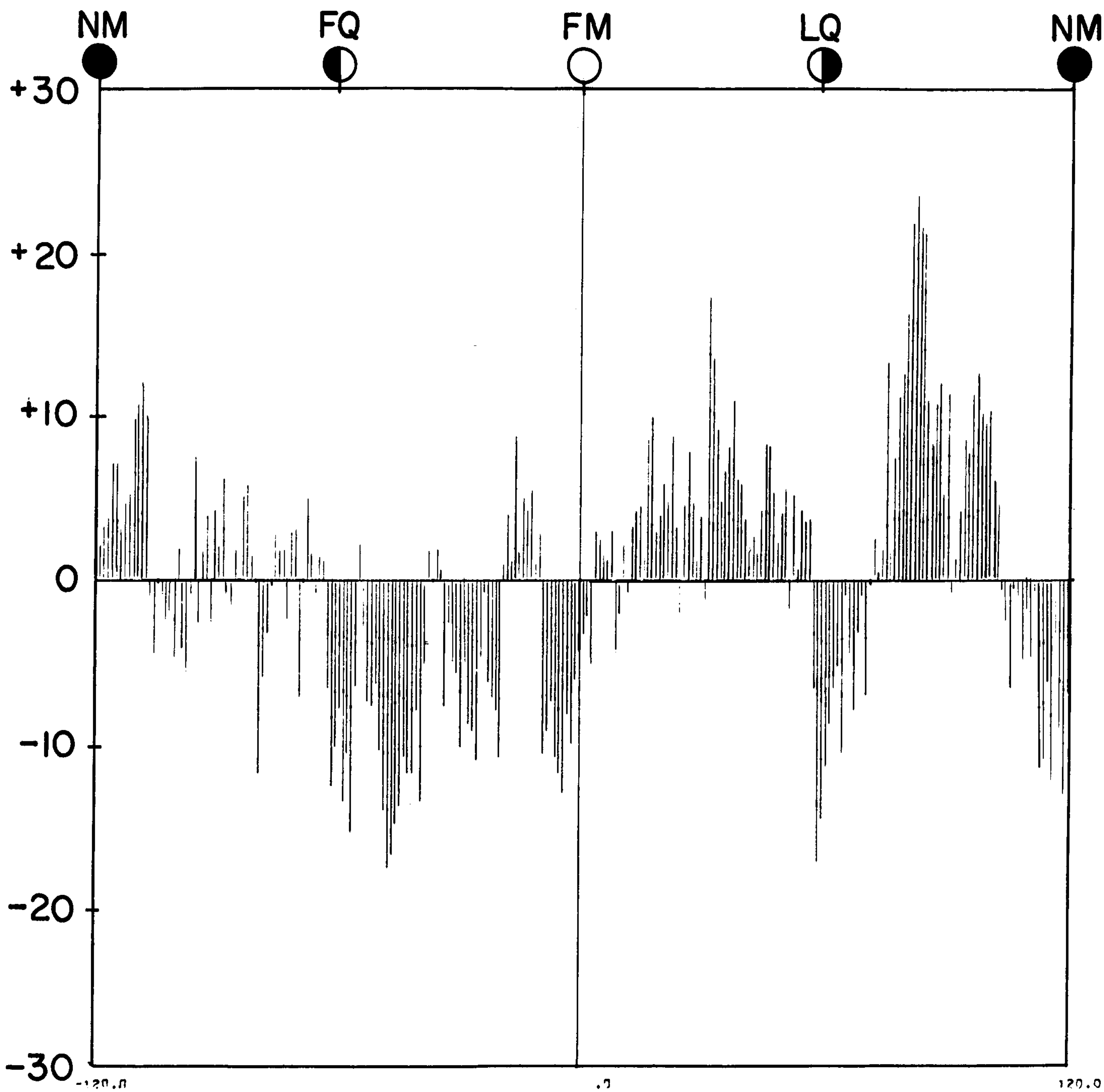
Fig. 6



MEAN OF PERCENT DEVIATION OF KP VS TIME IN 3 HOUR PERIODS

Fig. 7

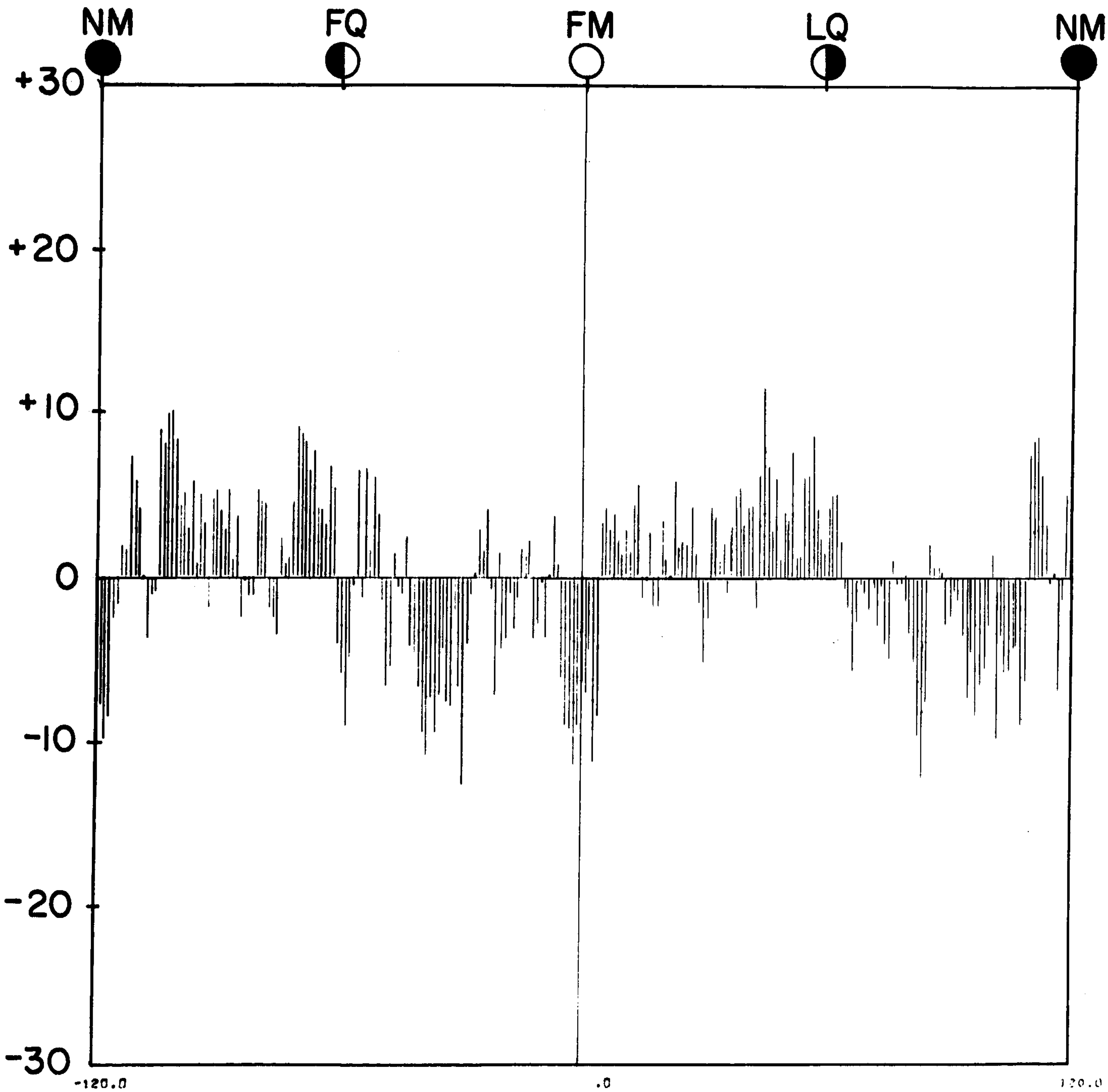


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Fig. 8