social dominance, and penalizing the less fortunate subordinates in the population that are prevented from breeding or feeding, or get squeezed out of the habitat. Yet it is self-evident that the conventional codes under which social competition is conducted are in practice not jeopardized from this cause: selection pressure, however great, does not succeed in promoting a general recourse to deadly combat or treachery between rivals, nor does it, in the course of generations, extinguish the patient compliance of subordinates with their lot.

The reason appears to be that social status depends on a summation of diverse traits, including virtually all the hereditary and environmental factors that predicate health, vigour and survivorship in the individual. While this is favourable to the maintenance of a high-grade breeding stock, and can result in the enhancement through selection of the weapons and conventional adornments by which social dominance is secured, dominance itself is again characterized by a low heritability, as experiments have shown. In many birds and mammals, moreover, individual status, quite apart from its genetic basis, advances progressively with the individual's age. Not only are the factors that determine social and breeding success numerous and involved, therefore, but the ingredients can vary from one successful individual to the next. A substantial part of the gene pool of the population is likely to be involved and selection for social dominance or fertility at the individual level correspondingly dissipated and ineffective, except in eliminating the sub-standard fringe.

Such methods as these which protect group adaptations, including both population parameters and social structures, from short-term changes, seem capable of preventing the rise of any hereditary tendency towards anti-social self-interest among the members of a social group. Compliance with the social code can be made obligatory and automatic, and it probably is so in almost all animals that possess social homeostatic systems at all. In at least some of the mammals, on the contrary, the individual has been released from this rigid compulsion, probably because a certain amount of intelligent individual enterprise has proved advantageous to the group. In man, as we know, compliance with the social code is by no means automatic, and is reinforced by conscience and the law, both of them relatively flexible adaptations.

There appears therefore to be no great difficulty in resolving the initial problem as to how intergroup selection can override the concurrent process of selection for individual advantage. Relatively simple genetic mechanisms can be evolved whereby the door is shut to one form of selection and open to the other, securing without conflict the maximum advantage from each; and since neighbouring populations differ, not only in genetic systems but in population parameters (for example, mean fecundity[12]) and in social practices (for example, local differences in migratory behaviour in birds, or in tribal conventions among primitive men), there is no lack of variation on which intergroup selection can work.

1 Wynne-Edwards, V. C., *Animal Dispersion in Relation to Social Behaviour* (Edinburgh and London, 1962).
2 Wright, S., *Anat. Rec.*, **44**, 287 (1929).
3 Wright, S., *Genetics*, **16**, 97 (1930).
4 Wright, S., *Ecology*, **26**, 415 (1945).
5 Haldane, J. B. S., *The Causes of Evolution* (London, New York and Toronto, 1932).
6 Sturtevant, A. H., *Quart. Rev. Biol.*, **13**, 74 (1938).
7 Williams, G. C., and Williams, D. C., *Evolution*, **11**, 32 (1957).
8 Carr-Saunders, A. M., *The Population Problem: A Study in Human Evolution* (Oxford Univ. Press, 1922).
9 Lack, D., *The Natural Regulation of Animal Numbers* (Oxford Univ. Press, 1954).
10 Jenkins, D., Watson, A., and Miller, G. R., *J. Anim. Ecol.*, **32**, 317 (1963).
11 Lerner, I. M., *Genetic Homeostasis* (Edinburgh and London, 1954).
12 Bagenal, T. B., *J. Mar. Biol. Assoc.*, **42**, 105 (1962).

GEOMAGNETIC PARAMETERS AND PSYCHIATRIC HOSPITAL ADMISSIONS

By Prof. HOWARD FRIEDMAN and Prof. ROBERT O. BECKER
Syracuse Veterans Administration Hospital, New York, and State University of New York Upstate Medical Center
AND
Prof. CHARLES H. BACHMAN
Syracuse University, New York

ALTHOUGH the relationship of natural environmental physical forces to human behaviour has always been a matter of general interest and speculation, there has been a paucity of systematic investigations in this connexion among modern scientific workers. Buettner[1], in a critique of the literature bearing on correlations between bioclimatological parameters and human health and behaviour, pointed to the general confusion in the field as well as to the very limited unequivocal findings consisting of the establishment of two 'potentially harmful' weather types. The literature in the field of geomagnetic parameters and human behaviour is more restricted in quantity and in significance of findings.

Possibly the most ambitious pertinent investigation is that of Düll and Düll[2]. In an analysis of approximately 40,000 cases over a period of 60 months they demonstrated graphically a clearly observable relationship between the 67 magnetic storms occurring during this time, and the incidence of nervous and mental diseases and suicides. Their results, however, were not subjected to statistical treatment. Berg[3], reviewing the literature pertaining to the relationships between environmental geophysical parameters and the human population, concluded that firm evidence for or against such relationships is still lacking.

The relative indifference of the behavioural scientists to this problem may possibly be due to the lack of that type of theoretical framework which could permit the interrelationship of the two parameters to be derived as a logical consequence. There has been, however, a growing appreciation of, and body of empirical findings related to, one circumscribed aspect of the overall area, the biological effects of magnetic fields[4–6], particularly with reference to infra-human organisms. A parallel related concern has been the investigations into the electrical organizations of the living organism. Thus, in a review of recent work in the relationship between direct current electricity and living organisms[7], it was suggested that the direct-current electrical system of the organism could be conceived as a control system which could be influenced by external force fields. These considerations led to a pilot investigation[8] which examined the relationship between gross manifestations of extreme human psychological disturbance and natural magnetic field intensity. The psychiatric admissions to two Syracuse, New York, hospitals were correlated with K-index[9] sums as measured at the Fredericksburg Magnetic Observatory, Virginia, for approximately a four-year period. The statistically significant correlation ratios obtained for non-linear relationships, η, of 0·26 and 0·27 suggested that at least some relationship exists between the incidence of psychiatric disturbance and some geophysical parameter associated with the magnetic field.

The investigation reported here is an extension of the pilot work utilizing a larger sample of psychiatric hospital

admissions and, as advised by Bartels[10], a linear measure of the magnetic field intensity, *ak*, the equivalent 3-h range, rather than the quasi-logarithmic scale of *K*-indices. In addition, *ap*, the planetary counterpart to *ak*, was used.

Daily admissions to seven central New York State psychiatric hospitals and to the Psychiatric Service of a Veterans Administration General Medical and Surgical Hospital during July 1, 1957–October 31, 1961, were obtained. Transfers from other psychiatric institutions were excluded. Total admissions included in the data are 28,642.

For the same period of time *K*-indices, as determined at the Fredericksburg Magnetic Observatory, were obtained from the Coast and Geodetic Survey, U.S. Department of Commerce. The *K*-index, as described by Bartels[10], reflects the amplitude, *a*, of the most disturbed component of the magnetic field, measured every 3 h. The values of *a* are customarily condensed, for convenience of reporting, into a quasi-logarithmic scale for *K*, ranging from 0 to 9. In this work each 3-h *K*-index was reconverted into the equivalent 3-h range, *ak*, by means of a table of Bartels[10], thus providing a linear measure. The eight daily values of *ak* were then summed to arrive at a daily *ak* sum.

The planetary 3-h *K*-indices, *Kp*, as furnished by the U.S. Department of Commerce, Bureau of Standards, Central Radio Propagation Laboratory, Boulder, Colorado, were also reconverted into 3-h equivalent planetary amplitudes, *ap*, and then summed to obtain a daily *ap* sum.

It was decided to examine 7-, 14-, 21-, 28- and 35-day time-periods to correlate with the corresponding periods of the geomagnetic parameters for the following reasons. First, the time between onset of psychiatric disturbance necessitating hospitalization and actual admission varies with a host of uncontrollable factors, not the least of which are differing hospital admission procedures. It is also impossible to specify *a priori* the most meaningful duration and extent of geomagnetic event. Secondly, inspection of the hospital admission data readily revealed one artefact among the many possible contributors to the number of uncontrolled variables in the crude measure of this parameter. Every Sunday was marked by a striking drop in admissions, undoubtedly reflecting differing admission policies and procedures. The selection of the aforementioned time-periods thus provided a constant number of Sundays when all the possible 7-, 14-, 21-, 28- and 35-day intervals were examined.

To obtain the 7-, 14-, 21-, 28- and 35-day values, the number of admissions for every possible consecutive 7-, 14-, 21-, 28- and 35-day period was summed and correlated with the geomagnetic parameter sums for the corresponding periods. Thus 7-day periods yielded 7 correlations obtained from using days 1 through 7, 8 through 14, 15 through 21, etc., for the first correlation; then days 2–8, 9–15, 16–22, etc., for the second correlation; and continuing on in similar fashion to the seventh correlation which used days 7–13, 14–20, 21–27, etc. This provided 3 correlations with 226 pairs of comparisons (N), and 4 with 225 pairs. The other time-periods were treated similarly, thus giving 3 correlations with N's of 113 and 11 correlations with N's of 112 for the 14-day periods; 10 correlations with N's of 75 and 11 with N's of 74 for the 21-day periods, 17 correlations with N's of 56 and 11 with N's of 55 for 28-day periods, and 10 correlations with N's of 45 and 25 with N's of 44 for the 35-day periods.

In order to compare admissions to the greater intensities of geomagnetic disturbance, a listing of the principal magnetic storms from July 1, 1957, until October 31, 1961, identified by the Fredericksburg Magnetic Observatory, Virginia, was obtained from reports contained in the *Journal of Geophysical Research* and *International Geophysical Year Bulletins*. The number of days of storm in the 7-, 14-, 21-, 28- and 35-day periods were then correlated with the hospital admissions for the corresponding time-periods.

The product moment correlation coefficients, r, derived from the comparison of total geomagnetic activity parameters, as reflected in *ak* and *ap*, with hospital admissions are negligible in magnitude regardless of time-period used. Table 1 presents the correlation coefficients obtained from the comparison of the 7-, 14-, 21-, 28- and 35-day periods of hospital admissions with the number of days of magnetic storm for the corresponding periods of time. The correlations between the number of days of magnetic storm and admissions for 7-day periods can be considered as negligible. The 14 correlation coefficients obtained by using the 14-day periods range from +0·077 to +0·221, the latter figure being statistically significant ($P < 0{\cdot}05$). The correlations of the 21-day periods range from +0·116 to +0·305 with 5 statistically significant ($P < 0{\cdot}05$) coefficients. The 28-day correlations range from +0·167 to +0·332, and 13 are statistically significant ($P < 0{\cdot}05$). The 35-day correlation coefficients range from a low of +0·222 to an unexpected high of +0·345, and 11 are statistically significant ($P < 0{\cdot}05$).

Table 1. CORRELATIONS BETWEEN DAYS OF MAGNETIC STORM AND PSYCHIATRIC HOSPITAL ADMISSIONS

Admission periods	No. of r's	Range	Median r
7-day	$3(N = 226) + 4(N = 225)$	−0·010–+0·122	+0·043
14-day	$3(N = 113) + 11(N = 112)$	+0·077–+0·221	+0·117
21-day	$10(N = 75) + 11(N = 74)$	+0·116–+0·305	+0·182
28-day	$17(N = 56) + 11(N = 55)$	+0·167–+0·332	+0·261
35-day	$10(N = 45) + 25(N = 44)$	+0·222–+0·345	+0·279

The use of unscreened heterogeneous hospital admissions as a measure of alteration in human behaviour is admittedly crude. The host of uncontrolled variables makes this at best a gross approximation to psychological disturbance in the human population at large. If one becomes intrigued with ætiological considerations there are then the further problems of the unknown time-period between occurrence of geomagnetic event and its significant effect on the organism, and the specification of the duration and extent of meaningful geomagnetic events. Since the purpose of this work was simply to investigate whether any relationship could be found to exist between geomagnetic parameters and human behaviour, it was hoped that some of the effects of the uncontrolled variables in the behavioural parameter could be crudely minimized by randomization within a large sample, and that the problem of unknown time for effect of geomagnetic event could be attenuated in part by the use of 7-, 14-, 21-, 28-, and 35-day time-periods. The results indicate that statistically significant low to marked linear relationships exist between geomagnetic parameters and a gross measure of human disturbance. These relationships are evident when the measure of the geomagnetic parameter is restricted to those periods of higher disturbance which can be categorized as magnetic storms. The total range of of geomagnetic activity, as reflected in planetary (*ap*) and more local (*ak*) natural magnetic field intensity parameters, does not reveal any significant relationship with psychiatric hospital admissions.

The use of the five time-periods provides no definitive information about the optimal time between geomagnetic event and onset of psychological disturbance or time to achieve hospital admission. However, inasmuch as the magnitude of the maximum correlation tends to increase with the size of the time-period used, it suggests, in part, that the optimal time may be closer to thirty-five days than seven days. In part, it probably also reflects the attenuation of transient artefacts inherent in the hospital admission data.

Although correlational investigations shed but little light on causal relationships, they nevertheless do provide a fertile field which can yield more significant testable hypotheses. In view of the diversity of the two variables under investigation and the grossness of the measures, the present investigation offers correlations of a surprising

magnitude. In general, the tentative conclusion of the pilot study can be reaffirmed: a significant relationship has been shown between psychiatric disturbance as reflected in hospital admissions and natural magnetic field intensity. In any interpretation of this relationship it should be cautioned that it is beyond the scope of this investigation to determine whether the more meaningful geophysical parameter is magnetic field intensity *per se*, or some other geophysical parameter intimately associated with it. Speculatively, the results are in keeping with the conception of the behaviour of an organism being significantly influenced, through the direct-current control system, by external force fields. Attention is thus invited to a hitherto neglected dimension in the complexity of psychopathology specifically, and perhaps generally in all human behaviour.

[1] Buettner, K. J. K., *Fed. Proc.*, **16**, 631 (1957).
[2] Düll, T., and Düll, B., *Deutsch. med. Wschr.*, **61**, 95 (1935).
[3] Berg, H., *Arch. Phys. Ther.*, **6**, 216 (1954).
[4] Davis, D. D., Pappajohn, K., and Plavnieks, I. M., *Fed. Proc.*, **21**, 5, Part 2 (1962).
[5] Becker, R. O., *Med. Electron. Biol. Eng.*, **1**, 293 (1963).
[6] Becker, R. O., *N.Y. State J. Med.*, **63**, 2215 (1963).
[7] Becker, R. O., Bachman, C. H., and Friedman, H., *N.Y. State J. Med.*, **62**, 1169 (1962).
[8] Becker, R. O., Bachman, C. H., and Friedman, H., paper read at Intern. Conf. High Magnetic Fields, Mass. Inst. Tech., Cambridge, Mass. (Nov. 1961).
[9] For a complete description of the technique of scaling *K*-indices see ref. 11.
[10] Bartels, J., *Annals Intern. Geophys. Year*, **4**, 227 (1957).
[11] Bartels, J., *Annals Intern. Geophys. Year*, **4**, 215 (1957).

SATELLITE GRAVITY MEASUREMENTS AND CONVECTION IN THE MANTLE

By Prof. S. K. RUNCORN

Physics Department, University of Newcastle upon Tyne, and Jet Propulsion Laboratory, California Institute of Technology

THE discovery of non-axial and odd axial harmonic terms in the Earth's gravitational field from surface gravity observations[1] and, more recently, from the orbits of satellites[2], has been widely interpreted as showing that the Earth's mantle possesses a finite strength and that in consequence the occurrence of convection currents in the mantle is excluded. The argument is that if the mantle acts as a fluid over periods of millions of years and convection currents are occurring in it, the continents should lie over the descending currents. Munk and MacDonald[3] compared the coefficients of the spherical harmonics which represent the distribution of the oceans and continents with those of the gravity observations and found that no correlation exists, so that a strong argument against convection seemed to have been found. (Jeffreys[1] had shown, on any reasonable isostatic hypothesis, that the gravitational attraction of the continental masses would be annulled by the deficiencies of mass supporting them below to about a milligal.)

Because of their wave-lengths, the sources of the low harmonic gravity anomalies are reasonably located in the deeper parts of the mantle[4]. These gravity anomalies

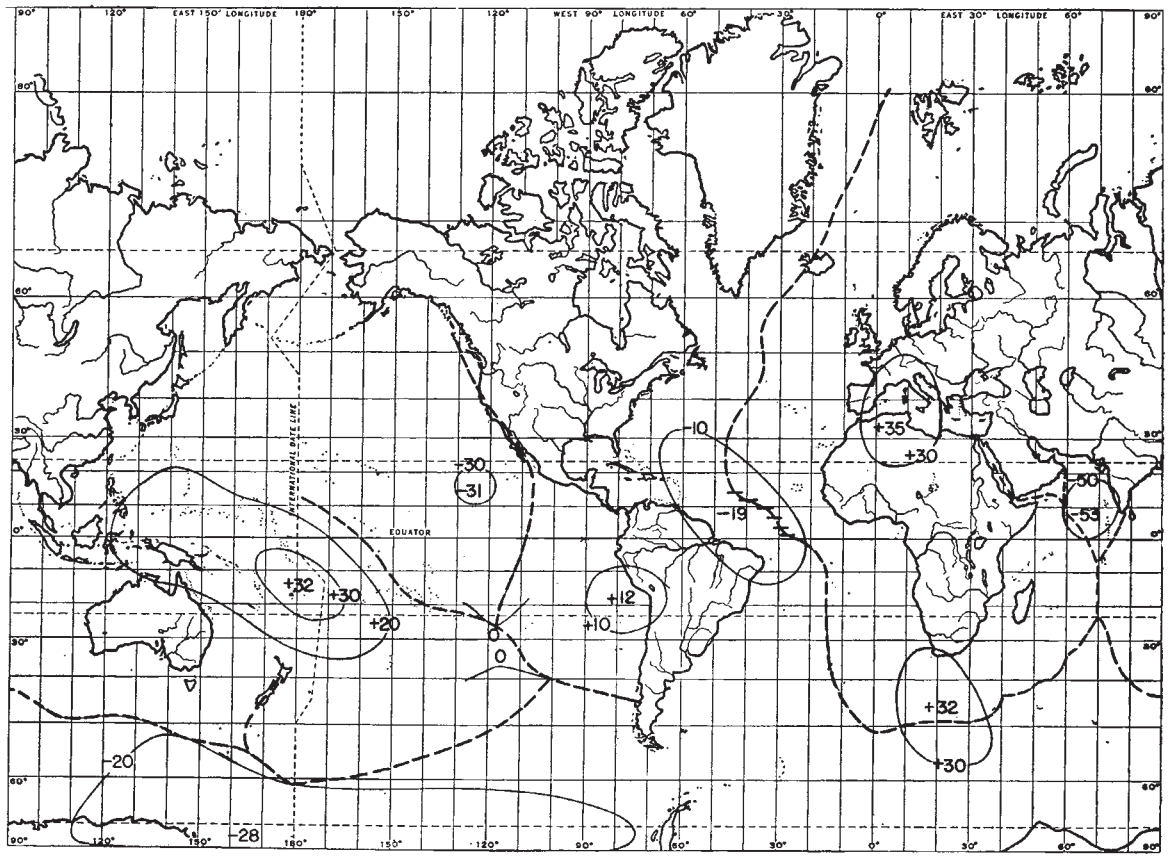

Fig. 1. Dotted lines are the ocean rises[9]; thin lines are contours of geoid surface[10] (in metres) (numbers given in centres of contour show positions and values of gravity highs and lows)