ANNUAL REPORT OF THE DIRECTOR OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM (1939-40) CARNEGIE INSTITUTION, WASHINGTON.

EXTRACTS

We reproduce herewith the following extracts from the very interesting report on the work of the Department of Terrestrial Magnetism from 1 July 1939 to 30 June 1940.

A better understanding of the Earth's general magnetic field and of its secular variation was obtained through a representation of the field by a series of properly disposed elementary magnets. From this new representation, inferences may be drawn regarding the depth at which the magnetic field originates and the quantitative relation between the general field and its secular variation. The general magnetic field may be effectively resolved into a symmetric field and a residual field. The inferences drawn from the representation are that the residual field originates at no greater depth than the surface of the Earth's inner core, which seismological evidence indicates is in a fluid state, and that secular change is a continual modification of this residual field — a modfication so extensive that in the course of a few centuries its entire structure is completely changed. No inferences may be drawn regarding the depth at which the symmetric field originates or whether it also is affected by secular change. It is clear that secular change does not affect this symmetric field to so great an extent proportionally as it does the residual field.

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A general theory of analysis of surface magnetic fields was developed. This method permits analysis of fields (such as those of magnetic storms) for which the method of spherical harmonic analysis is impracticable. It is based on Green's theorem and permits the separation of an observed surface magnetic field into its parts of external and internal origin. An application to the field of magnetic storms, hitherto not analyzed for high latitudes of the Earth, shows that about 60 per cent of the observed field is of external origin; departures from this value are greatest near the auroral zone.

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An extension of the theory permitting estimates of the space-distribution of electric currents responsible for the field is being attempted with a view towards its utility in geomagnetism and geophysical prospecting.

The magnetic storm of March 24, 1940, probably the greatest magnetic storm ever recorded, was an event of unusual geophysical interest. Disturbances of radio communication during great magnetic storms because of concomitant effects on the ionosphere, and disruption of wire-communication through electric currents induced in the Earth, have frequently been noted, but during this storm the induced earth-currents attained such magnitude that electric power-systems were severely affected— the first time such effects have ever been reported. Computations were made of the intensity of currents which could be produced by magnetic changes, and for extreme cases it was found to be sufficient to produce the observed effects on power-lines.

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A new method of representing the geomagnetic field was developed (McNish). The geomagnetic field can be represented to a first approximation by a dipole of moment 8.1×10^{25} CGS units appropriately placed near the center of the Earth, as has long been recognized. However, this single dipole represents only about 80 per cent of the observed field. It was found that the remainder of the field, the "residual field", can be represented to within the accuracy of the observations by 14 radially directed dipoles midway between the center and the surface of the Earth. This depth, which is identical with that at which seismological evidence indicates a discontinuity of the elastic properties of the Earth, was not arbitrarily chosen; placement of the hypothetical dipoles at a greater or lesser depth would have required a much greater number for the same closeness of representation. This is regarded as evidence that the residual field has its origin between the inner core of the Earth and the surface. On the other hand, the quantity of magnetic matter necessary to produce the residual field is so great that it cannot be confined to the outer subsurface layers of the Earth's crust. This first establishment of some definite basis for estimating the depth at which the Earth's field originates is of fundamental importance in the development of any theory of the origin of that field.

A similar representation of the field of magnetic secular variation was also developed, the dipoles being located at the same depth. However, a further restriction could be imposed in this case, namely, that the dipoles be all of the same intensity. The two systems of dipoles, those for the residual field and those for the secular-variation field, tend to be "orthogonal" that is, the secular-variation dipoles are close to the zero isodynamic lines of the residual field. The average strength of the dipoles of the residual field is 1/80 of that of the centrally located dipole, while the dipoles of the secular-variation field are about 1/100 as strong as those of the residual field. Accordingly, if secular variation were to proceed at its present rate for 100 years or so, a new residual field would be built up differing markedly from that which exists at present. In this connection, all historic records of secular change suggest that it does not continue in the same direction and sense at any one place for more than a century or so, and this generalization is supported by measurements of the residual magnetization of geological sediments.

The concept strongly emphasized by this study is that the residual field, which accounts for about 20 per cent of the magnetic field observed at the surface, and its changes originate largely or entirely at a lesser depth than that of the Earth's fluid core. Secular change consists almost entirely of the changes in this residual field, the form of which is completely altered from century to century.

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The Gaussian method permits the separation of an observed field over the Earth into its component parts of external and internal origin. A beginning has been made in the development of a more fundamental method. A general theorem, applicable to any regular closed surface S, gives the difference between the magnetic potentials of external and internal origin in the form

$$(V_e - V_i) = \frac{1}{2\pi} \int_s \left(\frac{Z}{r} - V \frac{\delta \frac{1}{r}}{\delta_n} \right) dS,$$

where Z and V are the total vertical force and potential on S, respectively, n is the outward normal, and r is the distance from the point on the closed surface at which $(V_e - V_i)$ is required, to the element of area dS. Since the potential $V = V_i + V_e$ is known (or can be derived apart from a constant taken to be zero in geomagnetic applications using observed horizontal components of force), a separation of V into parts of external and internal origin is effected. This integral simplifies in the case of a sphere. An analogous expression is used in the separation for vertical force. Various surface- distributions of magnetic matter giving rise to the observed field have been obtained. The known solutions for the problems of DIRICHLET and NEUMANN permit the continuation of the surface-values of the field into adjacent harmonic regions. The separation of the observed field into external and internal parts by means of surface-integrals is especially useful in the treatment of problems in which it is desirable to use data in the form of graphs, instead of in analytical form.

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The results of magnetic observations on land during 1927-1939 were revised by WALLIS and VESTINE, and preparation of manuscript for publication was begun. Summaries of magnetic data for Africa, Australia, and South America, including determinations of latitude and longitude, were furnished a number of interested government and private organizations.

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Grave concern is being occasioned by the present lack of magnetic observations over the oceans, which comprise the major part of the Earth's surface-area. Investigations are under way to determine the utility of continental observations in computing a rough continuation across the oceans of the field as observed on land, as well as the number, accuracy, and type of observations required on land. This project can yield at best but makeshift results, even though theoretically an accurate knowledge of the field-distribution over a single continent would suffice to determine the field at all points elsewhere on the Earth's surface. In problems of this kind a large number of observations of moderate accuracy would be more useful than a small number of observations of great accuracy, because the rate of change of the field with distance along the Earth's surface should be well defined. The problem of adjusting observations in conformity with the requirements of potential-theory is also under consideration in connection with improvements in techniques of constructing magnetic charts.