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Niedersächsische Staats- und Universitätsbibliothek Göttingen
Georg-August-Universität Göttingen
Platz der Göttinger Sieben 1
37073 Göttingen
Germany
Email: gdz@sub.uni-goettingen.de

ähnlich ist, liegt wahrscheinlich in einem tieferen Niveau noch unter der umkehrenden Schicht, also im Sonnenkern, der sehr wahrscheinlich mit einer einheitlichen Geschwindigkeit von etwa 20 Tagen rotiert*). Eine Möglichkeit, das Vorhandensein des Erd- bzw. Sonnenmagnetismus auf die Beschaffenheit der Materie im Erd- bzw. Sonnenkern zurückzuführen, wurde bereits diskutiert**). Es läßt sich aber denken, daß noch andere Deutungsmöglichkeiten (vielleicht in Verbindung mit erdelektrischen Erscheinungen) vorhanden sein werden.

Potsdam, Mai 1930.

On the distribution of permanent repeat-stations

By **J. A. Fleming**, Acting Director, and **H. W. Fisk**, Chief of Land Survey Section,
Department of Terrestrial Magnetism, Carnegie Institution of Washington

(With 2 Illustrations)

The Department of Terrestrial Magnetism of the Carnegie Institution of Washington esteems it a high honor and a privilege to be represented among the contributors to the Festschrift to be issued on the occasion of the seventieth birthday of Professor Adolph Schmidt. In forming the original conception of the Department as an organization for studying the problem of terrestrial magnetism on a world-wide and comprehensive scale, in laying and in executing the plan for a magnetic survey of the Earth, and in the theoretical discussions undertaken from time to time, the wise counsel, the broad experience, and the friendly interest of Professor Schmidt have been inspirations contributing largely to such success as has been achieved. As founder and for many years director of the Department, Dr. Bauer often turned to him for constructive and helpful suggestions, always sure of a friendly and helpful response.

The following contribution finds its special fitness in a publication dedicated to Professor Schmidt, in that it emphasizes one of the needs for which he has worked for many years, namely, a more satisfactory distribution of stations supplying reliable magnetic information. Since the publication in 1896 of his note „On the distribution of magnetic observatories over the globe“, there has been a great increase not only in the number of active observatories but also in the number of spots where magnetic measurements have been carefully made, and secular variation, which he perceived to be a phenomenon of outstanding significance in 1898, has become of increasingly greater interest as it has become better known.

*) Vgl. G. Angenheister: Das Magnetfeld der Erde und der Sonne. Nachr. d. Ges. d. Wiss. zu Göttingen, Math.-Phys. Kl., 1924.

**) Vgl. Jahrg. 5, Heft 8 dieser Zeitschr.

There is no phase of terrestrial magnetism which might not equally well be chosen as exemplifying his interest and activity. But the work of this Department has placed emphasis first on providing reliable knowledge of magnetic distribution, and second on learning the character of its year-to-year variation — both of which Professor Schmidt's work shows as of prime importance.

The problem of magnetic secular-variation, perhaps more than any other of the many geophysical questions of great interest, demands international cooperation. The ever-changing lines of magnetic force which move about on the surface of the Earth take no account of national boundaries, and are not retarded by obstacles which set limits to the areas traversed by the observer who seeks to make a record of those movements. Only a minor fraction of the Earth's surface is occupied by nations possessing sufficiently broad scientific interest in the subject, combined with such an abundance of material resources as make it possible to establish magnetic observatories and conduct systematic surveys at stated intervals. The interest of other nations needs the stimulation which will come with a better understanding of the close relation between magnetic manifestations and other terrestrial forces, and it is gratifying to record that signs of growing interest are appearing in many places. At the present time, and probably for many years to come, the assistance of those best able to offer it will be required to collect the data from those other great areas of both land and sea which a satisfactory discussion of secular variation demands.

In order that there may be no unwise expenditure of effort or money in duplication of surveys, or in working in regions where the need is less to the neglect of other regions where the requirements are much greater, there should be a plan of cooperation agreed to and respected internationally. Before any plan can be formulated, it is desirable to consider the general character of the secular-variation phenomena and the distribution of the areas where the rates or accelerations are of such especial interest as to demand the continuous records which can be obtained only from a fixed observatory, and to make preliminary decision as to what amount of data may be considered necessary, what number of stations may be regarded as sufficient, and what period of time may be allowed to intervene between observations to give the most satisfactory results. Fortunately there is now a network of repeat-stations which covers the whole Earth with the exception of a few regions difficult of access, such as the polar regions, some desert areas, and portions of the sea. From the data supplied by observations at these stations it is now possible to draw the picture of secular change for the whole world with greater attention to detail than hitherto and with some assurance that the picture is an approach to the truth.

Provisional isoporic charts (charts showing lines of equal annual-change) have been prepared in the Department of Terrestrial Magnetism of the Carnegie Institution of Washington for each of the elements, declination, inclination, horizontal intensity, vertical intensity, and total intensity, and are presented in a separate communication entitled "Isopors and isoporic movements". A

study of the charts and the data from which they were compiled brings to light a few significant facts which should be taken into account in considering the number and distribution of magnetic observatories and sites of permanent repeat-stations, as well as the most advantageous time-interval between occupations of the latter. Among these are: 1. Isopors tend to form closed ovals around

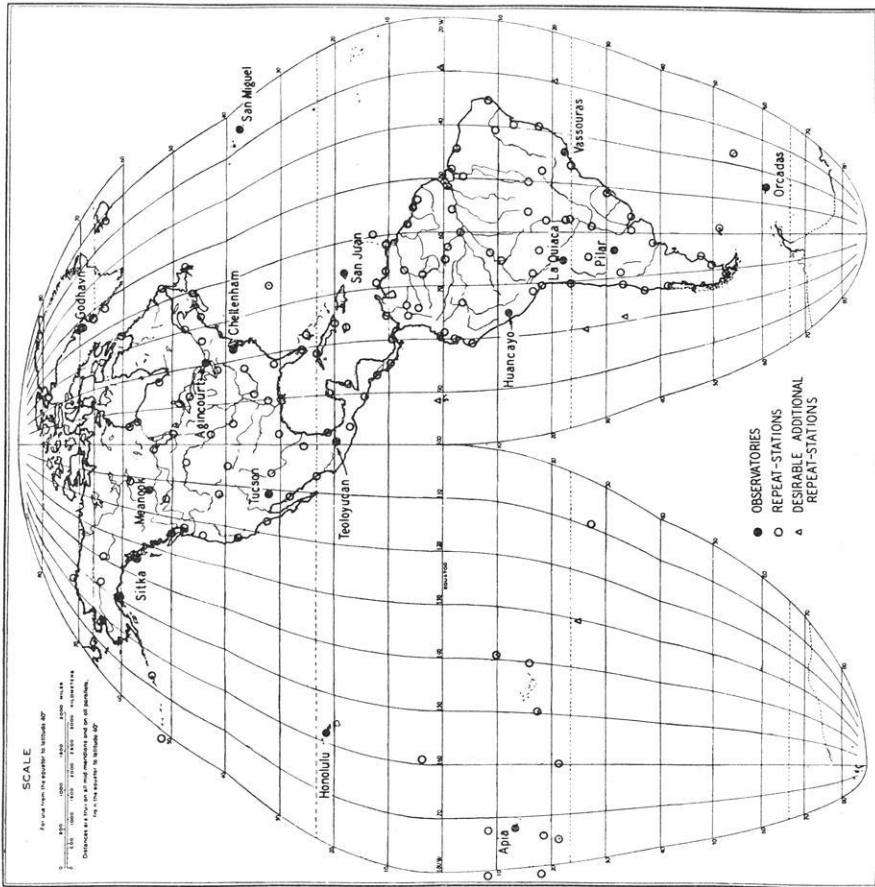


Fig. 1. Locations of observatories, repeat-stations, and desirable additional repeat-stations in Western Hemisphere

certain foci of very rapid annual-change; 2. in general the accelerations or change of rate from year to year are very large near these foci; 3. the areas of rapid change are not permanent but may appear or undergo radical changes in form or position in so brief a time as one or two decades; 4. these foci are practically all in one hemisphere, that bounded by the meridians 90° west and 90° east and containing most of the land of both hemispheres.

Considering only the demands of the problems of secular variation, it will be obvious, in view of the facts just enumerated, that a uniform distribution of

magnetic observatories would not be the best arrangement, neither is it necessary to select permanent repeat-stations so as to form a net of uniform density. Where

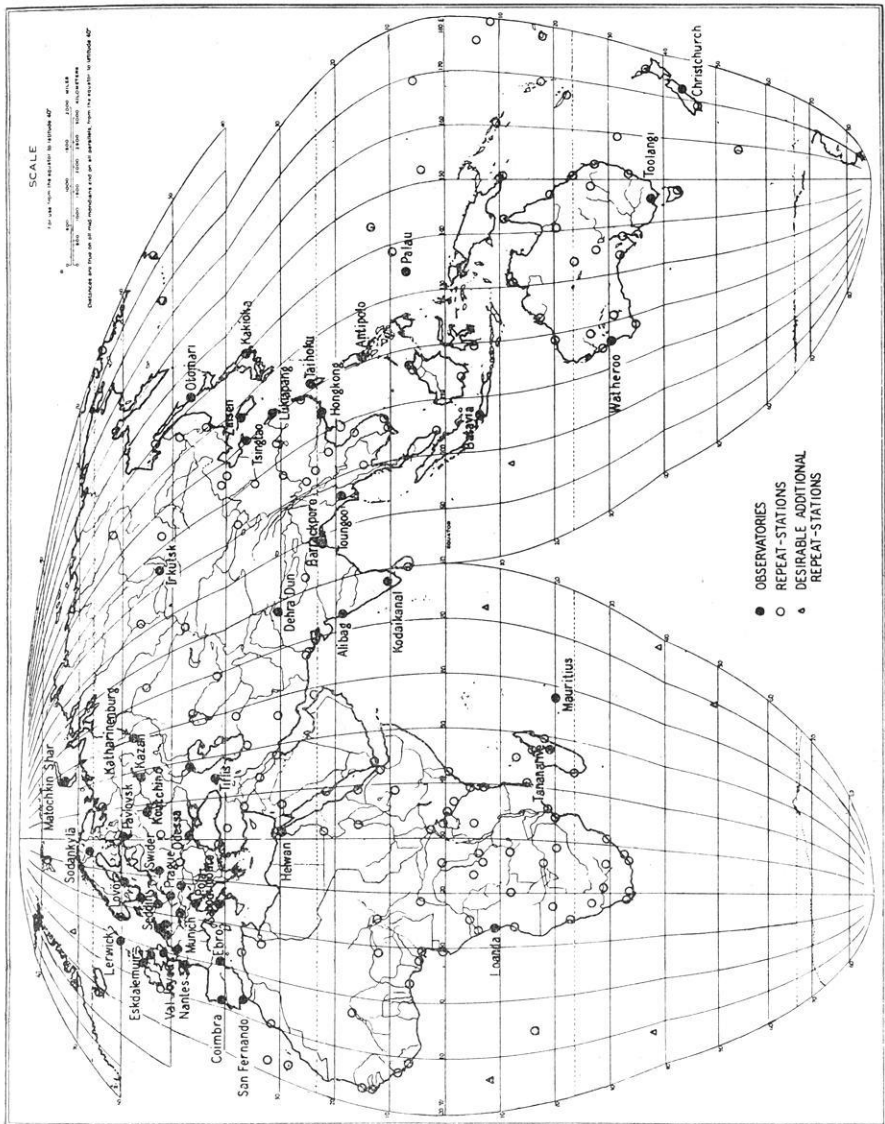


Fig. 2.

Locations of observatories, repeat-stations, and desirable additional repeat-stations in Eastern Hemisphere

accelerations are large, and changes in the position or form of the isoporic ovals are rapid, or where the contours form closed figures of short radii, only the continuous records from observatories comparatively near each other will furnish the desired information. On the other hand, the great area including most of

Australasia, the East Indian Archipelago, most of the Pacific Ocean, part of Siberia, and western North America shows very moderate rates of change of each element and the accelerations are in general not great. Within this area a small number of observatories satisfies the requirements of secular variation, fewer permanent repeat-stations are needed, and these may be reoccupied at longer intervals without danger of losing important features of the secular-change curve. In the northern part of North America the situation is complicated by the proximity of the north magnetic pole, but over southern Canada and the United States the isopors seem to be regular and the required data for supplementing that of the existing observatories can be well supplied by a suitable selection of repeat-stations, reoccupied at intervals of approximately five years. However, toward the south, in the Caribbean, the West Indies, and the northern part of South America, conditions rapidly change. The fragmentary information supplied by irregular field-observations, leads to the conclusion that very interesting developments have taken place there since the beginning of field-surveys in 1905. The records of the observatory at Vieques (Porto Rico) show great accelerations in the annual rate for horizontal intensity (H) at that place and from them inferences may be drawn as to the accelerations at other places. Between Porto Rico and Huancayo (Peru) there is an area of rapid change with its accompanying accelerations in inclination (I), vertical intensity (Z), and total intensity (F). Much of significance has been lost or left to conjecture which would have been supplied by a more adequate distribution of observatories. An observatory at Bogota or Caracas, and at Para or Natal would be abundantly justified by the importance of the secular-variation manifestation in that region. The annual change of inclination at Bogota was probably more than $+16'$ in 1917 but appears to have decreased to about $+12'$ at the present time. Going eastward the rate rapidly diminishes, becomes zero in Guiana, or near Manaos on the Amazon, and falls to $-12'$ in eastern Brazil. Probably the greatest negative rate is in the Atlantic between the two continents since rates as great as $-16'$ are found on the adjacent African coast. Although the rates in Colombia seem to be declining, those in Africa appear to be increasing, while the zero-isopor, or line between positive and negative rates, is drifting gradually farther west. This suggests another desirable location for an observatory, namely, in French West Africa, in Liberia, or in Sierra Leone.

In a similar way other important areas might be indicated, for example, the unusually large rate of diminishing H in South Africa, and the remarkable condensation of declination-isopors between East Africa and Mauritius. The arrangement of the isopors in each of these as well as other cases carry their own suggestions as to their desirability as locations for magnetic observatories.

Inasmuch as the cost is so great of maintaining the necessary trained personnel and of supplying the buildings and instruments needed for the efficient operation of a magnetic observatory, it is unreasonable to expect any considerable addition to the existing number for many years hence. Most of the information

which will be added to what the present observatories can supply must come from observations at repeat-stations. A good magnetometer with earth-inductor attachment might be obtained by many of the countries or dependencies not able to establish and operate an observatory, and skill in its manipulation can easily be acquired. Observations made at suitable intervals by use of such an instrument, in a hut of non-magnetic construction in a carefully chosen location, perhaps by some one connected with the meteorological or topographic-survey services, or by an interested person at an educational institution, while not by any means the equivalent of the continuous records such as obtained at an observatory, would nevertheless be an invaluable contribution. Near the centers of those regions known to be areas of active secular-change, observations should be frequent enough to furnish an approximation to the mean annual-value. As concrete examples of such locations, mention may be made of Bogota (Colombia), Kingston (Jamaica), Dakar (West Africa), or Cape Town (South Africa). At such places one day each month devoted to observations, making continuous observations throughout the day for declination and horizontal intensity on one day and continuous observations with the earth inductor on the observation-day of the succeeding month, would supply sufficient material for good secular-change determination, providing at the same time a reliable index to the accelerations of the annual rate and diurnal-variation data sufficient to control such observations as may be made in the surrounding country. The places named are of course mentioned only as examples of localities where this kind of a program is needed.

Farther from the centers, and where the establishment of a hut is for any reason inexpedient, observations at longer intervals over permanent piers in carefully chosen locations would suffice. To be satisfactory in the study of secular variation, repeat-observations must meet the two requirements of certainty that no artificial source of disturbance has been introduced into the magnetic field in the interval between occupations and of observations at each occupation for a sufficient number of days at such various hours of the day as to make reasonably sure that the results shall represent the true normal value for the place and the season. Much of the discordance found in secular-variation data arises from failure in one or both of the requisites. The justification for multiplying repeat-stations is in the probability that errors from these sources will disappear in an average of many values. Better results, even though at more widely scattered localities, would be derived from a longer series of observations at each occupation and by a more careful selection of stations. The proper protection and preservation of repeat-stations requires the enlistment of local interest and for this reason the cooperation of officials of the public services most closely concerned should be obtained or, where this is inexpedient, a location should be sought on the grounds of some educational institution or mission-station, where cordial assistance is invariably afforded. The station when located should be permanently marked by a pier or marker which should bear an inscription

indicative of its importance and such as to command respect and to appeal to the pride of local residents. When selected and established, these stations should be visited frequently enough to keep alive the interest upon which reliance is so largely placed for their future availability.

The present difficulty of carrying out such a program lies in the insufficiency of the number of instruments available and the slowness with which that number can be increased. If a market for a considerable number could be assured, responsible makers would be justified in giving their energetic attention to their production, whereas under present conditions, in order to keep the price within the reach of the purchasers, they are made in spare time not devoted to more profitable orders, much to the annoyance of those waiting for their delivery. A way out of this difficulty may be found by some cooperative form of combining orders.

By considering the isoporic charts for the several magnetic elements together with the positions already listed as repeat-stations, and adding other localities which might without undue difficulty be used as such, it is possible to draw up a tentative list of stations for systematic reoccupation so distributed as to cover the Earth with a reasonably complete net. To give the names and geographic positions of so many places is impossible in this article, but the distribution desired is well indicated by the two accompanying charts. Few additional stations are needed in Europe because of the concentration of magnetic observatories in that region. In some countries such as the United States, Canada, and several others which maintain their own organizations for making magnetic surveys, the places have been selected from their published reports. A large proportion of the remaining localities are those at which the Carnegie Institution of Washington has already made repeat observations. A few positions indicated on the charts by triangles are included because they are peculiarly suitable by reason of their location for supplying secular-variation data. The indicated positions are by no means the only ones at which repeat observations are needed, but are offered as a basis for considering some plan of international cooperation which shall insure the reoccupation at regular intervals of a sufficient number of stations all over the globe to supply the necessary data regarding the secular change in the Earth's magnetism.

July 23, 1930.
