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PRACTICAL USES OF THE EARTH'S MAGNETISM

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CONTENTS

*Sections containing definitions.

PRACTICAL USES OF THE EARTH'S MAGNETISM

INTRODUCTORY

1. The Coast and Geodetic Survey receives many inquiries regarding terrestrial magnetism and has issued at various times brief publications designed to supplement and clarify the information supplied in correspondence. The present paper continues that series and is largely composed of extracts from former publications. It supersedes Serial 272 and Special Publication 213. In accordance with a long-felt need, the discussions have been revised in the light of the latest concepts, and several topics have been more fully developed.

REASONS FOR MAGNETIC SURVEYS

2. The magnetic compass may well be considered one of the few inventions which have profoundly affected the development of civilization. Centuries have passed since its invention released the mariner from his age-old dread of the trackless oceans and made possible the discovery of new continents, but it still holds its important place in navigation and is the simplest and cheapest direction finder on land and sea and in the air.

3. The compass was one of the earliest surveying instruments. It is recognized that it is not an instrument of precision. Hence results of great accuracy are not to be expected in compass surveys, and the use of a compass as a surveying instrument should be avoided where circumstances permit, especially in areas where local control surveys have been made or where pronounced local magnetic disturbance renders the compass unreliable. However, it has the advantage of speed and simplicity and is useful for the retracing of old lines of surveys originally established by compass and for surveys where great accuracy is not required, particularly in wooded areas. Nearly all the early land surveys of the United States were made by compass. In recording deeds, the boundaries were often defined by compass bearings. In fact, it was partly to meet the needs of the land surveyor that the magnetic work of this Bureau was extended to cover the interior of the country, although this service now forms an important source of basic data for several modern fields of technology.

4. Practically every vessel of every description is equipped with one or more compasses, and the courses to be sailed from port to port are accurately laid down. For the traveler in unexplored regions, the compass is still indispensable. It is as necessary to the aerial navigator as to the mariner, particularly in the maintenance of year-round air-transport schedules, by means of "on-top" and

"blind" flying. Special forms of compasses have been developed to meet the specialized needs of aviation. Some operate without the use of magnets, having rotating coils in which an electric current is generated by the earth's field. When radio bearings of broadcast stations are used, they may be referred to the magnetic meridian as a convenient reference line for constructing position lines. The advent of the gyro compass on sea and in the air has provided a continuous check on the indications of the magnetic compass throughout a vessel's track and has thereby enhanced rather than curtailed the value of the magnetic compass as a reserve instrument which is practically immune to mechanical failure and not dependent on a source of motive power for its operation.

5. There are comparatively few places where the compass needle points to the true north. Moreover, the direction of the needle is continually changing. It is obviously essential that those who wish to use the compass should have correct information concerning the nature and extent of these changes. (For a detailed discussion of the magnetic elements and their distribution, see pars. 49–59.)

6. The location and development of deposits of magnetic iron ore, and other investigations of the geologist, have long been recognized as important applications of knowledge of the earth's magnetism. With the development of more and more refinement in the instruments and methods, "magnetic prospecting" has taken its place with other geophysical methods for mapping concealed geologic structures even where no magnetic ore is involved.

7. The study of the highly penetrating radiation known as cosmic rays has added one more field of physical science in which terrestrial magnetism plays a part, since there appears to be a definite connection between the distribution of this phenomenon and that of the earth's magnetic field. The transmission of messages by telegraph and cable is frequently interrupted by currents of electricity in the earth. Related electrical phenomena in the air have an important effect on the transmission of radio waves, and both these electrical manifestations are in turn closely allied with the earth's magnetism and its fluctuations.

8. With so many matters of everyday occurrence directly or indirectly affected by the earth's magnetism, it is very important that we should find out all we can about it—how it is distributed over the earth's surface; how it changes from hour to hour and from year to year; how it originated and what causes it to change; how it is related to earth currents, atmospheric electricity, solar activity, and other allied phenomena.

MAGNETIC SURVEY OF THE UNITED STATES

9. **Scope of Survey.**—To meet these various needs the United States Coast and Geodetic Survey has thus far made magnetic observations at about 7,000 places in the United States, including nearly every county seat. Each place where such observations have been made is called a *magnetic station.* The station is usually marked by a stone or concrete post with a bronze disk set in the top. Distances are measured to nearby objects, and the azimuths or true bearings of a number of distant objects are determined. With the aid of this

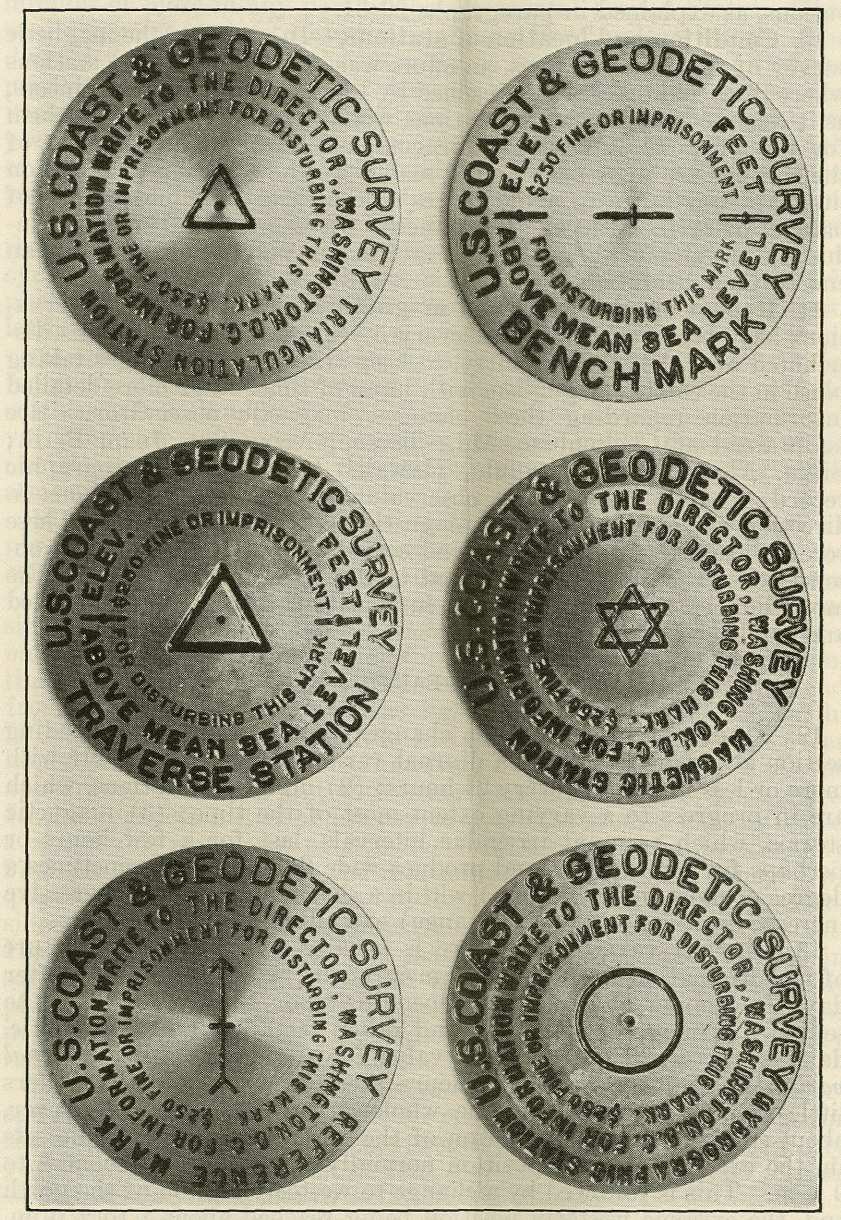

FIGURE 1.—Bronze disks used to identify various types of survey stations of the U. S. Coast and Geodetic Survey. (Disk for magnetic stations at right center.)

information it is usually possible to relocate the point of observation and determine the true meridian without further astronomical observations, as explained in paragraphs 29–31.

10. **Condition and location of stations.**—In planning the magnetic survey of the United States, an effort was made to place the stations where they could readily be reached by local surveyors and engineers, as it was recognized that the stations would be used by many of them for the purpose of testing their compasses. Accordingly most of the stations are in or near county seats. In the selection of a station site, care was taken to avoid places where there were indications of natural or artificial local disturbances. In many cases, however, industrial developments incident to increase in population have put an end to their usefulness.

11. **Repeat observations and magnetic observatories.**—Observations have been repeated about every 5 years at selected stations distributed over the whole country, to keep track of the changes taking place in the earth's magnetism with lapse of time. For more detailed information regarding these changes, magnetic observatories are maintained at Cheltenham, Md.; Tucson, Ariz.; San Juan, P. R.; Sitka, Alaska; and Honolulu, Hawaii. Continuous photographic records secured at these five observatories show the fluctuations in direction and intensity of the magnetic field at these places. These records are utilized in refining and correcting the results of field observations; they are also subjected to statistical processing, and the more important features of the information secured are tabulated and published every 2 years.

CHANGES OF THE EARTH'S MAGNETISM

12. **Kinds of changes.**—The changes mentioned in the preceding section are made up of (1) a diurnal variation, repeating itself with more or less regularity every 24 hours; (2) minor fluctuations, which are in progress to a varying extent most of the time; (3) magnetic storms, which occur at irregular intervals, last for a few hours or perhaps for several days and produce wide fluctuations (sometimes a degree or more in declination) within a short time; (4) a progressive increase or decrease (secular change) extending over many years.

13. **Diurnal variation.**—There is usually a systematic departure of the declination from its daily mean value, which occurs day after day, the amount of departure depending upon the time of day, the season, the magnetic latitude, and other factors. This systematic, daily departure from the mean value for the day is called *diurnal variation.* During the night hours the declination usually differs little from the average for the whole day of 24 hours. However, about sunrise an easterly motion of the north end of the needle sets in, the extreme easterly position normally being reached about 8 to 9 a. m. This is followed by a change to westerly motion of the north end, the extreme westerly position being reached about 1 to 2 p. m. By 6 p. m. it is usually back again to approximately the average position. These conditions prevail throughout the United States, whether the declination be east or west.

14. While the diurnal variation may ordinarily be neglected in the class of work done with a compass, yet where greater accuracy is required it should be given consideration. The difference in declination between morning and afternoon frequently amounts to 10 minutes or more in any part of the continental United States. This would amount to about 15 feet in running a line 1 mile in length. The diurnal variation affects the intensity as well as the direction of the magnetic field, each element having its characteristic curves for various conditions. The amplitude of the diurnal variation is not predictable for any one day, although its mean amplitude for a month or more will usually conform fairly closely to previous experience, provided the days of unusual disturbance are rejected from the mean.

15. **Irregular disturbance and magnetic storms.**—It will be noted that the diurnal variation is a phenomenon of local time; that is, the cycle of changes is not simultaneous for different longitudes, but each phase of the cycle in turn traverses the globe from east to west, leading or lagging the sun by a constant time interval. The magnetic elements are, in addition, usually disturbed to some extent by irregular fluctuations, some of which affect wide regions of the earth's surface simultaneously. These changes, as well as the diurnal variation, are evidences of complex changes in the distribution of electric space-currents in the ionized regions of the earth's outer atmosphere.

16. There is a well-established statistical connection between solar phenomena and the irregular magnetic disturbances, which fluctuate considerably in intensity from day to day. Ordinarily they are (except in high latitudes) a minor feature of the record, but occasionally they become suddenly violent and prolonged, constituting a *magnetic storm.* A magnetic storm may last many hours (sometimes several days) and the more severe ones are known to extend from pole to pole over both the light and dark sides of the earth. It is obvious from this that they are entirely distinct from all other kinds of storms. They are, however, directly associated with the appearance of aurora and with other phenomena of the ionosphere. In this connection it is of interest to note that studies have revealed a remarkable recurrence phenomenon with a period of approximately 27 days, corresponding to the rotation of the sun. The sequence of quiet and disturbed days does not form a permanent cyclical pattern, since a new disturbance may occur at any time or an old one die out. However, the trend is for any marked disturbance to reappear in several successive months before it permanently disappears. This phenomenon has been useful to operators of communication systems in forecasting conditions for radio transmission from the activity recorded at magnetic observatories.

17. **Secular and annual change.**—At any particular site the average value of a magnetic element for one year may differ from that for the next. In general, the change progresses in one direction for many years and is known as the *secular change.* The amount of secular change in one year is known as the *annual change.*

18. The change from year to year is not uniform, nor does it go on indefinitely in one direction. At some stations, where declination results are available covering a period of 200 years or more, two turning points are indicated. In eastern Maine an easterly extreme was reached about 1760, and since that time the north end of the needle has been moving toward the west, with a total change of about 9°. In

Illinois the easterly extreme occurred about 1825, and the change since then has been only about 4°. On the Pacific coast, east declination was increasing from 1780 up to about 1915, with a total change of about 5° in southern California and 7° in Washington. Around 1920 the north end of the compass needle was shifting toward the west for all of the United States except a strip along the southern edge of the country. The area in which the compass needle is shifting toward the east has been gradually spreading over the United States since about 1930, until it covers all the Southern States and reaches the Great Lakes. If the present trend continues the westerly extreme will soon be reached in the New England States as well.

19. Tables have been issued by this Bureau showing the amount of the secular change of the declination (also of other elements) in all parts of the United States since the earliest reliable observations. Information regarding the use of such data is given in paragraphs 35 to 41. Despite earlier attempts to predict secular change on the basis of theoretical studies, it is now recognized that because of the many unknown factors involved there is as yet no basis for such predictions. Secular change can be determined *only* by direct observation.

ISOMAGNETIC CHARTS AND LOCAL IRREGULARITY

20. **Magnetic charts.**—The distribution of any one of the magnetic elements is usually depicted by means of an isomagnetic chart. Thus an *isogonic chart* is a map on which lines have been drawn and numbered to represent the distribution of magnetic declination in a certain manner, to wit: Each line connects a series of points at all of which the declination has nominally the same value. The obvious procedure would be to draw the line for each value so that all greater observed values fall on one side and all smaller ones on the other. If this method were strictly followed, and if the magnetic stations were spaced closely enough to develop fully all the irregularities, it would be found that the real isogonic lines at any particular moment form an intricate pattern of complex bends and closed loops comparable with the contour lines on a topographic map. Since it is not feasible to obtain such detailed information, it is customary to smooth out the lines somewhat and disregard anomalous values unless they are supported by several observations at different places in the locality. The smoothing makes such charts more convenient for their intended purpose of scaling estimated values at places where no observations have been made, and in reality improves the accuracy of such estimates. The use of the charts in this way is further discussed in paragraphs 26 and 27.

21. In addition to isogonic charts, there are other isomagnetic charts, namely: *Isoclinic* charts showing distribution of inclination (dip) and *isodynamic* charts showing distribution of total intensity or (more commonly) of one of its components such as the horizontal or vertical intensity. The various isomagnetic charts issued by this Bureau are described in paragraphs 60 to 64.

22. Requests for out-of-print isogonic charts are occasionally received in conjunction with inquiries which evidently pertain to secular changes. It should be understood that such charts, even if they were available, would be apt to give false results when used to

determine secular change. The difference obtained for a given place by a comparison of charts for different epochs is by no means due entirely to secular change. The reason for this is that magnetic charts vary from edition to edition in regard to the delineation of local features in the distribution of the magnetic elements. This is an inevitable result of increased understanding of the subject resulting from an ever greater store of observational data. The method of computing secular change used and recommended by this Bureau does not involve the use of isogonic charts but is based entirely on the tables prepared expressly for the purpose and published by this Bureau (see par. 19).

23. Even though the user is not primarily interested in secular change as such, the early isogonic charts are not suitable for obtaining the best estimate of former values of declination, because of the sparsity of the data on which they are based. It is nearly always better for such a purpose to use the latest chart and then apply to the results a correction for secular change, the correction being based on the tables referred to above rather than on any former charts. (See par. 27.)

24. **Local disturbance.**—In some regions the declination may vary many degrees within a comparatively short distance. Considerable differences have been noted in small areas or by slight differences in height of the compass above the surface of the ground. Such local disturbances are said to be *natural* if caused by the presence of magnetic material in the geological formation at the site. They are said to be *artificial* if caused by the works of man such as pipe lines, steel structures, etc.

25. Local disturbance is often called *local attraction*, but this is a misleading term insofar as it represents the disturbance as a force urging the compass needle toward an attractive mass. It should be emphasized that any such force is likely to be entirely insignificant (see also par. 56). Even the more plausible view that the needle is merely deflected in the direction of a magnetic mass is almost always an over-simplification, the disturbance being generally too complex to be described in terms of a center of attraction. The term *local irregularity* is perhaps more descriptive than is "local disturbance." Areas of excessive local disturbance are encountered in, for example, northern Delaware, parts of Arkansas, Minnesota, and Iowa, and in regions where basaltic lava formations are at or near the surface as in parts of Idaho, Oregon, California, and in the Hawaiian Islands. Extreme natural disturbances or anomalies (those of several degrees or more) are usually ascribable to the presence of an iron ore called magnetite. However, there are other ores and geological formations which may cause lesser irregularities. The presence of local disturbance may usually be detected quite readily by observing the compass bearing of a line at two or more points on that line. If the compass bearings of the line are the same at the different points the area is probably free of local disturbance. Even in regions considered free from local disturbance, minor irregularities are common because of the widespread distribution of slightly magnetic material in the soil and rocks. For this reason it is not possible to give an accurate value of the

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declination at a specific point unless it has been actually measured at that point.

26. Lacking actual observations, the best estimate may be obtained from a good isogonic chart, and a value so obtained may be regarded as a kind of normal or mean value for a fair-sized region around the point in question. The actual declination at any particular point is ordinarily more or less than the normal value, but in any region free from magnetite the "probable error" of a value scaled from a good isogonic chart is perhaps one-half degree or less; that is, there is perhaps an even chance that the chart value will be within one-half degree of the actual value. The value is intended as a mean for several days, eliminating diurnal and irregular variations.

27. A value scaled from a chart is, of course, strictly valid only for the year stated to be the epoch of the chart used, but it may be reduced to another date by applying a correction for secular change. Many isogonic charts contain an auxiliary set of lines of equal annual change (called *isopors*) which may be used for this purpose if the desired date is within a few years before or after the epoch of the chart. If the desired date is a number of years preceding the date of the chart, the reduction should be made by using the tables mentioned in paragraph 19.

USES OF THE COMPASS AND OF MAGNETIC STATIONS IN SURVEYING

28. **Referring surveys to the true meridian.**—Since the direction of the compass needle is continually changing and since different compasses may not agree to the required accuracy, it is desirable to provide means for referring the compass bearings to a true meridian in every compass survey. The true meridian is the observer's plane through the earth's axis of rotation. The best method of determining its actual direction (assuming that there is no triangulation station within convenient distance) is to determine the true bearing of one of the lines of a survey by observations on Polaris or the sun.[1] This is not feasible for every survey. For this reason it is important to maintain a true meridian line in the field of operations where the surveyor may determine, at any time, the apparent value of the magnetic declination with the compass which is being used for the particular survey. The value of the declination so obtained may be recorded with the survey made at the time. When, in later years, another surveyor wishes to retrace the lines of the survey, he may redetermine the magnetic declination at the same station on the same meridian line and the difference between the old and the new values of the declination is the correction to be applied to the compass bearings of the earlier survey, provided no local disturbance has been introduced. The importance of this procedure has been recognized in several States by the enactment of laws requiring the establishment of meridian lines and the testing of surveyors' compasses at regular intervals.

29. **Using magnetic stations.**—Descriptions of most of the magnetic stations occupied by the Coast and Geodetic Survey are obtainable on request. The description gives the location of the station,

[1] Simplified methods of determining the true meridian are given in Serial 592, "Magnetic Declination in the United States, 1935."

the way in which it is marked, and the azimuths or true bearings of several prominent objects. True bearing is counted from either north or south toward either east or west. True azimuth is counted from south around by west from 0° to 360°. For example:

Azimuth of 21°=Bearing of S. 21° W.
Azimuth of 160°=Bearing of N. 20° W.
Azimuth of 200°=Bearing of N. 20° E.
Azimuth of 300°=Bearing of S. 60° E.

The same relation is true for magnetic azimuth and magnetic bearing. The above convention for azimuth is used in all the land work of the Coast and Geodetic Survey; in work on the water, azimuth is counted from the north around by east.

30. True azimuths or true bearings as determined by observations on the sun with a small theodolite (4-inch horizontal circle) usually have a "probable error" of 1 minute or less; that is, there is at least an even chance that a stated value is within 1 minute of the correct value. The probable errors of latitude and longitude observed with such an instrument are approximately one-half minute and 1 minute, respectively.

31. In some cases a second stone is set to mark the true meridian. Otherwise the direction of the true meridian can usually be found by turning off the proper angle from one or more of the prominent objects whose azimuths are known.

32. With the cooperation of local surveyors and others it has been possible to secure comparatively recent information regarding the availability of many of the stations, and it is contemplated to replace those that are no longer suitable for use, as opportunity offers. *As the maintenance of these stations is of great importance to local surveyors as well as to this Bureau, persons in control of a station site are earnestly requested to protect the marker from disturbance so far as possible and to inform this office if conditions develop which may affect the usefulness of the station.*

33. It sometimes becomes necessary to authorize removal of station markers when construction work is undertaken. In such circumstances a report is usually requested of the person authorized to remove the stone, and if a bronze disk has been used he is asked to mail it to this office. When a person is requested to forward such a disk, he is furnished a franked mailing container for the purpose. Where inscriptions have been made in the stone itself, it is usually requested that they be obliterated. These precautions are taken to prevent the use of the marker in an unsuitable manner by unauthorized persons. The report should be rendered after the marker has actually been removed, and the removal of the marker should of course be deferred until such time as it is actually necessary.

34. **Compass correction.**—The angle between the observed direction of the needle of a given compass and the actual magnetic meridian prevailing during the observations is known as the *compass correction* or *index correction*. This correction for any compass may be determined by observing at one of the Coast and Geodetic Survey magnetic stations where the magnetic declination has been determined by an instrument of precision. It is advisable to make two or more tests on different days and at different hours (preferable early morning and late afternoon). If the surveyor wishes to test his compass

in this way, he should request both the description of the station and the value of the magnetic declination at the station. Such a value, like one scaled from an isogonic chart, is intended to represent a mean for a period of several days or a month; the value at any particular moment is usually greater or less than the mean as a result of diurnal variation and irregular fluctuations as mentioned in paragraphs 13 to 15. After the tests have been made, this Bureau will undertake to furnish on request the estimated value at the date and hour of each test. With these refinements, the compass correction may often be determined with an uncertainty not much greater than that of reading the position of the needle. However, appreciable errors sometimes arise from artificial disturbance introduced at the station without the knowledge of this Bureau. Such artificial disturbance may sometimes be sufficient to render the station wholly useless for testing a compass. When this Bureau gives a value for a magnetic station it is always understood that it is applicable only if no artificial disturbance has been introduced since the last observations were made. Also, there is some uncertainty in the secular-change reduction in case the value of declination used is based on old observations.

35. **Retracing old lines originally run by compass.**—The known angles at the corners of a tract may be inconsistent with the recorded bearings of the lines. It was once a rather common practice to make compass surveys without actually measuring the angles at the corners of the tract. That is, only one pointing of the compass would be made at each corner, this being a sight to the next corner. Under these circumstances, the various bearings will necessarily reflect any irregularities of declination which may characterize the site. Although the bearings may have been reduced to "true" bearings by applying a constant correction for the average declination prevailing at the time of the original survey, such reduction would not rectify the irregularities mentioned.

36. If a reduction for declination has been made, any error in the original estimate of the declination will be incorporated in all the recorded "true" bearings. A systematic error arising from this or other cause may make it impossible to pre-determine the relation between the recorded bearings of a tract and the present magnetic bearings of the same lines. However, in view of the irregularities mentioned above, it may still be advantageous to use a compass in the resurvey in order best to duplicate the differences of successive bearings. That is, the differences would be expected to correspond to those derived from the earlier survey despite the systematic error, if we assume that the magnetic bearings of any one survey are all affected alike by the secular change.

37. While an understanding of former practice is thus helpful in recovering old lines, the application of the more up-to-date procedures mentioned in paragraph 28 is an essential precaution against the future recurrence of difficulties of the same kind. The assumption that the various azimuths of a tract are similarly affected by secular change usually holds good, provided there has been no change in the distribution of local disturbance during the interval. Such alterations may occur in the vicinity of metal structures and where electric currents are present in the ground, as from nearby electric railways.

38. The reader is cautioned against the use of annual-change rates or mathematical formulas to compute secular changes for extended periods. At one time such formulas were published by this Bureau, but each such formula was intended to be used only for periods of time within the interval covered by the basic data. Even for such periods, the formulas are now superseded by information published in the form of tables (see par. 19) which is more accurate because of the application of graphic methods based on a better understanding of the nature of secular changes. It is now considered that the normal rates of secular change in different parts of a region at any given time exhibit a gradual and smooth gradation from place to place, quite different from the marked local irregularity characteristic of the magnetic elements themselves. (The latter irregularities do, of course, have some effect on the secular change of some of the elements, but not sufficient to obscure the fact of the smooth basic distribution.) In the tables of secular change, advantage has been taken of this fact by the substitution of spatial or geographic smoothness for the extreme chronological smoothness resulting from the use of the formulas. Furthermore, it has been amply demonstrated that those formulas do not apply to the secular change which has occurred since their publication in the last century, thus giving point to the warning which always accompanied such formulas, that they were not to be used for predictions of future changes. Unfortunately, the old formulas have in some instances been quoted by authors who failed to include the precautionary notes.

39. When a surveyor is called upon to redetermine the boundary lines of a tract of land originally surveyed by compass and can find in the vicinity a well-defined line, known to have been established with the same compass at about the same time as the lines of the tract in question, he can do no better than determine the amount of change in the compass bearing of that well-defined line and use it to obtain the present compass bearings of the boundary lines to be established. In this way the effects of possible index corrections in the two instruments and of the uncertainty in the secular-change data will be eliminated. Only in the absence of such definite information is the use of secular-change data, as furnished by the Coast and Geodetic Survey in correspondence or in the form of publications, recommended.

40. In using such data the surveyor should bear in mind the uncertainties incident to the use of the compass and should not be surprised if, for example, the change of declination since the early part of the nineteenth century, as given by the tables, differs by as much as 30 minutes from the value indicated by his own retracing of the old lines. Even at the present time some compasses are in error by as much as a quarter of a degree, owing to imperfections in construction, to lack of proper care, or to other causes. Without doubt, such conditions were much worse a century ago. Moreover, while the data are intended to give the actual change in the magnetic declination, eliminating as far as possible the errors of individual instruments, they are only approximate, and the earlier portions are less reliable on account of the inferior character and limited number of observations upon which they are based. In order to reduce "rounding-off" errors, the secular change is customarily stated to minutes of arc. It should be understood that it is not known that accurately in any case.

41. The rate at which the declination changes is not at all constant. When a net secular change is stated to apply to a specified period of years, it should be understood that this does not mean that the figure so given is to be used for interpolating or estimating the changes during fractional parts of the interval. Indeed, it is quite possible that the change during a part of the interval may have exceeded the stated net amount, since there may have been a reversal of the trend of secular change. It is obvious, then, that each separate interval of time requires a new computation from the table. For continued work in a single locality, it will be found convenient to compute a table for the latitude and longitude of the locality, so that the secular change may thereafter be found with but a single interpolation for time. Such a table may be prepared with the aid of Serial 592 as explained on pages 9 and 10 of that publication.

HOW MAGNETIC OBSERVATIONS ARE MADE

42. In the foregoing paragraphs, the usefulness of magnetic stations to local surveyors was mentioned, also methods of determining the true meridian and the declination without extensive instrumental equipment. The more precise methods used by observers of this Bureau will be described briefly; for more extended information on this topic the reader is referred to the publication "Directions for Magnetic Measurements," Serial 166. In most cases all three magnetic elements—declination, dip, and horizontal intensity—and also the approximate latitude and longitude are determined. The regular outfit comprises a theodolite, a magnetometer, and a dip circle or an earth inductor, together with tent, accurate timepiece, and accessories.

43. The declination, as explained in paragraph 51, is the angle between the true meridian and the magnetic meridian. The true meridian is determined by observations of the sun or stars with the theodolite, unless the observations are being made at or near a triangulation station at which the geodetic azimuths of objects visible from the ground have been determined. The magnetic meridian is determined with the magnetometer, which contains a suspended tubular magnet, the homologue of the pivoted needle of a compass. The magnet is closed at one end by a collimating lens and at the other by a plane glass on which there are a horizontal line and a central vertical line situated at the principal focus of the collimating lens. The magnet is suspended by a silk fiber or very fine phosphor-bronze or gold ribbon in a wooden box which shields it from currents of air and from rapid changes of temperature. A telescope is attached to the box in such a way that it may be pointed on a distant object or (through the magnet lens) on the vertical line of the magnet. The box is mounted on a base with graduated horizontal circle, so that the angle between a distant object and the magnetic meridian defined by the magnet can be measured. If the angle between the same distant object and the true meridian has been determined by astronomical observations, the magnetic declination is found directly by taking the difference between the two angles, and applying the index correction of the instrument.

44. The horizontal intensity also is measured by means of the magnetometer. Two operations are involved, called *oscillations* and *deflections*. First, the magnet is started swinging back and forth through a small arc and the time of one swing or oscillation is determined very accurately by noting the time of a large number of swings, 100 for example. This time depends on the product of the strength of the magnet and the earth's horizontal intensity. Second, the same magnet is placed on the deflection bar attached to the magnetometer at right angles to the reading telescope, and an auxiliary magnet is suspended in the magnet house. This auxiliary magnet will be deflected out of the magnetic meridian by an amount depending on the ratio of the strength of the deflecting magnet and the horizontal intensity of the earth's magnetic field and on the distance between the two magnets. These two quantities—the time of one oscillation and the deflection angle—combined with certain instrumental constants serve to determine both the horizontal intensity of the earth's field and the magnetic moment of the deflector.

45. The inclination may be determined with a dip circle, in which a magnetized needle is supported at its center on a transverse axle so that it is free to swing in a vertical plane. The ends of the axle form very carefully turned and polished pivots which rest on agate knife edges. Concentric with the axle of the needle is a graduated circle, by means of which the inclination of the needle to the horizon may be measured. The needle is enclosed in a wooden and glass case to shield it from air currents.

46. The dip is now more often measured by means of an earth inductor, which is practically a small generator operating in the earth's magnetic field. In this instrument a coil of wire may be rotated about an axis which is so mounted that it may be inclined at any angle to the horizon. The axis of the coil is placed in the plane of the magnetic meridian and its inclination changed until a position is found for which there is no deflection of the attached galvanometer when the coil is rotated. The axis of the coil is then parallel to the lines of force of the earth's magnetic field, and the dip may be read on the graduated vertical circle. In using this instrument the brushes are adjusted to the position which results in the maximum flow of current for slight changes in the slope of the axis. It will be noted that the operation of the instrument differs in this respect from that of the earth-inductor compass sometimes used in aircraft.

47. The usual precautions are taken to eliminate circle errors. In using any of the instruments which contain magnets, observations are repeated with the magnet in different positions, in order to eliminate errors arising from a lack of coincidence of the magnetic and geometric axes of the magnet. There is another source of error which must be constantly guarded against, namely, the effect on the magnetic field of magnetic material or electric currents. Except for the magnets, the instruments are free from iron or steel or other magnetized parts. All iron and steel objects, even such as are usually carried on the person of the observer, must be removed to a safe distance. An automobile passing 75 or 100 feet away may ruin a set of observations and the same thing is true of an electric railway car a quarter of a mile away.

INFORMATION OF GENERAL INTEREST

48. From the correspondence of this Bureau it is apparent that many persons have a lively interest in the compass and its behavior, aside from the engineering and technical applications of the subject. Although the questions usually received are covered by existing printed matter it seems advisable to embody some of this material in the present publication as well.

49. **The magnetic elements.**—The earth acts like a great spherical magnet in that it is surrounded by a magnetic field, and the measurement of the earth's magnetism at any place consists in determining the direction and intensity of that field.

50. A magnet suspended in such a way as to be free to turn about its center of gravity would take a position with its magnetic axis directed along the lines of force of the earth's magnetic field. It is practically impossible to suspend a magnet in that way, but we may determine the direction of the earth's magnetic field by means of two magnets, one constrained to turn about a vertical axis, giving the direction in the horizontal plane (compass needle) and the other constrained to turn about a horizontal axis, giving the direction in the vertical plane (dip needle).

51. The *magnetic meridian* at any place is the vertical plane fixed by the direction of the lines of force at that place. The angle it makes with the plane of the astronomic or true meridian is called the *magnetic declination*,[2] *D*, and is considered east or west according as the north end of the needle points east or west of true north.

52. The *dip* or *inclination*, *I*, is the angle which the lines of force make with the plane of the horizon.

53. It is possible to measure the *total intensity*, *F*, of the earth's magnetic field, but it is usually more convenient to measure its *horizontal component*, *H*. These three quantities, declination, dip, and horizontal intensity, are usually spoken of as the *magnetic elements*, and from them the total intensity and its component in any direction may be computed by simple formulas.

54. **Distribution.**—The earth's magnetism is different in different parts of the earth, and its distribution over the surface is so irregular that observations must be made at a great many places in order to get a satisfactory picture of the phenomenon. There are, however, certain elements of regularity. There are two points, defined as the *magnetic poles*, at which the dip needle stands vertical and the earth's magnetic field is directed vertically, so that the horizontal intensity is zero and the compass needle cannot be used to determine direction. The north magnetic pole is approximately in latitude 71° N. and longitude 96° W., and the south magnetic pole in latitude 73° S. and longitude 156° E.

55. Going away from the magnetic poles the dip decreases and the horizontal intensity increases until the *magnetic equator* is reached. There the dip is zero and the magnetic field is exactly horizontal. The magnetic equator is south of the geographic equator in South America and north of it in Africa and southern Asia. The total intensity at the magnetic poles is roughly twice as great as at the magnetic equator.

[2] Known to some as the *variation of the compass.*

56. **The compass and the magnetic poles.**—There is a widespread and entirely fallacious idea that the compass is controlled by an attractive force centering in one of the magnetic poles. This has even led to the mistaken notion that the direction of the compass needle would reverse in crossing the equatorial regions. Actually, the direction and intensity of the magnetic field at any given point are probably controlled (or at least greatly influenced) by the nearest portions of the earth's active magnetic interior. While the compass needle points in a northerly direction for most of the surface of the earth, as a rule it does not point exactly toward either the magnetic pole or the geographic pole. In the United States it points 22° west of true north in northeastern Maine and 24° east of true north in northwestern Washington. Along the ninety-sixth meridian, where the needle would point true north if it were directed toward the magnetic pole, it actually points 9° or 10° east of true north. The agonic line, or line of zero declination, is a very crooked one, crossing the country from the vicinity of Marquette, Mich., to Savannah, Ga. As a matter of experimental fact, the compass needle is not perceptibly drawn toward the magnetic pole, or any other special point on the earth's surface. The effect of the earth's field on a compass needle or other magnetized object is primarily that of a turning force on each of the innumerable tiny magnets composing the object, rather than an attraction. When the needle is allowed to respond to this turning force, it simply indicates how the earth's field is oriented at the observer's location.

57. It is true that, for instance, an airplane which made a flight so as to travel always in the direction in which the north-seeking end of the compass needle points would eventually reach the vicinity of the earth's north magnetic pole in northern Canada, though its course would deviate considerably from the great-circle path. This result does not conflict with the previous paragraphs but shows that the earth's magnetism has a measure of world-wide coordination and (in conjunction with other observed facts) indicates that the earth behaves somewhat like a spherical magnet, as mentioned above. Now, a spherical magnet does not have "poles" in the narrow technical sense (i. e., points at which there can be imagined to be centers of attraction in such a way as to explain observed facts). If such poles are postulated as a device for describing the magnetic field of a uniformly magnetized sphere, it is found that they would both have to be at practically the same point, namely, the center of the sphere. Expressed in another way, the external magnetic field of such a sphere is the same as that which would surround an inert sphere having a very small and powerful bar magnet at its center. The earth's magnetic poles, then, are not centers of attraction at all but simply the localities at which the field happens to be perpendicular to the earth's surface. It is quite likely that there would be much less popular interest in the location of the magnetic poles if it were thoroughly understood that their positions do not determine the direction taken by the compass.

58. In most of the southern hemisphere the same end of the compass needle points north as in most of the northern hemisphere. The compass is fairly reliable over most of the earth's surface, provided allowance is made for magnetic declination. The amount of the

declination cannot be determined through a knowledge of the location of the magnetic poles, but can be mapped only by making actual observations at widely distributed places over the region in question.

59. There is another widespread misconception associated with the false concept of an attractive center, namely, the idea that secular changes are to be ascribed to a sort of precession or migration of the magnetic poles. This is a very old notion, dating back almost as far as the first realization of the great magnitude of secular change. As recently as 50 years ago it was given some credence despite the obvious difficulties of reconciling the conflicting directions and rates of change derived from records at different parts of the world. It is now known, however, that the secular changes are too complex to be accounted for in this way. Furthermore they are in most regions too great to be reconciled on this basis with the known facts concerning the position of the magnetic north pole, which has shifted very little during the century since it was first located.

PUBLICATIONS ON TERRESTRIAL MAGNETISM

60. The results of the magnetic survey are available in various forms. Every 10 years a publication is issued giving the summarized results of the magnetic observations up to approximately the time of issue, together with folded magnetic charts showing the distribution of declination, dip, horizontal intensity, and vertical intensity. The latest publication in this series is Serial 602, "U. S. Magnetic Tables and Magnetic Charts, 1935."

61. Once in 5 years an isogonic chart is prepared, showing the lines of equal magnetic declination for the United States for that year. This is published together with tables showing the change of declination by steps of 5 or 10 years since the date of the earliest usable observations, the latest publication in this series being Serial 592, "Magnetic Declination in the United States, 1935." The isogonic chart in Serial 602 is identical with the one in Serial 592, and it also may be purchased separately, printed on heavy paper and unfolded (chart 3077).

62. Information on the magnetic declination is also printed on the aeronautical and nautical charts published by this Bureau. Each new edition of such a chart is carefully revised to embody the results of the latest studies or estimates of the declination and its secular change in the area covered by the chart.

63. A decennial publication similar to Serial 602 is also issued for Alaska, the latest in this series being Serial 570, "Alaska Magnetic Tables and Magnetic Charts, 1930."

64. In addition to the maps and publications covering the entire country, there have been prepared a number of publications which give for a State or group of States full information regarding the magnetic declination, with descriptions of stations, secular change tables, and an isogonic chart. (See also par. 29 regarding individually prepared descriptions.) The isogonic charts in these publications show all the magnetic stations in the respective States and the observed values of declination reduced to the epoch of the chart. These reduced values are quite useful for showing readily whether our observations reveal any local disturbance, and are useful for that purpose even when the chart is 10 or more years old, since the same anomalies would be shown

if all values on the chart were reduced to the present date. Publications for Arkansas, Florida, California and Nevada, Missouri, North Carolina, and Texas, and one covering the States of Delaware, Maryland, Virginia, West Virginia, Kentucky, and Tennessee have been issued, and similar information in mimeographed form is available for the States of South Carolina, Georgia, Alabama, Mississippi, and Louisiana. The small isogonic charts in these mimeographed bulletins do not show the values of declination at magnetic stations.

65. A list entitled "Publications on Terrestrial Magnetism" describes these and other publications on this topic and explains how to obtain them. This list (ordinarily distributed as a companion to the present publication) is obtainable on request from the Director, United States Coast and Geodetic Survey, Washington, D. C.

OTHER WORK OF THE COAST AND GEODETIC SURVEY

66. The United States Coast and Geodetic Survey was established to make the surveys which are necessary for the production of mariners' charts of the coastal waters, and this is still its chief function. The work has been broadened, however, to cover geodetic surveys of the interior of the country as a basis for more detailed surveys by other organizations. Its work includes triangulation and traverse, base measurements, leveling, astronomical observations, gravity measurements, and magnetic observations for the whole country, and hydrography, topography, and tidal and current observations for the areas covered by the nautical charts. The Survey also prepares and prints special aeronautical charts for air navigation, using other data and facilities available. It is also charged with the study of earthquakes.

67. The Survey feels that its work is not complete until the results are in the hands of those to whom they may be of use. A letter addressed to the Director stating the information desired will be accorded a prompt reply, either furnishing the information or explaining how it may be obtained, if it is available.

PUBLICATION NOTICES

To make immediately available the results of its various activities to those interested, the Coast and Geodetic Survey maintains mailing lists of persons and firms desiring to receive notice of the issuance of charts, Coast Pilots, maps, and other publications.

Should you desire to receive such notices, you may use the form given below, checking the lists covering the subjects in which you are interested.

CUT ON THIS LINE

(Date) ____________________

Director, U. S. Coast and Geodetic Survey,
Washington, D. C.

Dear Sir: I desire that my name be placed in the mailing lists indicated by check below, to receive notification of the issuance of publications referring to the subjects indicated:

- ☐ 109. Astronomical work.
- ☐ 109–A. Base lines.
- ☐ 109–B. Coast Pilots.
- ☐ 109–C. Currents.
- ☐ 109–D. Geodesy.
- ☐ 109–E. Gravity.
- ☐ 109–F. Hydrography.
- ☐ 109–G. Leveling.
- ☐ 109–H. Nautical charts.
- ☐ 109–I. Oceanography.
- ☐ 109–J. Traverse.
- ☐ 109–K. Seismology.
- ☐ 109–L. Terrestrial magnetism.
- ☐ 109–M. Tides.
- ☐ 109–N. Topography.
- ☐ 109–O. Triangulation.
- ☐ 109–P. Cartography.
- ☐ 109–R. Aeronautical charts.

(Name) ____

(Address) ____

A catalog of the publications issued by all bureaus of the Department of Commerce may be had upon application to the Chief, Division of Publications, Department of Commerce, Washington, D. C. It also contains a list of libraries located in various cities throughout the United States, designated by Congress as public depositories, where all publications printed by the Government for public distribution may be consulted.

No. 3

Letter from U.S. Coast and Geodetic Survey April 16, 1947 and information leaflet MM-40 & Serial 618 "Practical Uses of the Earths Magnetism"

Filed in Current Misc. Information

INFORMATION LEAFLET
MM-40
APRIL 1946

DEPARTMENT OF COMMERCE

U. S. COAST AND GEODETIC SURVEY

PUBLICATIONS ON GEOMAGNETISM

The Coast and Geodetic Survey has issued numerous publications containing the results of its work in geomagnetism and general information on the subject. This leaflet describes the more recent ones, including all those for which there is much demand. It does not include various older publications, which may be consulted in any depository library and some of which are still for sale. In most cases, however, they are of historical interest only, since the material of current interest is all incorporated in the publications described below.

	Serial No.	Special Publication No.	Price	Order from
GENERAL				
Magnetism of the Earth	663	---	$0.35	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Distribution Coefficients of Magnets	---	157	.10	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Directions for Magnetic Measurements	166	---	~~.65~~ 1.00	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Practical Uses of the Earth's Magnetism	618	---	Free	Director, U. S. Coast and Geodetic Survey, Washington 25, D. C.
UNITED STATES				
Magnetic Declination in the United States in 1935. OUT OF PRINT. SUCCESSOR IN PREPARATION (WILL BE SERIAL 664).	592	---	----	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
United States Magnetic Tables and Magnetic Charts for 1935	602	---	.60	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
ISOGONIC CHARTS				
Isogonic Chart for 1945, United States; Chart No. 3077	---	---	.40	Director, U. S. Coast and Geodetic Survey, Washington 25, D. C.
Charts for areas outside the United States (see other side)	---	---	.40	Director, U. S. Coast and Geodetic Survey, Washington 25, D. C.
STATES				
Magnetic Declination in Missouri in 1925. 45 pages	323	---	.10	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Magnetic Declination in Delaware, Maryland, Virginia, West Virginia, Kentucky, and Tennessee, 1925. 112 pages	457	---	.20	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Magnetic Declination in North Carolina in 1930. 51 pages	537	---	.20	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Magnetic Declination in Florida, 1935. 37 pages	564	---	.20	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Magnetic Declination in California and Nevada, 1935. 64 pages	581	---	.20	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Magnetic Declination in Arkansas in 1935. 40 pages	601	---	.15	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
NAUTICAL				
Instructions for Compensation of the Magnetic Compass (Marine Type)	---	96	.15	Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

OUT OF PRINT

MAGNETIC OBSERVATORY RESULTS (see reverse side).

FIELD RESULTS (see reverse side).

ORDERING PUBLICATIONS

TO AVOID DELAY, THE REQUIRED REMITTANCE SHOULD BE ENCLOSED WITH THE ORDER, AND THE ORDER SHOULD BE SENT TO THE APPROPRIATE OFFICIAL EXACTLY AS DESIGNATED IN THE RIGHT-HAND COLUMN OF THE ABOVE TABLE.

Remittance may be made by postal money order, express money order, or check. Currency may be sent at the sender's risk. Postage stamps, defaced or smooth coins, or foreign money order will not be accepted.

There are two series of numbers, Special Publications and Serials. In ordering, both name and number should be given.

Most publications of the Coast and Geodetic Survey (not including processed reports) may be consulted in various public libraries which have been designated as Government depositories. A list of these libraries is given in the List of Publications of the Department of Commerce, available on request from that Department.

DESCRIPTIONS OF PUBLICATIONS

GENERAL

Magnetism of the Earth.--Serial 663. 79 + iv pages, 2 plates. 7 x 10 inches. 1945. 35 cents. This is the latest of three illustrated publications of somewhat similar scope, the other two being "Principal Facts of the Earth's Magnetism" (1915) and "The Earth's Magnetism" (1925), both now out of print and supplanted by the new publication. It is larger than "The Earth's Magnetism" and has been almost completely rewritten, so as to consolidate the new and old material in carefully organized divisions of the subject. Its six chapters discuss, respectively, the following topics: Characteristics of magnets and magnetic fields; the earth's general magnetic field (magnetic poles and equator, local irregularities, magnetic charts, etc.) and the secular changes that affect its direction and intensity in various places; the transient variations appearing in the earth's magnetism (such as daily variation and magnetic storms); magnetic surveys on land and sea; instruments for studying the earth's magnetism; and the history of the subject from the earliest times to the last century. The treatment of transient variations, in particular, has been considerably expanded in comparison with that given in the 1925 publication, reflecting the large amount of study that has been devoted to this phase of the subject in recent years. The publication discusses various theoretical developments and touches upon the relations of the earth's magnetism and its changes with earth currents, cosmic rays, auroras, sunspots, and radio wave transmission. The language employed is largely nontechnical, with the object of assisting the reader to secure a broad general view of the subject. Footnotes in the text, together with a list of important general references, serve to guide the reader to more detailed information elsewhere.

D324

Distribution Coefficients of Magnets.--Special Publication 157. 30pp. 1930. 10 cents. This contains detailed discussions of the formulas for the interaction of two magnets at any distance or orientation, a magnet being considered as representable by two point-poles with finite separation.

Directions for Magnetic Measurements.--Serial 166. 129pp. 3d (1930) Ed.--Corrected 1930 47 65 cents. This is intended primarily for the guidance of observers of the Survey doing work in geomagnetism. The endeavor has been to present the subject in such form that an observer who is familiar with the use of precision instruments but inexperienced in magnetic work may be able to make satisfactory determinations of the magnetic declination, dip, and intensity. In order that the observer may have a better understanding of what he is doing and why he is doing it, the principles involved have been explained in some detail. (The corrections made in 1932 consisted essentially of revision for typographical errors.)

Practical Uses of the Earth's Magnetism.--Serial 618. 19pp. 1939. Free. (To be ordered from the Director, U. S. Coast and Geodetic Survey.) This supersedes Serial 272 and Special Publication 213, discussions therein having been revised in the light of the latest concepts, and several topics more fully developed. It discusses in nontechnical fashion the necessity for magnetic observations and the instruments used, the general characteristics of the earth's magnetic field, the uncertainties of compass surveys, the uses of magnetic stations, the magnetic survey of the United States, and other aspects of geomagnetism having general interest. For fuller information on these and related topics, with references, consult the publication "Magnetism of the Earth" (described on p.1).

UNITED STATES

Magnetic Declination in the United States, 1935.--Serial 592. 46pp. 1 chart. (See next paragraph). 1937. This is intended primarily for the use of those making compass surveys. It contains for points at intervals of 2 degrees of latitude and longitude a table showing the change in the magnetic declination (variation of the compass) with lapse of time from as early a date as the available observations will warrant, down to 1935, together with an estimate of the annual rate of change since 1935. The distribution of the magnetic declination in the United States and its annual rate of change for the beginning of 1935 are shown graphically on a map of the country, by means of lines of equal magnetic declination and of equal annual change. Directions are given for determining the true meridian and the magnetic declination by methods suited to a limited instrumental equipment.

OUT OF PRINT

SUCCESSOR IN PREPARATION

The publications of this series are normally issued at five-year intervals but the one for 1940 was omitted because of war activities. The one for 1945 is scheduled to appear sometime in 1946; its number will be Serial 664.

United States Magnetic Tables and Magnetic Charts for 1935.--Serial 602. 160pp. 4 charts. 1938. 60 cents. This contains the observed values of the magnetic declination, dip, and horizontal intensity for all places in the United States at which reliable observations have been made, together with corresponding reduced values for January 1, 1935; tables giving the results of observations at repeat stations occupied between January 1929 and September 1937; tables giving the change of the magnetic elements with time; and magnetic charts showing graphically by means of isomagnetic lines the general distribution of the declination (see next paragraph), dip, horizontal intensity, and vertical intensity in the United States at the beginning of 1935. Each chart also shows the annual rate of change in 1935 by means of lines of equal annual change. The publications of this series are issued at ten-year intervals; the one for 1945 is scheduled to appear during 1947. Its number will be Serial 667.

It is to be noted that the chart showing declination in 1935 has been superseded by Chart No. 3077 for 1945 (see following item).

Information for Alaska for the epoch 1940, similar in form to Serial 602, is given in a processed report. It is available for free distribution, limited to those who show a definite need for the information.

ISOGONIC CHARTS

Isogonic Chart for 1945, United States.--Chart 3077. Scale 1 to 5,000,000. Overall size about 32 x 45 inches. 40 cents. For sale by the Director, U. S. Coast and Geodetic Survey, not by the Superintendent of Documents.

Lines of Equal Magnetic Declination and of Equal Annual Change in Alaska for 1940.--Chart 3069b. Scale 1:5,000,000. Overall size about 28 x 41 inches. 40 cents. For sale by the Director, U. S. Coast and Geodetic Survey, not by the Superintendent of Documents.

Lines of equal magnetic declination and of equal annual change for some parts of the world, besides United States and Alaska, were prepared during the war and are still available. The charts of this series are shown in information leaflet MM-41; the leaflet will be furnished on request. Each chart in this series sells for 40 cents and should be ordered from the Director, U. S. Coast and Geodetic Survey, not from the Superintendent of Documents.

STATES

All the publications listed under this heading are quite similar in their scope. The introductory part contains general information on the magnetic declination and the use of the publication. It is followed by: Secular change tables; tables giving the value of the declination at each magnetic station, reduced to the specified date; descriptions of the magnetic stations; and an isogonic chart. These charts show more information than does the U. S. chart, since observed values are given, from which the effect of local disturbance may be estimated.

Similar information in mimeographed form for the States of South Carolina, Georgia, and Alabama is available for free distribution to those who are willing to cooperate by reporting the condition of magnetic stations, or in other ways. (Requests for these mimeographed pamphlets should be made to the Director, U. S. Coast and Geodetic Survey, not to the Superintendent of Documents.)

NAUTICAL

Instructions for the Compensation of the Magnetic Compass.--Special Publication 96. 49pp. Prepared in 1923. Reprinted in 1938 by lithography with changes in certain tables. 15 cents. This publication is intended for the use of the mariner and explains the methods of determining the deviations of the ship's compass and their compensation by means of auxiliary magnets, iron spheres and the Flinders bar. It also gives methods for testing the performance of the compass and its auxiliary equipment.

MAGNETIC OBSERVATORY RESULTS

Since 1902 this Bureau has operated 5 magnetic observatories, at which the time-variations of the earth's magnetic field are determined by means of continuously operating photographic apparatus. At present, the observatories are located at Cheltenham, Md.; Honolulu, T. H.; San Juan, P. R.; Sitka, Alaska; and Tucson, Ariz. The results for recent years have been issued in processed biennial reports. The tabulations and mean values contained in these reports are useful primarily to institutions investigating the nature of the earth's magnetism, the relation of geomagnetism to radio transmission, etc. Investigators desiring to consult any of the reports should write to the Director, U. S. Coast and Geodetic Survey, stating their needs in enough detail so that they can be assisted in the most effective way.

FIELD RESULTS

Annual publications giving the results of field observations of magnetic declination, dip, and horizontal intensity, and descriptions of the stations occupied (including latitudes and longitudes and true bearings of prominent objects) have been printed for the years 1903 to 1930, inclusive. Because of the very limited demand for these publications, no more of them have been issued. Information in regard to any of these publications that are still available for distribution and in regard to results of observations that have not been issued in collected form may be had from the Director of the U. S. Coast and Geodetic Survey.

Note: If you desire to be notified whenever the Coast and Geodetic Survey issues a new publication on the subject of geomagnetism, please request the Director, U. S. Coast and Geodetic Survey, Washington 25, D. C. to add your name to mailing list No. 109-L.

List prepared April 1946.

current misc. File #3

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D324

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
WASHINGTON 25

IN REPLY ADDRESS THE DIRECTOR
U. S. COAST AND GEODETIC SURVEY
AND NOT THE SIGNER OF THIS LETTER
AND REFER TO NO. 49-el

32

16 April 1947

Mr. Bascom Giles
Commissioner, General Land Office
Austin, Texas

Dear Sir:

In reply to your letter of April 7, 1947, no successor to "Magnetic Declination in Texas in 1927" has been issued. However, more recent data are contained in Serial 602, "United States Magnetic Tables and Magnetic Charts for 1935," and Chart 3077, "Isogonic Chart for 1945, United States," which are described in the enclosed Information Leaflet MM-40.

Very truly yours

[signature]

Acting Director

Enclosures:
MM-40
Ser. 618

CC: Fort Worth office

RECEIVED
APR 19 1947
REFERRED TO MAP

73721

No. 3

Letter from U.S. Coast and Geodetic Survey April 16, 1947 and information leaflet MM-40 & Serial 618 "Practical Uses of the Earths Magnetism".

73722

Filed in Current Misc. Information

Current Misc. File 3