MAGNETIC POLES AND THE COMPASS

Although the magnetic compass has been widely used for centuries, its action is commonly misunderstood. Many of the misconceptions about the compass concern the nature of magnetic poles. These misconceptions are held by many authors of scientific books and technical manuals, and by many of those who write articles on science for the benefit of the general public. Under these circumstances, it is natural that these misconceptions are also held by practically all laymen. This is shown by the ambiguities in the inquiries addressed to the Coast and Geodetic Survey; for example, in the occasional requests for data on the magnetic pole in a context which shows that the writer actually wants something quite different.

**First misconception: That the compass points toward the magnetic pole.**—Most people assume that a compass points directly toward the magnetic pole, presumably under the influence of the pole. This is wholly incorrect. Some writers have even published drawings showing in detail how the compass points due north at points having the same longitude as the magnetic pole; how it points west of north for points in the United States that lie east of the longitude of the magnetic pole; etc.

Another form of this idea is shown in the oft-published statement that a compass does not point due north “because the geographic and magnetic poles are not at the same point.” This would surely give the reader the erroneous impression that the compass does point toward the magnetic pole.

If a compass really pointed toward the magnetic pole, it would be a simple job to find the magnetic declination at any point. We would need to measure the declination at just two points; by trigonometry, we could compute the location of the magnetic pole; and the declination at any other point could be computed. Actually, many nations maintain organizations which make frequent observations of the earth’s magnetism throughout their areas. These observations show that for most places the compass lacks a great deal of pointing toward the magnetic pole.

Figure 1 shows an isogonic chart of the United States, based on actual observations. For example, the compass points 15° to the east of north at any point on the line marked “15° E.”

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1 Magnetic declination is the angle between magnetic north (direction shown by a perfect compass) and true north. It is also called variation of the compass, or simply variation.
2 For the United States, magnetic observations are made by the Coast and Geodetic Survey.
3 The earth’s magnetic field is actually quite irregular; differences of 5 minutes of arc at nearby points are the rule, and differences of 1° within a mile or two are not rare. This map shows, however, the general trend of the declination, with the local disturbance smoothed out.
Next look at figure 2. It shows what an isogonic chart of the United States would look like if the compass pointed toward the magnetic pole. This is quite different from figure 1. For example, in figure 2, the hypothetical value is 0° along the 100th meridian; the actual declination shown in figures 1 ranges from 10° to 13° along that meridian.

*In computing fig. 2, the latitude of the north magnetic pole was taken as 73° N, and its longitude as 100° W. See "Third Misconception."
Figure 2.—What an isogonic chart of the United States would be like if the compass pointed toward the magnetic pole. Compare with figure 1.

Figure 3.—These lines show how much the compass points to the east or west of the north magnetic pole. They represent the difference between figures 1 and 2.

Figure 3 shows the difference between the quantities depicted in figures 1 and 2. For example, at Chicago, figure 1 shows a declination of 1° E; figure 2 shows that if the compass pointed toward the magnetic pole, the declination would be 7° W; figure 3 shows that the difference is 8°. It can be seen in figure 3 that for about half of the United States the compass fails to point toward the magnetic pole by more than 10°.

Some people will claim that the compass points toward the magnetic pole except for the effects of local disturbance and regional disturbance. To uphold such a viewpoint is merely to set up an artificial

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5 The local irregularity of the actual magnetic field has been smoothed out in fig. 3 even more than in fig. 1. This is a permissible practice, since fig. 3 is used only to illustrate a general idea.
criterion of disturbance, as will be clear if we reflect that the pattern of "disturbance" would be quite different if referred to the South magnetic pole instead of the North. Worse, this contention could only aggravate the confusion about the behavior of the compass with respect to the magnetic pole. The compass is in fact controlled neither by the magnetic pole nor by any other special point on the earth, but rather by the total effect of all parts of the earth.

A common attitude is illustrated in the remark of a writer of scientific articles for the popular press, when his attention was called to errors he had published about the magnetic pole. He inquired, "If the compass doesn't point toward the magnetic pole, what does it point toward?" The answer is: "Why assume that it points toward anything in particular?"

This matter is illustrated by figure 4. From each of the points marked by open circles, lines are drawn showing the direction of magnetic north. If the compass pointed toward any particular spot, these lines would converge on that spot. It will be seen that they do not meet at the magnetic pole, or at any other point.

**Figure 4.**—A compass placed at one of the open circles will take the direction shown by the adjoining solid line. All these lines would pass through the magnetic pole, if the compass pointed toward it. Map is on gnomonic projection; great circles on the earth are straight lines on the map, but shapes are somewhat distorted.

**Second misconception: That secular change of the earth's magnetism is caused by motion of the magnetic pole.**—This proposition seemed reasonable enough in the days when not many observations had been made, and especially when it was thought that the compass pointed toward the magnetic pole. This fallacy is to be found in otherwise reliable textbooks.

Once it is understood that the compass does not point toward the magnetic pole, the hypothesis that secular change is the result of motion of the magnetic pole becomes untenable. However, it could still be supposed that secular change arises from rotation of the magnetic field as a whole; or from rotation of a magnetized core while the surface remains fixed. Both of these hypotheses have been compared with observations; the actual secular change is quite different.

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6 The earth's magnetic field undergoes continual change. The secular change is the long-continued gradual change, the chief cause of the difference between successive annual means.
from the change which would occur if either of these hypotheses were correct.

If the secular change could be described so simply as by the rotation of the field as a whole, it would be necessary to measure the change at only a few places in order to compute it everywhere. Actually, secular change is a “regional phenomenon.” Secular change in Missouri is closely related to secular change in Iowa, but it bears no relation to the change in Madagascar; and the secular change in Alaska is not related to either one. To keep track of the secular change, every good magnetic survey must include regular observations at quite a number of “repeat stations.”

Third misconception: That the magnetic pole is a definite, determinable point.—A magnetic pole is defined as a point at which the earth’s magnetic field is vertical. At such a point, a dip needle will stand straight up and down. A compass cannot be used there to find direction—it will remain in any direction in which it happens to be placed.

Actually, in the general area of the point whose position is given in footnote 4, there are many magnetic poles. We know that this must be so, because the field everywhere shows local magnetic irregularities. Since the compass does not point toward any of these poles, save by accident, they would be very hard to find even if they were stationary. The direction and strength of the magnetic field are ever changing, and the magnetic poles are always moving about.

Finding the magnetic poles is further complicated by the limitations of instruments.

In practice, then, there is a rather large area within which the direction of a compass cannot be determined, and within which for practical purposes a dip needle will stand vertical. This may be called the “magnetic polar area.” The boundaries of this area could be found approximately (although it is not exactly defined), and then the center could be called the magnetic pole. We know that the North Magnetic Polar Area is not a circle—it is decidedly elongated in the direction NNW–SSE.

Locating a magnetic polar area is obviously a job requiring an extensive survey on all sides. (It is much harder than finding the geographic pole, which requires merely finding a point at which the altitude of the sun remains unchanged for 24 hours.) Although this job cannot be considered to be finished, the Canadian Government has recently made quite a number of observations for this purpose. The position given in footnote 4 is their latest estimate.

Fourth misconception: That the secular change of the magnetic field can be predicted.—This is closely related to the second misconception, but its importance warrants giving it a separate heading. If the secular change were caused by rotation of a magnetized core at a regular rate, it would be possible to predict it. Numerous mathematical formulas have been published to give the secular change at specified points; some of these were given only as a convenience in interpolating, but some were seriously proposed as methods of predicting the changes for years hence.

Actually, the future course of the secular change is quite unknown. When the Coast and Geodetic Survey is asked to estimate the declination 5 years hence, the best guess is to use the present value corrected
by the present rate of change. Were it not for the program of repeat observations, such estimates would get farther and farther from the truth. However, if the date for which the prediction is to be made is not too far in the future, the predicted value is adequate for nautical and aeronautical purposes.

The Coast and Geodetic Survey plans to make repeat observations throughout the United States every 5 years, and in Alaska every 10 years. In addition, we use the continuous photographic record of 6 "magnetic observatories," and the repeat stations and observatories of foreign countries.

To illustrate the uncertainty of prediction, consider figure 5, which shows the annual mean values of the declination at the Cheltenham Magnetic Observatory (latitude 38°44' N., longitude 76°50' W.). Before 1933, the rate was about 4' per year; since 1933, it has been nearly zero. If the rate prevailing before 1932 had been used in that year to predict the change from 1932 to 1948, the prediction would have been nearly 1° in error.

Figure 5.—Annual mean values of the magnetic declination at Cheltenham Magnetic Observatory. Note sudden change in rate in 1933.

In the vicinity of Lake Superior, the change in the rate was even greater. There, the actual total secular change since 1930 differs by 1° 20' from the change that one would compute by using for the entire period 1930–49 the rate shown on the 1930 isogonic chart.

An even more striking example is found in the records of the observatory at Tananarive, Madagascar. In 1911, the rate of change was about +11' per year; in 1938, it was about −11' per year.

SUMMARY

The earth acts like a great magnet. The source of its magnetism is not concentrated in any few places—rather, the source is distributed throughout a large volume within the earth. (Whether the basic cause is permanent magnetism, electric currents, or the manifestation

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1 Serial 718, "Magnetic Surveys," and Serial 618, "Practical Uses of the Earth’s Magnetism," are larger pamphlets giving general information about the earth's magnetism. They may be had by addressing a request to the Director, Coast and Geodetic Survey, Washington 25, D. C. Serial 663, "Magnetism of the Earth," is still larger, and is for sale for 35 cents by the Superintendent of Documents, Washington 25, D. C.
of some unknown physical law is a moot question. Many theories have been proposed, but none of them are generally considered to be adequate to describe the observed facts.)

The distribution of magnetism in the earth can be mathematically divided into two parts; one is homogeneous and regular, and the other is irregular and apparently capricious. The field which we observe, due to the combined action of all parts of the magnetic interior, is markedly irregular, although it has certain regular features. Hence, the surface field can be determined only by actual observation.

The magnetic poles are of only minor significance. They do not in any way pertain to the action of a compass in, say, the United States. A magnetic pole is merely a point at which the field is vertical. A compass is useless in its vicinity, and at somewhat greater distances the compass will be erratic.

For unknown reasons, portions of the magnetic interior undergo changes that produce changes in the magnetic field which we observe at the surface. In the course of decades, these changes may amount to a substantial fraction of the initial field. These changes follow no known law; they can be determined only by actual observation.

Although these changes usually persist in the same direction and at roughly the same rate for a number of years, there is never any assurance that they will continue to do so. Rather sudden changes in the rate occur from time to time, each affecting the rate over a considerable part of the earth's surface. Hence, observations to determine the rate of the secular change must be continued indefinitely.
The Coast and Geodetic Survey maintains mailing lists of persons and firms who wish to receive notice of the issue of new charts, maps, and publications. If you wish to receive such notices, fill out this form (indicating by check marks the subjects in which you are interested), and mail to

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