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Abstract

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GEOPHYSICS

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EXPERIMENTAL VERIFICATION OF A HYPOTHESIS ON THE NATURE OF MAGNETIC DECLINATION

Nine years ago we put forward a hypothesis ([1]) concerning the nature of magnetic declination. At that time the first experimental work in our country was begun to test this hypothesis ([2]). We assume that superimposed on the main magnetic field of the Earth—with a moment directed along the planet’ s axis of rotation—is a distorting magnetic field caused by the presence of electric currents in the ocean, discovered as early as 1935 ([3]); another part of this distorting field is apparently produced by currents in the ionosphere, directed along the contours of the continents.

The first investigations compelled us to assign to marine currents a rather modest role ([4]) in this respect. However, in 1956 Soviet investigators ([5]) found that the density of currents in the ocean (the Indian Ocean) increases with depth, and in 1957 we ourselves recorded on board a ship ([6]) a similar increase in current density with increasing depth in the Atlantic Ocean, between Africa and South America. In this connection the question arose anew of the very significant role that telluric currents of the oceans should play in the creation of magnetic declination. Judgment about their role became objective and reliable after L. A. Korneva proposed a new cartographic characteristic of the distorting magnetic field ([7]): she constructed maps of the latitudinal component of the intensity of the Earth’ s magnetic field.

Of special interest is the region of the Atlantic Ocean lying in the equatorial and tropical belts: here an isoline $Y = 10\,000$ gammas (i.e., 0.1 oersted) is drawn, of approximately elliptical form, whose minor axis intersects the magnetic equator. Inside this isoline the magnetic declination reaches 22.4°, and the latitudinal component of the intensity is 0.11 oersted.

It was precisely in this region of the Atlantic Ocean that an experimental verification of our hypothesis was carried out. For the experiments a region was chosen near the point with coordinates 1° S latitude and 25° W longitude, distinguished by the following valuable features: a) the constant South Equatorial Current is very stable here, b) meridional components of deep currents are unquestionably absent, c) the ocean depth does not exceed 3600 m, d) the wind is moderate and steady in its direction. A simple and reliable photorecording

Fig. 1

Figure 1: Fig. 1

instrument was constructed, making it possible, every 10 sec., to obtain on narrow positive motion-picture film clear photographs of a portion of the card of a 127-millimeter ship' s compass, with a course indicator, and of the dial of a small "Moscow" watch with hour, minute, and second hands. An enlarged positive image of one of the photographs is reproduced in Fig. 1. It was especially important to achieve parallelism between the diametral plane of the ship and the "diametral plane" of the recording instrument, placed inside a bronze container with a hermetically closing lid. For this purpose a reliable rudder with two ···

feathers (see Fig. 2). The three pointed pins of nonmagnetic stainless steel visible in the figure served, first, for the precise setting of the planes of the rudder relative to the course indicator of the compass and, second, to protect the protruding parts of the mechanism when the container was being closed with a heavy lid under shipboard conditions.

Fig. 1

The container, weighing 300 kg, was suspended from a cable on a swivel and, when being towed, responded well to the rudder. During the first series of experiments the angle of inclination of the cable to the vertical was 45°, and on the next day, during the second series, 66°. From the folding platform over the side of the ship it was easy to ensure that the plane in which the cable lay above the water was parallel to the diametral plane of the ship.

During the experiments the ship' s course was continuously recorded on a course recorder, the readings of which were systematically checked by separate readings from the gyrocompass repeater. Comparison of the true course of the ship with the readings (through a loupe) on the film strip removed from the container made it possible to determine the magnetic declination at the depth at which the instrument was being towed. In addition, for additional checking, during the experiments readings of the compass course were taken from the ship' s main magnetic compass and corrections for deviation in the equatorial region were introduced. Thus the value of the magnetic declination at the ocean surface in the region of the experiments, determined from a navigational chart by interpolation between declination isolines, was confirmed.

By these independent methods it was established that the magnetic declination at a depth of about 2000 m is at least 5° less than the magnetic declination at the ocean surface.

In view of the smallness of the towing depth in comparison with the height of the ionosphere, it must be assumed that the declination here changes only at the expense of the field of telluric currents in the ocean, manifested in two ways.

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

Namely, on the basis of work (6), let us adopt a scheme of increase of the current density i—linear, such as is shown in Fig. 3. Considering this scheme, we shall see that the latitudinal component of the intensity of the Earth' s magnetic field Y_1 at the depth z of the container towing changed, first, because under the container lies not the whole area of triangle ABC, responsible for creating the mag—

Fig. 2

of magnetic declination on the surface of the ocean, but only the area of the trapezoid $KLCB$; secondly, because above the container there appeared the area of the triangle ALK, which was absent under the conditions of the ocean surface. Both causes contribute to a decrease in the latitudinal component of the intensity of the Earth' s magnetic field at the depth z of towing of the container (in absolute value). For simplicity, in Fig. 3 it is assumed that i increases from the value 0.

Let the latitudinal component here be composed of two quantities: the quantity y, produced by currents in the ocean and therefore varying with depth in accordance with the scheme of their distribution over depth (Fig. 3), and a certain quantity Y, which, according to our present ideas, is produced by currents in the ionosphere (also connected with the distribution of oceans and continents on the Earth). In view of the smallness of the towing depth in comparison with the height of the ionosphere, Y may be considered constant from the ocean surface to this depth (and, possibly, to the ocean floor).

Fig. 3

Denote by ζ the ratio of the towing depth z to the ocean depth H, $\zeta = z/H$. Then, on the basis of the considerations set out, from the scheme of Fig. 3 one can obtain the simple relation:

$$Y_1 = Y + y = Y + y_0(1 - 2\zeta^2), \tag{1}$$

in which y_0 denotes the value of y at the ocean surface for $\zeta = 0$. The full value of the latitudinal component at the ocean surface according to (1) will be:

$$Y_0 = Y + y_0, \tag{2}$$

and consequently the difference between Y_0 and Y_1 is expressed as follows:

$$Y_0 - Y_1 = 2y_0\zeta^2. \tag{3}$$

But the same difference can be expressed otherwise: through the functions of the angles of magnetic declination at the ocean surface (D_0) and at the towing depth of the container (D), namely:

$$Y_0 - Y_1 = \frac{Y_0}{\sin D_0}(\sin D_0 - \sin D). \tag{4}$$

Equating the right-hand sides of (3) and (4) and carrying out the simplest transformations, we then obtain the relation between y_0 and Y_0:

$$\frac{y_0}{Y_0} = \frac{1}{2\zeta^2}\left(1 - \frac{\sin D}{\sin D_0}\right). \tag{5}$$

Substituting here the numerical values found from our experiments in the ocean, we obtain $y_0/Y_0 \approx 1/3$.

Thus, the telluric currents in the ocean here produce approximately one third of the latitudinal component of the intensity of the Earth' s magnetic field. In connection with this, at present it must be assumed that the missing two thirds are due to ionospheric currents, also connected with the distribution of oceans and continents on the Earth.

The conclusions following from the experimental work carried out show that our main theoretical considerations ([1,6]) have been confirmed and that our next task is to refine the methodology for recording magnetic declination at ocean depths. At the same time, it is necessary to organize investigations concerning the role of ionospheric currents in creating the latitudinal component of the Earth' s magnetic field.

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Note: Figure translations are in progress. See original paper for figures.