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Abstract

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A NEW TEST OF THE HYPOTHESIS ON THE NATURE OF MAGNETIC DECLINATION

At the end of 1959 one of the authors of this article carried out an experimental test (1) of the hypothesis concerning the role of telluric currents passing through ocean water in creating the latitudinal component of the intensity of the geomagnetic field, in other words, in the origin of magnetic declination (2). The expedition vessel *Sedov*, at low speed, towed a container with instruments, lowered to a depth of about 2000 m and provided with a reliable steering device. In the container, cast of bronze, there were a magnetic compass and an apparatus for photographic recording of its readings, as well as of the positions of the hands on the dial of a small clock. Comparison with the record of the ship’ s course on the course recorder and with accurate readings of the ship’ s gyrocompass showed that, at the depth to which the container was submerged, the magnetic declination was reduced by no less than 5°. On the basis of the Biot-Savart law, applied to the field of currents in ocean water, it could be concluded that these currents produce no less than 1/3 of the existing latitudinal component of the intensity of the geomagnetic field. The method of towing on a parallel course does not make it possible to sound the magnetic field at greater depths, owing to the enormous drift of the instrument and of the cable, on which a large hydrodynamic pressure acts. Meanwhile, it is precisely at great depths that it is especially important to determine the decrease in magnetic declination, which is insignificant in the layer down to 1000 m and, according to our hypothesis, must manifest itself sharply upon further immersion of the instruments.

Lowering the instruments to great depths is easily done while stopped, especially if the vessel is not being drifted by wind and current. But under such conditions a judgment about the orientation of the container relative to the meridian can be obtained only by placing in it an additional instrument indicating the direction of the geographic meridian.

In the new assembly that we used this time, a small-sized gyrocompass (3) was employed for this purpose. It was placed in a separate container 1, shown schematically in Fig. 1, at a sufficient distance from the magnetic compass installed in the smaller container 2. Before being brought into the meridian, the gyrocompass was powered from the ship’ s network, and after that it was switched to autonomous power from storage battery 3. Current from it entered converter 4, equipped with a frequency stabilizer and amplifier 5. Three-phase alternating current of high frequency went to the stator of gyrocompass 6, sus-

Fig. 1

Figure 1: Fig. 1

pended on gimbal rings 7. From the same converter were powered the stators of the selsyns: the transmitter located at the gyrocompass and receiver 8, connected by a common shaft with repeater 9, in the upper, small container 2. The three-phase wiring between the selsyn rotors passed through the same channel 10 connecting the cavities of both containers. The recording device used in work (^{1}) was reconstructed by its author. Now the field of lens 11 included: a segment of the card of magnetic compass 12, suspended on gimbal rings 13, small clock 14, and a portion of the cylindrical surface of profile repeater 9. By means of a system

polished nonmagnetic stainless-steel mirrors, the image of all three objects could be placed within the frame on narrow motion-picture film. It was rewound from reel to reel inside cassette 15. A gear mounted on the axis of the take-up reel was rotated by the reducer of a small synchronous motor 16. The same reducer drove a simple mechanism that closed the contact in the circuit of the “Molniya” flash lamp (17—the gas-discharge tube of this lamp, 18—the case with the capacitor and oscillatory circuit). Figure 2 reproduces an enlarged positive image of one of the photographs obtained in the laboratory, with an arbitrary position of the magnetic-compass card and arbitrary repeater digits.

Fig. 1

It is easy to show that the change in magnetic declination ΔD can be obtained from experiments in the ocean even without determining the deviation of the magnetic compass on the ship’ s deck and without matching repeater 9 with the ship’ s gyrocompass. Suppose that at some initial depth z_0, at which the effect of the ship’ s iron hull is already no longer perceptible, the photographic recording gave the reading M_0 of the magnetic compass and the reading G_0 of repeater 9. Then the magnetic declination at this depth may be represented as a trinomial:

$$D_0 = M_0 - G_0 + N,$$

in which the term N is unknown. Lowering the unit to a greater depth z_1, we obtain new readings of the instruments, M_1 and G_1, on the basis of which the magnetic declination at the new depth is represented analogously:

$$D_1 = M_1 - G_1 + N,$$

where the value of the unknown term N is the same as before. But in that case the sought change ΔD of the magnetic declination at depth z_1 as compared with depth z_0 will be

$$\Delta D = (M_1 - G_1) - (M_0 - G_0). \tag{1}$$

The experiments were carried out in the equatorial belt of the Atlantic Ocean, where the latitudinal component of the geomagnetic field is especially large (10,000–11,000 gamma). The unit was lowered from a boom below the water surface and was transmitted to a cable of equal resistance, running from a large winch, through the sheave of a short crambol, on board the expedition vessel *Mikhail Lomonosov*. Unfortunately, the operations of lowering and raising the unit affected the gyrocompass and caused oscillations of the gyroscope about the vertical axis. Therefore, after the first series of experiments we allowed a period sufficient for such oscillations to die out. In Fig. 3a the process of damping of the oscillations is clearly visible on the serrated curve, which represents the law of change of the quantity $(M_t - G_t)$ with time, where M_t and G_t denote, respectively, the readings of the magnetic compass and the gyrocompass repeater read from the frames of the film. The time intervals between every two points on the serrated curve are about 1/2 min. Between the teeth an averaging curve 1 has been drawn, which fits satisfactorily among the points.

Experiments by the second author of this article, carried out in the laboratory on the vessel *Mikhail Lomonosov*, showed, by recording the oscillations of the gy-

of the gyroscope on the course recorder that the damping factor of these oscillations near the equator is always equal to 3.0. The oscillations die out under the influence of a force moment directed vertically. Under natural conditions, when the instrument moves downward or upward, this moment changes in magnitude as a result of the deviation of the vertical axis of the instrument under the action of the Coriolis force: the corresponding component of this force reaches a maximum at the equator. But at the existing rates of descent and ascent (of the order of 1 m/sec), the change in the moment of force acting about the vertical axis could not exceed 0.2%. Therefore, in the experiments in the ocean, the damping factor should still have been equal to 3.0. Meanwhile, if the shape of curve 1 in Fig. 3a depended only on the damping of the gyrocompass oscillations, then a formal analysis ([3]) would have given a value of 7.1 for the damping factor. This is because in our experiments the "zero point" from which the quantities $(M_t - G_t)$ are measured was "displaced." In turn, the "zero displacements" were caused by a decrease in magnetic declination at depth. By the method of successive approximations we succeeded in separating the two effects. Curve 2 is plotted from the equation of damped oscillations with a factor of 3.0. Its ordinates are subtracted from the ordinates of the averaging curve 1. As a result, curve 3 was obtained, which describes the "zero displacement." From the time count on the film frames, by comparison with the records of the length of paid-out cable according to the counter, the depths at which the instrument was located at one or another moment of time were determined. These depths are marked in Fig. 3a within the range from 500 to 4200 m, where the instrument remained for a sufficiently long time.

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

Fig. 2

Fig. 3

In full agreement with work (1), curve 3 runs almost parallel to the abscissa axis down to a depth of about 500 m: the magnetic declination here practically does not change. The declination changes only slightly down to a depth of about 900 m, after which

changes sharply: curve 3 bends steeply downward. At a depth of 4200 m the magnetic declination is approximately 24° less than at a depth of 500 m or at the ocean surface. At the point where this series of recordings was made, at latitude 10°01′ S and longitude 20°36′ W, the declination at the ocean surface is 23.5° W. Consequently, at a depth of 4200 m it had practically fallen to zero.

Of considerable interest were the conditions under which the experiments were carried out at the point with coordinates: latitude 00°24′ N, longitude 29°51′ W. Here a fairly strong drift of the vessel was observed under the action of an existing current, ideally constant in speed and direction. The containers with instruments, lowered to a depth of 3500 m, were in fact towed by the vessel, as in the 1959 variant. Although the new model had no rudder, its function was performed by the frame on which the containers were mounted. As a result, during holding of the instruments at depth, the recording gave only small irregular oscillations of the quantity $(M_t - G_t)$ about a clearly expressed mean value, as is seen in Fig. 3b. The larger oscillations visible in the same figure during the stage of lowering the instruments and raising them were undoubtedly smaller than they would have been had there not been a stoppage of the repeater system that arose for an unexplained reason.

As before, the marks of depths according to the winch counter are entered below. As before, at depths down to 1000 m the magnetic declination decreases little, and afterward the decrease proceeds rapidly. The left—descending—and right—ascending—slopes of the curve in Fig. 3b agree satisfactorily with each other. In the presence of the mentioned scatter of points, only the lower level of the curve is reliably determined, where the arithmetic mean value of $(M_t - G_t)$, indicated by a dashed line, fits well with the most frequently repeated chains of points. The upper level can be determined only roughly, by averaging the values of this quantity at the last stage of Fig. 3b, where a dashed straight line is also drawn. We used the latter, and not the first, stage in view of the fact that after holding at a depth of 3500 m the mechanical system should have behaved more calmly.

As is seen in Fig. 3b, the magnetic declination at a depth of 3500 m changed by approximately 36° in comparison with its value at the ocean surface. On the basis of the map compiled by the Institute of Terrestrial Magnetism (4), the declination at the ocean surface at the point where the experiments were carried out was now 22° W. Hence it follows that at a depth of 3500 m it is about 14° E.

Our new apparatus has made it possible once again to confirm the hypothesis that the magnetic field of telluric currents in the ocean participates in creating the latitudinal component of the geomagnetic field strength, and hence also the magnetic declination. On the basis of the materials presented, it must be supposed that about half of the latitudinal component is produced by the field of telluric currents in the ocean. Both this value and the form of the curves in Fig. 3 speak in favor of the assumptions expressed in work (2). Unfortunately, in its present form our apparatus does not allow one to find the exact magnitude of the magnetic declination at different depths because of the unavoidable crudeness of the data obtained. There are grounds to count on improvement of the described method in the near future.

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Research vessel
"*Mikhail Lomonosov*"

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CITED LITERATURE

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