"The Earth's Magnetic Field and the World Ocean

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THE EARTH'S MAGNETIC FIELD AND THE WORLD OCEAN

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The high development of present-day technics of magnetic and electrical measurements is in direct contradiction to the level of existing theories of the Earth's magnetic and electrical field.

In particular, we completely do not understand: the deviation of the Earth's magnetic axis from its axis of rotation and the continuous variation of the elements of the geomagnetic field before our eyes. On the one hand, the non-coincidence of the axes is no way consistent with natural tendencies to treat the magnetic field as a consequence of the planet's rotation. On the other hand, no geological processes at all in the Earth's bowls can proceed with the speed with which the elements of the geomagnetic field vary.

In a glance at the picture of the elements of this field it is clear evident that there exists some connection between them and the outlines of the coast line which separates the continents from the World ocean. In this case it is impossible to see chance coincidence. But it is impossible here to agree also with the usual treatment of the problem: the depths of the ocean are so small in comparison with the Earth's radius that it is impossible to connect the outline of the continents with the outlines of some tremendous inhomogeneous medium of ferromagnetic masses in the planet's bowls. It is perfectly obvious how strong the desire would be to establish such connections.

In the present article we shall attempt to approach the problems touched upon from an entirely different point of view, without pretending to construct a quantitative theory, but only noting a way to such a construction. We shall try to find possible causes of: a) the deviation of the Earth's magnetic axis from the axis of rotation; b) the extremely rapid (on a historical scale) variation of the elements of the geomagnetic field; and c) the striking agreement between the outline of the shoreline of continents and the outlines of isolines on maps showing the elements of the magnetic field.

The first encounter with these attempts resulted in the discovery of electrical currents in the sea, which discovery was made in 1935 by A. T. Mironov (1). Unfortunately, inspite of the long period of time that has elapsed since that time, the density of these currents has been measured only at three points of the World ocean and only at the very surface layer of the waters. There it turned out to be of the order of 1 ampere per hectare of surface formed perpendicular to the direction of the vector of electrical-field strength in the sea water. The density of these currents increases sharply at the time of magnetic storms, in connection with those causes by which the latter are created. The variations of the amplitude of oscillations and, apparently, of the averaged "background" occur in agreement with the variations of Solar activity. Mironov's marine currents are undoubtedly related to terrestrial currents (telluric currents), which were observed long ago in the Earth's solid crust, but of an entirely different order of strength because of the high electrical conductivity of sea water.

It is essential to represent such a scheme: thanks to one or another cause the Earth's basic magnetic field is created, the axis of which coincides exactly with the planet's axis of rotation; the electrical currents in the waters of the World ocean create a supplementary magnetic field which is superimposed

upon the basic field; by this, first, the magnetic axis is displaced relative to the axis of rotation and, secondly, there arise isolines of the magnetic elements such as are organically connected with the outlines of the shoreline of continents, and, thirdly, conditions are created for the continuous variations of the elements of the geomagnetic field.

The measurements made by L. A. Korneva (2) on models indicated that such a scheme gives a better qualitative agreement with the true picture of the Earth's magnetic field according to the first two of three enumerated criteria. The third criterion (variations in time) of current was inaccessible to investigation in view of the absence of measurements of marine currents over the necessary period of time in various regions of the ocean.

It is still impossible to speak now of quantitative comparisons, in as much as we do not know the distribution of density of the electrical currents in the deep waters of the ocean. However, on the basis of measurements carried out on Korneva's model, it is possible to doubt the sufficiency of the density of the deep currents for obtaining the necessary additional magnetic field: apparently the order of this current density is too small. Probably the electrical currents in the sea create only a certain part of the supplementary magnetic field. Therefore the necessity arises of finding the exciters of the missing (very large) part of this supplementary field; moreover exciters which are connected so closely with the distribution of the ocean and of the continents on the planet.

The search for such exciters is facilitated thanks to the appearance of certain native [Russian] works in entirely different field of geophysics.

Namely, on the one hand, we (3) had observed that the thermal discrepancies between ocean and continents extend far into the stratosphere. Throughout the year the stratosphere over the ocean turns out to be colder than over the

continents (at the same latitudes). Thus there are created cyclonic motions of the air in the stratosphere around the continents. The tremendous speeds of these currents possess their greatest component directed parallel to the coast line; that is, directed namely just as in Korneva's model.

On the other hand, a large group of Soviet physicists in recent years have carried out remarkable studies on cosmic rays (survey report (4)) which clarify in a perfectly new way the problem concerning positive and negative charges in the stratosphere.

Now, it is still impossible to give the number of results of comparison of these two directions in the works: there is still no reliable data concerning air flows above 20 km above sealevel and concerning the distribution of electrical charges in corresponding layers of the atmosphere. Already, however, we can now show how closely connected are all these phenomena with the Earth's magnetic field. Namely:

1. There is every reason to assume that the primary cosmic-ray particles (i.e. protons) practically do not play a role below 4 to 5 km above sealevel and that their significance increases continuously from 6 to 20 km and higher. (Note: It is perfectly certain that in these high layers there must exist, together with the protons, also positive charges of a different origin: helium ions (or, according to a less probable assumption of other investigators, calcium ions), ejected from the sun, which cause the aurora polaris (northern lights) in the high latitudes and the illumination of the night sky in middle and lower latitudes all the way down to the equator). On the basis of the brilliant works of S. N. Vernov and others (5), we can judge the quantity of protons stopped during flight in various layers of the stratosphere. Designating by Z the height of an elementary layer dz and by N the number of protons causing the shower in the course of 1 minute, we can, on the basis of the curve $N = f(z)$ given by the cited authors, find the quantity proportional to the quantity of

protons stopped at the suitable corresponding height: namely the quantity $\partial N/\partial z$. It is important to note that this quantity must be proportional to the quantity of secondary, tertiary, etc positive and negative particles originating during collisions with the atoms of the gases in the stratosphere.

2. It is perfectly obvious that the electrical conductivity of the air and turbulent agitation of the masses lead to equalization of the density of the "proton gas" in the atmosphere. For qualitative considerations, however, we can consider the steady-state density of the "proton gas" also proportional to the values $\partial N/\partial z$ at the corresponding height z.

3. Undoubtedly the "proton gas" is absorbed by the atmospheric currents both in the zonal circulation around the earth and in that system, interesting us now, which is generated by the thermal discrepancies between ocean and continents. On the basis of our investigations (3) we can determine the values of the pressure gradients in this latter system. Knowing the values of gamma Γ (circulation) of the atmosphere's pressure gradient in the "ocean-continent" fields, we can determine the component velocity of the flows along the coast line. Obviously this velocity will be proportional to the quantity Γ/δ where delta δ designates the density of the air at height z.

4. The convective electrical current at height z possesses the density i, proportional to the density of the "proton gas" at this height and to the velocity of the corresponding air flow. In other words, the density of the convective electrical current at height z must be represented by the formula

$$i = k\frac{\Gamma}{\delta}\cdot\frac{\partial N}{\partial z} \qquad (1)$$

the coefficient k of proportionality at present cannot be determined even with an accuracy up to an order, according to considerations which we will discuss below. We can, however, even now judge the variation of i with height z by computing the product standing in the right hand side of equation (1), after the coefficient k of proportionality.

Figure 1 shows the curve computed by us in accordance with the cited sources, which represents this distribution $i = i(z)$. As we see, the density of the convective current i increases continuously in the limits from 6 to 20 km above sealevel and must increase at higher layers.

5. The direction of the convective current in the investigated layers coincides with that obtained by L. A. Korneva on models (2). Consequently, the presence of these currents qualitatively clarifies the cause of the convergence or agreement of the outlines of the Earth's magnetic field with the outlines of the continents' coast line; it clarifies also the deviation or deflection of the magnetic axis.

6. The quantitative side of the phenomena is very complex. On the basis of Korneva's experiments, by projecting all the elements investigated on to the ocean's surface, we can conclude that each linear centimeter is intersected by a current of the order of $1/10$ ampere, which creates the supplementary magnetic field of the earth. Knowing the order of velocities of the atmospheric flows at the heights, we can compute the order of the quantity of positive charges in a column with a base of 1 cm^2; namely, the charges which are transmitted by the [air] flows and which thus create the convective current in the stratosphere. Calculations lead to a number around $2 \cdot 10^{-5}$ coulomb/cm^2. On the average at the heights this amounts to 1 proton approximately per 10^{11} molecules of air.

If the convective current creating the Earth's supplementary magnetic field were due exclusively to these primary cosmic-ray particles, then the charge of the column resting on 1 cm^2 would create in the lower layers of the atmosphere an electrical field with a strength of the order of 10^8 volts/cm, which in actuality does not exist and cannot exist.

7. Hence it follows that the real origin of convective electrical currents in the stratosphere are considerably complicated. This is told in Figure 14 shown in the work of S. N. Vernov et alii (5).

Actually, then, during collision of primary protons with air molecules there occur secondary and particles of higher order: protons, mesons, electrons, and also photons. The quantity of occurring positive charges compares with the quantity of occurring negative charges. Consequently, the impetuous origin of particles of high order leads to a very sharp increase in the total number of particles in comparison with the number of primary protons and at the same time is reflected in noway at all in the strength of the earth's total electrical field. Moreover, the behavior of positive and negative particles generated by collisions is far from identical: the negative particles appear as secondary cosmic rays, but the positive particles are mainly absorbed simply by atmospheric flows, as a certain admixture or impurity into the stratosphere's gases, and take part in the general circulation of the air at corresponding heights. Namely, in this way the convective electrical currents of the necessary density can be created without causing an absurdly large electrical field intensity in the atmosphere.

8. In conclusion it should be noted that similar convective electrical currents must exist around the earth thanks to the presence of the atmosphere's zonal circulation. These currents create a magnetic field with an axis directed exactly along the earth's axis of rotation. It is still too early to decide

what is their role in the formation of the planet's entire basic magnetic field: even now it is still completely impossible to pick out the complex picture of the potential of the geomagnetic field, taking into account both the requirements dictated by the internal field and the complications which are introduced thanks to the presence of the Earth's magnetic body in the field of electrical currents. Obviously it would be very remarkable to reduce the origin of not only the supplementary field but also the basic field of the Earth to general related causes in each case. In the present state, however, the expounded hypothesis inevitably will lead yet to some improvements of the mentioned positions, while colliding with unavoidable contradictions (as all works on the theory of the Earth's magnetic and electrical field do).

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Literature Cited

(1) A. T. Mironov. Zhurnal Geofiziki, Volume 6, No. 5 (1936)

(2) L. A. Korneva. Ibidem (Doklady Akademii Nauk SSSR), Volume 76, No. 1 (1951).

(3) V. V. Shuleykin. Ibidem (Doklady), Volume 71, No. 6 (1950)

(4) D. V. Skobel'tysn. Vestnik Akademii Nauk SSSR, No. 4, 31 (1950)

(5) S. N. Vernov, N. L. Grigorov, and A. N. Charakhch'yan. Izvestiye Akademii Nauk SSSR, Seriya Fizicheskaya, Volume 14, No. 1, 51 (1950)

[Figure 1 follows]

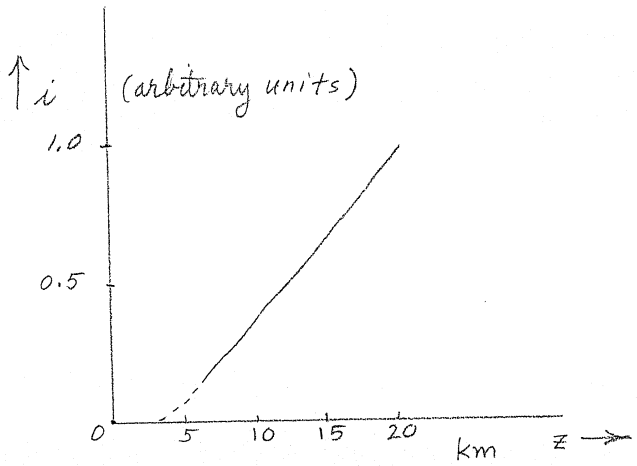

Figure 1

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