A New Theory of Geomagnetism Involving Electrostatic and Electrokinetic Phenomena

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Abstract—The origin of geomagnetism is unknown: the latest theory made by geologists tries to explain geomagnetism by MHD phenomena: unfortunately simulations –which represent geomagnetism- are made with non realistic values. Moreover, MHD assumptions work with the existence somewhere of a remaining magnetic field in the core of the Earth, even during the reverse periods. So, they fail to explain the geomagnetism reversal. Concerning certitudes, it seems that the relative movement of the liquid core is the main cause about the geomagnetism origin: this liquid core contains essentially iron, nickel, sulfur, and oxygen. But how does this system work? The very centre of the Earth is made of hard iron too hot to be ferromagnetic, but the liquid part of the core is in friction with the solid mantle at very high pressure and this movement evolves along time. Therefore, it appears that there must be a phenomenon of electrification due to the dynamic interface mantle-liquid core: this mysterious area (called D") is several kilometres thick, and contains liquid and solid composites clusters in movements. So, referring to that effect, this paper's aim is to give a new theory explaining the origin of geomagnetism by involving both electrostatic and electrokinetic phenomena.

We present, here, the basic aspects from geophysical data, and a general electrical theory to take account of the principal magnetic moment M of the Earth, the thermal and powerful aspects, the evolutions and the reversals of geomagnetism. Then we give an experimental evidence of flow electrification by charging on interface-glass-liquid metal and the numeric available results which can justify our theory. To finish, we discuss about the plausability of this new theory.

Keywords—Geomagnetism theory, flow electrification, electrostatic and electrokinetic phenomena

I. INTRODUCTION

So far we have not got any confirmed theory of geomagnetism: most specialists think that the phenomenon « would come from convective movements of the liquid core which would be a good electric conductor revolving in a magnetic field » [1]. At present no simulation based on MHD (magnetohydrodynamics) referring to plausible physic parameters seems satisfying. Experiments made with sodium revolving at high speed in copper gave positive results which seemed encouraging, but the experimental conditions have been questioned [2]. The long standing evocation (and in nearly most publications) of a geodynamo is surprising for electrotechnicians. As a matter of fact, the current given by a dynamo leads to a decrease of the genitor magnetic field (Lenz's law). Moreover in the case of the Earth, the active revolving conductor submitted to the perpendicular magnetic field can give a radial current in the direction of its electromotive force and therefore unable to create an axial current likely to engender the principal geomagnetism. So, we thought interesting to analyze the phenomenom differently and try to interpret the principal magnetic field by a theory based on the coupling of electrostatic and electrokinetic phenomena. First we have built the theoretic aspects then found the suitable numerical values and checked experimentally the likelihood of our assumptions and to finish we will discuss the results and their consequence.

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II. PROMLEMATICS

Today, geologists seem to agree with the following composition of our spherical planet:

-the mantle (silicate olivine) a bad electric conductor, goes from the surface (with a radius of 6470 km) to the Core Mantle Boundary (CMB with a radius r_0 = 3480 km). There the temperature goes up to 2250 ^{o}C. The origin of the inner thermal sources of our planet is essentially nuclear (40 Tw are produced in the mantle as power).

-the core contains principally liquid iron (85 %), Ni (7.5 %), Sulfur and Oxygen and goes from this interface to a radius of about r_1 = 1221 km where it becomes solid (the grain). The temperature there goes from 4000 to 5000 ^{o}C .The conductibility of the liquid would be about 10^6 S/m.

-the D" layer between the core and the mantle: it is a few tens of kilometers thick. There the temperature evolves very quickly from 2250 to about 4000 ^{o}C: certainly it is a very heterogeneous matter: there exists solid clusters of pallasites and siderites (iron and olivine) in this liquid magma. Geologists think that the liquid core is submitted to important convection movements (2 Tw are needed as power): apparently they have the shape of gigantic vortexes revolving on an axis almost parallel to that of the Earth with a maximum velocity of about some mm/s relative to the mantle [3].

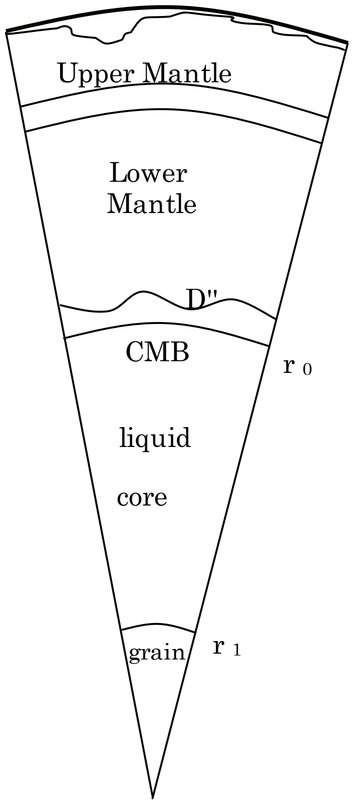

Fig. 1. Cross section of the Earth.

Geophysicians try vainly to simulate geomagnetism by MHD assumptions: they think the calculations need enormous computers to be built in the future [4].

Recent experiments made with sodium revolving in copper [2] showing random reversals of the magnetic field are discussed with the experimental conditions.

But does geomagnetism really come from the MHD phenomenon, or is there another phenomenon capable of producing it?

We think important to consider that the friction of a conducting liquid on a poor conducting solid (multiplications of contacts between two different materials) can also generate an electrostatic source. The latter can create an electric field which, in its turn, by influence or directly in contact with a good conductor, engenders a strong current sufficient to give geomagnetism.

III. Theory

Let's analyze the different phenomena appearing in the D" layer at the level of CMB.

We have particular conditions (high pressure of 130 GPa, high temperature of 4000 °C), interfaces silicate solid-iron liquid, many clusters of composites. This situation creates electrical effects: electrostatic, triboelectricity, pyroelecticity, and piezoelectricity. All these effects contribute to charge composite systems as capacities. These capacities can be discharged very quickly by a short circuit with the conducting liquid giving a strong current. Moreover the important movements of convection in this zone are able to maintain continuously these charges and these currents of discharges. The origin of the convection is thermal, so a part of this energy will be transformed in electric current and Joule losses. The direction of this current is linked to the direction of the convection: the current is therefore axial, but the way of the resulting current is random. So an important change of the convection even locally can reverse the total current and geomagnetism

This aspect can explain clearly the reversals of geomagnetism.

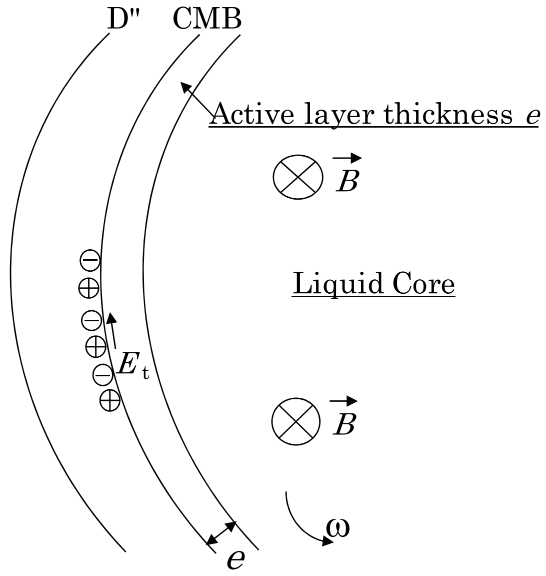

Fig. 2. Model.

A. Calculations

We use a very simple model to evaluate the order of magnitude concerning the different electric values.

Following this model (Fig. 2), we consider in D''-CMB area the tangential component Et of the electric field inside the conductor (the other components have a null contribution to the principal geomagnetism which is axial); the positive and negative charges represent capacities charged by triboelectricity, friction, piezoelectricity, pyroelectricity…To simplify e is the thickness of the active zone of E_t ($e << r_0$, radius of CMB sphere).

The conductibility of liquid iron σ is 10^6 S/m, and the magnetic momentum of the Earth is $M = 8 \times 10^{22}$ Am².

Taking account that the convection is function of the latitude we write:

$E_t = E_0\cos\theta$, being the latitude, E_0 is the mean value of all the concerned systems: it can be in a way or in the opposite one (reversal of geomagnetism).

Elementary current is $dI = J\, dS$, with $J = E_0\cos\theta$, elementary of surface is: $dS = r_0 e\, d\theta$, then the elementary magnetic momentum:

$$dM = dI\, \pi r^2, \text{ with } r = r_0\cos\theta$$

$$dM = E_0 d\theta\, e(r_0\cos\theta)^3,$$

By integrating from $-\pi/2$ to $\pi/2$, we found:

$$M = 4\pi\sigma E_0 r_0^3 e/3 \quad (1)$$

And the total current is:

$$I = 2\sigma E_0 r_0 e$$

The Electric power lost in one cube meter:

$$p = \sigma E^2$$

with the elementary volume

$$dv = 2r_0\cos\theta\, r_0 e\, d\theta$$

the elementary power:

$$dP = E_0\cos^3\theta\, 2\pi r_0^2 e\, d\theta$$

We obtain the power by integrating

$$P = 8\pi(E_0 r_0)^2 e/3 \quad (2)$$

Using that p is about 10^{-8} watt/m^3 [1] we found in comparing the 2 equations (1) et (2):

$E_0 = 10^{-7}$, $e = 4500$ m, et $P = 4.6 \times 10^9$ watt and $I = 3.1 \times 10^9$ A

These values seem realistic $e << r_0$ and $P < 2$ TW needed to the convection (which is the generator of this electric current).

To confort this general theory and to justify the order of the found values, we have made some experiments with the flow electrification mercury-glass

IV. Experiment

A. Introduction to mercury electrification

It is known for a long time that mercury rubbed on glass is electrified. Indeed, this phenomenon was first observed in barometer and called "Barometric light". Indeed it was first observed in 1675 by the French astronomer Jean Picard [5]. While he was transporting his barometer from the Observatory to Port Saint Michel during the night, he noticed a light in a part of the tube where the mercury was moving. This experiment was then repeated by several researchers with more or less success, to be finally explained by François Dufay [6] and Jean Antoine Nollet [7].

B. Experiments

Mercury is a metal, liquid at room temperature which electrical conductivity is around $1. \times 10^6$ S/m, its density is 13.58, its dynamic viscosity is rather low 0.1147×10^{-6} (while the dynamic viscosity of water is around $1. \times 10^{-6}$, and its contact angle on glass is 140° (while the water on glass contact angle is 0°).

Mercury behavior on glass is rather special as the cohesion between mercury molecule are greater than the cohesion between its molecule and molecule of glass for instance (this behavior is responsible of the mercury contact angle on glass. Thus if mercury is inside a burette, even if the tap is closed the mercury can fall down through the very small diameter of the orifice. As well in a tube the mercury meniscus is convex while it is concave for water, more the capillary forces are opposite. Indeed, the mercury level in capillary tubes immersed in a vessel level filled with mercury is lower for a thinner

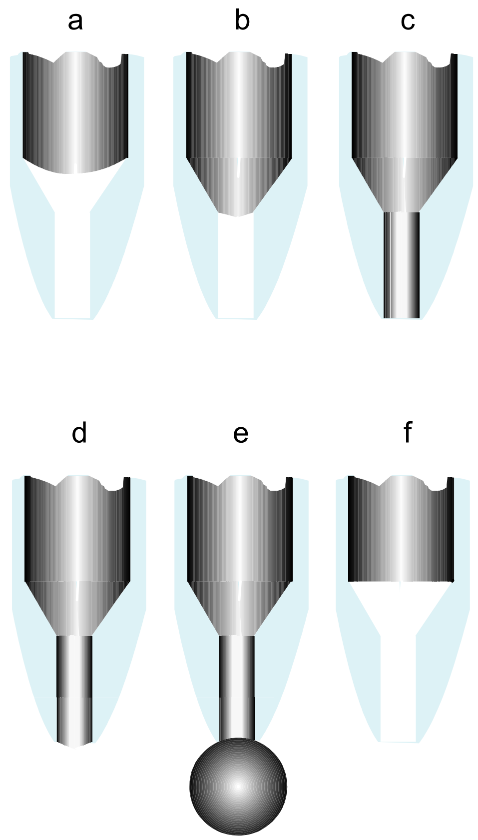

Fig. 3. Sketch of a droplet formation at the orifice of a burette.

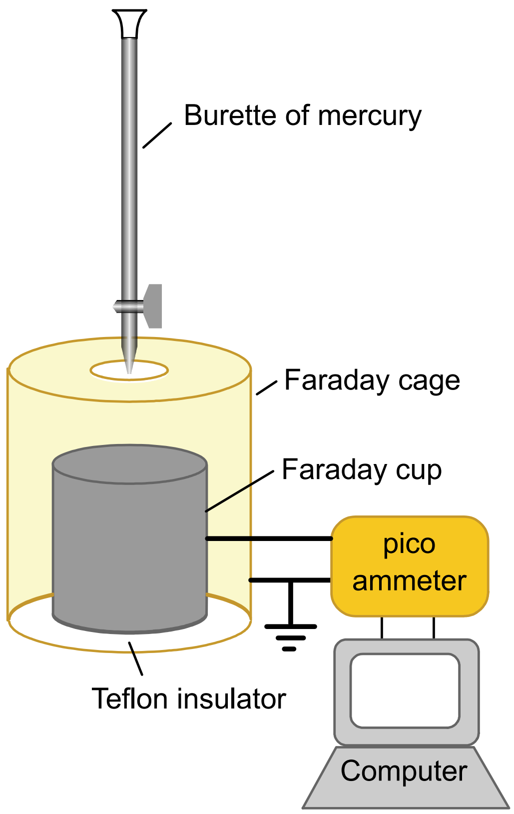

Fig. 4. Experimental setup.

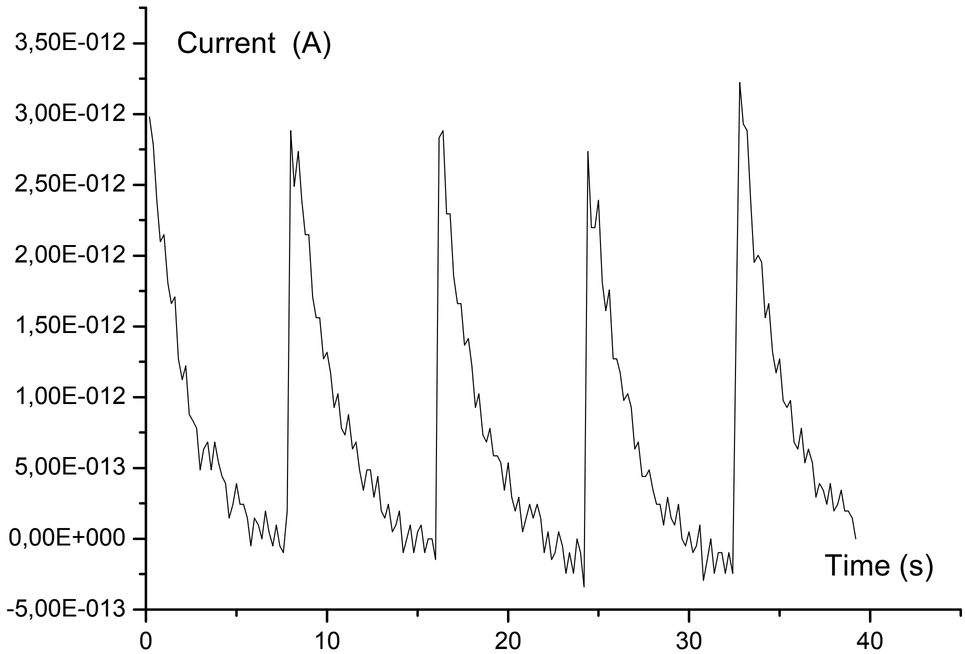

Fig. 5. Experimental results.

tube than for a thicker one and always lower that the level in the vessel, while in the case of water the level in the capillary tubes is always higher than in the vessel and higher for thinner tubes than for thicker ones.

We can see in Fig. 3 the different steps of the mercury droplets formation at the extremity of the small orifice of the burette. We start the different stage just after a droplet is fallen down.

First a meniscus is formed (Fig. 3a), then the mercury fill the cone (Fig. 3b), then it fill the cylindrical orifice (Fig. 3c), then a small meniscus is formed (Fig. 3d) and a spherical droplet is formed (Fig. 3e), finally the droplet fall down dragging the mercury in the cylindrical orifice (Fig. 3f).

C. Experimental setups

The experimental setup to measure the electric charge on a droplet is shown in Fig. 4. It is composed of a burette, previously filled with mercury. The tap of the burette is closed. As described in the previous paragraph, even with the tap closed, droplets form at the orifice of the burette, then grew unstill a given size for which it fall down due to its weight. The droplet falls inside a stainless steel faraday cup insulated from the faraday cage by a Teflon sheet. The faraday cage is grounded while the stainless steel cup is connected to a picoammeter Keithley linked with a Keithley data acquisition board and a computer.

D. Experiments and analysis

The electrical charge on the droplet is due to the contact between the mercury and the glass inside the cylindrical orifice. The dimension of the cylindrical orifice has been measured and is 0.5 mm in diameter and 1.5 mm in length, this means a volume of 0.2945 mm^3. The surface of the area in contact is 2.36 mm^2. In order to obtain the total volume of each droplet (the droplet itself added with the volume of the cylindrical orifice), we measured the weight of 10 droplet. We found that each droplet weight 18 mg. Taking into account the mercury density the volume of the total droplet is around 1.33 mm^3. This means that the total droplet volume is around 4.5 times greater that the cylindrical orifice alone. In another hand, we estimate that the velocity of the mercury falling down in the orifice after (between Fig. 1e and Fig. 1f) is roughly the same that the velocity of mercury during the droplet formation.

We can see in Fig. 5 the current recorded during the fall of 5 droplets: it appears an exponential decay of the current between each fall of droplet. This is due to the RC circuit of the cable and entry of the picoammeter used in "Normal" mode on 10^{-10} A range. The mean current is around 0.8 x 10^{-12} A, the mean time between two successive droplets is around 8s. The charge of the droplet is + 6.4 pC: it is due to the friction of the mercury in the cylindrical orifice of the burette with a surface of 2.36 mm^2. The velocity of the mercury in the cylindrical orifice is about 1 mm/s. This means that the charge per m2 due to the friction of mercury on glass at a velocity of 1mm/s is around 2.7 x 10^{-6} C/m^2. This charge is positive: so the glass is charged negatively: it takes electrons at the surface of mercury during the contact. The normal component of electric field is about 0.3 kV/mm taking a void permittivity: even with an other more greater permittivity the electric field stays important and justify a possible tangential component (>> 10^{-7}) taking account the geometry of the contact is not a plane.

When the tap is open, we observe a current due to the friction varying versus the velocity Fig. 6. The role of the velocity is very important: here it is linked with the

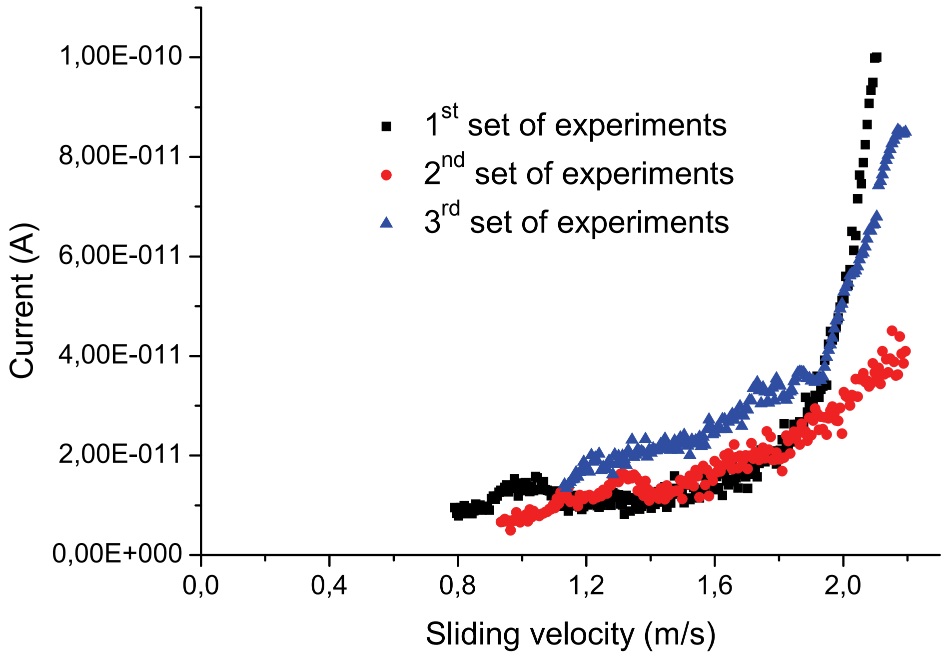

Fig. 6. Current versus the sliding velocity.

pressure of height of mercury: when the sliding velocity is 2 m/s the current maximum can reach 100 pA giving a sliding current density of 4 x 10^{-5} A/m^2 corresponding to a total current of 4 x 10^9 A with a surface of 10^{14} m^2 (surface of sphere with a radius r_0). In the earth at the CMB level the pressure is very high (1.30 Megabars): and the low velocity (1 mm/sec – ratio 2000 with 2 m/sec is therefore largely compensated by the very high pressure ratio 1.3 x 10^6): so see that it is possible to justify experimentally this flow electrification theory

V. Discussion and Conclusion

We have presented a theory involving electrostatic and electrokinetic phenomena to explain geomagnetism

Fist a general theory concerning all the electrostatic phenomena (triboelectricity, piezoelectricity, pyroelectricity ..) leads us the existence of charges in D'' area giving an electric field. The tangential component of this field induces in the conductor a strong current which can justify the geomagnetism.

Moreover we have presented some experimental data about the flow electrification mercury glass: with this alone phenomena we can obtain the values be able to justify geomagnetism by extrapolation to high pressure.

But certainly we have several phenomena (in particular piezoelectricity with the very high pressure and pyroelectricity with the high variation of temperatures) which appear together in our general theory (fl 1)

An important consequence of this theory is the explanation of the reversal of geomagnetism. The way of the resulting electric field is depending from the two different vortexes revolving in two opposite directions. Following the state of these turbulences, the way of geomagnetism is a random phenomenon: here we are agreed with the general opinion of geologists.

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