THE DESIGN OF A WEB SITE WITH STUDIES OF GEOMAGNETISM

ASIMOPOLOS Laurenţiu, ASIMOPOLOS Adrian-Aristide, ASIMOPOLOS Natalia-Silvia

Abstract. Within the framework of the core project of the Geological Institute of Romania entitled "Geomagnetism, a modern tool in space weather forecasting and rapid response to associated natural hazards for the protection of critical infrastructures and national air traffic security", PN23390401, we developed the content of the WEB platform. Thus, we introduced new chapters such as: geomagnetic field sources and geomagnetic field variability. Within the geomagnetic field sources, we described internal and external sources, and within the variability, we analyzed the associated occurrences and frequencies.

Keywords: geomagnetic field, web platform, geomagnetic field sources, oscillation variability.

Rezumat. Designul unui site web cu studii de geomagnetism. In cadru proiectului nucleu al Institutului Geologic al României intitulat "Geomagnetismul, instrument modern în prognoza vremii spațiale și în reacția rapidă la hazardele naturale asociate pentru protecția infrastructurilor critice și securitatea traficului aerian național", PN23390401, am dezvoltat conținutul platformei WEB. Astfel, am introdus capitole noi precum: sursele câmpului geomagnetic și variabilitatea câmpului geomagnetic. În cadrul surselor câmpului geomagnetic am descris sursele interne și sursele externe, iar în cadrul variabilității am analizat ocurentele și frecvențele asociate.

Cuvinte cheie: câmp geomagnetic, platformă web, surse de câmp geomagnetic, variabilitatea oscilațiilor.

INTRODUCTION

The Earth's magnetic field is variable over time, its changes having a great variety in the forms of presentation and in the mechanism of production, manifesting parallels with various geophysical and Helio-physical phenomena. The correlation of these phenomena based on their physical substrate has proven particularly useful for clarifying many problems regarding the morphology of the geomagnetic field. The part of the geomagnetic field that has a simpler structure and that predominantly determines its distribution in space is due to causes located inside the Earth, while that which diversifies its morphology has external causes. Present in the manifestations of the distribution in space and the evolution in time, the variety of manifestations of the geomagnetic field has external causes. This morphological variety is superimposed on the general background of the main field that has internal causes. The geomagnetic field of internal origin is more difficult to explain, the physical mechanism of its production being incompletely explained to date. In contrast, although of a much higher degree of morphological and phenomenological complication, the external field appears as the result of a chain of physical processes framed in coherent explanatory concepts and largely verified directly, by confrontation with reality [ASIMOPOLOS & ASIMOPOLOS, 2018; BELAND & KEVIN, 2004; CAMPBELL, 2003. The mechanisms inside and outside our planet are particularly important, from the processes in the core responsible for producing the main field to the phenomena in the ionosphere and magnetosphere whose effects appear in geomagnetic variations and disturbances.

SOURCES OF THE GEOMAGNETIC FIELD

The Earth's magnetic field varies permanently at all scales, both in time and space. Periodicities range from fractions of a second to hundreds of years, with amplitudes from fractions of nT to hundreds of nT, and in space the distribution at the Earth's surface has values between 3 and 7×10^4 nT.

Internal geomagnetic field The main field is produced by a dynamo-type mechanism in the outer core, while the crustal field is related to the distribution of rocks with magnetic properties. The inner core occupies a space with a radius of approximately 1200 km. In this metallic core, temperatures at depths ranging from 5100 to 6370 km are over 30,000 K. The outer core, between the Wiechert-Gutenberg discontinuity (2900 km) and the Lehman discontinuity (5100 km), is made up of a mixture of liquid metals forming a spherical corona about 2200 km thick around the solid inner core. The existence of the Earth's permanent field, despite Ohmic dissipation, is confirmed by paleomagnetic studies. This means that there must be a process that regenerates electric currents against Ohmic dissipation (Fig. 1).

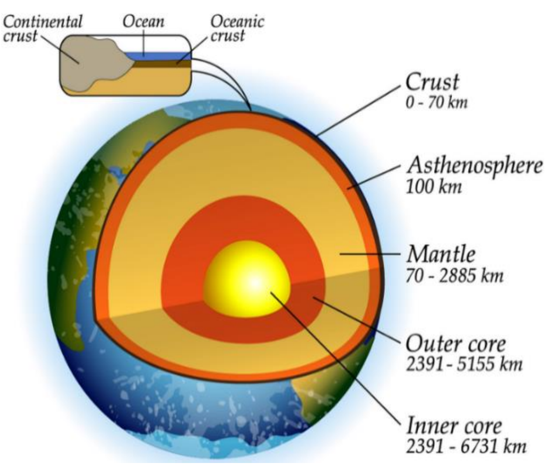

Figure 1. Earth in cross section (after CAMPBELL, 2003).

In a brief presentation, we can recall two models:

• Gilbert's model assumes that in the center of the Earth there is a permanently magnetized core, a kind of magnet with two poles, whose magnetic field manifests itself on the surface of the Earth's crust and theoretically extends to very large distances. This simple model was abandoned when it was found that at very high temperatures in the central area of the Earth, permanent magnetism disappears (Curie Point) and therefore cannot be the source of the secular geomagnetic field.

• The currently adopted model assumes a single possible source, namely the existence of electric conduction and convection currents in the semi-fluid and electrically conductive spherical corona represented by the external core. Since the flow of electric conduction currents implies the existence of electric voltages, according to Ohm's law, and this can be produced either by electrochemical reactions (imprinted electric fields) or by electromagnetic induction, the theory of the Geomagnetic Dynamo was formulated.

Crustal geomagnetic field. Local geomagnetic anomalies

Local variations in the geomagnetic field are the result of lithological variations in the Earth's crust. These anomalies sometimes have values that double the value of the main geomagnetic field. Usually, crustal anomalies have small spatial extents, which means that magnetic maps generally do not show large-scale regional anomalies. The presence of large and irregular variations in the crustal field leads to great complexity of magnetic maps. The sources of local magnetic anomalies cannot be very deep because temperatures at depths greater than about 40 km exceed the Curie point, the temperature at which rocks lose their magnetic properties. Consequently, the source of local magnetic anomalies must be located in the upper and middle part of the crust.

Magnetism of rocks and minerals

Magnetic anomalies are produced by ferromagnetic minerals (magnetite or pyrrhotite) contained in rocks. There are very few minerals with important magnetic properties. Based on their behavior in an external magnetic field, substances can be divided into the following categories:

1. Diamagnetic substances: they contain atoms with the spin motion of the orbital electrons oriented in the opposite direction to the external geomagnetic field and have a negative magnetic susceptibility. Diamagnetism prevails when the magnetic moment of all atoms is zero and the field is zero, a situation characteristic of elements with complete electronic levels. Among the best-known diamagnetic minerals are graphite, calcite, quartz and salt.

2. Paramagnetic substances: they are those whose magnetic moment is different from zero, the field is zero but they have a positive magnetic susceptibility.

3. Ferromagnetic substances such as iron, cobalt, nickel, etc. exhibit strong magnetic interactions such that the moments align within large areas called domains. This effect is called ferromagnetism and has amplitudes 106 times greater than those of paramagnetism or diamagnetism. Ferromagnetism decreases inversely with temperature, disappearing completely at the Curie temperature. In some rocks the domains are divided into subdomains oriented in opposite directions so that their moments almost cancel out although they can be considered ferromagnetic from the point of view of susceptibility. Such substances are called antiferromagnetic, an example being hematite.

4. Ferrimagnetic substances: they are found in most minerals and have magnetic subdomains aligned in opposition and their resultant moment is different from zero. This phenomenon occurs because one of the subdomains has a better magnetic alignment than the other, or there are several subdomains of the same type.

Remanent magnetism

The magnetization of rocks depends mainly on the current magnetic field and the content of magnetic minerals. Residual magnetism (called remanent magnetization) contributes to the total magnetization in both amplitude and direction. Its effect is complicated by the fact that remanent magnetization depends on the magnetic history of the rock. Natural remanent magnetization can be produced by several causes, among which we can list:

- Thermoremanent magnetization resulting when magnetic materials are cooled to the Curie temperature in the presence of an external magnetic field (usually the terrestrial one). Its direction depends on the direction of the magnetic field at the time and location where the rock was cooled. The remanence thus obtained is very stable. This is the main mechanism of magnetization of igneous rocks.
- Detrital magnetization occurs as a result of the slow settling of fine particles in the presence of an external magnetic field. This type of remanence is present in various types of clays.
- Chemical remanence occurs when magnetic minerals increase in size or change from one mineral phase to another as a result of a chemical interaction occurring at moderate temperatures, close to the Curie point. These processes can play an important role in metamorphic and sedimentary rocks.
- Isothermal remanence is the residual effect left after the field that produced the magnetization is removed. Such magnetizations are produced by lightning on confined surfaces.
- Viscous remanence is produced by prolonged exposure to an external magnetic field and is very stable over time. This type of remanence is a logarithmic function of time and is characteristic especially of fine-grained rocks.

External geomagnetic field

The external component of the geomagnetic field is responsible for the short-period variations of the geomagnetic field, representing the effect of the interaction of the Earth's magnetic field with the magnetic fields of the Sun and the Moon. This component can present periodic variations dependent on the position of the Sun and the Moon relative to the local meridian and aperiodic variations associated with the intensification or reduction of solar activity at a certain moment. Diurnal variations are evident during intervals of magnetic calm, the geomagnetic field changing its regularity with a period of one solar day (Sq variations) and its amplitude by several tens of nT. The equivalent ionospheric current system, responsible for the Sq variations measured at the Earth's surface, consists of two vortices directed in opposition, one in the northern hemisphere and the other in the southern hemisphere, with foci at the intersection of the meridian of the day (noon) with the geomagnetic latitude of 30°. The total current of each individual vortex is approximately (1-3)*105A. Sq variations are a category of signals with seasonal dependence - in summer the amplitudes are approximately twice as large as in winter. In polar regions (at geomagnetic latitudes greater than 60°) diurnal variations have a different spatiotemporal structure and are called Sqp variations. They have amplitudes of 100-400nT. Diurnal variations continuously show considerable daily changes, which are especially pronounced at high latitudes. The largest changes in diurnal variations are observed against the background of intensification of geomagnetic activity. These variations can be slow and repetitive (calm solar diurnal variation (Sq) and calm lunar variation) or can appear in the form of oscillations with low frequencies and amplitudes. Disturbed solar variation (Sd) is a particular case of solar diurnal variation and is manifested by the presence of low-amplitude disturbances against the background of diurnal variation.

We present in figure 2 a relevant sketch of the Magnetosphere.

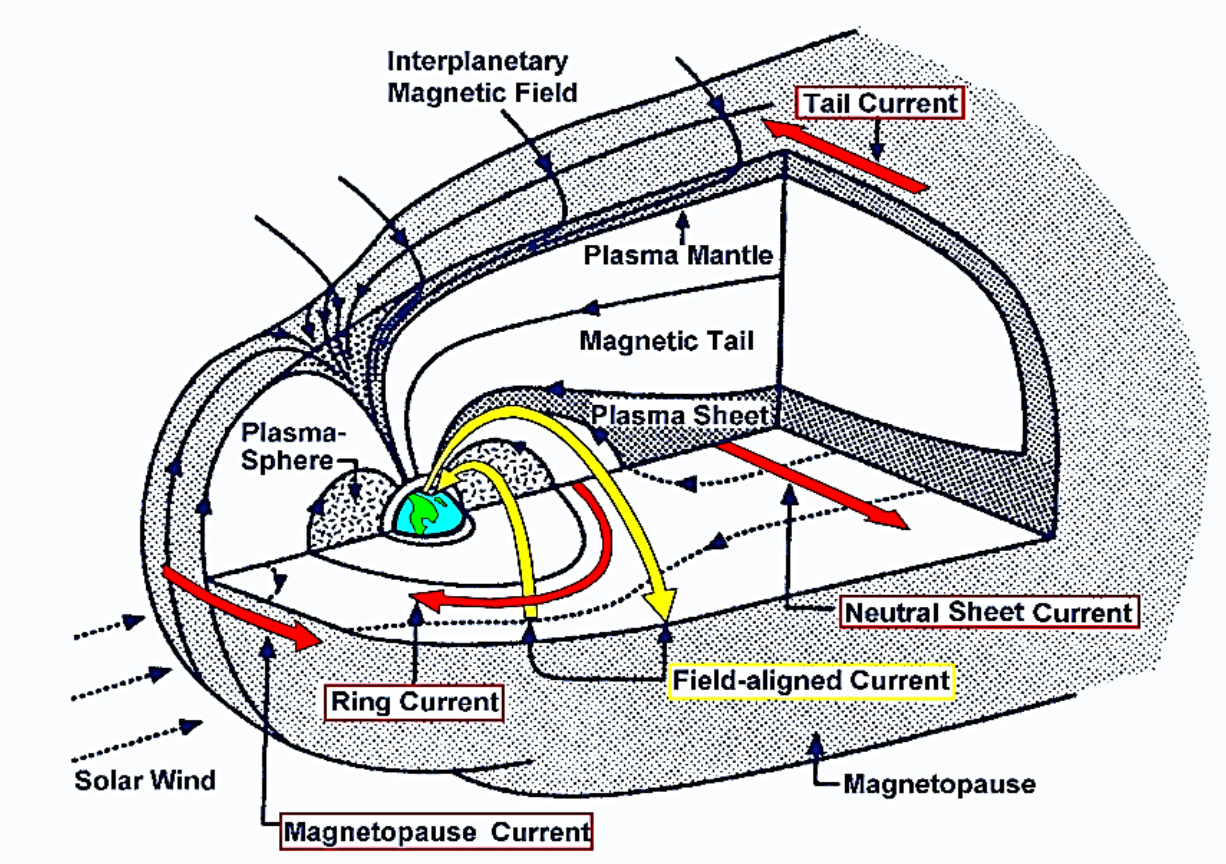

Figure 2. A sketch of the magnetosphere (modified from CONSTABLE, 2005).

VARIABILITY AND OCCURRENCE OF THE GEOMAGNETIC FIELD

Terrestrial magnetism has a determined spatial distribution and a characteristic evolution in time. The double variability of the geomagnetic field, with the place and time in which the observations are made, make its spatiotemporal structure particularly complex.

The persistent part of the field with a characteristic distribution in space, corresponding in a first approximation to the field distribution of a uniformly magnetized sphere, has a slow evolution in time, called secular variation.

The transient part of the geomagnetic field is represented both by calm and periodic variations and by agitated and sporadic changes.

The two constituent parts of the geomagnetic field highlighted - the persistent one through averaging over long time intervals, the transient one through momentary deviations from the averages - have different weights: the persistent part, called the main geomagnetic field, represents over 90% of the total geomagnetic field, while the transient one does not exceed 10% except during periods of extreme field agitation (geomagnetic storms). Both the main and transient geomagnetic fields can be evaluated by spherical harmonic analysis.

Spherical functions are characterized by two remarkable properties: the possibility of representing any distribution of values, however complicated, on a sphere and their character as "harmonic" functions, satisfying Laplace's equation, to which the values of a field derived from a potential must be subjected. Transient changes in the geomagnetic field are highlighted by continuous recordings of its elements, made at magnetic observatories.

On the obtained magnetograms, one can distinguish, on the one hand, periods of “magnetic calm", characterized by slow, regular and predictable variations of the recorded geomagnetic elements, with a quasi-sinusoidal appearance, and on the other hand, time intervals of "magnetic agitation", in which the field presents deviations with an irregular distribution in time, with unequal amplitudes of its elements, in relation to the intervals of magnetic calm.

The disturbance storm time (Dst) index prediction using time delay neural network during some extreme geomagnetic storms is show in EL-ERAKI et al., 2018 and space weather events in July 1982 and October 2003, and the effects of geomagnetically induced currents on Swedish technical systems are present in WIK et al., 2009.

A suggestive scheme regarding the contribution of physical processes on the geomagnetic field is presented in Fig. 3.

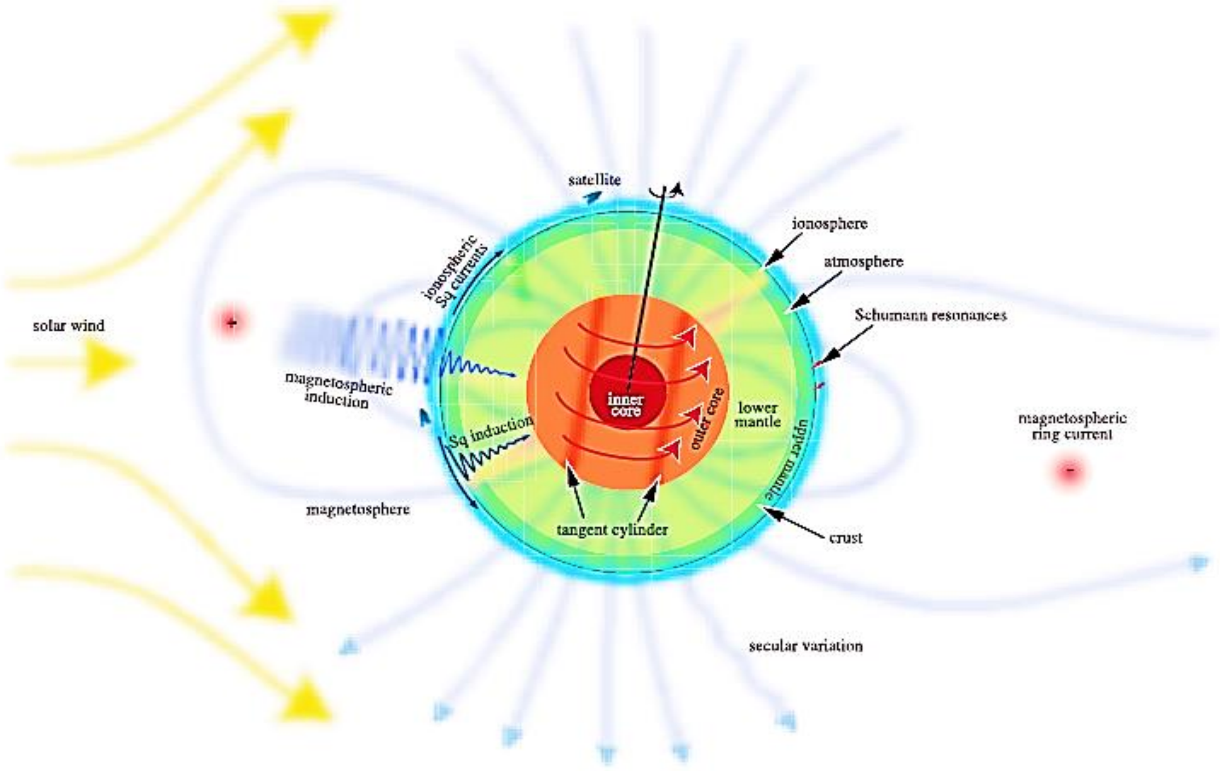

Figure 3. Scheme regarding the contribution of physical processes on the geomagnetic field (after: CONSTABLE, 2005).

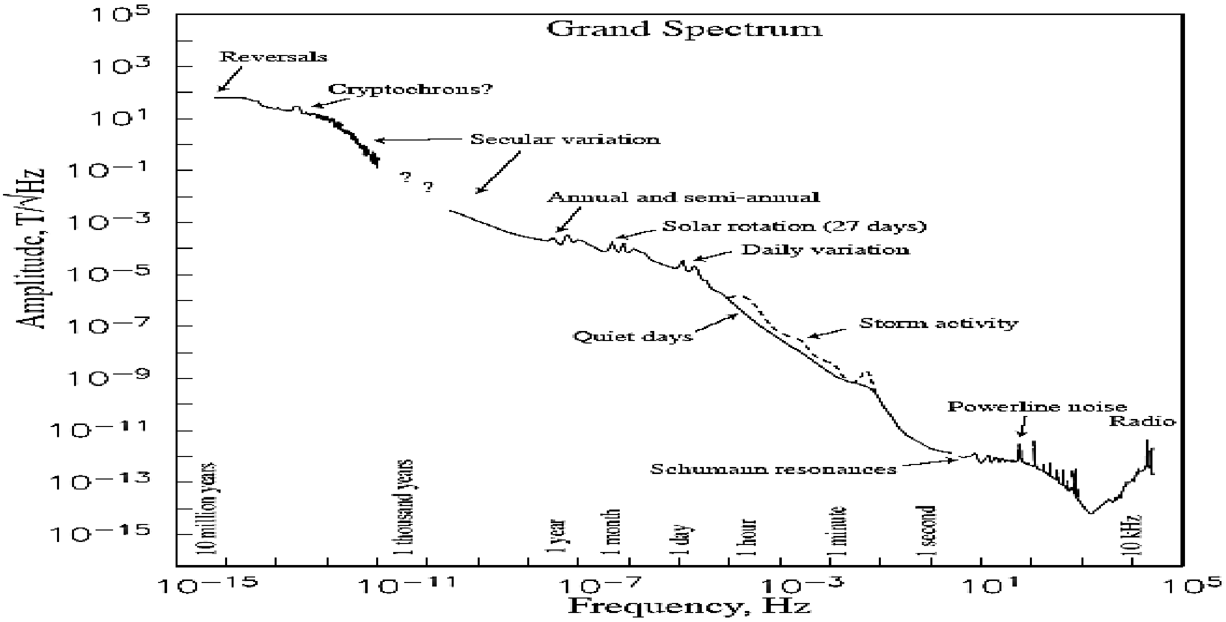

Figure 4. Broad amplitude spectrum for geomagnetic variations as a function of frequency and time (after CONSTABLE, 2005).

In table 1 the main variations of the geomagnetic field are presented in a concise form.

Table 1. Periods and amplitudes of geomagnetic phenomena at mid-latitudes (ROKITYANSKY, 1982).

The phenomenon	**Period**	**Amplitude (nT)**
Micropulsations and Pulsations	1 ms – 10 min	0.5 - 10
a) continuous Pc1-Pc6	P_{c1}(0.2-5s), P_{c2}(5-10s), P_{c3}(10-45s), P_{c4}(45-150s), P_{c5}(150-600s), P_{c6}(>600s)	
b) irregular Pi1- Pi3	P_{i1}(1-40s), P_{i2}(40-150s), P_{i3}(>150s)	
Substorms	1-2h	~10
Calm day solar variation, Sq	24h	~20
Daily solar disturbance, SD	24h	~5-20
Daily lunar variation, L	25h	~1
Temporal variation of magnetic storm, Dst		
a) initial phase	~4h	15
b) main phase	~8h	35
c) return phase	~60h	~35
External magnetic field	~<4 years	
Internal magnetic field	~>4 years	
Solar cycle variation	11 and 22 years	

CONCLUSIONS

In our paper, we describe the content of two chapters of the platform for the educational courses in geomagnetism was done in HTML (Hypertext Markup Language), CSS (Cascading Style Sheets) and JavaScript. HTML tells the browser what elements should be included in the web page (and in what order). CSS tells the browser how each element should be styled. JavaScript provides a means for web page authors to manipulate these elements programmatically and in response to end-user actions. HTML markup codes include basic markup that delimits the HTML page/document, its title and the body of the page, structuring the document, inserting subheadings, paragraphs, delimiting lines, formatting text, creating hyperlinks and inserting content objects (e.g. tables, formulas, images or multimedia objects retrieved from files, forms). In the WEB platform we have included many links about extreme geomagnetic phenomena, taken from prestigious institutions in the field [https://www.spaceweather.com/, https://www.swpc.noaa.gov/, https://www.usgs.gov/]. Magnetic storms are phenomena with a large extension in time, on the order of days, during which oscillations with amplitudes that can reach the order of hundreds of nT, and with high frequencies appear. They are associated with periods of maximum solar activity. They are causally linked to the penetration into the ionosphere of a large quantity of electrically charged particles (solar wind), which bring changes in the values of the external component of the magnetic field. Magnetic storms can be best highlighted by studying the horizontal component of the magnetic field because it undergoes the most significant changes. Regardless of the time at which it occurs, the magnetic storm begins with an increase in the horizontal component, an increase that persists for 2 - 4 hours. This represents the initial phase of the storm. After this phase, there is a significant decrease in the value of the horizontal component below the value in the calm period that preceded the onset of the storm. This decrease is much larger than the increase in the initial phase, can last several hours and constitutes the paroxysmal phase of the storm. After this phase, there is a gradual return of the value of the horizontal component to the level of the previous period of the storm. This return is accompanied by disturbances and can sometimes extend over several days. The analysis of these phenomena is done by spectral and wavelet methods and have been exemplified in many works by the authors according to https://www.mathwoks.com/.

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Asimopolos Laurențiu
Geological Institute of Romania
1st Caransebeş Street, 012271 - Bucharest, Romania.
E-mails: laurentiu.asimopolos@igr.ro, asimopolos@gmail.com

Asimopolos Adrian-Aristide
National University for Science and Technology POLITEHNICA of Bucharest,
Faculty of Transports, 313 Splaiul Independentei, 060042 - Bucharest, Romania.
E-mail: adrian.asimopolos@gmail.com

Asimopolos Natalia-Silvia
Geological Institute of Romania
1st Caransebeş Street, 012271 - Bucharest, Romania.
E-mails: natalia.asimopolos@igr.ro, asi_nata@yahoo.com

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