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MAGNETIC SUSCEPTIBILITY, REMANENT MAGNETIZATION AND COERCIVITY VARIATIONS ALONG SOIL PROFILE

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ABSTRACT

The determination of magnetic susceptibility χ, remanent magnetization *Jr* and coercivity *Bcr* variations along Glifada automorphic soil profile has been carried out using χ - meter MS2-B and unique lab coercivity spectrometer permitting to distinguish paramagnetic magnetization and saturation remanent magnetization and to determine *Jr* and coercivity *Bcr.* These parameters give the consideration of soils components in terms of paramagnetic, ferromagnetic, ferrimagnetic, or antiferromagnetic states. The results have revealed that investigated soil profile was recorded in magnetic parameters variations and controlled by environmental factors.

Keywords: magnetic minerals, magnetic susceptibility, remanent magnetization, coercivity, soil.

1. INTRODUCTION

Investigations of magnetic properties of soils are known from 50^{th} years of XX century and involve different aspects of soil magnetism [1]. Soils are stratified. We develop the question how magnetic properties (magnetic susceptibility, remanent magnetization and coercivity) reflect their stratification and genesis on samples collected from soil profile near-by Glifada resort on island Korfu.

Soil is surface layer of the Earth's lithosphere, which represents a multifunctional heterogeneous open four phase (solid, liquid, gas and living organisms) structural system, formed by the weathering of rocks and biological activity. The soils are a function of climate, topography, initial parent rocks, microorganisms, plants and animals, human activity and change over time.

There are many soil profile classifications in science. In present work it was used simple soil profile classification from [2]. This scheme contains four main horizons:

Horizon	**characteristics**
A	The leaching of mineral components
B	The accumulation of nutrients
C	Parent rock exposed to weathering
D	Bedrock

Horizon	**sub horizons from up to low**	
A	Fresh litter	A0
	Partially decomposed litter	A1
	Humus 1	A2
	Humus 2	A2
	Eluvial acid destructed	A3

All soils have magnetic properties due to the fact that main components of the mineral part of soils contain iron compounds - magnetite ($Fe_2O_3{\cdot}FeO$), pyrrhotite ($Fe_{1-x}S$), titan iron ore ($FeO{\cdot}TiO_2$), limonite ($Fe_2O_3{\cdot}nH_2O$), hematite (Fe_2O_3), etc. Magnetite, which is widely dispersed in the solid phase of the majority of soils, has strongest magnetic properties.

In general, soil is a multiphase dispersed system, the solid part of which consists of particles of different sizes: from gravel and pebbles to colloidal fraction that has a particular effect on the properties of soils. Magnetic susceptibility of soils have been investigated most of all in comparing with another parameters such as remanent magnetization and coercivity.

The magnetic susceptibility (latin: susceptibilis "receptiveness") is the degree of magnetization of a material in response to an applied magnetic field.

The volume magnetic susceptibility, represented by the symbol χ_v (often simply χ, sometimes χ_m - magnetic, to distinguish from the electric susceptibility), is defined by the relationship

$$M = \chi_v H,$$

where, in SI units, *M* is the magnetization of the material (the magnetic dipole moment per unit volume), measured in amperes per meter, and *H* is the magnetic field strength, also measured in amperes per meter.

The magnetic induction *B* is related to *H* by the relationship.

$$B=\mu_0(H+M)= \mu_0(1+ \chi_v)H= \mu H,$$

where μ_0 is the magnetic constant, and $(1 + \chi_v)$ is the relative permeability of the material. Thus the volume magnetic susceptibility χ_v and the magnetic permeability μ are related by the following formula:

$$\mu= \mu_0 (1+ \chi_v)$$

Sometimes an auxiliary quantity, called intensity of magnetization (also referred to as magnetic polarisation *J*) and measured in teslas, is defined as:

$$J = \mu_0 M$$

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This allows an alternative description of all magnetization phenomena in terms of the quantities *J* and *B*, as opposed to the commonly used *M* and *H*.

If χ is positive, then $(1+\chi_v) > 1$ and the material can be paramagnetic, ferromagnetic, ferrimagnetic, or antiferromagnetic. In this case, the magnetic field in the material is strengthened by the induced magnetization. Alternatively, if χ is negative, then $(1+\chi_v) < 1$, and the material is diamagnetic. As a result, the magnetic field in the material is weakened by the induced magnetization.

Volume magnetic susceptibility is measured by the force change felt upon the application of a magnetic field gradient.

Usually, χ measured by the coil. Empty coil has some induction. After we apply a sample inside of coil induction varies depending on the ability of this sample to magnetize in a magnetic field of coil. Usually magnetic susceptibility is measured in very weak magnetic fields (about the earth's magnetic field).

Remanence or remanent magnetization is the magnetization left behind in a permanent magnet after an external magnetic field is removed. It is also the measure of that magnetization. Colloquially, when a magnet is "magnetized" it has remanence. It is also the magnetic memory in magnetic storage and the source of information on the past Earth's field in paleomagnetism.

The default definition for remanence is the magnetization remaining in zero field after a large magnetic field is applied (enough to achieve saturation). A magnetic hysteresis loop is measured using instruments and the zero-field intercept is a measure of the remanence. In physics this measure is converted to an average magnetization (the total magnetic moment divided by the volume of the sample) and denoted in equations as M_r or J_r. If it must be distinguished from other kinds of remanence it is called the saturation remanence and denoted by M_{rs}.

The coercivity, also called the coercive field or *coercive force*, of a ferromagnetic material is the intensity of the applied magnetic field required to reduce the magnetization of that material to zero after the magnetization of the sample has been driven to saturation. Coercivity is usually measured in oersted or ampere/meter units and is denoted H_c or B_c.

To study J_r and B_c and B_{cr} (after exclusion of paramagnetic magnetization) it was used method of coercive spectrometry, developed in paleomagnetic lab of Kazan Federal University [3]. This method allows measuring changes in the magnetization curves of samples in a magnetic field with a continuous increase in intensity of this field inductively magnetized samples. Besides of this, coercive spectrometer is unique because it allows measuring the normal curve of remanent magnetization. In this instrument the sample is placed on the wheel. Wheel rotates, and the sample enters the interpolar space of the magnet, where he becomes magnetized. There are measuring coils, which measure the inductive magnetization of the sample. The sample leaves interpolar space and within 0.01 seconds gets into another measuring coil, which is already out of the magnetic field. It is measured remanent magnetization of the sample. Paramagnetic, diamagnetic, and other induced magnetizations are absent here. The result is two curves. On magnetization curves two parameters were determined: the remanent magnetization J_r, inductive magnetization J_i and coercivity B_c and B_{cr}.

Data on χ, J_r, B_{cr} are used to study magnetic image of soil stratification.

2. EXPERIMENT

Experiment tested one Glifada soil profile on next parameters: magnetic susceptibility χ; remanent magnetization in terms of J_r, B_{cr}.

We used the following plots:

a) typical soil profile scheme;
b) variations of magnetic susceptibility with depth;
c) curves of magnetization J_r, J_i vs. B;
d) curves M_i vs. B (to find B_{cr});
e) variations of J_r and B_{cr} with depth.

Procedure

- Recognition the samples of investigated soil profile in terms of typical soil scheme.
- Maintaining magnetic susceptibility.
- Maintaining types of soils components in terms of magnetism: paramagnetic, ferromagnetic, ferrimagnetic, or antiferromagnetic states, paramagnetic magnetization, remanent magnetization, and coercivity by hysteresis loop and Ox axis intersection on curve M_i vs. B.

Materials and equipment list

Collection of 12 samples from Glifada soil profile; χ - meter MS2-B; unique lab coercivity spectrometer [3].

2.1. Object

Object of study is one of the upper terraces of the hillside (100 m above sea level), rising above Glifada resort, where it grows the olive grove and elsewhere is rolled mesh to collect the next harvest olives.

The object is automorphic soils; soil formation is taking place at well-drained watersheds, i.e., under the influence of atmospheric moisture, the systematic downward currents, which cause the movement of chemical elements from the top down. Groundwater is located relatively deep.

Samples represent soil profile P1 by typical scheme (Figure-1).

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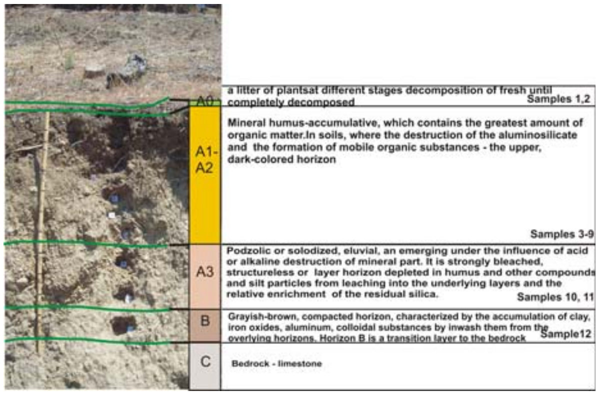

Figure-1. Tested soil profile P1.

Detailed sampling is shown in Table-1.

Table-1. Sampling.

Sample N	Depth, m	Horizon, Sub horizon
P1-1	0.05	A0
P1-2	0.1	A0
P1-3	0.15	A1-A2
P1-4	0.2	A1-A2
P1-5	0.25	A1-A2
P1-6	0.3	A1-A2
P1-7	0.4	A1-A2
P1-8	0.5	A1-A2
P1-9	0.6	A1-A2
P1-10	0.75	A3
P1-11	0.9	A3
P1-12	1.1	B

2.2. Data

Typical curves on horizons to reveal types of magnetization through J_r, J_i vs. B are represented on Figures 2-5 (for each horizon (subhorizon): on left - curves of magnetization by field increasing in one direction (green curve) and another direction (black curve); on right - curves of magnetization: red -inductive magnetization (paramagnetism was identified), black - remanent magnetization).

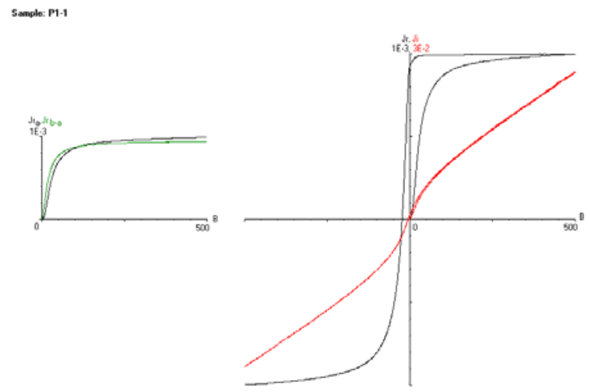

Figure-2. Curves of magnetizitation. Subhorizon A0.

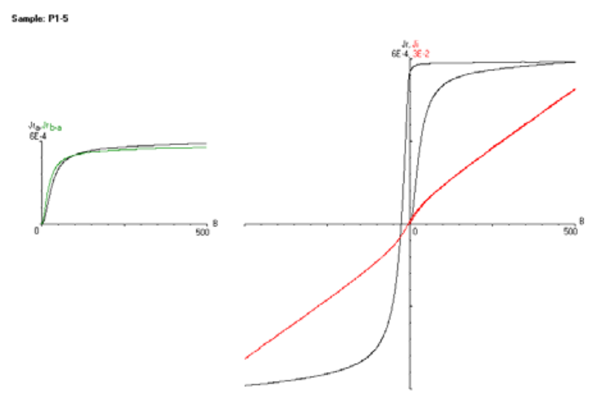

Figure-3. Curves of magnetizitation. Subhorizons A1-A2.

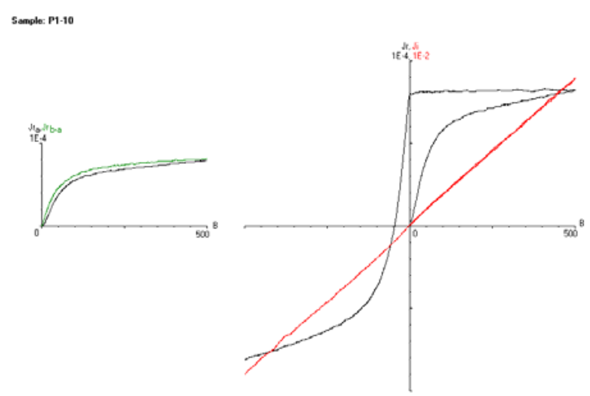

Figure-4. Curves of magnetizitation. Subhorizon A3.

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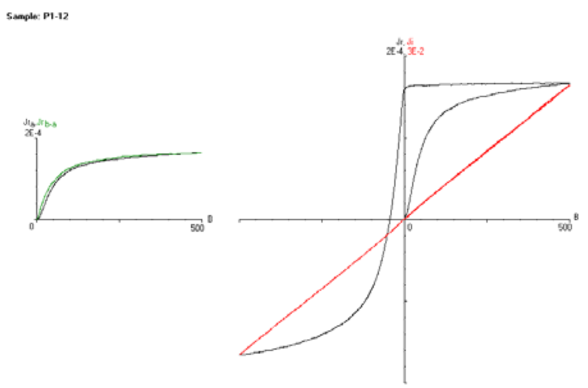

Figure-5. Curves of magnetizitation. Horizon B.

Steps to determine B_{cr} are shown on Figures 6-8. Results of measurements on all samples are shown in Table-2.

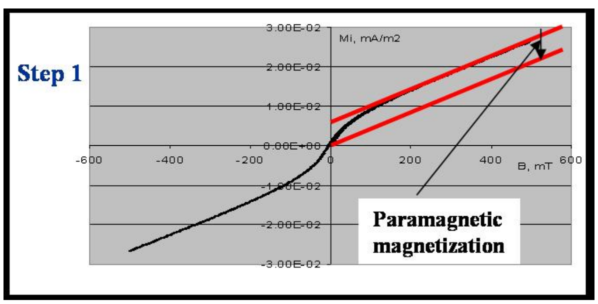

Figure-6. Finding the paramagnetic magnetization.

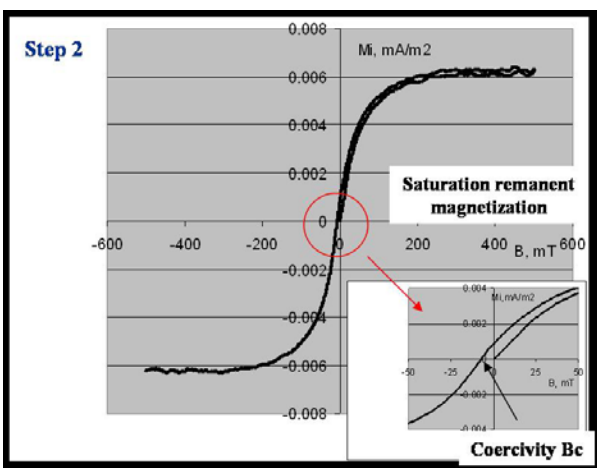

Figure-7. Finding the coercivity B_c.

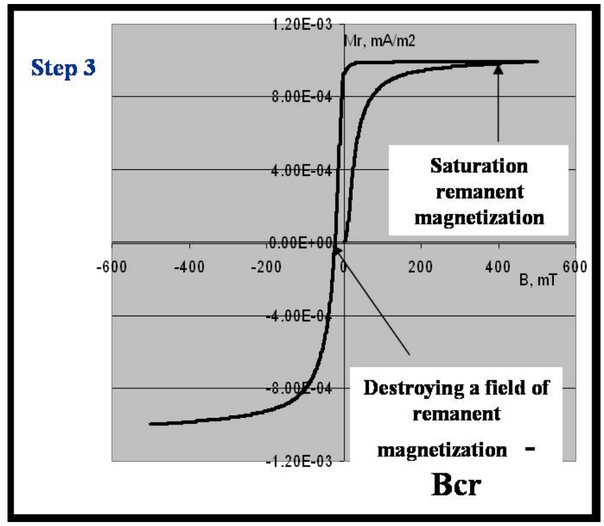

Figure-8. Finding the B_{cr}.

Table-2. Results.

Sample	J_r, mA/m^2	B_{cr}, mT	χ, SI units
P1-1	9.24E-04	23.2	4.13E-05
P1-2	7.20E-04	25.4	4.15E-05
P1-3	6.07E-04	25.3	3.92E-05
P1-4	6.03E-04	25.1	4.24E-05
P1-5	5.52E-04	25.7	4.26E-05
P1-6	4.65E-04	25.4	3.81E-05
P1-7	2.78E-04	29.6	4.07E-05
P1-8	2.30E-04	30.9	3.72E-05
P1-9	1.56E-04	38.7	3.33E-05
P1-10	7.90E-05	44.7	1.75E-05
P1-11	1.78E-04	41.4	4.56E-05
P1-12	1.60E-04	42.8	4.89E-05

Variations of χ, J_r, B_{cr} with depth are shown on Figure-9.

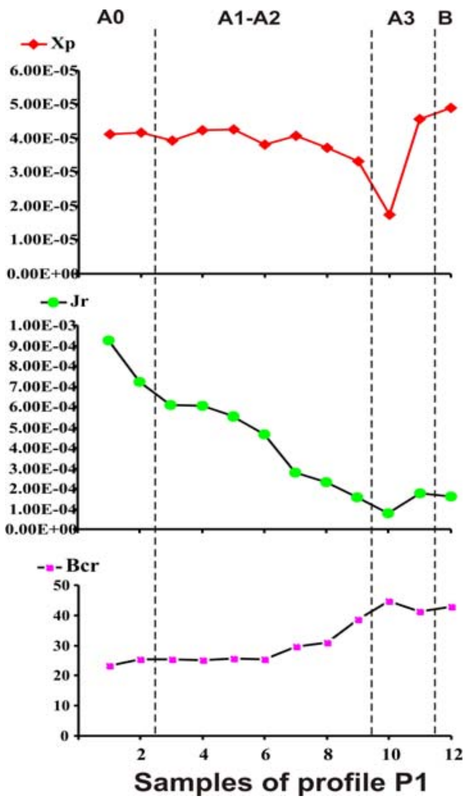

Figure-9. Variations of χ, J_r, B_{cr} with depth.

4. DISCUSSIONS

Variation of magnetic susceptibility with depth shows that the soils of Glifada are characterized by small fluctuations in horizons A0-A2 and more considerable fluctuations in horizons A3 and B (Figure-9).

In general, magnetic susceptibility of Glifada soils differs from those of Russian soils. Comparing Glifada data with data on Volga or Oka rivers floodplains one can mention that magnetic susceptibility of the first is 2-8 times less than the second [4], which confirms automorphic type of investigated soil.

J_r and B_{cr} are more expressive parameters that reflect soil stratification.

By curves of magnetization horizons A3 and B (Figures 4, 5) are recognized as substance of paramagnetic type with very small ferrimagnetic minerals. Central curve looks like a straight line.

Horizons A1-A2 and A0 are recognized as substance of ferrimagnetic type. Central curve contains considerable winding at low magnetic fields (Figures 2, 3). The ferrimagnetic component decreases by ~10 times from A0 to B (Figure-9).

Changes of B_{cr} are characterized by less values in upper subhorizons A0-A2 and increasing of values in A3 and B (Figure- 9) that corresponds to magnetically “soft” minerals and magnetically “hard” minerals (for example, hematite).

In general, intensive biological processes characterize the upper part of the soil. There is a lot of organic matter, which is processed by microorganisms. Among these microorganisms, there are bacteria, which include iron in its life cycle. In the presence of large amounts of organic matter iron is reduced to Fe^{2+}.

Upon contact with oxygen it is oxidized iron. Bacteria absorb ferrous, and the wastes of their life are magnetite, Fe_3O_4, or iron sulfides, among which there are magnetic sulfide - greiggite (for example, Fe_7S_8).

A magnetite is one of the most powerful of ferrimagnetic minerals. Maximum concentration of magnetite is in the layer A0, as well as the substance migration in automorphic soil occurs from the top down, so iron-bacteria community also extends to the horizons A1-A2. The fact that approximately the same grains of magnetite formed in A0 and A1 is confirmed by the constancy of destroying a field of remanent magnetization.

5. CONCLUSIONS

Magnetic susceptibility, remanent magnetization and coercivity variations record soil and rock substance change due to environments, including substance (iron-oxides) supply and biological activity. Such variations can be used to classify soils types by magnetic minerals composition and genesis. Sampling and magnetic measurement of soil profiles in different places can bring database on magnetic images of soil substance.

REFERENCES

[1] В.Ф. Бабанин, В.И. Трухин, Л.О. Карпачевский, А.В. Иванов, В.В. Морозов. 1995. Магнетизм почв. ЯГТУ. http://www.rfbr.ru/rffi/ru/books/o_528#1.

[2] Мультимедийный учебник по биологии (biology guide). 2007. http://www.ebio.ru/eko03.html.

[3] P.G. Yassonov, D.K. Nourgaliev, B.V. Bourov and F. Heller. 1998. A modernized coercivity spectrometer. Geologica Carpathica. 49(3): 224-226.

[4] V.S. Semenov and V.I. Pakhotnova. 1998. An investigation of the magnetic properties of soils. Russian Physics Journal. 41(7): 656-661.