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NEW AND UPDATED GEOMAGNETIC REPEAT STATIONS IN THE REPUBLIC OF KOSOVO

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Abstract

Each country is good to have their own geomagnetic repeat stations for monitoring and defining the geomagnetic anomaly field. The paper presents and defines the network of geomagnetic stations in the Republic of Kosovo. A network of 10 geomagnetic stations has been defined on the territory of the Republic and on the basis of the performed observations and measurements that were conducted during the SFRY, a new and updated network for monitoring the geomagnetic field in the Republic of Kosovo is defined.

The research for the selection of locations for geomagnetic stations according to INTERMAGNET standards is presented.

Key words: *net, repeat station, INTERMAGNET, Kosovo.*

INTRODUCTION

The geomagnetic field reflects the Earth's structure, processes within it, as well as the external influences. The field is presented as a sum of three components:

- Normal geomagnetic field which reflects the causes of magnetism in the core and the mantle. This component includes agents that are in the depths of the earth's crust, but they are spreading throughout the territory of the Republic of Macedonia;
- Regional geomagnetic anomalous field affected by characteristic generators of the magnetic field in the separated neotectonic zones in the Republic of Macedonia;
- Local geomagnetic field which is in direct correlation with the geological structures in the upper part of the Earth's crust with expressed magnetic features (increased concentration of ferrous magnetic minerals).

For complete monitoring of the geomagnetic field in a given area, it is necessary to have a basic network of stations for periodic observation of the field and a geomagnetic observatory that permanently measures the temporal changes of the geomagnetic field.

In order to define the coefficients of dependence of the geomagnetic field on the latitude and longitude of a given point for a certain area (usually a country), in addition to the existence of a geomagnetic observatory which is a reference point, a relatively homogeneous network of geomagnetic stations is required.

The basic network of geomagnetic stations serves for periodic measurements of those points in an interval of 3 - 5 years, and, based on the observed data, a geomagnetic model is formed for that territory. [1]

For a given epoch (period of five years) the value of any component of the geomagnetic field can be calculated for a given point belonging to the space (country) covered by the geomagnetic observatory with coordinates φ_o and λ_o.

MATERIAL AND METHODS

Magnetic field of the Earth

The geomagnetic field is a reflection of the structure of the Earth, the processes in it, as well as external influences. [2]

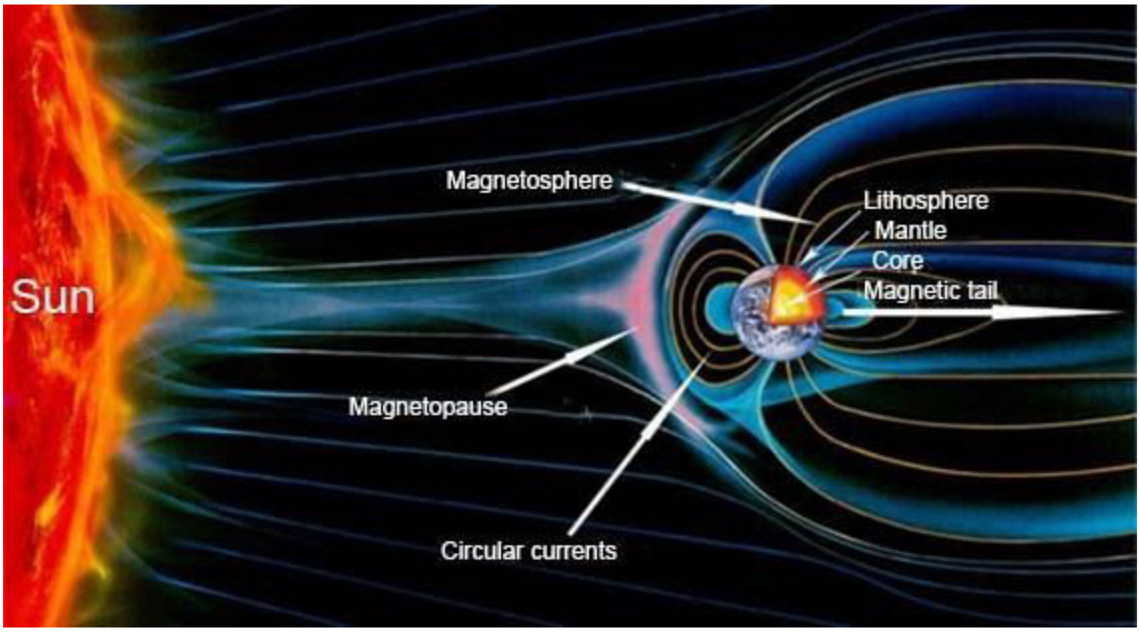

Figure 1. Schematic representation showing the Earth's source regions of the geomagnetic field

The components of the geomagnetic field originating from the earth's interior can be represented by:

$$T_z = T_o + T_m + T_a \tag{1}$$

T_z – geomagnetic field generated by the earth's interior;
T_o – a field of the homogeneously magnetized Earth, which can be represented as the field of a dipole magnet whose center is at the center of the Earth, which is called a dipole field;
T_m – a field caused by inhomogeneities and magnetic factors in the deeper parts of the Earth, which is called non-dipole or continental field;
T_a – a field caused by magnetic agents in the upper part of the earth's crust.

In the total value of the component T_z, T_o is present approximately 80%, $T_M \approx 10$ - 15 % and $T_a \approx 5$ %. The anomalous field T_a can be divided into components depending on the space they occupy:

$$T_a = T_a^{GR} + T_a^{MR} + T_a^{L} \tag{2}$$

T_a^{GR} – Large regional anomalies occupy an area of several hundreds of square kilometers of the Earth's surface;
T_a^{MR} – Regional anomalies with scales of several tens of kilometers on the earth's surface;
T_a^{L} – Local anomalies with a scale of up to ten kilometers.

The total magnetic field of the Earth consists of the field from its interior T_z, the external fields that are generated in the atmosphere (especially in the ionosphere), the influence of the Sun (solar wind) and the magnetic phenomena that occur outside the atmosphere; that field is called external T_e.
A field of variations δT that depends on the position of the Earth, the Sun and the Moon stands out. The total magnetic field of the Earth can be represented as:

$$T = T_z + T_e + \delta T \tag{3}$$

or

$$T = T_o + T_m + T_a + T_e + \delta T \tag{4}$$

Previous research has shown that the best physical filter is the observation of the geomagnetic field at different heights above the Earth's surface, while the effects of external fields - T_e and the influence of the field - δT should be eliminated from the measurement results.

Table 1 shows the dependence between the observation point, i.e., the height h in relation to the Earth's surface, and the influence of the components of the geomagnetic field in the measurement result.

Table 1. Presence of geomagnetic components depending on the height H

(km)	Presence of geomagnetic components in the measurement result
0	$T_o + T_m + T_a^{GR} + T_a^{MR} + T_a^{L}$
10	$T_o + T_m + T_a^{GR} + T_a^{MR}$
50	$T_o + T_m + T_a^{GR}$
500	$T_o + T_m$
10,000	T_o

A magnetic field can be generated by charged bodies in motion and permanent magnets. According to the magnetic permeability μ, materials can be divided into:

$\mu < 1$ diamagnetic
$\mu = 1$ air
$\mu > 1$ paramagnetic
$\mu >> 1$ ferromagnetic

Research on the dependence of permeability on temperature has shown that for each type of material there is a T_c (Curie temperature) above which the material cannot be magnetized, i.e., $\mu<1$.

The highest Curie temperature was registered for magnetite $T_c = 550^o$ C. Since the temperature increases (on average 33^o C per 1 km) going from the surface to the interior, in general, magnetized structures should not be expected at depths greater than 20-30 km.

Taking into account the structure of the Earth and the physical – chemical processes in it, it is concluded that the factors that generate the geomagnetic field are the following:

- In the upper part of the lithosphere, there are geological structures that contain ferromagnetic minerals, as well as fluids that generate their own magnetic field.
- Geological structures containing magnetic minerals
- The filtration of fluids through rock masses that are more or less ionized.
- The tectonic stresses in the rock masses of the lithosphere
- Physical-chemical processes in the upper mantle.
- Induced geomagnetic fields in the conduction zones of the Earth under the influence of external magnetic fields T_e
- The main magnetic field originates from processes in the core.

The core is composed of an outer part, which is in a fluid phase, and an inner part, which behaves as if it were in a solid state. The high temperatures and pressures that prevail in the core create conditions for the matter that makes it up to be highly ionized. Modern knowledge shows that there is a differential movement of the outer core in relation to the inner core (the inner core rotates faster than the outer core, i.e., it creates a dynamo machine (Bullard) that generates the main magnetic field T_o.

RESULTS AND DISCUSSION

Magnetic repeat stations distribution and reoccupation rate

The average distance from one station to another should be no larger than 200 km and a mean distance of about 125 km was considered to be desirable at the Niemegk meeting. While a repeat interval of one year is desirable, an interval of two years is considered to be a good compromise between expense and value of the results. Longer time intervals are not recommended. For secular variation determination, it is more valuable to have denser time series at fewer stations than sparse time series at a larger number of stations. The same is true for accuracy: In case the survey cannot be performed at all repeat stations in a country in one year, it will be more valuable to obtain accurate data at a subset of regularly distributed stations, than to sacrifice accuracy in order to occupy more stations. Because of the different geology structures in the Republic of Kosovo, and to have our own magnetic map, we distribute ten magnetic repeat stations.

Network of geomagnetic stations (repeat stations) in the Republic of Kosovo

Today two methods of modeling of the geomagnetic field prevail, one is the method of spherical harmonic analysis and the other is a method of polynomial analysis. The studies show that for areas with less than 15° - spatial angle, spherical harmonic analysis is an effective method. Our analysis showed that for similar - sized territory of the Republic of Kosovo polynomial model is appropriate. For the calculation of values of coefficients, the method of least squares is used [3].

The extensive research carried out during the realization of the thesis allowed the definition of 10 points on the territory of the Republic of Kosovo, which make up the network of geomagnetic stations.

The basic network of geomagnetic stations serves for periodic measurements of those points in an interval of 3-5 years and based on the equation: [4, 5]

$$E(\Delta\varphi, \Delta\lambda) = a_1 + a_2\Delta\varphi + a_3\Delta\lambda + a_4\Delta\varphi^2 + a_5\Delta\lambda^2 + a_6\Delta\varphi\Delta\lambda \tag{5}$$

where

- E $(\Delta\varphi,\Delta\lambda)$ - value for normal field of the point with coordinates φ_1 and λ_1;
- φ_1 and λ_1 – geographic latitude and longitude of the place;
- φ_0 and λ_0 – geographic latitude and longitude of the point in respect of which measurements are reduced;
- $\Delta\varphi = \varphi_1 - \varphi_o$ – difference of geographic latitudes in minutes;
- $\Delta\lambda = \lambda_1 - \lambda_0$ – difference of geographic longitudes in minutes;

a_i – coefficients for corresponding differences in nT/min (γ/min.), i.e., minutes / minutes or gammas and minutes. Usually, the differences of latitude and longitude are calculated in terms of coordinates of the geomagnetic observatory located on that territory.

By analyzing the geological, tectonic, and regional map of the Republic of Kosovo, and taking into account the previous two geomagnetic stations measured during SFRY, the table shows the central coordinates of the new network of geomagnetic stations.

In order to define exactly where the geomagnetic stations will be placed and which standards they should have according to INTREMAGNET, it is necessary to prepare a detailed description for each location. [6, 7]

Table 2. Central points of the new geomagnetic network of the Republic of Kosovo

Repeat station	X - coordinate	Y - coordinate	Height
1. Bachke	20°39'38.99" E	41°59'36.12" N	1540 m
2. Kojush	20°35'45.99" E	42°13'12.53" N	666 m
3. Radonik lake	20°24'44.71" E	42°30'24.82" N	479 m
4. Novo Selo	20°18'7.79" E	42°43'48.91" N	820 m
5. Gazivoda	20°39'8.11" E	42°55'47.37" N	867 m
6. Vrelo	20°59'15.32" E	42°34'12.73" N	930 m
7. Kachanik	21°13'20.02" E	42°13'12.05" N	960 m
8. Devaja	21°24'32.36" E	42°23'51.91" N	625 m
9. Novo Brdo	21°23'33.23" E	42°39'4.45" N	1030 m
10. Zitinje	21° 3'5.99" E	43° 2'57.94" N	1055 m

Measuring stations no. 7 Kacanik and no. 8 Devaya are measured by SFRY. [8]

The picture that follows is a presentation of the layout of geomagnetic stations in the Republic of Kosovo.

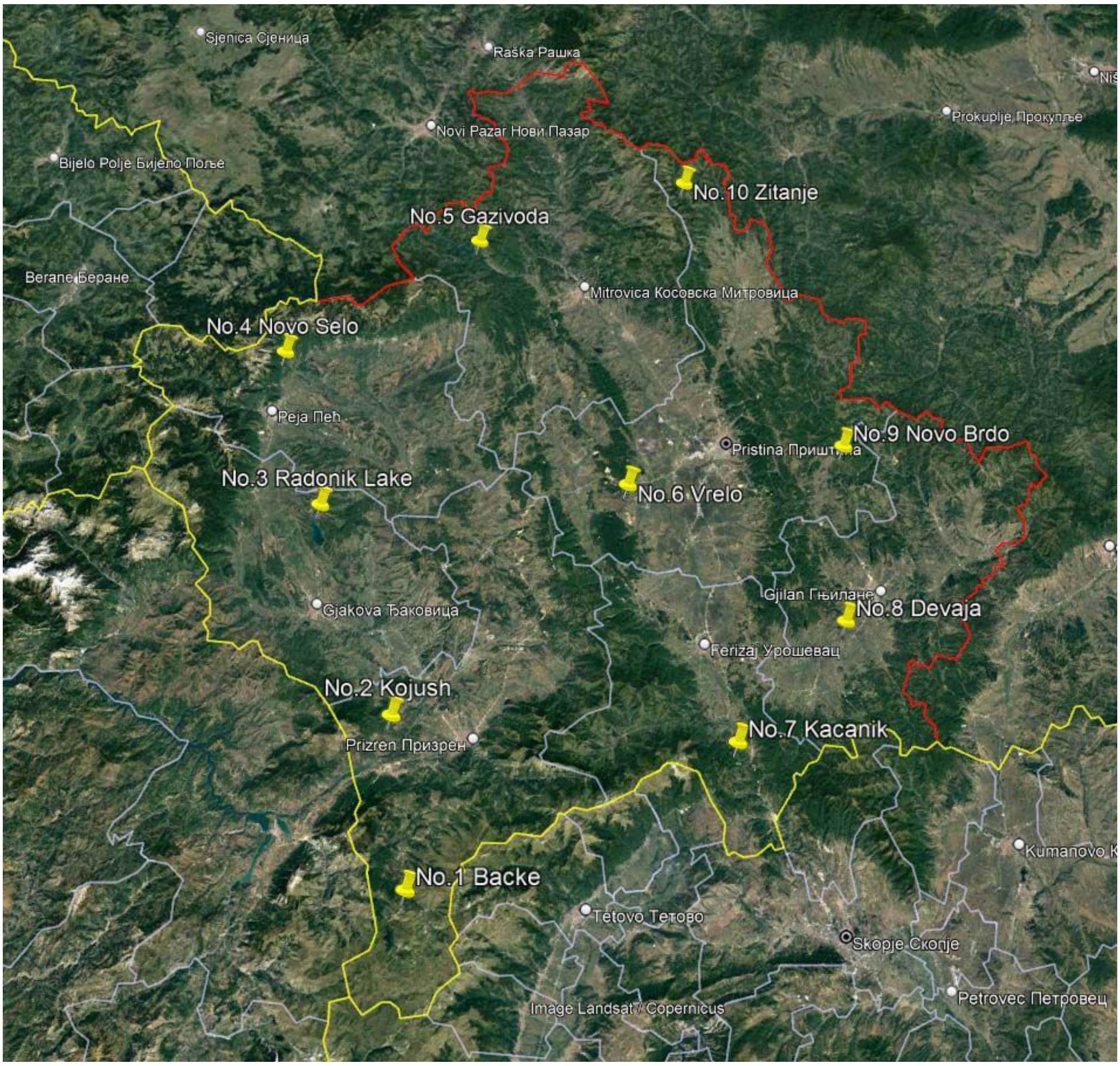

Figure 2. Network of measuring points (repeat stations) in the Republic of Kosovo

Description of the magnetic repeat station Kacanik [9]
WGS84 / GPS
Longitude 42°13'12.05"N
Latitude: 21°13'20.02"E
Height: 960 m

Location and maps

The measuring station Kacanik is located in the southern part of Kosovo, near the border with the Republic of North Macedonia.

Figure 3. Topographical map of the surroundings of the Kacanik magnetic station

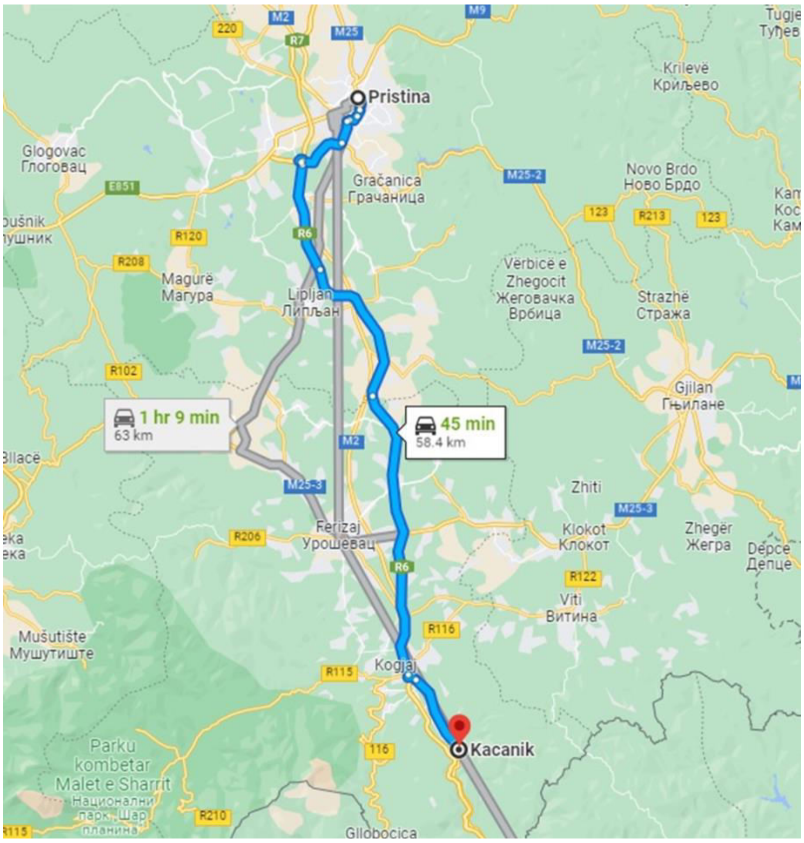

Figure 4. Road map of the surroundings of the Kacanik magnetic station

Regional driving directions

From Pristina follow Geladin Rekaliu and Fehmi Ladrovci to R6 (9 km). Follow R6 and exit R6 after 43.1 km. Drive to Ruga Agim Bajrami in Kacanik (about 6.3 km). From Kacanik head east to the new highway, pass under it to the quarry which is west of Kacanik. As soon as you reach the quarry, you will ask for permission to go to the measuring station which is located about 600 m from the mine road (more specific information can be added in the future).

Description of the target for azimuth determination

The target should be an object or antenna in the distance (horizon) that will not change in the next 30 years. Or, if it can be placed close to the measuring station but be protected. If there is a violation of the target, it is necessary to define a new target.

Magnetic cleanliness

The magnetic clearance will be defined during the placement of the magnetic station.

Other

It is necessary to enter all the data to define the magnetic station Kacanik. This station is of special interest because there are geomagnetic data from the time of SFRY. Because the former magnetic measuring station Kacanik is magnetically polluted (there is a settlement), it is moved to 2200 m toward east.

CONCLUSION

The analysis of the presented data and taking into account the optimal number of geomagnetic stations for the given space, their homogeneous arrangement is defined.

The processed data for the given network of stations and the shown methods for their processing will enable the creation of the maps of the elements of the geomagnetic field of Kosovo according to Intermagnet standards. In that way, Kosovo will join the countries that observe and study the geomagnetic field on their territory. [10, 11]

With the establishment of the new network of geomagnetic stations, in the future one of the stations may be defined as a geomagnetic observatory.

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НОВИ И АЖУРИРАНИ ГЕОМАГНЕТНИ МЕРНИ СТАНИЦИ ВО РЕПУБЛИКА КОСОВО

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Резиме

Секоја земја е добро да има свои геомагнетни мерни станици за следење и дефинирање на геомагнетното аномално поле. Во трудот е претставена и дефинирана мрежата на геомагнетни станици во Република Косово. Дефинирана е мрежа од 10 геомагнетни станици на територијата на Републиката и врз основа на извршените набљудувања и мерења кои се вршени за време на СФРЈ, дефинирана е нова и ажурирана мрежа за следење на геомагнетното поле во Република Косово.

Презентирани се истражувањата за избор на локации за геомагнетни станици според стандардите на ИНТЕРМАГНЕТ.

Клучни зборови: *мрежа, мерна станица, ИНТЕРМАГНЕТ, Косово*