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Original scientific paper

OF REPEAT STATIONS AND TECTONIC REGIONALIZATION OF THE REPUBLIC OF MACEDONIA

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A b s t r a c t: Geomagnetic field is vector sum of causes deep in the Earth's interior and their influence can be felt in the whole Earth. There are sources of magnetic fields which are characterized for larger regions and local anomalous geomagnetic fields. When selecting the location of base station, regions where local geomagnetic anomalies are present, should be avoided, with aim to receive measured results which gives the geomagnetic field characteristic for that region. The territory of the Republic of Macedonia has complex relief, and also has complex geological structure and these features have high influence on the regional geomagnetic field. Bearing in mind the complex relief and geological structure, strict procedure of geomagnetic field observations were conducted for every selected location for repeat station. Maps from the measurements in 2004 are also presented in this paper.

Key words: repeat station; geomagnetic field; declination; inclination; total field

INTRODUCTION

This paper presents neotectonic regionalization of the Republic of Macedonia. In the central part of Macedonia, Vardar zone is located. On the eastern side of it is Eastern Macedonian zone (Serbian–Macedonian massif), and on the west is Western Macedonian zone. These mega structures have their influence on the geomagnetic field and in that way create the characteristic field for this region (GETECH, 1997)

When forming the net of the repeat stations (first order net), the arrangement of the measured points should be such as to cover the territory of the Macedonia as much as homogenous.

Conducted procedure when selecting the measured points, i.e. homogenity of the geomagnetic field, horizontal and vertical, must satisfy the standards of INTERMAGNET (Delipetrov T., 2004).

The maps of the elements of the geomagnetic fields are presented in this paper. They are compiled from the measurements on the net of the repeat stations done by Dr. Jean Rasson and MSc. Marjan Delipetrev.

The method of declination, inclination and total field measurements was used (Delipetrov T., 1991, 1996, 2003;. Delipetrov T., et al. 2006; Slimak Š, 1996).

NEOTECTONIC CHARACTERISTICS AND REGIONALIZATION OF THE TERRITORY OF THE REPUBLIC OF MACEDONIA

The geological evolution during the Neocene and Quaternary in all of Macedonia is characterized by continental development, uplift, overthrust and subsidence. .During this period, volcanic activity, the outflow of large andesite-dacite volcanic masses and tuffs occurred only in the area of Zletovo. Along reactivated deep faults there was outflow of volcanic material of some 1000 km^3. A

similar volcanic mass also developed in the area of Kožuf–Vitačevo. According to data, the volcanic activity took place periodically, although it started earlier in the Zletovo area. In the area of Kožuf it continued to the beginning of the Quaternary.

Modern relief was formed in limnic basins due to active neotectonic processes. Terrigenous layers of molasse with interbeds of coal were deposited in the depressions. During the Pliocene the terrigenous material became coarse as a result of atomization caused by tectonic movements. These processes have continued to the present time and manifest themselves as earthquakes (Skopje in 1963, Valandovo in 1931 etc.). At the end of the Pliocene and at the beginning of the Quaternary the volcanic activity consisted of outflows of basalts near Nagoričani and some other localities. Today, only traces of this activity can be seen in the area of Ohrid (the village of Kosel) in the form of sulphatara – fumarola.

All geotectonic units mentioned, starting in the Neocene, developed as continental phase. During the first phase, peneplenisation of structures developed through orogenic processes (end of Paleocene–Oligocene). In the second phase, commencing in the Miocene, a neotectonic phase took place and basic structures seen today as modern relief were formed. Mountainous massifs formed as elements of uplift and depressions formed in areas of relative subsidence.

The neotectonic processes spurred the development of new structures and at the same time reactivated structures formed earlier. Many of the underthrust faults reactivated such as the Drim fault zone, some in the Vardar zone and other places.

Neotectonic regionalization of the Republic of Macedonia took place (Fig. 1). In the western part, morpho-structures of uplift up to 2000 m in size formed. These structures of uplift are blocks elongated with meridian strike. Graben structures were formed with meridian strike as well.

This indicates that during the neotectonic stage the pattern of general uplift was an east–west expansion. The morphostructures in the Vardar zone are characterized by mountainous massif morph structures of uplift of 1000 to 1500 m (500 m lower than those structures in western Macedonia).

In the Vardar zone, depressions were the dominant structures. Skopska I, Ovčepolska II, Tikveška III, are situated above the older structures and consist of complex shapes of 100 to 400 m height. From the intensity of vertical movements, whose impact can be seen in the modern relief, and based on higher order morph structures, it is concluded that the horizontal component of extension is of a different orientation in the zones.

Unlike the Vardar zone, the morphostructures of uplift in eastern Macedonia are present as mountainous massifs 1600 – 1800 m high and the depressions are present as grabens oriented east–west. The main strain is of vertical extension, whereas the axis of extension is of meridian strike.

The neotectonic zones of Western Macedonian, Vardar, and Eastern Macedonia are rather different.

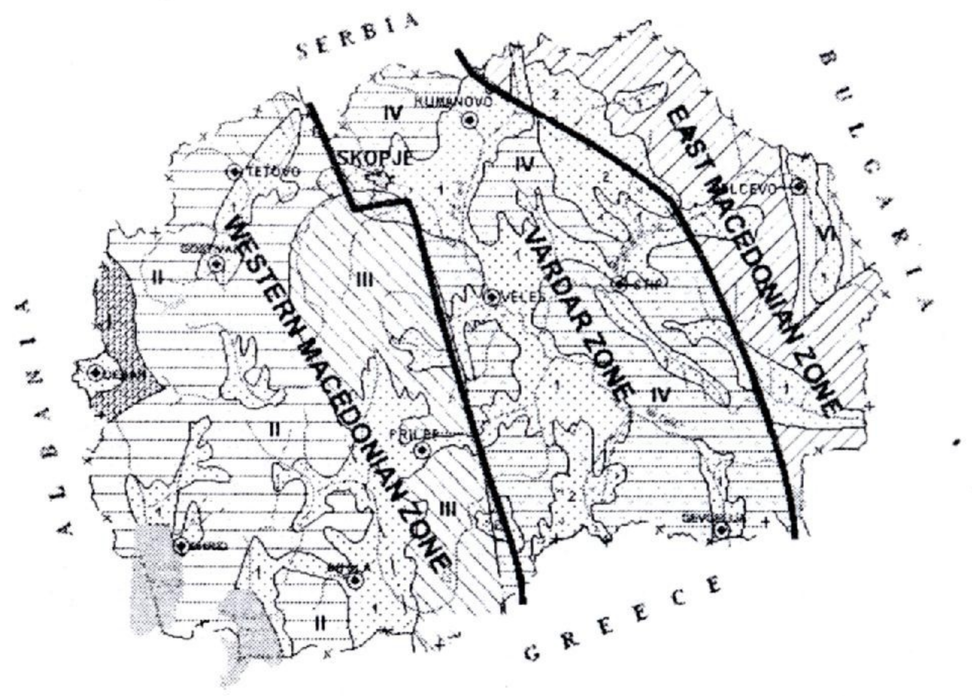

Fig. 1. Neotectonic map of the Republic of Macedonia

NET OF GEOMAGNETIC STATIONS

For complete monitoring of the geomagnetic field of a given space, it is necessary to have a basic network of stations for periodic observations of the field and geomagnetic observatory which permanent measures the weather changes of the geomagnetic field.

For definition of the coefficients of dependence of the geomagnetic field from geographic latitude and longitude of a point to a particular area (usually the state), despite the existence of geomagnetic observatory which is a benchmark point, required is relatively homogeneous network of geomagnetic stations. Performed extensive field studies, allowed defining of the 15 points on the territory of the Republic of Macedonia, which made up the network of geomagnetic repeat stations (Table 1, Figure 2).

The basic network of the repeat stations is used for periodical measurements of that point in the interval of 3 to 5 years. According the relation that follows, for a given epoch (a period of five years) we can calculate the value of any component of the geomagnetic field for a given point that belongs to region (state) that covers geomagnetic observatory with coordinates φ_0 and λ_0.

$$E(\Delta\phi,\Delta\lambda) = a_1 + a_2\Delta\phi + a_3\Delta\lambda + a_4\Delta\phi^2 + \\ + a_5\Delta\lambda^2 + a_6\Delta\phi\Delta\lambda$$

where is:

– $E(\Delta\phi,\Delta\lambda)$ is the value of the normal field at the point with geographic coordinates φ_1 and λ_1;

– φ_1 and λ_1 is geographic latitude and longitude of the point;

– φ_0 and λ_0 is geographic latitude and longitude of the reference point;

– $\Delta\varphi = \varphi_1 - \varphi_0$ is difference of geographic latitude in minutes;

– $\Delta\lambda = \lambda_1 - \lambda_0$ is difference of geographic longitude in minutes;

– a_i is coefficients of the differences in nT/minutes, minutes/minutes, or nT and minutes.

Table 1

GPS coordinates of the geomagnetic stations

Measured point	Geographic		Altitude
	latitude	Longitude	(m)
1. "Bajlovce"	42° 13' 16"	21° 55' 17"	592
2. "Crna Skala"	41° 59' 41"	22° 47' 28"	833
3. "Gradot Island"	41° 23' 15"	21° 57' 06"	317
4. "Egri"	40° 57' 56"	21° 26' 54"	626
5. "Galičica"	40° 57' 23"	20° 48' 51"	1684
6. "Luke"	42° 20' 39"	22° 16' 29"	1180
7. "Mavrovo"	41° 42' 58"	20° 43' 38"	1418
8. "Nikolić"	41° 15' 54"	22° 44' 36"	300
9. "Plačkovica" – location for geomagneticobservatory	41° 47' 41"	22° 18' 13"	677
10. "Ponikva"	42° 01' 35"	22° 21' 29"	1618
11. "Prilep Lake"	41° 24' 11"	21° 36' 32"	870
12. "St. Marija Precesna"	41° 37' 38"	21° 11' 36"	837
13. "Slivnica"	41° 36' 54"	22° 51' 46"	1252
14. "Tetovo-Želino"	41° 59' 09"	21° 04' 46"	522
15. "Vodno"	41° 58' 40"	21° 24' 57"	569

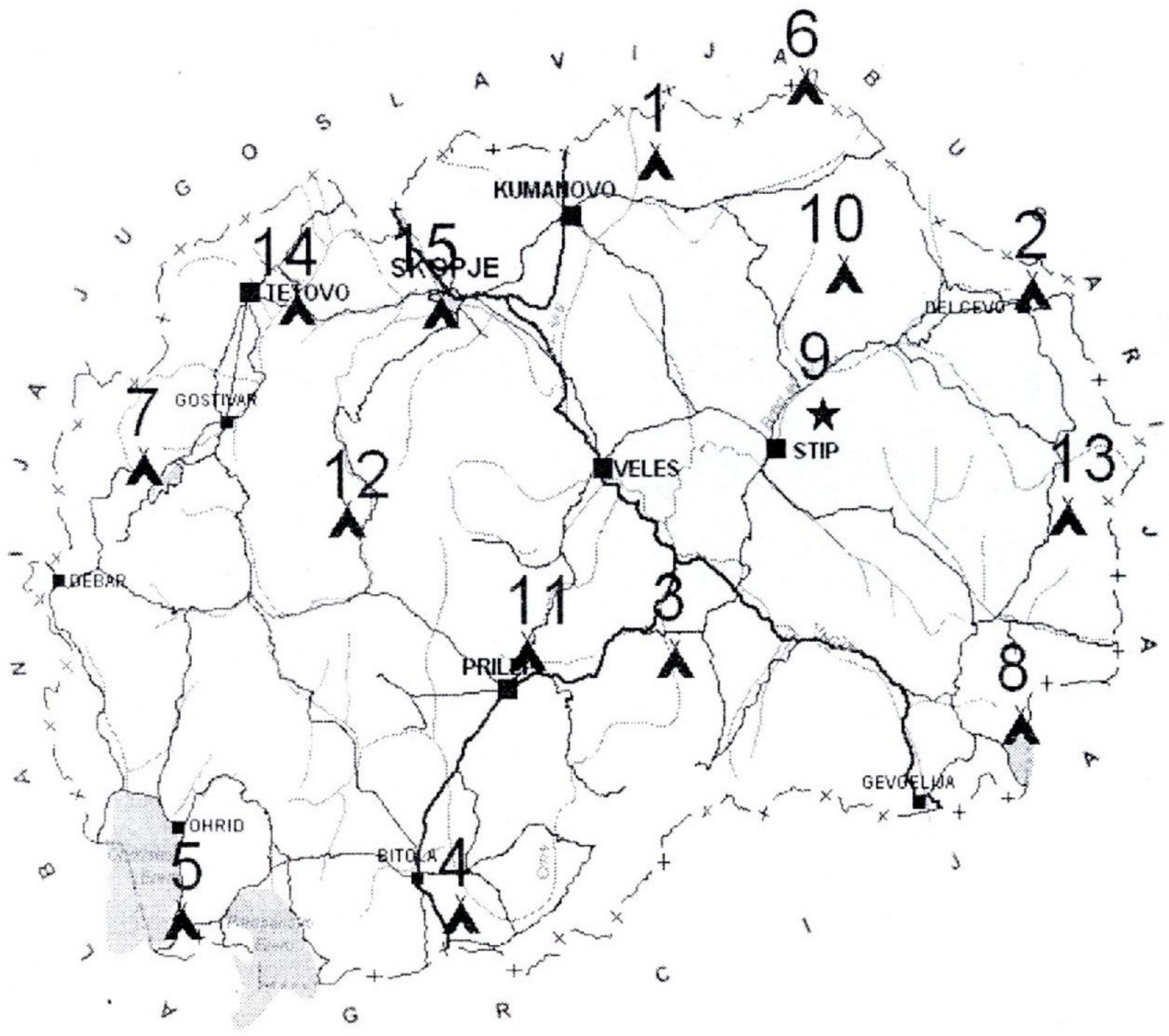

Fig. 2. Map of the geomagnetic stations in Macedonia

Galicica Magnetic Repeat Station Description

Coordinates of the Repeat Station

WGS84 / GPS

Longitude :	20°48'51"	20.8141°
Latitude :	40°57'23"	40.9563°
Altitude :	1684 m	

Hermannskogel / Bessel 1841

Longitude :	20°49'09"	20.8192°
Latitude :	40°57'21"	40.9558°
Altitude :	1635 m	

Location Maps

Yugoslavian topographic map 1:25000 1971
Ljubanista 2-1
190-2-1
Ohrid

Driving and Regional Details

From Ohrid, take the road Southwards to Sveti Naum.

Reaching the village of Trpejca you take left uphill following signs for the national park of Galicica.

After heavy ascending on a sinuous road the climb almost ends with a big turn. You have reached the mountain pass (Fig. 3). There is a parking place on the right side with a small religious monument overlooking over spectacular cliffs the Ohrid Lake and Sveti Naum.

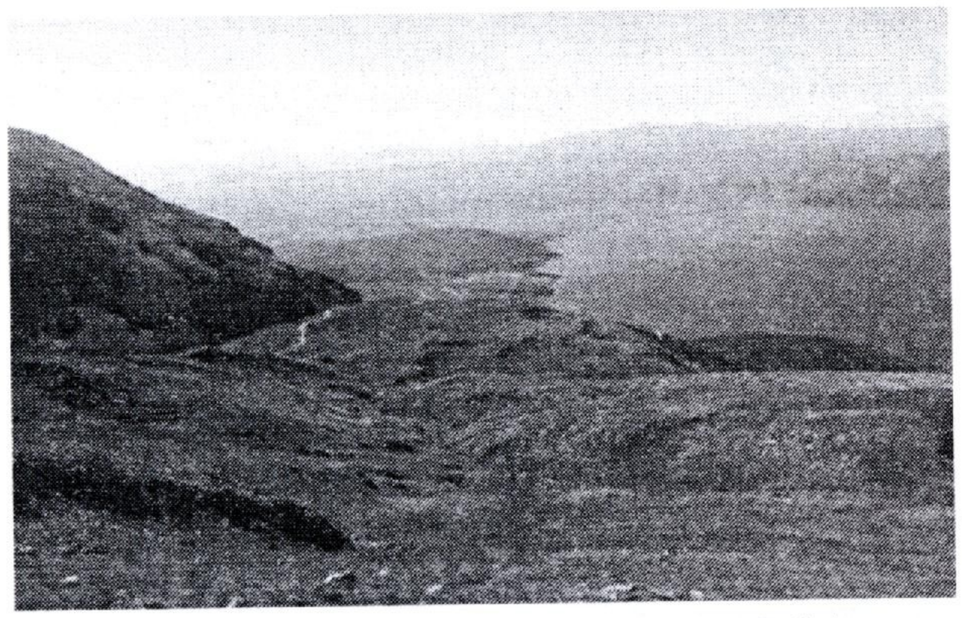

Fig. 3. Access road to geomagnetic station Galicica (J. Rasson, 2004)

Access

Leave the car on the abovementioned parking and start climbing on foot towards uphill on the left side of road (towards NE). You should climb up to a little plateau seen on **Error! Reference source not found.** 3. When you cross an eroded ditch remaining from a previous Balkan trench warfare you have arrived on site.

We plan to drive a pin marker into this rock to locate the station more accurately.

Station Marker

Location: The marker is located on a little plateau. It is on a local maximum in height.

Description: The marker is a big rock firmly seated into ground (**Error! Reference source not found.** 4) and painted yellow. The very station place is the highest part of the rock.

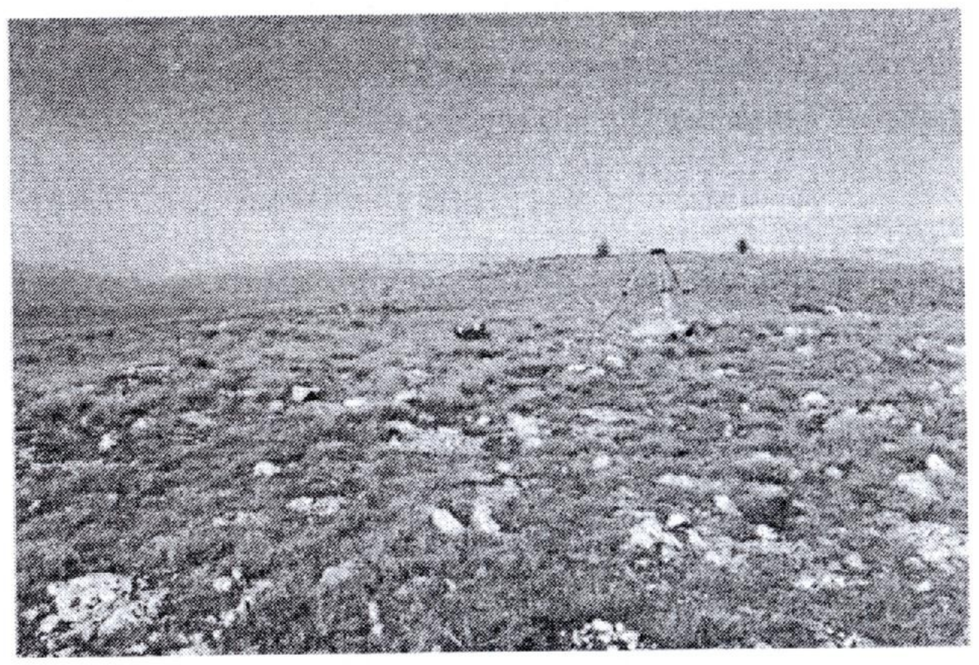

Fig. 4. Photo of measurement point Galicica (J. Rasson, 2004)f

Targets for Declination Measurement

Target description and Azimuth

Meteo Station in Albania: red/white antenna at 275° magnetic

Date of measurement:		8 august 2003
Azimuth:	282.4969°	282°29'49"

Target B description and Azimuth

Meteo Station in Albania: left corner of house at 275° magnetic

Date of measurement:		20 october 2002
Azimuth:	282.4437°	282°26'38"

Target C description and Azimuth

Sveti Naum Church Tower left at 229° magnetic

Date of measurement:		20 october 2002
Azimuth:	232.7148°	232°42'54"

Target D description and Azimuth

Antenna on Albanian Border in color red/white at 300° magnetic.

This target was used in oct 2002 for declination measurement.

Date of measurement: 20 october 2002
Azimuth: 306.6588° 306°39'32"

Target E description and Azimuth

Kalishta Struga Church right of hotel at 320° magnetic

Date of measurement: 20 october 2002
Azimuth: 326.4650° 326°27'54"

Target F description and Azimuth

Minaret Livada North from Struga at 340° magnetic

Date of measurement: 20 october 2002
Azimuth: 347.1383° 347°08'18"

Target G description and Azimuth

Top of Mountain like camel in direction of Prespansko lake

Date of measurement: 20 october 2002
Azimuth: 94.3919° 94°23'31"

Remarks

Magnetic Cleanliness

Survey made in october 2002. To be repeated in 2004

Proton survey with 1 pace separation; 46000nT + … nT

Other

Both Ohrid and Prespa lakes are visible from the station (Figs. 5, 6 and 7,).

Temperature is rather cold in morning, wear warm clothes even in summer.

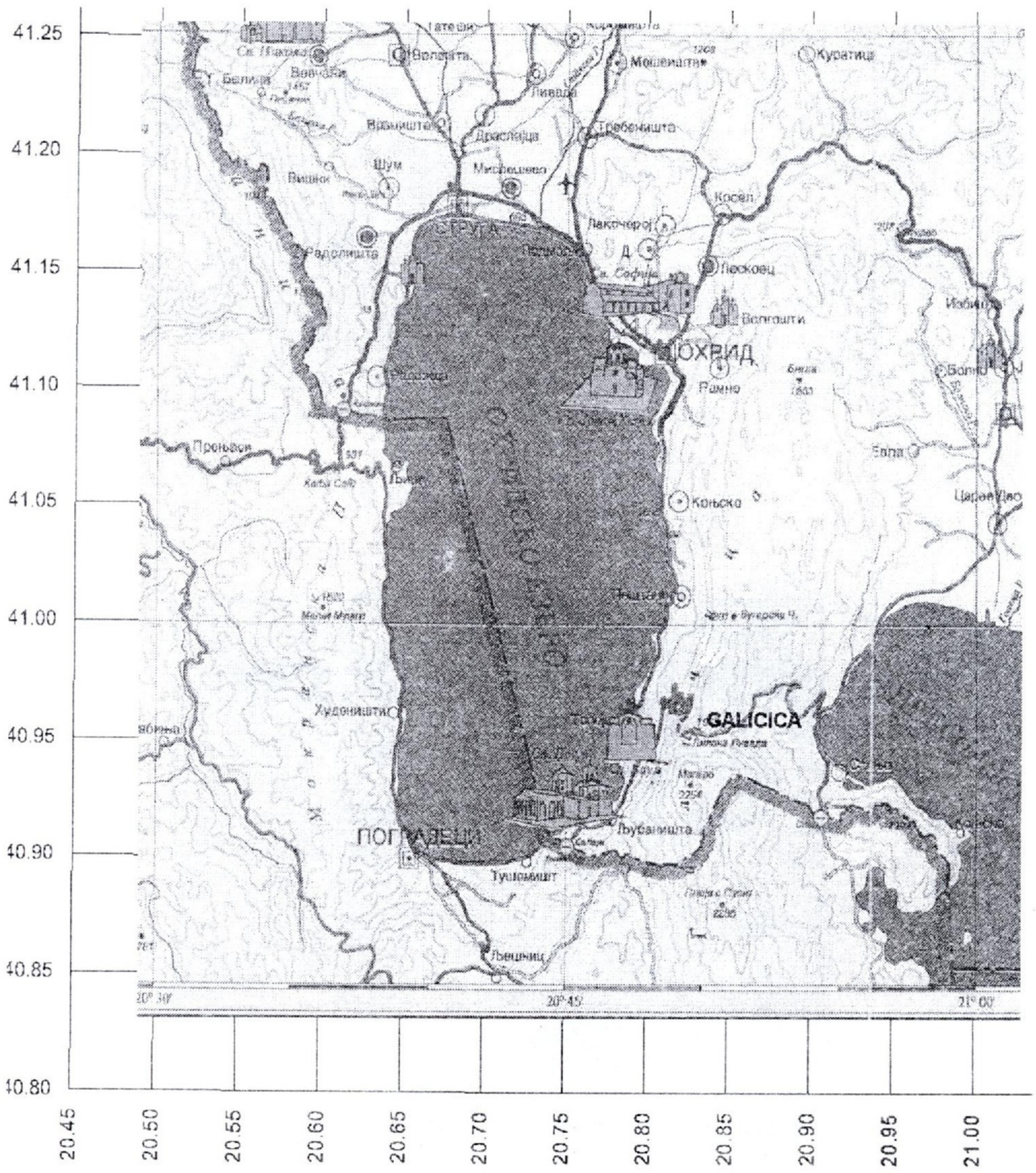

Fig. 5 Part of travel map of Macedonia - point Galicica

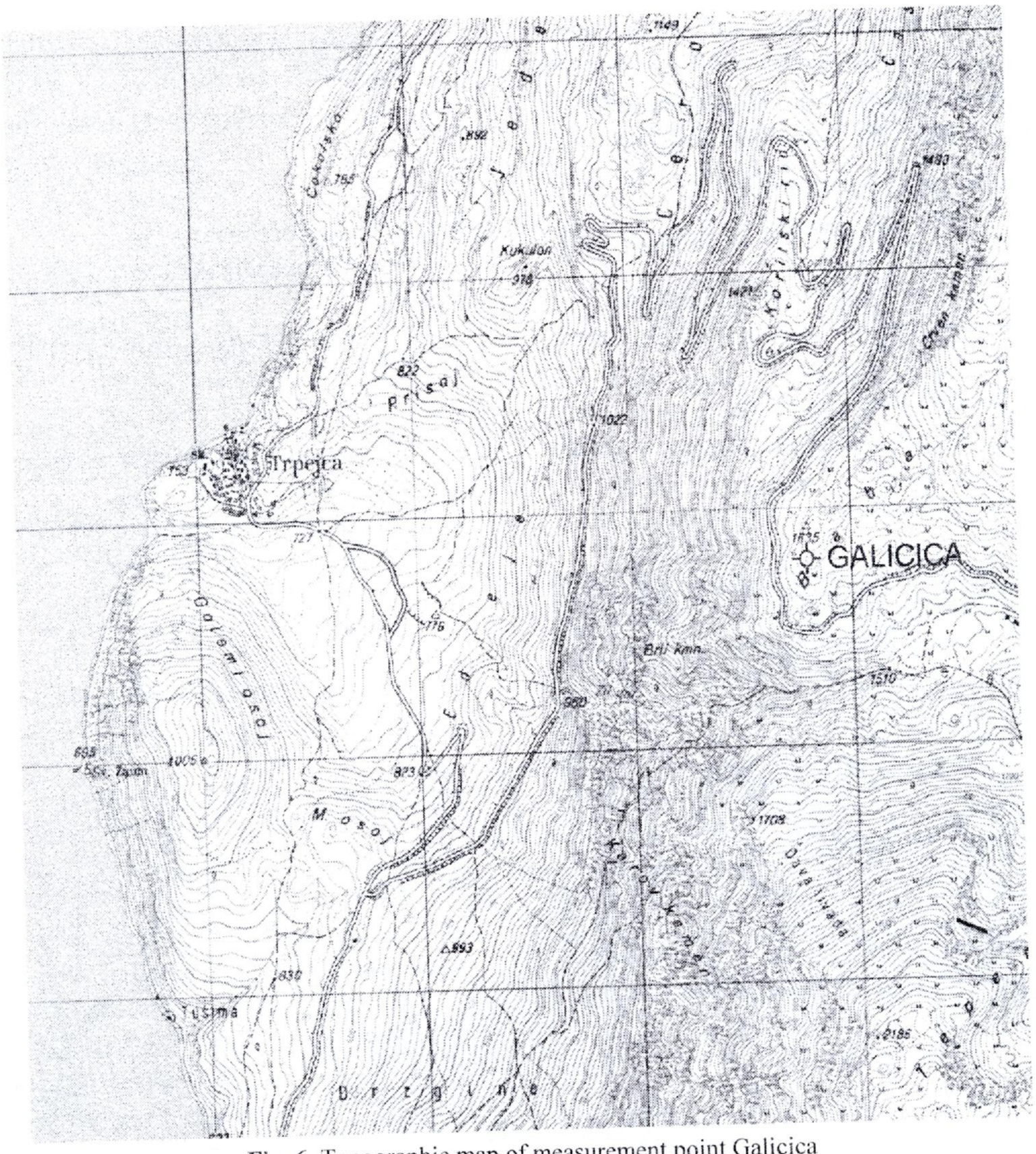

Fig. 6. Topographic map of measurement point Galicica

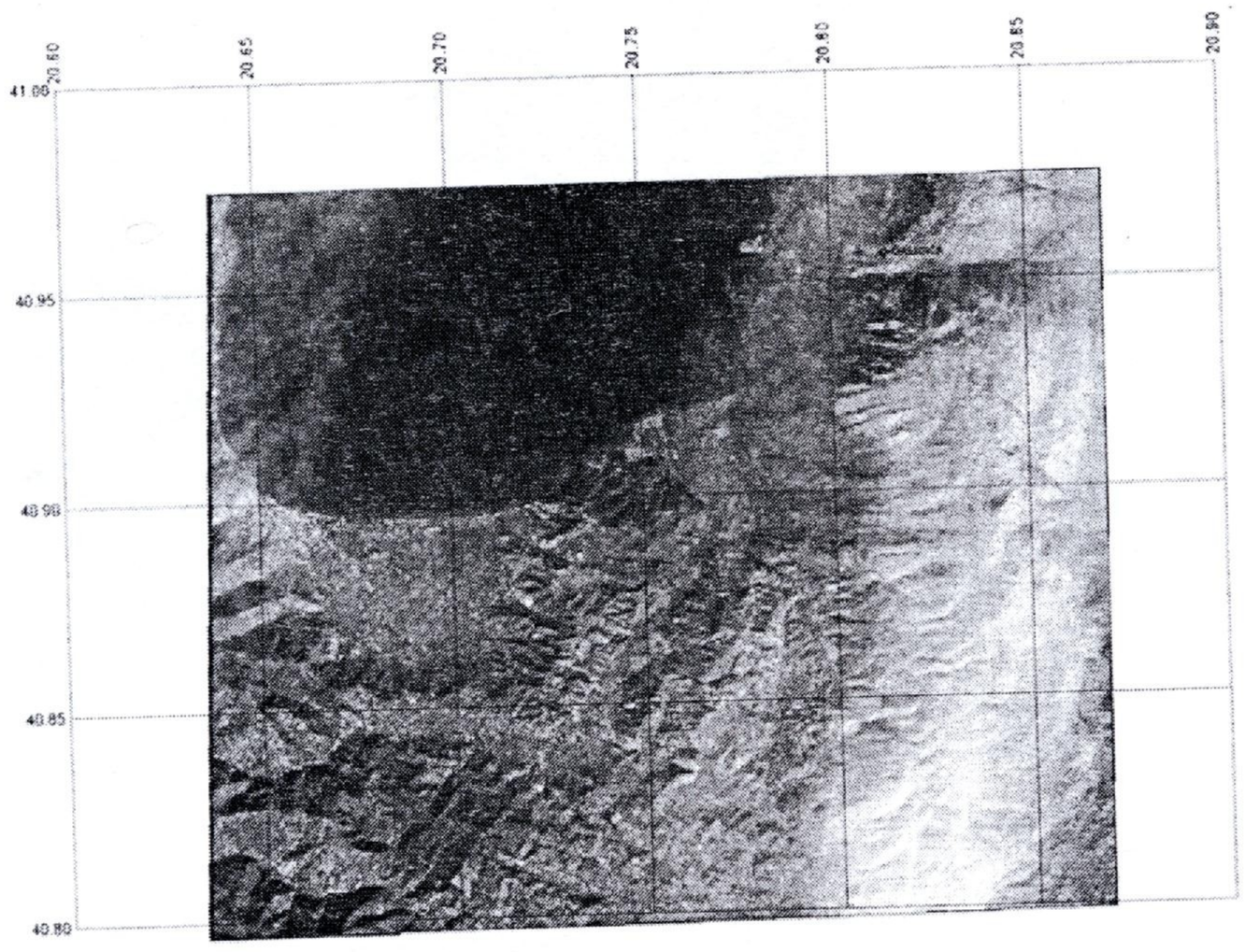

Fig. 7. Satelite photo of the terrain

GEOMAGNETIC MAPS

According the measurements on the established net of the repeat stations in 2004, maps of the magnetic field elements were compiled (Table 2, Fig. 8 – 10).

Table 2

Results from the measurements 2004

Geomagnetic stations 2004.5		Total field T	Inclination I	Declination D
Code	Locality	Mean value		
BAI	Bailovce	46758.4	59.269	2.997
CRN	Crna skala	46920.4	58.883	3.260
EGR	Egri	46430.1	57.765	3.097
GAL	Galicica	46291.2	57.694	2.955
GRA	Ostrovot Gradot	46438.4	58.083	3.576
LKA	Luke	47036.7	59.390	3.337
MVR	Mavrovo	46561.4	58.577	3.058
NIK	Nikolic	46594.8	58.203	3.146
PLC	Plackovica	46679.2	58.619	3.229
PON	Ponikva	46825.7	58.994	2.868
PRP	Prilepsko Ezero	46665.8	58.277	3.101
SLI	Slivnica	46696.9	58.509	3.442
SMP	St. Marija Precesna	46562.2	58.443	3.137
TET	Tetovo	46747.1	58.762	3.186
VOD	Vodno	46740.1	58.787	3.274

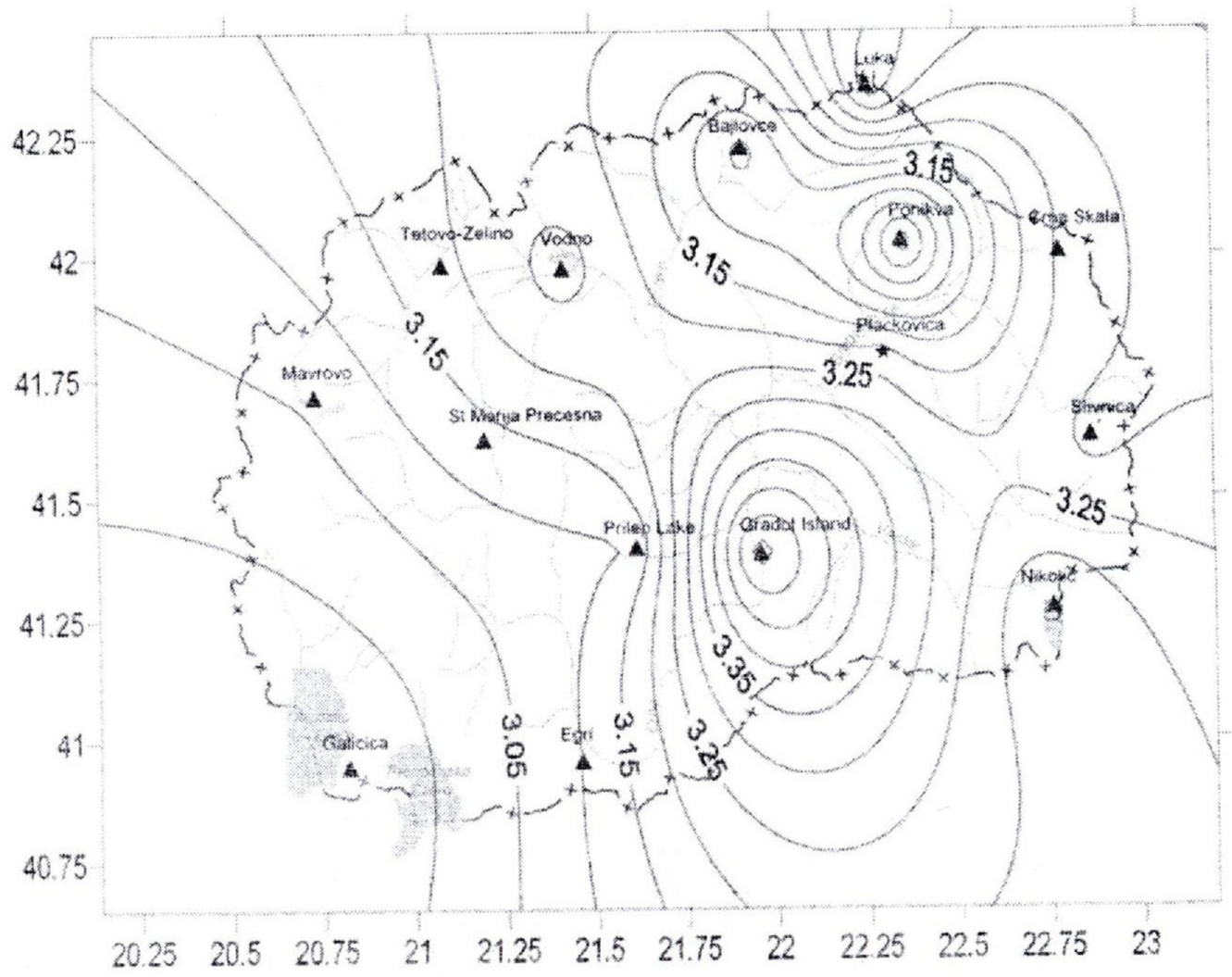

Fig. 8. Map of declination, D for 2004 (M. Delipetrev, 2004)

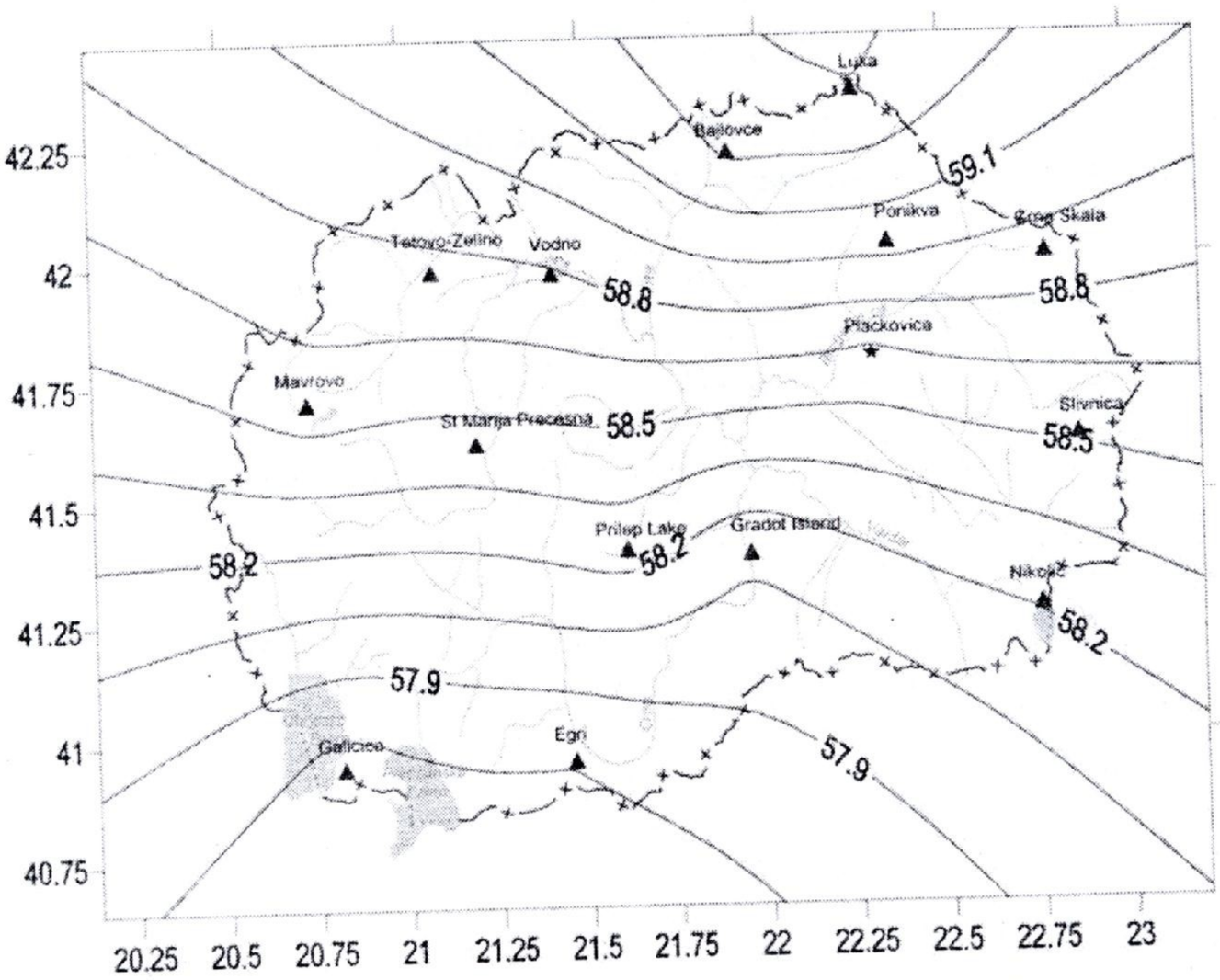

Fig. 9. Map of inclination, I for 2004 (M. Delipetrev, 2004)

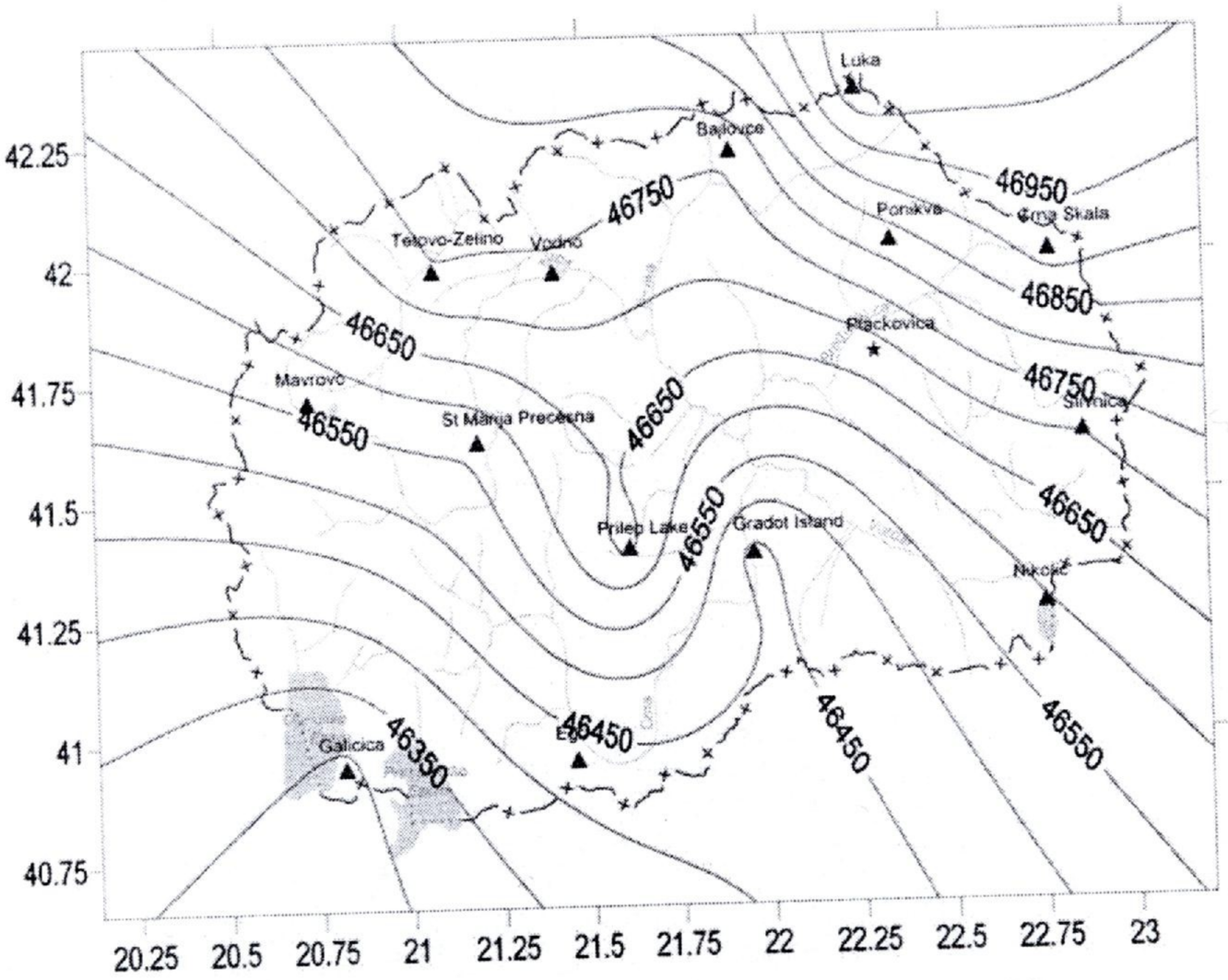

Fig. 10. Map of total field, T for 2004 (M. Delipetrev, 2004)

CONCLUSION

Net of 15 repeat stations satisfy criteria for geomagnetic net of first order;

– Number of measurement points is adequate, bearing in mind the complex relief and the geological structure;

– Elements of the geomagnetic fields of the investigated area vary for:

Total vector	≤ T ≤
Inclination	≤ I ≤
Declination	≤ D ≤

– Geomagnetic field is in good correlation with neotectonic regionalization of the Republic of Macedonia.

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Р е з и м е

МРЕЖА НА МЕРНИ СТАНИЦИ И ТЕКТОНСКА РЕОНИЗАЦИЈА НА РЕПУБЛИКА МАКЕДОНИЈА

Марјан Делипетрев[1], Жан Л. Расон[2], Благица Донева[1], Тодор Делипетров[1]

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Клучни зборови: мерна станица; геомагнетно поле; деклинација; инклинација; тотално поле

Геомагнетното поле е векторски збир на причинители кои се наоѓаат длабоко во земјината внатрешност и нивното влијание може да се почувствува на целата Земја. Постојат изнори на магнетни полиња кои се карактеристични за големи региони и локални аномални геомагнетни полиња.

При избирање на локација за мерна станица, треба да се избегнуваат региони каде има локални геомагнетни аномалии, со цел мерните резултати што ќе се добијат, да бидат карактеристични за тој регион.

Територијата на Република Македонија има комплексен релјеф, а исто така и комплексна геолошка градба и овие особини имаат големо влијание на регионалното геомагнетно поле.

Имајќи ги во предвид сложениот релјеф и комплексната геолошка градба, за секоја избрана мерна станица беше спроведена строга процедура за мерење на геомагнетното поле.

Картите креирани од мерењата во 2004 година се презентирани во овој труд.