GEOMAGNETIC FIELD OF THE REPUBLIC OF MACEDONIA

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Abstract. The paper presents geomagnetic investigations carried out in the territory of the Republic of Macedonia. It also gives the geologic and geographic location of the country on the Balkan Peninsula. The detailed description of the tectonic setting contains reference of the neotectonic distribution. The paper presents investigations that commenced in the 19th century and those carried out in 2003. Geomagnetic investigations have been separated from investigations of the normal magnetic field and those of the anomalous geomagnetic field and presented in a chronologic manner. Analysis of activities carried out during geomagnetic investigations indicate that the most intense were those of 1950s and 1960s for the discovery mineral deposits and those in 1970s for the investigation of normal magnetic field. Of note are investigations that have been carried out since 2002 in order to study the normal magnetic field in the territory. During this short period of time a grid of repeat stations was established and the site for the construction of the geomagnetic observatory in the country was selected.

Keywords: Geology, Republic of Macedonia, Geomagnetism, Balkans

1. Geotectonic position of the Republic of Macedonia

The territory of the Republic of Macedonia occupies the south central part of the Balkan Peninsula which geotectoniclly belong to the Alpine - Himalayan geosynclines area.

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During the tectonic evolution, eight geotectonic units were differentiated in the Balkan Peninsula, which were later separated into eight younger units also important for the regional geotectonic setting of the area. The geotectonic units, from east to west include (see Figure 5):

- The Mesian plate
- The Carpatho - Balkanides
- The Rhodope mass - Serbo - Macedonian massif
- The Vardar Zone
- The Dinarides - Helenides
- The Adriatic massif (Apulian plate)

Of these, the following are present in the Republic of Macedonia; parts of the Carpatho - Balkanides (separated as Strumica zone), the Rhodope mass - Serbo Macedonian massif (separated as Macedonian massif), the Vardar zone, Dinaride - Helenides (separated as Serbo - Macedonian zone and Pelagonian massif) and the Adriatic massif (present as a small part at the border with Albania, separated as Korabides).

The Mesian platform represents the western part of the Ponto - Caspian table which belongs to the Russian platform. The Mesian platform includes part of northeastern Serbia, a large part of Romania and northern Bulgaria as far as the Black Sea.

The Carpatho - Balkanides is part of the northern border of the Alpian orogeny, which, in the eastern Alps, is an arc that continues through the Carpathian mountains in Romania and follows the Danube to eastern Serbia. From there it goes to Bulgaria, and continues east to the Black Sea.

The Rhodope mass - the Serbo Macedonian massif, as a first order geotectonic unit embraces the central and eastern part of Serbia, the eastern part of Macedonia, from where it continues to central and southeastern Bulgaria, eastern Greece, and continuing to Romania in the north. In the east and northeast the massif overthrusts the Carpatho - Balkanides, and in the west and southwest overlies the Vardar zone.

Starting from the Alps, the Dinarides - Helenides extend to the south through the terrain of Slovenia, Croatia, Bosnia and Herzegovina, the western parts of Serbia and Macedonia, Albania and Greece where they bend to the east continuing to Asia Minor.

According to their strike, the Dinarides are divided into Dinarides (proper), developed as far as the Skutari - Pec fault, to Helenides which include the western terrains of Macedonia (west of the Vardar zone), Albania, Greece, and to Taurides which are developed in the central and western parts of Asia Minor (Turkey).

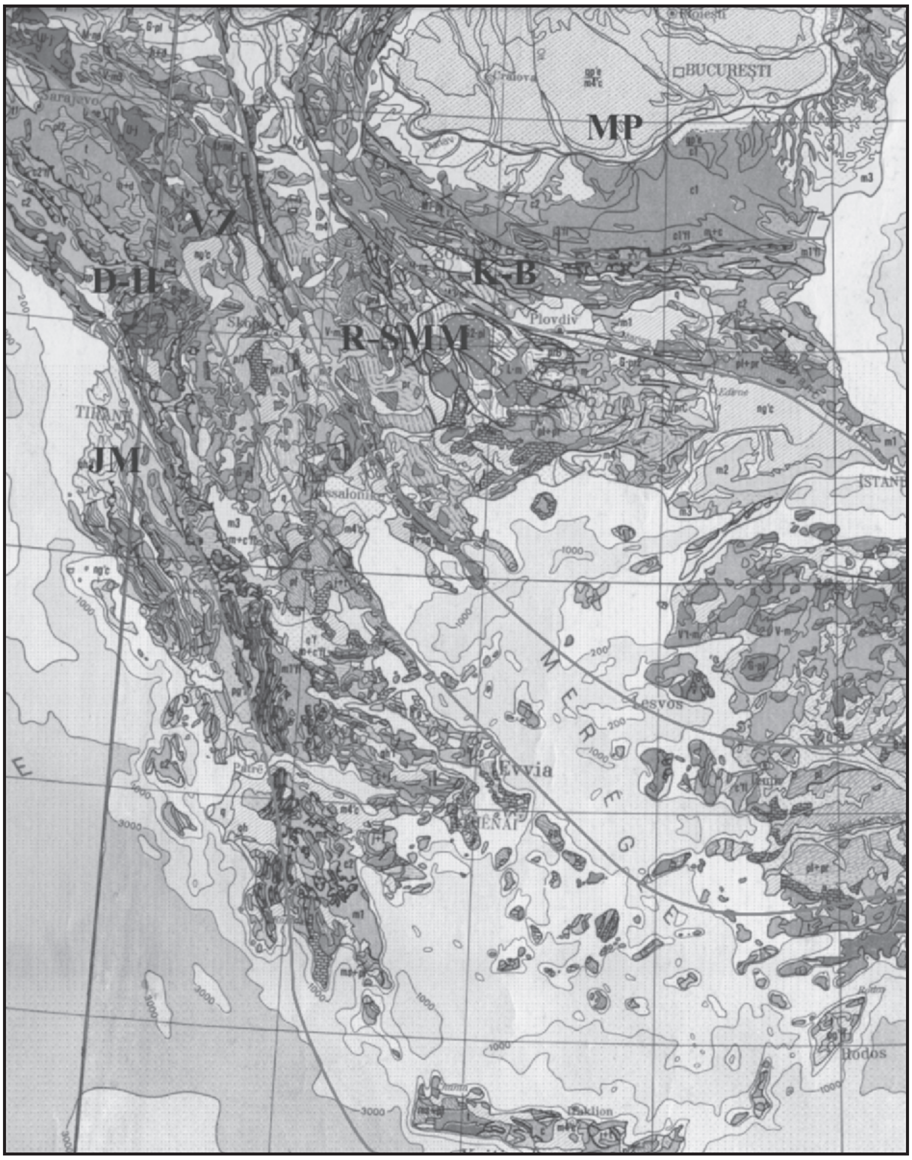

Figure 5. Map of Balkan Peninsula with some geotectonic units MP - Mesian plate, K-B - Karpatho-Balkanides, R-SMM - Serbian-Macedonian massif, VZ - Vardar zone, DH - Dinarides-Helenides, JM - Adriatic massif (Apulian plate).

The Vardar zone, an old geosyncline, was formed during the break up of the Grenville earth crust in the Riphean - Cambrian. Until the Triassic it had geosynclinal development. During the Jurassic, the opening of the continental crust in the area resulted in the formation of ocean type crust within the Vardar- Izmir- Ankara zone.

The Adriatic massif is situated between the Alpine - Apeninian and Dinaride - Helenide geosyncline system, representing part of the African platform. It played an important role during the formation of the Dinaride - Helenide tectonic structures in the east and the Apennines in the west. The massif is also known as the Apulian platform (part of the African platform), the Adriatic geosyncline area, and an intermountainous depression.

2. Regional tectonic setting

Information offered by many authors (Arsovski at al. 1975) helped to compile Figure 6 and give the regional tectonic setting of the Republic of Macedonia.

The Republic of Macedonia belongs to the Dinaride and the Rhodope system. The part of Macedonia west of the Presevo - Zletovo - Strumica - Dojran line belongs to the Dinaride system and east of the line is part of the Macedonian massif which, with the Ograzden massif, joins the Rhodope system.

The Macedonian massif in this part of the Alpine orogeny is a geological anticline zone, or mid - position massif that separates the Dinarides from the Carpatho - Balkanides. In the area bordering Bulgaria east of the Berovo - Pehcevo line, elements of the Carpatho - Balkanides have been forced as a wedge into the old Rhodope massif, known as Strumica zone (Kraistides) separating the Rhodope and the Eastern Macedonian massif.

The territory of Macedonia, west of the Presevo - Zletovo - Strumica - Dojran line belongs to the Dinaric system. Four zones have been distinguished: the Vardar zone, the Pelagonian horst - anticlinoriums, the western Macedonian zone, and the Serbo Macedonian massif.

These zones represent individual structural facies units with their own geological evolution.

The structural zones are characterized by their own geological evolutions which can be seen from various lithological complexes that differ in composition, age, and dislocation.

Different types of rocks (metamorphic, intermediary to igneous), from Precambrian to Cenozoic are present.

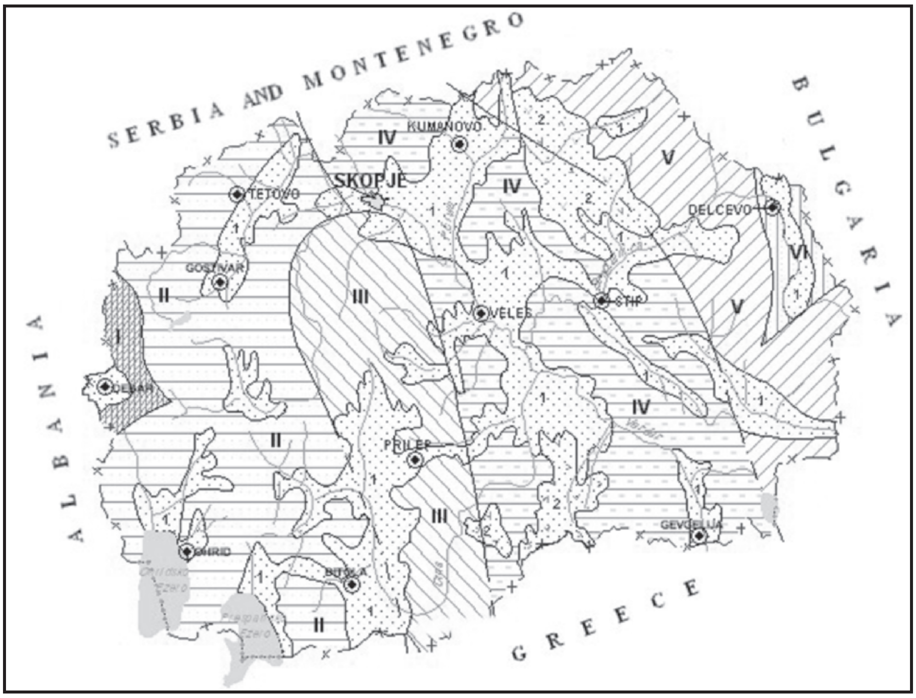

Figure 6. Regional tectonic setting of the Republic of Macedonia I - Cukali Krasta zone, II - Western Macedonian mass, III - Pelagonian horstanticlinorium, IV - Vardar zone, V - Serbo-Macedonian massif, VI - Kraistide zone.

2.1. NEOTECTONIC CHARACTERISTICS AND ZONATION 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 Kozuf - Vitacevo. According to data, the volcanic activity took place periodically, although it started earlier in the Zletovo area. In the area of Kozuf 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 Nagoricani 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 zonation of the Republic of Macedonia took place (see Figure 7). 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.

Figure 7. Neotectonic map of the Republic of Macedonia.

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, Ovcepolska II, Tikveska III, are situated above the older structures and consist of complex shapes of 100 - 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.

3. Review of geomagnetic investigation carried out

Geomagnetic investigations can be divided into three periods: those started in the 19th century up to 1945, those carried out between 1945 and 1991 when Macedonia was a constitutional part of Yugoslavia, and those after the declaration of independence in 1991.

During the first period, due to unstable political conditions and the scientific backwardness of the Turkish Empire and the Kingdom of Serbs, Croats and Slovenians, scientists from European countries investigated the magnetic field of the Balkans including a small part of the territory of Macedonia only on rare occasions. These investigations are of historic importance but due to their sparcity did not offer any deep scientific understanding of the geomagnetic field in the area.

During the time of the Federal Republic of Yugoslavia, a geomagnetic observatory was established in Grocka, near Belgrade. They initiated and carried out geomagnetic investigations on an ongoing basis and occasionally acquired data from geomagnetic field stations across Yugoslavia. During this period field stations were established in Ohrid and Strumica. The observatory also initiated all field investigations in terms of defining areas of geomagnetic anomalies.

After the Second World War, particularly during the 1950,s and 1960’s, intensive geomagnetic investigations were completed with the aim of discovering new deposits of mineral raw materials.

The following two sections of this paper discuss the geomagnetic investigations carried out so far. Section 3.1. discusses investigation and study of the geomagnetic field, and section 3.2. discusses geomagnetic investigations for the discovery of deposits of mineral raw materials.

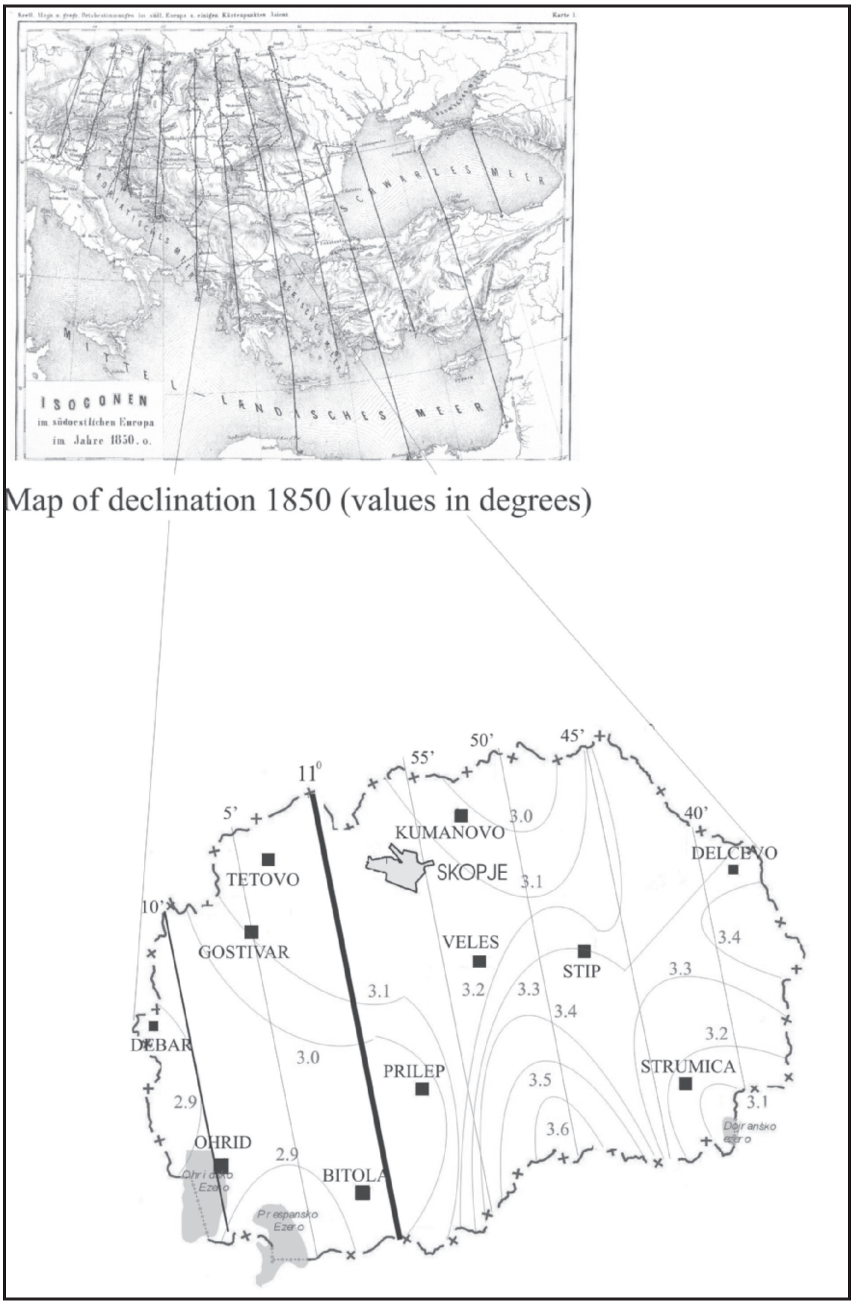

Figure 8. Map of declination in Macedonia 1850.0 and 2003.5.

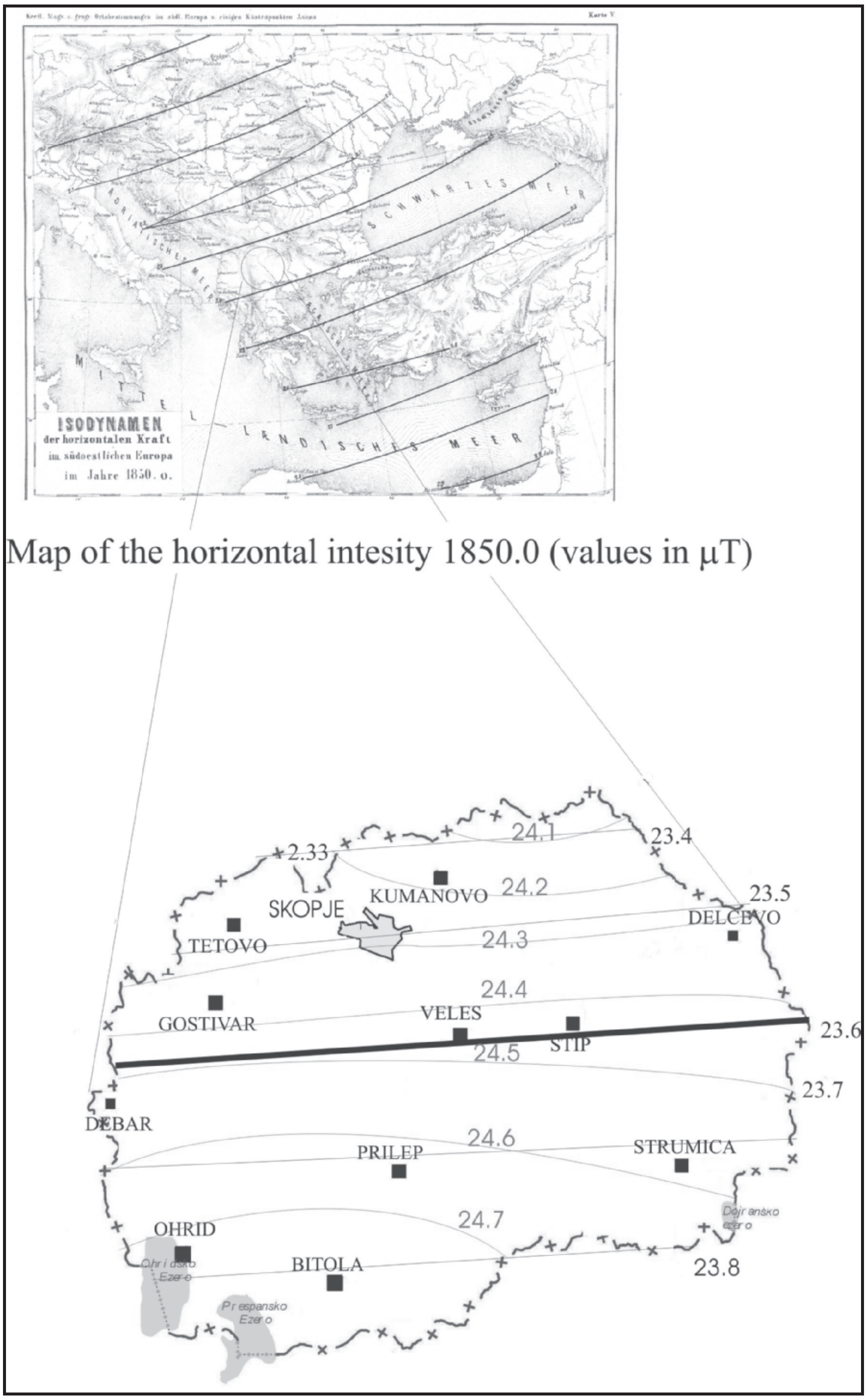

Figure 9. Map of horizontal intensity in Macedonia 1850.0 and 2003.5.

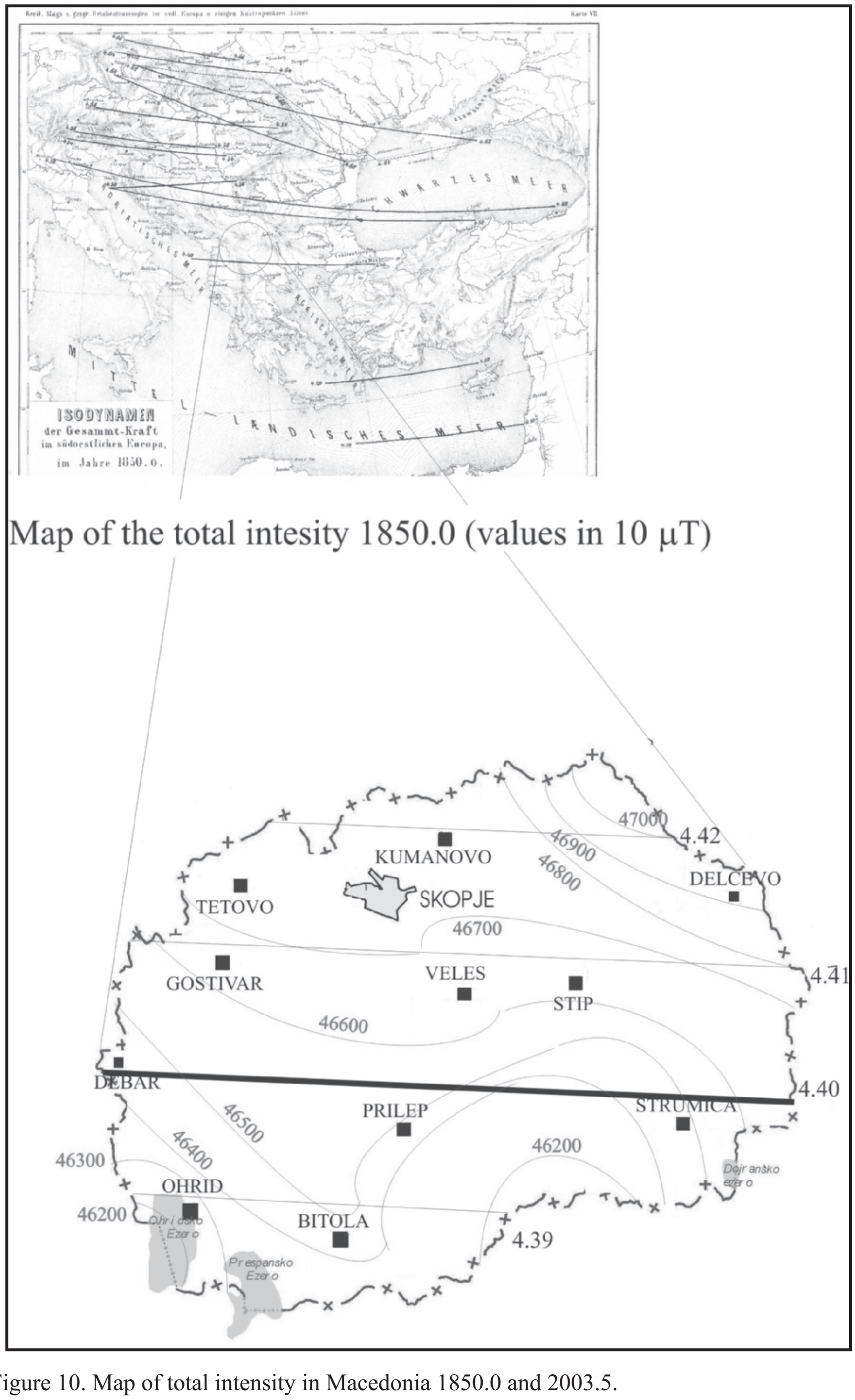

Figure 10. Map of total intensity in Macedonia 1850.0 and 2003.5.

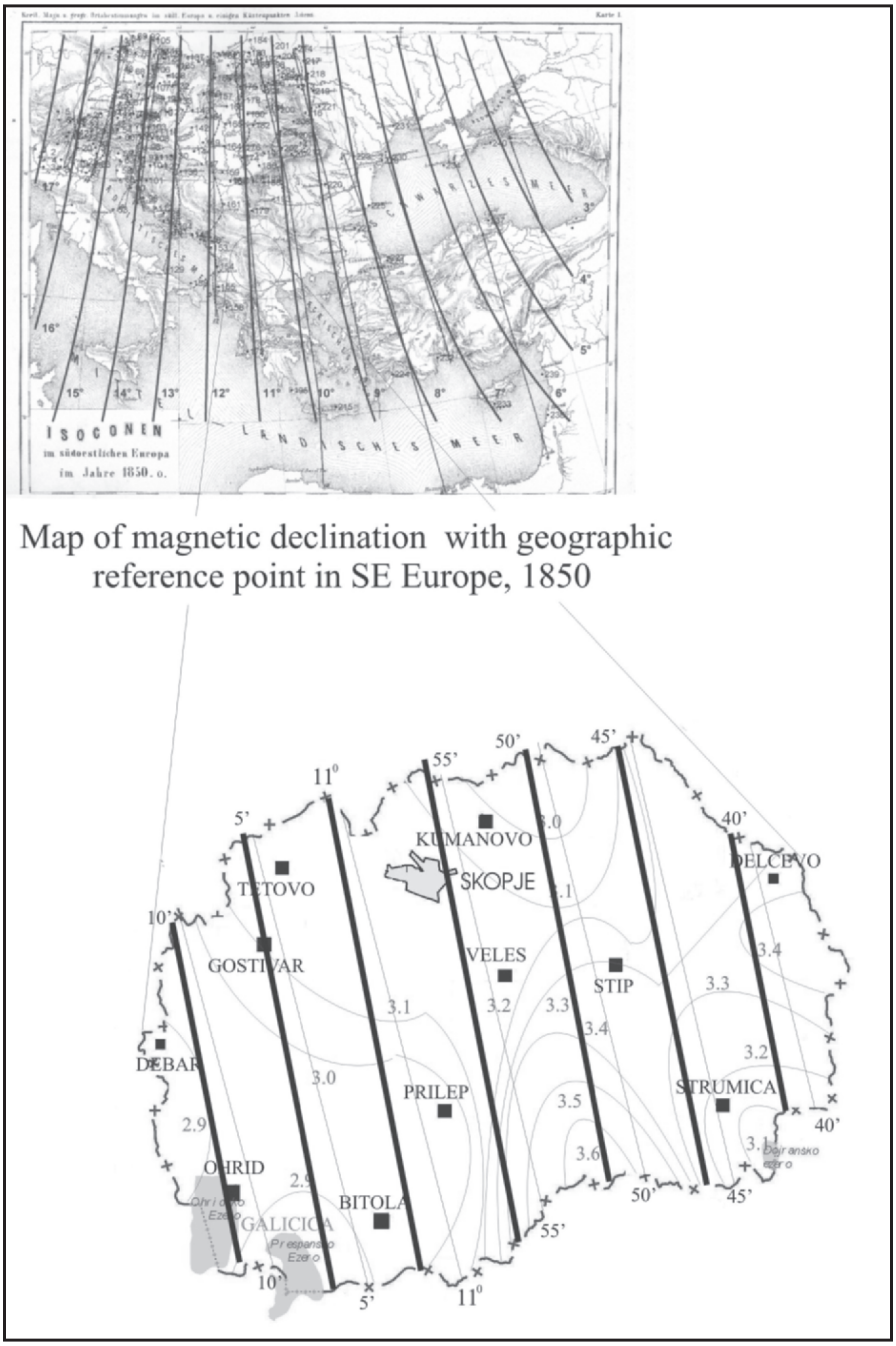

Figure 11. Presentation of lines of equal declination with geographic reference point in Macedonia, 1850.0 and 2003.5.

3.1. INVESTIGATION AND STUDY OF THE GEOMAGNETIC FIELD

Geomagnetic measurements carried out in the territory of Macedonia show that during the 19th century magnetic observations were made over a wide area of eastern Europe, although with a sparse grid. This paper presents the maps compiled for the 1850.0 epoch by Karl Kreil[8].

Black isolines on the maps indicate the result of Kreil's investigations and red isolines show results of the investigations carried out in 2002 and 2003 by Jean Rasson and Marjan Delipetrov[4] (see Figure 8 – Figure 11).

During the 1960's the territory of Yugoslavia was investigated with a relatively dense grid of field stations. A map of the vertical or Z component of the anomalous geomagnetic field of Yugoslavia with a scale of 1 : 500 000 was compiled[2] (Figure 12).

All investigations were centralized and marked as "top secret". Purchase of instruments for geomagnetic measurements was impossible.

During the 1970's a project was implemented for central and eastern Europe which included the observatories given in Table 2.

Table 2. Observatories in central and eastern Europe.

IAGA Code	Name	Country	Operation	Latitude	Longitude
FUR	Furstenfeldbruck	Germany	1939-	48.17	11.28
AQU	L' Aquila	Italy	1960-	42.38	13.32
BDV	Budkov	Czech Republic	1967-	49.07	14.02
WIK	Wien Kobenzl	Austria	1851-	48.27	16.32
NCK	Nagycenk	Hungary	1961-	47.63	16.72
THY	Tihany	Hungary	1955-	46.90	17.89
HRB (OGY)	Hurbanovo	Slovakia	1894-	47.87	18.19
GCK	Grocka	Serbia	1958-	44.63	20.77
CST	Castel Tessino	Italy	1965-	46.05	11.65
ROB	Roburent	Italy	1964-1973	44.30	07.90
PRU	Pruhonice	Czech Republic	1946-1972	50.00	14.55
REG	Regensberg	Germany	(1931-1956)	47.50	08.45
POL	Pola	Austrian Empire	1847-1909	44.87	13.85
PAG	Panagyurishte	Bulgaria	1948-	42.50	24.20
LVV	Lviv	Ukraine	1952-	49.90	23.75
PEG, PEG2	Penteli	Greece	1959-	38.10	23.90
SUA	Surlari	Romania	1949-	44.68	26.25
ISK	Kandili	Turkey	1947-	41.06	29.06

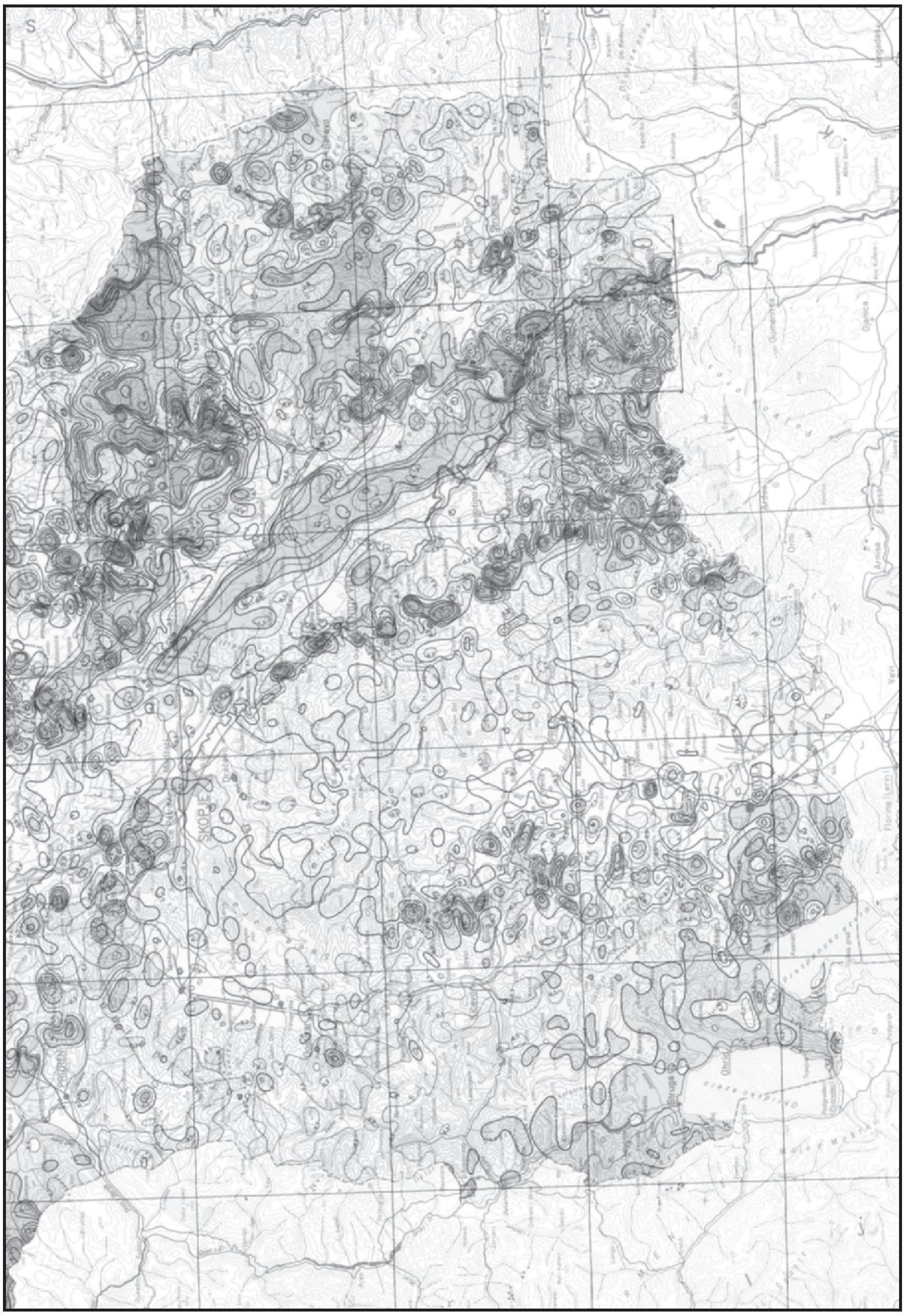

Figure 12. Map of the vertical or Z component of Macedonia.

The maps that follow (Figure 13 - Figure 16) show the location of observatories and components of the normal geomagnetic field for the 1970.5 epoch.

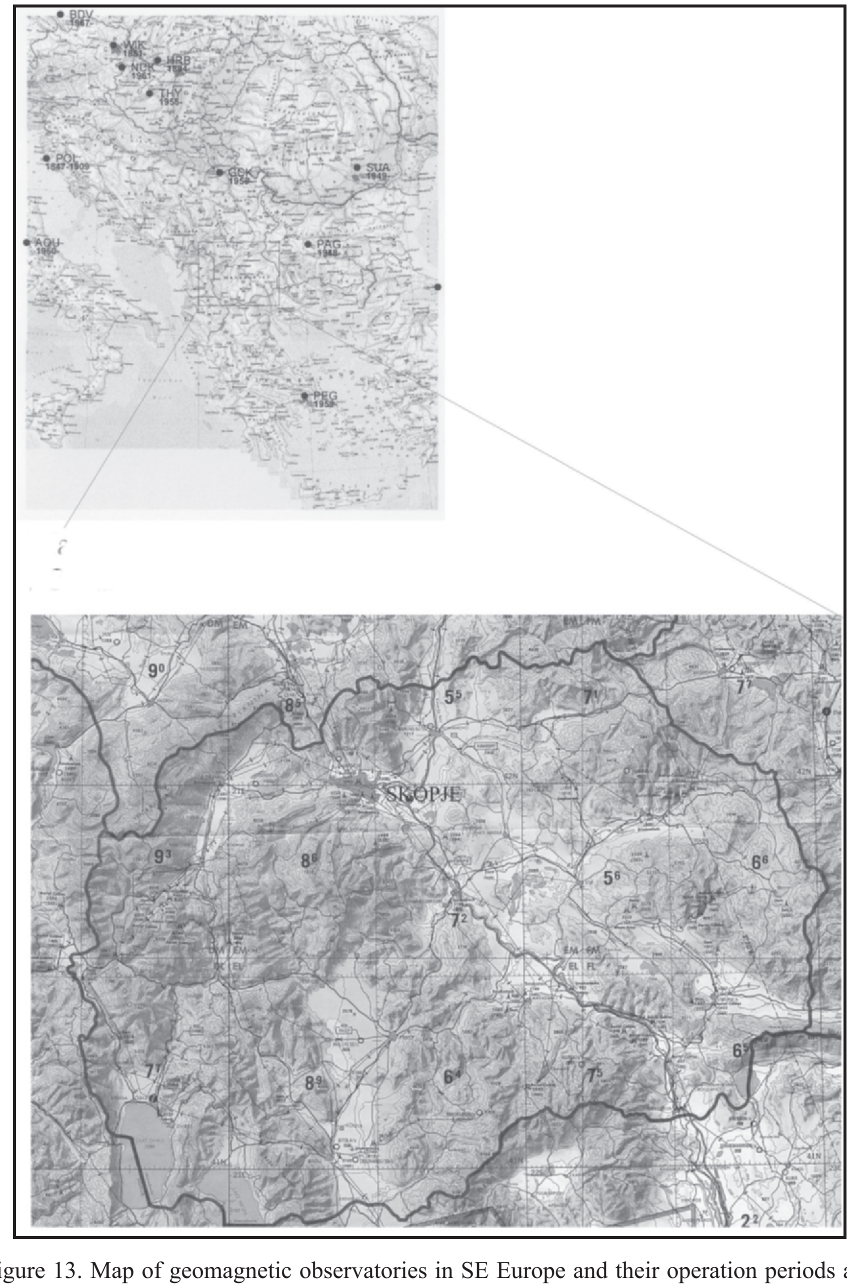

Figure 13. Map of geomagnetic observatories in SE Europe and their operation periods and map of Macedonia.

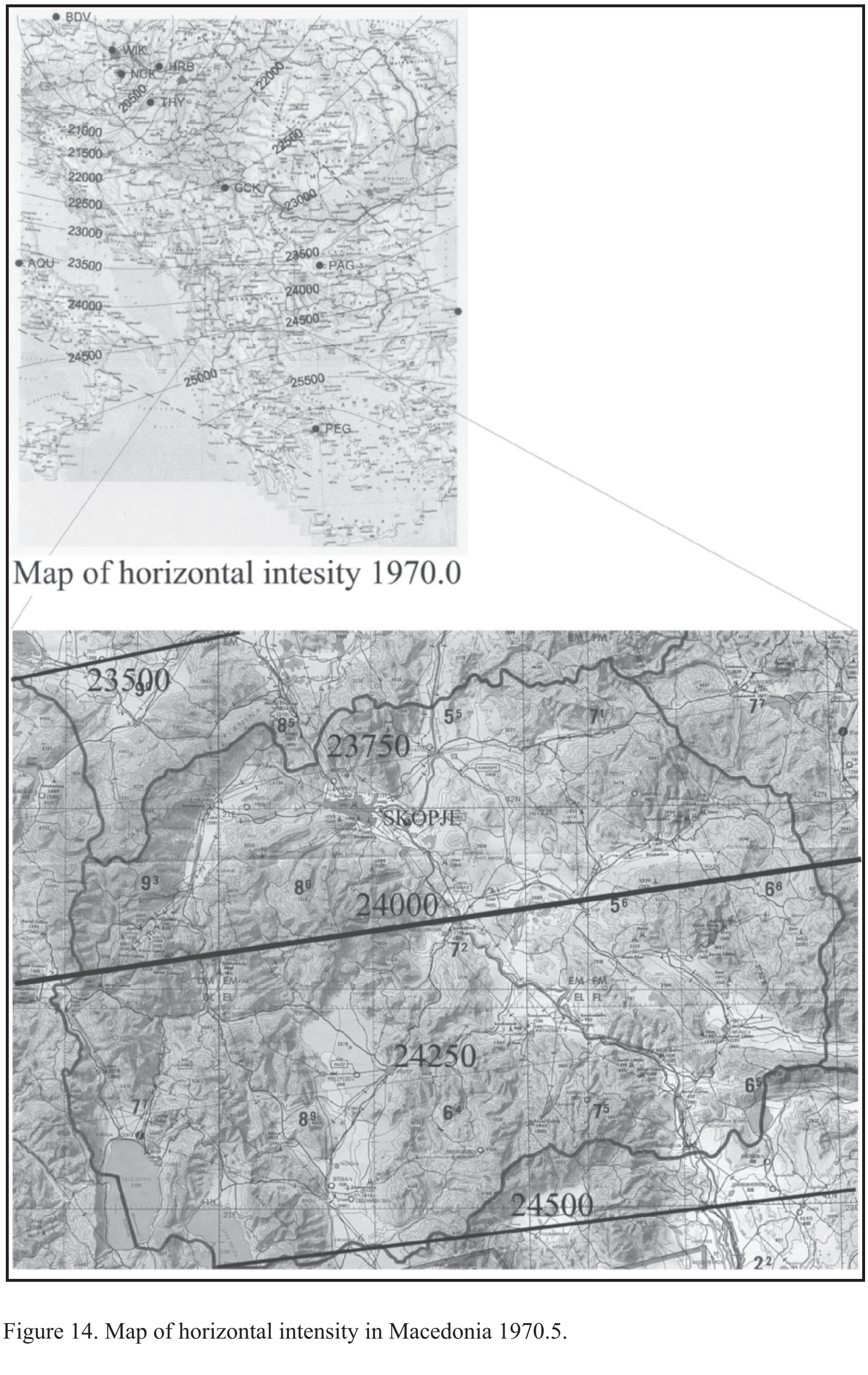

Figure 14. Map of horizontal intensity in Macedonia 1970.5.

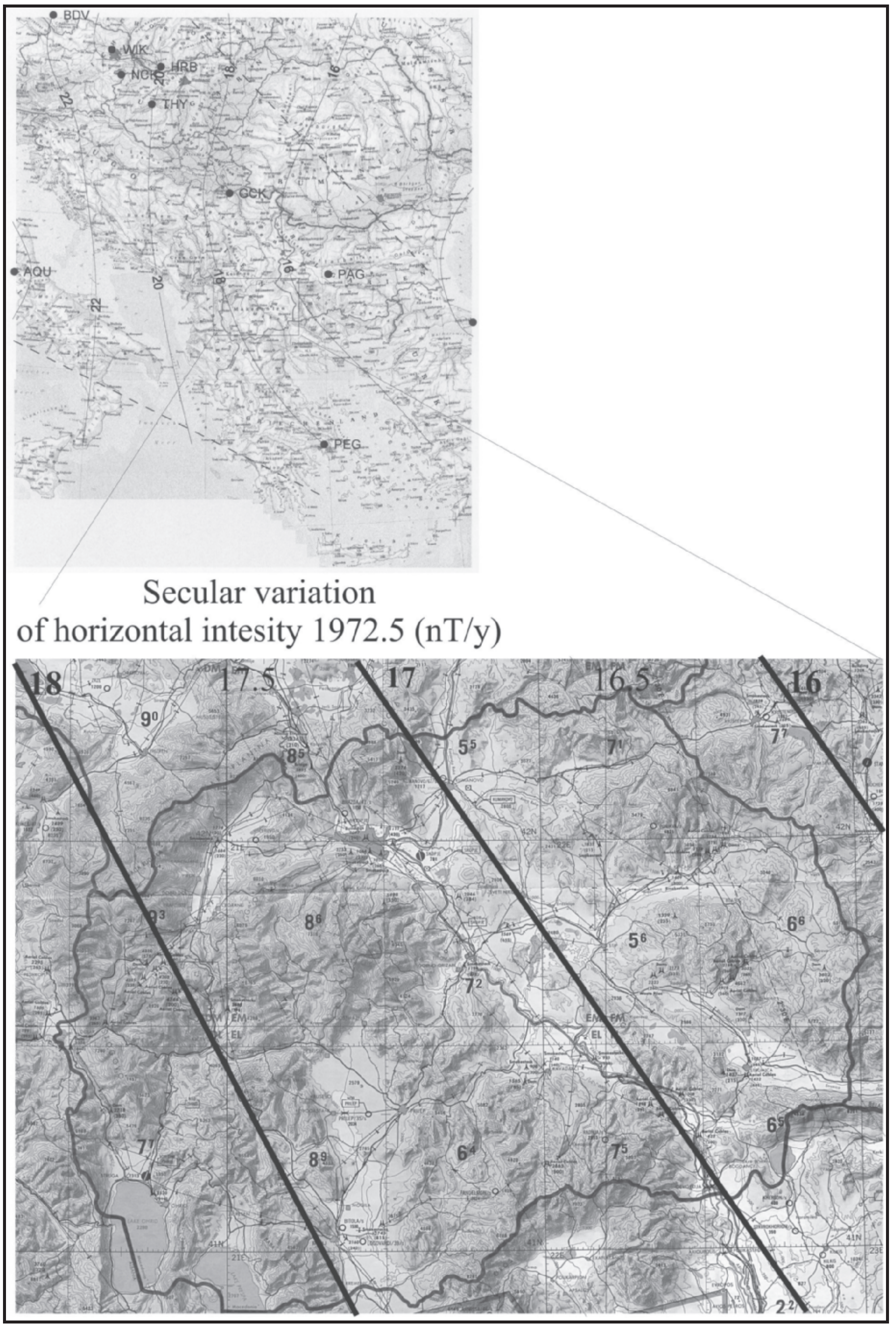

Figure 15. Map of secular variation of horizontal intensity in Macedonia 1972.5.

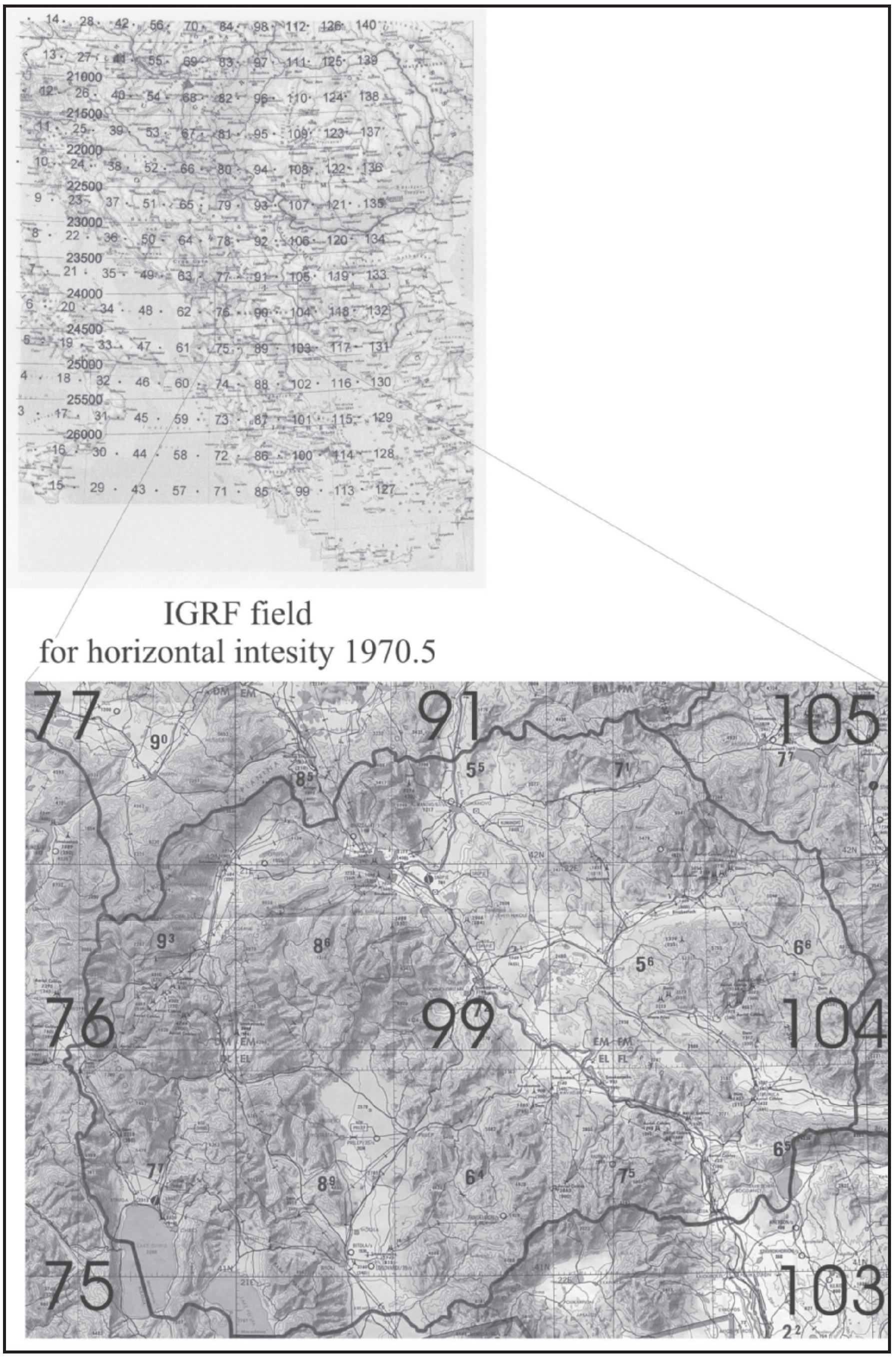

Figure 16. Map of IGRF field for horizontal intensity in Macedonia 1970.5.

In 1997 a project was implemented under the title "Eastern Europe Magnetic Project" (EEMP) in which Report 8[6] was carried out for Macedonia in cooperation with GETECH, Geophysical Exploration Technology. The collaborator from the Republic of Macedonia was Prof. Dr. Todor Delipetrov. The following maps offer a presentation of investigations carried out (Figure 17 – Figure 22).

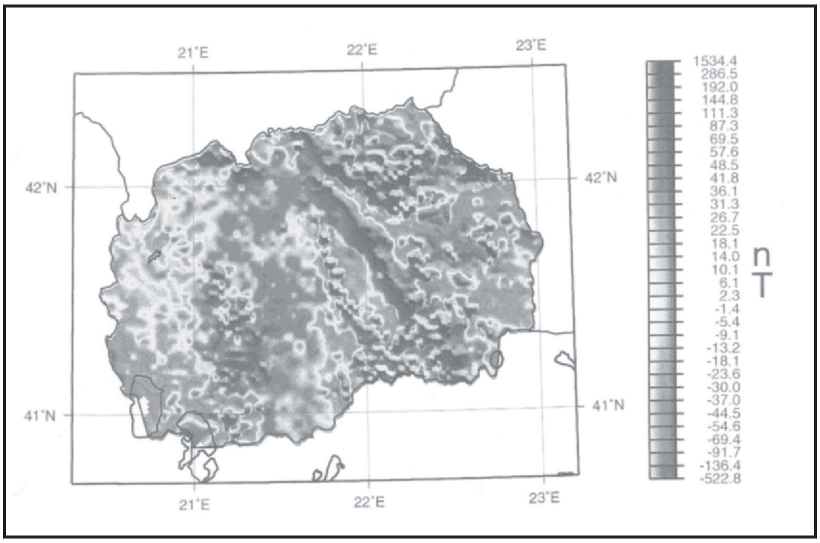

Figure 17. Vertical field (ΔZ) anomaly map of Macedonia based on 1 km grid at original survey elevation (~1 m above ground).

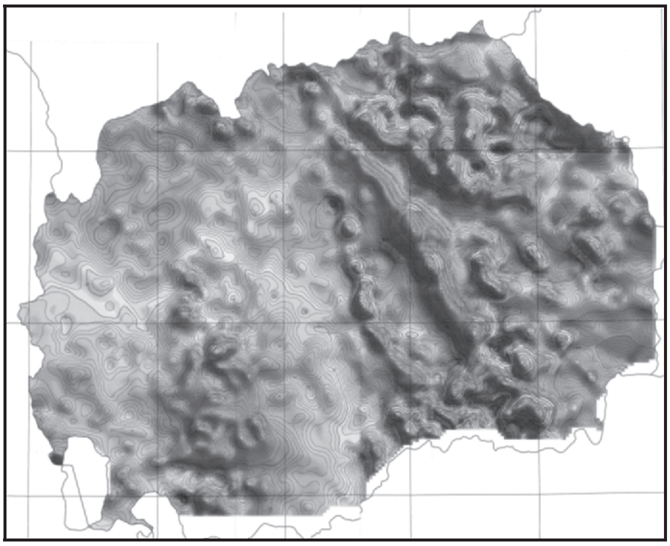

Figure 18. Topography map of Republic of Macedonia.

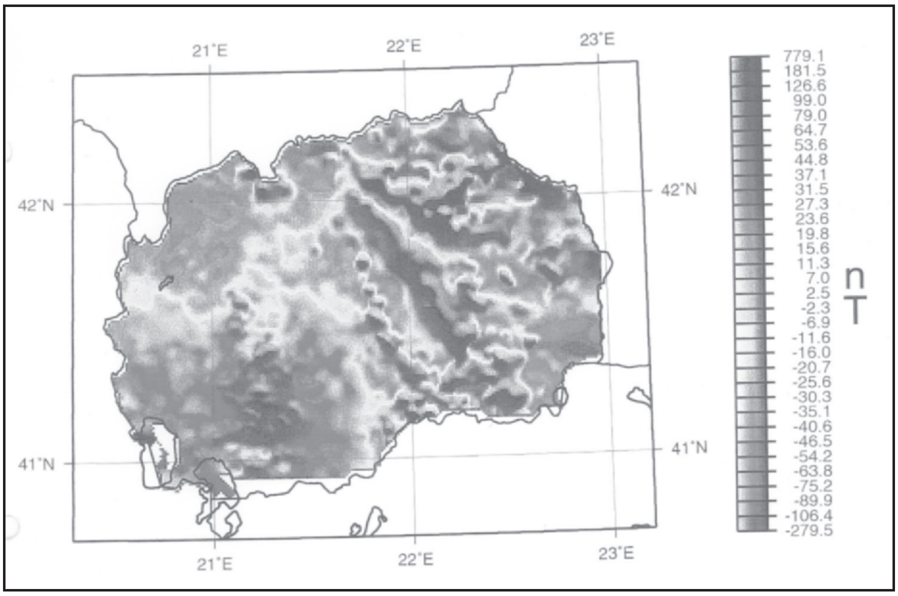

Figure 19. Derived total magnetic field anomaly map of Macedonia based on 1 km grid upward continued to 1 km above topography and linked to Albania, Serbia and Greece.

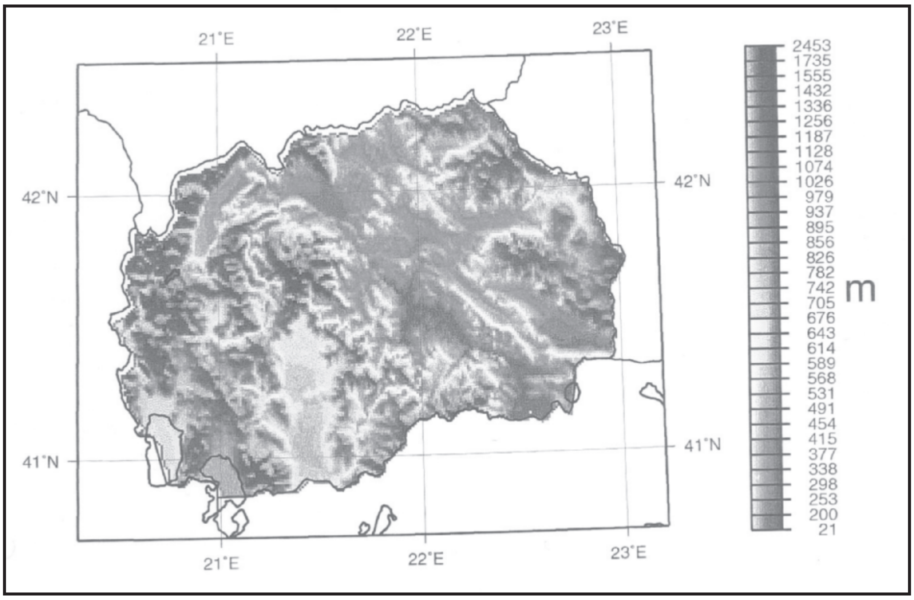

Figure 20. Digital terrain model of Macedonia at 1 km grid.

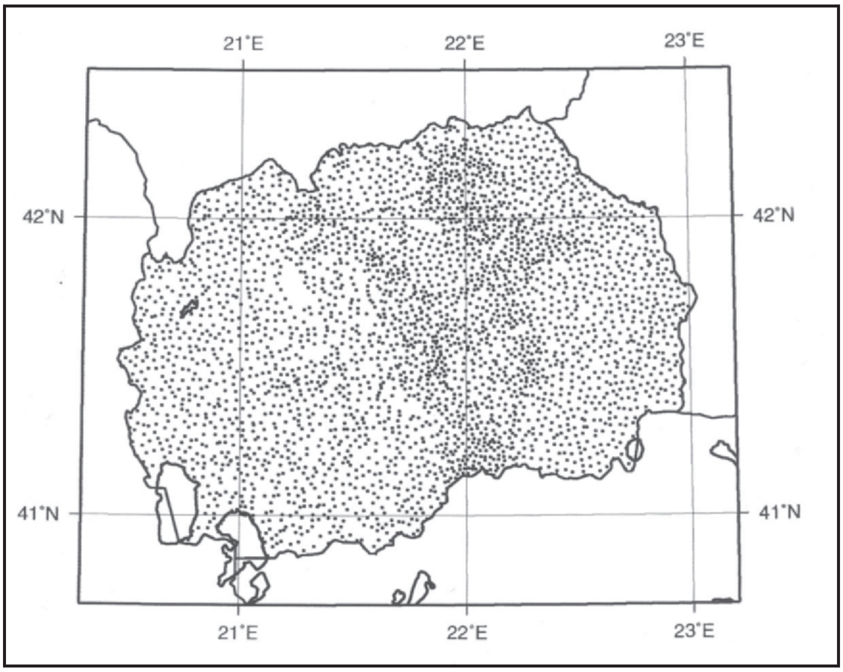

Figure 21. Gravity station distribution for Macedonia used to generate 8 km grid.

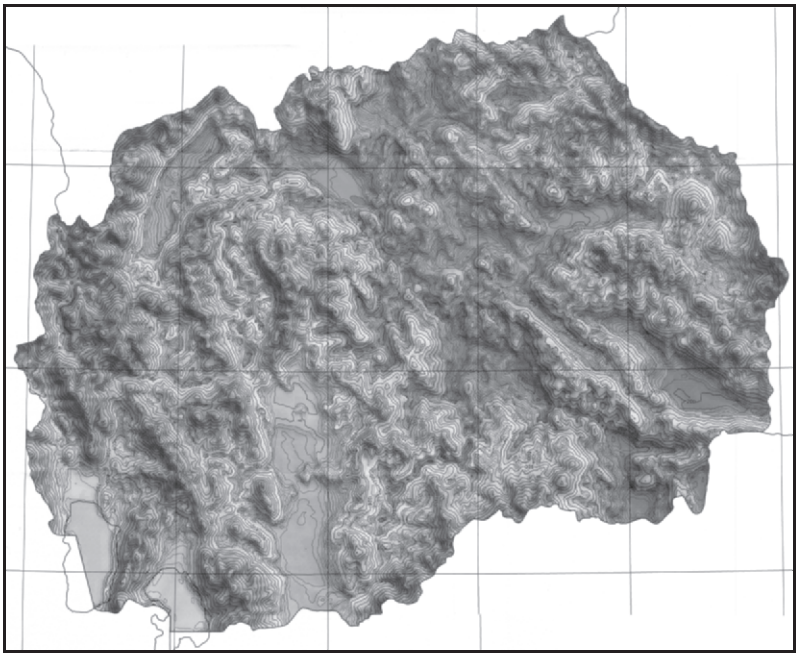

Figure 22. Total magnetic field anomaly map.

Vertical component magnetic field anomalies (ΔZ anomalies) were measured at approximately 8000 stations in Macedonia between 1954 and 1972. Analysis was carried out by Fourier transform technique. The field was upward and continued to 1 km above topography. The data were linked to data from Serbia, Albania and Greece.

ΔZ anomaly was first calculated with the formula

$$\Delta Z = Zm - Zn$$

Where Zm is the measured value of the vertical component and Zn is the normal value for the vertical component according to the point with latitude 44^{o} and longitude 18.5^{o} E. Zn was calculated with the formula

Zn = 39.964 + C1 * DF + C2 * DL +C3 * DFF + C4 * DFDL + C5 * DLL

where

C1 = 10.76986; C2 = 1.21625; C3 = 0.0023555; C4 = 0.005743; C5 = 0.0012558;

DF = [latitude (degrees) - 44 (degrees)] * 60 .... (in minutes)

DL = [longitude (degrees) - 18.5 (degrees)] * 60 .... (in minutes)

DFF = DF * DF

DFDL = DF * DL

DLL = DL * DL

For the purpose of this study, the original values of the vertical components of the field were cross checked (calculated again) and the values of IGRF were eliminated.

During the past several years magnetic measurements have been carried out in Macedonia to detail the geomagnetic field and to compile a new map of geomagnetic anomalies. The measurements were useful to determine locations for a grid of geomagnetic stations.

After 2000, cooperation with the Royal Meteorological Institute, Geomagnetic Observatory in Dourbes, Belgium and the Department for Geology and Geophysics at the Faculty of Mining and Geology in Stip was established. The study of the geomagnetic field of the Republic of Macedonia was undertaken. A basic grid of repeat stations was set up and a location for a new geomagnetic observatory was selected.

3.2. GEOMAGNETIC INVESTIGATIONS IN SOME LOCALITIES FOR THE DISCOVERY OF DEPOSITS OF MINERAL RAW MATERIALS[1, 5, 7]

Before World War II, geomagnetic investigations were undertaken to explore for mineral raw materials. These investigations intensified during 1950s.

In 1930, investigations were carried out with a magnetic balance instrument to determine vertical intensity in the Orasje and Ravniste mines near Skopje in order to determine whether this magnetic method could successfully be used in investigation of chromium ores.

During the 1950s investigations were carried out at several localities. In 1952, geomagnetic investigations were carried out in Tajmiste in order to determine the location of magnetic anomalies and the possible presence of schists with ore beneath limestones. In 1952 and 1953, geomagnetic investigations were carried out at Slopce in order to test the geomagnetic methods on known shamosite occurrences, and if they proved applicable, to continue investigations on new occurrences. In 1953 the area of investigation was widened to include Sopur and Damjan. Geomagnetic methods were employed to explore for iron ores and to delineate the areas of interest.

In 1954 geomagnetic investigations were carried out at Sloesnica, Valandovo to determine the extent of the shamosite zone. It was determined that the zone extended eastward of the original site.

In 1955 the localities of Valandovo and Tajmiste as well as those of Konce, Mitrasinci, Curkov Dol, and Galicnik were investigated. The goal of the investigations was to determine the possible application of geomagnetic methods to ore exploration.

In 1956 a number of investigations were carried out at several localities. At Damjan, investigations were made to determine the extension of the ore zone to the north. A study of the contact zone between flysch and andesite to the south and south-west of the area was also undertaken. Magnetic measurements were carried out at Demir Hisar to locate ore bodies at Sapotnicko, Sapotnicko Pole, and Seliste. Reconnaissance studies of the Majdaniste district were carried out to determine the extent of the ore zone like the occurrence of shamosite shists at Sv. Ilija. Geomagnetic investigations were carried out southeast of 'Rzanovo in order to distinguish nickeliferous oolites.

In 1959 similar geomagnetic measurements were carried out at Kozjavki Kamen near Alsar to determine the extent of the magnetic anomaly that was found during the geological prospecting.

In 1960 detailed geomagnetic investigations were carried out southeast of 'Rzanovo at the location of newly discovered outcrops of nickeliferous iron. Also, in 1960 the Smilevica, Algunja, Prespa, Kriveni and Pusta Reka areas were investigated. The objectives were to determine the size of known magnetite deposits, and to discover primary deposits of magnetite ore. The Figure 23 to Figure 26 show some anomalies in the geomagnetic fields of the Republic of Macedonia.

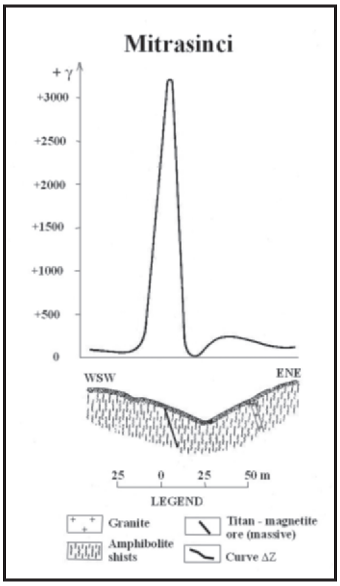

Figure 23. Geomagnetic anomaly.

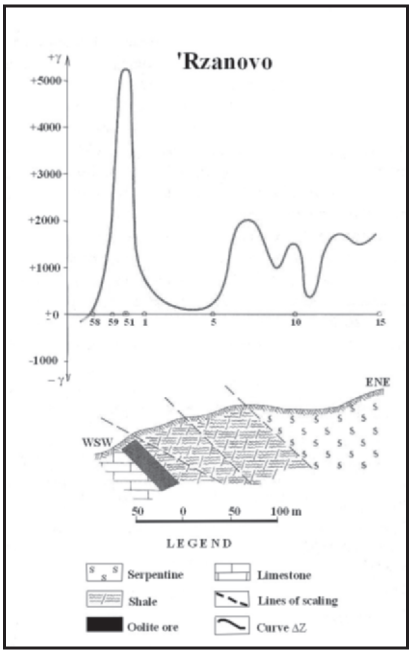

Figure 24. Geomagnetic anomaly.

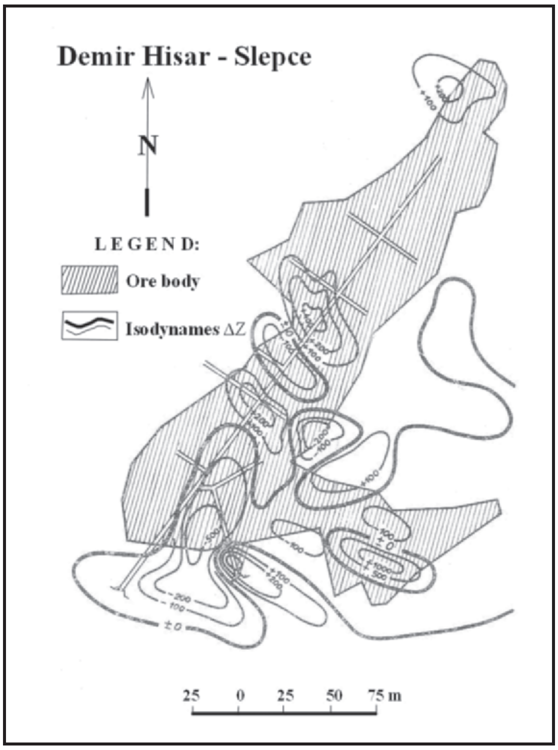

Figure 25. Isodynames ΔZ above ore body with uneven content of magnetite.

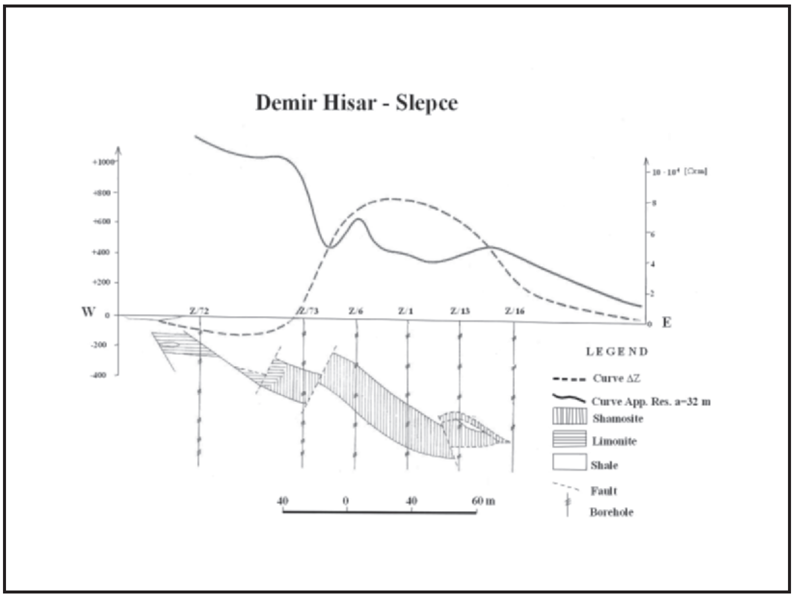

Figure 26. Geomagnetic anomaly and curve of apparent receptivity.

After independence in 1991, the Department of Geology and Geophysics at the Faculty of Mining and Geology in Stip purchased proton magnetometers in order to investigate magnetic anomalies caused by ore deposits. The instruments were also used to locate archeological sites and structural composition of certain areas. The technique was also used to locate archeological structures at Zajcev Rid and Skopje. They helped uncover and define the walls around the ancient city of Skupi. Measurements of stability of the terrain around the classical settlement at Bansko, Strumica were performed including archeological investigations using magnetic measurements at Vrsnik - Tarinci, Stip.

Magnetic measurements at Strumica, Berovo - Delcevo and the Kocani depressions were carried out to define their structural compositions.

4. Anomalous magnetic field of the territory of the Republic of Macedonia

Regional magnetic provinces have a multicomponent anomalous field. Many geologic structures at various depths of the earths crust create this effect. In other words, the magnetic field has an integral influence on the surface from many deeply seated geologic causes.

Figure 27. Map of vertical component of anomalies of the magnetic field of Macedonia.

4.1. THE DINARIDE - ALPINE MAGNETIC PROVINCE

This province dispalys a magnetic minimum across the Balkans. It can be traced from Rijeka to Pec, in Albania. Its influence at depth is manifested again in the Korab zone in the western part of Macedonia (Figure 27).

4.2. INNER MAGNETIC PROVINCE

The inner magnetic province occupies more than half of the territory of Serbia and Montenegro and stretches into Macedonia. The Macedonian part of this province has the following zones:

1. Western Macedonian zone,
   - Pelagonian zone
2. The Vardar zone,
3. Eastern - Macedonian zone
   - Strumska zone.

Essential magnetic features of the province are a clearly pronounced pattern of positive magnetic anomalies that alternate interspaces of negative sign. One pattern of magnetic anomalies starts in the region of Kozuf, continues towards Veles, and goes on to Gnjilane in Serbia. Another pattern of magnetic anomalies enters Macedonia from neighboring Greece at Gevgelija and goes further to the northwest via Sveti Nikole. It then goes south of Kumanovo where it diverges and translaterally goes further for about 20 km to the west. Then from Skopje it continues over the eastern slopes of Mt. Sara, passing further into the territory of Serbia and joins the known gravimetric and magnetic anomaly of the Metohija ultramafites that enter our region from Albania. The interception and translateral movement of this pattern to the west, some 20 km from the Kumanovo - Skopje region could be related to the regional fault of transverse strike to the Vardar strike (Debar - Mavrovo - Skopje - Kumanovo - Kustendil), or with magmatites deposited along that area.

Above were described two marked patterns of geomagnetic anomalies that, in part, traverse the territory of Macedonia. However, their extension exceeds the area under consideration. South of Kumanovo, a geomagnetic anomaly with the Vardar extension is distinguished. The territory that it occupies coincides with that of the Vardar zone. The reason for the occurrence of this anomaly may be in some deep magnetic formations. It may also be from the continuing presence of basites below Tertiary sediments (Vukasinovic, 1965, Jancic, 1970) or from the complex influence of the deep causes of magnetic formations at the base of the basic and ultrabasic members of the Jurassic complex and Tertiary eruptions (Ciric, 1970). The Tertiary sediments, whose thickness to the magnetic base amounts to 0.9 - 2 km (Jancic, 1970), probably overlie young dacite - andesites. These formations, where exposed, have high magnetic anomalies. The values of the vertical components of the geomagnetic field of the anomalous field in the zone depend on the composition of the deep parts of the Earth's crust, bearing in mind that the Vardar zone, as a rift zone, is crosscut by deep faults along which penetrate material of the deep parts of the earth crust and the upper mantle. The normal continuous extension of the Vardar anomalous zone was distinguished by the method of profiling when some young eruptive occurrences were neglected.

The Pelagonian magnetic zone, mostly overlaps the Pelagonian massif. It is characterized by a quiet magnetic field and Z anomalies of small intensity and irregular form. A magnetic field with such characteristics is an indicator of homogenous geology. Exceptions are the anomalies of some dacite - andesite intrusions and tuffs.

The characteristics of the magnetic field of the Pelagoian zone, which is built up of Precambrian metamorphic rocks and granitoides and Neocene - Quaternary mollases in young depressions, can be interpreted by purely expressed magmatism in the formations mentioned. Additionally, the Pelagonian massif is a homogenous block of the Earth's crust deeply embedded in the upper envelope at significant depth. The faults in the block are shallow.

The Porecka - Demir Hisar zone extends to the west of the Pelagonian zone with high anomalies (Ciric, Stojkovic, Veljkovic, Jancic, 1971).

The composition of the zone is variable and crosscut with faults. However, the magnetic field is rather homogenous and its intensity does not correlate to the discovered geological structures.

Most probably it is a reworked block of the Earth's crust from the Tertiary, and separated by deep faults in the Pelagonian and Western Macedonian zones into which the granitoides are forced with apical parts with common bases. The magnetic anomalies of high intensity correlate to the apical parts of the granitoides. The extension of the anomalies of the vertical component of the geomagnetic field may lead us to conclude that the major fault at the western edge of the Pelagonian depression is of meridian strike.

The Western Macedonian magnetic zone occupies the area of the Porec - Demir Hisar zone to the Albanian border. It is characterized by a uniform magnetic field with anomalies of vertical component with a negative sign. The geology of the zone consists of several formations of various composition and magneticity. The recorded anomalies are almost the same values for all the different formations. This opens the possibility of many variations for their interpretation. However, the occurrence of magnetic anomalies of the same values of non-magnetic limestones at Galicica and the neighboring diabase-chert formation and its basic and ultrabasic magmatites could be interpreted as the existence of an overthrust of the limestones over the diabase - chert formation at Jablanica. This possibility needs to be proven.

The Serbo - Macedonian magnetic zone, which, to the west is in contact with the Vardar zone and to the east extends to the border with Greece can also be distinguished. The zone coincides with the Serbo-Macedonian massif and is distinguished as an individual geotectonic unit. The Serbo - Macedonian massif is composed of high crystalline schists, amphiboles, gneisses, michashists, greenshists, marbles, and quartzites. The schists are occasionally intruded by granites so there is a contact metamorphosis of the neighboring granite - gneiss rocks. Occasionally the mass is intruded by basic and ultrabasic rocks, young Tertiary granites and granitoides, and dacite - andesites. With neotectonic movements the Serbo - Macedonian massif was broken up and turned into a series of trench and horst structures. The grabens are filled with Neocene layers up to 3 km depth.

In the area made up of various formations, the anomalies of the vertical component of the geomagnetic field correlate with the geological structures. Crystalline schists that are homogenous have a relatively quiet and balanced field. Intercalations of amphibolites cause significant increases in the intensity of Z anomalies.

Other causes of high Z anomalies that do not fit the characteristic magnetic pattern of the crystalline basement and the earlier granite - gneiss cores, are always linked with young magmatic phenomena, visible on the surface or inside the Earth. Characteristics of the anomalies of the vertical component connected to the occurrence of younger magmatic rocks are "swarms" with alternating sign and high intensity, most probably connected to the amounts of magnetic minerals in the rocks. With Neocene depressions in the Serbo - Macedonian massif, anomalies express magneticity of the basement and their intensity is reciprocal to the depth of the depression.

The described magnetic zones have a characteristic elongated shape. In the explanation that follows, description will be given on some local anomalous areas that deviate from the general anomalous model. This anomalous group is characterized by rapid change of the sign and intensity of magnetic field. In the main anomalous zones, a ring-like magnetic structure is distinguished in the Vardar zone and the Serbo - Macedonian zone. They are located in the Kozuf, Demir Kapija, Bucim and Kratovo areas.

It can be concluded that the system of the anomalous magnetic model described covers the area of Macedonia that was affected by tectonic - magmatic atomization during the long period of the Hercynian volcanic phase (Permian - Carbon) through the youngest volcanism.

5. Conclusion

For further scientific and applied studies, we must address the problem of establishing a geomagnetic observatory. Therefore, our efforts and activities will be directed to the construction of a geomagnetic observatory.

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DISCUSSION

Question (Jean Rasson): There is a repeat station near Kavadarci where we have anomalous results. Can you give me the geological causes of this anomaly?
Answer (Todor Delipetrov): The anomaly occurring at the Gradot Island repeat station is due to the central deep fault of the Vardar Zone (The Vardar Zone, on the west is separated by a fault form the Pelagon, and in the east from the Serbian Macedonian massif. The zone is divided into three subzones, the left deep fault being close to the repeat station). Along the fault and on the surface on the terrain tectonitic serpentinites have been mapped. From the geological point of view they are the cause for the anomaly.
Questions (Angelo De Santis):
1. As is known, the close presence of a railway can heavily affect the recording of any magnetic observatory. Are there railways in your country?
2. I saw from your presentation that in your country gravity and magnetic measurements were made. From these measurements you propose also

some interpretations in terms of structure models of density and/or magnetization. Were there also magnetovariational or magnetotellurics measurements made in order to get some information about the possible conductivity structure underneath the Republic of Macedonia?

3. In one of the lat slides you present a simple field map of the magnetic anomalies in your country. Do you know which reference field was used for the reduction of data?

Answers (Todor Delipetrov):

1. There is a railway, but it is not close to the terrain considered for the construction of the Observatory at Mt. Plackovica.

2. Magnetovariational and magnetotellurics measurements have not been carried out in Macedonia.

3. It is a scheme of magnetic measurements carried out in 1965. The measurements help to compile the map for geomagnetic anomaly of the Republic of Macedonia.