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SOME RESULTS OF SYSTEMATIC OBSERVATIONS OF GEOMAGNETIC FIELD CHANGES IN THE WIDER AREA OF RUDNIK THRUST REGION

M. Popeskov

Geomagnetic Institute, 11306 Grocka, Yugoslavia

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SUMMARY: Based on the results of periodically repeated surveys of the geomagnetic total field intensity in the wider area of Rudnik thrust region, within the period 1981-1990, the analysis of space-time field changes has been performed in attempt to establish a relationship with geological-tectonic structure and geodynamic processes which are going on in the investigated area. Obtained results indicate that the characteristic features of the spatial distribution of the rate of geomagnetic field secular change are related to particular geotectonic units and therefore, most likely, with corresponding regional differences in stress distribution.

1. INTRODUCTION

Tectonic stresses as a result of geodynamic processes cause changes of the magnetization of crustal rocks, producing in paricular cases detectable geomagnetic field changes on the earth's surface – so called tectonomagnetic effect. This is a well known fact both theoretically founded (piezomagnetic effect) and experimentally established through numerous field observations.

Within the Project initiated and partly realized in the past few years, whose main goal was to study the mean changes of the geographical coordinates of Belgrade relative to Warsaw, an attempt has been made to investigate contemporary movements of crustal blocks in the wider area of Belgrade, i. e. to monitor geomagnetic field changes and study their spatial and temporal variations, searching for correlation with actual geological and tectonic structure (Popeskov et al., 1988). It has been pointed out on that occasion that such a kind of investigation requires data sistematically collected in a relatively long period of time in order to be able to establish possible relation between geomagnetic field changes and geodynamic processes. The analysis of data from Rudnik thrust region offers exactly such an opportunity and the obtained results may have important references to the future planning and methodology of the investigations defined by the afore mentioned Project.

First systematic geomagnetic investigations of any thrust region in our country, aimed to establish eventual connection between tectonic processes and geomagnetic field changes within particular area, were initiated in 1977 in the wider area of Rudnik mountain – known as one of seismically most active regions in Serbia. Thill 1981, repeated surveys of declination (D), horizontal (H) and total intensity (F) of the geomagnetic field were measured at 14 sites along 60 km long profile between Takovo and Rača. In 1981, the network was expanded to 39 measuring sites (see Fig. 1) covering much wider area than Rudnik thrust region, hoping to be able to estimate the influence of different geological and tectonic units, blocks and other structures. Since then only the total field intensity F has been measured, which is the usual methodology used in this kind of investigation.

In ten-year period 18 surveys have been carried out, thus providing a unique data set on the basis of which the time-space pattern of the geomagnetic field variations was analysed. Some of the most interesting results will be presented here. Geology and tectonics of investigated area will be mentioned only in the scope which is necessary for the interpretation of obtained results.

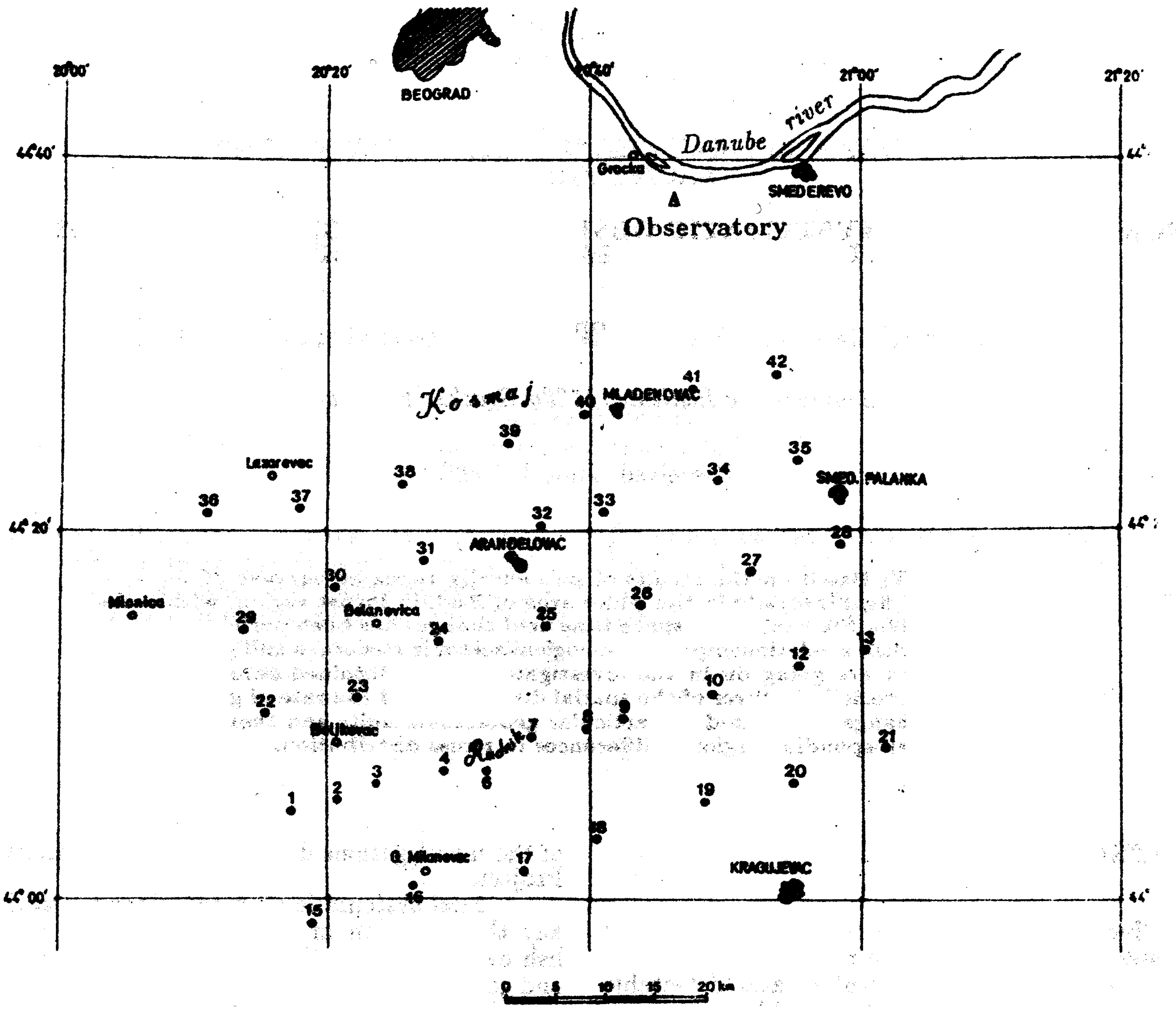

Fig. 1. The network of measuring sites in the wider area of Rudnik thrust region.

2. RESULTS AND DISCUSSION

In geomagnetic investigations of seismically-active areas, which are being carried out within multidisciplinary projects oriented towards studying phenomena preceding or accompanyng the earthquake occurrence, it is necessary to achieve simultaneous insight into temporal and spatial changes of the geomagnetic field as possible indicator of tectonic stress changes. The aforementioned process is based on piezomagnetic effect i. e. on stress induced changes of the magnetization of crustal rocks, manifested as detectable geomagnetic field changes on the earth's surface.

Continuous monitoring of geomagnetic field variations at one or more locations in the investigated area enables us to study in detail their time changes, whereas in order to study spatial changes repeated survey method has to be employed. Since we where unable to realize continuous field monitoring, the second method was applied in Rudnik thrust region. Most surveys were carried out with proton precession magnetometer of ±1 nT accuracy, while recently magnetometers (GSM-10 type) of ± 0.2 nT accuracy are being used.

In the process of data reduction continuous records of the total field intensity at Grocka geomagnetic observatory were used in order to correct measured (instantaneous) field values for daily variation. This is justified by the assumption that the total intensity variations at the Observatory and in Rudnik area do not differ much, since the distance between the Observatory and survey sites is about 60-70 km. (Of course, it has to be pointed out that the best results would be achieved with reference station within the survey area.) Taking into account all relevant facts, the overall accuracy of final, reduced field value, can be estimated to better than 1.5 nT.

2.1 *SECULAR CHANGE OF THE GEOMAGNETIC FIELD*

Time variation of the total field intensity changes at few measuring sites (out of 39) is shown in Fig. 2. Using linear approximation of secular change trend, the rate of secular change (expressed in nT/yr) is obtained. These values vary between -0.4 and +0.6 nT/yr from one site to another and their spatial distribution is presented in Fig. 3. The

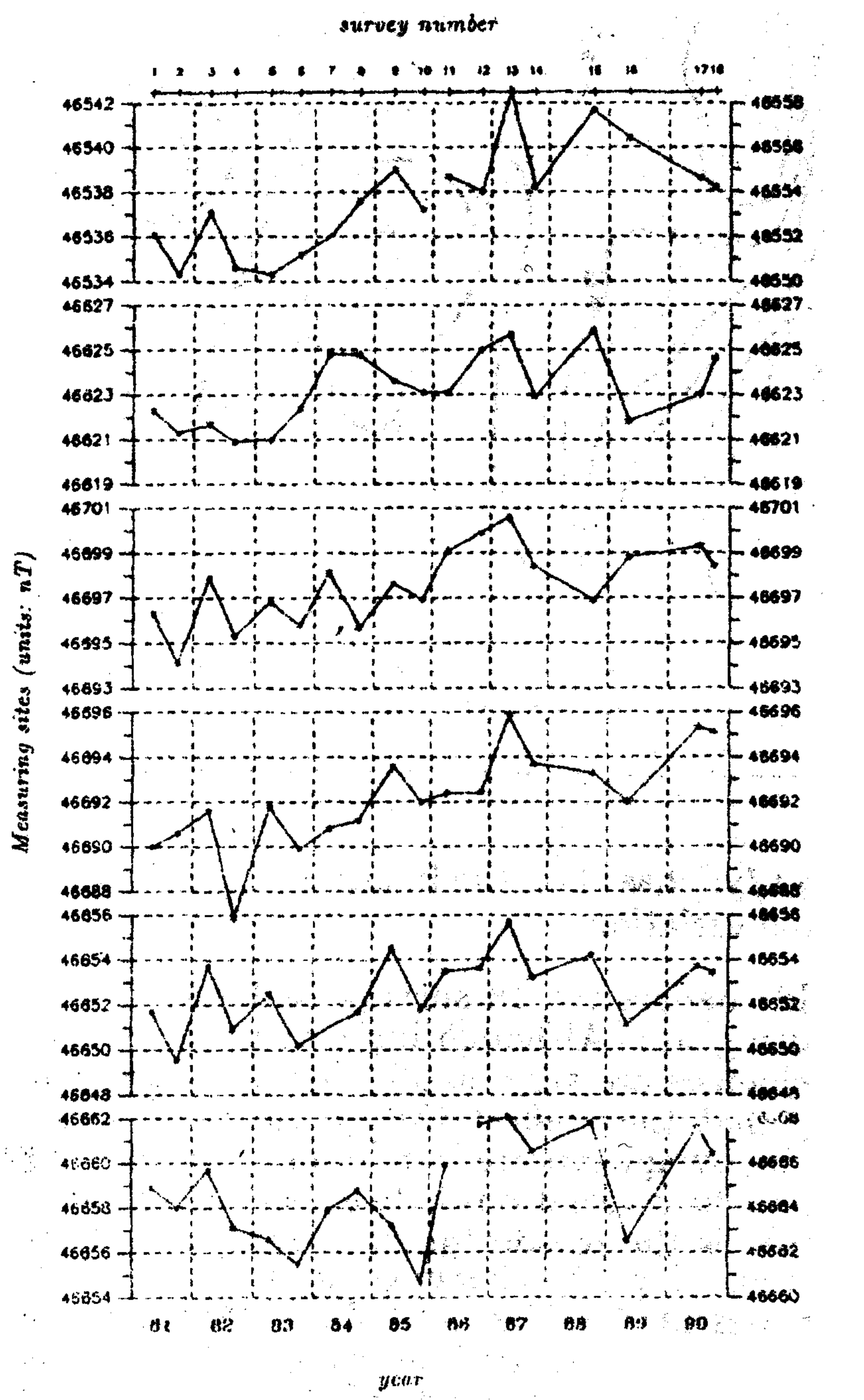

Fig. 2. An example of time variation of the geomagnetic total field intensity at few measuring sites in Rudnik area.

obtained pattern of distribution is used for interpretation of the differences in the rate of total field intensity change in particular smaller regions within the area of investigation.

It is known that Rudnik thrust region belongs to geotectonic unit Ljig – Rudnik which together with units Maljen – Takovo and Mionica – Brajkovac define this thrust region in the wider sense. Particular units are separated by marked Boljkovac and Mionica – Belanovica faults. Nothern border of Rudnik seismic zone is neotectonic rift Mionica – Belanovica (in W-E direction), while tectonic rift of Zapadna Morava river costitutes its southern border. The part of the highest seismic activity is bounded by Rudnik mountain, Gornji Milanovac town and rivers Dičina and Gruža (Sikošek et al. 1988). If the direction and spatial extension of geotectonic units, identified within the area concerned, is taken into account, certain correspondence can definitely be noticed between them and the regions defined by the lines of the equal rate of geomagnetic total field intensity secular change.

For instance, south from Mionica and west from Boljkovac fault, the direction of Mesozoic structures is E-W, being at the same time the direction of extension of smaller areas with the equal rate of the secular change of the geomagnetic field total intensity. East from Boljkovac fault (Ljig – Rudnik unit), dominant orientation of geological formations and faults is NW-SE. Spatial pattern of the areas of the equal rate of the geomagnetic secular change are again in good agreement with it.

On the basis of previous discussion, it could be concluded that the differences in the rate of secular change reflect the fact that particular group of sites belong to different geological and tectonic units, thus experiencing different stress states both in direction and intensity. The highest rate of geomagnetic field secular change is found at sites 8, 15 and 18, which are in immediate vicinity of highly magnetic rocks (serpentinite), as well as at sites 4 and 22 nearby volcanic rock complexes. This argument might be in favour of the assumption that detected geomagnetic field changes are of stress induced nature, i. e. that they reflect changes of rock magnetization in the upper layers of the earth's crust.

Average rate of secular change for the whole survey region is +0.25 nT/yr. With respect to this characteristic value, the area concerned is devided in two parts: eastern, with the rate of secular change smaller than the average and western part, with the rate of secular change larger than the average. This line follows the direction of faults which separate geotectonic units Ljig – Rudnik and Maljen – Takovo in the west from the structures of Jarmenovci in the east, i. e. it follows the border between West Serbian and Šumadian part of Inner Dinarides. This line bends in the area of serpentinites south of Stragari and then continues in the afore mentioned NW-SE direction. Considering the spatial extension of these areas, the cause of such a distribution is probably of

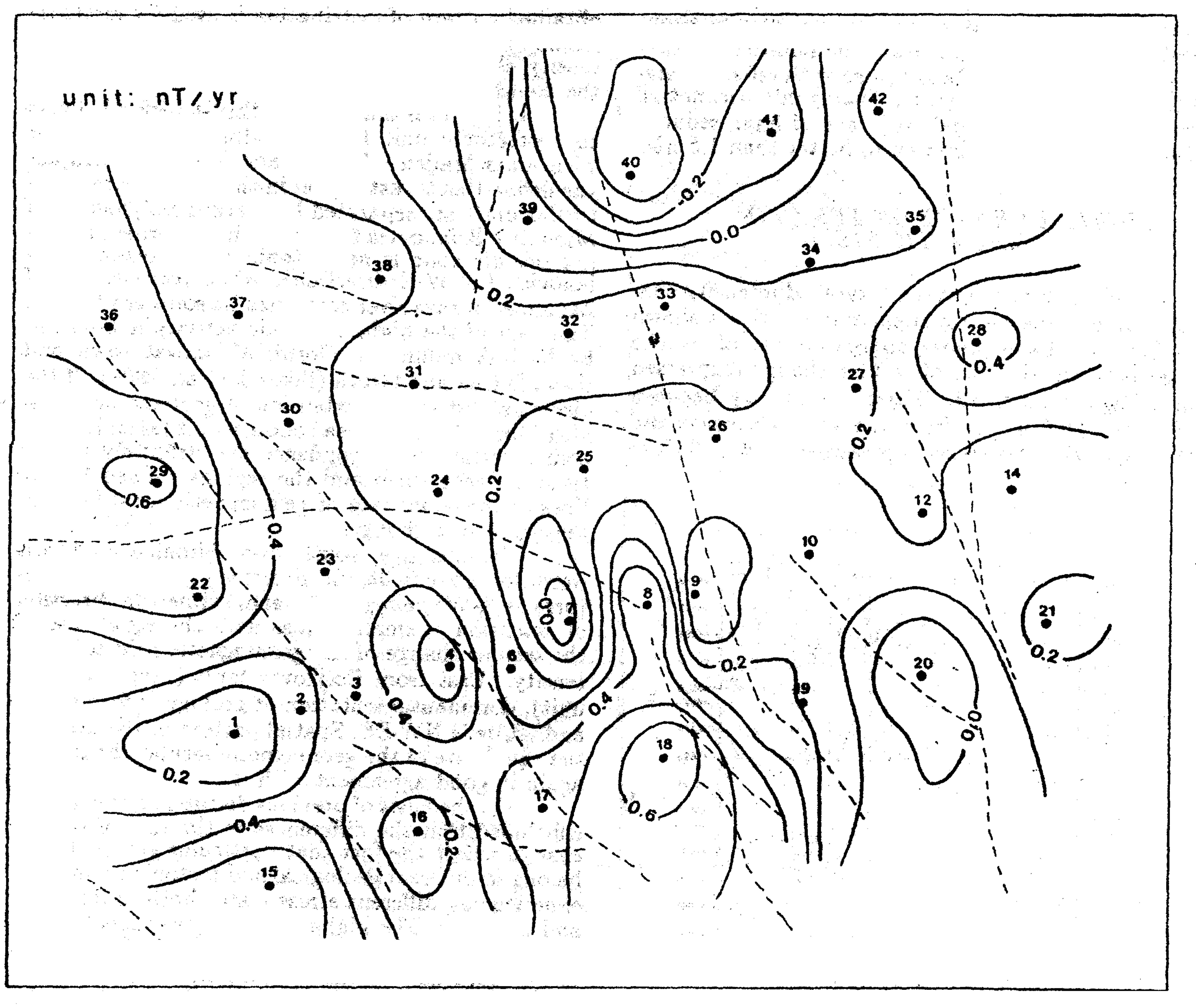

Fig. 3. Spatial distribution of the rate of secular change (in nT/yr) based on the linear trend approximation of the geomagnetic field time variation.

regional character. In this particular case these areas belong to two large geotectonic units – eastern part of Dinarides and western boundary part of Serbo – Macedonian mass. The observed division also quite well reflects the border between regions with different velocities of recent vertical movements. In fact, the western part is rising up faster than the eastern for 2 mm/yr on average.

2.2 GEOMAGNETIC FIELD SPATIAL CHANGES

An example of spatial distribution of total field intensity changes between consecutive surveys is shown in Fig. 4 while Fig. 5 presents average value of field changes for 18 surveys and each particular measuring site. Although individual values of mean field changes are very small, they are significant in a way that they reflect the existance of particular trend in, by appearance, random fluctuations of geomagnetic field variations between successive surveys, and that is the reason for the resemblance between Fig. 5 and Fig. 2. Therefore, in the analysis of the result presented in Fig. 5 similar explanation can be ofered. The overall negative change of small intnsity prevails on the eastern side of the investigated area where Miocene sediments dominate. The most intensive overall increase can be observed in the region of Mionica – Belanovica fault up to its intersection with Boljkovac fault. On the south-west side of the line which follows the direction of Rudnik fault, the average value of total field intensity increase is between 0.2 and 0.4 nT. In comparision with predominantely sedimentary structures on the eastern side, this area is characterized by the appearance of more magnetic rocks.

Spatial distribution of the standard deviation of field differences between successive surveys is shown in Fig. 6. This quantity indicates how much individual field differences deviate from the mean level for the whole survey period. The cause of large standard deviation may be error which results from measuring and data reduction method and, therefore, from statistical point of view, it is equally probable for each measuring site. On the other hand, actually larger field changes at certain mesuring site may also result in larger standard deviation and in that sense a connection between the areas of larger standard deviation and geological and tectonic structure should be searched for. It should also be noticed, for instance, that within the areas of the most intensive positive field changes, standard deviation is smaller than the average value (which is 1.92 nT for the whole area), which leads us to conclude that the observed field changes in those particular areas are not of a random character.

It is also interesting to notice the following fact: regarding the value of standard deviation, the whole investigated area is devided (by the line approximately at the position of Boljkovac fault) in two nearly equal parts – nothern and southern. Generally speaking, with the exception of few measuring sites, standard deviation has larger value (>2 nT) in the south than in the north and it actually increases slowly from north to south. The possible explanation migh be the distance of certain measuring sites from Grocka observatory (referent station) which could result in larger error in the process of data reduction (because of the inequality of short-period geomagnetic field variations).

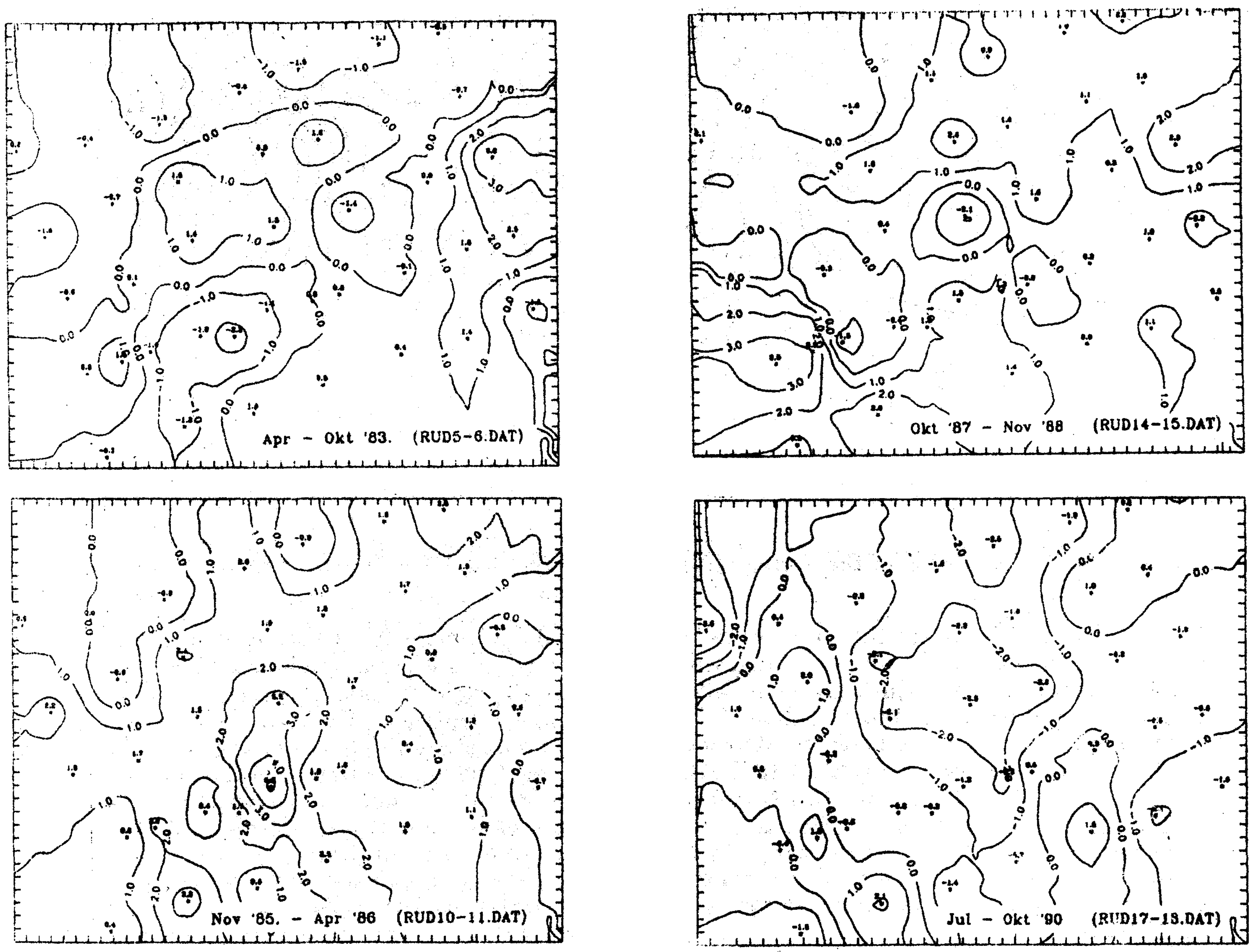

Fig. 4. Few examples of the spatial distribution of the total field intensity changes between successive surveys.

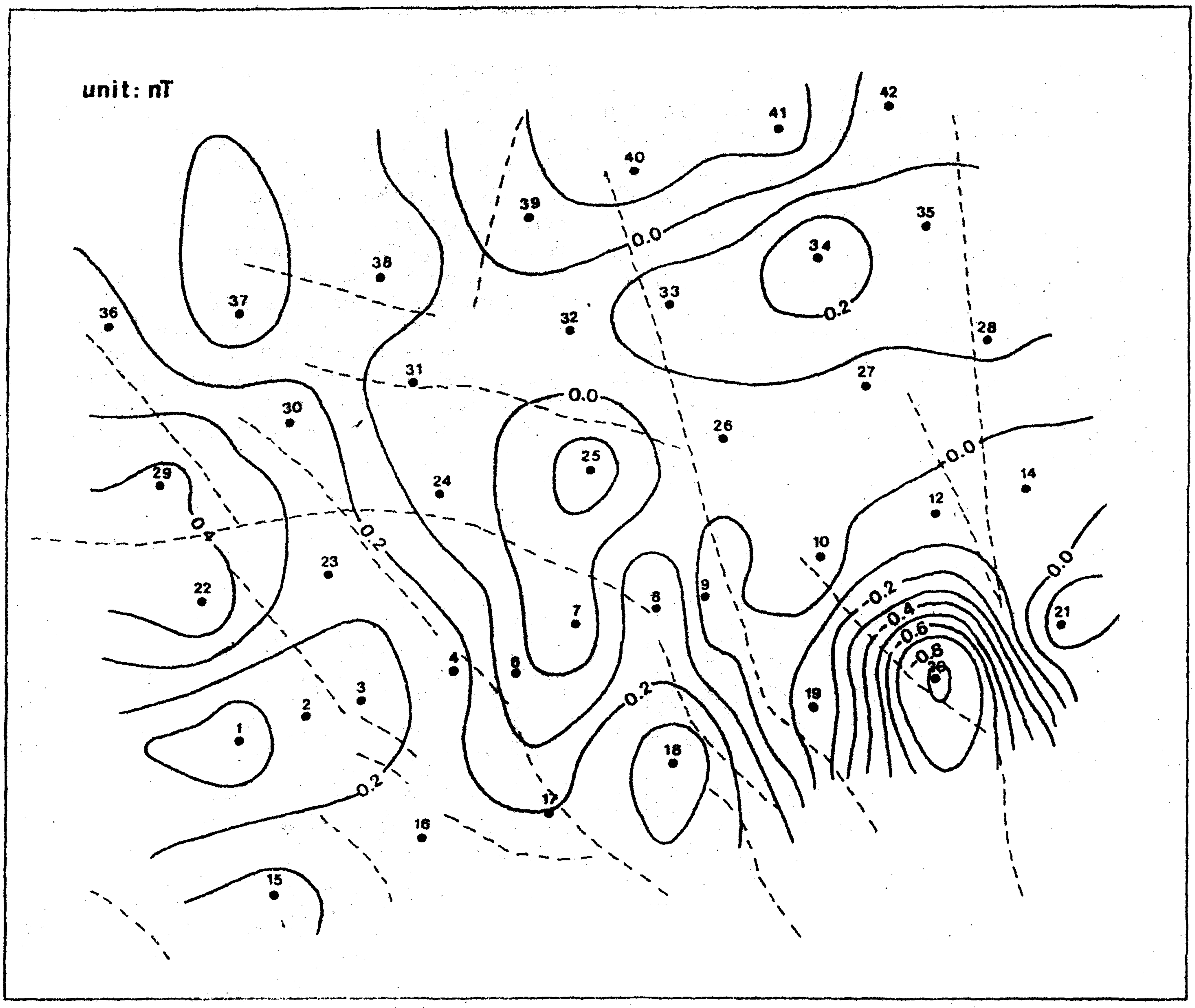

Fig. 5. Spatial distribution of the average (for all 18 surveys) total field intensity changes over the area of investigations.

Let us consider again the mean value of the rate of secular change for the whole investigated area. This value is 0.25 nT/yr, which gives the difference between Observatory and Rudnik of about 1.5 nT in 6-year period. The difference in the total field intensity changes between secular stations 1000 (Grocka observatory) and 1126 (near Niš), in a 6-year period between the epochs 1983.5 and 1989.5 is also of the same order, i. e. 1 nT, and at the same time total intensity increases from north to south, which is in agreement with previously stated result for the wider area of Rudnik.

If we neglect the sign of total field intensity changes between successive surveys and take the differences as absolute values, their mean value for all surveys present the most probable amplitude of the total field intensity variations at a given measuring site which is its characteristic feature (some kind of typical response) due to particular geological and tectonic structure. For instance, site No. 6 which is in immediate neighbourhood of Rudnik fault, has a considerably higher value of the amplitude of total field intensity changes with respect to the neighbouring sites (except site No. 7) which at the same time has large standard deviation, so that the nature of the geomagnetic field changes at this site should be clarified, considering the fact that it lies on sedimentary layers and that field changes are most probably not of a stress induced nature.

Finally, let us discuss the result shown in Fig. 7. It presents regional total field intensity change. Since those values are average field changes for all

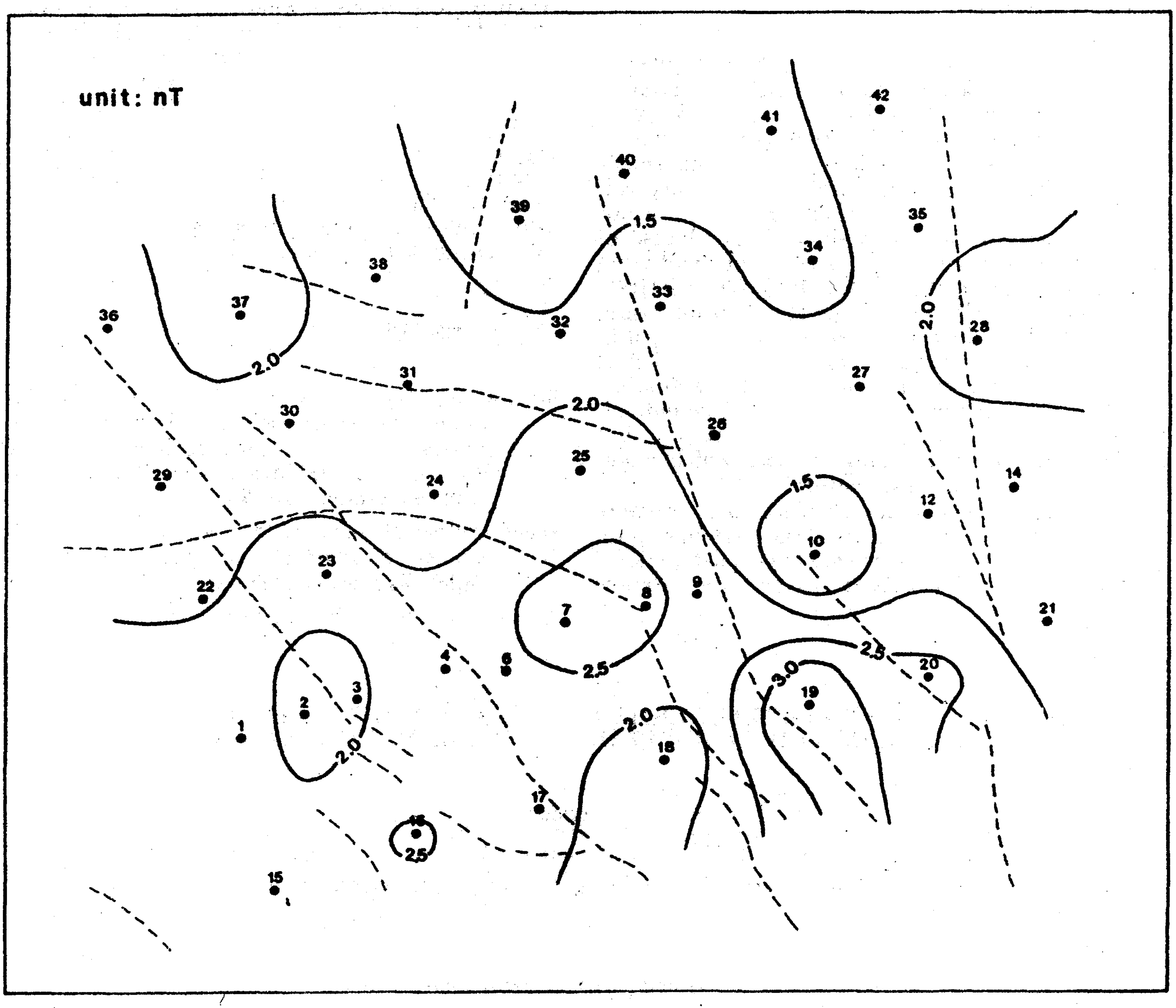

Fig. 6. Spatial distribution of the standard deviation of field differences between successive surveys.

sites and each particular survey, they point out characteristic trend of changes common for the whole survey area. With respect to the sign and rate of secular change, the whole period can be devided into two intervals: from 1981 up to the beginning of 1987 with the rate of change +0.5 nT/yr, and the second interval from 1987 and further on with the value of −0.2 nT/yr. Since characteristic year 1987 is by no means significant considering the seismic activity in Rudnik area, there remains a possibility that the obvious change of regional geomagnetic field trend – from slow increasing to slow decreasing – reflects the regional stress field changes and eventual precursor of future seismic activity in this thrust region.

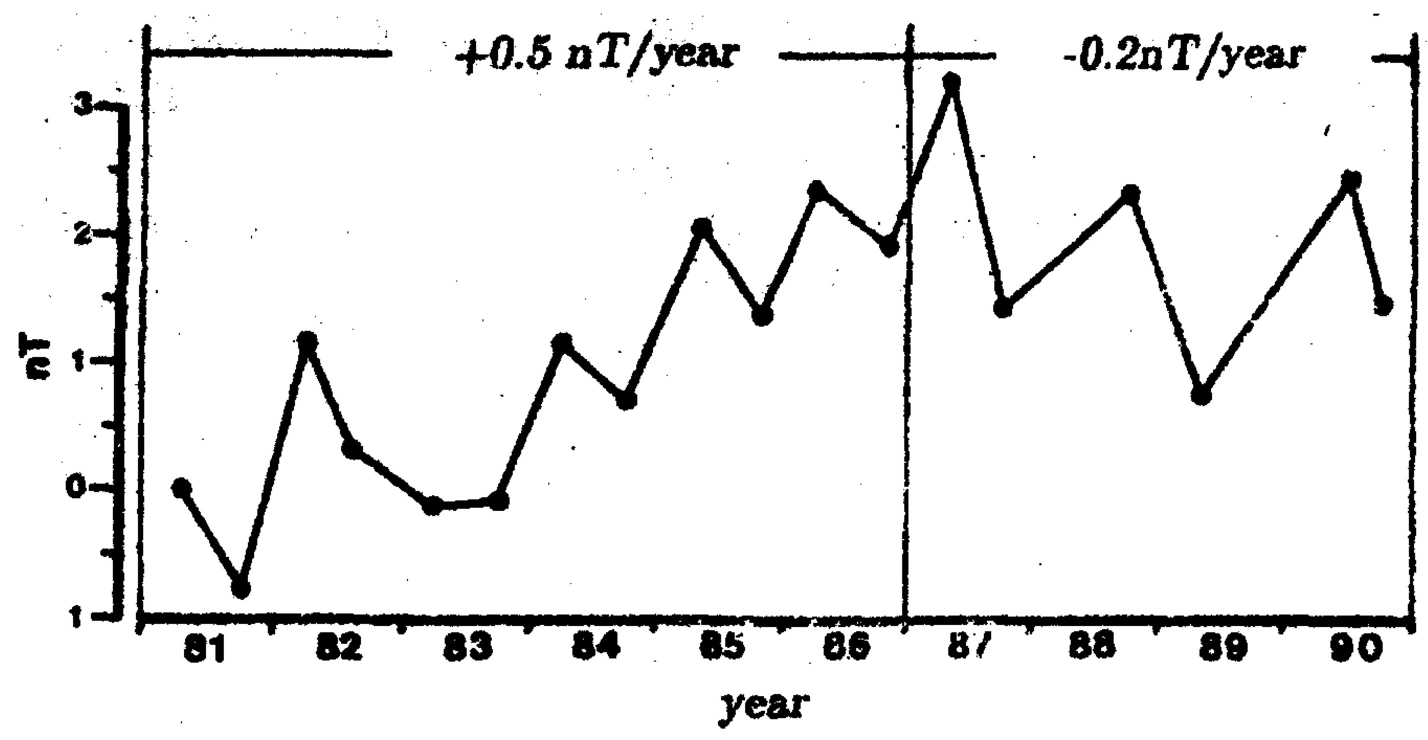

Fig. 7. Regional changes of the geomagnetic total field intensity in the wider area of Rudnik thrust region.

3. CONSLUSION

Unfortunately, but only from the scientific point of view, Rudnik thrust area was seismically-quiet during the time period considered in this work. Some small magnitude earthquakes were recorded within the measuring network but not at a time convenient to eventually influence the total field intensity values for particular survey. Therefore, we have not had a chanse to analyze a single isolated case of geomagnetic field change in a sense of identifying possible seismomagnetic effect. However, relatively large number of data and the lenght of encompassed time interval, enabled us to obtain results which in a statistical sense express common features of field changes in the studied region. In such a statistical approach it is not that important how large individual field changes at a given measuring site are, but rather what are the changes of trend which might have a long-term precursor nature.

On the basis of results obtained so far, we were able to estimate the intensity and the pattern of total field intensity changes in seismically- quiet periods. This is very important as it is necessary to know "normal" level of geomagnetic field variations in order to be able to identify eventual anomalous field changes. Applying new measuring technique (simultaneous differential measurements with two GSM-10 proton magnetometers of ± 0.2 nT accuracy), we shall be able to discriminate the total field intensity changes of one to few nanoteslas, with standard deviation less than 1 nT. This will considerably increase our chances to detect eventual geomagnetic field changes of stress induced nature in connection with seismic activity in Rudnik thrust region.

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Basic geological map: 1978; 1980, shits Gornji Milanovac, Kragujevac and Obrenovac (with legends), Savezni geološki zavod.

НЕКИ РЕЗУЛТАТИ СИСТЕМАТСКИХ ОПАЖАЊА ПРОМЕНА ГЕОМАГНЕТСКОГ ПОЉА НА ШИРЕМ ПОДРУЧЈУ РУДНИЧКЕ ТРУСНЕ ОБЛАСТИ

М. Попесков

Геомагнетски институт, 11306 Гроцка, Југославија

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Оригинални научни рад

На основу података периодично обнављаних премера тоталног интензитета геомагнетског поља на ширем подручју рудничке трусне области у периоду од 1981. до 1990. године, извршена је анализа просторно–временских промена у настојању да се установи веза са геолошко – тектонском структуром и гео динамичким процесима који се одвијају у истраживаној области. Добијени резултати указују да су карактеристике просторне расподеле брзине секуларне промене геомагнетског поља у вези са припадношћу различитим геотектонским јединицама па отуда, највероватније, у вези са одговарајућим разликама у расподели регионалног напрезања.