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# ON THE POSSIBILITY OF A TECTONOMAGNETIC EFFECT DETECTION AT THE LOCATION OF GROCKA GEOMAGNETIC OBSERVATORY

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**SUMMARY:** Some basic issues regarding necessary conditions for a tectonomagnetic effect detection in a given area are briefly reviewed and discrepancies between the reports by different authors are pointed out. A particular case of Grocka geomagnetic observatory is discussed and the geomagnetic field behaviour in the period including the July 12, 1991, M=5.7 Timisoara (Romania) earthquake has been analyzed. The data from four other European observatories - Panagyurishte, L'Aquila, Niemegk and Dourbes - are used for comparison because of their different location with respect to the earthquake epicenter. It has been found that the geomagnetic field at Grocka exhibited peculiar variation around the middle of 1991. If further analysis would prove that the observed changes are earthquake-related, it might have important implications on the application of geomagnetic methods in eventual future investigations aimed at clarifying the cause of astronomically established relative shifting of geographical coordinates of Belgrade with respect to Warsaw, from the point of view of possible role of geodynamic processes in the genesis of this effect.

## 1. INTRODUCTION

Project titled *A multidisciplinary study of the variations in the geographic latitudes of Belgrade* (see Sadžakov et al, 1991) has been realized as an initial step toward clarifying the cause of astronomically observed relative shifting of geographical coordinates of Belgrade with respect to Warsaw. It included among other disciplines the investigations of possibly stress induced local geomagnetic field changes in the wider area of Belgrade. The justification for the application of magnetic methods for this purpose is based on the fact that the motion of larger or smaller blocks of the Earth's crust under the action of tectonic forces, causes stress variations which are responsible for the surface geomagnetic field anomalies i.e., the so-called tectonomagnetic effect. This term, or generally tectonomagnetism, was proposed by Nagata (1969) and means the study of magnetic changes associated with various kinds of tectonic activity such as earthquakes, volcanic eruptions, gradual crustal movement and so on, although it sometimes assumes only the study of magnetic field of piezomagnetic origin. Sasai (1991) offers perhaps the best definition of tectonomagnetism, saying that it should be regarded as the study of generating mechanisms of various tectonic events through geomagnetic observations disregading the origin of magnetic changes that may be either stress, temperature or ground water or their combination.

Since the publication of the paper which presented the first results of the Project (Popeskov et al., 1988), a few others were published in this Journal treating the problem of tectonomagnetism (Bicskei, 1988; Bicskei and Popeskov, 1991). This article is devoted to the same topic aiming, on one hand, to bring closer the subject of tectonomagnetism to that part of scientific community which is not familiar with this kind of study and, on the other hand, to argue in favor of suggestion that the investigations carried out within the Project should be continued, since its duration, at least as far as geomagnetic investigations are concerned, was too short to offer any definite answer to the problem stated above.

The interpretation of the results of two-year investigations in the wider area of Belgrade (Popeskov et al., 1988) based on relevant geologic, tectonic and seismic data, led to the conclusion that it is hardly likely to expect stress induced local magnetic field changes due to contemporary tectonic processes. In this paper, without intention to deny this conclusion since most of the facts that have been established so far are in its favor, we want to discuss it in the light of some results which still leave this question open, showing that there are actually no strictly defined conditions which guarantee either a generation or detection of tectonomagnetic effect.

## 2. SOME CONTRADICTIONS REGARDING CONDITIONS FOR A TECTONOMAGNETIC EFFECT DETECTION

There are numbers of reports on anomalous geophysical, physical and other local field disturbances recorded in seismically-active regions. Magnetic field changes, as a response to crustal stress, have a strong theoretical basis (Stacey and Johnston, 1972) and support from laboratory experiments (Ohnaka and Kinoshita, 1968). Together with experimental results from field observations, these issues enable us to outline some general conditions under which a possible tectonomagnetic effect can be detected. Let us consider the following examples.

Using the data on precursors collected in Japan, Rikitake (1988) has shown that the main shock magnitude (M) and the distance (D) between the place where precursor is observed and an earthquake epicenter, are directly related. It is expressed by an empirically established relation of the form

$$M = a + b \log D_{max} \qquad (1)$$

where $D_{max}$ is the maximum distance at which a precursor can be observed, whereas coefficients a and b differ from one physical discipline to another, i.e. they depend on precursor type. In the case of the geomagnetic field changes, the value $D_{max}$ of only 25 km is obtained for M=6.0 earthquake.

Johnston (1978) reports on a stress induced geomagnetic total field intensity change at one of continuously recording stations along the San Andreas fau lt zone in the U. S. A. but again it was very close, only 11 km, to the epicenter of M=5.1 earthquake near Holister, California. The same author (Johnston et al ., 1994) detected seismomagnetic offsets of about 1 nT at the sites 17 and 24 km from the epicenter of M=7.3 Landers, California, earthquake. These findings are in agreement with model calculations based on the theory of piezomagnetic phenomenon, which reveal that detectable local geomagnetic field changes are confined to a rather narrow region of a few kilometers near the active fault (e.g. Sasai, 1991).

The intensity of a possible tectonomagnetic effect is in most cases not more than a few nanoteslas (nT). Although it was realized before, Zlotnicki and Cornet (1986) have shown that magnetically inhomogeneous structure i.e. the presence of strongly magnetic rock masses in the vicinity of active tectonic structures, intensifies expected stress induced local magnetic field changes.

Taking into account the above mentioned point, the idea that the local geomagnetic field disturbance in relation with Timisoara earthquake could be detected at the location of Grocka observatory, does not seem very promising. Namely, the observatory is situated in a magnetically homogeneous environment characterized by uniformity of sediments and their great thickness to the basement layer (Jančić, 1983), implying no enhancement of eventual tectonomagnetic signal. Fur thermore, Grocka observatory is about 90 km from the earthquake epicenter, that is too far considering previously discussed detectable distance of possible precursory changes.

However, the following examples throw somewhat different light on this matter. According to Dobrovolsky et al. (1979), the zone of effective manifestation of precursory deformations is the circle with a center in the epicenter of an impending earthquake. The radius r (in km) of this circle, the so-called strain radius, is defined by the expression

$$\log r = 0.43 M \qquad (2)$$

where M denotes a magnitude. The above given relation holds for precursors of different physical nature, including the geomagnetic field changes. For instance, for an earthquake of M=6.0 a precursory change might be observed at the distance of approximately 380 km, assuming the strain value of $10^{-8}$.

Therefore, considering the relation (1), it turns out that there is no point in searching for seismomagnetic effect in connection with Timisoara earthquakes at the location of Grocka observatory. On the other hand, if a concept of a "strain radius" is accepted, Fig. 1 shows that besides the main shock, there were also several stronger aftershocks which

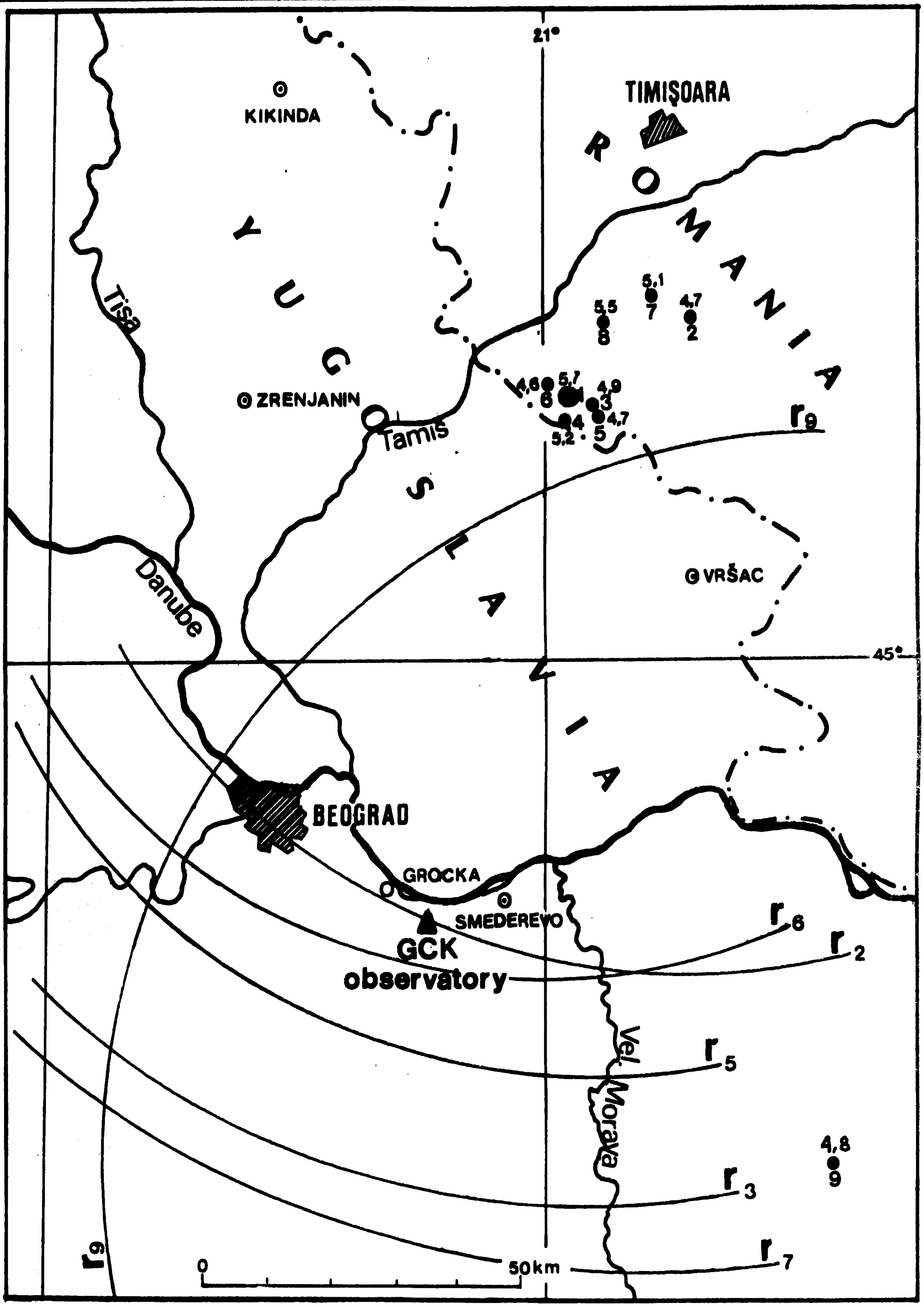


**Fig. 1** The location of Grocka (GCK) geomagnetic observatory with respect to the 1991 Timisoara earthquakes (dots present their epicenters with respective mag nitudes written above). Letters r1 to r9 denote strain radii for earthquakes numbered 1 to 9.

could have influenced the geomagnetic field behaviour at Grocka i.e., their strain radii calculated from relation (2) encompass this observatory.

Shapiro et al. (1978) have also stated that large total field intensity changes have been detected along a profile at Kyzyl-Kum polygon in the Middle Asia, 5-6 months before the M=7-7.5 Gazly earthquake at the distance of 180-250 km from the epicenter. It was their judgment that the region of stress accumulation with the deformation value of $10^{-7}$ may have occupied a territory with the radius of 600-700 km.

The condition concerning the presence of a strongly magnetic rock masses in order to intesify stress induced field changes, also appears to be questionable. Namely, there is report by Shapiro and Abdullabekov (1982) on anomalous magnetic field variations near the city of Andizhan in the Fergana Valley (Middle Asia), which actually led to the first successful Soviet prediction of the time and approximate place of strong M=7.0 Alay earthquake on November 2, 1978. Because there are no static magnetic anomalies greater than 10 nT in a radius of 25-30 km around Andizhan, since basement rocks as well as those closer to the surface are essentially non-magnetic, authors claim that "... it is thus difficult, - more precisely, impossible - to generate a tectonomagnetic explanation of the observed anomalies." Yet, an anomalous change which reached +23 nT a few days before the earthquake, was undoubtedly detected. Conclusion was that, in this case, processes other than those of piezomagnetic origin must have taken place, such as, for instance, electrokinetic phenomena (Fitterman, 1978).

The former discussion was meant to provide some basic insight into this topic. It was by no means intended to give quantitative estimation of a possible seismomagnetic effect at the location of Grocka (GCK) observatory. As a matter of fact, it is quite clear that any currently existing model calculations would not reveal detectable geomagnetic field changes at 80-90 km from the earthquake source region. Being aware of this situation we wanted to point out to reported examples of earthquake related geomagnetic field variations that are contradictory regarding some "accepted' (measured or computed) tectonomagnetic effect parameters. We are primarily interested in those field changes which are of large intensity or large spatial spread, giving thus a justification to the idea that tectonic processes responsible for 1991 earthquake activity in Timisoara region, could have exerted influence on the geomagnetic field recorded at Grocka observatory.

In order to examine this possibility, an extensive analysis has been conducted using the data set from five geomagnetic observatories including GCK. The most illustrative examples are selected and presented in the following section.

## 3. GEOMAGNETIC FIELD VARIATIONS AT GROCKA OBSERVATORY DURING THE 1991 TIMISOARA EARTHQUAKE

Analysis of the features of the geomagnetic field at Grocka observatory is based on data including: instantaneous values at 02 00 UT, hourly, daily and monthly means and values of the daily range of the geomagnetic field components - declination (D), horizontal (H) and vertical (Z) intensity. The time interval covered by these data has been chosen on the basis of relation $\log T = 0.6\ M - 1.01$ given by Rikitake (1975, 1979), where T denotes the so-called precursor time (in days) and M is the earthquake magnitude. For the main shock magnitude M=5.7 of Timisoara earthquakes, T=257 days or approximately 8.5 months is obtained, meaning that eventual local disturbances at GCK could have already appeared before the end of 1990. Longer time interval is convenient for observing something that can be assumed as normal trend with respect to which an anomalous field variation would be defined.

When dealing with phenomena spatially localized within a limited region around particular observation site, it is necessary to differentiate field values at that site with respect to simultaneous observations at one or more locations which are presumably beyond the influence of the source of disturbance that is to be investigated. That is the purpose of using the data from observatories Panagyurishte (PAG)-Bulgaria, L'Aquila (AQU)-Italy, Dourbes (DOU)-Belgium and Niemegk (NGK)-Germany. For such a distribution of stations and large separation between them, the simple difference technique of data processing is not the most appropriate for the elimination of non-local variations of the geomagnetic field i.e . variations originating in the ionosphere and magnetosphere. However, the application of other, more sophisticated methods imposes certain conditions which are not fulfilled in this case. Thus all results presented bellow have been obtained by the simple difference method.

The following two examples have been selected to illustrate peculiar field behaviour at Grocka observatory during the year 1991. They both refer to the differences of instantaneous values at 02 00 UT. It is not strange, because these field values have certain advantages for the analysis of local field changes since at the reading time the effect of the Sun, conductivity anomalies and the like are at a minimum level.

*The first example* – It is presented in Fig. 2 and shows one detail from the analysis of the monthly means of the differences in D, H and Z. It can be seen that the differences in declination between observatories Grocka and Panagyurishte, which are practically constant from June 1990, exhibit noticeable decrease

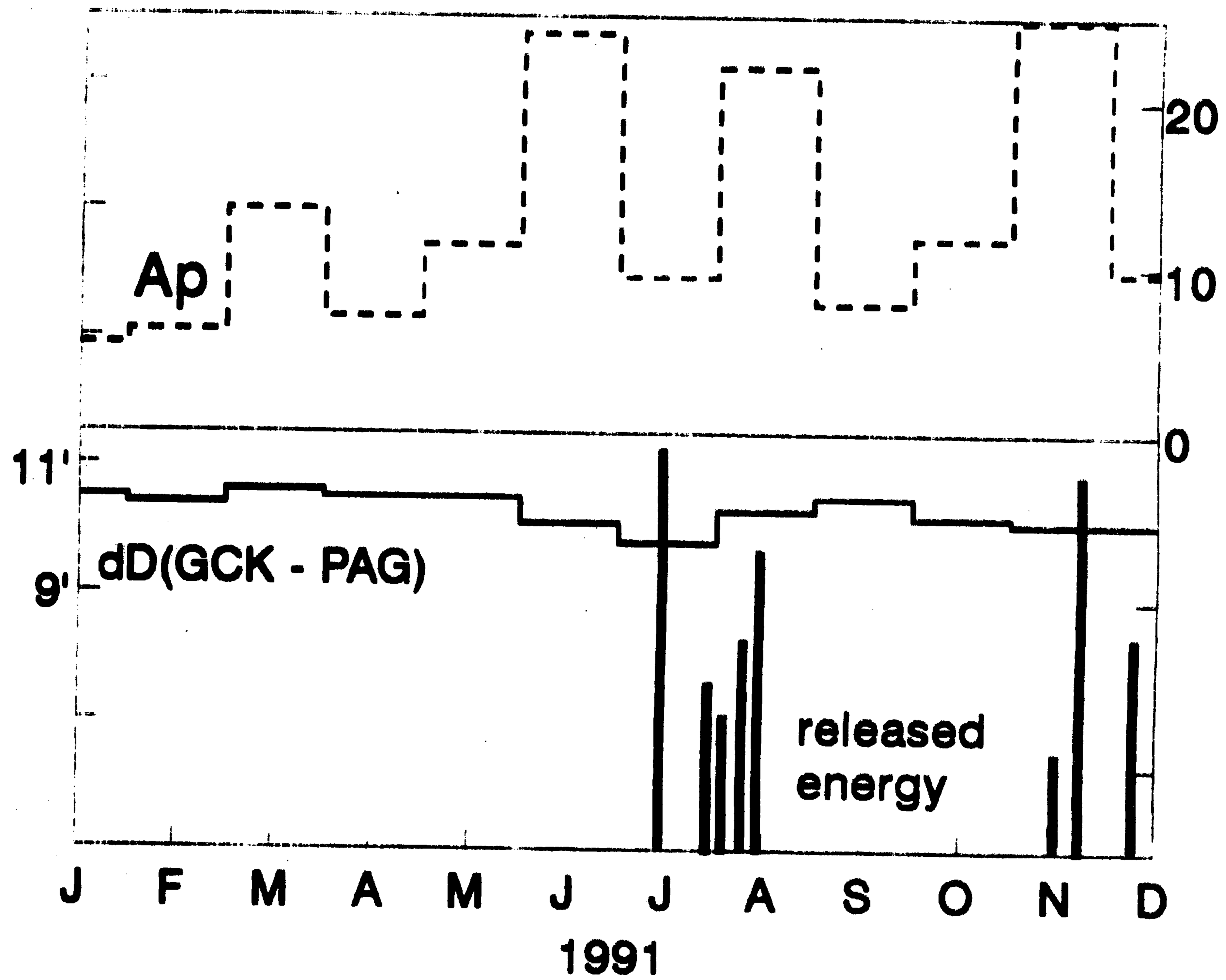


Fig. 2 Monthly means of the differences in declination at 02 00 UT betw een Grocka and Pana-gyurishte, mean values of Ap for ten selected days in a month when 02 00 UT values are read and released seismic energy.

starting in June 1991. Another decrease appears in October 1991. In both cases, one and a half month later, released seismic energy shows remarkable increase. Unfortunately, the cause of such a behaviour cannot be unambiguously ascribed to increased seismic activity since the geomagnetic activity, indicated by the planetary index of geomagnetic activity Ap, also increased in June and October, thus certainly influencing the differences ΔD(GCK-PAG). However, the decrease of ΔD(GCK-PAG) around the time of the main shock of Timisoara earthquakes with respect to the level which is almost constant from the middle of 1990, is about 0.′5 – 0.′6 with corresponding change in standard deviation of only 0.′1. The increase of geomagnetic activity might increase the standard deviation of ΔD differences, but not necessarily decrease their mean value.

*The second example* – In order to study the details of the field behaviour using instantaneous values at 02 00 UT, the differences in D, H and Z were analyzed as series of ten individual values in a month, without averaging. No particular variation has been observed that could be associated with July 12, 1991, earthquake, except perhaps slight decrease starting at the beginning of May. However, at the beginning of September the level of differences in declination between Grocka and Panagyurishte undergoes unusual change (see Fig. 3). Obviously, this offset of level (of about 1.′0 in intensity) is characteristic only for differences including GCK observatory. It cannot be seen in ΔD(DOU-NGK). After careful inspection of the correctness of respective declination values at Grocka, and taking into account that differences ΔD(GCK-PAG) do not exhibit such a feature, it could be supposed that its cause is probably of a regional character, encompassing both Grocka and Panagyurishte as the two closest observatories. Regarding this point, it is worth mentioning that the earthquake with magnitude M=4.8 (No. 9 in Fig. 1) occurred on September 28, 1991, in Homolje region, Eastern Serbia, actually between GCK and PAG.

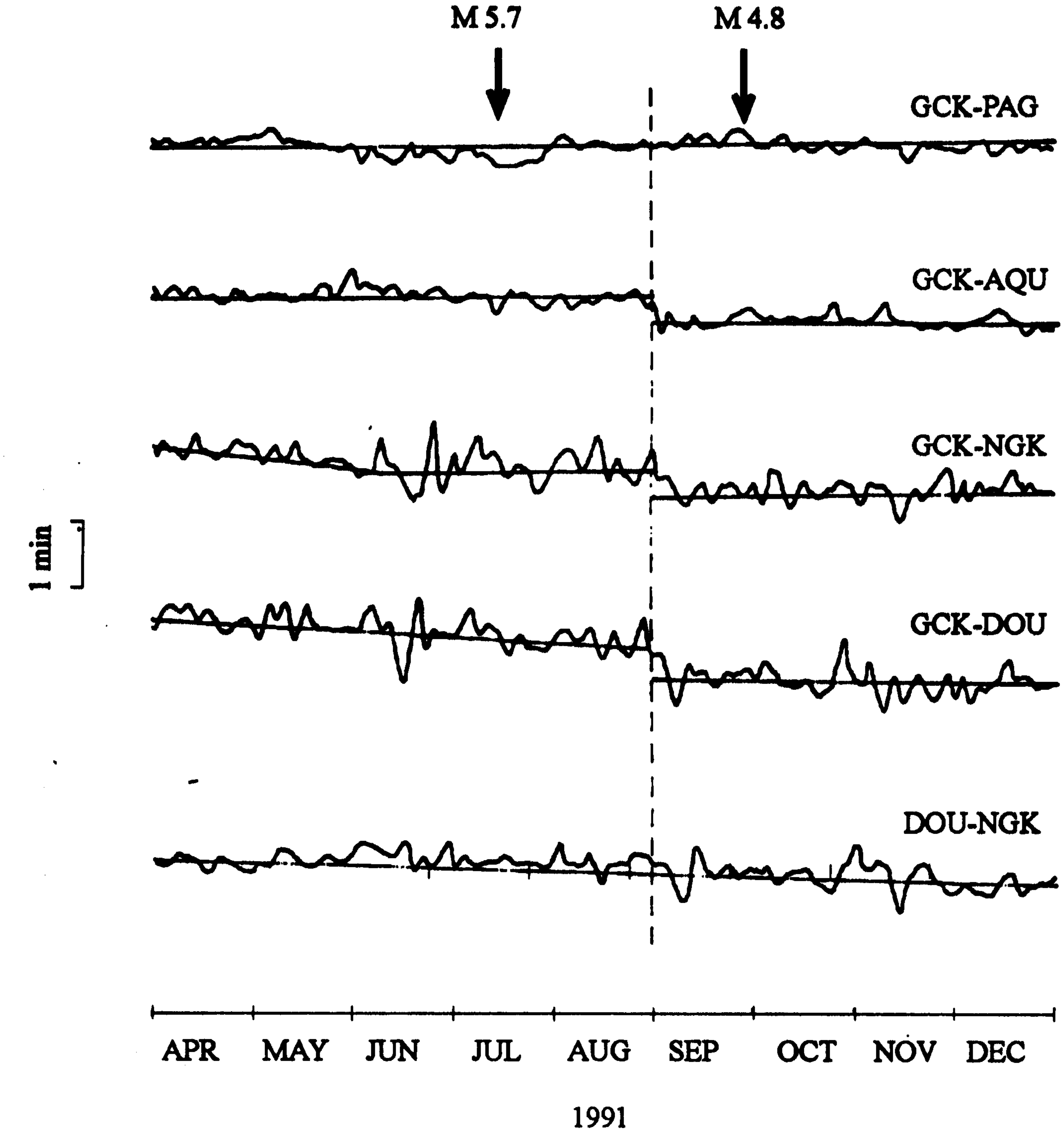


**Fig. 3** Offset in the linear trend of the differences in declination at 02 00 UT, well expressed in the case of differences including Grocka observatory, preceding M=4.8 earthquake in Homolje region, Eastern Serbia on September 28, 1991.

## 4. CONCLUSION

Peculiar geomagnetic field variations, particularly noticeable in declination (D), have been observed at Grocka observatory during 1991 in time intervals including some stronger earthquakes that occurred within 90 km from the observatory. Although there are some basis for assuming that the observed changes are earthquake-related, they cannot be uniquely attributed to them. Evaluation criteria for earthquake precursors require more than merely time coincidence between the two phenomena. Supposed relation should be supported by detected anomalies in some other geophysical or physical fields or parameters as well. However, if the possibility of real connection between geomagnetic field changes at Grocka and seismic activity in Timisoara region is accepted, mechanism of anomaly generation is probably not of a piezomagnetic nature. In any case, if the above assumption should prove to be correct, it might have an important bearing on the application of geomagnetic methods in eventual future projects aimed at investigation of astronomically established relative shifting of geographical coordinates of Belgrade with respect to Warsaw.

Another issue that should be pointed out is the possibility of using standard geomagnetic observatory data for this kind of study. It might be useful in the case as the one considered here, when there are no specially planned and conducted measurements over the area of interest. Otherwise, it is recommended to follow commonly accepted methodology in the field of tectonomagnetism.

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## О МОГУЋНОСТИ ДЕТЕКЦИЈЕ ТЕКТОНОМАГНЕТСКОГ ЕФЕКТА НА ЛОКАЦИЈИ ГЕОМАГНЕТСКЕ ОПСЕРВАТОРИЈЕ ГРОЦКА


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*Оригинални научни рад*



Дат је кратак преглед неких основних ставки које се тичу потребних услова за детекцију тектономагнетског ефекта на одређеном подручју и указано је на неслагања између извештаја различитих аутора. Анализиран је случај понашања геомагнетског поља на опсерваторији Гроцка у периоду који обухвата земљотрес од 12. 07. 1991. године, магнитуде M=5.7, у околини Темишвара (Румунија). Коришћени су подаци још четири европске опсерваторије - Panagyurishte, L'Aquila, Niemegk и Dourbes - због њихове различите локације у односу на епицентар земљотреса. Нађено је да геомагнетско поље у Гроцкој показује необичну промену половином 1991. године. Ако даље анализе покажу да опажене промене имају везе са земљотресом, то би могло имати важне импликације на примену геомагнетских метода у евентуалним будућим истраживањима која би била усмерена ка разјашњавању узрока релативног померања географских координата Београда у односу на Варшаву, установљеног астрономским опажањима, са аспекта могуће улоге геодинамичких процеса у настанку овог ефекта.