SEISMIC INTENSITY FIELD ALONG THE BULGARIAN-GREEK BORDER (1981-1990)

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A B S T R A C T

This study concerns the macroseismic intensity field along the Bulgarian-Greek border on the territory of Bulgaria during the 1981-1990 decade. The maximum observed intensity distribution has been obtained both by a traditional technique and an approach that specifies different types of the oscillations that have affected the site depending on source-to-site distance. It is expected that the idea proposed in this paper will provoke a search for other criteria of engineering refinement of the wave pattern that causes the macroseismic field of one and the same intensity.

ΚΑΤΑΝΟΜΗ ΤΩΝ ΕΝΤΑΣΕΩΝ ΚΑΤΑ ΜΗΚΟΣ ΤΩΝ ΕΛΛΗΝΟ-ΒΟΥΛΓΑΡΙΚΩΝ ΣΥΝΟΡΩΝ

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Π Ε Ρ Ι Λ Η Ψ Η

Η μελέτη αυτή αφορά την κατανομή των μακροσεισμικών εντάσεων κατά μήκος των Ελληνο-Βουλγαρικών συνόρων από την πλευρά της Βουλγαρίας κατά τη διάρκεια της δεκαετίας του 80. Η κατανομή των εντάσεων που παρατηρήθηκαν έχει παρουσιασθεί μία προς μία ως αποτέλεσμα των ακόλουθων ομάδων σεισμικών πηγών: των τοπικών πηγών της Νότιας Βουλγαρίας, των πηγών που βρίσκονται στη βόρεια πλευρά των συνόρων καθώς και των πηγών στα νότια των συνόρων. Η μελέτη που έγινε μπορεί να προκαλέσει μια ολοκληρωμένη εργασία κάλυψης του χώρου της Βόρειας Ελλάδας, επίσης.

INTRODUCTION

Nowadays, studying the seismic risk, in general one needs to know firstly the spatial and temporal distribution of possible source activation together with the source maximum potential and secondly a real distribution of the expected seismic movement on or near the Earth's surface. The intensity observed characterizes the entire set of influence factors such as source rupture properties, geological and local site conditions or so on; it also reflects ground motion changes along the attenuation path.

In cases of deficit or lack of instrumental strong motion data, at the second stage of processing, the maximum observed macroseismic intensity becomes necessary to be a starting point for obtaining average assessments. When the map of maximum intensity covers a long time (at least one manifestation of a severe earthquake from every one possible source), then it presents the distribution of generalized consequences from the earthquake excitation. And it might be extrapolated in correspondence with the maximum prognostic strength of expected earthquakes.

A current compilation of maximum observed intensity maps (concerning several years, a decade or two, depending on the earthquake activity) is necessary in connection with produced damages. In this paper several maps of maximum intensity observed during the decade of 80-ies are presented.

INPUT DATA, TECHNIQUE AND A NEW PHYSICAL APPROACH

Macroseismic data of earthquakes for the period 1981-1990 provided the main basis for the study of the maximum intensities distribution.

The territory studied was affected by local earthquakes in southwestern or southern Bulgaria and by strong earthquakes (M>5) occurring in the neighbouring countries predominantly. The locations of the events that provided the greatest excitation are shown in Fig.1. The earthquake main parameters are given in the Table 1.

Concerning the earthquakes localized on Bulgarian territory, the entire macroseismic field was taken into consideration. When the earthquake sources were in neighbouring countries, places of perception only in Bulgaria were of interest. During the investigated period the border area did not experience any significant shaking either from Bulgarian earthquake or from another country seismic source.

All the earthquakes that were felt by residents in the region were a subject of intensive macroseismic investigation. Letters of inquiry were mailed to the post and administrative officials and after coming back to the Seismological department the reports were analyzed. The investigations were usually supplemented by numerous telephone calls. The results of macroseismic studies provided data for drawing up isoseismals of a respective intensity. The estimation of intensity degree, based on the effects observed on the Earth's surface, was made according to the macroseismic scale of Medvedev, Sponheuer and Karnik (MSK).

The final maps shown in Figures 2 to 5 are the result of synthesis of isoseismal maps for both the shocks in Bulgaria (Glavcheva, 1993) and that ones occurred in the surroundings (intensity evaluation by the author). Compiling those maps, the maximum intensity felt in each inhabited place during the given period is taken into consideration.

For crustal sources the interest here is in the presentation of the real intensity distribution depending on the site-to-source distance. With this goal, crustal earthquake sources which caused the greatest effects during the 80-ies have been grouped as 1) situated nearer than 100 km ("near earthquakes") or 2) far off the site of observation of more than 100 km ("distant earthquakes").

Our criterion for the above classification evolves from the observed phenomenon of changing the gradient of both the intensity-distance relations (Rautian, 1960; Ergin, 1970; Papaioannou et al., 1985) and the instrumentally determined energy parameters vs. distance (Slunga, 1981; Singh et al., 1982; Malevskaya, 1984) at about 100 km from the seismic source. Then our idea was to use the general tendency, the higher the frequency the higher the attenuation of strong motion when going away from the radiation source. At that one can find that the shape of the acceleration Fourier spectra "does not vary appreciably in the distance range between about 10 and 100 km" (Trifunac, 1976), i.e. the attenuation with distance is essentially frequency independent up to 100 km. Finally, the empirical fact of transferring the maximal seismic energy through

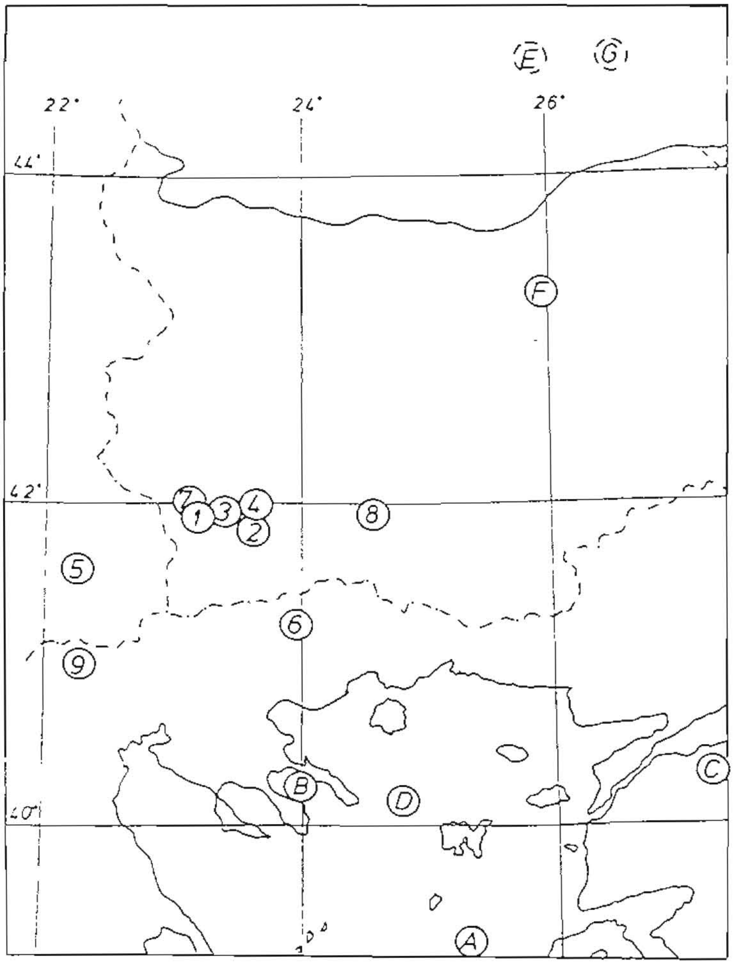

Fig.1. Location map. Epicentres of the events used are shown by circles and characters inside which correspond to the numbers of the Table 1.

the direct S-waves at short distances and in Lg-waves farther of the source supports the reason of distinguishing sources of macroseismic excitations according to the hypocentral distance in two types. Thus, different groups of construction damages could be assumed in principle.

The classification suggested has been reflected in the Table 1 together with the earthquake main parameters.

Table 1. Earthquakes which were used for the compilation of the maximum observed intensity maps.

Event' mark in Figs.	Date	Time GMT		M	h	Type of event,	Sources of data	
		h	min	(mb)	km	distance (r)	Main para-meters	Macro-seismic assess-ments
1	1981, Aug.26	19	42	3.6	11	crustal, r<100 km	Glavcheva,1993	
2	1981, Oct. 1	12	10	3.8	7	"	"	
3	1984, Jan.23	10	26	4.4	7	"	"	
4	1985, Feb.16	06	34	3.9	11	"	"	
5	1985, Sep.28	14	50	5.3	7.4	"	NEIS	RG*
6	1985, Nov. 9	23	30	5.3	22	"	"	"
7	1986, May.15	16	45	4.5	22	"	Glavcheva,1993	
8	1987, May. 2	09	05	3.6	11	"	"	
9	1990, Dec.21	06	57	5.9	13 G	"	NEIS	RG*
A	1981, Dec.19	14	10	6.7	10 G	crustal, r>100 km	" "	" "
B	1982, Jan.18	19	27	6.8	10 G	"	"	"
C	1983, July 5	12	01	6.1	10 G	"	"	"
D	1983, Aug. 6	15	43	7.0	? 2.4	"	"	"
E	1986, Aug.30	21	28	(6.4)	132	mantle	"	"
F	1986, Dec. 7	14	17	5.7	13	crustal, r>100 km	Glavcheva,1993	
G	1990, May.30	10	40	(6.7)	90	mantle	NEIS	RG*

*RG: Glavcheva, Unpublished assessments.

RESULTS AND DISCUSSION

As is seen from the exposition above, one and the same technique and two approaches in data processing have been applied.

The first approach is the classical one: For the period under investigation the set of highest intensity values is used. The maximum observed intensity map is constructed on the basis of all this data according to the traditional technique.

The generalized map of maximum intensities in Bulgaria observed along the Bulgarian-Greek border and inland is shown in Fig.2. Two different degrees of maximum intensities were observed along the border area within the territory of Bulgaria. The greatest intensity was of degree V° MSK, i.e. except for fine cracks or falling of small pieces of plaster and some cracking or partial falling of chimneys, any significant structural damage was not observed in those places. On the top side of the map the field of intensity V° has been produced by the intermediate depth earthquakes that occurred in Vrancea region /events E and G in the Table 1/.

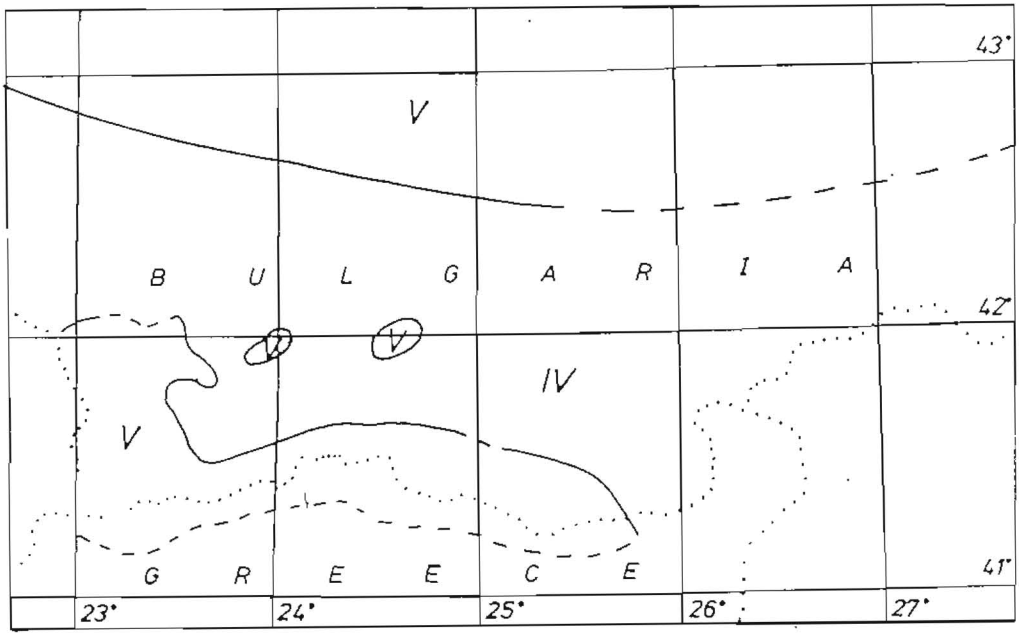

Fig.2. Maximum observed intensities - generalized fields (a classical approach).

Excluding the Vrancea zone, in the 80-ies exactly like during the period 1800-1970 (Grigorova, Christoskov, 1974), the general appearance of the maximum observed intensity map was pre-determined by relatively shallow earthquakes with focal depths not exceeding 25 km. Using the approach proposed above, the latter events were arranged into two groups. Thus, the same initial data were divided according to their origin, namely a "near earthquake" /events 1 to 9 in the Table 1/ or a "distant earthquake" /events: A to D, and F/. In this way, applying again the traditional technique, the maps in Figs. 3 and 4 have been produced. In Fig.5 the summarized maximum intensity map has been presented. In the Figures, the areas of equal maximum intensity are hatched according to specific keys.

As it is already known, the highest intensity observed in the border region was of V° MSK. Figs.3 to 5 show that different parts of the region were subjected to wave fields of different features. The effects in the central part of the border region were the result of an activation of crustal sources situated at distances longer than 100 km. At the same time, the consequences in the western part of the region were produced by local or near crustal seismic sources (at distances r<100 km), i.e. under conditions of high-frequency macroseismic field. A small area only, extended east-west of nearly 60 km, in the very central part of the border region, was put under excitation some times from near sources, and other times from distant ones.

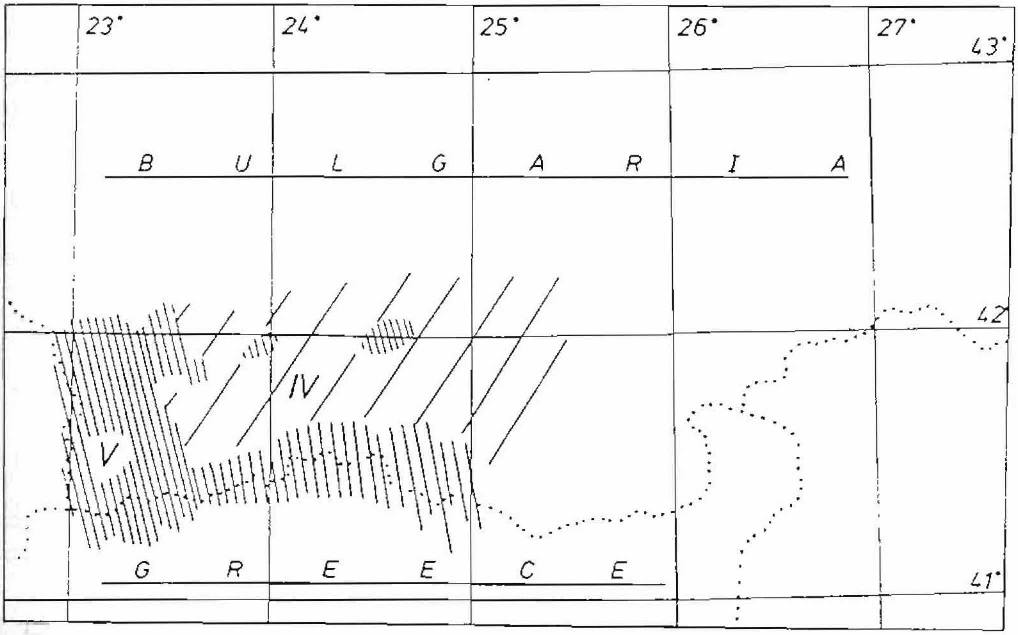

Fig.3. Maximum observed intensities from "near earthquakes" (site-to-source distances less than 100 km) - generalized fields

In Fig.5 the intensity field of IV° MSK is shown as a totality, having in mind that the man-made constructions therein suffered no damage. The IVth degree field spreads inbetween two Vth degree fields: in north-south direction of about one longitudinal degree and in east-west direction across the whole territory of Bulgaria.

Especially, for the case of the intermediate depth Vrancea earthquakes a low frequency character of ground motion was proved (Vrancea earthquake in 1977, 1983) This effect might be connected with the significant absorption of high-frequency oscillations through the lower velocity layers in the upper mantle.

For the earthquakes considered, the influence of the nature of rupture process on the strong motion /see, for instance, Hartzell and Brune, 1979; Steinberg, 1983 and 1984/ is most likely to be of little importance in the border region. Such an assumption is legal because of the following. The proportion between source sizes and source-to-site distance pre-determines the influence of source mechanism properties on the intensity field. During the 80-ies, even the so-called "near" sources (r<100) acted on the territory investigated like "point sources". The last argument helps a consideration of eliminating the source influence.

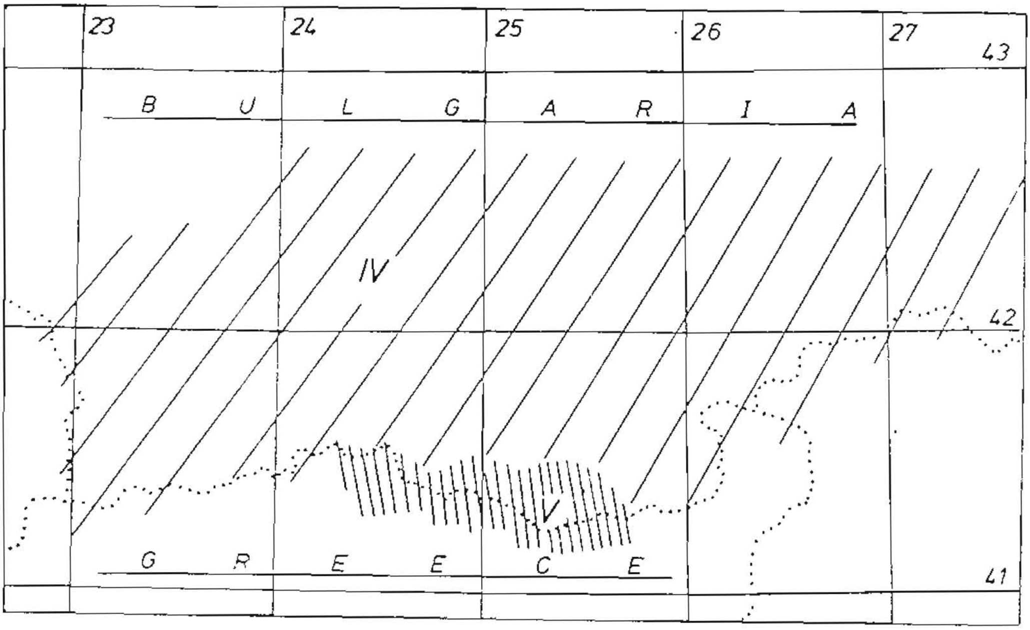

Fig.4. Maximum observed intensities from "distant earthquakes" (site-to-source distances greater than 100 km)- generalized fields.

At many earthquakes local areas of a higher or lower intensity within the macroseismic field of a given intensity are observed. Such kind of anomalies are mainly caused by near surface soil conditions. Using as a base the corresponding generalized map of maximum observed intensity, the frequency modifying under the influence of site special features have to be analyzed extraordinarily

The ground motion characteristics might be influenced also by tectonic boundaries through the way of seismic propagation. It was found, for instance, that the elastic waves lost their high-frequency component, because of diffraction, spreading along the contact between crystalline and sedimentary complexes (Methods for detailed study of seismicity, 1960). The influence of geotectonic set-up is legal to be discussed for concrete source-to-site directions.

When thick geological structures of significant horizontal homogeneity, as platform areas, extent through the seismic wave path, a superposition of supplementary low-frequency oscillations to the initial high-frequency ones has to be supposed (this is the case at powerful events when thick layers are constrained to vibrate) and then the energy redistribution to be taken into account.

The basic assumption here is that the main features of the felt areas with different maximum intensities are controlled by both the source-to-site distances and attenuation path; and some details only are to be added as it was discussed.

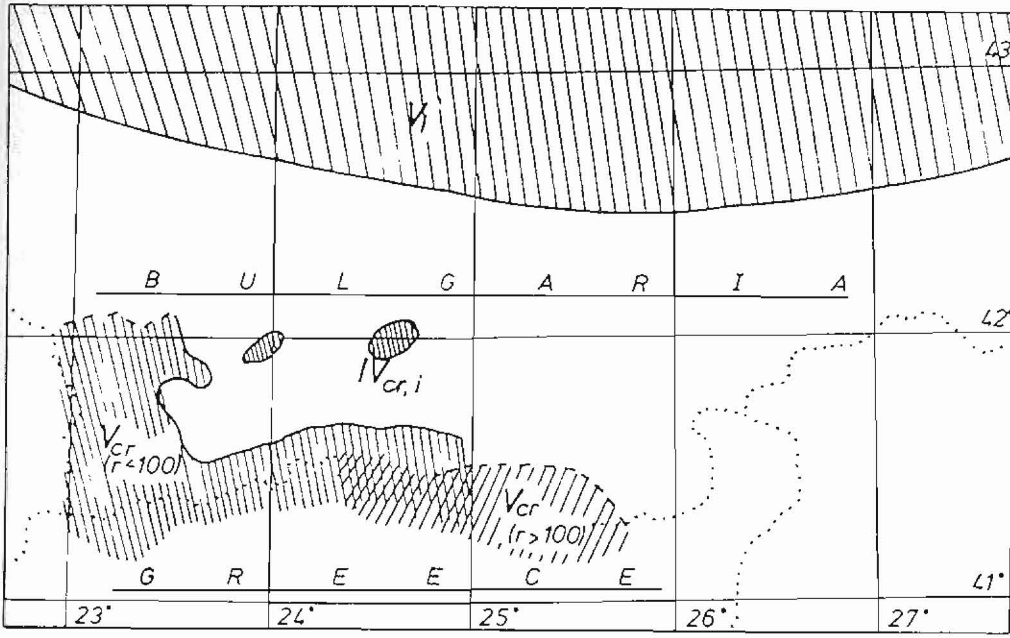

Fig.5. Summarized maximum intensity distribution (compiling from the maps in Figs.3 and 4).

CONCLUSIONS

During the decade of 80-ies there were no visible changes of the construction structures because of the earthquake excitation. Nevertheless, the vulnerability of man-made constructions might have been increased. Even, due to this reason, maps of maximum observed intensity is desirable to be elaborated periodically. Such a procedure seems to be rather important regarding to time intervals during which new construction types appear in large numbers. Then, the approach of compiling "frequency dependent" maximum intensity maps seem to be going to gain some positive significance for examination of the vulnerability-classification of the buildings, presented in the latest MSK variant (European Macroseismic Scale-1992, 1993) as well as that classification to cover also some other man-made constructions.

The presentation here does not pretend to be sufficient enough for engineering purposes. It is quite possible, a more suitable criterion of characterizing the wave pattern in the macroseismic field from engineering point of view, to be found in the future.

Nevertheless, for regions where there is lack of strong motion records, an elaboration of new long time maximum observed intensity maps seem to be advisable taking into account the attempt of "frequency distinction" suggested in this study. Such kind of intensity maps would give an approximate idea of the vulnerability and possible reaction of different man-made objects during future earthquakes.

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