

REEVALUATED MACROSEISMIC MAP OF VRANCEA (ROMANIA) EARTHQUAKE OCCURRED ON NOVEMBER 10, 1940

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In order to set the basis of some rigorous standards and norms of antiseismic design, capable of assuring maximum security to buildings, in accordance with the idea of promoting and developing a national system, compatible with the European standardizing systems, we initiated a very large research activity especially of reevaluating and harmonizing of the macroseismic maps of the significant earthquakes occurred on the Romanian territory [9], [10], [11]. In this paper there have been reevaluated the macroseismic effects of the strongest vrancean earthquake occurred at 10th of November 1940. The reevaluating operation of the macroseismic data consisted in the reinterpretation of over 4500 macroseismic questionnaires, as well as the critical and serious research of the expertise reports, monographies, photos, scientific papers published both inside and outside the country regarding the severity of the macroseismic effects that were noticed “in situ” in the damaged areas.

Taking into consideration the geological and tectonic complexity, as well as the distribution of the seismic active areas on the Romanian territory and in the transborder areas that influence the seismicity, we considered that it is necessary, for a better graphic representation of the distribution of the macroseismic field generated by the earthquake from the 10th of November 1940, to give up to the classical method of elaborating the isoseismal maps based on the smoothing operation of the excessively agitated isoseists.

Key words: macroseismic intensity, subcrustal earthquake, Vrancea seismogenic zone.

1. INTRODUCTION

Earthquake intensity in spite of its obvious semi-empirical nature it is still a very useful seismic parameter.

The intensity, measured mainly on MM or MSK scales, often presents something of enigma to civil or structural engineers, however, it is the best single parameter for meaning the severity of damage [14]. When properly assessed at a uniform and sufficient number of sites the seismic intensity may shows regular patterns attributable to source (generation), propagation (transmission and attenuation) and site effects as well as to other random (distorting) effects [2].

Properties and distribution of seismic intensity may be used to estimate: i) epicenters, (ii) focal depths, (iii) near-field and far field absorption coefficients, (iv) event's size, (v) future strong ground motions, or more generally (vi) intensity is used in assessment of earthquake hazard. Another major advantage of earthquake intensity is its unlimited temporal span (that is, historical and instrumental periods). The plentiful availability of intensity data (as temporal, areal and quantitative points of views) makes the intensity as a worthy and valuable study parameter. Having said the above arguments one could conclude that earthquake intensity issues (that is macroseismology) far to be absolute can be a convenient complement to modern quantitative (digital) seismology [7].

Having as a purpose the prevention and the diminishing of the catastrophic consequences of the earthquakes, there was utterly necessary the accomplishing of some major scientific research that could assure a base of veridic data in order for the antiseismic design of the civil, industrial, nuclear units etc. An important role in such activities has the research for reevaluating the macroseismic maps, research which is mainly based on reinterpreting and requantification of the toughness of the macroseismic effects produced by the significant crustal and subcrustal earthquakes from the Romanian territory. On the basis of the reevaluated maps, the corresponding ministries, together with the specialists from the institutes of antiseismic design of the constructions, willingly, there will be disposed urgent measures which are needed for adopting some new standards, capable to give the veridical parameters of design and/or consolidation of the built fund, especially, of the damaged constructions by the significant earthquakes, so that, to assure their resistance to some future earthquakes. The initiation of such research is sustained by the still vivid memory of tragic loses of human lives and of the huge material damages produced by earthquakes, thus evidentiating the serious vulnerability of the human settings. We mention, in this way, that, in the 20th century, the Romanian territory was shaken by two strong earthquakes: on the 10th of November 1940 ($M_{GR}=7,4$) and on the 4th of march ($M_{GR}=7,2$). But, the strongest vrancean earthquake, was the one produced on the 10th November 1940 [$M_{GR}=7,4$; $I_{max} (MSK)=IXI/2$], at 4 and 39 minutes (local hour), when the majority of the population was in houses. The pleistoseist area of this earthquake was of 80.000km^2 and the macroseismic effects were felt on a surface of over $2.000.000\text{km}^2$, being reported on vast areas, thus: in the north up to St. Petersburg, at over 1300km , where there have been estimated seismic intensities of IV-V (MCS degrees), in the south, up to Greece, in the east, up to the Harcov-Moscow line, with estimated intensities of V-VI (MCS degrees), in the west, up to Belgrade, Budapest, Warsaw. This amplitude of the macroseismic effects and their destructive force, unknown for the vrancean earthquakes, states the huge energy released during the seimogenesis process of the earthquake from the 10th

November 1940. The parameters of the earthquake from the 10th of November 1940 could not be determined from the instrumental recordings, because the first impulse of the longitudinal wave destroyed inferior suspension of the only seismograph installed on the ground floor of the Romanian Observatory from Bucharest [12]. The earthquake produced important damages also at the seismic stations from Sofia, Bruxelles, and Rome etc. This situation created great difficulties for the Romanian and foreign specialists, in their research regarding the establishing the real parameters of the earthquake. In order to approximately determine the parameters of the earthquake from the 10th of November 1940, there was used the macroseismic method based on the evaluation of the effects produced by the earthquake on the Romanian territory and within the transborder zones. The number of the victims of the vrancean earthquake from the 10th November 1940 could not be either exactly established or said because of the censure imposed by the state of war, but, by some authors, it is more than sure that it has exceeded over a thousand, under the conditions in which the population of the big cities from the outer area of the Carpathic chain (Ploiesti, Buzau) and, especially, of the capital, Bucharest, was considerably smaller than that existing at the occurred moment of the earthquake from March 4, 1977.

2. THE CHARACTERISTICS OF THE VRANCEA SEISMOGENIC ZONE

From the previous research results that the Romanian territory is geographically situated within the geodynamic assembly of the East-Mediterranean alpine region, being strongly marked by the complex interaction of the structural geotectonic global and regional elements. The complexity and the variety of the tectonics of the Romanian territory and of the adjacent areas of it, determine as the seismicity (the frequency and the energy of the earthquakes) to vary in large limits, according to the characteristics of the active tectonic subunities. In this aspect, we mention that, besides the intracrustal sporadic earthquakes, generated on various type of faults, which are specific to the seismic zones Banat, Fagaras, Crisana, Maramures etc., there produce also subcrustal earthquakes (intermediate-depth), more numerous and stronger in Vrancea Seismogenic Zone, which is situated at the curvature of the Oriental Carpathians. It is obvious the fact that, generally speaking, the seismicity of the Romanian territory is strongly determined by Vrancea intermediate earthquakes. From the seismicity studies, there has been stated that the major vrancean earthquakes produce disastrous macroseismic effects on a surface of approximately 50% from the Romanian territory, these being also strongly felt in the transborder zones. The damages made on large surfaces can be explained through the huge energies

released within the subcrustal seismogenetics processes, which are expanded by the mobility of the local complex geological structures, as well as by the dynamics of the crustal, subcrustal, regional and local tectonic structures. A factor that determines the distribution of the macroseismic effects on the surface of the Romanian territory is the type of the source mechanism, because the radiation scheme of the seismic energy is asymmetric and presents maximal in the slipping plan of the fault and minimal on the nodal plan.

3. THE NECESSITY OF REVISING THE MACROSEISMIC MAP OF THE EARTHQUAKE FROM 10.11.1940

By its politics, the communist regime installed in Romania in 1945 wanted the achievement of some “economies” as big as possible, even in the “sensitive” field of consolidating the civil, industrial and agro-zootechnical constructions, starting from the inhuman premise that : “ a one unit reducing of the seismic intensities on the macroseismic map of the Romanian territory corresponding to some antiseismic design at a low degree of seismic risk that would be equal to a drastic minimizing of the execution costs of the constructions”. This type of “economies” determined the government to put pressure on the Standardizing Commission, thus imposing to adopt, for standardization, the macroseismic map of the earthquake from 10.11.1940 elaborated by the Institute of Metallurgy and Applied Mechanics, map whose seismic intensities were at least a MCS degree lower compared to the macroseismic maps realized by the scientists Gh. Demetrescu, Gh. Petrescu, I. Atanasiu, Th. Kräutner and by E.A. Sagalova (USSR).

This is that, in 1952, the map elaborated by the Institute of Metallurgy and Applied Mechanics, with underevaluated macroseismic intensities, it was standardized and has been the basis of elaborating all the standards and norms of antiseismic design (STAS 2932-52; STAS 3648-61; STAS 111100/1-77 etc.). By this action, the seismic design standards and rules have been delimited, in their essentiality, by the macroseismic underevaluated map of the strongest Vrancea earthquake that took place on the Romanian territory on 10th November 1940. In time those standards caused an increase in vulnerability of the projected and edified buildings in the areas exposed to the action of the earthquakes, fact which was confirmed by the big loses of human lives and materials that happened during the earthquake from the 4th of March 1977. In order to underline the statements previously made, we will present some examples regarding the discretionary and dangerous way of diminishing the intensity values in the seismic zonation maps, for example for the capital of Romania:

1. In the seismic zonation map STAS 2923-52 [16], the area separated from isoseist of the VIII degree (MCS) was spreading up to Targoviste, and the area of Bucharest had VIII degree (MCS) ;

2. In the seismic zonation map from 1961 (STAS 3648-1961)[17], the seismic intensity for Bucharest was diminished with one degree, $I=VII$ (MCS) ;
3. Under the influence of the disaster produced by the earthquake from the 4th march 1977 earthquake and of the guilt feeling, by the decree no. 66/1977, there have been immediately brought modifications to the seismic zonation map from 1961, so that, for Bucharest, there was introduced the intensity of $VIII \frac{1}{2}$ (MSK) ;
4. As a consequence of some new political pressure, in the same year (1977), when the physiological and psychological traumas caused by the earthquake were still alive and painful, it is approved the new standard from which it was eliminated the half of the degree previously added to the intensity (STAS 11100/1-77) [19];
5. We mentioned that, by the earthquake from the 4th of March 1977 there was the seismic microzonation standard STAS 8879/6-73, but this was also declined by the severity of the produced effects that surpassed far beyond the mentioned intensities and, consequently, it was out of use;
6. Presently, the seismic zonation of the Romanian territory is presented under the form of a map with observed maximum intensities, having mentioned the return periods of the intensities, reflecting a probabilistic point of view (SR 11100/1-93) [20]. The map evidentiates modifications on the line of expanding the limit of the intensity area VIII, for Bucharest, the seismic intensity being of $I=VIII$ (MSK), with a 50 years return period.

These political malversions, with no precedent within the international seismology, have strongly imposed their destructive way over all standards and norms regarding the antiseismic design, having catastrophic consequences at the March 4, 1977 earthquake. This situation still persists and there increases the probability as, during the next decades, the Romanian society and its infrastructures to be catastrophically affected by strongest earthquakes than that from the 4th of March 1977 or than those occurred on November 10, 1940 and October 26, 1802.

4. THE REEVALUATED MACROSEISMIC MAP

When lacking instrumental recordings, the seismic intensities determined from the macroseismic questionnaires and from the “in situ” research reports become the most important elements for a more exact quantification of the severity of the seismic motion of the ground. As a rule, the reevaluation activities of the macroseismic map are mainly based on the reinterpretation and requantification of the macroseismic effects, previously evaluated using prescriptions of the old postponed intensity scales. In reality there are reinterpreted the information took out from the macroseismic questionnaires using the new prescriptions of the actual seismic intensity scale.

In order to reevaluate the macroseismic effects caused by the earthquake from the 10th of November 1940 there have been gathered documents that contain information concerning the effects on people and animals, usual objects, buildings, as well as over the geological medium (landslides, liquefactions, hydrological effects etc). From the documents that have been studied, we can mention: macroseismic questionnaires, photos, monographs, scientific papers, expertise reports made “in situ” post seismic, in the damaged areas and other documents from the country and abroad regarding the severity of the macroseismic effects.

In the case of the present research, the reevaluation process consisted of analyzing and reinterpreting of 4500 of macroseismic questionnaires where there are described the macroseismic effects produced by the earthquake from the 10th of November 1940 on the whole territory of Romania. The reevaluation of the macroseismic effects produced by this earthquake and the establishing of the seismic intensities was made according to the prescriptions of the seismic intensity scale MSK-64 (*Medvedev, Sponheur, Karnik*) –STAS 3684-71 [15]. As it can be noticed from the reevaluated macroseismic map, not representing the corresponding macroseismic intensities of the places from the NV of the country, as well as from the Neamt County, is due to the lack of the macroseismic questionnaires from the institute archive.

The reevaluated macroseismic map of the earthquake from the 10th of November 1940 was achieved using maximum seismic intensities (fig. 1). This map is comparable, as form and essence, with the macroseismic maps realized by the Romanian scientists Gh. Demetrescu and Gh. Petrescu [4]; I. Atanasiu and Th. Kräutner [3] (fig. 2, 3) and with the macroseismic map elaborated by E.A. Sagalova (USSR) [13] (fig. 4). The reevaluated macroseismic map, together with the macroseismic maps elaborated by the above mentioned authors, represents the argument that states an indubitable fact that the Romanian standard 11100/1-1993 [20] has to be urgently changed up to, so that it was realized on the basis of the modifications in time of the map “The seismic zones on the territory of R.P.R.” (fig. 5), elaborated by The Institute of Metallurgy and Applied Mechanics, map where the seismic intensities were diminished up to two degrees MCS. The map “Seismic zones on the territory of R.P.R.” (fig. 5) had important consequences over the antiseismic design in Romania, because this was the base of elaborating the standards : STAS 2923-1952 [16]; STAS 3648-61 [17]; STAS 111100/1-77 [19], standards by which, in time, it was made the antiseismic design of the civil and industrial constructions from the Romanian territory. The consolidated buildings in Romania, in the areas exposed to the earthquake action, were made on the basis of old standards and norms, leading to the incontrollable increase of the constructions vulnerability and , implicitly, to the increasing of the seismic risk. This statement is based on the statistics regarding the damages caused by the earthquake from the March 4, 1977, from which it results that, an important part from the designed buildings by the mentioned standards was badly damaged or, even worse, they collapsed, burying numerous victims.

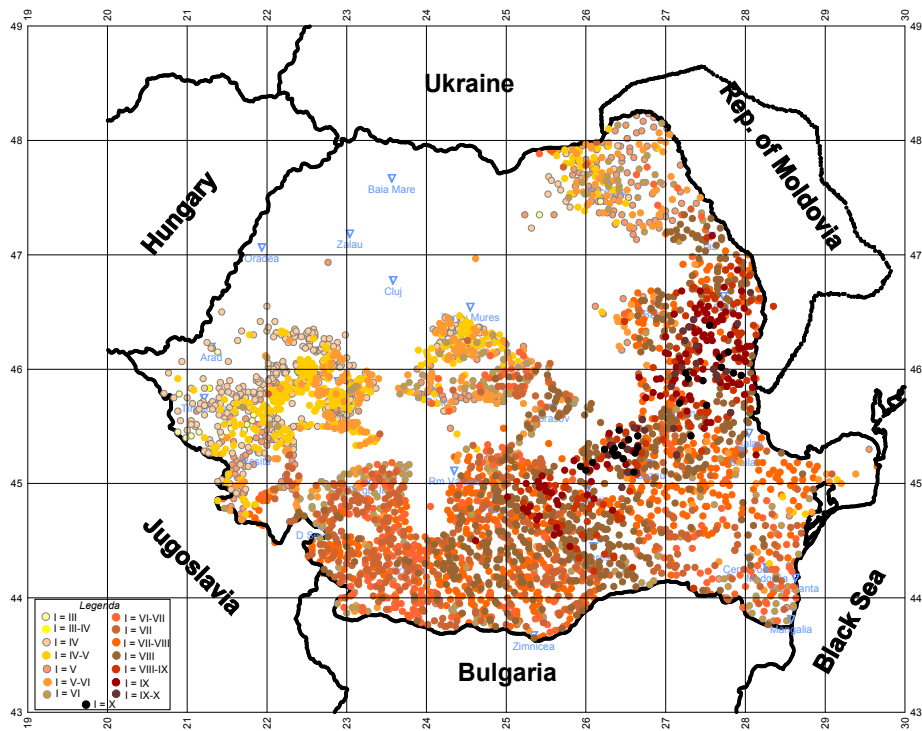


Fig. 1 – Reevaluated macroseismic map of November 10, 1940 earthquake.

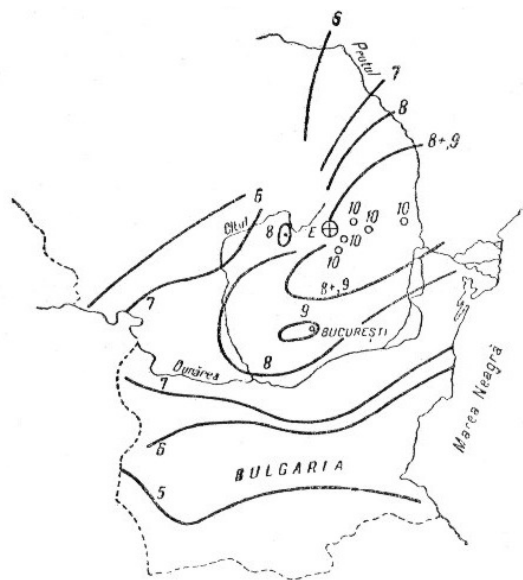


Fig. 2 – Macroseismic map of November 10, 1940 earthquake. (after [4]).

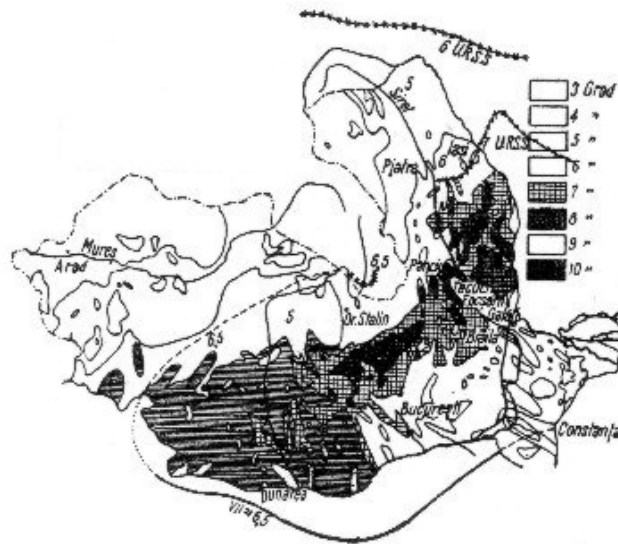


Fig. 3 – Macroseismic map of November 10, 1940 earthquake. (after [3]).

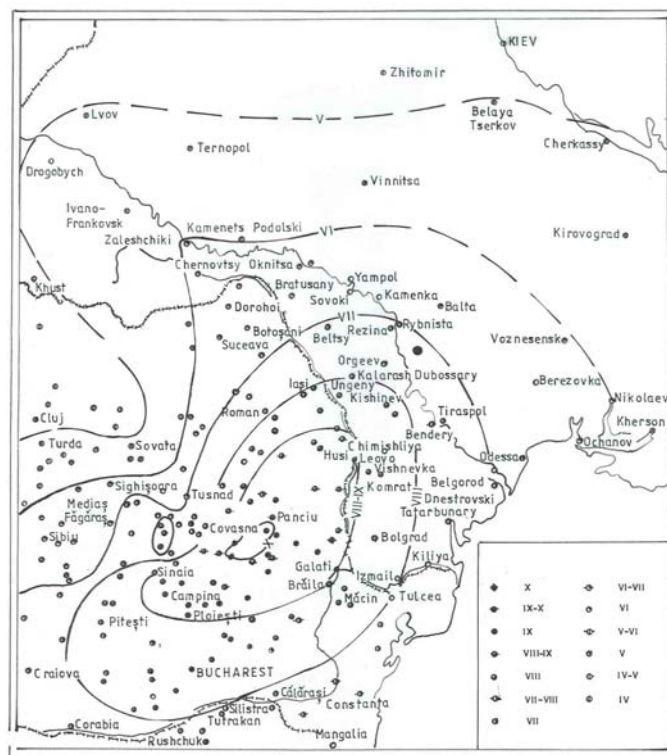


Fig. 4 – Macroseismic map of November 10, 1940 earthquake. (after [13]).

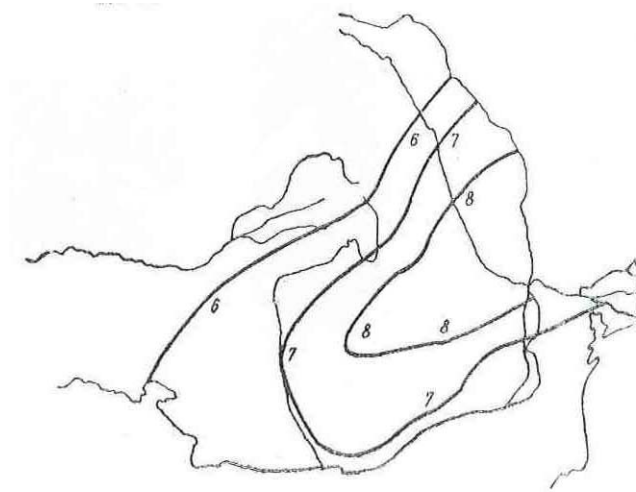


Fig. 5 – Map “The seismic zones on the territory of R.P.R.”.

When comparing the actual Romanian standard STAS 11100/1-1993 [20] with reevaluated macroseismic map of the earthquake from the 10th November 1940, we notice that generally have bigger values of the seismic intensities. These abnormal differences could be eliminated after the earthquake from March 4, 1977.

Another existing difference between the reevaluated macroseismic map and the Romanian standard STAS 11100/1-1993 [20] is represented by the fact that, from logical reasons, which are in accordance with the scientific and methodological requests, we gave up delimiting isoseists. The explanation consists in the fact that, in the case of isoseismal maps, in their first elaboration stage, the form of the intensity variation curves is more « agitated », in the second stage it is achieved the smoothing operation of the curves, meaning that, it is desired as the graphic representation of the isoseismals to present soft variations of the radius of curvature. By this operation it is obtained “the form” not “the essence”. Taking into consideration this aspect, we thought that, in order to accomplish a rigorous antiseismic design, it is useful to give up the “traditional artistic” part (isoseismal map) and to come up with a macroseismic map where we should properly render the field reality. By adopting this way of representation, the macroseismic map will present graphically the descriptive content of the macroseismic questionnaires, thus, the designer will know directly the value of the macroseismic intensity for the pointed site. There can be said that the smoothing of the isoseists is nonconservative (uncovering) and certainly this hides a dangerous seismic potential. Moreover, the smoothing of the isoseists is achieved without taking into account the influence of the local conditions, such as the case of some localities from the neighbourhood which are situated on different geological and tectonic structures to whom there are attributed the same intensity or the viceversa, when

these are situated on identical geological and tectonic structures but which are separated by a isoseist, thus the designer task in choosing a right intensity being very laborious.

We have to say that, through the classical method of elaborating the isoseismal maps, there are arbitrarily eliminated or included, areas from the territory of the country, within inappropriated seismic areas, thus introducing uncertainties which can have dangerous or uneconomical consequences for designing buildings in such areas.

5. CONCLUSIONS

The achievement of the reevaluated macroseismic map in those two ways, offers a greater degree of precision and security within the antiseismic design, compared to the classical maps with isoseists. From the thorough research of the macroseismic field generated by the earthquake from the 10th of November 1940, there are evidenced the following aspects:

- 1) Directivity of the macroseismic field is oriented on the SSV-NNE direction;
- 2) Weight constructive interference of the cowaves produced by successive shocks (dislocations) (like earthquake from March 4, 1977), which produced strong pulses of large displacements at nearby sites toward which the rupture is progressing.
- 3) The multishock character of the earthquake from the 10th of November 1940 is, according to the authors, obvious because the focusing of the seismic energy on SSV-NNE direction, indicates the fact that there was a phenomenon of progressive rupture with sudden accelerations and decelerations that generated strong shocks, phenomenon that was similar to that produced at the earthquake from the 4th of March 1977, the difference being that, in the case of this earthquake the propagation of the rupture was made on the NNE-SSV direction. Only in this way there can be explained the fact that, the macroseismic effects were stronger in the NNE, unlike the earthquake from March 4, 1977 for which the macroseismic effects were stronger in the SSE part of the sources. The increasing intensity of the macroseismic effects towards SSV, in the case of March 4, 1977 earthquake and towards NNE in the case of the earthquake from the 10th of November 1940, was determined, in both cases, by the constructive interference of the cowaves produced by successive shocks. Only by admitting that the earthquake from the 10th of November 1940 was of a multishock type, we can explain the major macroseismic effects produced in Focsani, Odobesti, Marasesti, Panciu, Barlad, as well as in the areas from the neighbourhood of the source where the seismic intensity exceeded the X (MCS) degree (Lopatari, Targu Bujor, Neculele). In all these places 70% from the houses have been completely destroyed, burying a great part of the inhabitants. In Bucharest and in the cities situated in the S and SV part of the Vrancea Seismogenic Zone, the victim number was lower compared to that

from March 1977. The fact that there were fewer victims in the case of the earthquake from the 10th November 1940, it can be explained through the situation of the existing built fund, as well as by the regime of its height that were incomparable with today (the heights were smaller), which means a more reduced vulnerability.

As regards the rupture process, in the case of the two major earthquakes that occurred on the 10th of November 1940 and 4th of March 1977, it is known the fact that this takes place within real mediums with areas more or less resistant, thus the latest ones being considered asperities [5] and barriers [1]. The asperity model of fault rupture assumes that the shear stresses prior to an earthquake are not uniform across the fault because of stress release in the weaker zones by creep or foreshocks [6]. Release of remaining stresses held by asperities produces the main earthquake that leaves the rupture surface in a state of uniform stress. In barrier model, the pre-earthquake stresses on the fault are assumed to be uniform. When the main earthquake occurs, stresses are released from all parts of the fault except for the stronger barriers; aftershocks then occur as the rock adjusts to the new uniform stress field. The significance of asperities and barriers lies in their influence on ground-shaking characteristics close to the fault. A site located close to one of these strong zones may experience stronger shaking than a site equally close to the fault but farther from a strong zone. At large distances from fault the effects of fault nonuniformity decrease [6].

We also have notice that the macroseismic map made by Sagalova [13] for the earthquake from the 10th November 1940 (fig. 4) is very close to the macroseismic map achieved in this paper.

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