

VRANCEA (ROMANIA) SUBCRUSTAL EARTHQUAKES: HISTORICAL SOURCES AND MACROSEISMIC INTENSITY ASSESSMENT

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The aim of the present paper is that of bringing in additional information regarding the macroseismic effects of the historical earthquakes that occurred on the Romanian territory with the purpose of improving the macroseismic maps. It is known the fact that in time, the Romanian territory has been shaken by strong earthquakes, most of them being centered within Vrancea Zone, which is situated at the bending zone of the South-Eastern Carpathians. As results from the contemporaries' notes, such major earthquakes occurred also during the 19th century, on the 26th of October 1802 and the 23rd of January 1838, causing numerous victims and major material damages. Additional information that refer to the macroseismic effects produced by the above mentioned earthquakes, have been recently discovered due to the investigation of old books fund which exists in some monasteries and museums. The results of the investigation were concretized in discovering 37 historical records that allowed us to make a correct interpretation of the destroying impact of these earthquakes over the society and the environment. New elements regarding the research of these earthquakes were obtained after reevaluating the information from certain areas (especially from the epicentral zone), concerning the environmental effects. In this paper, the information referring to these earthquakes, identified as a result of investigating historical sources, are interpreted and evaluated with the purpose of assigning some seismic intensities for elaborating the macroseismic maps.

Key words: historical earthquake record, Vrancea zone, macroseismic map.

1. INTRODUCTION

The Historical Seismology offers sporadically new precious information which, due to their raw character don't have to be regarded superficially because through their correct interpretation we can obtain notable results which can influence the seismotectonic studies and can correct the estimations of seismic risk.

If the seismic activity associated to the earthquakes occurred on the Romanian territory, it is known from the instrumental recordings due to the appearance of the "Romanian Instrumental Seismology" in 1935, as well as from

the concomitant and methodic study of the macroseismic effects, we can't say the same thing about knowing the seismic activity, previous 1935. This inconvenient make us investigate, despite all the difficulties, the information of paleoseismic, archaeological and historical nature (hidden within the oldest writings), such research representing true challenges for seismologists.

For the moment, in this study we present several information about some historical earthquakes, information that were obtained as a result of the research extended in the past as the new discovered sources allowed us.

Thus, in order to deepen the studies over the major Vrancea earthquakes that occurred on October 26, 1802 and January 23, 1838, there has been analyzed a great number of records made by the contemporaries at that time, some of these being discovered as a result of the research made through more archives, old book funds belonging to some churches and monasteries [3]. It can be said that the investigations were directed especially in finding new primary and original information existing in some of the historical sources mentioned above, information that are scientifically the most important without being affected by some interpretations, usually subjective of those who collected and compiled. That's why, the new elements from this study consist of using, as much as possible, the information coming from the primary sources.

The credibility degree of the information from the records regarding the producing of the earthquakes is high considering the fact that these were made by the men of the church which is a source of Christian and laic culture that eliminates the possibility of recording some false information connected by their effects.

Unfortunately, as a result of the numerous wars and military occupation, fires or storms, very many manuscripts were destroyed or disappeared, mainly towards the end of 17th century and the beginning of the 18th century.

2. THE POLITICAL, SOCIAL AND ECONOMICAL CONTEXT EXISTING AT THE MOMENT OF PRODUCING THE TWO EARTHQUAKES

Within the process of revising the historical earthquakes, besides other factors as the repeated administrative divisions followed by changing the names of the localities, it is also important to know the geography, local history and the political and social conditions existing at the moment of producing the earthquakes.

In time, on the Romanian territory, there have been numerous political, economical and social changes as a result of many invasions and occupations of some foreign hostile people. As such tragedies happened the names of many localities have been changed and because of that, during the investigating process of the historical information, there has been given a special attention to this aspect.

At the end of the 18th century and the beginning of the 19th century, the surface that represents the actual territory of Romania contained the three Principalities: The Romanian County (Walachia), Moldavia and Transylvania.

Thus, Transylvania was annexed to the Habsburg Empire since 1775 having an administration subordinated to the Austrian crown and at the same time to the Hungarian and German elites and The Romanian County and Moldavia have been for many centuries under the interference area of the interest spheres of the Ottoman and Russian Empires. Under the social aspect, The Principalities were still functioning on the basis of some medieval structures, the society having a pyramidal organization: in the top of the hierarchy there was the voivode followed by the aristocratic class, by members of the church and peasantry.

In the first half of the 19th century there has been registered a demographic and economic growth sustained by the bourgeoisie's appearance which had an important role in the political, social and economical modernization of the Romanian Principalities.

Another essential aspect for defining the political and social situation in the Principalities during the first decades of the 19th century, is represented by The Church which had a fundamental social role in that period. The importance of the Church as an institution was emphasised especially in education, most of the schools being detained and administered by churches and monasteries, but also in economy, as the church property represented almost 20% of the properties from the Principalities. The access of the churchmen to culture and to everything that meant study materials, led to the appearance of these sources of information referring to earthquakes which are useful for the scientific class in order to study the seismic history of the Romanian territory.

3. THE COLLECTING, ANALYSIS AND INTERPRETING OF THE INFORMATION ABOUT HISTORICAL EARTHQUAKES

Generally speaking, in order to evaluate the historical earthquakes parameters, the only major problem consists in locating both in time and space the sources that contain historical information of seismic motions. Collecting the data that are found under the form of descriptive accounts on the manuscripts and old books, illustrates, maps, newspaper articles, chronicles, scientific papers, seismograms (where is the case), constitutes the first step which usually necessitates most time and financial resources.

Sometimes many of these information are not clear and because of that it is not easy and possible that, on their basis, to assess the intensity, to locate the epicenter and to estimate the magnitude.

As a parenthesis we can mention the following statement made by Poey in 1855 [17] which referred to the lack of information from certain periods of time, mainly: "Unfortunately the researchers abandon too easily the search of the historical sources. It seems that they fear to find new information". There has to be mentioned that the "source" concept should be used just for the original (primary) sources or for the faithful copies, the translations and the descriptions and not for

the compilations that were achieved later on the basis of some inaccessible or disappeared primary sources [25]. It is an important piece of advice but more difficult to follow considering the fact that it is almost impossible the access to some records made a long time ago which, as it has been mentioned before, probably no longer exist.

It can be said that, compared to other countries that have information about earthquakes only for the last 100–200 years, Romania has a good archive of historical sources from which there can be obtained precious information.

Another valuable source of information about the effects of the historical earthquakes is represented by the reports made by the employees of the Meteorological National Service who, at Hepites's advice, after each earthquake, they used to go in the field and gather data about the macroseismic effects from the people from that area. The system worked efficiently between 1893–1926, with 4–5 years of interruption (between 1916–1920) during the world first war [2].

As regards the location of these historical sources, it is well known the fact that the big cities, localities or the big populated areas represent the major sources of macroseismic information. Generally speaking, in the case of the events occurred within the areas from the surroundings of these cities and, of course, according to the earthquakes magnitude, the information regarding the reported macroseismic effects are better both qualitatively and quantitatively than those which refer to the events occurred in the isolated areas.

Most of the records about the historical earthquakes present only the fact that these were felt in a certain area or there haven't been reported damages. When referring to the information concerning the ampleness of the macroseismic effects, there was considered that, in general, people have a selective and passing memory, thus being memorized especially the human losses and the damages caused by significant earthquakes. Sometimes, even in the case of strong earthquakes, as it is the case of those studied in this paper, some records are short, they mentioning only the fact that the earthquakes were felt without describing their effects over people, over buildings and environment, while other sources speak about the producing of such effects. In this way it can be explained the fact that some notes about some unknown earthquakes do not contain descriptions of the macroseismic effects, so it might be the case of moderate earthquakes.

A special interest must be shown to the information regarding major earthquakes, especially those which were not studied enough, in this way, it is necessary to look at the sources of national and international information which were less investigated, where we could discover new aspects. On the other hand it shouldn't be ignored the less reliable information regarding the historical earthquakes considered insignificant, as by gathering all these information we will obtain a more complete image of the active seismotectonic systems, thus facilitating a better predictability of the seismic potential. Moreover, through a thorough research of the new historical sources, we can discover that some seismic

events, considered small, have generated under specific conditions, bigger intensities. Generally, this affirmation is valid for the known events only from the information coming from some big cities and not from their surroundings, thus existing situations that these earthquakes to have registered bigger intensities. As a conclusion, we must keep our attention over the moderate seismic events even if the research prove to be more difficult due to the lack of information, compared to those that refer to strong earthquakes. Paradoxically, even the most significant seismic events have not always been completely exploited from seismological and seismotectonical point of view. All these statements lead to emphasizing the importance of those historical investigations which are necessary for achieving the completeness of the earthquake catalogue, including the research with the purpose of discovering some new earthquakes and a better documentation of the less known ones.

Even if they have a small accuracy, the historical information are very important, fact that determined some researchers to state the following: “The starting point which encourages this research is the same that determined the construction of some catalogues with information from the past, being based on the idea that the historical records offer useful information that should help us protect from the future earthquakes” [9].

With the purpose of obtaining the macroseismic intensities, there have been analyzed, interpreted and evaluated a set of information recently discovered or coming from published manuscripts/papers and reports made by some authors on the basis of primary data. The recently discovered information represent the records made on the old books existing within the archives of some monasteries, churches and museums, records for whom there were necessary some activities connected with their transcription, transliteration and translation from the Cyrillic, Slavonic, Greek and Latin alphabet. The identification of the records is the most laborious activity, on the one hand due to the language diversity they were written and, on the other hand due to the random way in which they appear on the book (some being legible written while others are unreadable or even difficult to understand; some have the text on one page, others are spread all over the book or are written among the lines). Also, within the research activities a special attention was given to identifying the book circulation in time. This thing meant consulting more reference materials, as well as deciphering of the other records from the book in order to establish the place where the book was at the moment of producing the seismic event.

4. OCTOBER 14/26, 1802 EARTHQUAKE

The earthquake occurred on the 14th/26th October 1802 on a Tuesday, at 12:55 the local hour, causing numerous victims and huge damages on the Romanian territory and also in the adjacent areas. The earthquake was felt up to

Constantinople, Kiev, Moscow, St. Petersburg, Warsaw, Varna, Vidin [24]. The earthquake from 1802 has an uncontested scientific signification, not just through the fact that it is considered the biggest known Romanian earthquake, but because of the huge macroseismic effects caused by it on the territories of the surrounding countries, thus representing a study subject of international interest. The magnitude of this earthquake was estimated by various authors as follows: $M = 7.5$ ([20], [21], [22]); $M_s = 7.7$ ([4], [13]), $M_w = 7.9$ [15]; $M = 7.4$ [12]. About this devastating earthquake there was written an impressive number of scientific papers and the subject generated numerous philosophical debates and religious interpretations, inspiring even poets.

Each new discovered information comes to confirm and to complete the image of the disaster caused by the earthquake from 1802 over the population and the buildings from that period which were considered very important and solid. It might be due to this fact that this earthquake appears in all the records under the name of "*the big earthquake*" which the inhabitants of Bucharest heard of up to these days.

The damages caused by such a violent earthquake over the churches, the buildings and generally over the environment emphasized the people's incapacity (observers and victims) to react rationally and efficiently in front of the forces of nature. Among the churches and monasteries that have been damaged at the earthquake from 14th/26th of October 1802 we mention: Coltea, Stavropoleos, Sarindar, St. Apostoli, St. Gheorghe Nou, Mihai Voda, St. Atanasie Bucur, Udricani, monasteries: Cotroceni, Vacaresti, Plumbuita, Margineni and Negru Voda. And, of course, there has to be mentioned Coltea tower which represents the most important point in the majority of the historical records, especially in those that refer to the damages caused by the earthquake in Bucharest. (see fig. 1).

When comparing the number of the dead and the wounded reported after producing these earthquakes with the impressive number of human losses and material damages produced by the major earthquakes from the 20th century, there can be stated that the population of those times was less exposed to the action of the earthquakes. The phenomenon can be explained through the fact that in those times the density and the concentration of population in urban centers were considerably reduced. Another explanation can be that the regime of height of the buildings was modest, many buildings being made out of stone with thick walls which gave them a greater resistance to the seismic action. The biggest human and material losses were registered generally where the density of the constructions was bigger, the phenomenon of destruction being more emphasized by the collapse of the walls or of some buildings over the ones nearby.

Very important are the records that contain descriptions of the environmental effects produced by this earthquake, sometimes being included appreciations of the observer about the coseismic phenomena of liquefaction. Such an example is the

record from the Parusi's paper [16], extracted from "The Chronicle of the craftsman Ioan Dobrescu (1802–1830)" whose textual description we present as follows: "During the year 1802, on Tuesday the 14th of October, on St. Parascheva Day [...] there was a great earthquake [...] and here in Bucharest many churches shook, others for good; the inns, the big houses also fell down. **And the earth here and there opened a whole as if a man with a horse could enter in it and after the earthquake ended the earth was split until the next day. Then Coltea, the high tower from Bucharest fell down and it had inside a big clock which was beautifully made with stones that could be seen far from Bucharest at three hours distance, but when the sky was serene it could be seen even farther. And this earthquake happened around noon, and through the cracks of the earth appeared water with black clay which smelt badly like brimstone**".

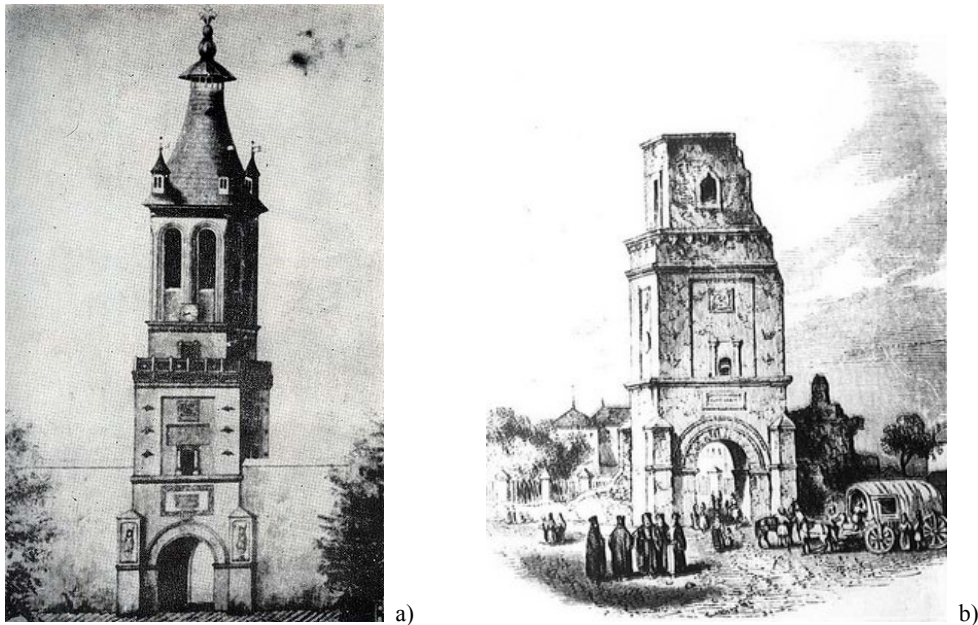


Fig. 1 – Coltea tower a) before and b) after October 26, 1802 and January 23, 1838 earthquakes [b) drawing by M. Doussault-published in *l'Illustration* 1842].

Such a description of the disaster caused by this earthquake in Bucharest we can meet also in the record made in the Cyrillic alphabet on the book "Pentecostarion": "To be known since the earth has shaken from the year 1802 October the 14th on the day of St. Parascheva and it has shaken very hard the walls fell down and also Coltea tower from Bucharest fell down and **ground cracked and appeared water with sand** and I wrote myself Raducan, the son of the priest Radu Ciochina" [3] (see fig. 2b).



Fig. 2 – a) Coltea tower in 1888 (after [16]) and b) Historical record of October 26, 1802 earthquake.

5. JANUARY 11/23, 1838 EARTHQUAKE

During the 19th century occurred the earthquake from the 11th/23rd January 1838 which can be compared to that from 1802 but with more disastrous effects. The earthquake from the 11th/23rd January 1838 caused numerous victims and material damages written down with great grief by many contemporaries. The earthquake occurred at 20:45 being felt strongly in Bucharest and also all over the country up to Lvov (Lviv), Sevastopol, Constantinople (Istanbul), Odessa etc. [1]. In Bucharest the earthquake was felt for 30 seconds [8], being followed by a series of aftershocks from which we mention only two (the 12th/24th and the 13th/25th of January) and for whom we have records. As well as for the previous seismic event the magnitude for the earthquake occurred on January 23, 1838 was estimated by the same authors: $M = 6.7$ [19]; $M = 6.9$ [12]; $M_s = 7.3$ [4]; $M_w = 7.5$ [15].

In Bucharest there have been registered very many damages, starting with the walls of the royal palace which collapsed, remaining uninhabitable and going on with St. Gheorghe's inn, which in the moment of collapsing destroyed other buildings causing losses of human lives. Within a first report made immediately after the earthquake there has been communicated the death of 8 people (but their number grew continuously during the days that followed the earthquake, finally reaching to 600), other 14 being wounded (reaching 600), a number of 36 houses were totally destroyed and most of the others had major damages [24], [18].

The descriptions of the macroseismic effects produced by the earthquake from 1802 over the buildings, population and environment are available also for the earthquake from 1838, but we have to mention that the effects of the earthquakes from 1802 and 1829 were more visible over the resistance of many constructions. Lately, due to this situation these buildings had to face many problems (see fig. 3).

Large ground cracks and sand blows appeared during the vrancean earthquake that occurred on the 23rd of January 1838, these being very well described and easy to interpret in some historical documents. During this earthquake, in some areas, especially the epicentral zone, mainly in Vrancea, Buzau, Braila and Dambovita counties appeared large ground cracks and liquefaction phenomena. Generally, these macroseismic effects appeared on slopes and the river shores where the ground is water saturated. The explanation of the appearance of such macroseismic effects, on restricted areas, according to the dates we dispose of up to the present, is given by the behavior of the superficial geological structures to the transitory action of the seismic perturbation of certain intensity.



Fig. 3 – Images showing the disaster caused by the January 23, 1838 earthquake (after [16]).

6. MACROSEISMIC INTENSITY ASSESSMENT

Presently the geophysicists, seismologists and engineers give a great importance to a better interpretation and quantification of the macroseismic data as well as to completeness of the earthquake catalogue. Even if the “*intensity*” is not a scale which is based on instrumental measurements, it is yet destined to quantify, on large areas, the damages caused by earthquakes, thus having a character which no other instrumental parameter can have [10]. Presently there is a complex activity in order to evaluate and reevaluate the macroseismic intensities from the

preinstrumental period. Thus, to obtain some good seismological interpretations of the historical information, with the purpose of assessing the macroseismic intensity, there are needed elaborate knowledge of geophysics and geology, as well as solid knowledge of history, in this perspective collaborating with historians and paleography specialists.

Within the process of assessing the macroseismic effects of the major earthquakes there must be underlined especially the damages caused to the buildings and then over the effects on people and objects because, considering the emotional state of those who practically have lived such experiences, contemporaries of the earthquake, their appreciations could be a little bit exaggerated. But, also in the case of buildings the specialists have to take into account the following aspects like: the types of materials used and the construction techniques from the period before 1900 were different from those applied in the present. Also, we must consider the fact that the information referring to the types of buildings are few and unavailable. The information about the buildings existing in the first half of the 19th century allow us their classification in classes with low resistance (A and B), described in the macroseismic scale MSK-64 used in Romania. Within the process of evaluating the macroseismic effects produced by historical earthquakes over the buildings, there has to be paid a special attention to the degree of previous damage of the resistance structures because the repeated actions of the earthquakes undermine in time the resistance of the construction material having as an effect some more accentuated damages over the built fund. In most of the records, there is reference to the damages caused to all the buildings, but sometimes there are described only the effects over the more important buildings (churches, towers) which form the constructive point of view can be classified in class B. Some of the major problems in assessing the intensity from the historical records is given by the fact that often we come across cases in which there is reference to a single monumental building, fact that induces two negative aspects: one is the assessment of vulnerability class and the second is the difficulty in determining the quantitative effects of the grades damage which cannot be determined on statistic basis [14].

In this paper the macroseismic intensities have been estimated on the basis of intensity scale MSK (Medvedev, Sponheuer, Karnik - STAS 3684-71) [26] with 12 degrees. For a more precise assessment of the seismic intensity there has been made a positive compromise by introducing the half-degrees. The presence of half-degrees implies that the statistical evaluation is situated between two intensity levels (two levels of the intensity scale).

For the information concerning to the environmental effects produced by these historical earthquakes, there has been tried the application of the new

intensity scale – INQUA [27] used in many countries of the world. The seismic intensities obtained on the basis of this scale are comparable to those gathered on the basis of MSK-64 scale.

7. MACROSEISMIC MAPS OF THE INVESTIGATED EARTHQUAKES

Considering the fact that the main purpose of evaluating the macroseismic effects caused by earthquakes is that of giving the necessary information for the antiseismic design of the civil and industrial buildings, there is absolutely necessary the achievement of the macroseismic maps.

On the macroseismic maps the numbers from the proximity of each city and village represent the intensities (MSK), evaluated on the basis of the macroseismic effects. In the case of some cities and villages for whom there haven't been described effects in the text of the record and thus there couldn't be attributed intensities, it was decided to give them letters as follows: F = felt, S = severe and H = heavy, although the mentioned earthquakes are strong with major effects all over the country. There has been adopted this method to emphasize the fact that for these earthquakes there has been discovered an important number of records, only that not all of them render what we, seismologists would want to find, mainly more detailed descriptions of the macroseismic effects.

The macroseismic maps of the earthquakes from the 26th October 1802 and 23rd January 1838 are represented in fig. 4 and 5, the obtained intensities were evaluated on the basis of MSK scale. These results contain values of the macroseismic intensity determined from data coming from more sources among which we mention: [11], [23], [5], [6], [7] etc., as well as an important number of information gathered from recently discovered sources, not used in other study [3].

The intensities reevaluation for these two earthquakes that occurred in the first half of the 19th century revealed the fact that a part of the intensities evaluated by other authors have been underestimated. Moreover, in this work there have been obtained some values of macroseismic intensity for some locations for which in the previous studies there weren't information about the macroseismic effects caused by these earthquakes.

But, in order to obtain as many values of the macroseismic intensity as possible and thus for determining the real macroseismic field of each historical earthquake, there are necessary many information which practically "*are waiting*" to be discovered within the multitude of existing materials in various types of historical sources that have not been searched until now.

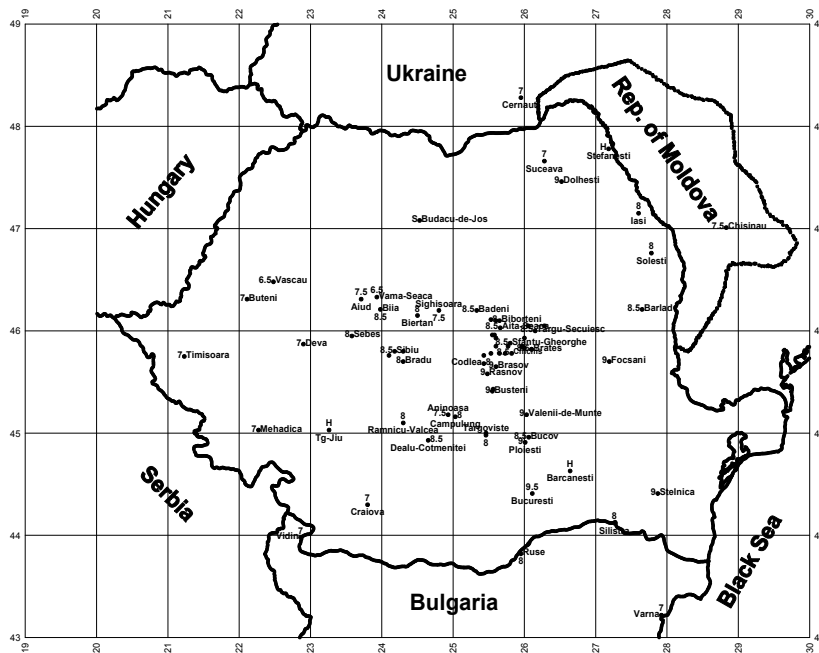


Fig. 4 – Macroseismic map of October 26, 1802 earthquake.



Fig. 5 – Macroseismic map of January 23, 1838 earthquake.

8. CONCLUSIONS

The antiseismic design of some national important objectives and of course the occurrence of some destructive seismic events, determine the seismologists to apply to the database offered by the Historical Seismology.

The two earthquakes studied in this paper occurred in a period when the quantity and quality of the historical records were in a continuous increasing and practically these natural calamities made people write down their effects under different forms and in any available document.

The information coming from records represent the basis of establishing the macroseismic intensities of the historical earthquakes, these having an unquestionable importance for the attenuation studies which are crucial for the seismic hazard assessment and the seismic risk reduction which leads to intensifying the research necessary for achieving of the databases and the macroseismic maps. Presently, due to their complexity the macroseismic observations are considered a challenge of the seismological research, thus these are and will be very important for properly assessing of the past, present and future seismic activity of a territory.

The macroseismic maps of the historical earthquakes represent key points in measuring the potential major seismic movements and it is essential to know the history of the earthquakes from certain areas for probabilistic assessment of the seismic hazard.

The main conclusion that comes out of this research consists in discovering some new information which come from primary sources that lead to improving the quality and to increase the number of data about historical earthquakes.

For some periods of time for whom the written information do not exist, the data can be provided by Archaeoseismology and Paleoseismology. In the future we want to extend the research in the field of Archaeoseismology through creating collaboration with archeologists whose knowledge and provided information can bring a significant contribution in improving the seismological database.

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