SEISMOLOGICAL DATABASE
FOR BANAT SEISMIC REGION (ROMANIA) – PART 1:
THE PARAMETRIC EARTHQUAKE CATALOGUE

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The most comprehensive Seismological Database for Banat Seismic Region has been achieved. This paper refers to the essential characteristics of the first component of this database, namely the Parametric Earthquakes Catalogue for the Banat Seismic Region (PECBSR). PECBSR comprises 7783 crustal earthquakes ($3 \leq h \leq 25$ km) with $0.4 \leq M_i \geq 5.6$ (M_i is M_L, M_D, M_S, M_W, Mm and/or mb from compiled sources) occurred in the Banat region and its surroundings between 1443 and 2006. Different magnitude scales were converted into moment magnitude scale, Mw. The completeness of PECBSR strongly depends on the time.

Key words: earthquakes, hypocenter parameters, macroseismic data, databases, Banat Seismic Region.

1. INTRODUCTION

The western and southwestern territory of Romania, called, in this paper, *Banat Seismic Region* (BSR), is the most important region of the country as concerns the seismic hazard determined by crustal earthquakes sources. The seismic risk in the region is also very high due to local risk factors and vulnerabilities: weak dwellings, old and unprotected buildings in the large cities, dams and chemical factories, high density of localities, great towns, and so on. The studies of seismicity and seismotectonic sources used for a realistic local hazard assessment and the reliable inputs for seismic hazard computations need high quality data and information. Consequently a high quality seismological database has been elaborated focused on BSR (*Seismological Database for Banat Seismic Region, SDBSR*).

SDBSR has been designed in a comprehensive format because BSR is a transfrontier region of Romania and thus the local seismic hazard is also determined by the earthquakes occurred in the neighboring areas of Hungary, Serbia, Bulgaria and also in nearby seismic provinces of Romania (*e.g.* those defined by [2], namely Crisana, Transylvania and Western Muntenia). On the other hand, the seismotectonic peculiarities identified inside BSR pass beyond its boundaries. SDBSR has conceived as a relational database and it has two main

components: the *Parametric Earthquakes Catalogue for BSR (PECBSR)* and the *Catalogue of Focal Mechanism Solutions for BSR (CFMSBSR)*. The two catalogues are linked together and to other components of SDBSR (*e.g.* macroseismic data, digital archives, etc.).

PECBSR is the result of an elaborated and well-documented research work started in 2003 as doctoral studies of the first author. Partially these studies have performed into the framework of several projects of the National Institute for Earth Physics (NIEP) Bucharest. These are the projects from the Program „Researches about seismic hazard on national and local scale", 2003–2005 and the Project "Assessment of seismic hazard due to earthquakes occurred in southwestern part of Romania and neighboring areas: its implications on environment security and territory development", Hasver/Ceres 2004–2006. The work also benefited by the results of the first author's partnership into an International Project of European Seismological Commission, known as EuroSeismos ("Saving and Studying the Seismograms of the strongest Euro-Mediterranean Earthquakes") that started in 2002 and is on development.

The final catalogue has a high level of homogeneity and is up-to-date until the end of 2006. Its elaboration was possible especially because good scientific and informational conditions fulfilled. Firstly, a long tradition of seismological research focused on local seismicity and seismotetconics exists at Timisoara [7, 15]. Secondly, the region was instrumentally monitored for a long time by a local seismic network with good performance, called Banat Seismic Micro-network [8]. The first seismograph was installed at Timisoara in 1942 [7, 8, 15]. The EuroSeismos Project (www.storing.ingv.it/es_web) provides us with many unique instrumental data for early historical events (since 1900).

There are many sources representative for PECRSB compilation. Other parametric and/or descriptive catalogues are very important. To our knowledge, only few regional catalogues focused on BSR earthquakes exist, such as [9, 12–14]. A comprehensive catalogue covering Carpatho-Pannonian Realm was published by [21]. Enlarged catalogues were compiled for a European/North Balkan area and have special significance for our work, *e.g.* [16, 17]. Additional several catalogues of international agencies, such as [22], were published for a long time period.

The main aim of this paper is to prezent PECBSR, the core of SDBSR. The another catalogue, CFMSBSR, is to be published as a separate paper due to particularities of its content and structure [10].

2. THE PARAMETRIC EARTHQUAKES CATALOGUE, PECBSR

2.1. ELABORATION PROCEDURE

The users of Parametric Earthquakes Catalogues consider them as samples of primary data, which is unfortunately false. Generally, these ones are

compilations and it is important to know all about their content and structure. In other words, they have to be transparent as much as possible. PECBSR has been elaborated into a comprehensive format and it is based on compiled and/or reinterpreted earthquakes data and new computed focal parameters. The links with other information fields of SDBSR assure a high level of transparency of the catalogue.

The work out of PECBSR followed the next stages: settling the geographical limits of the catalogue; identifying earthquake catalogues needful for selecting all seismic events occurred between previous limits; collecting all data and primary information (historical, macroseismic and instrumental ones); analyzing and compiling the final parameters. Then all collected data were processed using uniform criteria and principles. Additional investigations established when they was necessary. A special attention was paid to the historical and macroseismic available primary data that was analyzed taking into account some recommendations of [18, 19].

The *homogeneous cataloguing* of earthquakes is the master principle of PECBSR elaboration. Thus, each earthquake has a uniform standard set of parameters, like origin time (GMT time), geographical coordinate of epicenters (latitude and longitude), focal depth, magnitude, and epicentral intensity (degree on EMS98 scale). Errors are also associated with each above-mentioned parameter. Except the date and origin-time, the other parameters mutually correlated according the *conformity principle in Seismology* used by [13].

2.2. SPACE, TIME AND MAGNITUDE LIMITS

To establish the space limits of PECBSR we define two areas: BSR *senso stricto (BSRss) and* BSR *senso largo, (BSRsl)* respectively. BSRss is the area of interest for the study with a surface of about 25000 km^2 and is bounded by 46.5–44.5 N latitude, 21.3–22.8 E longitude as well as the national frontiers with Hungary and Serbia. BSRss is defined mainly using the limits of historical provinces [4], seismic risk factors and the conditions of instrumental monitoring [7]. BSRsl is an enlarged area of BSRss and it has critical significance for seismic hazard assessment. Its borders have been drawn at a distance defined conservatively. Firstly, we chose an earthquake scenario with the M_{max} observed in the southern Europe, $Ms = 6.6$ [17] and the maximum focal depth in the region $h_{max} = 25$ km [10]. Then we established $I = VI^O EMS$ as the minimum intensity that can be produced by this maximum earthquake into at least one locality situated inside BSRss, nearby its borders. Finally, using the intensities attenuation relationships from [17] we computed an average critical distance of 80 km, resulting BSRsl area of about 100000 km^2. The epicenters located outside BSRsl, up to 10 km distance from its borders are also catalogued.

PECBSR covers a time interval of 563 years (1443–2006). No pre-established limits for magnitudes and intensities exist.

2.3. DATA SOURCES AND PROCESSING OF INFORMATION

All available sources of data and information used to elaborate PECBSR have been classified by their structure, nature and quality of useful information and the level of reliability. Thus, three groups of sources were identified, namely i) *main or core sources for compilation* with earthquakes data (parametric and descriptive earthquake catalogues [*e.g.* 1, 2, 6, 15, 16, 20], internal reports of National Institute for Earth Physics [*e.g.* 11–13], earthquake catalogues elaborated in the framework of several national projects [*e.g.* 9], international bulletins [21]; ii) *sources of primary information about historical earthquakes* (studies of particular earthquakes (*e.g.* [19]), macroseismic chestionaires, manuscripts, documents, corespondences and notices from different archives, historical documents like monographies, cronicles, documents from national archives, newspapers reports, original historical seismograms obtained by direct partenership in EuroSeismos Project (www.storing.ingv.it/es_web), analogic and digital seismograms, seismic bulletins, etc.); iii) *auxiliary sources with non-seismic information* (documents and papers about history, education, religion, and so on, needed to interpret correctly the historical data); iv) *analog and digital seismograms*, obtained especially since 1980 by National Seismic Network; v) *seismograms* recorded with mobile stations network which were installed on July and December 1991.

Three categories of investigations were applied on the datasets: i) *historical investigations* for being able to interpret correctly all available information; ii) *macroseismic investigations* for obtaining all intensity data points and for mapping the macroseismic field based on new criteria; iii) *instrumental investigations* for refining and/or computing new hypocentral parameters.

Historical investigations have been applied especially for become acquainted with the conditions of recording, preservation and recovering of any useful information for the region. Thus, the culture of the inhabitants, demography data and political conditions, religions, economical and administrative development, the name of localities, migrations, wars, etc. are very important information. As an example, it is very important to know that a terrible war between 1718 and 1789 destroyed completely numerous localities from southeastern zone of the region and it has been repopulated after many years only. These historical circumstances tell us a lot about the chances to find out some seismic information. This information tell us that only some official war reports or letters of soldiers probable preserved into an archive, a library or somewhere else could be a chance to recover new seismic data about the region.

By studying historical documents, papers, books, newspapers and letters, it was also possible to improve the parameters of some earthquakes.

The parameters of all historical earthquakes have been revised using calibrated macroseismic data on well-documented earthquakes basis. We obtain some new equations of the macroseismic field, describing the mutual relationships between magnitude, intensities and distance from the source.

Instrumental data concerning arrival times of P and S, L, R waves, amplitudes and duration of seismic signal were obtained directly by us from original seismograms or seismic bulletins. The earthquake occurred on October 19, 1915 is the first local event from PECBSR that has been studied using instrumental data. We used Seisan software package [3], a simple velocity model and station corrections to (re)locate the catalogued earthquakes. Magnitude M_D is routinely determined using local stations recordings. M_L and M_W were also computed when digital waveforms were available. Macroseismic magnitude, Mm, is (re)determined using the new equations. Finally, PECBSR comprise all types of magnitudes determined by us or collected from other sources. The homogenized M_W magnitude was obtained using a hierarchically conversion scheme similar with [6] for conformity with national catalogue, but we also applied some new conversion relationships obtained in this work.

2.4. STRUCTURE, FORMAT AND COMPOSITION

PECBSR has a complex structure due to the characteristics of processed data and information and to the compiled results. There are several informational levels interconnected and linked with the other components of the database. The core of PECBSR is presented in a standardized form with the following parameters: Date (year, month and day/yyyymmdd), Origin time GMT (hour, minutes and seconds/hhmmss.s), latitude N (degree, F5.3), longitude E (degree, F5.3), depth (km, F4.1), magnitudes (F2.1), intensity (degree, F3.1). There are many events without any locations, too. In this case, the parameters are the origin time, magnitude/intensity, P polarities, S-P differences if instrumental data exist, and geographical coordinates of the locality with maximum intensity and/or corresponding to the azimuth and to the epicentral distances computed using 3 components polarities and arrival time differences. These events are marked with distinct flags being eventually connected with a main shock of a seismic sequence, with an earthquake swarm, a locality or a map or with any other useful data.

Macroseismic maps, intensity data points (IDP), instrumental data and so on constitute information included into PECBSR but as complementary data being accessible either separately as independent information or as a link with the standard main catalogue.

The catalogue finally comprises 7783 earthquakes. Magnitudes and intensities range between $0.2 \leq Mi \geq 5.6$ (Mi are magnitudes collected from original sources and may be M_D, M_L, M_S, M_W, mb) and $2.0 \leq Ii \geq 9.0$, respectively (Ii is maximum observed or epicentral intensity). Fig. 1 displays a map of earthquake epicenters (locations obtained using minimum three stations arrival times, explosions have been excluded as far as possible). Their distribution show many clusters of epicenters related with areas of high seismic activity and with destructive potential historicaly confirmed ($I_O = VIII^O$EMS) [10]. Two groups of clusters could be separated from this distribution: one in the North-West of BSR, called Banat Seismogenic Zone and the other in South-East, or Danube Seismogenic Zone, respectively [1, 10].
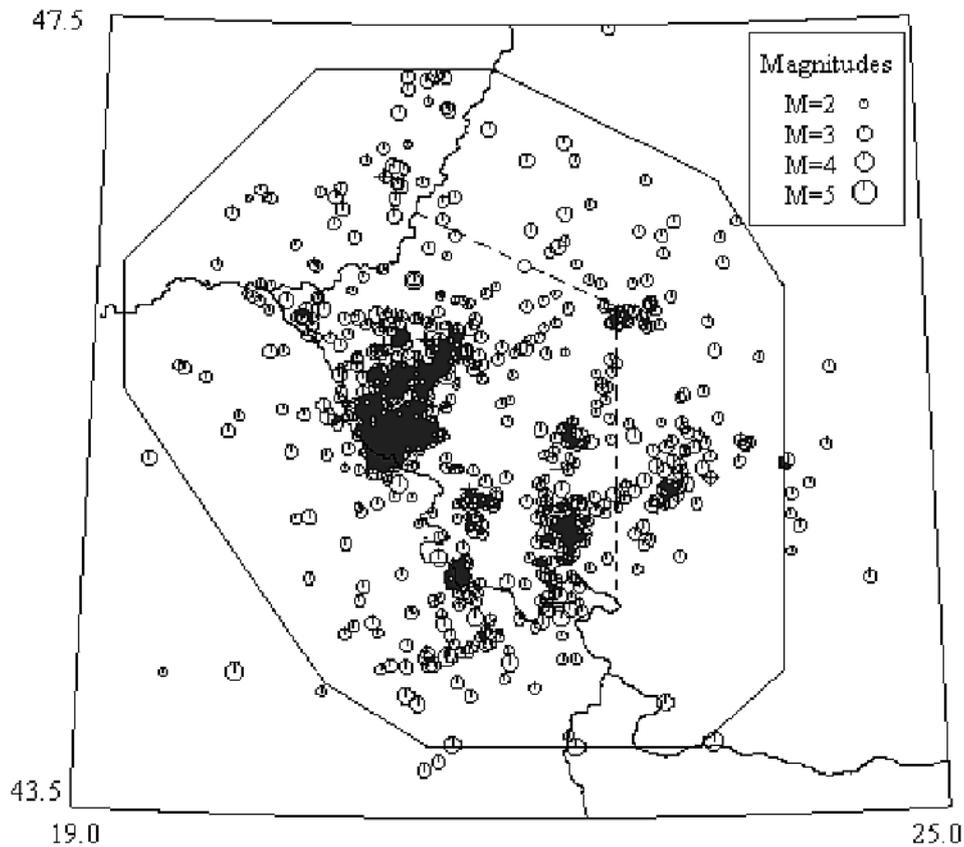
Fig. 1 – Map of epicenters for PECBSR (1443–2006). Magnitudes are in M_D. Dashed line bounds Banat Seismic Region. The continuous line limits the critical area around BSR (details in text).

Magnitude distribution prezented in Fig. 2 has a multimodal character. Two main maxima with several secondary picks are highlited. These ones may be

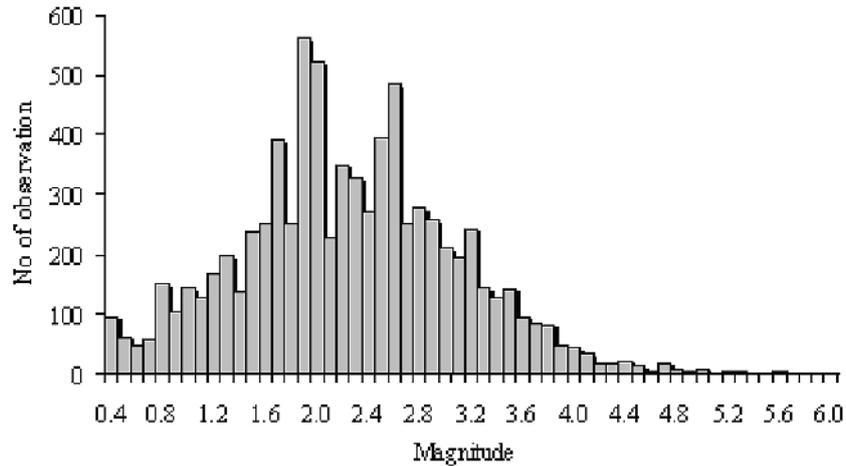related to seismic sequences occurred frequently in the region, both as seismic swarms and aftershocks series.

Fig. 2 – The frequency-magnitude (dM = 0.1) distribution for PECBSR (1443–2006).

Focal depths distribution is presented in Fig. 3. As it can be seen, the focal depths vary in the region between $h_{min} = 3.0$ km and $h_{max} = 25$ km (these
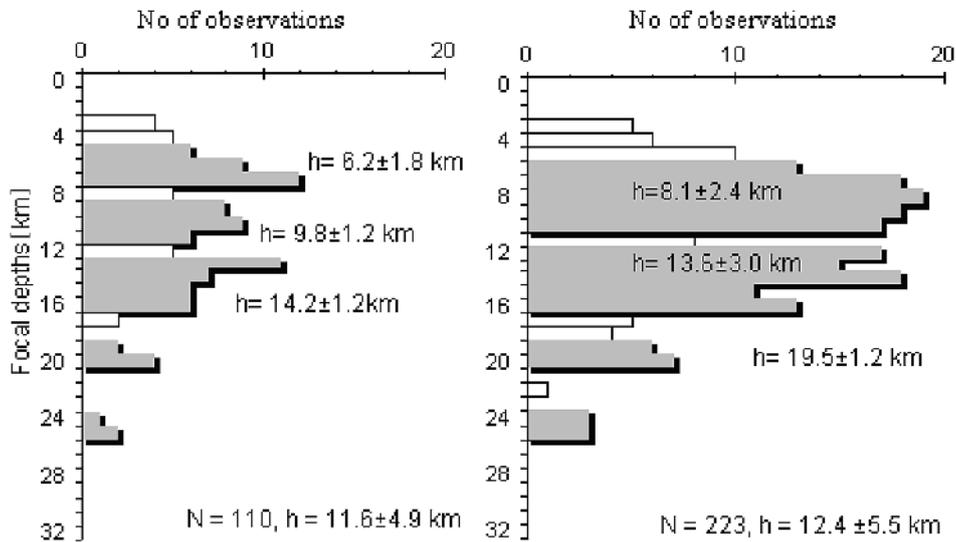

Fig. 3 – The distributions of focal depths for PECBSR (after [10]). Statistics has computed only for earthquakes with high quality of focal depths: for earthquakes with macroseismic focal depths errors are $\sigma < 0.25\,h$ (for $h > 10$ km) and $\sigma < 0.5\,h$ for $h < 10$ km; for instrumental computed focal depths $\sigma < 5$ km. The two diagrams display the distributions for BSRss (left) and BSRsl (right) (see the text for explanations).

extreme values correspond to the statistics of only high quality locations from the catalogue). This distribution emphasizes a relative concentration of the hypocenters at different levels into the crust. The average depths computed at BSRss and BSRsl scale, h = 11.4 and h = 12.4 km respectively, are similar to the average depth found out by [21] for all Carpato-Pannonian Basin, without Vrancea epicentral area.

The time distribution of threshold magnitudes displayed in Fig. 4 shows a common trend of earthquakes catalogues in Seismology: lower limits of magnitudes strongly depend on the different historical circumstances being higher and higher as we go back in time. The clustering of strongest earthquakes in the catalogue (M = 5.1–6.0) could reflect a specific time behaviour of seismic activity with significance for hazard and prediction studies.
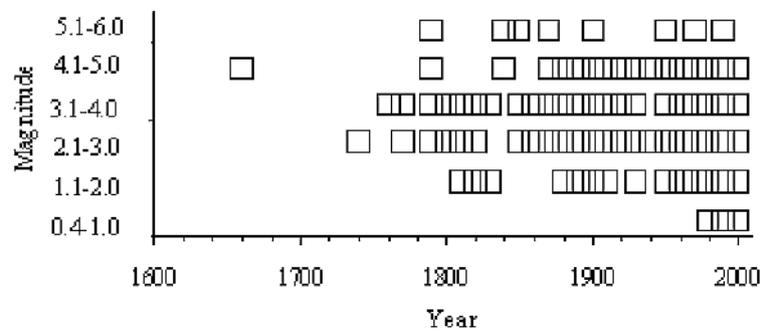

Fig. 4 – Time distribution for earthquakes with different magnitude classes (1600–2006).

3. CONCLUSIONS

A high quality seismological database for Banat Seismic Region (SDBSR) composed by two main components, Parametric Earthquakes Catalogue (PECBSR) and the Catalogue of Focal Mechanism Solutions (CFMSBSR) respectively, was elaborated recently in the framework of several projects of NIEP and the Minister for Education and Research. The work also used the results obtained by the first author as partner into the ESC EuroSeismos Project.

The paper presented the main characteristics of PECBSR. PECBSR comprises 7783 events. It fulfills all criteria and principles required by this kind of informational samples. Thus, it is i) homogenous (all entries were analyzed and processed using the same philosophy, methods, algorithms and software); ii) complete (depending on time), iii) accurate (errors of hundred meters to tens of km depending of the data); iv) up-to-date (until December 2006). PECBSR, by its structure and format, assures an easy access to many types of data, as: standardized parameters of earthquakes sources, the primary data and information,

complementary datasets, maps, other catalogues and so on (*e.g.* focal mechanism solutions, macroseismic maps, historical/digitized/analog and digital seismograms, etc.).
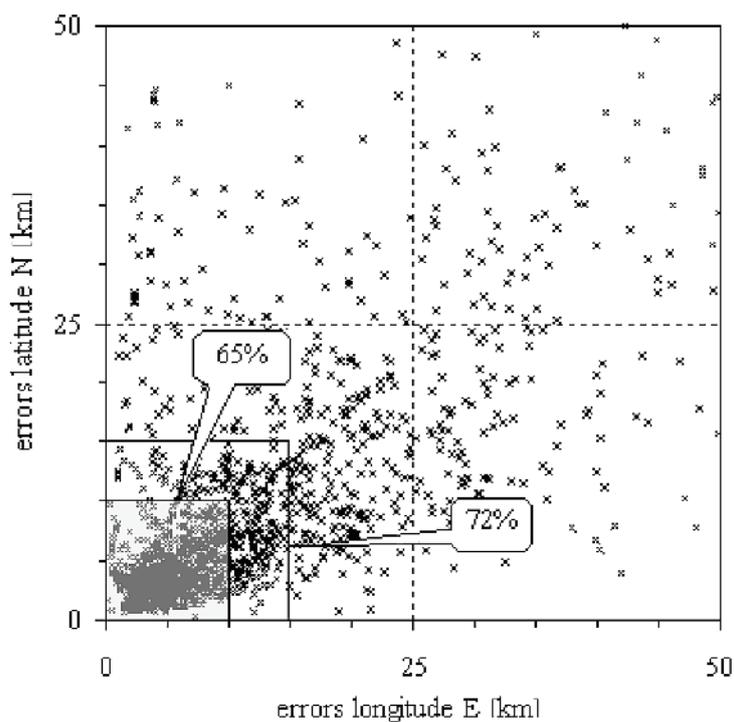

Fig. 5 – The distribution location errors for the earthquakes occurred since 1900. 72% of location errors are smaller than 15 km in latitude and longitude, from which 91% are smaller than 10 km.

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