In memory of past seismologist generations
which contributed at Romanian science progress

ROMANIAN SEISMOLOGY – HISTORICAL, SCIENTIFIC AND HUMAN LANDMARKS

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Séismologie roumaine – repères historiques, scientifiques et humains. L'auteur a essayé de reconstituer l'évolution de la séismologie roumaine depuis le début (fin du XIXe siècle) jusqu'à nos jours. On présente les contributions des personnalités de marque dans le domaine: Ştefan Hepites, Mathei M. Drăghiceanu, Gheorghe Demetrescu, Ion Atanasiu, Gheorghe Petrescu, Liviu Constantinescu, Ion Cornea, Cornelius Radu et d'autres. On mentionne des éléments liés au developpement des appareils utilisés, les résultats des études des tremblements de terre, de la séismicité dans la croûte et dans le manteau supérieur sur le territoire roumain, ainsi que les résultats des études de microzonation et de séismologie.

Key words: seismicity, seismology, earthquake, seismic focus, active seismic area.

Remarks on damages and human victims produced in Romania were mentioned in the medieval chronicles of the XVIIIth century of Grigore Ureche and Ion Neculce in Moldavia and Radu Popescu and Chesarie Daponte in Wallachia. Also, in Transylvania such observations appear in Ostermayer and Thomas Tartler chronicles from Braşov, or Hannes Hutter work from Mediaş, paper of Andreas Oltard and György Cserei of Aita Mare and the book of Jacob Schnitzler from Sibiu (Cernovodeanu, Binder, 1993). So, we read from these documents about the Vrancea earthquake of August 29, 1471, the oldest known seismic event of 7.3 estimated magnitude (after Constantinescu, Mârza, 1980). Also, there are mentioned the strong shocks on August 9, 1679 (M = 7.3, after Constantinescu, Mârza (1980); it produced great damages of Suceava Fortress and many churches and houses collapsed), June 11, 1738 (M = 7.5, after same authors, with "very wide extent heavy damage at Iaşi and Bucharest"), April 5, 1740 (8.5 degree in epicentral area), April 6, 1790 (M = 6.8), October 26, 1802, named "The Big Earthquake of God's Friday" (it was considered the strongest earthquake – M = 7.7, of Romania, after Constantinescu, Mârza, 1980, felt from Moscow to the Ithaca island), November 26, 1829 (8.5 degree of epicentral intensity, felt over a very large area from Tisa to Bug and from Mureş to the Danube, with heavy damages in Bucharest) and January 23, 1838 (M = 7.3, felt over a wide area, in Romania, Hungary, Ukraine and Balkan Peninsula, with very heavy damages in Wallachia and southern Moldavia). The 1802 earthquake produced great damages, especially in Bucharest, where was demolished the Tower of Colţea and numerous churches; major destructions were also produced in Transylvania – at Braşov and in Moldavia – at Iaşi and Cernăuţi.

In the Royal Geographical Society Bulletin, published at London in 1882, is reproduced the report of the German counselor Gustav Schüller about the seismic shocks produced in Wallachia in 1838. He inspected the Buzău and Râmnicu Sărat counties (after earthquake) and he founded many damages and cracks caused by event, through which mud and black waters, combined with sands, emerged to soil surface. An official report of the police established in Bucharest 8 dead, 14 wounded people, 36 demolished buildings and many damages at buildings, among the Princely Palace, Manuc Inn and Saint New George Church (Ştefãnescu, 1901).

Also, in the XIXth century we must mention the paper of the French mathematician and seismologist Alexis Perrey (1846), *Mémoire sur les tremblements de terre dans le Bassin du Danube*, including the earthquakes felt in Transylvania and in the Romanian Principalities during 1793–1827 (Cernovodeanu, Binder, 1993).

Systematic seismological observations (macroseismic) carried out beginning with 1892 by Ştefan C. Hepites in national network of the meteorological observations (Rădulescu, 2001, 2003). In fact this action initiated by Hepites anticipated a decision of the International Meteorological Committee which established in 1900 (in Petersburg) that all meteorological stations must carry out seismic observations (Demetrescu, 1941; Constantinescu, 1977).

Ph.D. in physics and mathematics of the University of Brussels (1973) and engineer of the Polytechnical School (1875), Ştefan C. Hepites was founder and first director of the Meteorological Institute from 1884. In this position he was permanently preoccupied by the endowment of recording equipments for earthquakes monitoring. So, in 1889 were imported from Italy two warning Brassart type seismoscopes, one of them being mounted in the manager office.

Excluding the financial difficulties in the respective period, Ştefan Hepites succeeded the development of the meteorological department by extension of meteo stations net. If in 1884 were three stations, in 1890 more than 70 and in 1908 – 418 stations. In reduced financial conditions, achievements of the office led by Hepites appear meritorious in national and international context, Romania being an active presence in the modern tendencies promotion of the scientific researches. We must mention that the meteorological department made international changes of publications with 450 partners from all the continents (from 342 in Europe). So, in 1896, J. Vallot (director of Mont Blanc meteorological observatory) made excellent remarks on Hepites achievement, considering the Romanian meteorological department being the best all over the world. Also, F. Montessus de Ballore admired the macro-seismic net carried out by Hepites. He was inspired by the same network in Chile (Demetrescu, 1941; Constantinescu, 1977; Rădulescu, 2003). In fact, Ştefan Hepites made part from the Permanent Seismological Committee set up in 1899 at Berlin and in 1901, at the first International Seismological Meeting from Strasbourg, he presented the work *Report on activities and seismic works in Romania*. At this meeting participated twenty states (including Romania) and was decided the establishment of the International Association of Seismology. In 1904 the Kingdom of Romania adhered to this international association. At the second International Seismological Meeting in 1903, Ştefan Hepites was appointed member of Permanent Commission of Seismology, position kept until its dissolving after the First World War (Florinescu, 1964). He represented in 1919 the Romanian Academy in frame of the International Union of Geodesy and Geophysics (Rădulescu, 2003). The information system created by Hepites permitted the beginning (since 1893) of the elaboration of some earthquake lists, published in *Annals of the Romanian Meteorological Institute* and yearly, also, since 1894, in *Annals of the Romanian Academy*. The first list of 1893 contains the earthquakes occurred in Romania between 1838 and 1892. These papers published annual, which continued until 1907, presented information on seismic events as: recording hour of micro-seismic movement and of maximum phase, maximum amplitude and total length of seismic motion; it were also presented photocopies of some strong earthquakes.

In 1895, Hepites mounted in the basement of Bosianu buildings from the Carol Park a Guzzanti microseismoscope and a Tacchini pendulum. It was the first Romanian seismological observatory (Bucharest-Filaret), which works up to the present certainly with different endowment. In 1902 were mounted two horizontal Bosch seismographs with 10 kg mass, mechanical amplifications of 5, 10, 15 times and recording on a reel covered with blacked paper; an electric clock marks the minutes on this paper. These apparatuses with low performance worked continuously until 1908 and later in 1928–1935 period (Demetrescu, 1956; Petrescu, 1959); the N–S component of the seismograph worked until 1958 (Constantinescu, 1977).

At the end of the XIX^th century (in 1896) Mathei Drăghiceanu (1844–1939) published in French, the paper *The earthquakes in Romania and neighbouring countries.* He mentioned the strong historical quakes of October 26, 1802, February 19 and March 26, 1832 and January 23, 1838. He also referred on the seismic activity of the 1892–1894 period, felt in eastern and western part of Romania. He supposes that the generation of these shocks is connected by faults or important fracture zones (for example the Râmnicu Sărat–Mizil–Buzău, Danube, Siret faults). Along these "seismic lines" may accumulate the tectonic tensions and the seismic foci may migrate from one sector to other. Drăghiceanu specified the Cerna line along migrated the earthquakes from Herculane Spa to south on Serbia territory and to north, in Transylvania. In the final part of the work, Drăghiceanu presented a map of 1892 (VIII^th degree of epicentral intensity in Orşova–Mehadia area), 1893 (Motru epicentral area), 1894 (Turnu Severin epicentral area) earthquakes isoseists. He also mentioned the Banatic earthquakes occurred in October 10, 1879 – April 13, 1880 period (Moldova Nouă epicentral area). In this work, Drăghiceanu approached the prediction of earthquakes. He mentioned that he predicted the Vrancea earthquake on August 13, 1894 (VIII^th degree of epicentral intensity). Respective prevision based on the fact that in Balkan Peninsula – Black Sea – Caspian Sea area the seismic activity migrated along of some "lines of great dislocations" (E–W oriented), from Istanbul (where occurred a seismic shock of July 10, 1894) to west, in Romania (where was localized a strong shock of August 31, 1894).

In May 1901, Grigore Ştefănescu presented in the framework of the Scientific Section of the Romanian Academy the paper *The earthquakes of Romanian during 1391 years, from the year 455 to 1846*. In this work he made some hypotheses on the earthquakes causes, such as: water vapour and gas condensation from the underground cavities, which produce an increase of the crustal stress; landslide of the underground layers in regions with a complex geological structure.

The beginning of the XX^th century marked the setting up of Timişoara seismological observatory (in 1904) that worked continuously until 1914 (Curea, 1961). Later, in September 1, 1943, prof. I. Curea re-installed this station by assembling two horizontal mechanical pendulums of 540 kg and after a new interruption period (1944–1950), it worked until the present day (Oros, 2003). The observation data from the Timişoara observatory were very useful for local events studies (with epicenters at Periam, Parţa–Şag, Banloc, Voiteg) and seismic shocks of the Southern Banat (Herculane Spa and Orşova–Moldova Nouă areas).

At two mentioned stations (Bucharest–Filaret and Timişoara) it added in 1919 the Cluj and Cernăuţi stations yielded to Romania by the Austro-Hungarian Empire about the Paris Peace Treaty. Unfortunately they did not work for long time after the end of the First World War (Demetrescu, 1937). The only Romanian seismological observatory which continuously worked was the station Bucharest–Filaret (Silver Knife). In 1914 this was equipped with two Galitsin seismographs (horizontal pendulums) of high sensitivity, mounted just in May 1937 due to prof. Octav Onicescu's insistences and with the financial support of the manufacturer Nicolae Malaxa (Demetrescu, 1937).

Interesting instrumental information was supplied by the Bucharest–Filaret station records of the strong earthquakes occurred at the Carpathians' bend, in the Vrancea active seismic region (unknown still at the beginning of the XX^th century) such as: February 6, 1904 ($M = 6.3$), October 6, 1908 ($M = 6.3$), May 25, 1912 ($M = 6.4$, 5.8 and 5.4) and November 1, 1929 ($M = 5.8$). Concerning the Vrancea earthquake of 1929 we must mention that this strong event was recorded by 51 stations distributed all over the globe and it was studied by the famous English seismologist Harold Jeffreys. He estimated the depth of the seismic focus at 184 km; further determinations supplied different values of this parameter: 198 km (Demetrescu, 1939) and 160 km (Constantinescu, Mârza, 1980). We must specify that B. Gutenberg and C.F. Richter determinated the epicentral coordinates of the Vrancea earthquakes produced on November 1, 1929 ($M_s = 5.8$), September 5, 1935 ($M_s = 5.6$) and July 13, 1938 ($M_s = 5.6$). Depth of the seismic foci from 1938 was established by Gutenberg and Richter at 150 km and by Demetrescu at 163 km (Demetrescu, 1941); Constantinescu and Mârza (1980) indicated 120 km.

All useful seismic information were afterwards used for the elaboration of some earthquake catalogues by Hepites (1893), Mathei M. Drăghiceanu (1896), Grigore Ştefănescu (1901) and later by N. Al. Rădulescu (1930), Ioan G. Popescu (1938), Aurelian Florinescu (1964) and Liviu Constantinescu and Vasile I. Mârza (1980).

After the new organization of the Meteorological Institute in 1908 and its inclusion in the Astronomic Observatory, the seismological activity was considerably restrained. This low activity (short notes of monthly meteorological bulletin) continued until January 1, 1935, when the Romanian Seismological Department was founded under the direction of prof. Gh. Demetrescu (Petrescu, 1956); he occupied this function until 1963.

Astronomer Gh. Demetrescu (1885–1969), doctor in mathematical sciences (1915, Faculty of Science – Bucharest), was appointed vice-director (1928) and director of the Astronomic Observatory of Bucharest (1943). He has important contributions in astronomy research to begin with development of material foundation (Drâmbă, 1969, 1992).

Prof. Gh. Demetrescu reorganized the seismological activity by improving the instrumental endowing and setting up five new stations: Focşani (1942), Bacău (1942), Câmpulung Muscel (1943), Iaşi (1951) and Vrâncioaia (1952), all working till now. The extension of the Romanian seismological network happened after the Vrancea major earthquake of November 10, 1940 (M = 7.4).

Prof. Gh. Demetrescu organized with M. Marcopol mechanic help the construction of 13 seismic pendulums (horizontal and vertical with 540, 450 and 150 kg masses). These apparatuses had a 170–180 times static amplification and they were equipped with a time recording device (Demetrescu, 1956). The mechanic Marcopol conceived and materialized an air damping system for the 540 kg mass pendulum (Marcopol, 1956).

In 1940 the Bucharest-Filaret station was equipped with the following instruments: two mechanical horizontal pendulums Mainka type of a 540 kg mass each (installed on January 1, 1935), two horizontal Galitsin pendulums of a 7.2 kg mass and photo galvanometric recording (installed in 1937), a vertical Alfani pendulum of a 27 kg mass and photo recording (monted in 1940).

From 1935 the seismic bulletin was published, half-yearly in first year and then monthly in next years, the activity continued until the present day. This bulletin contributed at the establishing of scientific connections with more than 130 seismological stations of all the world and publication exchanges (Demetrescu, 1937; Petrescu, 1956).

Prof. Gh. Demetrescu published in 1937–1941 period few seismological notes where he presented the problems of the seismic waves interpretation and the determination of the seismic foci coordinates. He studied the Vrancea earthquakes of November 1, 1929, July 13, 1938, October 22, 1940 (M = 6.2) and November 10, 1940. Regarding the strong shock of November 10, 1940 (M = 7.4) he elaborated the map of the macro-seismic intensities for the Romanian and Bulgarian territories (Demetrescu, 1941). On this image appear some local maxima (X^{th} degree) in different points without epicentral area. Macro-seismic intensities of V^{th} degree appeared in Moscow area (at 1,300 km distance) and in southeastern Bulgaria (at 600 km). First, he evidenced the deep seismic focus in the bending zone of the Carpathians, a persistent and isolated focus comparable with the foci of the Hindukush Mts (Afghanistan) and Bucaramanga (Columbia, South America).

Gh. Demetrescu performed a didactic university activity at the Sciences Faculty of Bucharest University, where he taught general astronomy, stellary cinematics and dynamics and seismology courses. His seismology course, in fact first Romanian course, included three main chapters: notions on the elasticity theory and the seismic waves theory; earthquakes study, discontinuity surfaces, seismicity seismographs, seismic pendulums, galvanometer theory (Demetrescu, 1947). The professor mentioned Romania's seismicity, especially the seismic focus of the Vrancea region. He presented, also, the computing methods of the epicenter coordinates and the depths foci determination.

In the inter-war period we must mention the earthquake catalogue of N.Al. Rădulescu (1930) (professor at the Faculty of Sciences of the University of Bucharest), which contains the events occurred in Southern Moldavia in time interval 1802–1929. He utilized the information of V.A. Urechia (1894–1895), Gr. Ştefănescu (1901–1902), Şt. Hepites (1901–1906), M. Drăghiceanu (1896). The data were included in the Annals of the Meteorological Institute (1894–1900), the monthly Bulletin of the Meteorological Institute (1901–1907), the monthly Bulletin of the Astronomic and Meteorological Observatory of Romania (1908–1916) and the monthly Bulletin of the meteorological observations of Romania (1921–1929). The author elaborated for 1893–1929 period a map of the Southern Moldavia with following seismic foci: Galaţi, Tecuci, Focşani, Brăila and Râmnicu Sărat. He made a correlation between tectonics and seismicity of these areas. He showed that the Zăbala–Focşani–Nămoloasa–Galaţi fault represents a line with highest seismicity. The author also mentioned the main seismic focus of the Bârlad–Avrămeşti region.

In another paper, N.Al. Rădulescu (1938) analyzed the earthquakes felt in the Oltenia county in the 1892–1923 period. He remarked the intense seismic activity in 1893, 1912, 1913 and 1916. Thus, in January 11–April 15, 1916 time interval "earthquakes in series" (a term proposed by E. Oteteleşanu) were produced among he remarked the well-known main shock of January 26, 1916 (M = 6.4 after Constantinescu, Mârza, 1980) with epicenter in the Făgăraş Mts, having a large macro-seismic area comprised between Vienna, Sofia and St. Petersburg. This principal event was followed by three strong aftershocks with magnitudes of 5.2, 5.0 and 4.4.

The seismological station Cernăuţi worked since 1936 and it was endowed with a Mainka horizontal seismograph (with two components and 450 kg mass), a vertical Wiechert seismograph (80 kg mass) and a horizontal Conrad seismograph (Popescu, 1938). The activity of this observatory was mainly due to prof. Ioan G. Popescu (from the Faculty of Sciences in Cernăuţi). He also performed a study on the earthquakes felt in Bucovina (Popescu, 1939) in the 1109–1937 period. Among 700 shocks only 31 were felt in this region and 6 events occurred here being connected with an important fault situated 20 km south of Cernăuţi.

In another paper, Ioan G. Popescu (1938) presented the earthquakes felt in Dobrogea in the period 1871–1929. He identified 170 events, only 117 having the epicenter in this eastern part of Romania. The author divided Dobrogea in three seismic regions: the northern sector between the Danube Delta and the Peceneaga–Camena fault; the median sector between Peceneaga–Camena (to north) and Rasova–Mangalia (in south) lines; southern sector with an intense seismicity.

After the strong Vrancea earthquake of November 10, 1940 (M = 7.4), the Romanian specialists' interest for these natural phenomena considerably grew up, especially for these subcrustal events occurred in Vrancea region. Among we must mention I. Popescu–Voiteşti (1940, 1941), I. Atanasiu and Th. Kräutner (1941) and G. Petrescu (1940, 1943). Important contribution in the knowledge of Romanian seismicity had the professor geologist Ion Atanasiu. So, in frame of the Geological Institute, Ion Atanasiu and Theodor Kräutner collect data on this strong earthquake effects and they elaborate a Romania's map of seismic intensities, published in 1941 in Scientific Annals of the Romanian Academy. Prof. Ion Atanasiu published in 1949 (year of his death) the paper *Earthquakes and seismic sensitivity in Romania*, where he analyzed the effects of the earthquakes occurred on the Romanian territory and he made a summary characterization of seismicity of the country. After his death (April 14, 1949) a monographic volume remained in manuscript, which, due to prof. Emilia Saulea, was published in 1961 by the Publishing House of the Romanian Academy (Atanasiu, 1961). This book is a monograph of comparative macro-seismology being based on rich observational data (more than 400 seismic events). The author presents the image of surface effects of seismic shocks and he makes correlation elements with geological surface structure. He identified the main seismic foci, their mode of manifestation and some seismic sensitivity lines, he elaborated the first seismotectonic map of Romania (scale 1:2,000,000), where he indicated epicenters of the active earthquakes. So, he remarked the following active seismic foci: Timişoara, Vinga, Pârdani and Moldova Veche (in Banat), Târgu Jiu (in Oltenia), North Bazna (in Transylvania), Câmpulung, Urziceni and Mânzăleşti (in Muntenia), Focşani, Tecuci, Avrămeşti, Bârlad, Tazlău, Târgu Ocna and Tudor Vladimirescu (in Moldova).

The following seismic sensitivity lines are mentioned: Orşova-Tismana, Turnu Severin-Târgu Jiu, Tomşani-Urziceni-Silistra, Tulcea-Galaţi-Cudalbi, Plopana-Avrămeşti-Bârlad and Dorohoi-Botoşani. He correlates these "seismic lines" with structural alignments of crystalline basement. Prof. I. Atanasiu inferred that these natural phenomena may constitute a precious source for deciphering the deep structure of the country subsoil. I. Atanasiu classified the earthquakes occurred in Romania in the following categories: Moldavian (with epicenter situated at the Carpathian arc bend), Danubian (on the Vršac-Moldova Nouă line), in Banat (Arad-South Timişoara), Transylvanian (between Mureş and Târnava Mare rivers), Pontic (the Black Sea coastline until the Shabla Cape, in Bulgaria) and in Făgăraş Mts (Southern Carpathians).

He divides the seismic shocks into two categories: polykinetic earthquakes (corresponding to the Danubian, Pontic and the Făgăraş Mts) which, after an initial strong shock, is followed by a long series of seismic motions (epicentral area well outlined and a macro-seismic area relatively small) and monokinetic earthquakes (corresponding to the Moldavian, Transylvanian and Banat earthquakes), represented by a principal shock and smaller aftershocks (diffuse epicenter and a large macro-seismic area).

Concerning the Moldavian earthquakes (with epicenters in the Vrancea region) I. Atanasiu remarks two-three local maxima of the macro-seismic intensities placed in the middle part of Moldavia (between Siret and Prut rivers), in the Subcarpathian hills of Muntenia and in Dobrogea or in the eastern part of the Romanian Plain. Like effects were later observed in the case of strong event on March 4, 1977, which produced great damages in the Subcarpathian region (Cislău, Vălenii de Munte) and in southern areas of the Romanian Plain (Zimnicea, Turnu Măgurele). Macro-seismic features of this major seismic event is due to the multi shock character of earthquake which determined a directivity effect of seismic waves generated in the focus (Iosif, Iosif, 1977; Mueller *et al.*, 1979).

Since 1941, the seismologist Gh. Petrescu (1905–1965) brought important contribution in the seismological domain. He carried out studies on position of seismic foci, structure of the crust, general seismicity of the country, the producing mechanism of earthquakes. He studied the Vrancea earthquakes of October 22, 1940 (M = 6.2), August 23, 1942 (M = 5.1) and April 28, 1943 (M = 5.5), as well as the crustal earthquake of January 5, 1940 (M = 4.5) occurred in Câmpulung Muscel area (Petrescu, 1940, 1943).

He was also interested by the determination of epicenter coordinates of the near earthquakes (Petrescu, 1944). In 1959 he published the book *The earthquakes* (in Romanian, Technical Publishing House), the first Romanian synthesis on the knowledge of these ill-fated phenomena.

Gh. Petrescu contributed at co-ordination and interpretation of seismic data as well as spreading of the seismological material to majority of similar departments of all over the world. He was member of the International Union of Seismology, member of European Seismological Commission and secretary of National Committee of Geodesy and Geophysics. He represented Romania at numerous international conferences and congresses of seismology.

In a paper published in 1960, Gh. Petrescu and C. Radu make a characterization of Romania's seismicity on the basis of historical data (macroseismic information) and instrumental data obtained until 1960. They evidenced five epicentral regions as: Banat, Câmpulung Muscel, Carpathian region, Romanian Plain and Black Sea. The Carpathian region includes the seismic shocks from Vrancea area limited by the following geographic coordinates: $25^0.9$ – $27^0.6$ eastern longitude and $45^0.3$ – $46^0.0$ northern latitude. On the map of foci distribution these are situated in an area with deep events (depth greater than 100 km) and other, placed in eastern part of region, with crustal earthquakes. In the second zone they mentioned the foci of Râmnicu Sărat, Mărăşeşti and Tecuci (Petrescu, Radu, 1960). In specified paper the authors present also information about total thickness of the crust and of crustal layers (sedimentary, granitic, basaltic) from Bucharest, Focşani and Câmpulung Muscel regions. Respective values (63 km in Bucharest, 68.6 km in Focşani and 57.0 km in Câmpulung Muscel) were modified in time by the results of deep seismic sounding performed in 1967–1976 period (Rădulescu, 1988).

In 1955 (May 14–16) an international meeting on seismological problems was organized in Bucharest. Except Romanian scientists (S. Stoilov, Gr. Moisil, Gh. Demetrescu, Gh. Atanasiu, A. Iacovache), known seismologists participated from Soviet Union (E.F. Savarenski, D.A. Harin) and Bulgaria (I. Petkov). Here, prof. Gh. Demetrescu mentioned the Romanian Seismological Department activity during twenty years (1935–1955) and some principal aspects of Romania' seismicity. He specified the seismic foci of Periam and Câmpulung Muscel (depths of 8–10 km), Râmnicu Sărat and Mărăşeşti (depths of 50–65 km) and of course the persistent focus of the Vrancea region (depths of 100–150 km) with a middle epicenter situated at $45^0.7$ N latitude and $26^0.06$ E longitude (Demetrescu, 1956). Gh. Demetrescu also mentioned the studies on the Vrancea earthquakes of October 22 and November 10, 1940. These works made possible the elaboration of the macro-seismic maps of the country (Demetrescu, Petrescu, 1940) and an official required document in the building activity – the 2923–52 *Macroseismic intensities zones* State Standard elaborated by the Metallurgy and Applied Mechanics Institute of the Romanian Academy. In these maps appears a very strong intensity zone (of VIIIth degree) in Bucharest area and in a large region in the eastern part of the country (N Vaslui–Soveja–S Întorsura Buzăului–Teşila–Pucioasa–Pucheni–Urleasca–Brăila line).

Rich observational material, macroseismic and instrumental, permitted the elaboration of some Romanian catalogues as the Florinescu' (1958) and Constantinescu and Mârza' (1980).

The Florinescu' catalogue contains earthquakes occurred in the period between 1st century b.Ch. and 1916 end. He remarks destructive effects of strong events of August 29, 1471 (M = 7.3), July 19, 1545 (M = 6.8), August 10, 1590 (M = 7.0), June 11, 1738 (M = 7.5), October 26, 1802 (M = 7.7), November 26, 1829 (epicentral intensity 8.5 degree), January 23, 1838 (M = 7.3), February 6, 1904 (M = 6.3) and January 26, 1916 (M = 6.4). Except seismic shock of 1916, occurred in Loviştea region (Brezoi–Titeşti Basin, east of Făgăraş Mts., in Southern Carpathians) the others were generated in the active Vrancea region. The earthquakes series of the Făgăraş Mts. of January – April 1916 were studied by geologists H. Grozescu and C. Gheocălescu. So, the main seismic shock of January 26, 1916 (M = 6.4) was placed at 21 km depth, after Constantinescu and Mârza (1980). In epicentral area were reported macroseismic intensities of VII–VIII degree (Rossi-Forel scale); the earthquake was felt in a large area, from Curtea de Argeş–Jiblea in south and Bistriţa-Năsăud (Transylvania) to north.

The Constantinescu and Mârza' catalogue refers to the 984–1979 period. Taking into account possible errors (of time, epicentre and depth localization, of magnitudes), the authors established six steps of quantification (from A to F). For example, the A class (exceptionally) has errors of 0.1 second, 1 km for epicenter determination, 5 km for depth, 0.1 unit for magnitude and 1/4 degree for intensity (MSK-64). The authors considered nine seismological-physiographic provinces of Romania as: Vrancea, Banat, Crişana, Maramureş, Moldavia, Transylvania, Western and Eastern Muntenia and Dobrogea. Within the framework of these provinces the authors identified the following seismic zones: Vrancea (intermediate and normal earthquakes), Banat (Sânnicolau Mare, Arad, Timişoara, Moldova Nouă, Romania/Serbia border), Crişana (Carei, Bihor, Romania/Hungary border), Maramureş (Oaş, Vişeu, Northern Romania/Ukraine border), Moldavia (Bucovina, Central Moldavia), Transylvania (Făgăraş, Târnăveni, Sălaj, Deva, Cluj, Bistriţa),Western Muntenia (Câmpulung, Northern Oltenia, Southern Oltenia), Eastern Muntenia (Northern Romanian Plain, Southern Romanian Plain, Romania/Bulgaria border) and Dobrogea (Northern, Southern, Black Sea). The authors used except Romanian sources and other information given by Centre séismologique européoméditerranéen (Strasbourg, France), International Seismological Centre (Edinburgh/Newbury, UK), U.S. Coast and Geodetic Survey-National Earthquake Information Center (Denver, Colorado, USA) and UNDP-UNESCO Project – Survey of Seismicity of the Balkan Region, part I, II, III (1974). Also, data published by Kárnik (1968,1971) added.

After 1955, the Department of Seismology benefited by the presence of young specialists prepared within the framework of Faculty of Mathematics-Physics of the Bucharest University and Technical Geology Faculty of the Institute of Oil, Gas and Geology. These were the following: Traian Iosif, Dumitru Enescu, Cornelius Radu, Dumitru Jianu, Sieglinde Iosif, Vasile Mârza and Aurelian Pântea. Since 1961 this department belonged to the Geophysical Research Center of the Romanian Academy (Manager, Prof. Sabba S. Ştefănescu and assistant manager, Prof. Liviu Constantinescu). From 1970 this department was integrated in the Institute of Applied Geophysics (afterwards transformed in 1974 in the Institute of Geology and Geophysics, now the Geological Institute of Romania). In 1977, the Department of Seismology was included in the Center for Earth Physics (manager, Dr. Ion Cornea), now – the National Institute for Earth Physics – NIEP (Bucharest–Măgurele). Dr. Cornelius Radu (1933–1995) was between 1978 and 1990 the head of the Seismological Laboratory.

Prof. Liviu Constantinescu (1914–1997), physicist, carried out a remarkable activity in the seismology field, recognized on the international plan. So, he was vice-president of International Union of Geodesy and Geophysics (1969–1971) and vice-president of the European Seismological Commission (1972–1976). In Romanian Academy he was agreed as corresponding member in 1963 and titular in 1990. He was president-founder of the Romanian Society of Geophysics (in 1990) and general secretary and then vice-president of the National Romanian Committee of Geodesy and Geophysics. Since 1990, prof. Liviu Constantinescu was the president of the Section of Geonomical Sciences of the Romanian Academy. He was member and president (1970–1977) of the coordinating Committee of the UNDP-UNESCO Project *Survey of the Seismicity of the Balkan Region* (Rusu, 1999).

In 1985, L. Constantinescu together with D. Enescu published the book *The Vrancea earthquakes within their scientific and technological* framework (at the Publishing House of the Romanian Academy, Bucharest). This represents an important synthesis on the earthquakes occurred in the active seismogenic Vrancea region. After a general historical and planetary perspective, the authors presented the following aspects of seismological studies as: the macroseismic investigations results in the last two centuries; localization problems of the Vrancea earthquakes on the basis of instrumental information; the focal mechanisms of the Vrancea shocks; physical and geometric parameters of seismic foci; the directivity, functions and synthetic isoseismals based on focal parameters and of propagation medium structure; the contribution of researches concerning the prediction problem of the Vrancea earthquakes; structural elements of the lithosphere in Romania inferred on basis of the Vrancea earthquakes records; technological aspects of the terrain response to seismic motions generated by strong Vrancea events; speculations concerning the phase transition process as a generating factor of these earthquakes, due to interactions between the palaeosubducted lithosphere and the surrounding medium.

In the next twenty years (since 1975), Romanian seismologists approached different directions of the studies: complex quantification of seismic events (especially of Vrancea and Banat areas); seismicity and seismotectonics of Romania; focal mechanism of intermediate and crustal earthquakes; geometric, dynamic and kinematic parameters of the seismic sources and modelling of the break processes; precursory phenomena associated to strong earthquakes; structure and thickness of the crust and information on the upper mantle structure. Many of seismological researches results elaborated in the country or in co-operation within the framework of an international project (UNDP-UNESCO) *Survey of the Seismicity of Balkan Region* were materialized in some synthesis works. So, we mention the following: Seismicity of Europe, Catalogues of Balkan earthquakes, Isoseismal Maps of Balkan earthquakes, Catalogue of focal mechanism of Balkan earthquakes, Seismotectonic Map of Europe.

In this respect, it must be specified the dr. Cornelius Radu's prodigious activity. He graduated the Faculty of Mathematics-Physics of the Bucharest University (in 1957) and after graduation he worked at the Bucharest Astronomic Observatory of the Romanian Academy. From the beginning of his scientific activity he was attracted by the seismology and by the remarkable personality of prof. Gheorghe Demetrescu. Since 1961, dr. C. Radu worked at the Geophysical Research Center of the Romanian Academy. So, how it was mentioned before, dr. Radu was head of the Seismological Laboratory from the Center for Earth Physics turned up in 1977 within the framework of the Central Institute of Physics (now the Institute of Atomic Physics). In November 1975 – May 1976 he was the Director of the UNDP-UNESCO Project on Seismicity of Balkan region. Later on, he was actively involved in other research projects such as: *Survey of Seismicity of the Balkan Region* (until 1985), *Earthquake Risk Reduction Network of the Balkan Region* (1985–1995). Since 1987 he represented Romania and he was the president of the Standing Coordination Committee of the UNDP-UNESCO Project about seismic risk reduction. Also, he was member and he contributed to the activity of some Working Groups of the European Seismological Commission (ESC) such as: *Study of Earthquake Prediction*, *European historical earthquakes* (since 1987), *Statistical methods and models in seismology* (since 1992), *History of seismometry* (since 1994) and *Macroseismology* (since 1993).

In the period 1980–1985, C. Radu was convenor of the ESC working group "European seismic zoning maps", where he supervised the drawing up of the *Map of maximum observed intensities in Europe*. Between 1977 and 1990 he represented Romania within the Group of Scientific Experts for Seismic Events Identification and Discrimination of the UN Disarmament Commission of Geneva (Rădulescu, Lungu, 1999).

In the country, dr. Cornelius Radu coordinated the *Standard of seismic intensity scale* (1971) and the last versions (1977, 1991, 1993) of the *Standard of seismic macrozoning of the Romanian territory*, very important documents in designing the civil buildings in Romania.

After the major Vrancea earthquake of March 4, 1977, the seismological studies recorded an intensification which coincided with the establishment of the new Center for Earth Physics managed by dr. Ion Cornea until 1988 and after by physicist Crişan Demetrescu. After this strong event, Romania profited by a UNDP-UNESCO financial aid which permitted in 1978 the installation of 15 Chinese equipments DD-1 (with three components) in existent seismological stations, completed later on with 5 apparatuses. These equipments worked until 2004.

In the 1977–1978 period among the new installed stations count the Bucharest-Măgurele (BUC), Buziaş (BZS), Carcaliu (CFR), Carei (CEI), Cluj (CJR), Drăgăşani (DRA), Istriţa (ISR), Mediaş (MDB), Odobeşti (ODB) and Topalu (TLB) stations.

In 1980 within the frame of same project it created a telemetred seismic network (with 10 stations) for monitoring the Vrancea earthquakes. These stations telemetred at Bucharest–Măgurele and Cheia–Muntele Roşu were the following; Bordeşti (BRD), Carcaliu (CFR), Călugăreni(CGN), Cheia–Muntele Roşu (MLR), Coloneşti (CLI), Istriţa (ISR), Popeni (PPE), Sfânta Ana (AAR), Topalu (TLB) and Vrâncioaia (VRI). The network worked in real time and it was endowed with a PDP 11–34 computer with extended memory and being programmed in FORTRAN IV language (Cornea *et al.*, 1981). The working system offered a better accuracy of the location parameters for the Vrancea seismic shocks and seismological information about neighbouring areas.

Before the event of March 4, 1977, the Romanian seismological network was extended with several stations as: Suşara (SSR, in Banat, 1968), Gura Zlata (GZR, Retezat Mts, 1971), Cheia–Muntele Roşu (MLR, Ciucaş Mts, 1974) and Deva (DEV, Poiana Ruscă Mts, 1975) (Oros, 2003; Visarion, 2004).

In the 1970–1988 period, dr. Ion Cornea (1923–1996) carried out a fruitful activity in the national and international seismological domain. He was co-director and director of the UNDP-UNESCO Project on the seismicity of the Balkan Region. Together with dr. C. Radu he co-ordinated the studies connected to the March 4, 1977 earthquake in the monograph *Seismological researches on the March 4, 1977 earthquake* came out at Central Institute of Physics (in 1979). Besides this important monograph, dr. I. Cornea (Cornea *et al.*, 1981) co-ordinated the book *The 1977 March 4 earthquake in Romania* (in 1982, of the Publishing House of the Romanian Academy). The authors (19) present in ten chapters general considerations on this strong earthquake, seismotectonic elements of Romania, seismic phenomena of the Vrancea region and behavior of buildings at seismic motion. The big volume of the seismological information and of the seismic engineering data supplied ideas and practical solutions for the effective improvement of the stability and resistance of the buildings placed in seismic areas. For this important scientific contribution he received the Prize "Aurel Vlaicu"of the Romanian Academy, for the year 1983. Formerly, in 1972, dr. Cornea received the Prize "Grigore Cobălcescu" of the Romanian Academy (Popescu, Rădulescu, 1996). He was also awarded with the *Scientific Merit Medal* (in 1979) and the *Scientific Merit Order* 3rd Class (in 1981). His efforts in the seismic prospection domain for oil and gas were rewarded with the Medal (1964) and Order (1965) for *Distinction in Labour*. Together with prof. geologist Vasile Lăzărescu, dr. Ion Cornea elaborated in 1980 a synthesis of Romania's seismotectonics and geodynamic evolution printed out at Central Institute of Physics (Bucharest – Măgurele).

In 1987 he published (with Gheorghe Mărmureanu, Mihnea Corneliu Oncescu and Florin Bălan) a remarkable book, *Introduction in seismic phenomena mechanics and seismic engineering* (the Publishing House of the Romanian Academy). After a first part dedicated to some theoretical and structural problems (seismicity of the Earth, the seismic source and seismic waves), the authors discuss different aspects as: methods of analysis of the seismological data, the dynamic behavior of soils, the influence of ground local conditions on seismic response, processing of strong motion accelerograms (response spectra), the generation of artificial earthquakes and design response spectra. This book represents an important contribution in the earthquake engineering field.

After the 1977 event, the seismological studies were developed in different scientific directions. These coincided with the engagement of a new generation of physicists as: Mihnea-Corneliu Oncescu, Luminița Ardeleanu, Mircea Radulian, Valeriu Burlacu, Eugen Druță, Emilia Popescu, Victoria Oancea, Cezar-Ioan Trifu, Mihaela Rizescu, Mihaela Popa. Some tackled scientific problems were the following: seismicity and seismotectonics of the Romanian territory (Lăzărescu, 1980; Radu, Polonic, 1982; Cornea, Enescu, Zugrăvescu, 1990), earthquake catalogue and localization of seismic events (Radu, 1979; Constantinescu, Mârza, 1980; Oncescu, 1984; Oncescu *et al.*, 1999), physics of seismic source from the Vrancea region (Enescu *et al.*, 1977; Enescu, 1981; Constantinescu, Enescu, 1985; Radulian, Popa, 1993, 1996; Popa, Radulian, 2000, 2001; Popescu *et al.*, 2003; Popa, 2007), the lithospheric structure of the Vrancea region (Enescu *et al.*, 1982; Oncescu, 1982, 1984, 1986; Oncescu *et al.*, 1984), the Vrancea earthquake of March 4, 1977 (Műller *et al.*, 1978; Fuchs *et al.*, 1978, 1979; Iosif, Iosif, 1979; Iosif *et al.*, 1979; Mârza, 1979a, b; Radu *et al.*, 1979a; Radu *et al.*,1979b; Enescu, 1980; Enescu *et al.*, 1982), macroseismic field of the Romanian earthquakes (Radu, Apopei, 1977, 1979; Radu *et al.*, 1979), model of organization of matter structure in the active seismic zones (Anghel, 1981, 1989, 1998), models for the earthquake-triggering effect of the Earth tides, of the geomagnetic field and of the solar activity (Anghel, 1979a, b; Zugrăvescu *et al.*, 1979), seismic microzonation and risk and hazard evaluation (Mândrescu, 1966, 1972, 1973, 1976, 1979a, b, 1981, 1989; Mândrescu, Radulian, 1999; Radulian *et al.*, 2000; Aldea, 2002) and contributions to blasting seismology (Enescu *et al.*, 1971; Mârza, 1977; Mârza, Pântea, 1979; Enescu, Almăşan, 1987).

The mentioned scientific directions were continued in several doctoral theses with interesting and original results (Oncescu, 1984; Trifu, 1991; Anghel, 1998; Moldoveanu, 1998; Radulian, 1998; Rizescu, 1998; Popescu, 2000; Enescu, 2001; Popa, 2003).

Interesting studies were connected by the analysis of coda waves characteristics of some Vrancea intermediate earthquakes (Radu *et al.*, 1983; Oancea, 1994; Oancea *et al.*, 1991). So, respective studies estimated the coda quality factor (temporal and spatial variations) for the Romanian territory and attenuation of seismic waves for events occurred in different active areas of Romania.

Also, physicist Marius Anghel (1989, 1990) suggests a new model of organization of matter structure. He proposes a quantum model of a seismic zone, called "SEISMON" and he presents some applications of his theory in seismic prediction, in deduction of relation frequency – magnitude of Gutenberg-Richter type and in interpreting observed deviations of this known relation. This quantum model of the seismic source and the postulates of the universal quantification theory were developed in this doctoral thesis (1998).

Scaling of the source parameters, inhomogeneous behavior of the faulting process, the numerical simulation of the generation process and analysis of the heterogeneity of generation of crustal and subcrustal Vrancea earthquakes were different problems approached by physicist Mircea Radulian and his fellow-workers (1991, 1994, 1996). In his thesis (1998) he developed the faulting dynamics and implications on the modelling of the Vrancea seismic processes.

Some crustal earthquake sequences (Râmnicu Sărat, Câmpulung–Făgăraş, Banat) were also subjects of the study for different researchers as Emilia Popescu, Olivia Bazacliu, Mircea Radulian, Ana Utale (1992–2000), Luminița Ardeleanu, Smalbergher (1991); Malia, Rădulescu (1999). Complex study of these crustal sequences was discussed in Emilia Popescu Ph.D. thesis (presented in 2000 and published in 2007).

Seismic prediction of Vrancea earthquakes was another direction of study (Enescu *et al.*, 1973, 1974, 1975, 1996, 1998; Carmen Moldoveanu, 1998; Enescu, 2001).

Important results were obtained in the seismic microzoning study (Mândrescu, 1966, 1972, 1973, 1976, 1977, 1979 a,b, 1981; Mândrescu *et al.*, 1999, 2004; Radulian *et al.*, 2000; Moldoveanu *et al.*, 2003). The geologist Nicolae Mândrescu performed numerous *in situ* measurements in different sites of Romania, including in principal the Bucharest city area. Here the recent studies were designed to the better knowledge of the local geological conditions beneath city area and collect, analyze and correlate the information concerning the distribution of shear-wave velocity in sedimentary layers (Mândrescu *et al.*, 2004). The studies supplied data concerning seismic risk and geological hazard evaluation in Romania (Mândrescu, 1984, 1989).

Other studies referred to present-day stress field on the Romanian territory determined by the focal mechanisms solutions (Zugrăvescu, Polonic, 1997, 2003; Polonic *et al*., 2005).

Romanian researchers were involved in some international scientific projects as the followings: COPERNICUS Project (*Quantitative seismic zoning of the Circum-Pannonian region*, 1995–1998, and *Assessment of Seismic Potential in European Large Earthquake Areas*), *Microzonation of Bucharest, Russe and Varna in connection with Vrancea earthquakes* (NATO Project, 1996–1998), *Seismic safety of urban areas: ground motion modelling and intermediate-term earthquake prediction* (UNESCO Project, 1999–2004), CALIXTO Project (*Seismic Tomography in the Vrancea Region, Romania*, 2000–2003), *Structure of the Earth's lithosphere beneath Vrancea area, Romania, from seismic-refraction investigation and tomography inversion* (NATO Project, 2001–2003), *Novel Optical Devices and Techniques for Seismic Activity Detection and Measurement* (EC Project, 2002–2005), *Seismic Attenuation and Anisotropy in the Carpathians and Adjacent Basins: Upper Mantle Role in the Last Stages of the Tethyan Closure* (National Scientific Foundation, Project USA, 2004–2006), *The enhancement of the station Bucovina (BURAR) for signal detection and seismic phase identification at regional and teleseismic monitoring* (Romanian-American Project, 2006–2008), *Network of Research Infrastructures for European Seismology* (FP6, 2006–2010) and *Seismic Early Warning for Europe* (SAFER, FP6, 2006–2010).

Besides these international projects the seismological activity was supported by some national research programs (CERES, CORINT, MENER, CEEX 2005, 2006). These national projects referred to following seismological fields: seismic tomography of the Vrancea area, monitoring of seismicity and studies concerning the national network improvement, investigation of deep structure of the Vrancea region and determination of source and propagation parameters on the basis of data of digital accelerometers net, study of attenuation of seismic waves in the Earth's core, modelling of soil motion and medium-tern prediction, optical devices and techniques of seismic detection, alarm system in real time for strong earthquakes, complex system of seismic monitoring and processing by modern techniques of precursory factors of major events, integrated studies concerning genesis of the Vrancea intermediate earthquakes, advanced system for seismic monitoring in industrial areas with high seismic risk, database for earthquakes of Romania, seismic microzonation of dense population zones.

In 1994, Romanian specialists (Mihnea Corneliu Oncescu and Mihaela Rizescu) together with German specialists of the Geophysical Institute, Karlsruhe, conceived and carried out SAPS system (Seismological Acquisition and Processing System, Oncescu *et al*., 1996; Rizescu, 1998). This advanced system (in real time) operates in Freiburg (since 1994), Bucharest (since 1995), Bensberg, Köln University (since 1995) and Timişoara, Romania (since 1996). Data of this system are transmitted at the following seismological centers: International Data Center (Washington, USA), Seismological Office (Zűrich, Suisse), Geophysical Institute (Karlsruhe, Germany) and Seismological Center Euro-Mediterranean (Strasbourg, France).

SAPS system utilizes an original program, solid and stable, named HYPOPLUS, developed from HYPO program (Oncescu, 1984) using Geiger iterative method (1910).

In 1995–1997 a new strong motion network of digital accelerographs (Kinemetrics K2) has been installed in Romania, in the framework of the Romanian-German co-operation, within the project *Strong Earthquakes: A Challenge for Geosciences and Civil Engineering* (University of Karlsruhe, Germany, Bonjer *et al.*, 2000). This net was centered around the Vrancea seismic region, covering an area with a diameter of up to 500 km (Grigore, Grigore jr., 2008). The network is equipped with Kinemetrics K_2-dataloggers, three-component sensors and GPS timing system; most stations have velocity transducers in addition (Bonjer *et al.*, 2002). Ivan (2003) used the recordings of this seismic network; he used 42 Vrancea seismic events and he obtained a preliminary 1-D attenuation model of this area. Also, he evaluated the attenuation corrections for the seismological stations; the results derived in the frequency range 1.562–10.156 Hz showing an increasing of Q factor with depth.

In present-day the National Seismic Network (from the frame of NIEP – National Institute for Earth Physics) includes a real-time seismic net consisting of 14 short-period analog stations (10 situated in Eastern and Southern Carpathians and telemetred by radio to Bucharest, three stations situated in western part of the country and telemetred to Timişoara, one in southern Transylvania telemetred to Sibiu); a digital strong motion network of 36 K2 stations, synchronized by GPS time receivers and flash card memory; BURAR-Bucovina and VRÂNCIOAIA-Ploştina Arrays consist of 10 digital stations (in boreholes) and respective of 4 digital stations. Starting from 2002 the new system BURAR (Suceava county) become operational by continuons recordings and transmitting data in real-time (via satellite) to the National Data Center of Romania, in Bucharest and the National Data Center of USA, in Florida.

This seismic array is the result of collaboration between NIEP and Air Force Techical Applications Center (AFTAC) of USA. It consists of 10 seismic sensors (9 short-period and one broad band) located in boreholes and distributed on a 5×5 km area (Grigore *et al.*, 2004).

In the last time our specialists (from National Institute for Earth Physics) and researchers of Geophysical Institute (Karlsruhe University, Germany) accomplished an earthquake Early Warning System (EWS) for Bucharest and industrial zones around the Vrancea region (Grigore, Grigore jr., 2008). EWS uses the time interval (about 25 seconds for Bucharest) between the moment of seismic waves detection at surface in epicenter area (Vrancea) and time arrival of these waves in the protected sites. EWS works in the following phases: detection of P waves and first arrivals analysis, alarm generation and distribution of alarm to the users. For the detection of P waves in epicenter is monitorized the ground motion of two different locations situated in Vrancea, Vrâncioaia observatory (VRI) and Ploştina site (PLOR). In the second site two accelerometers are installed, one in a 50 m depth borehole and other on the surface. In the present the EWS is in the testing phase. A nuclear installation of "Horia Hulubei" National Institute of Physics and Nuclear Engineering use EWS at this moment.

In 2002, the National Institute of Research and Development for Earth Physics (NIEP) marked, by an international symposium, *25 Years of Research in Earth Physics and One Century of Seismology in Romania*. In the presentation volume of this scientific event and of the institute history are mentioned the major research areas of NIEP: monitoring of seismicity, lithosphere structure and dynamics, seismic source and seismotectonics, seismic hazard and earthquake prediction and assessment and mitigation of the seismic risk.

There were presented 55 oral and poster works; authors came from Universities of Trieste and Parma, National Institute of Geophysics and Abdus Salam International Centre for Theoretical Physics – Trieste (Italy), Geophysical Institute – University of Karlsruhe and Institute of Meteorology and Geophysics – Frankfurt an Main (Germany), International Institute of Earthquake Prediction Theory and Mathematical Geophysics (Russian Academy of Sciences), Institute of Earthquake Engineering and Engineering Seismology (Republic of Macedonia), University of Brasilia (Brazil), Center for Monitoring Research (Arlington, USA), Bulgarian Academy of Sciences. The Romanian involved institutes were the followings: NIEP, "Sabba S. Ştefănescu" Institute of Geodynamics (Romanian Academy), National Institute of Research and Development for Optoelectronics, Faculty of Geology and Geophysics (University Bucharest), Geotech S.A., Bucharest and Building Research Institute.

In this brief history of Romanian seismology we must also mention the prodigious activity of the "Sabba S. Ştefănescu" Institute of Geodynamics of the Romanian Academy. Since its foundation (1990), the institute focused interest on fundamental research implied by the Priority Program of the Romanian Academy, *Complex geophysical research in geodynamic active areas concerning especially the Vrancea seismogenic area*. The researches implied the following aspects: study of space-time variations of some parameters linked to cumulating of stress responsible for earthquake generation; crustal deformation monitoring; tectonic hazard studies; monitoring of space-time variations of gravity, geomagnetic, geoelectric fields and Earth tilts; modelling of therm-mechanical evolution of the lithosphere; non-linear analysis of geodynamic systems, etc. The institute has a network of observatories and observation points. The network is concentrated in three geodynamic polygons: Căldăruşani-Tulnici, Crăciuneşti-Sarmizegetusa Regia-Padeş and Danube Delta – Mangalia. The measurement equipment from geodynamic observatories is the result of a long-term experience in constructing sensors for geodynamic research, such as: horizontal quartz, water-tube tiltmeters, extensometers. Also, a mobile geodynamics laboratory which has been used for complex geophysical measurements in the active seismogenic areas (Zugrăvescu, 1985; Cornea *et al.*, 1980; Enescu, Zugrăvescu, 1990; Zugrăvescu, Polonic, 1997, 2003; Polonic *et al.*, 2005).

In 1993–1996 period, Vasile I. Mârza was head of the Seismological Laboratory (in frame of the National Institute for Earth Physics). Vasile I. Mârza (1945–2006), physicist, Ph.D. in earthquake prediction from the University of Bucharest (1982), in the last period of his life (1996 to 2006) was visiting professor of the University of Brasilia, Brazil. He was medallist of the Romanian Society of Geophysics (1995) and winner of the Romanian Academy's "Ştefan Hepites" Award for 1993. He approached the following seismological studies: location and analysis of local, regional and global earthquakes; seismicity; field investigations of microearthquakes and seismic sequence; earthquake prediction; engineering seismology; geotechnical investigations. He was the principal investigator in various research projects mainly involving seismicity, seismic hazard, earthquake prediction and blasting seismology (since 1971). He was active in different international co-operation projects. He was chairman of the Working Group on Seismicity of the Carpathian-Balkan Region, sub-commission 1 (1984–1996);

national supervisor of the Joint Japanese-Romanian Earthquake Prediction Program in the Vrancea Zone, Romania (1985–1989); convener of the task-group 11, *Earthquake Prediction* of the UNESCO Project *Earthquake Risk Reduction Network in the Balkan Region* (1987-1990); co-convener of the IASPEI/ESC Project on *The Practice of Earthquake Hazard Assessment* (1990–1994); research director for *Seismicity Monitoring and Seismic Hazard Analysis in Romania* (1993–1996).

Except Mârza's contributions concerning Romania seismicity, especially Vrancea region, we must mention his important results in blasting seismology domain (Mârza, 1977, 1979; Enescu *et al.*, 1971, 1973).

Since 1960's years in frame of the geological studies were initiated works about evaluation of geological hazards and seismic risk of the Romanian territory (Mândrescu, 1981). In this research direction we must specify the seismic microzoning studies of different areas and cities (Mândrescu, 1966, 1972, 1973, 1976).

In this field research a remarkable activity had the geologist Nicolae Mândrescu. He identified the geographical distribution of the Romanian regions susceptible of permanent deformations during earthquakes. He performed thorough analyses of the geological, seismological, geotechnical, hydrogeological, etc conditions of these areas. The results are very important for elaboration some realistic antiseismic norms with a view to the protection of buildings.

A special attention was accorded to the data concerning seismic microzonation of Bucharest city (Mândrescu, Radulian, 1999; Moldoveanu *et al.*, 2003; Mândrescu *et al.*, 2004). Some studies referred to the strong Vrancea earthquake of March 4, 1977 (Mândrescu, 1979 a, b), which produced important damages in Bucharest and in some southern localities.

Results from the Bucharest area permitted the elaboration of the seismic microzonation map, proposed to be a design norm in the building activity (Moldoveanu *et al.*, 2003). The complex studies in other areas of Romania supplied useful information for drawing up of the *Seismic hazard map of Romania*, later on in format USGS-USA and EC8.

In connection with strong event of March 4, 1977, the seismic record performed by National Building Research Institute put in evidence, for the first time, the spectral content of long period seismic motion of Vrancea earthquake, the duration, the number of cycles and values of accelerations (Georgescu, 2002). This information has changed the seismic coefficients K_s, spectral curve and seismic zonation map. Recent data determinate implementing of the Earthquake Code P 100/1992 and harmonization with Eurocodes.

The last seismic engineering data permitted to Gh. Mărmureanu to introduce a new term – *nonlinear seismology* – of the seismology of the XXI-st century (Mărmureanu *et al.*, 2004). He was inspired by Aki's finding (in 1993) on nonlinear effects in ground motion during strong earthquakes. Mărmureanu and his collaborators consider that studying nonlinear site effects in 2-D and 3-D geological structures will open up a new challenge for seismologists of the XXI-st century. This new research direction was developed in collaboration with German (University of Karlsruhe) and Italian (University of Trieste) specialists, in frame of a NATO Project.

In 1977–1985 time period, there were performed complex studies on site conditions concerning a possible nuclear power plant. So, Romanian specialists investigated numerous locations placed in Dobrogea (5), Wallachia (1), Transylvania (4) and Moldova (9). Between these ones, from Dobrogea, it was chosen one site, situated in Ilie Barza quarry (Cernavodă), where was build Cernavodă nuclear power plant. These works carried out in frame of the Center of Earth Physics and, since 1979, in the new set-up "Laboratory of soil mechanics" (changed into "Laboratory of engineering seismology", leaded in the first period by eng. Alecsandru Vaicum). He was preoccupied with different problems of seismic engineering, in principal with the following aspects: assessment of the structure response spectra to seismic activities, dynamic interaction of the building structure – Earth mass, site conditions, etc. (Vaicum, 1983, 1985; Mărmureanu *et al.*, 1983). We must mention his book, published in 1985, *Site conditions in seismic engineering* (Publishing House of the Romanian Academy). This important book was dedicated to the memory of the great constructor and scientist Acad. Aurel A. Beleş. The famous professor published in 1962 a first book including elements of engineering seismology (Beleş, Ifrim, 1962). In Vaicum's book, the author analyzed in detail the dynamics interaction of the building structure and his modelling, inclusive the influence of principal factors on main average effective voltage and damping factor. In the final subchapter he indicated the general conclusions on principal directions in this research field.

In the "Laboratory of engineering seismology" (now leaded by dr. Florin Bălan), worked an excellent mathematician, dr. Mircea V. Mişicu (1926–2005), with remarkable contributions in some domains of continuous medium mechanics as: elasticity theory and material resistance; plasticity, rheology and dislocations mechanics; theoretical seismology; probability theory. He got the Prize "Aurel Vlaicu" of the Romanian Academy (1965) and he published three important books: *Mechanics of deformable media*, 1967; *Theory of elastic mobility*, 1972; *Bending and Torsion*, 1973). In seismological field he published studies on a seismic source from a fault and directivity of seismic waves emitted by this dislocation type (especially for the March 4, 1977 earthquake).

In time, the Romanian studies contained, also, the results of blasting seismology works. These began in 1967 through some studies on effects of explosions produced in Pietreni-Bistriţa quarry (Enescu, 1967); respective explosions affected Arnota Monastery. Similar studies were performed in other quarries as: Anina, Păuliş, Teliuc, Cernavoda, Negoiul, Roşia Poieni, Băiţa (Mârza, Pântea, 1979).

Experience obtained in frame of these works permitted the elaboration of the book *Blasting seismology* (published in 1987, by D. Enescu and B. Almăşan). This book treats theoretical and practical aspects of the principal problems of blasting seismology. One of the most main aspects of this domain is represented by the seismic effects of explosions on the buildings. The book presents, also, some results obtained in Romania by application of different studying methods of seismic effects of blastings.

First attempt of the prediction problem by long term of strong Vrancea earthquakes was made by Enescu *et al.* (1973, 1974). Later, Enescu and Ianăş (1975), Purcaru (1979) and Mârza (1982) supplied new elements in this complex problem. Much later, Romanian researches connected these events with some geophysical phenomena as Earth tides, gravity tide and electromagnetic field (Zugrăvescu *et al.*, 1979, 1989; Enescu, 2001). So, since 1997, two electromagnetic observatories were set up at Cheia–Muntele Roşu (MLR) and Vrâncioaia (VRI).

In the first studies, the authors evidenced some statistical peculiarities of these earthquakes, the seismic gaps (in time or in depth) and premonitory fluctuations of the *b* coefficient (from appearance frecquency-magnitude) (Mârza, 1982; Radu, Ardeleanu, 1982). Some specialists used the CN algorithm for Vrancea earthquakes prediction (Novikova *et al.*, 1995; Moldoveanu, 1999).

Seismological studies were also performed by the Institute of Hydrological Studies and Designing and, after 1990, by Geotech S.A. Specialists approached the monitoring of the seismic activity in areas of great dams (Argeş, Bicaz, Drăganu, Fântânele, Lotru, Sebeş, Surduc); they studied the influence of the level of accumulation lakes on seismic activity and obtained some interesting results.

Finally, we are sure of the existence of the possible gaps, considering the long analyzed time period, but we think that the principal problems, research directions, personalities and some main results were specified in this relative short review. We consider that the general information is very useful for specialists, especially for young researchers and generally for the evolution of this science in Romania.

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