.

COUNTRY ASSESMENT REPORT
ROMANIA

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National Institute of Research and Development for Earth Physics

1. Introduction

Black Sea Earthquake Safety Net(work) – ESNET project deals with earthquakes and prevention of natural disaster generated by such events. The Black Sea region has a long history concerning the earthquakes. In the past, the earthquakes in the Black Sea basin have generated lots of casualties and material loses, therefore it is extremely necessary to review the seismic hazard, and existing monitoring and intervention systems. Participation of the NIEP in the ESNET project is crucial and useful for solving common problems as risk reduction and population safety.

2. Seismicity

2.1. Overview

Romania is a country with rather high (medium to high) seismicity: about 300 earthquakes of magnitudes M>2.5 are yearly recorded. In the complex tectonic environment of the Romanian territory, several individual seismogenic zones have been identified: Birlad Depression(BD), Predodrogean Depresion (PD), Romanian Plain (a sector of the Intra-Moesian fault), Crisana-Maramures (CM) in the North, Transilvanian Depression (TD) and Fagaras-Campulung zone (FC) in the central Romania, Banat (BA) and Danubian (DA) zones in the western part of the country. The most active seismogenic zone is Vrancea, lying at the eastern corner of the Carpathian Belt.

As can be been in Fig. bellow, earthquakes originating in most of these zones are of medium magnitudes and superficial (crustal)foci. Fagaras (FC) seismogenic region is the second seismic source in Romania as concerns the largest observed magnitude (Mw = 6.5), after the Vrancea intermediate-depth source. Once per century, an event with epicentral intensity larger than VIII is expected in this area (Moldovan et al, 2007), the last major event occurred in January 26, 1916 has Mw=6.5 and I_0=VIII-IX in MSK scale.

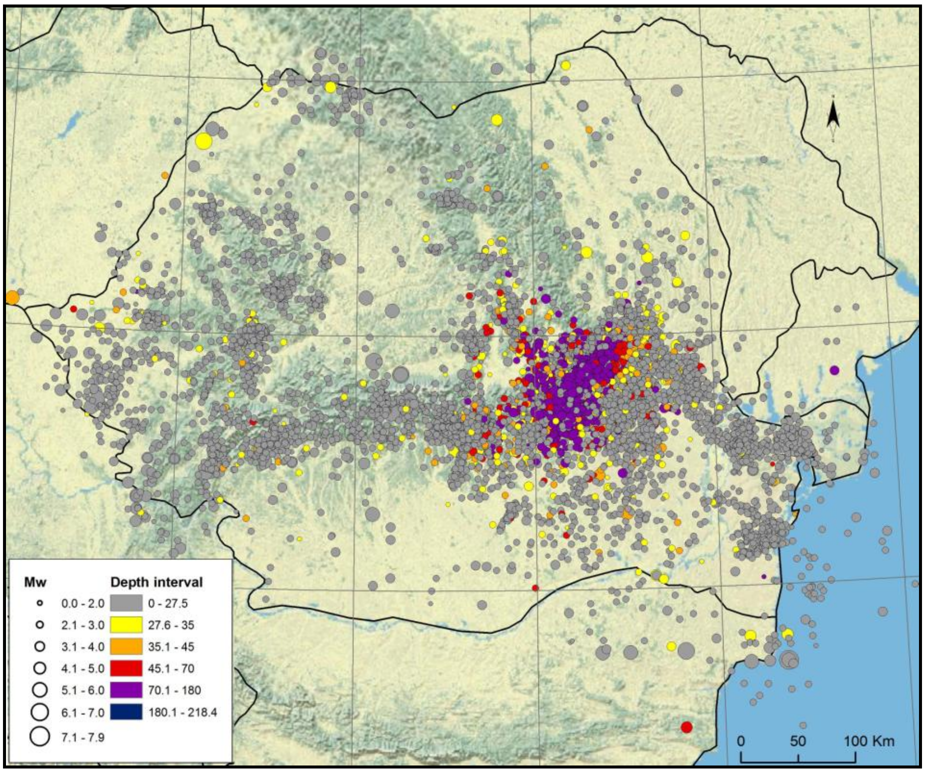


Figure 1 Seismicity of Romania

Most of the crustal earthquakes in Romania are of low energy, the seismicity is characterized by many earthquakes with magnitudes Mw close to 5, but not exceeding 5.6 (e.g. BA zone where the largest earthquake occurred after 1900 is the one from July 12, 1991, Mw = 5.6).

Historical information suggests potential earthquakes greater than 6 in several zones like CM (the maximum reported event is October 15, 1834 with Mw=6.5) and TD (maximum evaluated at Mw=6.5) but few events of magnitude 4 were reported in the last hundred of years.

A zone with scarce seismicity but high seismic potential is Shabla (SH), on the territory of Bulgaria. The latest strong event (Mw=7.2) occurred here in March 31, 1901 produces severe effects in NW Bulgaria and SE Romania.

Vrancea is a complex seismogenic zone created by the continental convergence of at least 3 major tectonic units: East-European plate, Moesian and Intra-Alpine sub-plates. It is the most active on the territory of Romania. Considering the hypocenters depth, in this area 2 subdivisions can be identified: VRN with normal/crustal events (up to 40km depth) and VRI generating intermediate-depth earthquakes.

The seismic activity in VRN is located in front of the Southeastern Carpathians arc, spread over a stripe area delimited to the north by the Peceneaga-Camena fault and to the south by the Intramoesian fault. The seismicity consists only in moderate-magnitude earthquakes (Mw<5.6) generated in clusters. The catalog contains a single earthquake of Mw = 5.9 occurred on March 1, 1894, with magnitude estimated from historical information, possibly overestimated (Moldovan et al., 2007).

VRI zone is a very confined area covering the epicenters of the intermediate-depth events (70-180km), generating 3-5 events with Mw>7 per century and a high seismic moment release (1.2x1019 Nm/year). Only in the XX-th century 4 strong events occur here :November 10, 1940 (M_W = 7,7; M_0= 5,1 x 1020 Nm ; h= 150 km), March4 , 1977 (M_W = 7,4 ; M_0= 1,5 x 1020 Nm ; h= 93 km), August 30, 1986(M_W = 7,1; M_0 = 0,6 x 1020 Nm ; h= 131 km) and May30, 1990 (Mw=6.9). Earthquake of October 26, 1802 (M_W = 7.9) is considered the strongest earthquake originating in VRI. The characteristic mechanismfor 90% of these events is the reverse faulting with T axes nearly vertical and P axes almost horizontal, fault plane oriented NE-SW. This resides in a characteristic ellipsoidal macroseismic field, regularly SW-NE oriented, affecting also Moldavia, Ukraine, Bulagaria, Macedonia, Serbia.

2.2. Seismicity of the Black Sea Basin

Tectonic settings

The Black Sea is the largest European back-arc basin, situated at the transition zone between a group of orogenic belts formed during the closure of Paleo and Neo-Tethys oceans and a tectonic mosaic of units deformed in Late Proterozoic to Paleozoic times at the southern margin of the East-European craton(Okay et al., 1996; Robinson et al., 1996; Stephenson et al., 2004; Saintot et al., 2006).

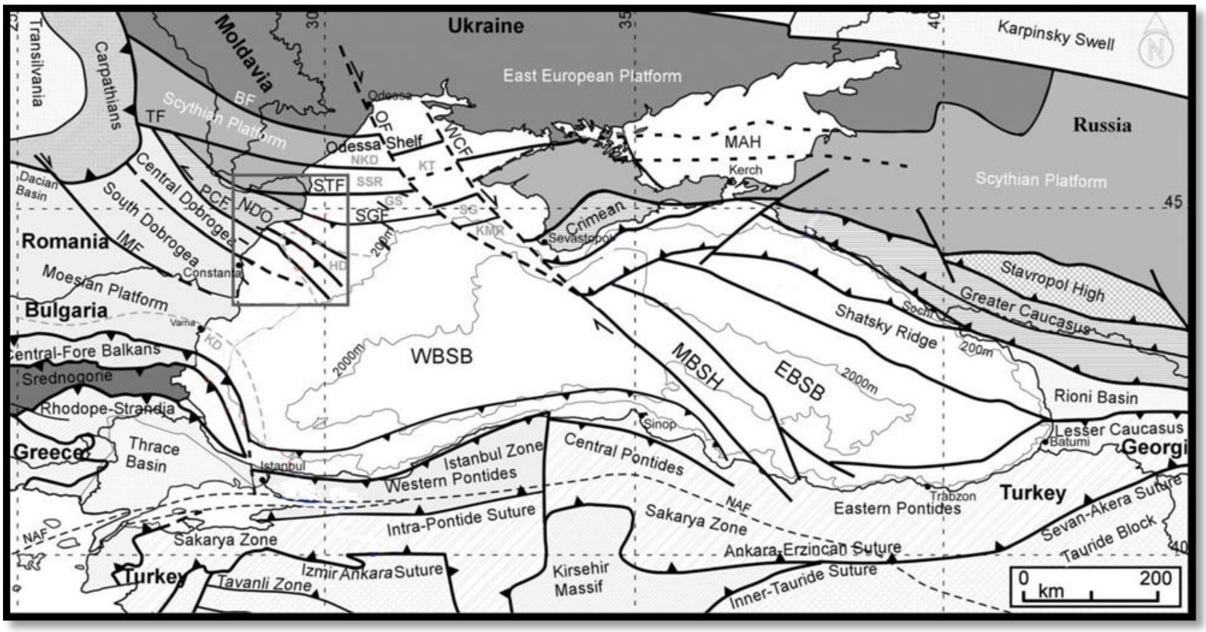


Figure 2. Tectonic map of the Black Sea and adjacent areas (after I. Munteanu et al., 2011). The inset is the location of the figure3..BF, Bistriţa Fault; IMF, Intramoesian Fault; NAF, North Anatolian Fault; OF, Odessa Fault; PCF,Peceneaga-Camena Fault; SGF, Sfântu Gheorghe Fault; STF, Sulina-Tarhankut Fault; TF, Trotuş Fault; WCF, West Crimea Fault; EBSB, East Black Sea Basin; WBSB, West Black Sea Basin; GS, Gubkin Swell; HD, Histria Depression; KD, Kamchya Depression; KT, Karkinit Trough; KMR, Kalamit Ridge; MAH, Mid Azov High; MBSH, Mid Black Sea High; NDO, North Dobrogea Orogen; NKD, North Kilia Depression; SG, Shtormovaya Graben; SSR, Surov-Snake Island Ridge.

The evolution of the Black Sea basin was controlled by different processes active during the northward subduction of the Neotethys beneath the Rhodope-Pontides volcanic arc (Adamia et al., 1977; Letouzey et al., 1977; Zonenshain and Le Pichon, 1986; Okay et al., 1994). Black Sea Basin consist of two sub-basins, eastern (EBSB) and western (WBSB). Both of these subbasins, having oceanic or sub-oceanic crust, are separated by the Mid-Black Sea Ridge (High), Fig.1, which is composed of thinned continental crust (I. Munteanu et al., 2011).

The Western Black Sea Basin, interpreted as a remnant or extensional back-arc basin related to the Nothward subduction of the Neotethys behind the Serbomacedonian – Rhodope – Pontide, was open in **late Early Cretaceous** times (Aptian-Albian)(Finetti et al., 1988; Görür, 1988; Ţambrea, 2007). **Eastern Black SeaBasin** has opened later, during **late Cretaceous, Paleocene or Eocene** **(**Robinson et al., 1996; Banks, 1997; Kaz'min et al., 2000) times by the rotation of the Shatsky Ridge away from the Mid Black Sea High(ridge)(Okay et al., 1994).

The Early Cretaceous back-arc opening of the Black Sea Basin, in different and successive deformation phases, was followed by a major extensional episode that took place during Late Cretaceous times, the results being large grabens filled with syn-kinematic volcano-clastic sediments. Normal faults can be laterally followed along their strike onshore, where the Late Cretaceous extensional structures are observed in the Srednogorie back-arc basin of the Balkanides. Near the northern margin of the Western Black Sea, the Odessa Shelf, syn-kinematic deposition in (half-) graben structures demonstrates an Early Cretaceous–early Late Cretaceous age of extension, subsequently followed by a latest Cretaceous – Eocene period of post-rift thermal subsidence(Munteanu I., et al., 20111).

The Eocene opening of the Eastern Black Sea has induced renewed extension in the western basin, which, offshore Romania and Bulgaria, generated faults with offsets in order of tens to hundreds of meters (Munteanu I. et al., 2011). A notable exception is a NE-SW oriented, ~2 km high fault escarpment, located offshore Varna, which is inherited from the initial late Early Cretaceous opening and reactivated during Eocene times (Munteanu I et al., 2011, Tari et al., 2009) . The overall Upper Cretaceous-Eocene is characterized by a passive margin evolution. This passive margin evolution is interrupted by the middle Eocene collision (Okay et al., 1994). The collision between the major tectonic units of the Pontides and the Taurides represent the time when the last remnants of the Neotethys Ocean were closed along the Izmir – Ankara Suture Zone (Munteanu I. et al. 2011). This collision induced large scale uplift that exhumed the southern margin of the Black Sea(Okay et al., 2001).

The major contraction from the southern margin of the Black Sea led to the onset of inversion recorded in the extensional basins and to the formation of other foreland and thrust-sheet top basins. The inversion from the NE part of the Western Black Sea led to the formation of Oligocene-Miocene reverse faults and associated folds with Northward vergence and offsets in the order of tens to few hundreds of meters. Along this northern margin, the structural grain changes rapidly east of the Odessa-West Crimea fault system, where the Crimean Orogen is thrusted S-wards over the Black Sea domain from Oligocene to recent times (Munteanu I. et al., 2011).

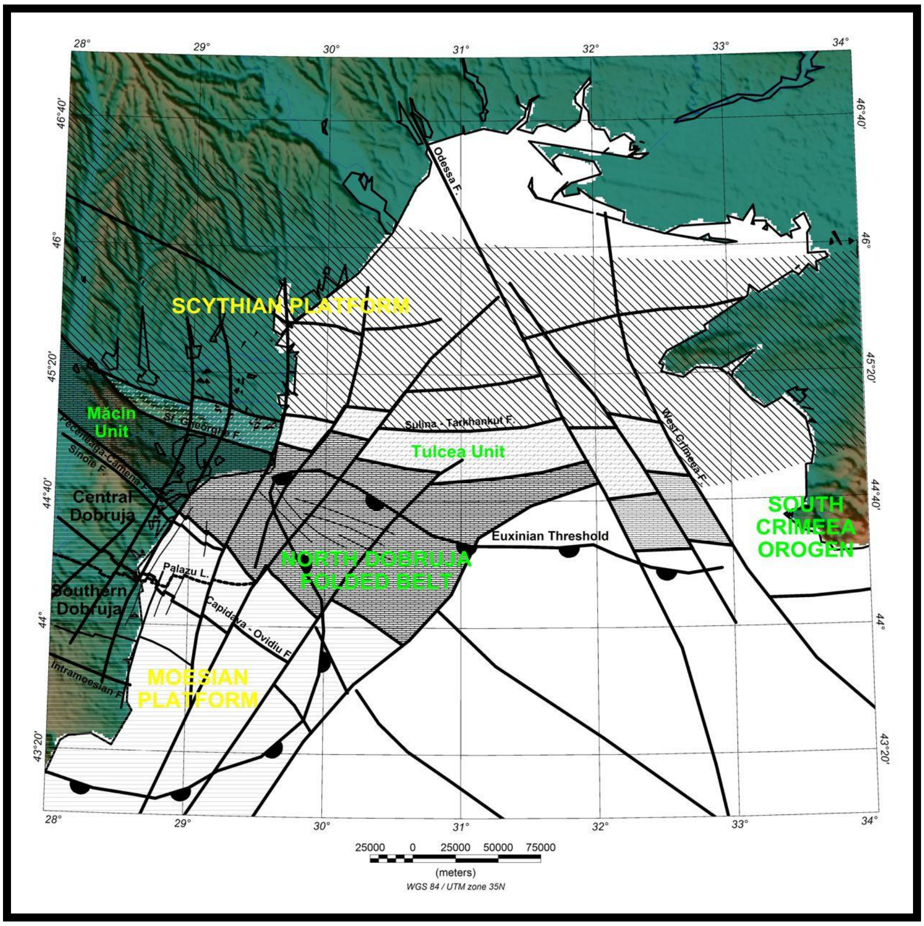


Figure 3.Tectonic map of the Western Black Sea Basin, after Dimitriu et al., 2009

Concerning the Romanian Black Sea we highlight:

A) the Scythian Platform, by Precambrian age; its study was made only through indirect methods: magnetometry, gravimetry, seismic and drilling, was separated a system of major overthrusts, with regional character and northern vergence, such as Chilia, Serpilor Island, Sulina-Tarhankut and Golitin overthrusts. This unit is bounded to the south by Sulina -Tarhankut fault and to the North by Trotus fault;

B) Northern Dobrogea, known also as North Dobrogea Orogen, represents a relative narrow area situated between the Scythian Platform at North and Moesian Platform to the South, bounded Sulina -Tarhankut fault to the North and Peceneaga-Camena fault to the south. The Northern Dobrogea has a complex structure, being formed by a several tectonic units between which there is an over thrusting relations, the vergence being north eastern;

C) Moesian Platform border westwards Black Sea, spread from north, from Peceneaga-Camena fault until south, in front of Balkans, being formed from a Baikalian basement and a phanerozoic sedimentary cover.

Concerning the faults from the Western Black Sea Basin consists almost of three fault systems. The first one contains the prolongations of the terrestrial faults such as: Sulina-Tarhankut fault, Luncavita Fault, Peceneaga-Camena fault, Sinoe Fault, Horia-Pantelimonul de

Sus fault, Ovidiu Fault, Mangalia fault, Intramoesian Fault. The second one is composed by the faults parallel to the Black Sea coast such as Razelm Fault, Lacul Rosu fault, West Midia fault. The last system is represented by the group of faults with a NW to SE orientation such as Nistru Fault, Odessa Fault, and West Crimea Fault.

Analysis of each identified seismic sources

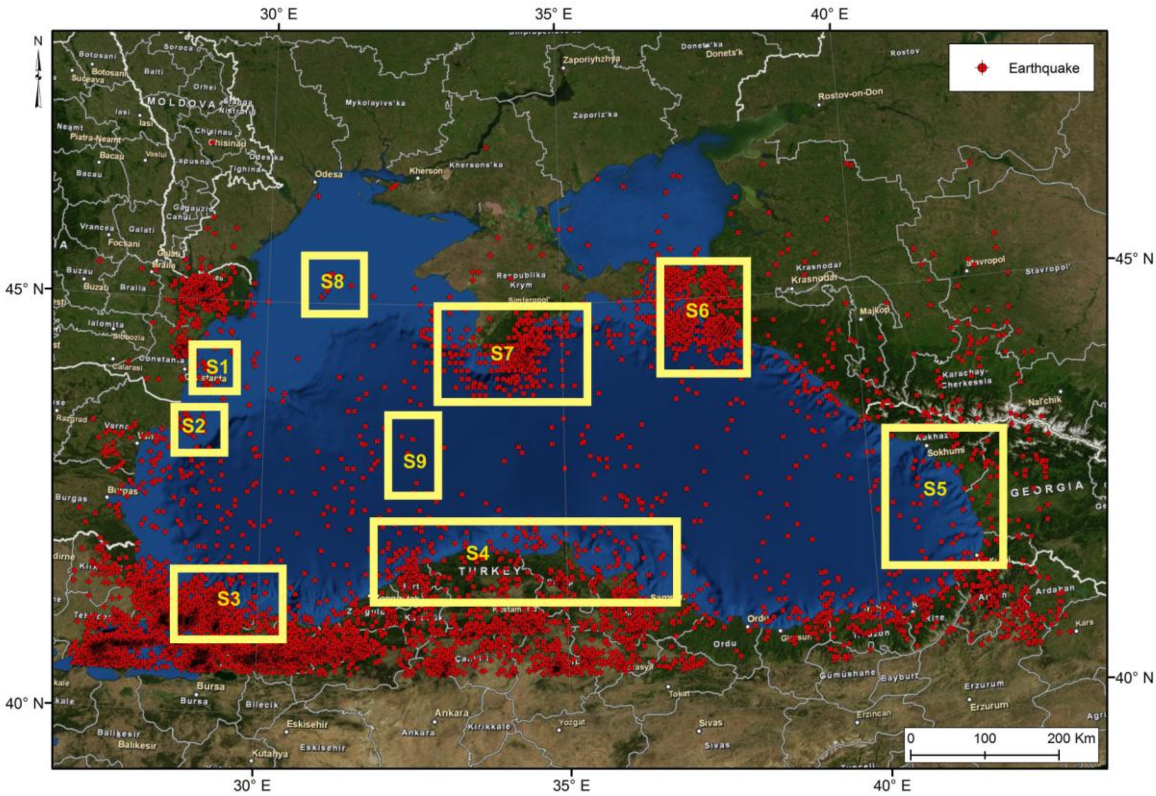


Figure 4. Seismic sources on Black Sea areal

S1- CENTRAL DOBROGEA

Seismic source cover all informed seismic events what was appeared in 543-2010 period. The earthquake in this area are associate by Capidava – Ovidiu fault and Horia – Pantelimonul de Sus fault. as like as transversal fault which frame the Medgidia city.The maximum magnitude observed for 1980-2010 period. it was Mw=5(12.12.1986). for 11 earthquakes, $M_w \geq 3$.

Earthquakes catalog with $M_w \geq 3$

Earthquake catalogue number*	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth km	M_w	EDc km	HDc km
241	1980	1	14	15:07:19	43.9	29	33	4.6	42.37	53.70
328	1982	6	5	11:55:30	43.8	29.3	33	3.4	66.92	74.61
548	1986	12	12	19:29:22	43.89	28.95	10	5	40.19	51.14

Earthquake catalogue number*	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth km	M_w	EDc km	HDc km
1203	1993	4	18	02:02:51	44	29.2	33	3.6	48.97	59.05
1370	1994	4	8	04:24:31	44	29	0	3.2	34.38	34.38
1441	1994	10	9	17:42:24	43.91	28.94	0	3	37.96	37.96
1476	1995	3	9	20:44:15	44	29	0	3.2	34.38	34.38
1905	1997	12	30	04:38:59	44	29	0	4.8	34.38	34.38
2041	1999	3	22	19:25:25	44	29	0	4.3	34.38	34.38
2064	1999	4	29	18:43:43	44	29	0	4.7	34.38	34.38
2798	2004	6	7	05:53:05	43.87	29	15.6	3	44.65	47.29

*Black Sea Earthquake Catalogue

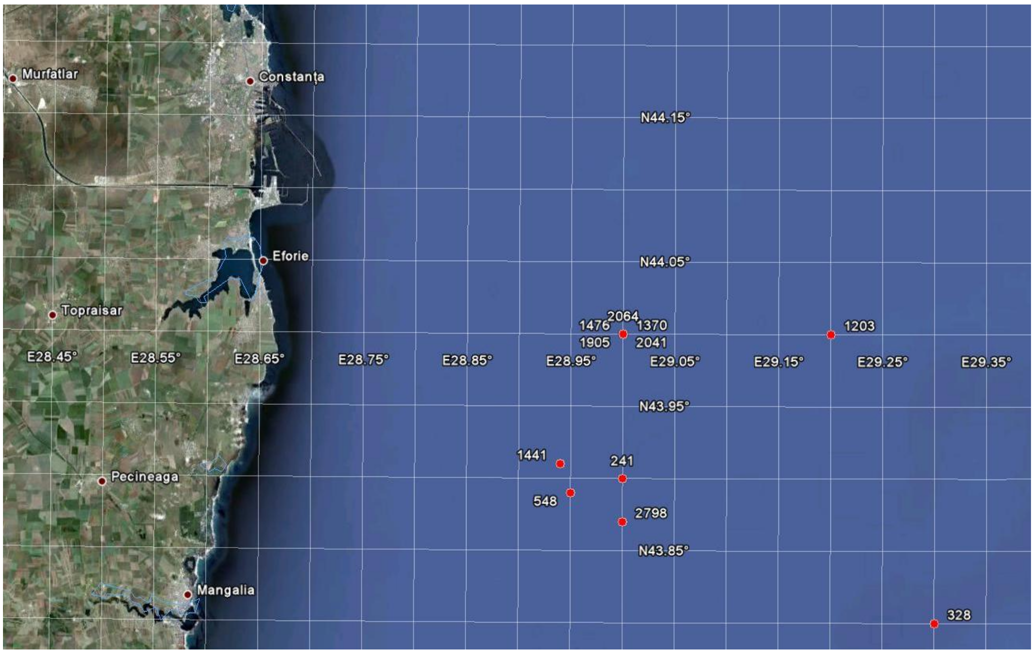


Figure5: Earthquakes distribution for Central Dobrogea seismic source

Seismic activity v_0 is defined as the annual average number of earthquakes with magnitude higher than m_0. For Central Dobrogea, minimum magnitude was considered m_0= 3 (M_w). Seismic activity v_0 = no. of seismic events/T(years) = 11 seismic events/30 years= 0.367 seismic events/year.

The maximum observed magnitude in Central Dobrogea was M_w= 5 (12.12.1986). Applying the practice of increment the maximum observed magnitude, the expected value of the maximum possible magnitude is considered to be $M_{w.max}$= 5.2 with an error value of ± 0.1

The distribution function of the focal depths of the earthquakes from Central Dobrogea seismic zone is shown in Table 3.1.5

Distribution of the focal depths

No.	H (km)	Relative frequency
1	0-4.99	0.464
2	5-9.99	0.178
3	10-14.99	0.143
4	15-19.99	0.071
5	20-24.99	0
6	25-29.99	0
7	30-34.99	0.107
8	35-94.99	0
9	95-99.99	0.035

S2. SHABLA

The Shabla seismic area developed in Bulgarian territory, from tectonic point of view, belong to south border of Moesian Platform. In Sabla – Cap Caliacra area it was localized a normal crop of foci. with development in NE-SW direction. along are distributing the epicenters of normal crustal earthquakes. This active tectonic area is the north-east border of major crustal foci which is developed collateral by Black Sea. with NE-SW direction and which sinks in Burgas area. The foci by Shabla have imitated development. the active sector having a 20-25 km length wiht 15 earthquakes having $M_w \geq 4$.

The distribution of epicenters marks the coupling between existent structural lines in Shabla area which are characterized by the 7.2 (31.03.1901) powerful maxim.

Earthquakes catalog with $M_w \geq 4$

Earthquake catalogue number	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth km	M_w	ED km	HD km
17	1901	3	31	07:10:24	43.4	28.7	14	7.2	85.77	86.90
18	1901	3	31	11:30:00	43.6	28.7	30	5	63.90	70.59
19	1901	4	25	22:25:00	43.4	28.5	10	5	terrestrial	
20	1901	4	26	01:10:00	43.4	28.5	10	4.5	86.90	87.47
22	1901	7	30	03:30:00	43.4	28.7	15	6	85.77	86.35
24	1902	5	25	22:30:00	43.5	28.5	10	4.5	terrestrial	
26	1904	2	8	06:16:00	43.5	28.5	15	4.5	terrestrial	
241	1980	1	14	15:07:19	43.9	29	33	4.6	41.69	53.17
411	1984	2	7	11:16:05	43.2	29.1	33	4	114.10	118.78
1014	1991	9	1	01:15:26	43.1	28.8	0	4.6	121.12	121.12
1905	1997	12	30	04:38:59	44	29	0	4.8	35	35

Earthquake catalogue number	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth km	M_w	ED km	HD km
2041	1999	3	22	19:25:25	44	29	0	4.3	34.95	34.95
2064	1999	4	29	18:43:43	44	29	0	4.7	34.95	34.95
3338	2006	3	6	10:40:08	43.599	28.678	33	4.2	63.76	71.79
4099	2009	8	5	07:49:03	43.45	28.69	10	5	81	81.62

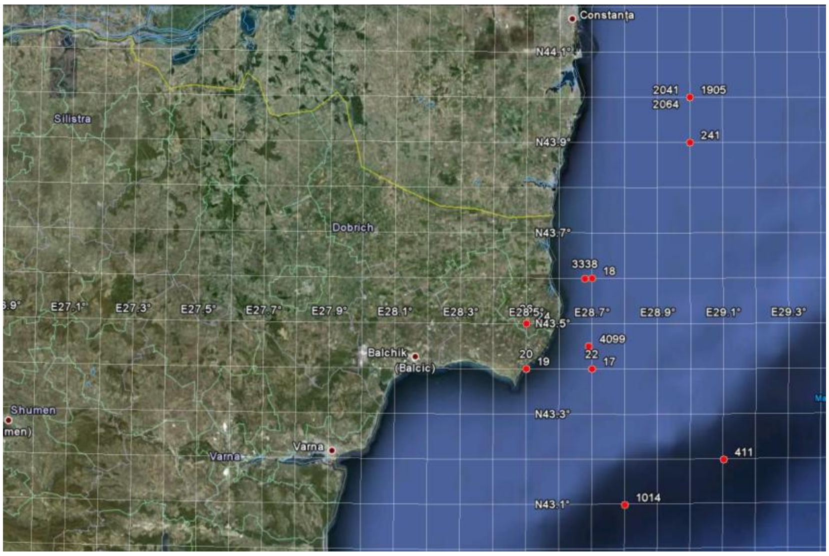


Figure 6: Earthquakes distribution for Shabla seismic source.

Seismic activity v_0 is defined as the annual average number of earthquakes with magnitude higher than m_0. For Shabla, minimum magnitude was considered m_0= 4 (M_w). Seismic activity v_0 = no. of seismic events/T(years) = 15 events/109 years= 0,139 seismic events/year.

The maximum observed magnitude in Shabla region was M_w= 7.2 (31.03.1901). Applying the practice of increment the maximum observed magnitude, the expected value of the maximum possible magnitude is considered to be $M_{w.max}$= 7.3 with an error value of ± 0.1

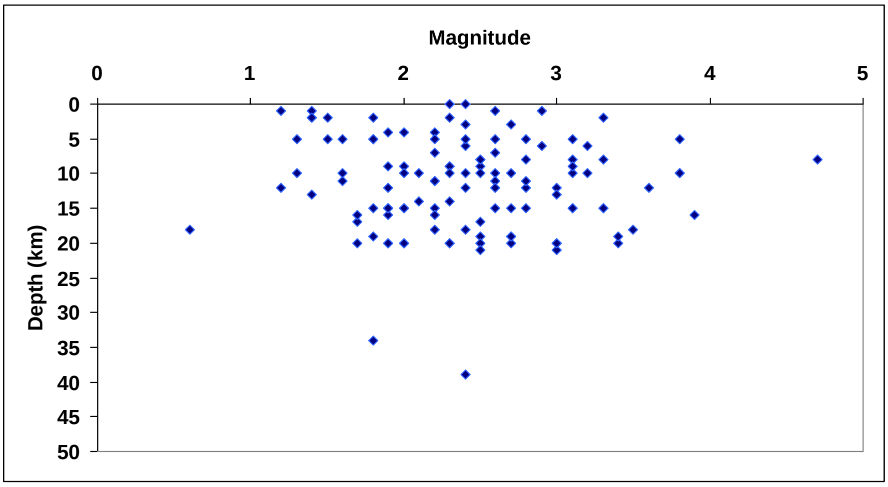


Figure 7. Magnitude-Depth distribution of instrumentally recorded seismic events.

From the Figure7 it is visible that the main seismogenic layer is down to 20 km. This means that the seismogenesis is located in the upper earth's crust and no deeper events can be expected.

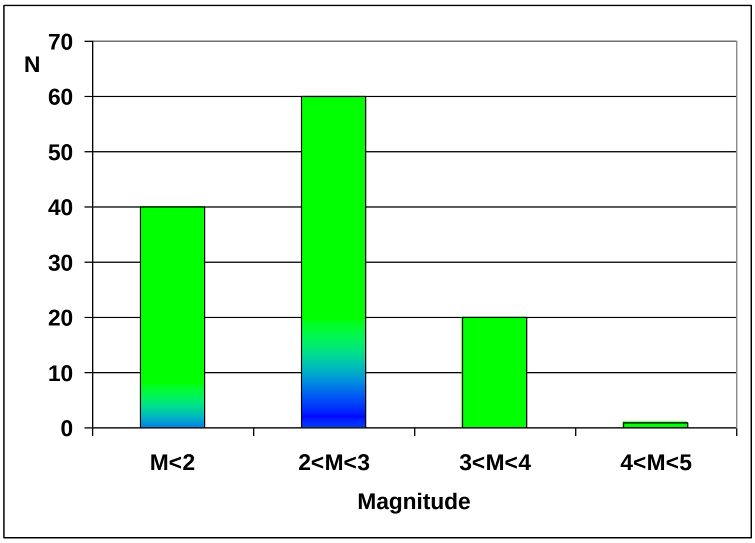


Figure 8: Frequency magnitude distribution – 1990-2011

The distribution function of the focal depths of the earthquakes from Shabla seismic zone is shown in the table below. The weighted average depth is 15 km

No.	H (km)	Relative frequency
1	0-4.99	0.267
2	5-9.99	0
3	10-14.99	0.333
4	15-19.99	0.133
5	20-24.99	0
6	25-29.99	0

7	30-34.99	0.267

S3. ISTANBUL SOURCE

The distribution of epicenter which characterizes Istanbul source, mark the flections of the structural lines belonging to the North Anatolian faults system. The maximum observed in this area is 6.2 (Mw) in 20.06.1943 (41^{0}Lat N and 30^0 Long E. depth 35 km). In instrumental era the maximum observed is 6.7 (MW) 6.08.1983 (41.1 ^{0}Lat N and 30^0 Long E. depth 33 km). The continental maximum observed is 7.6(Mw) on 17.08.1999 (41.01^0 N and 29.97^0 E. depth 17 km).

The faults from Istanbul area have an ample development, the active sectors being of hundreds of km. Maximum of possible magnitude exceed maximum of observed magnitude. Istanbul seismic source is characterized by epicenter distribution of 874 crustal earthquakes during 984-2010 period with $M_w \geq 2$.

Earthquakes catalog with $M_w \geq 4$

catalogue number	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth km	Mw	ED km	HD km
46	1943	6	20	15:32:53	41	30	35	6.2	370	371,65
68	1963	9	24	02:10:45	41	29	33	4.6	terestru	
70	1964	4	18	21:52:54	41.1	29	33	4.2	terestru	
80	1967	7	22	18:07:21	41	30	33	4.7	374,14	375,59
84	1967	8	6	14:09:33	41	28.8	0	4.3	terestru	
193	1978	1	1	07:39:00	41	30	0	5	369	369
393	1983	8	6	15:43:51	41.1	30	33	6.7	358,9	360,41
814	1990	6	10	11:36:45	41.25	29.33	17	4.1	328,41	328,58
897	1990	12	19	12:39:45	41.5	28.9	33	4.3	297,24	299,07
1085	1992	4	23	16:43:51	41	29	0	4	terestru	

catalogue number	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth km	Mw	ED km	HD km
1314	1993	10	26	09:35:55	41.42	29.31	10	3.1	310,87	311,03
1332	1993	12	12	17:21:16	41.4	29.4	2	4.1	315,22	315,23
2123	1999	8	17	00:01:50	41.01	29.97	17	7.6	371,15	371,54
2138	1999	8	20	00:03:00	41.2	28.91	10	5	terestru	
2265	2000	7	7	00:15:34	41.18	29.42	0	4.1	terestru	
2310	2000	12	7	12:16:38	41.409	29.362	0	5	313,15	313,15

Figure7. Earthquakes distribution from Istanbul seismic source

Seismic activity v_0 is defined as the annual average number of earthquakes with magnitude higher than m_0. For Istanbul area, minimum magnitude was considered m_0= 4 (M_w).Seismic activity v_0 = no. of seismic events/T(years) = 16 events/67 years= 0.24 seismic events/year

The maximum observed magnitude in Istanbul was M_w= 7,6 (17.08.1999). Applying the practice of increment the maximum observed magnitude, the expected value of the maximum possible magnitude is considered to be $M_{w.max}$= 7.8 with an error value of ± 0.1.

The distribution function of the focal depths of the earthquakes from Istanbul seismic zone is shown in the table below.

Distribution of the focal depths

Nr.	h (km)	Frecventa relativa
1	0-4,99	0.375
2	5-9,99	0
3	10-14,99	0,125
4	15-19,99	0,125
5	20-24,99	0
6	25-29,99	0
7	30-35	0,375

S4. NORTH ANATOLIAN FAULT SEIMIC SOURCE

We are talking here about a fault system situated to the north of North Anatolian fault, which present an intens tectonic activity during 1954-2010 interval, with more than 265 earthquakes (M_w≥2).The distribution of epicenters mark the associate of existents structural lines in area with maximum magnitude observed 6.1 (19.08.1954).

Next table highlight earthquakes occurred in North Anatolian seismic area between 1954 and 1999 having a magnitude higher than 4 (M_w) and crustal depth (according Starostenko et al., 2004).

Earthquakes catalog with M_w≥ 4 and crustal depth

Earthquake catalogue number	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth km	Mw
52	1954	8	19	21:03:27	42	35.5	0	6.1
75	1966	5	7	22:09:09	42.2	35.7	32	4.4
93	1968	9	3	08:19:52	41.81	32.39	5	5.7
94	1968	9	3	09:13:12	41.646	32.273	33	4.6
95	1968	9	3	10:56:15	41.77	32.444	11	4.5
96	1968	9	3	12:22:01	41.78	32.45	33	4.3
97	1968	9	3	14:09:10	41.7	32.4	14	4.6
99	1968	9	9	11:49:19	41.6	32.3	33	4.4
100	1968	9	10	01:48:41	41.727	32.408	33	4.2
101	1968	9	28	03:25:53	41.75	32.1	38	4
104	1969	1	10	16:33:14	41.641	32.589	18	4.6

Earthquake catalogue number	Year	Mo.	Day	Time	Lat⁰N	Long⁰E	Depth km	Mw
105	1969	2	25	13:43:51	41.6	32.294	31	4.3
120	1970	5	4	13:47:33	41.88	32.67	0	4.2
133	1971	7	5	16:52:48	41.7518	32.4801	5.4	4.3
134	1971	9	20	08:02:36	41.5411	32.6625	0	4
135	1971	9	20	10:57:35	41.5812	32.4425	0	4.2
142	1972	7	4	06:17:19	41.7048	32.4391	0	4
165	1976	2	18	23:07:09	41.864	32.428	3	4.5
199	1978	6	10	05:34:55	42	32	33	4.9
370	1983	2	14	07:28:04	41.996	32.818	10	4.1
469	1985	4	27	12:33:00	42.1	34.9	0	4
2122	1999	8	17	05:09:53	41.69	32.91	10	4.8

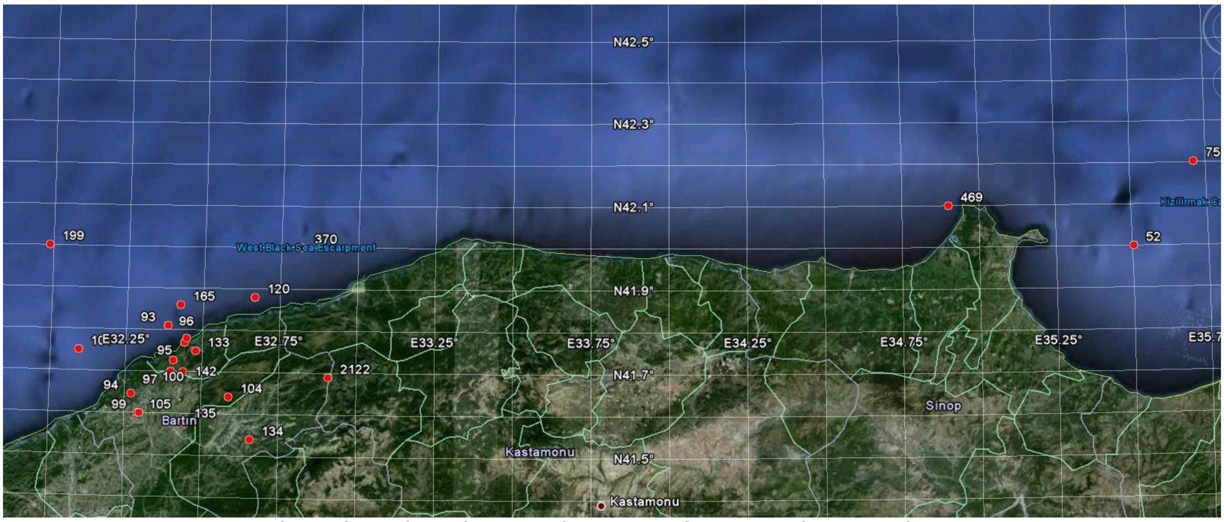


Figure 8: Earthquakes distribution from North Anataolian Fault seismic source

Seismic activity v_0 is defined as the annual average number of earthquakes with magnitude higher than m_0. For North Anatolian Fault area, minimum magnitude was considered m_0= 4 (M_w).Seismic activity v_0 = no. of seismic events/T(years) = 22 seismic events/56 years= 0.39 seismic events/year

The maximum observed magnitude in North Anatolian Fault was M_w= 6.1 (19.08.1954). Applying the practice of increment the maximum observed magnitude, the expected value of the maximum possible magnitude is considered to be $M_{w.max}$= 6.3 with an error value of ± 0.1

The distribution function of the focal depths of the earthquakes from North Anatolian Fault seismic zone is shown below and is calculated relative to 22 earthquakes (both marine and terrestrial earthquakes).

Distribution of the focal depths

Nr.	h (km)	Frecventa relativa
1	0-4,99	0.5
2	5-9,99	0,091
3	10-14,99	0,285
4	15-19,99	0,045
5	20-24,99	0
6	25-29,99	0
7	30-34,99	0,318
9	35-39,99	0,045

S5. GEORGIA

Georgia seismic source is characterized by epicenter distribution of 356 crustal earthquakes during 1958-2010 periods with $M_w \geq 2$ and 22 crustal(depth less 35 km, according V. Starostenko et al.. 2004) earthquakes with $M_w \geq 4$ during 1958-2010 period. The distribution of epicenter mark the associate of existents structural lines in Georgia area, which are characterized by the powerful maximum observed 5.8 (16.07.1963).

Earthquakes catalog with $M_w \geq 4$ and crustal depth

Catalogue number	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth km	Mw
57	1958	7	5	02:05:57	43	41.5		4.8
58	1959	5	20	19:49:12	41.8	42		5.5
64	1963	7	16	18:27:18	43.1	41.5	33	5.8
66	1963	7	17	11:57:07	43.1	41.5	33	5.3
170	1976	8	12	09:38:00	42.35	40.2535	0	4.2
196	1978	2	28	22:58:04	43	42		5.1
238	1979	12	21	11:53:03	42.66	41.44	33	4.4
239	1979	12	27	21:16:54	42.46	41.74	33	4.4
440	1984	7	4	21:25:54	42.781	41.139	33	4.7
483	1985	6	28	18:19:56	41.25	40.47	10	4
541	1986	11	1	03:18:10	41.4	40.8		5.4
634	1988	6	29	02:32:25	43	40.1		4.6

Catalogue number	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth km	Mw
641	1988	9	6	19:16:34	41.9	41.43	3	5.5
942	1991	4	29	20:25:03	43	40		5
1640	1995	10	1	14:20:27	41.81	41.26	0	4.2
1702	1996	5	28	04:50:06	41.27	41.27	33	4.9
1892	1997	11	9	17:25:25	43.13	41.47	5.2	4.2
1921	1998	4	3	10:43:57	41.55	41.7	13.1	4.2
2017	1998	12	29	17:40:20	43.194	41.492	10	4.2
2185	1999	11	7	16:53:34	41.4	40.6	10	5.3
2226	2000	3	19	07:20:32	43.195	41.423	6	4
2639	2003	8	24	08:52:53	42.13	40.69	9	4.3

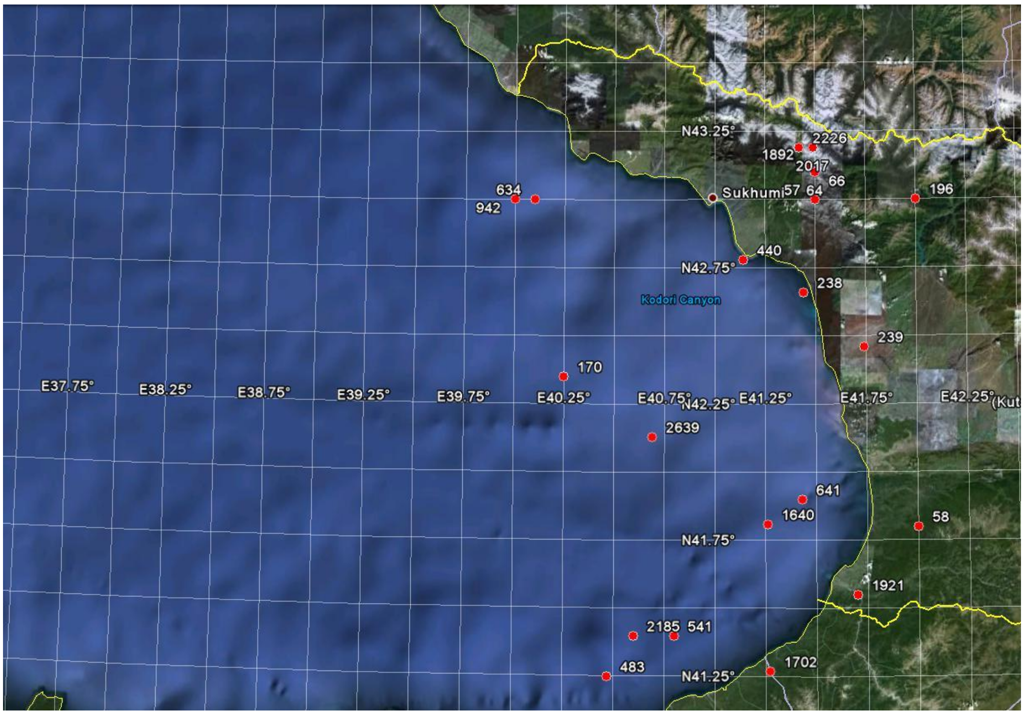


Figure 9. Earthquakes distribution from Georgia seismic source

Seismic activity v_0 is defined as the annual average number of earthquakes with magnitude higher than m_0. For Georgia area, the minimum magnitude was considered m_0= 4 (M_w). Seismic activity v_0 = no. of seismic events/T(years) = 22 seismic events/52 years= 0.42 seismic events/year.

The maximum observed magnitude in Georgia was M_w= 5.8 (16.07.1963). Applying the practice of increment the maximum observed magnitude, the expected value of the maximum possible magnitude is considered to be $M_{w.max}$= 6.0 with an error value of ± 0.1

The distribution function of the focal depths of the earthquakes from Georgia seismic zone is shown in the table and is calculated relative to 22 earthquakes (both marine and terrestrial earthquakes).

Distribution of the focal depths

Nr.	h (km)	Relative frequency
1	0-4,99	0,41
2	5-9,99	0,136
3	10-14,99	0,181
4	15-19,99	0
5	20-24,99	0
6	25-29,99	0
7	30-34,99	0,272

S6. NOVOROSSIYSK

Seismic source Novorossiysk is characterized by 26 crustal epicenters with M_w≥ 4 occurred in 1966-2010 period. The epicenters distribution mark the associate of existents structural lines in Novorossiysk area, characterized by a maximum 5.7 (3.09.1978) observed.

Earthquakes catalog with M_w≥ 4 and crustal depth

Eq.catalogue no.	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth	Mw
76	1966	7	12	18:53:05	44.72	37.31	2	5.5
91	1968	5	25	07:06:36	45.1	38.1	33	4.5
103	1969	1	8	23:48:25	44.829	37.004	34	4.5
108	1969	7	12	03:05:42	45.02	37.17	19	4.7
111	1969	10	10	01:41:54	44.7	38.3	33	4.2
143	1972	7	22	05:10:39	44.927	36.91	33	4.6
154	1974	8	14	13:01:39	45	37	0	4.7
202	1978	9	3	00:21:15	44.404	38.052	33	5.7
284	1981	10	21	00:50:14	44.793	37.226	33	4.2
659	1988	12	11	14:39:24	44.8	38	0	4

1139	1992	8	27	08:49:11	44.88	37.31	3	4.4
1629	1995	9	7	10:38:04	45.24	37.24	10	4.4
1716	1996	7	11	18:07:53	44.92	37.89	0	4
1958	1998	6	21	12:47:48	44.8352	37.2801	0	4.1
1960	1998	6	26	02:24:10	44.681	37.501	33	4.1
2237	2000	4	6	13:55:28	44.949	38.047	33	4.5
2359	2001	6	17	14:38:43	45.002	37.169	10	4.1
2386	2001	10	18	17:28:12	44.895	37.706	13	4
2543	2002	11	9	02:18:17	45.188	37.493	10	5.3
2554	2002	12	21	00:42:11	44.78	36.83	17	4.1
3056	2005	3	13	01:31:13	44.92	37.36	2	4.7
3344	2006	3	19	00:52:22	44.942	37.547	18	4
3352	2006	3	30	21:37:24	45.05	36.926	24	4
3402	2006	8	13	05:46:41	45.052	36.838	18	4.2
3496	2007	4	4	15:46:30	44.69	38.61	21	3.9
3630	2007	10	5	23:17:53	45.207	37.155	14	4.5

Figure 9. Earthquakes distribution from Novorossiysk seismic source

Seismic activity v_0 is defined as the annual average number of earthquakes with magnitude higher than m_0. For Novorossiysk area, minimum magnitude was considered m_0= 4 (M_w). Seismic activity v_0 = no. of seismic events/T(years) = 26 seismic events/44 years= 0.59 seismic events/year

The maximum observed magnitude in Novorossiysk was M_w= 5.7 (3.09.1978). Applying the practice of increment the maximum observed magnitude. the expected value of the maximum possible magnitude is considered to be $M_{w.max}$= 5,9 with an error value of ± 0.1

The distribution function of the focal depths of the earthquakes from Novorossiysk seismic zone is shown below and is calculated relative to 26 earthquakes (both marine and terrestrial earthquakes).

Distribution of the focal depths

Nr.	h (km)	Relative frequency
1	0-4,99	0,269
2	5-9,99	0
3	10-14,99	0,192
4	15-19,99	0,154
5	20-24,99	0,076
6	25-29,99	0
7	30-34,99	0,308

S7. CRIMEA SOURCE

In Crimea seismic area was record 36 crustal earthquakes Mw≥2, produced in 1927-2010 period and 14 earthquakes with M_w≥4. The epicenter distribution marks the existents tectonic lines, characterized by a maximum observed of 6.5 M_w (11.09.1927).

Earthquakes catalog with M_w≥ 4 and crustal depth

Earthquake catalogue number	Year	Mo.	Day	Time	Lat^{0}N	Long^{0}E	Depth Km	Mw	ED km	HD km
43	1927	6	26	11:20:48	44.5	34.5	35	6	468,45	469,75
44	1927	9	11	22:15:47	44.5	34.5	35	6.5	468,45	469,75
55	1957	3	18	23:17:27	44.5	33	0	5.2	349,79	349,79
92	1968	7	22	09:04:09	44.878	34.409	33	4.2	terestrial	
113	1970	2	27	14:59:22	44.44	34.1	0	4.5	436,15	436,15

192	1977	12	23	07:31:44	44.818	32.801	10	4.4	338,97	339,12
441	1984	7	5	03:07:18	44.427	34.338	33	4.2	455,22	456,40
540	1986	10	30	06:37:24	44.002	33.933	10	4.2	424,56	424,71
607	1988	4	2	08:13:03	44.915	32.795	33	4.2	340,29	341,88
832	1990	7	2	00:35:48	44.84	34.75	33	4.1	terestrial	
847	1990	8	16	04:32:26	44.5	32.8	33	4.4	333,94	335,56
2004	1998	10	16	15:24:08	44.0574	33.5193	22.5	4.2	391,10	391,75
2370	2001	7	29	22:30:24	44.015	34.496	33	4.2	469,64	470,79
3800	2008	4	30	03:59:41	44.514	34.623	9	4.1	478,77	478,85

Figure 10: Earthquakes distribution from Crimea seismic source

Seismic activity v_0 is defined as the annual average number of earthquakes with magnitude higher than m_0. For Crimea area, the minimum magnitude was considered m_0= 4 (M_w). Seismic activity v_0 = no. of seismic events/T(years) = 14 seismic events/44 years= 0.17 seismic events/year

The maximum observed magnitude in Crimea was 6.5 M_w (11.09.1927). Applying the practice of increment the maximum observed magnitude, the expected value of the maximum possible magnitude is considered to be $M_{w.max}$= 6.7 with an error value of ± 0.1

The distribution function of the focal depths of the earthquakes from Crimea seismic zone is shown below and is calculated relative to 14 earthquakes (both marine and terrestrial earthquakes).

Distribution of the focal depths

Nr.	h (km)	Relative

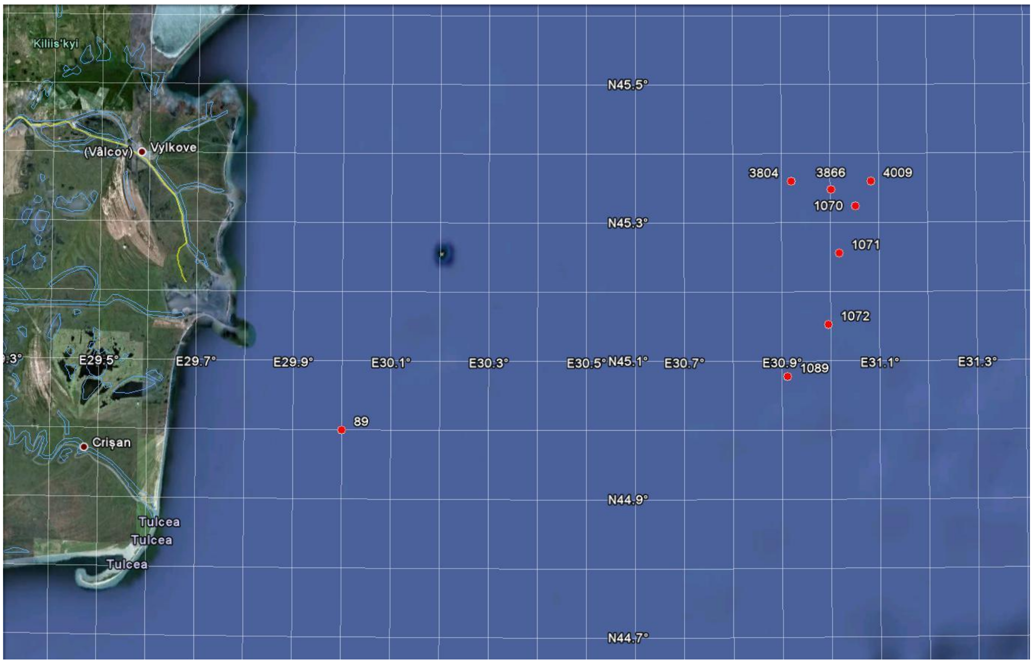
		frequency
1	0-4,99	0,142
2	5-9,99	0,071
3	10-14,99	0,142
4	15-19,99	0
5	20-24,99	0,071
6	25-29,99	0
7	30-35	0,571

S8. WEST BLACK SEA SOURCE

The geometry of seismic source of West Black Sea Fault (WBS Fault) is defined by distribution of 8 crustal earthquakes epicenter what was appeared in 1970-2010 period. The maximum magnitude observed in West Black Sea Fault was Mw=4.9 (07.05.2008).

Earthquakes catalog with crustal depth

Earthquake catalogue number	Year	Mo.	Day	Time	Lat^{0}N	Long^0 E	Depth km	Mw	ED km	HD km
89	1967	12	12	20:04:26	45	30	33	4.1	141,6	145,39
1089	1992	5	5	21:27:45	45.078	30.911	12.2	3.7	206,20	206,56
1072	1992	3	31	01:10:15	45.153	30.995	33	3.4	216,59	219,09
3866	2008	7	4	16:40:23	45.348	31.002	0	3.1	227,50	227,5
1071	1992	3	29	23:45:14	45.256	31.018	10	3.3	223,47	223,69
1070	1992	3	29	21:48:04	45.324	31.052	10	3.4	229,09	229,31
3804	2008	5	7	08:00:21	45.36	30.92	10	4.9	223,06	223,28
4009	2009	3	15	01:28:23	45.36	31.084	0	3.4	234,49	234,49

Figure  11:

Earthquakes distribution in West Black Sea areal

Seismic activity v_0 is defined as the annual average number of earthquakes with magnitude higher than m_0.For West Black Sea area, minimum magnitude was considered m_0= 3 (M_w). Seismic activity v_0 = no. of seismic events/T(years) = 8 seismic events/43 years= 0.186 seismic events/year

The maximum observed magnitude in West Black Sea was 4.9 M_w (07.05.2008). Applying the practice of increment the maximum observed magnitude, the expected value of the maximum possible magnitude is considered to be M_w= 5.1 with an error value of ± 0.1

The distribution function of the focal depths of the earthquakes from West Black Sea seismic zone is shown in the next table, calculated relative to 14 earthquakes (both marine and terrestrial earthquakes).

Distribution of the focal depths

Nr.	h (km)	Relative frequency
1	0-4,99	0,25
2	5-9,99	0
3	10-14,99	0,5
4	15-19,99	0
5	20-24,99	0
6	25-29,99	0
7	30-35	0,25

S9. MID BLACK SEA

In seismic area entitled Mid Black Sea Ridge in 1970-2006 period occurred produced, 11 crustal earthquake. The seismic activity is characterized by a maximum observed 5.3 (10.12.2007).

Earthquakes catalog with crustal depth

Earthquake catalogue number	Year	Mo.	Day	Time	Lat ^{0}N	Long ^{0}E	Depth Km	Mw	ED km	HD km
87	1967	9	8	11:06:43	43	31	33	4.4	231,64	233,98
197	1978	3	1	09:51:58	43.067	31.8541	33	3.6	287,69	289,57
487	1985	7	10	01:09:20	43.3092	31.6324	35.2	4	264,64	266,97
995	1991	7	25	08:26:22	43	31.4		3.7	258,97	258,97
1331	1993	12	2	13:56:05	43.3	31.69	0	3.4	259,63	259,63
1464	1995	1	18	07:42:11	42.84	31.32	10	3.5	262,80	262,99
2121	1999	8	17	04:13:48	42.691	30.876		4.2	245,95	245,95
2183	1999	11	5	06:39:48	42.762	31.205	33	3.2	260,67	262,75
2220	2000	2	26	03:04:03	43	31	10	3.6	231,64	231,85
2277	2000	8	14	11:02:03	42.53	31.09	15	3.6	270,92	271,33
3685	2007	12	20	09:49:06	43.366	32.481	15	5.3	323,13	323,48

Seismic activity v_0 is defined as the annual average number of earthquakes with magnitude higher than m_0.For Mid Black Sea area, minimum magnitude was considered m_0= 3 (M_w). Seismic activity v_0 = no. of seismic events/T(years) = 11 seismic events/43 years= 0,256 seismic events/year

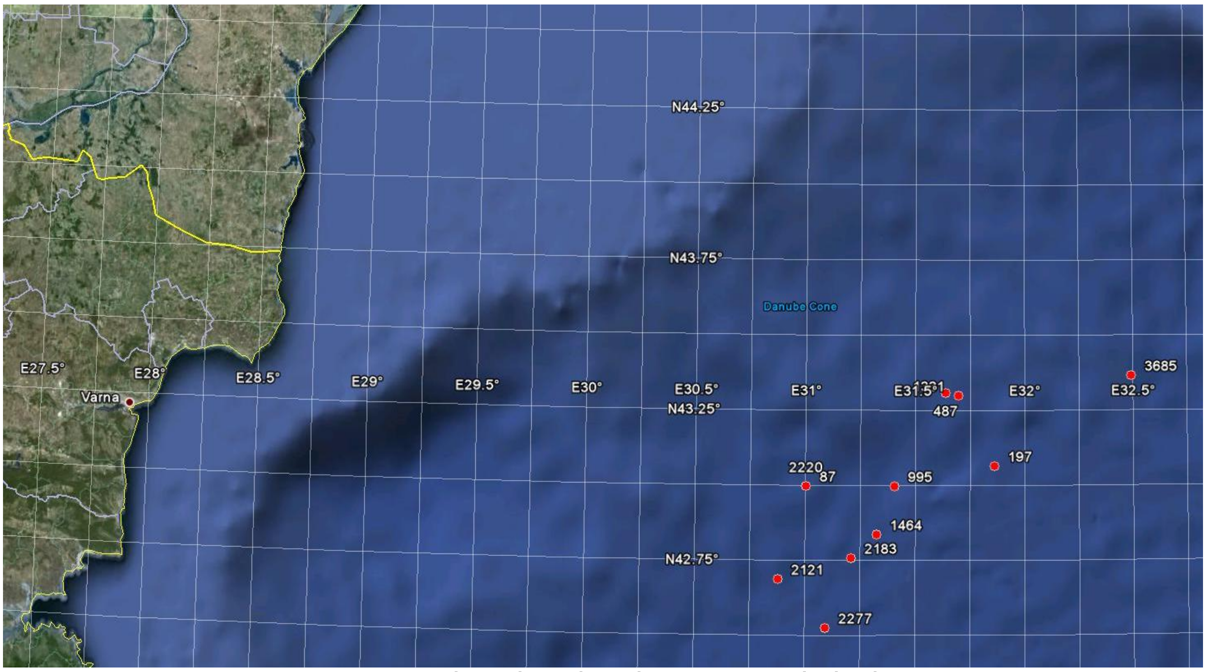


Figure12: Earthquakes distribution in Mid Black Sea

The maximum observed magnitude in Mid Black Sea was Mw=5.3 (10.12.2007). Applying the practice of increment the maximum observed magnitude, the expected value of the maximum possible magnitude is considered to be $M_{w.max}$= 5.5 with an error value of ± 0.1

The distribution function of the focal depths of the earthquakes from Mid Black Sea seismic zone shown below is calculated relative to 14 earthquakes (both marine and terrestrial earthquakes).

Distribution of the focal depths

Nr.	h (km)	Relative frequency
1	0-4,99	0,27
2	5-9,99	0
3	10-14,99	0,18
4	15-19,99	0,18
5	20-24,99	0
6	25-29,99	0
7	30-35	0,36

2.3. Monitoring Network

The ability to reduce the impact of earthquakes on society depends on the existence of a large amount of high quality observational data. The development in the last few years of the seismic network and setting an advanced acquisition system are essential factors to achieve this goal(Neagoe & Ionescu, 2009).

The National Institute for Earth Physics (NIEP) operates a real-time seismic network that is designed to monitor the seismic activity in the Romania territory, which is dominated by the Vrancea intermediate-depth (60-200km) earthquakes.

Starting in 2002, the modernization of the NIEP's seismic network was based on the installation of new seismic stations operating in real time. This network consists of digital seismic stations that are equipped with acceleration sensors (EpiSensor) and velocity sensors (broad-band: STS2, CMG3ESP, KS2000, CMG40-T; or short period: MP, SH-1,S13, Mark Product).

The real-time digital seismic network presented in Fig. consists of 86 seismic stations (with three components) and two arrays: BURAR (with 12 elements) and PLOR (7 elements). All of the data recorded by this network are transmitted in real time to the NIEP for automatic processing, analysis and dissemination. The remote seismological stations have three-component seismometers for weak motion and three-component accelerometers for strong motion.

In cooperation with the Kishinev Institute of Geophysics and Seismology, Republic of Moldova, seismic stations have been installed in the Republic of Moldova at Leova (LEOM), Giurgiulesti (GIUM), Milestii Mici (MILM), Chisinau (KIS) and Soroca (SORM). Data from the seismic stations installed in the Republic of Moldova territory are received in real time at the NIEP National Data Centre (NDC) using seedlink connections.

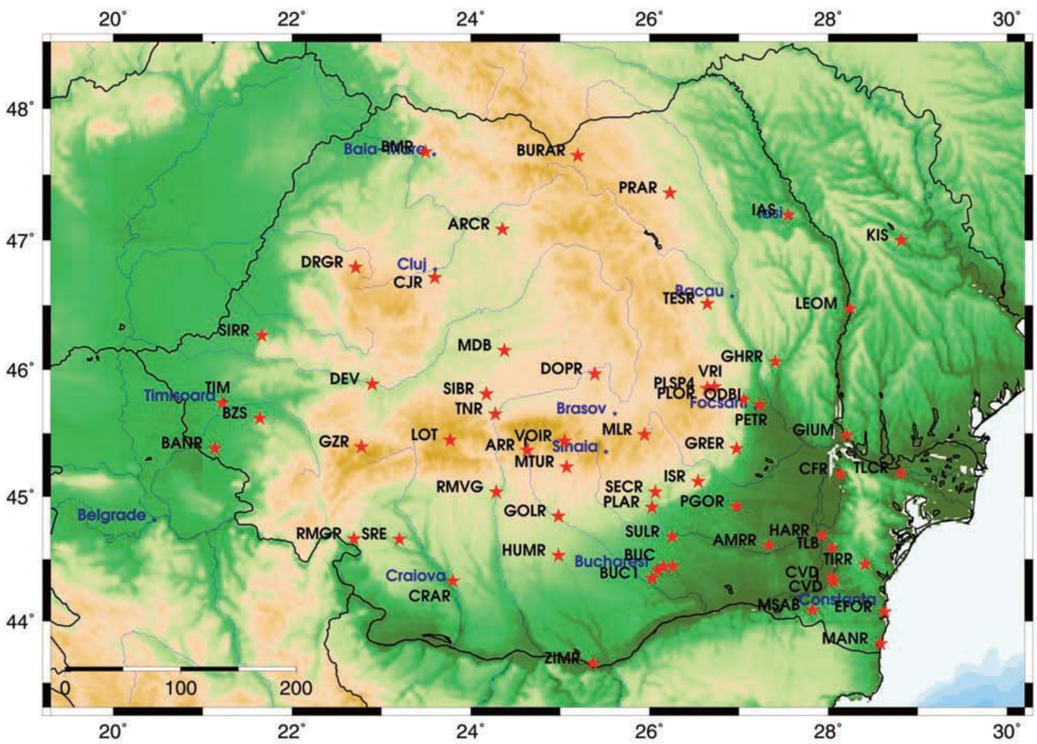


Figure 13: NIEP: real-time seismic network

The Seedlink and AntelopeTM program packages are used for this real-time data acquisition and exchange. The Antelope [BRTT 2011] real-time system provides automatic event detection, arrival picking, event location, and magnitude calculation. In order to refine the automatic solutions, Antelope is further used for manual processing (e.g. association events, magnitude computation, database, sending seismic bulletins, calculation of peak ground acceleration and velocity), for generating ShakeMap products and interacting with international data centers.

The Romanian Seismic Network is linked with IRIS and ORFEUS organizations and other European countries via Internet and is contributing with near real-time waveform data from 6 broadband stations and BURAR array for regional and international exchange.

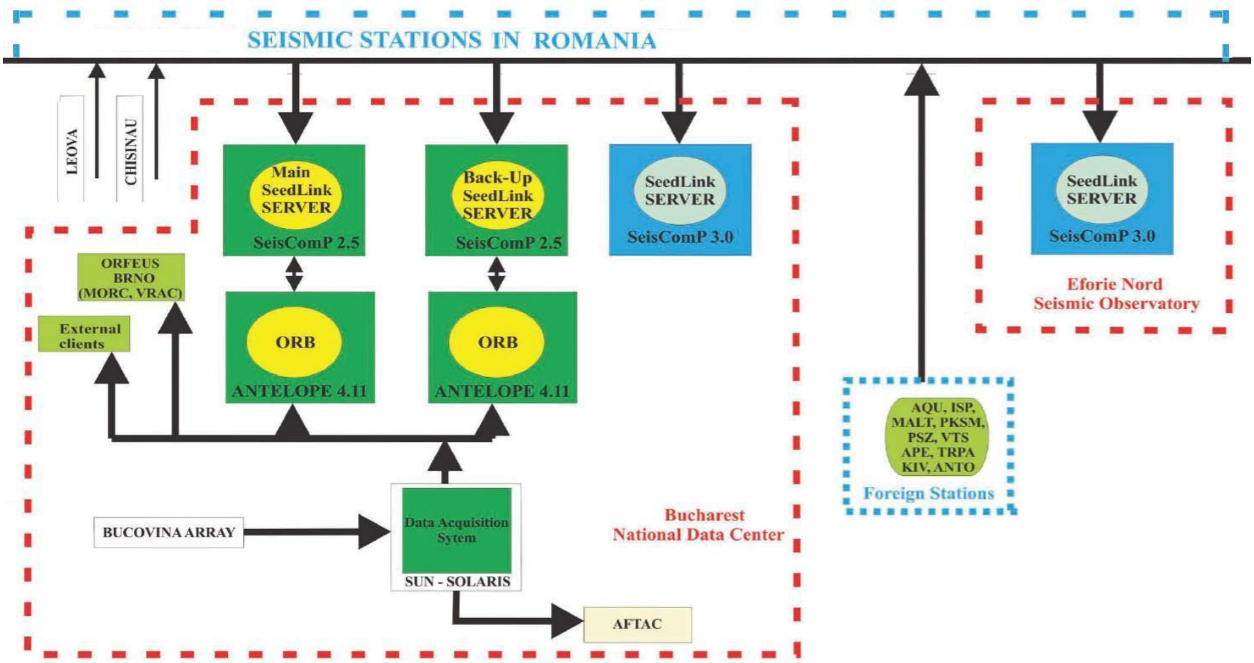


Figure 14: The data flow at the Romanian National Data Centre - simplified from Neagoe et al, 2011

In parallel, SeisComP3 [SeisComP3, 2011] is running at NIEP Bucharest and Eforie Nord Seismic Observatory as a complementary data acquisition and back-up automated system, data quality control, real-time data exchange and processing, network status monitoring, etc. as can be observed in Figure .

Additional seismic monitoring in Romania is performed by the National Seismic Strong Motion Network for Constructions of URBAN-INCERC (National Institute for Research in Constructions, Urban Planning and Sustainable Spatial Development). Especially designed and developed for structural engineering applications, this network (Figure..) contains also free field (-like installed) instruments which give valuable records of the past strong Vrancea earthquakes.

In 2003, in the frame of a national project (NUMBER!!!!), NIEP and INCERC have created a common strong motion database with their records from 4 important earthquakes (March 4, 1977, Mw=7.2; August 30, 1986; Mw=7.1; May 30 and 31, 1990 events with Mw=6.9 and 6.4, respectively).

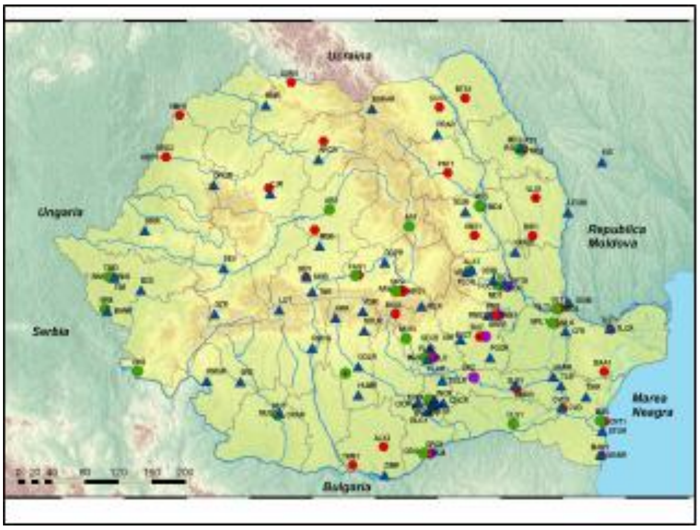


Figure 15: Seismic Strong Motion Network for Constructions (from www.incerc.ro)

At the present moment there is not an automatic data exchange between NIEP and INCERC: both institutions are upgrading their databases with records of the recent important earthquakes within the frame of the ongoing projects.

An important number of seismic instruments in Romania are installed at locations of dams, hydro-electric and nuclear power plants. Their records are only locally analyzed for engineering purposes. In the absence of a protocol or a legal frame at national level, most of these records are not accessible and not stored at the National Data Centre. Consequently, a lot of valuable information exists without being accessible to the seismological and engineering community. This constitutes a permanent obstruction in the seismic site effects evaluation studies and microzonation activity.

3. Seismic Hazard

3.1. Definitions and methods

Seismic hazard at a site is characterized by a measure of the seismic movement severity estimated for a certain time interval.

Nowadays, two major classic approaches for Seismic Hazard Assessment (SHA) are widely used: Probabilistic (PSHA) and Deterministic (DSHA), (Reiter 1990). The traditional probabilistic seismic hazard analysis (PSHA)- Cornell-McGuire approach- was developed in 1970’s with the aim to estimate seismic hazard in terms of a ground motion and its annual probability of exceedance (or return period) at a site. It has become mostly used approach worldwide, claiming on its abilities: (a) to consider all uncertainties in earthquake source, path and site conditions and (b) to provide a seismic hazard estimate to satisfy any need or requirement because its end result is a curve that provides a range of hazard (i.e. from 0.0 to 10.0g PGA or even greater).

A brief description of the classical seismic hazard assessment methodologies as summarized by Panza et al., 2008 is provided bellow:

<table>
<tr><th></th><th>PSHA</th><th>DSHA</th></tr>
<tr><td>Step 1:</td><td colspan="2">Seismic sources : Identification of active/capable faults, seismogenic zones geometry and focal mechanism;</td></tr>
<tr><td>Step 2:</td><td>Recurrence rate - can be represented by a linear relation only if the size of the study area is large with respect to linear dimensions of sources.</td><td>Scenario Earthquakes – Choice of the Controlling Earthquake: fixed magnitude and distance to the site.</td></tr>
<tr><td>Step 3:</td><td colspan="2">Seismic movement at the site is estimated from attenuation relations (dependency of ground motion parameters on random variables like magnitude, distance and measurement error, thus is the source of systematic error in SHA)</td></tr>
<tr><td>Step 4:</td><td>Seismic hazard assessment in terms of Probability of exceedance of a given ground motion measure</td><td>Seismic hazard assessment in terms of a fixed ground motion measure, regularly I or PGA, depending on the information available at the target site.</td></tr>
</table>

The choice of seismic hazard assessment procedure is influenced by the available input data, the seismic environment characteristics, the scale of the analysis (for a site, multi-site or a whole region).

In seismic hazard analyses, deterministic (DSHA) versus probabilistic (PSHA) approaches have differences, advantages, and disadvantages in assessing earthquake hazards and risks that often make use of one advantage over the other. Prevalence of one type of analysis over the other is mainly depending on the purpose, on decision need to be taken and on the characteristics of the seismic environment. Complex decisions and subtler seismic environment – on which we know many details - strongly suggests the use of probabilistic analysis. Simple decisions for seismic zones where seismicity and tectonics are well-understood are regularly based on the results of a deterministic analysis. This does not mean that one type of analysis should be exclusively and/or independently used over another. Deterministic and probabilistic seismic hazard analyses should be complementary. Actually, the best results (closest to reality) is a combination of both, allowing to the probabilistic analysis to guide us in the choice of the most representative earthquake scenario and letting the deterministic events to refine the results of the probabilistic analysis (R.K.McGuire, 2000).

The procedure for deterministic seismic zoning developed by Costa et al. (1993) represents one of the new and most advanced approaches, which can be used as a starting point for the development of an integrated procedure that combines the advantages of the probabilistic and of the deterministic methods, thus minimizing their drawbacks. Synthetic seismograms are constructed to model ground motion at the sites of interest, using the available knowledge of the physical process of earthquake generation and wave propagation in realistic inelastic media. In first-order zoning a database of seismograms covering the area of interest (at a regional scale) is computed, with a low order approximation of the effects of lateral heterogeneities. Synthetic seismograms are very efficiently generated by the modal summation technique (Panza, 1985; Florsch et al., 1991). The procedure does not require significant processing time (CPU), so it is possible to perform detailed parametric analyses at reasonable costs. For example, different sources and structural models can be taken into account in order to create a wide range of possible scenarios from which to extract essential information for decision making. Once the parametric analysis is performed and the gross features of the seismic hazard are defined, a more detailed modelling of ground motion is possible.

The main advantage of the neo-deterministic procedure, proposed by Panza et al. (2001) is the simultaneous treatment of the contribution of the seismic source and seismic wave propagation media to the strong motion at the target site/region, as required by basic physical principles. From the theoretical seismic signals computed at the investigated site it is possible to estimate the maximum ground velocity and displacement in a given frequency band (PGV and PGD respectively), Design Ground Acceleration (DGA) or any other parameter relevant to seismic engineering. This procedure has been successfully verified at different sites worldwide (http://users.ictp.it/www_users/sand/index_files/Projects.html) and is particularly useful to obtain a realistic estimate of the seismic hazard in areas for which scarce historical or instrumental information is available.

A brief presentation of the necessary steps in neo-deterministic seismic hazard assessment (**NDSHA**) is provided bellow:

Step 1: Seismic sources :Identification of Seismogenic Zones and capable faults, epicenters; geometry and focal mechanism (identical with step1 of PSHA and DSHA);

Step 2: Choice of several Scenario Earthquakes possible/expected at the site – fixed magnitudes, distances and specific seismic source properties.

Step 3: Synthetic ground motions simulation (No need of attenuation relations!).

Step 4: Seismic hazard assessment : Envelopes of PGA or other Ground Motion Measures

3.2 Results

The classical probabilistic approach is based upon physical assumptions and averaged empirical models (e.g. recurrence and attenuation relations). A deficiency of this approach is that it does not take fully into account some of the critical local aspects like, fault rupture processes and specific regional geology and site effects.

Some of the newest PSHA estimates for Romania (Ardeleanu et al., 2005; Leydecker et al., 2008) use a different empirical approach - it does not consider attenuation relations continuous in space, but discrete (in space) coefficients - to take into account the specific energy attenuation of Vrancea intermediate-depth events. The maps provided as a basis for a new building code supply macroseismic intensities that in Bucharest can be roughly estimated around VIII (MSK) at a recurrence period of 475 years and around VII (MSK) for recurrence period of 95 years.

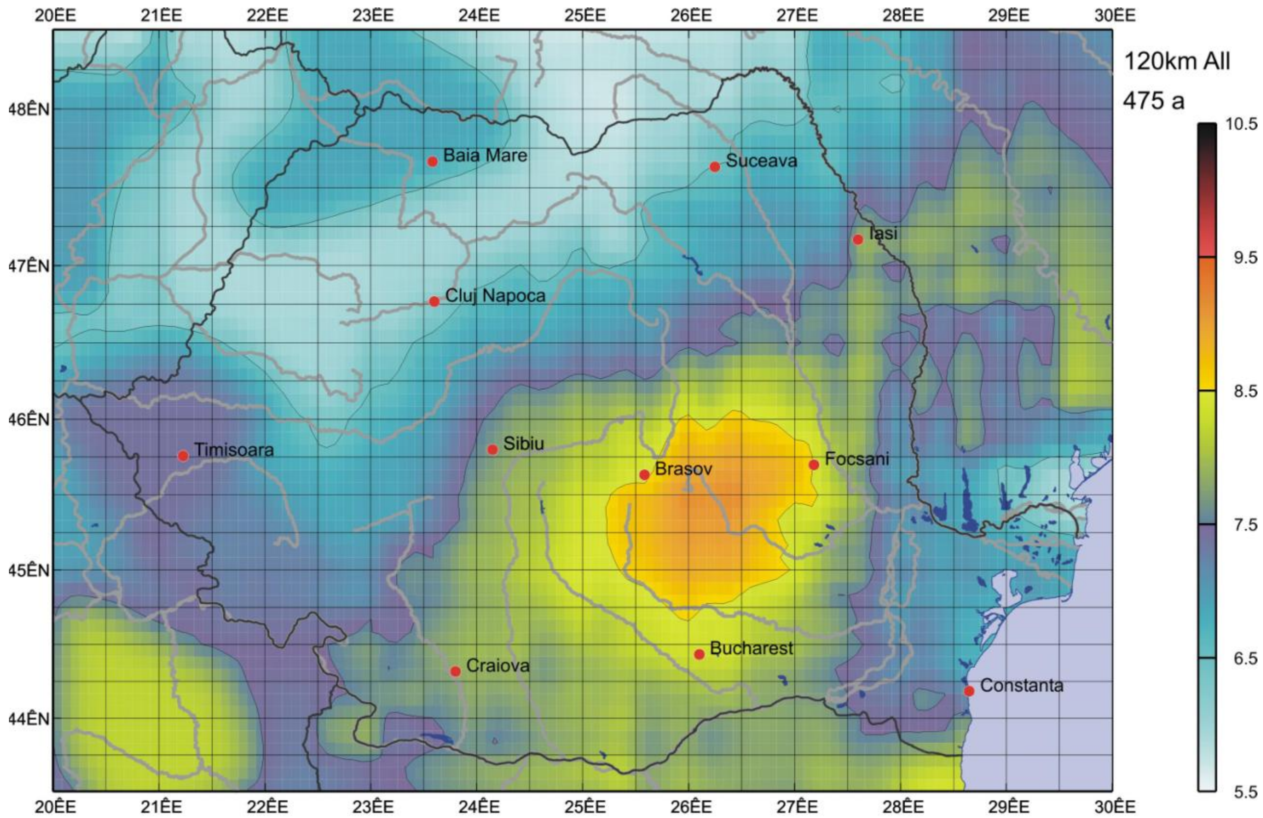


Figure 15: Seismic hazard map in terms of macroseismic intensities MSK for 475 years return period, from Ardeleanu et al., 2005

For the NDSHA the Step1 is identical with the others analyses.In **Step2** of for each seismic source a representative earthquake scenario have been chosen, with respect of the predominant faulting mechanisms in the areas, the maximum magnitude being the maximum credible earthquake for the zones.

In the 3th step of NDSHA, based on the available information on the lithospheric characteristics, it is necessary to define structural polygons and associate a layered structural model with each polygon. The different layers are described by their thickness, material density, and relevant seismic waves propagation phase-velocities V_s and V_p, and phase attenuations □ and □. Vrancea structure and Romanian structures, used as regional models were firstly published by Radulian et al. (2000). Important changes in several of these structures have been implemented from the results of seismic refraction experiments Vrancea'99 and Vrancea 2001(Hauser et al., 2001 and 2006). Some of them were refined later through seismic tomography and nonlinear inversion of S waves by Raykova and Panza (2006). For the target area of this study we have used the structural model for Dobrogea published by Radulian et al, 2000 setting the depth of Moho discontinuity according to Raykova & Nikolova, 2008. Using the scenarios chosen in step 2 and the structural model of the propagation media, complete P-SV-waves and SH-waves seismograms are generated by the modal summation technique (Panza et al., 2001) on a regular grid covering the target territory. The synthetic signals are computed with the cutoff frequency of 1 Hz. For each point of the grid, the contribution of each seismic source (by its characteristic event, with maximum designated magnitude) was computed in terms of displacements for SH waves and velocities for P-SV ones.

In the next step **(4)** from all the time series computed in the grid points covering the city and surrounding area, only the one with the maximum amplitude is picked to be reported in the map and the collateral time series are derived from it (velocities, accelerations).The hazard is then expressed in terms of displacement, velocity and acceleration time histories. From these we extract and use spatial representations of the maximum computed values (PGD, PGV and PGA) for each point of the grid. Extension of the frequency domain has been done here by using the normalized response spectra as recommended in EC8 to obtain the Design Ground Acceleration (DGA).

In Figure 16 we present the results of NDSHA procedure applied for crustal sources. Conversion of the computed DGA to macroseismic intensities has been done according to the Medvedev (1977) shown in the table below. We have to specify that MSK-76 scale and associated average peak values of ground motion printed in table below are equivalent with the European intensity scale EMS-1992 as presented by Lliboutry, 2000.

Intensity MSK	PGA [g]	PGV [cm/s]	PGD [cm]	Intensity EMS	Acceleration [g]
V	0.025	2	1	V	0.012-0.025
VI	0.05	4	2	VI	0.025-0.05
VII	0.1	8	4	VII	0.05-0.1
VIII	0.2	16	8	VIII	0.1-0.2
IX	0.4	32	16	IX	0.2-0.4
X	0.8	64	32	X	0.4-0.8
				XI	0.8-1.6
				XII	>1.6

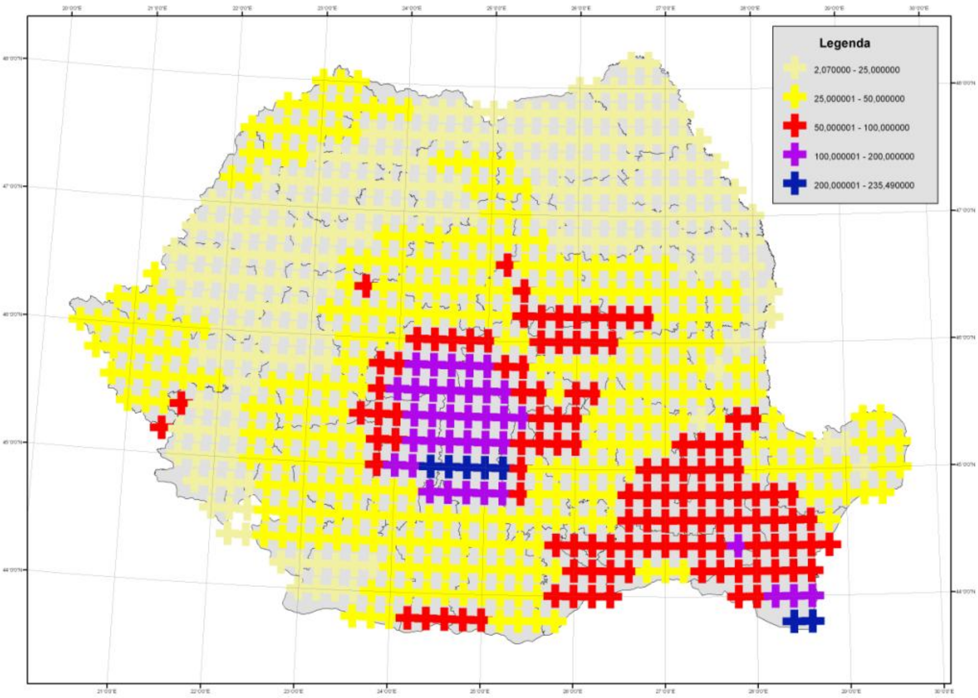


Figure 16: NDSHA results for crustal earthq.- maximum resultant acceleration, expected Imax=VIII-IX

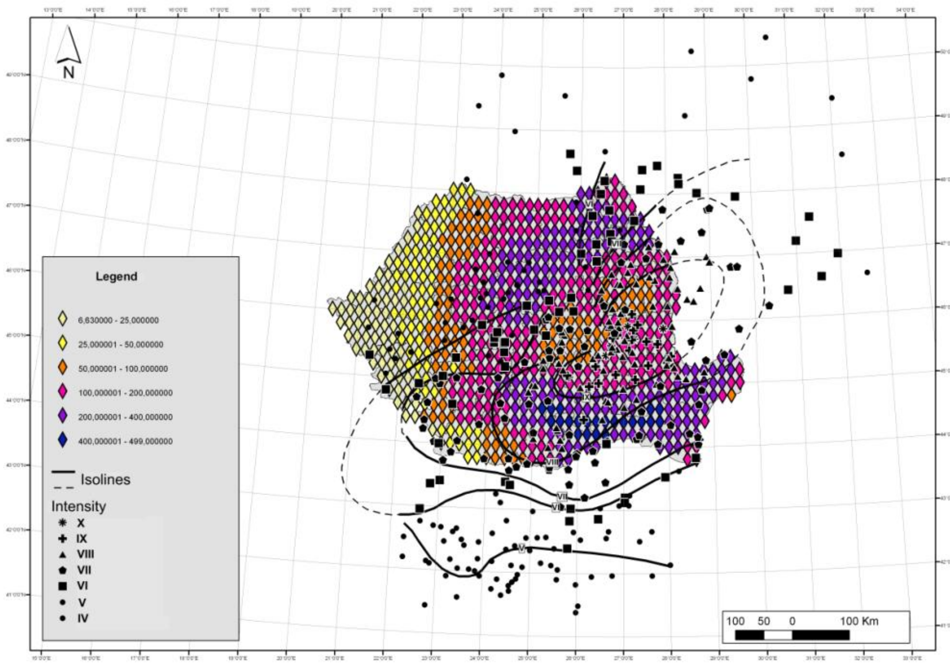


Figure 17: NDSHA – design ground acceleration for the 1940 Vrancea scenario earthquake

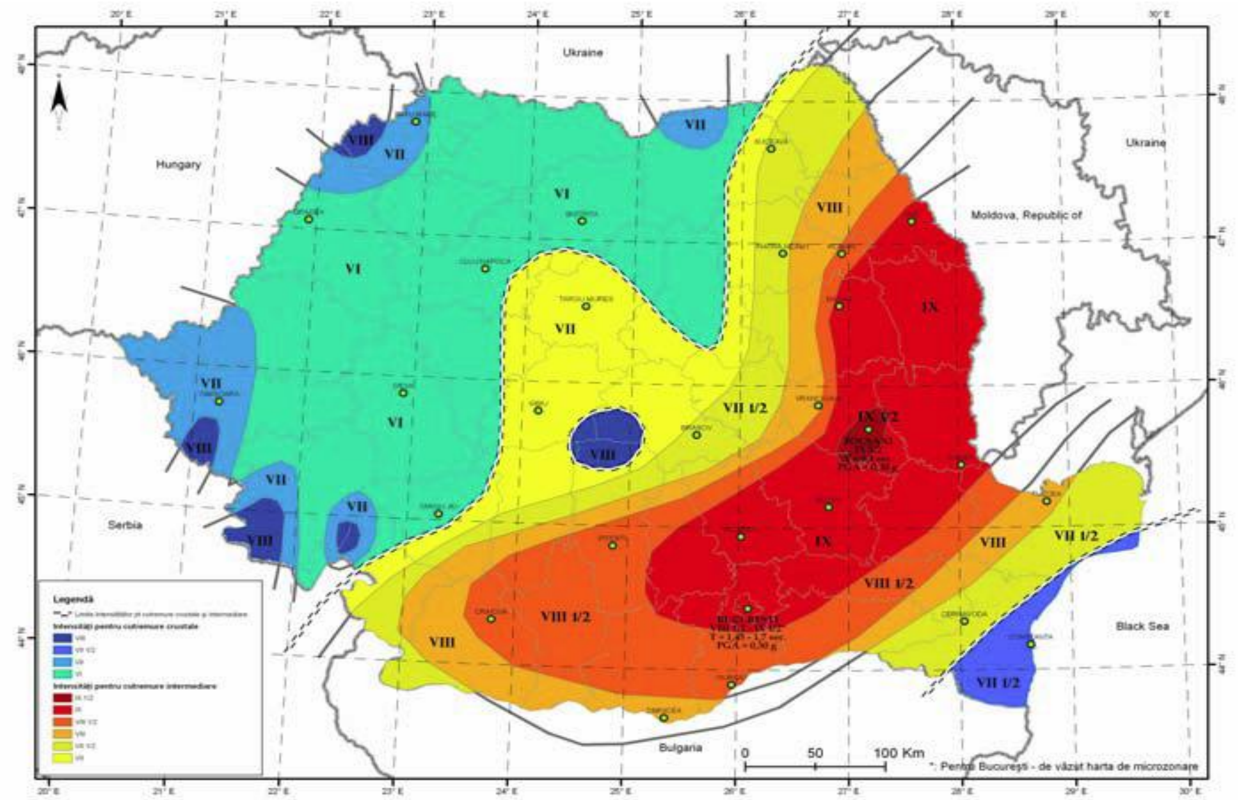


Figure 18 : Maximal macroseismic intensities expected, according to Marmureanu et al. 2009

3.3 Seismic codes and regulation in the field of building practices regarding earthquake risks

In Romania there are norms for designing the civilian, industrial, agricultural and animal related buildings earthquake resistant, that have been applied since 1941. At present time, the requirements for earthquake resistance design are regulated through the following documents:

a) The new Code no. P-100-1/2006 to be harmonized with Eurocode 8;

b) Law no. 10/1995 regarding the quality in constructions together with additional regulations, approved by Governmental Decision no. 766/1997, with subsequent modifications and enlargements.

The concern for earthquake resistant structures design was triggered mostly by the impact of the 1940 earthquake, that led to a first regulation of the Ministry of Public Works for earthquake resistant design (1943). After 1950, the check against lateral forces became systematic, but only in 1963 the seismic design code was endorsed. New editions of the seismic design code were endorsed in 1970, 1978, 1981, 1991, 1992, 1997, 2004.

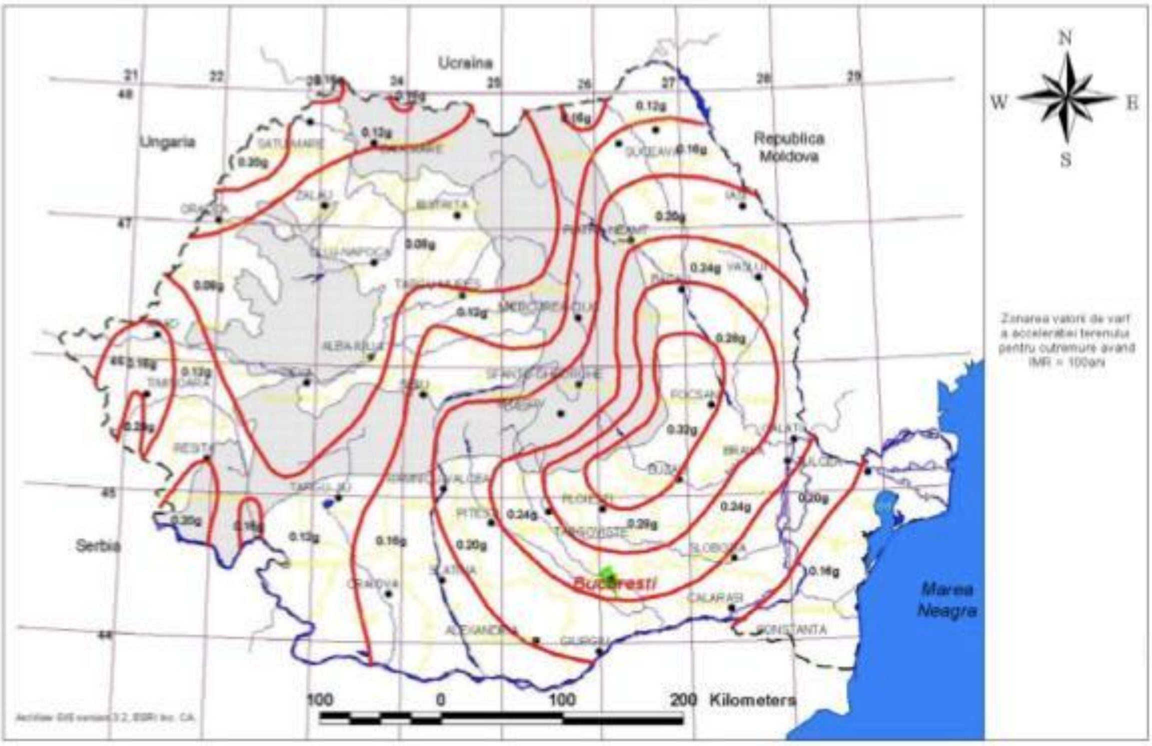


Figure 19 : Seismic zonation of the Romanian territory in terms of design ground accelerations for a medium reccurence interval of 100years from P100-1/2006.

The new seismic design codes after P100/ 1991, revised 1992 and 1997, introduced in chapters 11 and 12 the obligation to evaluate and, if required, to rehabilitate the existing buildings according to a set of criteria, with some public financing. This policy led to important technical, social, legal and financial demands, whose consequences proved the difficulty of this necessary approach. In order to improve the legal backing on this issue, a Government Ordinance on Strengthening of Existing Buildings (Ordinance no. 20/ 1994) was adopted. The main legal gain of the Ordinance is the statement concerning the " national interest " represented by the activities related to the safety of the existing buildings stock, which led to a set of duties for the Ministry of Transport, Construction and Tourism and other departments as well as duties for public and private owners of constructions. Some thousands of evaluation reports and preliminary strengthening projects were already drafted, but the works are costly and delayed because the owners are still reluctant to apply for loans under the clauses of mortgaging their property until the return of debts.

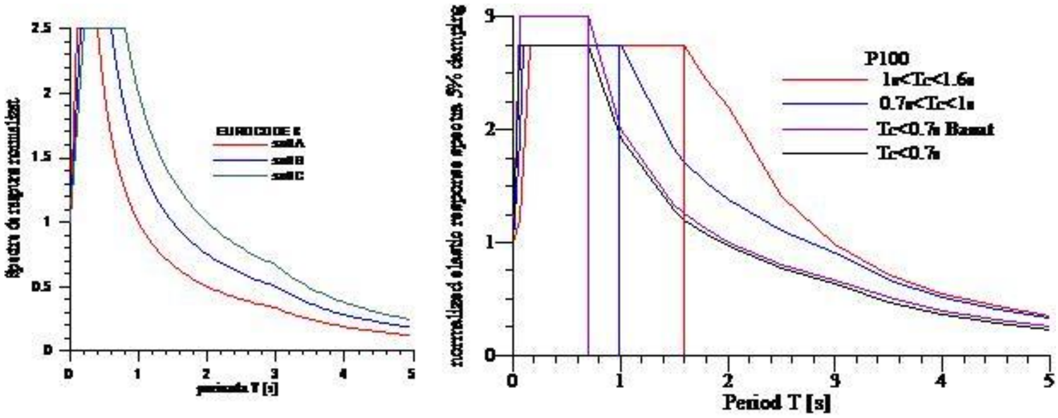


Figure20 Normalized elastic response spectra recommended in EC8 for 3 soil types (left) and in P100-1/2006 according to the control periods of response spectra (right side)

4. Seismic risk

4.1.General methods to decrease seismic risk

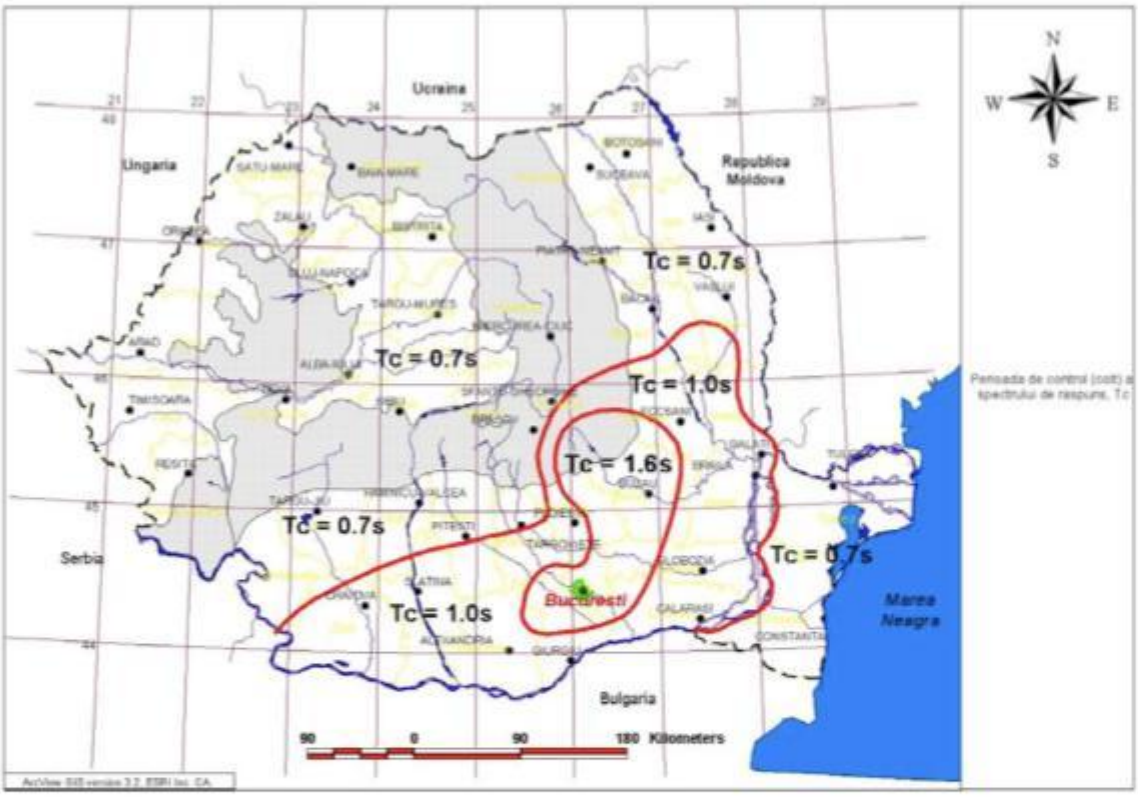


Figure 21: Seismic zoning of Romania in terms of control (corner) periods Tc of the response spectra (P100-1/2006)

4.2. Vulnerability studies

In the last couple of years, one of the main focuses of the National Institute for Earth Physics (Romania) was to make use of its real time seismic network in the purpose of obtaining seismic risk loss estimations, and also to give a proper image of how a big earthquake would affect the actual society. This is why a number of important projects were undertaken, in collaboration with the Norsar Institute (Norway) and the Technical University of Civil Engineering Bucharest (Romania), and the work has just begun:

- Studies on seismic risk and loss assessment for Bucharest, within the "Seismic early warning for Europe (SAFER)" Project (2006-2009)
- Near real-time implementation of a damage assessment system for the Romanian-Bulgarian border region, within the "Danube Cross-border system for Earthquakes Alert (DACEA)" Project (2010-2013).

Within the SAFER Project, a test study on Bucharest has been done, in order to check if the SELENA Software (SEimic Loss EstimatioN using a logic tree Approach, ©NORSAR) can be used for loss estimation of the damage produced by a Vrancea earthquake. The simulated events have given veridical results, and the system was found optimum for further use.

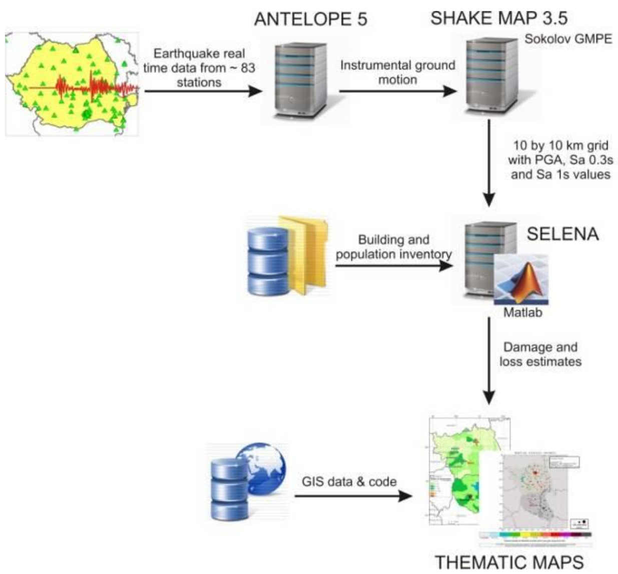


Fig. 22: Flowchart of Selena loss estimation system in real-time

In the DACEA Project, the goal was to make the next step and implement SELENA in (near) real-time, linking it with the ShakeMap system at NIEP. In fig.22, the system flowchart is described. Also, the complexity of the analysis was increased, by describing more territory-specific capacity curves for the buildings and decreasing the level of the analysis to administrative-territorial units. With the automation of the loss estimation process was added and a GIS representation code, in order to generate ready-to-use maps, to be used in emergency cases and rapid assessment of the estimations. The already working system was not designed just for the regions of the project (7 southern Romanian Counties), but also to be upgraded and extended with other counties and data.

In (near) real-time vulnerability analysis, Selena makes use of acceleration and spectral values provided by ShakeMap, so for an intermediate Vrancea depth earthquake or a surface earthquake - like the ones that occur in the Black Sea for example, damage estimates can be obtained with the same procedure, if the input is provided. Beside real-time analysis, there can be also applied a deterministic analysis – requiring a specific ground motion prediction equation (GMPE).

Giving that within the DACEA Project a database for the Constanta County and Dobrich District was put together, a trial Selena deterministic analysis was attempted for a Shabla Earthquake similar to the 1901/03/31 event (Mw 7.2, depth 14 km). Based on the description of Selena, provided below, the map in figure 2 was obtained. The GMPE was not strictly characteristic for the Shabla earthquakes (Boore et al. GMPE was used), but still provided a good estimation for the possible values. This figure and the test shows that the current system at NIEP can be used also for showing the vulnerability of the Black Sea region, as it does for Vrancea earthquakes also.

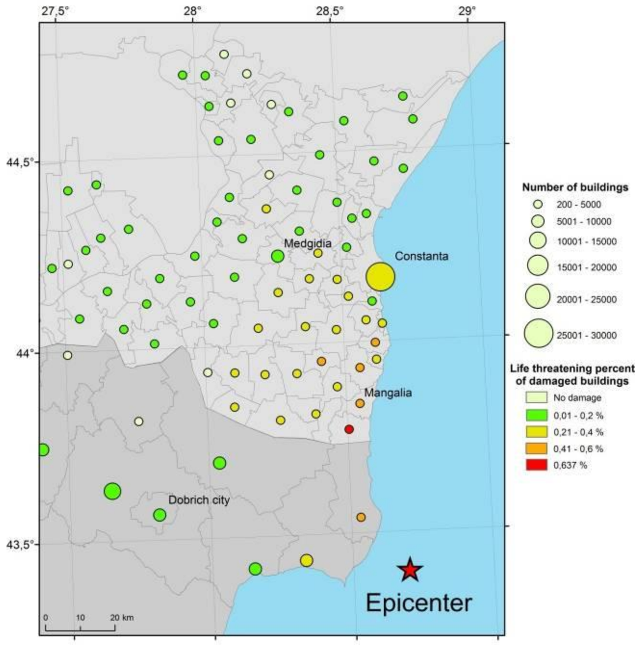


Fig. 23: Percentage of life threatening buildings for a simulated earthquake similar to the 1901Shabla event Ms=7.2

SELENA description

SELENA is based on the HAZUS methodology that has been developed as a multi-hazard risk assessment tool for the US (FEMA, 2004), adapting it to the European conditions (specific GMPE's), adding new methods (MADRS, I-DCM) and replacing ESRI ArcGIS dependencies, with Matlab processing or with other processing tools. Also, SELENA is an open-source and customizable software. The software offers three types of analysis: probabilistic, deterministic and real time. For a real time analysis, the user must supply the data in figure 24, in order to obtain the required output.

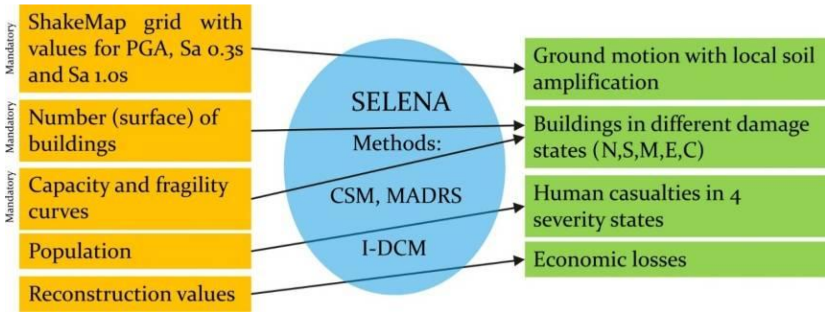


Figure 24: Input and output of SELENA, for real-time analysis

SELENA computes the probability of damage in each one of the four damage states (slight, moderate, extensive, and complete) for the given building types. This probability is subsequently used with the inventory data to express the results in terms of damaged area (square meters) or number of damaged buildings. Finally, using a simplified economic model, the damage is converted to economic losses in the respective input currency and human casualties in terms of different injury types and casualties are computed (Molina et al. 2010). A lot of high uncertainty factors are added along the way, so the first level of results (damaged buildings) is probably the most significant.

The methods for obtaining damage probabilities can be:

- Capacity-Spectrum Method (CSM)
- Modified Capacity Spectrum Method (MADRS)
- Improved Displacement Coefficient Method (I-DCM)

The philosophy in all methods is that any building is structurally damaged by the displacement (and not by the acceleration itself). For each building and building type, the inter-story drift is a function of the applied lateral force that can be analytically determined and transformed into building capacity curves. Building capacity curves naturally vary from a building type to another and also from region to region reflecting local building regulations as well as local construction practice.

Because of the large amount of damage estimates, a mean damage ratio formula can be applied (1); this is meant to quantify all damage data into an easily readable parameter that was described as: percentage of life threatening buildings.

$$\text{Life threatening buildings \%} = \frac{\Sigma Ed + \Sigma Cd}{\Sigma Nb} \quad (1)$$

where Ed is the number of buildings with extended damage, Cd the number of complete damage and Nb the total number of buildings

4.3 Shake Maps

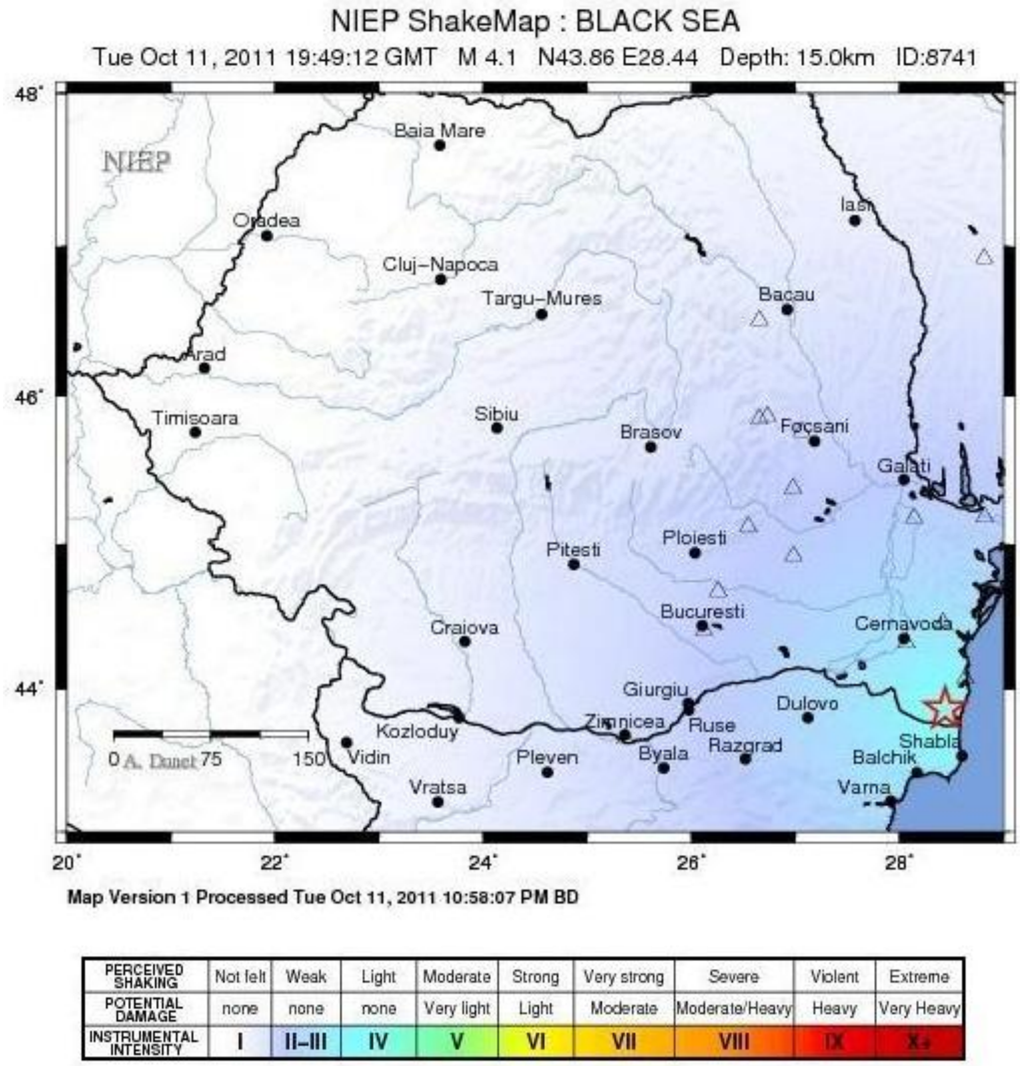


Figure 25

4.4 Early Warning System

One of the cities most affected by earthquakes in Europe is Bucharest. Situated at140–170km distance fromVrancea epicenter zone, Bucharest encountered many damages due to high energy Vrancea intermediate-depth earthquakes; theMarch4, 1977 event(Mw=7.2) produced the collapse of 36 buildings with8–12 levels, while more than150 old buildings were seriously damaged. A dedicated set of applications and a method to rapidly estimate magnitude in4–5s from detection of P wave in the epicenter were developed at NIEP (AMarmureanu et al, 2011). They were tested on all the recorded data. The magnitude error for 77.9% of total considered events is in the interval [-0.3,+0.3] magnitude units. This is acceptable taking into account that the magnitude is computed from only3 stations in a 5s time interval (1s delay is caused by data packing). The ability to rapidly estimate the earthquake magnitude combined with powerful real-time software, as parts of an early warning system, allows to send earthquake warning to Bucharest in real time, in about 5s after detection in the epicenter. This allows 20-27 s warning time to automatically issue preventive actions at the warned facility.

5. Emergency Reaction

National policy in disaster risk reduction field is expressed through various legislative documents for the hole field and different risk types, administrative authorities, public institutions and specialized institutions with responsibilities in disaster prevention and response management.

The relevant laws regarding the national policy for disaster management are Government Ordinance (GO) no. 47/1994, regarding the defense against disasters, approved by Law 124/15.12.1995, Law no.106/25.09.1996 – Civil Protection Law, modified by G.O. no.21/15.04.2004 regarding the National System for Emergency Situations Management.

According the Emergency Ordinance no.21/2004, the National System for Emergency Situations Management is composed by:

a) Emergency Situations Committees;

b) General Inspectorate for Emergency Situations;

c) Professional Emergency Services;

d) Operative centres for emergency situations;

e) Action commander.

The committees for emergency situations will be organized on levels, as follows:

a) National Committee for Emergency Situations;

b) Ministerial committees and other central public institution's committees for emergency situations;

c) Bucharest Municipal committee for emergency situations;

d) County committees for emergency situations;

e) Local committees for emergency situations.

The National Committee for Emergency Situations, organized under the Ministry of Administration and Interior, and the ministerial committees for emergency situations are responsible for application of the disaster risk reduction policy at national level.

At national level the system for emergency situations management is under reorganization and redefinition of all responsibilities for national and local institutions with responsibilities in this field. According to the new laws which are in full process of development, new institutions and operational structures will be organized, which will ensure people protection, infrastructure and environmental protection during an emergency situation, in a coordinated and professional manner.

In the regard of the national strategy for earthquake and landslides risk reduction, the main directions are:

- Completion of legislative and organizational framework in order to reduce the consequences of earthquakes and to put in safe the building stock;
- Improvement of legal framework and technical tools (software, handbooks, guides, equipment) for technical expertise, development of projects and buildings consolidation works;
- Setting up the technical and organizational condition needed for the collection, stocking and automatic processing of information regarding the buildings with high seismic risk;
- Diversification of resources and financing condition to continue the design and execution activities for the consolidation of dwellings;
- Improvement of earthquakes insurance system for buildings;
- Improvement of disaster management, particularly in case of earthquake, taking into account the main aspects of prevention, protection and intervention, as well as the public education regarding the earthquakes.

The General Inspectorate for Emergency Situations, set up in Romania at the end of 2004, is a unified structure of the Civil Protection Command and the General Inspectorate of Military Fire-fighters from the Ministry of Administration and Interior.

The General Inspectorate for Emergency Situations is the specialized body from the Ministry of administration and Interior, which will ensure the coordination of the prevention and the management of emergency situations. The General Inspectorate for Emergency Situations include the prevention department, national operational centre and other adequate structures needed in emergency situation management.

The General Inspectorate for Emergency Situations, through the national operational centre, ensure the Standing technical Secretariat of National Committee, being responsible for cooperation at national level in civil protection field, protection against fires and emergency situation management.

The main attributes of The General Inspectorate for Emergency Situations are as follows:

- Assess, evaluate and monitor the risks, make predictions regarding these risks in order to identify the potential emergency situations, and take decisions to prevent the extent of situation and to warn the public;
- Ensures the unitary co-ordination of prevention actions and management of emergency situations, which cover the whole territory of the country;
- Co-ordinates the national development programmes in the field of defense against disaster;

- Uses the media to inform the public regarding the imminence of emergency situations and the actions that must be taken to limit and reduce their effects;
- Ensures the technical and specialized co-ordination of operational and operative centres, maintains the permanent informational flow of them;
- Co-operates with the international bodies, as part of international conventions and agreements;
- Co-ordinates, at national level, the resources needed in emergency situation management and elaborates the plan with human, material and financial resources for these situations;
- Provides technical specialized assistance to local and central authorities in emergency situations management.

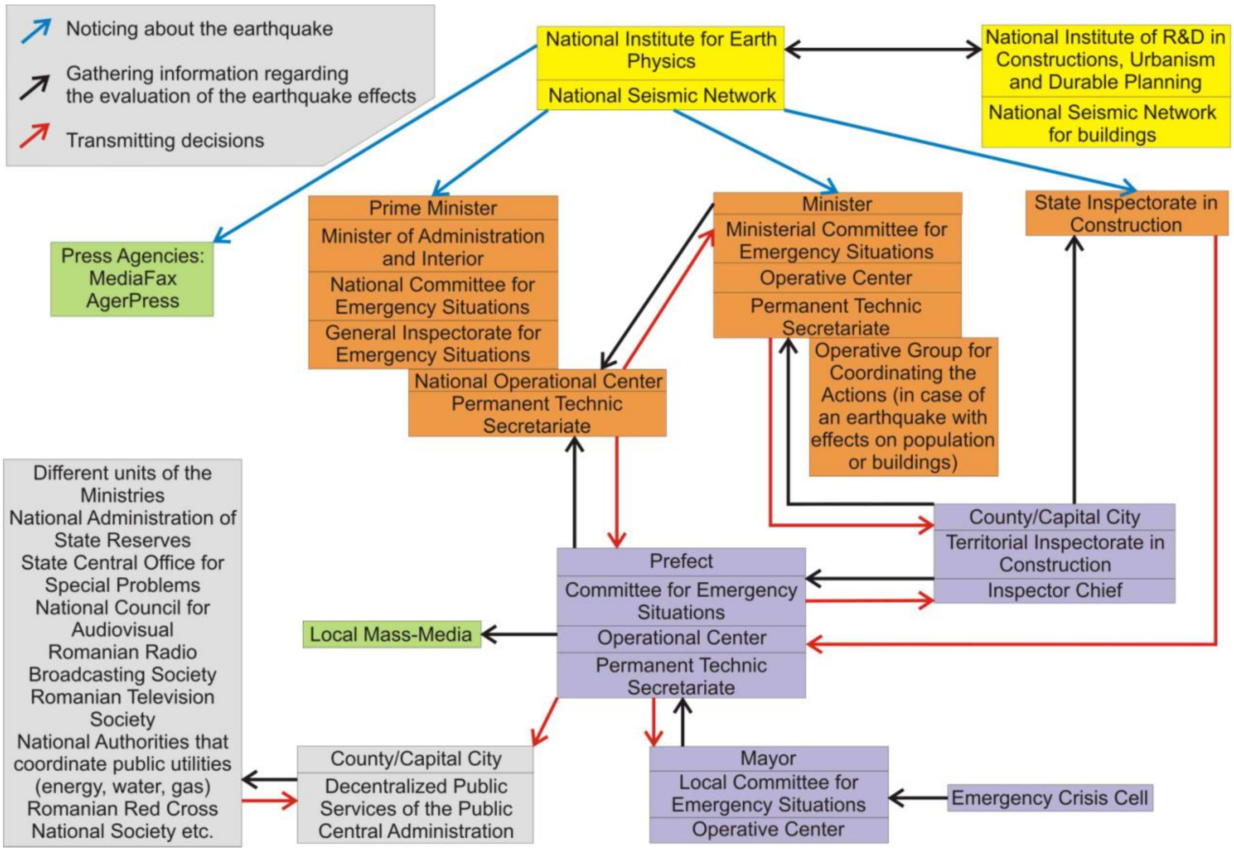


Figure 26: Informational flux in case of a major earthquake

Risk disaster reduction is also integrated in the implementation plans of the projects carried-on in the framework of Disaster Prevention Preparedness Initiative, Stability Pact for South-East Europe, III. The contact institution for this initiative is Civil Protection Command which is to function until the establishment of General Inspectorate for Emergency Situations.

Also, through cooperation between the Black Sea Basin countries, it has been envisaged the implementation of disaster prevention measures within the implementation plans of the „Agreement between the Governments of the Black-Sea Organization for Economic Cooperation participating Countries regarding the cooperation in the field of emergency assistance and response to natural and man-made disasters".

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