SEISMOLOGICAL DATABASE FOR BANAT SEISMIC REGION (ROMANIA) – PART 2: THE CATALOGUE OF THE FOCAL MECHANISM SOLUTIONS

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A high quality Catalogue of Focal Mechanism Solutions of the earthquakes occurred in the Banat Seismic Region (Romania) (CFMSBSR) is presented. It comprises focal mechanism solutions (FMS) for 140 events, spanning 47 years (1959–2006). CFMSB includes three kinds of the FMS: i) collected FMS with their original parameters, ii) compiled FMS with modified parameters, iii) new FMS.

Key words: earthquakes, faults, focal mechanism solutions, Banat Seismic Region.

1. INTRODUCTION

The earthquake source parameters provide critical information for global, regional and local tectonic studies and seismic hazard analysis, as well as for many types of seismological investigations. The knowledge of the stress field for a given region, with a specific geological structure and tectonics, and the understanding of the seismotectonic processes, which generate strong earthquakes, are essential clues to define and characterize the seismogenic sources.

The systematic studies of the focal mechanism solutions (FMS) in a large geo-informational context, furnish fundamental data about some of the main factors that control the seismic phenomenon, *e.g.* stress field peculiarities and the types of faulting, the geometry of the faults and their spatial position against maximum horizontal stress. These studies request particular Seismological Databases that have to include a Catalogue of Focal Mechanism Solutions (CFMS) for the earthquakes occurred within the territory of interest.

The main purpose of this paper is to present the complete and revised CFMS for the earthquakes occurred in the western and south-western part of Romania, known as Banat Seismic Region (BSR). This catalogue is one of the main informational components of the Seismological Database elaborated for BSR by [11]. CFMSB has also an important data field, not included in the present paper, namely Digital Tectonic and Geologic Map [10], a tool for realistic use of CFMSB.

We used all available data about FMS from literature as well as new information gathered from seismograms and seismic bulletins (*e.g.* polarities, amplitudes and travel times for P and S waves). High quality hypocentral parameters and moment magnitude, M_w, have been computed for all earthquakes catalogued. The parameters of the most FMS have been reconsidered on a new data basis. New solutions were determined for the earthquakes occurred after 2004.

The catalogue contains FMS determined for 140 seismic events with $2.8 \leq M_w \geq 5.6$, which occurred in BSR between 1959 and 2006. It is accessible both in electronic and hard print formats. We consider CFMSB as being an important contribution to improve and to update the existing seismological databases, especially the seismotectonic one, elaborated for Romania and for the Carpatho-Pannonian Basin.

CFMSB has a particular significance for the local seismic hazard assessment in BSR because it brings new and valuable information useful for knowing better the state of the stress in the crust and lithosphere and to highlight the mutual relationship between the specific tectonics of the region and the known patterns of seismicity revealed by [7–9, 12, 13].

2. DATA, ANALYSIS AND RESULTS

The information used to compile CFMSB presented in this paper come from different sources, among which the most important are the following: i) focal mechanism solutions collected from literature (published papers, manuscripts and research reports, earthquake catalogues and bulletins); ii) travel times and polarities of the first P waves gathered from the seismic bulletins and the catalogues of the international seismological agencies, seismic stations or/and seismological observatories; iii) travel times and polarities of the first P waves picked from original seismograms obtained into the framework of the international project EuroSeismos (www.storing.ingv.it/es_web); iv) travel times and polarities of the first P waves from digital seismograms recorded by the Romanian National Seismic Network after the ’80s and by the Banat Local Seismic Network between 1995 and 2004 (http//:www.infp.ro); v) travel times and polarities of the first P waves recorded by mobile stations; vi) amplitude of P and S (SV, SH) waves.

A detailed analysis of the new sets of information and data was conducted and the final processing of the inputs followed the next steps:

1. All events with FMS collected from the literature, the new ones identified in this study using new data and those occurred since 2004 were

(re)located using the Seisan Software package [4]. The moment magnitude, M_w is adopted in the paper according to the Romanian Earthquake Catalogue, Romplus [6]. M_w has been directly computed from digital seismograms when these ones were available or it has been obtained by conversion of the original reported magnitudes M_i to M_w (Mi was M_L, M_D, M_S or mb). We applied the scheme for conversions defined by [6].

The seismic stations used in the study are shown in Fig. 1. The picture emphasizes the good coverage of the stations used in our study *vs.* the position of the epicenters from BSR. The short distances between epicenters and some of the seismic stations assured better constraints to estimate the focal depths and the parameters of FMS. The catalogue drafted in this phase covers the time interval 27.05.1959–28.06.2006 and comprises 167 events with solutions of focal mechanisms that occurred in BSR and its neighborhoods.

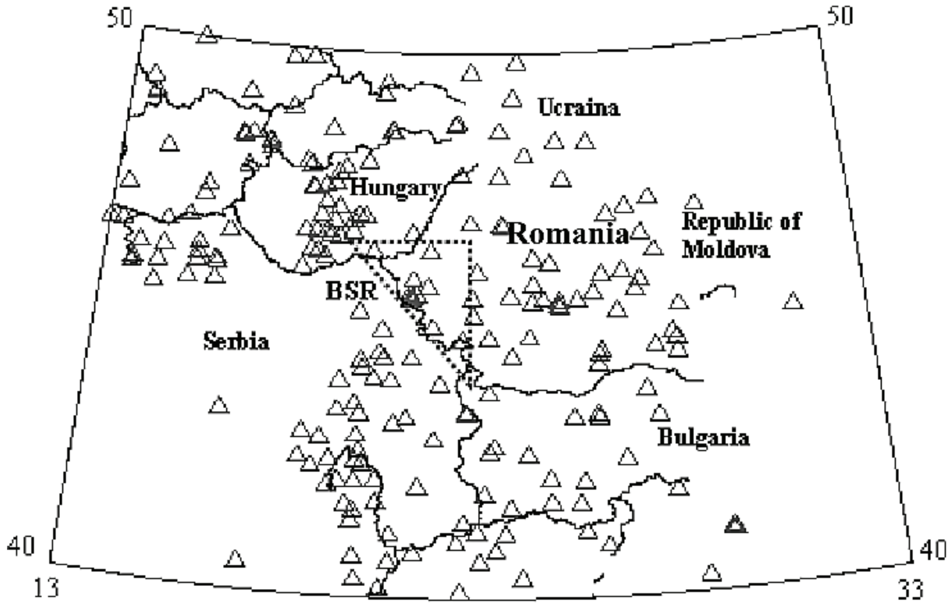

Fig. 1 – The map of seismic stations which recorded at least one earthquake listed in the CFMSB. Only the nearest stations to Banat Seismic Region (BSR) are displayed. The large triangle with dotted limits encloses BSR. Small open triangles symbolize the seismic stations.

2. Focal mechanisms calculated for all earthquakes that occurred only within the limits of the BSR drawn by [8], have been carefully selected for location accuracy, with special attention on the station coverage and the number of the polarities. A final catalogue with 140 FMS resulted. The map of epicenters for these events is displayed in Fig. 2. In Fig. 3 the frequency distributions for magnitudes and focal depths are displayed. As it can be seen in Fig. 3, the most

catalogued events have magnitudes $M_w \leq 4.3$ (92%) and cluster within three focal depth intervals.

Table 1

Basic statistics of hypocenters quality locations for the earthquakes listed in Table 2

errors	Mean	Median	Mode	Minimum	Maximum	Std.Dev.
longitude E	3.4	3.6	2.5	1.4	14.3	2.12
latitude N	2.3	2.5	1.8	1.1	12.1	1.83
depth	3.4	3.6	2.8	1.4	12	2.03
errors/h ratio	0.29	0.32	0.29	0.11	2.15	0.30

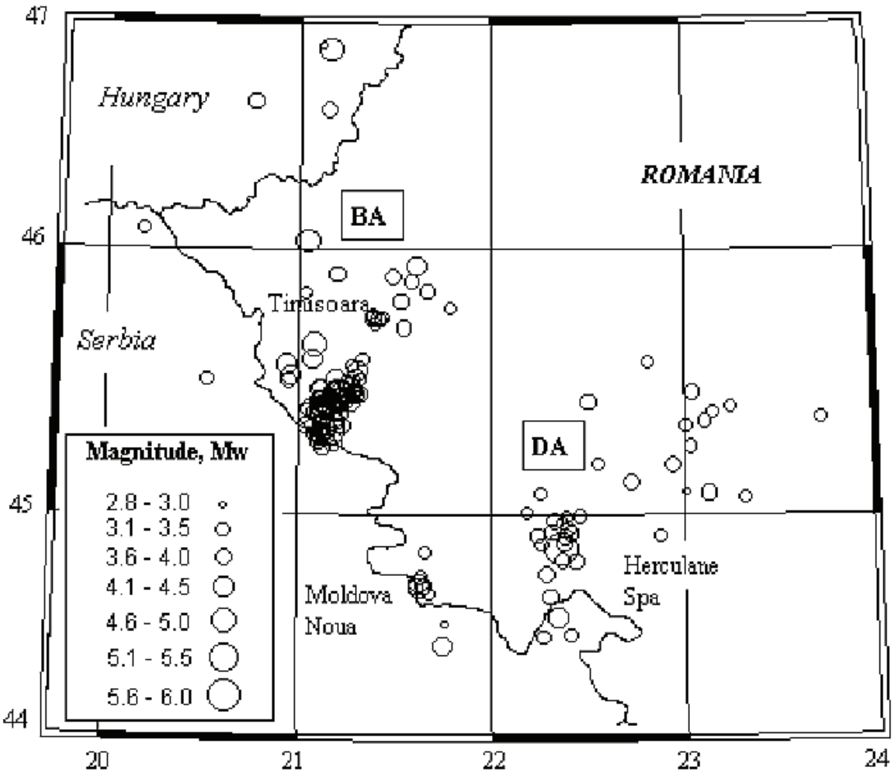

Fig. 2 – Map of epicenters for the earthquakes listed in Table 1. BA, DA means Banat and Danube Seismogenic Zones, respectively.

The high quality of the hypocentral parameters is pointed out by the errors statistics synthesized in Table 1 and by the two main distributions presented in Fig. 4, the latitude/longitude errors and the quality classes, defined by [6], respectively. Most of the location errors are smaller than 5.0 km (75.1 % on longitude and 88.3% on latitude).

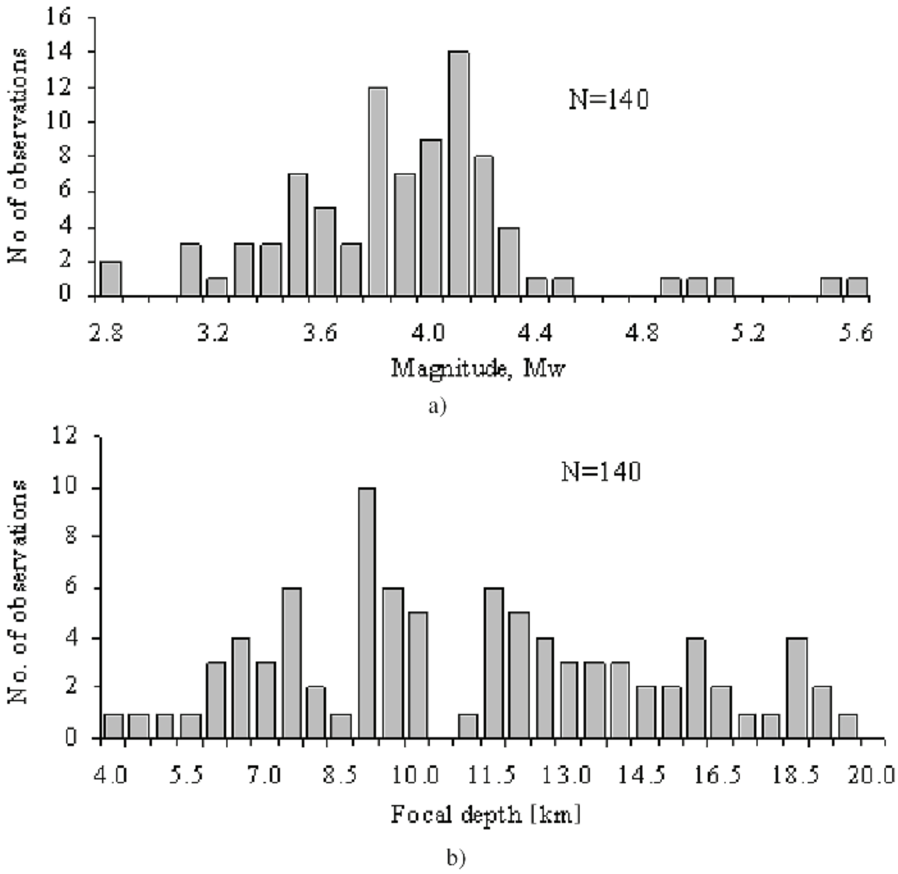

Fig. 3 – Frequency distributions of the a) magnitude (Mw) and b) focal depth for the events listed in CFMSB (Table 2).

The earthquakes with FMS mapped in Fig. 2 are grouped into two main seismo-active tectonic setting defined by several studies as major seismogenic zones [7–9, 12, 15]. Thus, in the North-West the Banat Seismogenic Zone (BA) develops corresponding to a depression area (Western Plain of Romania) and in the South-East the Danube Seismogenic Zone (DA) that overlaps on the area of the Carpathians Mountains is known.

3. All 140 events were checked for parameters of FMS consistency with the new locations, new data and sometimes additional constraints (*e.g.* additional polarities, amplitude of P and S waves on three components and ratio of SV/P, SH/P, SH/SV amplitudes). Subsequently the FMS were recomputed with the FocMec software [4, 17] using the new information: only P polarities (90%) or P polarities and amplitude ratios (10%). More FMS have been (re)analyzed using only the data from seismograms recorded at local distances, sometimes nearer

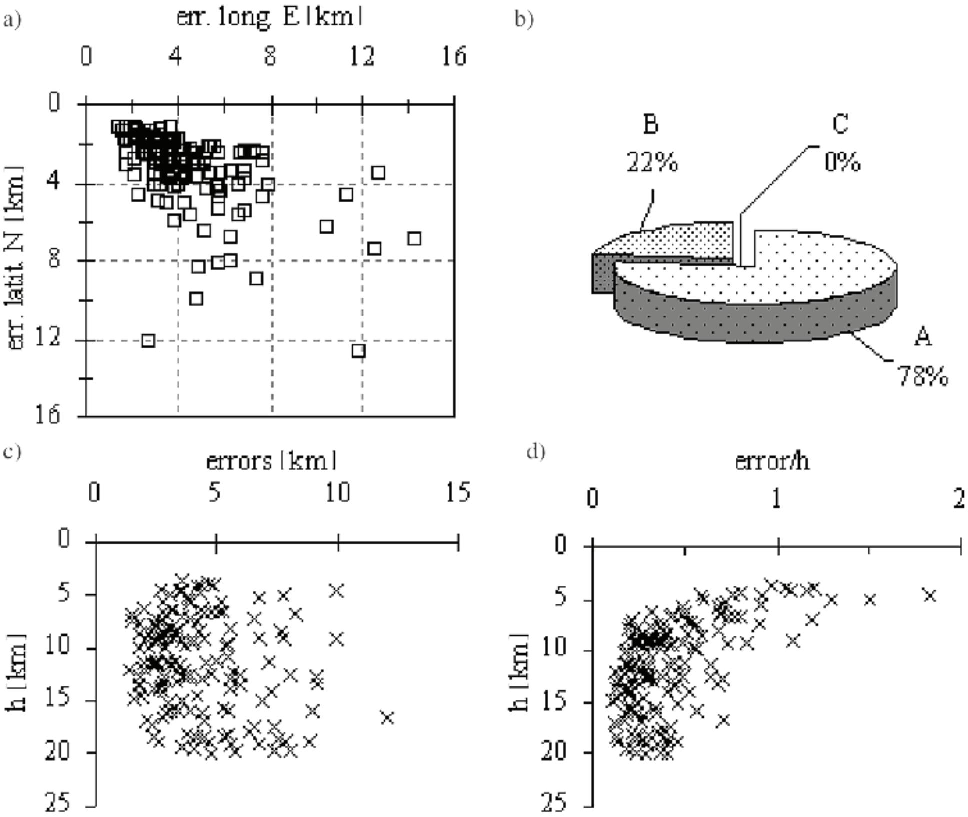

Fig. 4 – Error limits and quality classes of the new hypocenters parameters: a) the distribution of the errors of geographical coordinates of epicenters, b) the frequency of the quality classes of location (A, B and C quality classes have been defined by [6]; A refers to the best quality), c) the distribution of focal depth errors (km) *vs.* focal depth (km), d) the distribution of the focal depth errors/focal depth ratio *vs.* focal depth.

than 1.5 times the focal depth, what means solutions well constrained [20]. We determined new FMS for the earthquakes occurred after 2004, too. The main parameters of the final FMS are listed in the simplified version of CFMSB presented in Table 2.

In the Fig. 5 is displayed the distribution of the main types of faulting as they are revealed by the statistics of the main parameters of FMS. The solutions were sorted into faulting types based on strike, dip, and rake orientation following the convention of Aki and Richards [1980]. Because these categories are based on the fault slip angle, we determined the most probable fault plane in order to determine the proper rake. For each focal mechanism, the fault plane was chosen as the nodal plane that most closely matched the orientation of faults in the vicinity, compiled and digitized by [10]. In most cases, the faulting type was the same regardless of which nodal plane was assumed to be the fault plane.

Table 2

Focal mechanism solutions for Banat Seismic Region of Romania. The parameters of focal mechanism solutions are given in the two nodal plane (azimuth, dip and rake for Plane 1 and Plane 2) and P an T axis (azimuth and plunge) following the convention by [1]. Explanation of catalogue entries: Date/d, m, y-the date of earthquake/day, month and year; Ho/h, m-the origin time of earthquakes/hour and minutes; lat and long-the geographical coordinates of the epicenters; h-focal depth; Mw-moment magnitude; Plane 1 and Plane 2/Az, Di, Sl-nodal planes, strike, dip and rake; P and T/Az, Pl-P and T axes/azimuth measured counter wise from North and their plunge; Po-number of polarities used to determine the focal mechanism solutions; Ref-references sources used for collected and compiled data

No	Date			Ho		lat	long	h	M_w	Plane 1			Plane 2			P		T		Po	Ref
	d	m	y	h	m					Az	Di	Sl	Az	Di	Sl	Az	Pl	Az	Pl		
1	27	5	1959	20	38	45.64	21.09	9	5.0	229	49	–153	121	70	–44	76	45	180	13	19	[8]
2	17	4	1974	1	31	46.03	21.04	16	4.9	271	61	172	5	83	29	135	15	232	25	18	[8]
3	22	6	1978	2	33	46.75	21.16	15	4.9	164	78	137	265	48	16	221	19	115	38	23	[3*]
4	22	6	1978	2	57	46.77	21.12	17	3.0	151	52	148	262	65	43	24	8	122	47	11	[3*]
5	21	10	1985	18	33	45.19	22.56	5	3.1	15	83	–156	282	66	–8	241	22	146	12	8	[3#]
6	22	4	1988	1	23	45.50	20.96	5	3.8	81	66	33	336	60	152	207	4	300	40	9	[8]
7	12	5	1988	7	8	45.46	23.05	19	3.6	95	60	–145	346	60	–35	311	45	221	0	10	[8]
8	29	11	1988	1	23	45.70	21.55	10	3.9	343	85	–38	77	52	–174	293	30	36	22	21	[13]
9	10	3	1989	16	24	45.35	23.11	7	3.5	33	59	–13	130	79	–148	356	30	258	13	7	[7#]
10	15	2	1990	10	18	45.57	22.82	19	3.3	87	80	38	349	53	167	213	18	315	33	6	[14#]
11	17	4	1990	4	35	44.92	22.88	19	3.4	133	60	52	10	47	137	249	7	350	57	14	[8,16]
12	12	7	1991	10	42	45.38	21.10	11	5.6	9	89	–168	279	78	–1	235	9	143	8		[20]
13	12	7	1991	16	29	45.42	21.12	11	4.3	100	59	–133	341	51	–41	315	54	219	5	27	[8,10]
14	12	7	1991	20	42	45.35	21.21	6	3.9	180	81	158	274	68	10	227	9	137	23	9	[8]
15	13	7	1991	4	33	45.40	21.17	14	3.8	4	72	4	273	86	162	320	10	227	15	13	[8]
16	13	7	1991	5	10	45.39	21.09	9	3.8	273	86	65	174	25	170	24	36	159	44	7	[8]
17	13	7	1991	14	6	45.42	21.13	10	4.1	310	56	–12	47	80	–145	274	31	174	16	10	[8]
18	13	7	1991	17	27	45.42	21.17	19	4.2	274	46	–27	23	71	–133	249	46	143	15	29	[8,10]
19	13	7	1991	17	56	45.38	21.22	13	3.9	41	53	–137	282	57	–46	249	54	342	2	20	[8,10]
20	13	7	1991	19	3	45.41	21.21	9	4.1	274	77	121	25	33	25	341	26	217	49	13	[8]
21	14	7	1991	17	3	45.41	21.15	9	4.1	192	52	–121	56	48	–57	38	66	303	2	16	[8,10]
22	14	7	1991	23	59	45.45	21.33	18	4.0	190	52	–135	69	56	–48	37	56	130	3	26	[8,10,16]
23	15	7	1991	15	45	45.38	21.12	12	4.2	24	51	–16	124	78	–140	352	36	249	17	11	[8]
24	18	7	1991	11	56	44.87	22.37	15	5.6	75	52	–124	303	49	–54	282	64	189	2		[20]
25	18	7	1991	12	3	44.77	22.29	13	3.6	35	76	–153	298	64	–16	259	29	165	8	15	[8]
26	18	7	1991	14	3	44.69	22.31	9	3.8	32	61	–129	271	47	–41	250	56	149	8	10	[8]
27	18	7	1991	21	51	44.99	22.47	17	3.3	203	80	–145	106	56	–12	70	31	330	16	9	[8]
28	19	7	1991	1	19	45.32	21.15	7	4.2	48	81	–143	311	54	–11	276	32	174	18	36	[8]

(continues)

Table 2 (continued)

No	Date			Ho		lat	long	h	M_w	Plane 1			Plane 2			P		T		Po	Ref
	d	m	y	h	m					Az	Di	Sl	Az	Di	Sl	Az	Pl	Az	Pl		
29	19	7	1991	1	27	45.31	21.17	10	5.1	199	77	–163	105	73	–14	63	21	332	3	53	[3*]
30	19	7	1991	2	23	45.33	21.08	6	3.7	36	49	–132	270	56	–52	238	59	334	4	9	[8]
31	19	7	1991	2	43	45.33	21.23	4	3.9	221	51	–63	2	46	–119	195	69	292	3	10	[8]
32	19	7	1991	5	24	45.28	21.11	8	3.8	31	65	–148	286	61	–29	250	40	158	3	13	[8,10]
33	19	7	1991	8	6	45.41	21.20	6	3.8	281	81	–49	21	42	–167	228	39	340	25	9	[8]
34	19	7	1991	15	42	45.08	22.26	13	3.5	258	82	–23	351	67	–171	212	22	306	10	10	[8]
35	19	7	1991	16	19	44.99	22.39	8	3.5	355	46	10	258	83	136	315	24	206	35	9	[8]
36	20	7	1991	3	36	45.30	21.12	9	4.2	40	44	61	258	53	115	330	5	228	69	22	[8,10]
37	20	7	1991	3	58	45.34	21.14	8	4.2	189	75	–140	87	52	–19	55	38	313	15	21	[8,10]
38	22	7	1991	15	45	45.40	21.15	15	3.8	17	75	–160	282	71	–16	240	24	149	3	8	[8]
39	29	7	1991	20	46	44.82	22.44	14	3.7	69	48	–38	187	63	–131	47	53	305	9	7	[8]
40	31	7	1991	11	22	45.31	21.12	7	3.9	17	51	56	244	50	125	130	1	221	64	19	[8,10]
41	1	8	1991	12	57	45.41	21.13	12	3.9	201	74	145	302	57	19	255	11	157	36	7	[8]
42	2	8	1991	0	51	45.27	21.18	12	4.1	199	60	–37	310	59	–144	164	46	255	1	23	[8]
43	6	8	1991	15	4	45.40	21.12	7	4.1	188	80	–15	281	75	–170	144	18	235	3	19	[8,10]
44	7	8	1991	19	24	45.29	21.15	12	4.0	191	71	–17	287	74	–160	150	25	59	2	26	[8,10]
45	12	8	1991	4	59	45.41	21.14	9	4.4	208	86	–21	300	69	–176	162	18	256	12	38	[8,10]
46	14	8	1991	23	36	45.45	21.30	12	4.5	111	65	–141	2	55	–31	331	45	234	6	26	[8,10,16]
47	15	8	1991	1	34	45.42	21.27	6	4.1	259	57	–163	160	76	–34	115	34	213	12	15	[8,10]
48	15	8	1991	19	35	45.42	21.28	11	4.1	289	60	–40	42	56	–143	254	49	346	2	10	[8]
49	4	9	1991	18	13	44.89	22.39	13	3.6	219	61	–73	7	33	–118	164	69	297	15	9	[8]
50	7	9	1991	7	28	45.45	21.22	16	3.7	293	75	–48	39	44	–158	244	44	353	19	10	[8]
51	9	9	1991	20	48	44.97	22.33	5	3.7	291	62	–47	48	50	–142	253	52	352	7	9	[8]
52	11	9	1991	22	10	45.33	21.04	13	3.6	202	80	127	305	38	16	264	26	147	43	9	[8]
53	13	9	1991	7	8	44.93	22.32	11	3.7	235	75	–45	340	47	–159	187	42	294	17	9	[8]
54	13	9	1991	12	12	45.44	21.16	10	3.5	277	71	–23	15	68	–159	235	30	326	2	9	[8]
55	15	9	1991	0	11	44.97	22.37	4	3.5	96	48	–121	318	50	–60	295	68	27	1	11	[8]
56	15	9	1991	18	26	44.91	22.39	13	3.9	20	40	–34	137	69	–125	5	53	252	17	14	[8]
57	17	9	1991	3	2	44.61	22.35	12	4.1	172	52	–168	75	81	–39	26	33	129	19	35	[8,10,16]
58	19	9	1991	20	40	45.00	22.19	20	3.5	48	67	–132	295	47	–32	271	49	167	12	7	[8]
59	25	9	1991	11	30	45.25	21.13	11	3.7	186	66	147	291	60	28	240	4	147	40	7	[8]
60	8	10	1991	8	51	45.46	21.23	9	4.1	307	61	28	203	66	148	256	3	163	39	14	[8]
61	14	10	1991	20	56	45.43	21.25	9	4.0	267	54	–37	21	61	–138	237	49	143	4	10	[8]
62	17	10	1991	14	37	45.43	21.16	5	3.9	274	75	–47	20	45	–158	225	43	334	18	10	[8]
63	24	10	1991	16	38	45.36	21.19	9	3.8	16	46	–9	112	84	–136	344	34	236	25	9	[8]

(continues)

Table 2 (continued)

No	Date			Ho		lat	long	h	M_w	Plane 1			Plane 2			P		T		Po	Ref
	d	m	y	h	m					Az	Di	Sl	Az	Di	Sl	Az	Pl	Az	Pl		
64	1	11	1991	12	29	45.19	22.95	20	3.8	247	54	–48	10	53	–133	218	57	309	1	14	[8,16]
65	21	11	1991	2	16	45.51	21.30	18	4.3	329	52	–51	96	52	–129	303	60	213	0	30	[8]
66	26	11	1991	19	15	45.45	21.29	18	3.8	317	47	111	108	47	69	213	0	303	75	8	[8]
67	2	12	1991	8	49	45.45	21.21	9	5.5	103	72	–13	194	86	–162	60	16	327	9		[20]
68	2	12	1991	10	52	45.49	21.25	13	4.0	322	54	–36	75	62	–138	292	48	197	5	9	[8]
69	12	12	1991	12	2	45.45	21.25	9	3.8	113	36	–30	228	73	–122	101	51	342	21	11	[8,10]
70	17	12	1991	6	22	45.40	21.12	11	3.5	14	48	–37	131	63	–131	351	52	249	9	11	[8,10]
71	18	12	1991	10	24	45.80	21.53	16	4.0	278	75	–31	17	60	–163	234	32	330	10	16	[7,10]
72	19	12	1991	3	12	45.94	21.62	19	4.1	148	65	–164	51	76	–26	7	28	101	7	55	[7,10]
73	21	12	1991	11	43	45.88	21.59	14	3.9	294	48	–30	45	68	–134	269	47	165	12	16	[8,10]
74	24	12	1991	11	11	45.44	21.17	6	4.0	47	61	172	141	83	29	271	15	8	25	15	[8,10]
75	26	12	1991	3	13	45.46	21.29	15	3.6	299	61	–5	31	86	–151	259	23	161	17	9	[8]
76	17	2	1992	11	0	44.83	22.37	14	3.6	47	41	–139	284	65	–57	239	57	350	14	12	[8,16]
77	2	3	1992	20	33	45.89	21.49	12	4.0	270	76	24	174	67	165	41	6	134	27	43	[7,10]
78	24	5	1992	15	46	45.84	21.67	4	3.8	63	61	138	177	54	37	121	4	27	49	9	[8]
79	11	6	1992	11	20	44.94	22.40	19	3.6	188	77	121	299	33	25	255	26	131	49	8	[8]
80	19	12	1992	9	34	45.56	20.95	9	4.2	289	62	41	177	55	145	52	4	146	48	47	[8,10]
81	23	12	1992	21	5	45.52	20.96	7	4.3	283	45	82	114	46	98	199	1	103	84	28	[8,10]
82	11	1	1993	0	49	45.90	21.20	15	3.8	82	75	–130	334	42	–23	312	45	201	20	11	[8]
83	14	1	1993	8	23	45.58	21.08	7	4.1	130	46	29	19	70	132	80	14	334	47	23	[8,10]
84	13	10	1994	13	49	45.54	21.31	16	4.1	51	68	–11	145	80	–158	10	23	276	8	20	[8,10,16]
85	13	10	1994	23	31	45.48	21.27	11	4.1	295	59	62	161	41	128	45	10	155	64	11	[8,16]
86	15	10	1994	1	42	45.47	21.12	19	4.3	63	61	42	309	54	143	185	4	279	49	35	[8,10,16]
87	12	11	1994	19	34	45.51	21.20	16	4.2	29	57	–161	288	74	–35	244	36	342	11	19	[8,10,16]
88	3	2	1995	0	55	45.56	21.28	16	3.5	38	58	–162	298	75	–33	254	34	351	11	12	[8]
89	12	2	1995	6	5	45.44	21.17	13	4.1	74	55	155	179	70	38	303	9	42	40	8	[8,16]
90	24	8	1995	15	14	45.41	21.15	10	4.1	23	80	29	288	61	169	152	13	249	28	20	[8,10,16]
91	20	12	1995	14	59	45.08	23.02	4	3.0	85	88	–168	355	78	–2	311	10	219	7	14	[8]
92	6	3	1996	10	50	46.28	23.55	8	3.7	275	71	–47	24	46	–153	229	46	335	15	9	[8]
93	24	3	1996	9	13	45.43	21.18	13	3.5	23	48	54	250	53	123	317	3	222	64	24	[8,10,16]
94	10	2	1997	8	38	45.37	23.71	10	3.1	84	82	158	177	68	9	132	10	39	21	8	[8]
95	17	6	1997	13	33	46.55	20.77	8	3.7	245	54	20	143	74	142	198	13	98	38	10	[19]
96	16	1	1998	5	13	45.06	23.32	4	3.5	245	64	131	2	47	37	307	10	204	52	21	[7,10]
97	22	4	1998	13	35	46.08	20.19	7	3.1	280	81	–120	175	31	–17	160	46	34	30	8	[8]
98	29	7	1998	15	31	45.38	23.15	13	3.3	88	83	60	346	31	166	203	31	328	44	16	[7]

(continues)

Table 2 (continued)

No	Date			Ho		lat	long	h	M_w	Plane 1			Plane 2			P		T		Po	Ref
	d	m	y	h	m					Az	Di	Sl	Az	Di	Sl	Az	Pl	Az	Pl		
99	30	7	1998	4	54	45.45	23.24	5	3.2	80	87	–41	173	49	–176	28	30	134	25	21	[7,10]
100	26	9	1998	11	15	44.95	23.81	8	3.0	124	62	53	1	45	138	239	9	343	56	11	[8]
101	29	9	1998	22	34	45.77	21.80	19	3.3	277	81	–42	15	49	–168	227	35	333	21	17	[7]
102	21	1	1999	18	44	45.58	21.34	14	3.5	240	59	15	142	77	148	194	12	97	32	8	[8]
103	3	9	1999	9	38	46.53	21.15	17	3.8	118	75	–160	23	71	–16	341	24	250	3	13	[7,10]
104	3	10	1999	4	43	45.84	21.04	13	3.2	254	61	–107	106	33	–62	129	69	356	15	20	[7,10]
105	8	10	1999	17	26	45.29	21.11	9	3.1	267	89	–24	357	66	–180	219	17	315	16	18	[7,10]
106	9	10	1999	1	1	45.39	21.05	9	3.1	194	66	–59	318	38	–139	146	57	262	16	15	[7,10]
107	9	10	1999	20	49	45.31	21.11	12	3.8	232	46	–125	97	54	–59	66	65	166	4	15	[7,10]
108	20	12	1999	23	40	44.50	21.76	13	4.4	28	44	–110	235	49	–72	212	76	312	3	28	[7]
109	21	12	1999	3	22	45.08	23.13	5	3.7	254	42	–144	136	67	–54	90	53	200	14	28	[7,10]
110	18	7	2000	13	54	44.54	22.42	15	3.3	25	63	–149	280	63	–31	243	40	153	0	14	[7,10]
111	22	7	2000	7	23	45.73	21.42	11	3.6	226	40	17	123	79	129	184	24	70	42	22	[7,10]
112	22	7	2000	7	51	45.74	21.44	12	3.3	256	41	–41	19	65	–123	244	57	133	14	13	[7]
113	16	8	2000	22	13	45.47	21.30	17	3.5	159	53	–30	268	66	–139	129	45	31	8	27	[8]
114	21	8	2000	10	28	45.72	21.40	7	3.4	260	68	–117	134	34	–41	133	58	10	19	8	[7]
115	5	10	2000	23	4	45.74	21.39	12	4.0	48	53	124	180	49	54	115	2	20	63	23	[7,10]
116	30	10	2000	16	53	45.75	21.39	10	3.6	58	54	120	194	46	56	127	4	28	66	15	[7,10]
117	3	1	2001	8	8	44.88	22.27	10	3.4	195	86	–15	286	75	–176	150	13	241	8	14	[7,10]
118	15	6	2001	8	4	45.25	23.04	5	3.5	214	46	16	113	79	135	171	21	63	39	14	[7,10]
119	20	6	2001	15	44	45.73	21.43	7	3.5	226	50	–134	102	57	–51	69	58	165	4	14	[7,10]
120	24	6	2001	0	52	45.35	21.13	11	3.4	21	84	8	290	82	174	155	1	246	10	8	[7]
121	2	8	2001	21	50	45.48	21.12	7	4.0	152	77	–57	262	35	–156	97	48	217	25	23	[8,10]
122	20	8	2001	19	44	45.75	21.40	8	3.3	65	75	149	164	60	17	117	10	21	32	10	[7]
123	6	4	2002	14	5	45.30	21.09	10	3.6	53	59	–46	171	52	–139	18	53	113	4	11	[7]
124	3	5	2002	13	10	44.73	21.62	7	3.6	27	66	–59	151	38	–139	339	57	95	16	8	[8]
125	17	5	2002	8	10	45.34	23.01	15	3.5	271	87	137	4	47	4	326	26	218	31	11	[8]
126	23	5	2002	3	26	44.73	21.66	8	3.4	180	47	–73	336	46	–107	168	78	258	1	26	[7,9,10]
127	24	5	2002	20	42	44.72	21.64	9	4.6	191	53	–148	80	65	–42	40	47	138	7	66	[7,9,10]
128	2	8	2002	9	31	44.76	21.64	20	3.4	3	79	–136	263	47	–15	233	38	126	20	6	[8]
129	2	8	2002	9	37	44.74	21.63	7	4.2	161	71	–36	264	56	–157	118	39	215	10	48	[7,9,10]
130	4	8	2002	18	27	44.85	21.67	18	3.5	156	70	55	40	40	148	271	17	25	52	9	[8]
131	19	6	2003	18	2	44.93	22.42	19	3.7	30	66	0	120	90	156	252	17	348	17	19	[8]
132	2	9	2004	16	40	45.51	20.53	16	3.4	288	54	–143	174	61	–42	138	49	232	4	11	[new]
133	22	10	2004	5	37	44.92	22.25	15	4.0	239	46	–126	105	54	–59	74	65	173	4	22	[new]

(continues)

Table 2 (continued)

No	Date			Ho		lat	long	h	M_w	Plane 1			Plane 2			P		T		Po	Ref
	d	m	y	h	m					Az	Di	Sl	Az	Di	Sl	Az	Pl	Az	Pl		
134	14	2	2005	23	37	45.42	22.51	20	3.7	98	56	–53	225	49	–131	66	60	163	4	11	[new]
135	20	3	2005	9	51	45.12	22.73	8	3.6	202	57	–14	300	78	–146	166	32	67	14	13	[new]
136	17	7	2005	7	30	45.52	21.32	6	2.8	250	51	16	150	78	140	205	17	102	36	11	[new]
137	17	7	2005	7	39	45.51	21.30	6	2.8	255	51	146	8	64	44	129	8	228	49	11	[new]
138	10	12	2005	7	56	44.53	22.27	19	3.5	179	75	20	84	71	164	311	3	42	24	8	[new]
139	5	2	2006	10	52	44.70	21.69	12	3.3	164	52	–117	24	45	–60	12	69	273	4	12	[new]
140	28	6	2006	17	24	44.58	21.77	8	2.9	19	64	–124	256	42	–41	243	57	133	12	7	[new]

n.b.– *from [18]; # from [16]; [new] are the FMS computed in this study.

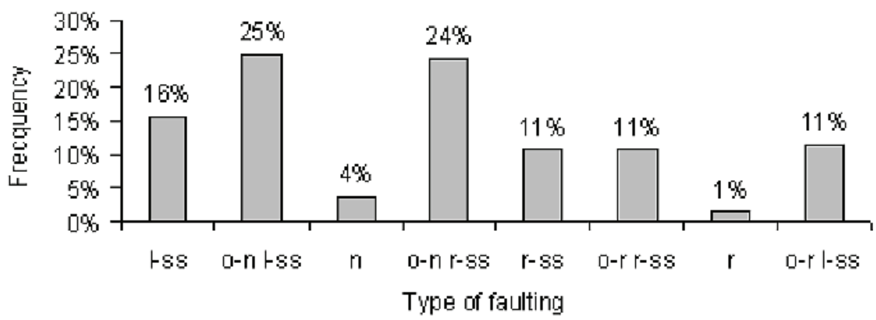

Fig. 5 – The distribution of the main types of faulting in Banat Seismic Region (1959–2006): l-ss, left-lateral strike-slip; o-n l-ss, oblique-normal left-lateral strike-slip; n, normal; o-n r-ss, oblique-normal right-lateral strike-slip, r-ss, right-lateral strike-slip; o-r r-ss, oblique-reverse right-lateral strike-slip; r, reverse; o-r l-ss, oblique-reverse left-lateral strike-slip.

For a total of 50 events the faulting is oblique normal, for 6 – normal, for 37 – strike slip, for 45 – oblique reverse, and for 2 – reverse. This great variety of faulting types may be explained by the fact that in the catalogue there are many earthquakes belonging to some complex seismic sequences (foreshocks and aftershocks) and also many earthquakes with small magnitudes occurred in different geological settings. It is known that generally these events are controlled by stress-strain ratio after a strong earthquake and also by the local stress conditions and geology.

3. CONCLUSION

The most recent and comprehensive Catalogue of Focal Mechanism Solutions (CFMSB) for the Banat Seismic Region (BSR, the western and south–western territory of Romania) has been achieved and presented in this paper.

This catalogue, along with the Digital Tectonic and Geological Maps of Banat Seismic Region, are main components of a high quality seismological database elaborated at regional scale [11].

CFMSB is of great importance for the complex study of the entire Carpatho–Pannonian Realm due to its content (140 Focal Mechanism Solutions) and the high quality of the parameters of the location of hypocenters as well as of the FMS parameters.

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REFERENCES

1. K. Aki, P. Gp. Richards, *Quantitative seismology*, W. H. Freeman, New York, 1980.
2. M. Caciagli, E. Oros, *On the XXth Century strongest western Romanian earthquakes: preliminary results from EuroSeismos Project*, Abstracts „1st ECEES Assembly" (Joint ESC/EAEE Conference), Geneva, Switzerland, 3–8 September 2006, **ID 1991**, (2006).
3. P. Gerner, *Catalogue of Earthquake Focal Mechanism Solutions for the Pannonian Region (42–52 N; 12–28 E)*, Manuscript, Geophysical Dept., Eotvos Univ., Budapest, p. 39, (1995).
4. J. Havskov, L. Ottemoller (eds.), *Seisan: Earthquake analysis software*. Inst. of Solid Earth Physics, Univ. of Bergen, Norway (www.ifif.uib.no).
5. M. C. Oncescu, E. Crisan, *Focal mechanism of the Romanian earthquakes occured in 1989* (in Romanian), Raport CFP/IFA, 30.86.3/1991, **I**, A10, Bucuresti, (1991).
6. M. C. Oncescu, V. Marza, M. Rizescu, M. Popa, *The Romanian earthquakes catalogue between 1984–1999*, In Vrancea Earthquakes: Tectonics, Hazard and Risk Mitigation; F. Wenzel, D. Lungu (eds.), 43–47, Kluwer Academic Publishers, (1999). Updated version: www.infp.ro.
7. E. Oros, *Seismo-active faults in the Banat Region (Romania)*, Abstr., Symposium "NIEP 25 years of research in Earth Physics", 27–29 September, 2002, Bucharest, (2002).
8. E. Oros, *Seismicity, faults and faulting mechanisms in the South-Western region of Romania*, XXIX General Assembly of ESC, 12–16 Sept. 2004, Potsdam, Germany, Book of Abstracts, **SCC–3 P 148**, (2004a).
9. E. Oros, *The April–August Moldova Noua earthquakes sequence and its seismotectonic significance*, Revue Romain of Geophysics, **48**, 49–68, (2004b).
10. E. Oros, *The Seismotetctonic Database for Banat Seismic Region – The Catalogue of Focal Mechanism Solutions and the Digital Tectonic and Geologic Regional Maps* (in Romanian), Report of Research for the Project Ceres/Hasver, 4–15/4.11.2004, January 2005, Bucharest, (2005).
11. E. Oros, M. Popa, I. A. Moldovan, *Seismological Database for Banat Seismic Region of Romania–Part 1: The Parametric Earthquakes Catalogue*, Romanian Journal of Physics (this issue).
12. G. Polonic, Z. Malita, *Geodynamic processes and seismicity in Banat* (Romania). Revue Roumain de Geophysique, **41**, 67–78, (1997).
13. C. Radu, M. C. Oncescu, *The focal mechanism of the November 19, 1988 Banat earthquake*, Studii și Cercetări de Geologie, Geografie, Geofizică, seria Geofizică, **27**, 3–6, (1989).

14. C. Radu, M. C. Oncescu, A. Utale, *Focal mechanism of some Romanian earthquakes occured in 1990* (in Romanian), Report CFP/IFA 30.91.3/1991, **II**, A5, 69–98, Bucharest, (1991).
15. Radulian M., Mandrescu N., Panza G.F., Popescu E., Utale A, *Characterization of Sesimogenic Zones of Romania*. PAGEOPH, **157**, 57–77, Birkauser Verlag, Basel, (2000).
16. M. Radulian, E. Popescu, A. Bala, A. Utale, *Catalog of fault plane solutions for the earthquakes occurred on the Romanian territory*, Romanian Journal of Physics, **47**, 5–6, 663–685, (2002).
17. J. A. Snoke, J. W. Munsey, A. G. Teague, G. A. Bollinger, *A program for focal mechanism determination by combined use of plarity and SV–P amplitude ratio data, Earthquake Notes*, **55**, p. 15 (1984) and http://www. geol.vt.edu/outreach/vtso/focmec (2003).
18. L. Toth, P. Monus, Zsiros T, *Hungarian Earthqauke Bulletin, 1997*, Georisk, Budapest, p. 68, (1998).
19. L. Toth, P. Monus, T. Zsiros, M. Kiszely, *Seismicity in the Pannonian Region–earthquake data*, EGU Stephan Mueller Special Publication Series, **3**, 9–28 (2002).
20. G. P. Waite, R. B. Smith, *Seismotectonics and stress field of the Yellowstone volcanic plateau from earthquake first–motions and other indicators*, J. Geophys. Res., 109, B02301, doi: 10. 1029/2003JB002675, (2004).
21. *** *International Seismological Centre, 1991–1992 ISC Catalogues*, Newbury, www.isc.ac.uk.