

Seismic activity on the territory of Slovakia in 2017

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Abstract: The National Network of Seismic Stations of Slovakia (NNSS) consists of eight short period and five broadband permanent seismic stations and a data centre located at the Earth Science Institute of the Slovak Academy of Sciences (ESI SAS). The NNSS recorded and detected 10 719 seismic events from all epicentral distances in 2017. Totally 73 earthquakes originated in the territory of Slovakia in 2017. This paper provides basic information on the configuration of the NNSS, routine data processing, seismic activity on the territory of Slovakia in 2017 as well as macroseismic observations collected in 2017.

Key words: Slovakia, National Network of Seismic Stations, seismicity, macroseismic observations

1. Introduction

The aim of this paper is to provide a quick overview of earthquakes which originated on the territory of Slovakia or were macroseismically felt on the territory of Slovakia in 2017. The seismic activity on the territory of Slovakia and adjacent areas has been reported on the daily basis by the so called Seismo Reports published on the web sites of the Department of Seismology, ESI SAS http://www.seismology.sk/Seismo_Reports/reports.html and in annual reports as a part of the project Partial monitoring system – Geological factors (*Liščák et al., 2018*) which is solved with a contract between ESI SAS and State Geological Institute of Dionýz Štúr.

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2. Seismic stations operating in 2017

The seismic monitoring of the Slovak territory is provided by the NNSS operated by the ESI SAS (*ESI SAS, 2004*), *Local Seismic Network in Eastern Slovakia* operated by the Faculty of Mathematics, Physics and Informatics of the Comenius University in Bratislava and local network of seismic stations around NPPs Jaslovské Bohunice and Mochovce operated by Progseis Ltd. company. The networks of seismic stations cooperate and the exchange of data is on the regular basis. The positions of the seismic stations on the territory of Slovakia are shown in Fig. 1.

In 2017 the NNSS consisted of thirteen permanent seismic stations, from which eight are short period and five are broadband. Broadband stations are: Červenica (CRVS), Kolonické sedlo (KOLS), Modra (MODS), Vyhne (VYHS) and Železná studnička (ZST). Short period stations are: Hurbanovo (HRB), Izabela (IZAB), Iža (SRO1), Kečovo (KECS), Liptovská Anna (LANS), Moča (SRO2), Stebnícka Huta (STHS) and Šrobárová (SRO). The HRB is the oldest NNSS seismic station that has been in operation since 1909 (*Pajdušák, 1997*). In the year 2017 no significant changes were realized in instrumental equipment of the seismic stations. The NNSS permanent seismic stations and their instrumentation are summarized in Table 1. More

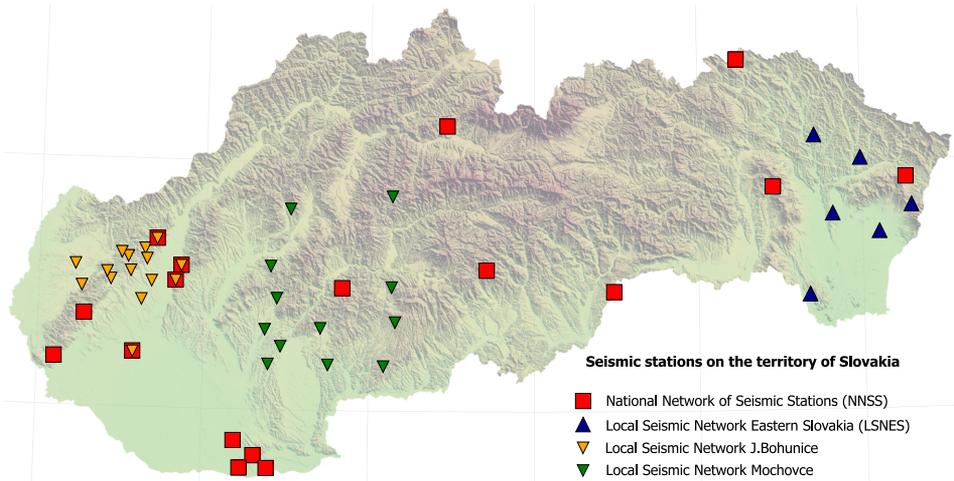


Fig. 1. Seismic stations operational on the territory of Slovakia in 2017.

details can be found on the web page http://www.seismology.sk/National_Network.

Table 1. Equipment of seismic stations of the NNSS operating in 2017.

Station	ISC code	Lat. [°N]	Long. [°E]	Alt. [m]	Sensor	DAS	Sampl. freq.	Data format
Bratislava Žel. Studnička	ZST	48.196	17.102	250	3×SKD	Wave24	100/sec	mSEED
Červenica	CRVS	48.902	21.461	476	STS-2	Wave24	100/sec	mSEED
Vyhne	VYHS	48.493	18.836	450	STS-2	Wave24	100/sec	mSEED
Modra-Piesok	MODS	48.373	17.277	520	STS-2	Wave32	100/sec	mSEED
Hurbanovo	HRB	47.873	18.192	115	2× Mainka	Analog	–	smoked paper
Izabela	IZAB	48.569	19.713	450	3×SM3	Wave24	100/sec	mSEED
Iža	SRO1	47.7622	18.2328	111	ViGeo	Gaia	100/sec	mSEED
Kečovo	KECS	48.483	20.486	345	LE3D	Wave24	100/sec	mSEED
Kolonické sedlo	KOLS	48.933	22.273	460	Guralp-6T-30s	Wave32	100/sec	mSEED
Liptovská Anna	LANS	49.151	19.468	710	LE3D	SEMS	100/sec	mSEED
Moča	SRO2	47.763	18.394	109	Guralp-40T-1s	Wave24	100/sec	mSEED
Stebnícka Huta	STHS	49.417	21.244	534	LE3D	Wave24	100/sec	mSEED
Šrobárová	SRO	47.813	18.313	150	3× SKM-3	Wave24	100/sec	mSEED

Four additional short period seismic stations has been operated on the jointly bases of ESI SAS and the other institutions. The seismic stations Banka (BAN), Podolie (POD) and Jalšové (JAL) located in the Little Carpathians have been operated in cooperation with Progseis Ltd. company and the Institute of Rock Structure and Mechanics of the Czech Academy of Sciences (IRSM CAS) (*Fojtíková et al., 2015*). The seismic station Pusté Úľany (PULA) has been operated in cooperation with the IRSM CAS. These stations have been installed as temporary seismic stations.

3. Data processing

Digital data from all NNSS stations (except the analog seismic station HRB) are transferred in real-time to the data centre at the ESI SAS either by the internet or satellite telemetry. Software package SeisComp3 (*Weber et al., 2007*) and SeedLink server are used for data acquisition and exchange.

Beside observations from the NNSS stations the data centre at ESI SAS also use the data from the above mentioned local networks of seismic stations in Slovakia and observations from networks of neighbouring countries: Austrian Seismic Network (*ZAMG – Zentralanstalt für Meteorologie und Geodynamik, 1987*), Czech Regional Seismic Network (*Institute of Geophysics, Academy of Sciences of the Czech Republic, 1973*), Hungarian National Seismological Network (*Kövesligethy Radó Seismological Observatory, 1992*), Local seismological network for monitoring NPP Dukovany (*Institute of Physics of the Earth Masaryk University, 2014*), GEOFON Seismic Network (*GEOFON Data Center, 1993*), *Polish Seismological Network*. These stations form a so-called Regional Virtual Network of ESI SAS that consists of approximately 55 seismic stations.

Routine analysis of the digital recordings at the ESI SAS has been performed by the Unix package Seismic handler (*Stammler, 1993*). Interactive locations of seismic events within Seismic Handler are performed by external program LocSat. The collected digital observations are manually processed on the daily basis. The epicentre locations are based on the IASPI91 travel-time curves. Local magnitudes have been determined from the maximum vertical trace amplitudes of Sg waves, using the pre-defined Seismic Handler formula for local events. Continuous raw seismic data from the NNSS are stored in a local archive and seismic data interpretations (together with information on equipment of stations) are stored in a web accessible database.

4. Seismic activity in 2017

The NNSS analyzed 10719 local, regional and teleseismic events in 2017. More than 42200 seismic phases were determined. Seismic events identified as quarry blasts were excluded from further processing and were not included in the event statistics. All events recorded by the NNSS and analyses at the data centre at ESI SAS has been reported in the so called Seismo Reports and published on the above mentioned web sites of the Department of Seismology, ESI SAS.

Altogether 73 seismic events located by the NNSS originated in the territory of Slovakia in 2017 (Fig. 2). Known quarry blasts are not included in this number. 40 earthquakes reached local magnitude 1.0 or more and

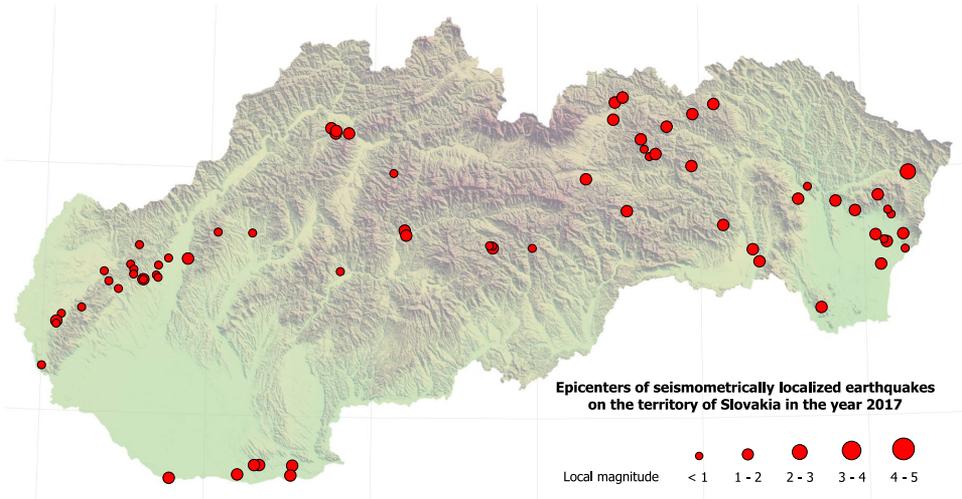


Fig. 2. Map of epicentres of local earthquakes originated on the territory of Slovakia in 2017. Diameters of the circles are proportional to local magnitudes.

are listed in Table 2. The strongest earthquake was detected on June 16 at 13:38 UTC with local magnitude M_L 2.3.

The seismicity of the Slovak territory is dominated by the Little Carpathians and Komárno seismic source zones (Hók *et al.*, 2016). The strongest earthquake in the Little Carpathians source zone was detected on the March 25 at 19:11 UTC with local magnitude M_L 1.7. The strongest earthquake in the Komárno source zone was detected on the December 12 at 16:28 UTC with local magnitude M_L 1.8. Although the low level of seismic activity from the last decades remained unchanged also in 2017, these two source zones remain of the primary interest for the monitoring of seismic activity within the territory of Slovakia.

5. Macroseismic observations

Five earthquakes were macroseismically felt on the territory of Slovakia in 2017 (Table 3), all of them with the epicentre on the territory of Slovakia (Fig. 3). These five earthquakes were also seismometrically observed and processed. Intensities were estimated by the European Macroseismic Scale 1998 (EMS-98) introduced by Grünthal (1998).

Table 2. List of earthquakes originated on the territory of Slovakia in 2017 with $M_L \geq 1.0$.

Date [YYYY-MM-DD]	Origin Time (UTC) [HH:MM:SS]	Lat. [°N]	Lon. [°E]	Depth [km]	M_L [NNSS]	I_0 [°EMS]	Region
2017-01-21	22:16:21.06	48.36	17.08	0	1.6		Little Carpathians
2017-02-12	08:55:25.40	47.74	17.79	3.3	1.4		Gabčíkovo – Komárno – Štúrovo
2017-02-22	11:59:15.95	47.80	18.53	1.5	1.0		Gabčíkovo – Komárno – Štúrovo
2017-02-23	01:35:37.53	49.15	18.84	0	1.3		Žilina region
2017-03-01	12:36:27.73	48.89	22.09	7.9	1.9		Vihorlat Mts.
2017-03-16	11:29:22.88	48.84	20.55	3.1	1.4		Volovec Mts.
2017-03-17	11:44:02.90	48.87	21.83	0	1.3		Vihorlat Mts.
2017-03-25	19:11:39.40	48.54	17.60	2.6	1.7		Little Carpathians
2017-04-15	04:12:26.38	48.76	19.19	0.1	1.6	3	Banská Bystrica region
2017-04-15	04:23:45.82	48.74	19.20	0	1.4	felt	Banská Bystrica region
2017-04-24	07:31:54.76	48.88	21.60	0.2	1.0		Slanské Hills
2017-05-03	01:49:27.05	48.73	22.24	4	1.5		Vihorlat Mts.
2017-05-14	21:50:06.53	47.76	18.20	4.9	1.4		Gabčíkovo – Komárno – Štúrovo
2017-05-18	10:16:48.78	48.78	21.14	0	1.3		Volovec Mts.
2017-05-26	08:35:03.48	49.13	20.64	0	1.5		Levoča Mts.
2017-05-31	11:55:04.23	48.70	22.14	0	1.3		Eastern Slovak Lowland
2017-06-05	14:32:21.41	49.23	20.96	0	1.5		Čergov Mts.
2017-06-06	08:41:54.08	49.21	20.47	0	1.3		Levoča Mts.
2017-06-07	10:10:28.05	49.27	21.09	0	1.6		Čergov Mts.
2017-06-16	13:38:20.58	48.98	22.28	10.8	2.3		Bukovec Mts.
2017-06-29	15:03:14.18	49.02	20.95	10	1.6		Šariš region
2017-06-30	23:53:22.30	48.69	19.73	0	1.4		Vepor Mts.

Table 2. Continued from the previous page.

Date [YYYY-MM-DD]	Origin Time (UTC) [HH:MM:SS]	Lat. [°N]	Lon. [°E]	Depth [km]	M_L [NNSS]	I_0 [°EMS]	Region
2017-07-13	03:25:02.68	48.73	22.07	7.7	1.6		Eastern Slovak Lowland
2017-08-21	10:37:34.91	48.63	21.36	0	1.1		Slanské Hills
2017-08-21	10:44:09.68	49.18	20.80	0	1.0		Levoča Mts.
2017-09-04	15:30:13.37	48.61	22.10	5.2	1.9		Eastern Slovak Lowland
2017-09-12	14:58:34.96	49.28	20.48	0	1.6		Spiš Magura
2017-10-09	08:14:28.58	48.83	21.95	5.9	1.1		Vihorlat Mts.
2017-10-15	04:06:42.66	49.30	20.53	0	1.2		Spiš Magura
2017-10-23	01:04:11.48	48.97	20.30	0	1.1		Spiš region
2017-10-23	14:42:22.25	48.68	21.32	0	1.1		Košice basin
2017-11-02	11:49:04.77	49.07	20.73	0	1.6		Levoča Mts.
2017-11-10	07:50:48.82	49.17	18.73	0	1.0	felt	Žilina region
2017-11-14	16:22:45.98	49.15	18.76	2.3	1.5	3	Žilina region
2017-11-15	15:34:05.16	48.44	21.73	0	1.2		Zemplén Mts.
2017-12-08	10:33:14.35	47.76	18.52	8.6	1.3		Gabčíkovo – Komárno – Štúrovo
2017-12-11	13:04:56.46	49.16	18.76	0	1.5		Žilina region
2017-12-12	06:53:27.88	48.63	17.87	1.1	1.4		Považský Inovec Mts.
2017-12-12	16:28:32.89	47.80	18.33	10	1.8	3	Gabčíkovo – Komárno – Štúrovo
2017-12-12	23:05:36.16	47.80	18.30	0	1.7		Gabčíkovo – Komárno – Štúrovo

The earthquake on April 15 at 4:12 UTC with epicentre near Banská Bystrica and local magnitude 1.6 was macroseismically felt on 2 locations (Table 4). 5 macroseismic questionnaires were filled. The event was described as a light trembling. The epicentral intensity was determined at 3° EMS-98. The aftershock with local magnitude 1.4 occurred 11 minutes

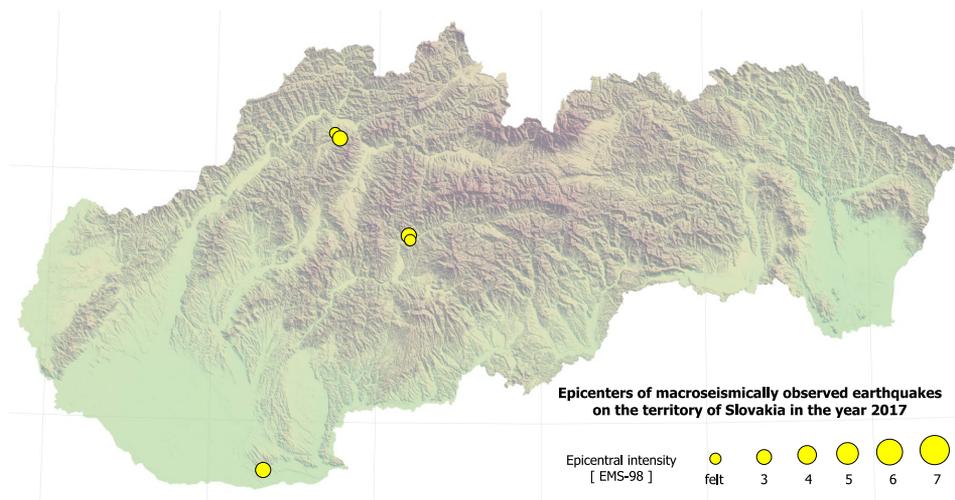


Fig. 3 Map of epicentres of macroseismically observed earthquakes on the territory of Slovakia in 2017. Diameters of the circles are proportional to epicentral intensity.

Table 3. List of macroseismically observed earthquakes on the territory of Slovakia in 2017.

Date [YYYY-MM-DD]	Origin Time (UTC) [HH:MM:SS]	Lat. [°N]	Lon. [°E]	Depth [km]	M_L [NNSS]	I_0 [°EMS]	Region
2017-04-15	04:12:26.4	48.76	19.19	0.1	1.6	3	Banská Bystrica
2017-04-15	04:23:45.8	48.74	19.20	0	1.4	–	Banská Bystrica
2017-11-10	07:50:48.8	49.17	18.73	0	1.0	–	Žilina
2017-11-14	16:22:45.9	49.15	18.76	2.3	1.5	3	Žilina
2017-12-12	16:28:32.9	47.80	18.33	10	1.8	3	Komárno

Table 4. Macroseismic observations for April 15, 2017 earthquake, 4:12 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	I [°EMS-98]
Banská Bystrica	48.733	19.143	4	3
Selce	48.764	19.207	1	felt

later at 4:23 UTC. Because of lack of macroseismic data it was not possible to determine the epicentral intensity of the aftershock (Table 5).

The earthquake on November 10 at 7:50 UTC with epicentre near Žilina and local magnitude 1.0 was macroseismically felt on 1 location (Table 6). Because of lack of macroseismic data it was not possible to determine the epicentral intensity.

The earthquake on November 14 at 16:22 UTC with epicentre near Žilina and local magnitude 1.5 was macroseismically felt on 6 locations (Table 7). 27 macroseismic questionnaires were filled. The event was described as a light trembling. Some people reported acoustic effects – light detonation similar to a blast in a distant quarry. The epicentral intensity was determined at 3° EMS-98.

The earthquake on December 12 at 16:28 UTC with epicentre near the village Marcelová (Komárno source zone) and local magnitude 1.8 was macroseismically felt on 1 location (Table 8). 7 macroseismic questionnaires were filled. All people reported acoustic effects – explosion similar to an explosion of a gas cylinder. The event was described as a light trembling. The epicentral intensity was determined at 3° EMS-98.

Table 5. Macroseismic observations for April 15, 2017 earthquake, 4:23 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Banská Bystrica	48.733	19.143	1	felt

Table 6. Macroseismic observations for November 10, 2017 earthquake, 7:50 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Turie	49.149	18.753	1	felt

Table 7. Macroseismic observations for November 14, 2017 earthquake, 16:22 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Turie	49.149	18.753	21	3
Porúbka	49.154	18.725	2	3
Poluvšie	49.121	18.697	1	3
Bytčica	49.178	18.739	1	felt
Lietava	49.170	18.673	1	felt
Lietavská Svinná	49.152	18.675	1	felt

Table 8. Macroseismic observations for December 12, 2017 earthquake, 16:28 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Marcelová	47.792	18.283	7	3

6. Conclusion and discussion

The NNSS is operated by the ESI SAS, Bratislava. Data from all stations (except station HRB) are transferred in real-time to the data centre at Bratislava. Data processing and routine analysis are performed digitally by interactive seismological software Seismic Handler. Digital data are accessible both on-line and off-line in standard data format. So called Seismo Reports of seismic events recorded by NNSS are published on the web page of the ESI SAS <http://www.seismology.sk/SeismoReports/reports.html>.

The lack of system approach to financing of the NNSS persisted also in 2017. The costs of NNSS are higher than a financial contribution from the budget of the Slovak Academy of Sciences. Besides this fact, only finances for a day-to-day operation were provided with no amount for an equipment modernization.

Epicentres and local magnitudes were determined for 73 earthquakes originated in the territory of Slovakia in 2017. Weak seismic activity was recorded from several seismic source zones: Little Carpathians., Komárno, Banská Bystrica, Vihorlat Mts. and Levoča Mts.

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