

Seismic activity on the territory of Slovakia in 2016

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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 10888 seismic events from all epicentral distances in 2016. Totally 87 earthquakes originated in the territory of Slovakia in 2016. This paper provides basic information on the configuration of the NNSS, routine data processing, seismic activity on the territory of Slovakia in 2016 as well as macroseismic observations collected in 2016.

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

1. Introduction

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., 2017*) which is solved with a contract between ESI SAS and State Geological Institute of Dionýz Štúr. The aim of this paper is to provide a quick

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overview of earthquakes which originated on the territory of Slovakia or were macroseismically felt on the territory of Slovakia in 2016.

2. Seismic stations operating in 2016

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 2016 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), Iža (SRO1), Kečovo (KECS), Liptovská Anna (LANS), Moča (SRO2), Stebnícka Huta (STHS) and Šrobárová (SRO). The HRB

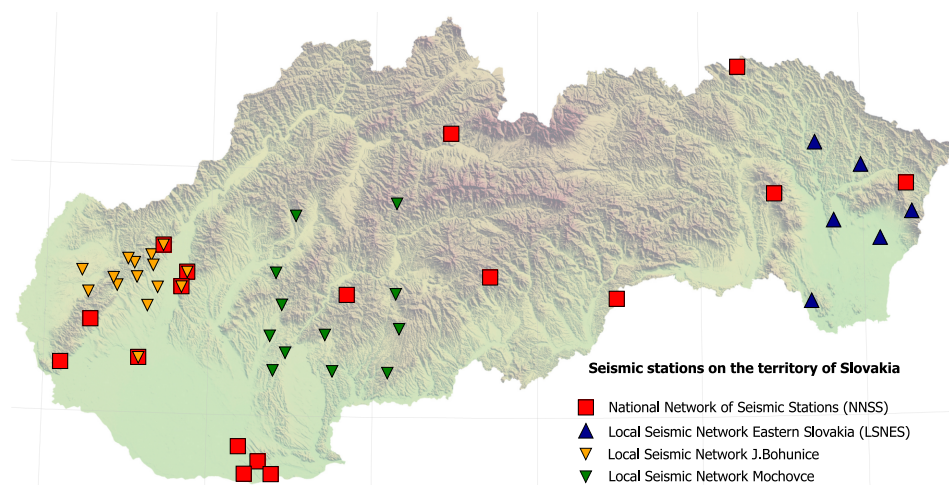


Fig. 1. Seismic stations operational on the territory of Slovakia in 2016.

is the oldest NNSS seismic station that has been in operation since 1909 (*Pajdušák, 1997*). In 2016, the seismic station Izabela (IZAB) has been added to the NNSS as a new permanent short period seismic station. This station has been jointly operated by ESI SAS and Progseis Ltd. company. In this year the seismic station MODS has been upgraded with a 6-channel 32-bit digitizer and an EpiSensor has been installed. The NNSS permanent seismic stations and their instrumentation are summarized in Table 1. More 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 2016.

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 has 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 forms 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 has 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 2016

The NNSS analyzed 10888 local, regional and teleseismic events in 2016. More than 40600 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 87 seismic events located by the NNSS originated in the territory of Slovakia in 2016 (Fig. 2). Known quarry blasts are not included in this number. 28 earthquakes reached local magnitude 1.0 or more and are listed in Table 2. The strongest earthquake was detected on April 18 at 13:20 UTC with local magnitude M_L 1.9.

The seismicity of the Slovak territory is dominated by the Little Carpathians and Komárno seismic source zones. The strongest earthquake in the Little Carpathians source zone was detected on the December 12 at 21:43 UTC with local magnitude M_L 1.4. The strongest earthquake in the Komárno source zone was detected on the June 23 at 21:52 UTC with local magnitude M_L 1.4. Although the low level of seismic activity from the last decades remained unchanged in 2016, these two source zones remains of the primary interest for the monitoring of seismic activity within the territory of Slovakia.

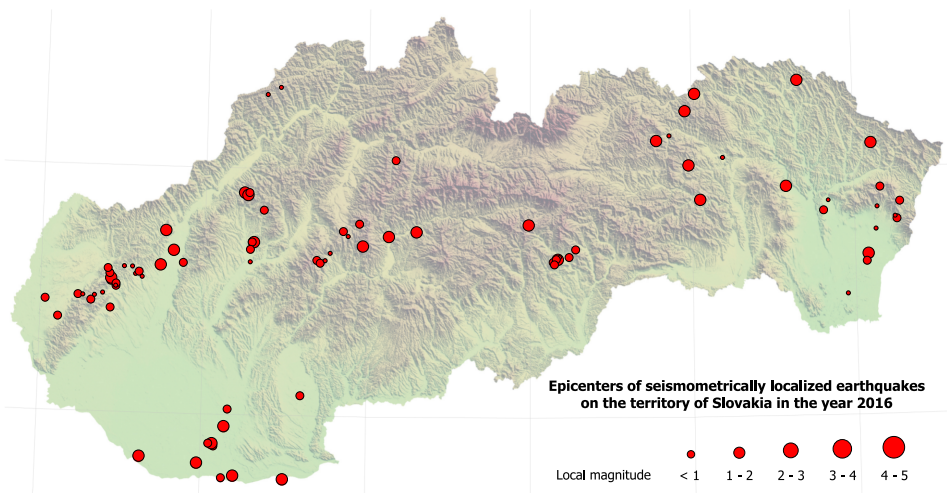


Fig. 2. Map of epicenters of local earthquakes originated on the territory of Slovakia in 2016. Diameters of the circles are proportional to local magnitudes.

Table 2. List of earthquakes originated on the territory of Slovakia in 2016 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
2016-01-24	22:18:56.83	48.64	20.17	0	1.6		Revúca Highlands
2016-02-13	21:34:17.90	48.75	19.30	0	1.0		Upper Hron River region
2016-03-31	09:10:51.76	47.74	18.50	0	1.2		Šamorín – Komárno – Štúrovo
2016-04-15	12:56:16.97	48.65	22.08	2.4	1.5		Eastern Slovak Lowland
2016-04-15	17:30:25.25	48.70	18.30	0.2	1.0		Strážov Mts.
2016-04-18	13:20:39.86	49.24	20.96	0	1.9		Čergov Mts.
2016-05-03	05:12:59.03	47.88	18.07	0	1.0		Šamorín – Komárno – Štúrovo
2016-05-05	08:18:20.67	49.36	21.66	21.6	1.6		Laborec Highlands
2016-05-29	08:26:21.82	47.80	17.98	1.5	1.1		Šamorín – Komárno – Štúrovo
2016-06-01	05:34:50.91	48.54	17.43	1.9	1.1		Little Carpathians
2016-06-10	07:43:05.26	48.88	21.05	0	1.1		Šariš
2016-06-23	21:52:19.25	47.75	18.20	0	1.4		Šamorín – Komárno – Štúrovo
2016-06-24	08:44:43.24	48.74	17.76	8.3	1.3	3	Little Carpathians
2016-06-25	00:33:01.20	48.73	19.13	0	1.1		Banská Bystrica region
2016-06-30	19:35:51.24	48.60	17.73	2	1.1		Little Carpathians
2016-07-11	10:37:40.28	49.31	21.02	4.2	1.6		Čergov Mts.
2016-07-26	10:46:55.58	48.93	21.58	6	1.1		Slanské Hills
2016-07-30	09:36:11.71	49.10	22.11	0	1.5		Laborec Highlands
2016-08-07	19:20:12.61	48.69	18.97	0	1.4		Kremnica Mts.
2016-08-13	22:30:30.47	48.90	18.24	1	1.3		Strážov 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
2016-08-25	04:58:42.28	47.95	18.14	0	1.3		Šamorín – Komárno – Štúrovo
2016-08-26	23:50:14.51	48.89	18.26	2.4	1.1		Strážov Mts.
2016-09-29	05:58:11.72	48.78	19.99	0	1.3		Muráň Plateau
2016-10-09	20:45:11.06	47.82	17.63	0	1.4		Šamorín – Komárno – Štúrovo
2016-10-17	11:39:51.89	49.02	20.98	7.1	1.6		Šariš
2016-11-25	09:29:47.57	49.12	20.78	0	1.4		Levoča Mts.
2016-12-12	21:43:31.28	48.66	17.81	3.7	1.4		Little Carpathians

5. Macroseismic observations

Two earthquakes were macroseismically felt on the territory of Slovakia in 2016, one with the epicentre in Austria and one with the epicentre on the territory of Slovakia (Table 3). These two earthquakes were also seismometrically observed and processed. Intensities were estimated by the European Macroseismic Scale 1998 (EMS-98) introduced by *Grünthal (1998)*.

The earthquake on April 25 at 10:28 UTC with epicentre near Vienna, Austria and local magnitude 4.1 was macroseismically felt on 9 locations within the territory of Slovakia (Table 4). 12 macroseismic questionnaires were filled. People reported weak trembling or shaking and acoustic effects

Table 3. List of macroseismically observed earthquakes on the territory of Slovakia in 2016.

Date [YYYY-MM-DD]	Origin Time (UTC) [HH:MM:SS]	Lat. [°N]	Lon. [°E]	Depth [km]	M_L [NNSS]	I_0 [°EMS]	Region
2016-04-25	10:28:23.6	48.02	16.16	14.1	4.0	5–6	Austria
2016-06-24	08:44:43.2	48.74	17.76	8.3	1.3	3	Little Carpathians

Table 4. Macroseismic observations for April 25, 2016 earthquake, 10:28 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Bratislava 5	48.111	17.112	3	3
Bratislava 4	48.159	17.052	2	3
Bratislava 1	48.147	17.102	1	3
Galanta	48.198	17.734	1	3
Kolíňany	48.351	18.229	1	3
Orechová Potôň	48.036	17.564	1	3
Pezinok	48.298	17.270	1	3
Modrý Kameň	48.248	19.324	1	felt
Veľká Lomnica	49.112	20.354	1	felt

– rumbling. The maximum intensity on the territory of Slovakia was determined at 3° EMS-98.

The earthquake on June 24 at 8:44 UTC with epicentre in the northern part of Little Carpathians (near Nové Mesto nad Váhom) and local magnitude 1.3 was macroseismically felt on 1 location (Table 5). 2 macroseismic questionnaires were filled. The event was described as a light trembling. The epicentral intensity was determined at 3° EMS-98.

Table 5. Macroseismic observations for June 24, 2016 earthquake, 8:44 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Nové Mesto nad Váhom	48.758	17.829	2	3

6. Conclusion and discussion

The NNSS is operated by the ESI SAS, Bratislava. In 2016 a new seismic station Izabela was added to the NNSS and an EpiSensor was installed in the Little Carpathians source zone in seismic station MODS. 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/Seismo_Reports/reports.html.

Epicentres and local magnitudes were determined for 87 earthquakes originated in the territory of Slovakia in 2016. Weak seismic activity was recorded from several seismic source zones: Little Carpathians, Komárno, Strážov Mts., Čergov Mts., Revúca Highlands and Vihorlat Mts.

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