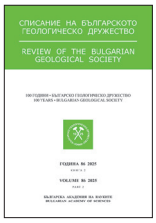
СПИСАНИЕ НА БЪЛГАРСКОТО ГЕОЛОГИЧЕСКО ДРУЖЕСТВО,
год. 86, кн. 2, 2025, с. 216–220

REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY,
vol. 86, part 2, 2025, p. 216–220



Seismic station GIOL: preliminary seismogram analyses

Elitza Pandourska, Lyuben Kodinov, Lyuba Dimova, Milen Tsekov, Reneta Raykova

Faculty of Physics, Sofia University "St. Kliment Ohridski", 5 J. Bourchier Blvd., 1164 Sofia; Email: elitzapiano@gmail.com

Elitza Pandourska, Lyuben Kodinov, Lyuba Dimova, Milen Tsekov, Reneta Raykova. 2025. Seismic station GIOL: preliminary seismogram analyses. – *Rev. Bulg. Geol. Soc*., *86*, 2, 216–220, https://doi.org/10.52215/rev.bgs.2025.86.2.216.

Abstract. Seismic station GIOL is the third station from the Bulgarian University Seismic Network, operated at the Faculty of Physics of Sofia University "St. Kliment Ohridski". The station was recently installed (August 26th, 2025) and is equipped with the broadband seismometer SS08, and digitizer with internal memory SL06. Preliminary analyses of the registered seismograms include noise spectra analysis, seismic phase identification, earthquake spectra parameter determination, frequency-time analysis for dispersion curve extraction. Noise analysis reveals the station GIOL as the quietest one among all three stations. Seismic phase identification guided by theoretical travel times and joint analysis of records from several stations is necessary. Accumulation of a large number of earthquake spectra in time will lead to seismic moment magnitude definition. Dispersion curves indicate the properties of the structure along the wave propagation path. Results of the analyses are organized in a database facilitating future studies.

Keywords: Seismic Network, Seismic Station, seismic noise, seismic phases, dispersion curves.

Introduction

The Virtual Seismological Network of Sofia University (VSNSU) was established in 2015 with the support of the Scientific Research Fund of Sofia University "St. Kliment Ohridski". Open real-time seismic data from several national and international stations located on the Balkan Peninsula were analyzed (Raykova et al., 2018; Dimova et al., 2019; Dragomirov et al., 2021). The first real seismic station was established in 2023, and the Bulgarian University Seismic Network (BUSN) is officially registered with code "B" through the International Federation of Digital Seismograph Networks (https://doi.org/10.7914/tawk-rh33). The first station SOFSU (location code 00) was installed in the Faculty of Physics and included a Geophone seismometer (4.5 Hz) (Dimova et al., 2023). Later, the Velbox seismic set combining a SS02 seismometer (0.2 Hz) and an SL06 digitizer of SARA Electronic Instruments s.r.l. was added (location code 10). The second station, SRKO, has been operating in the village of Sredni Kolibi since August 2024. It consists of a broadband SS08 seismometer (flat response from 50 Hz to 120 s) and an SL06 digitizer with internal memory. The performance of the station is excellent, and several studies have been done using the data from SRKO (Dimova, Raykova, 2024).

In September 2025, a third station with station code GIOL and with the same equipment as SRKO station, was established in Giolechitza, Rila Mountains near Govedartzi village. In this work we present preliminary analysis of the seismic data from this station: seismic noise, seismic phase identification, dispersion curve extraction for teleseismic events.

Location of the station GIOL and its equipment

Gyulechitsa station (GIOL) is located in the Rila Mountains, near the village of Govedartsi in the

© Българско геологическо дружество и Българска академия на науките, 2025

Gyulechitsa locality, where a holiday base of the Sofia University is situated (see Fig. 1a). The place is far from anthropogenic sources of noise, and the seismometer is installed on the ground floor that is two levels under the main floor of the building. The station has coordinates 42.230543°N, 23.399712°E and an elevation of 1435 m.

The seismological equipment is produced by SARA Electronic Instruments s.r.l. and consists of a broad-band seismometer SS08 and a digitizer SL06 (Fig. 1b). The response spectrum of SS08 is flat between 50 Hz and 120 s. The instrument is able to register local, regional, and teleseismic earthquakes. The digitizer SL06 has internal memory

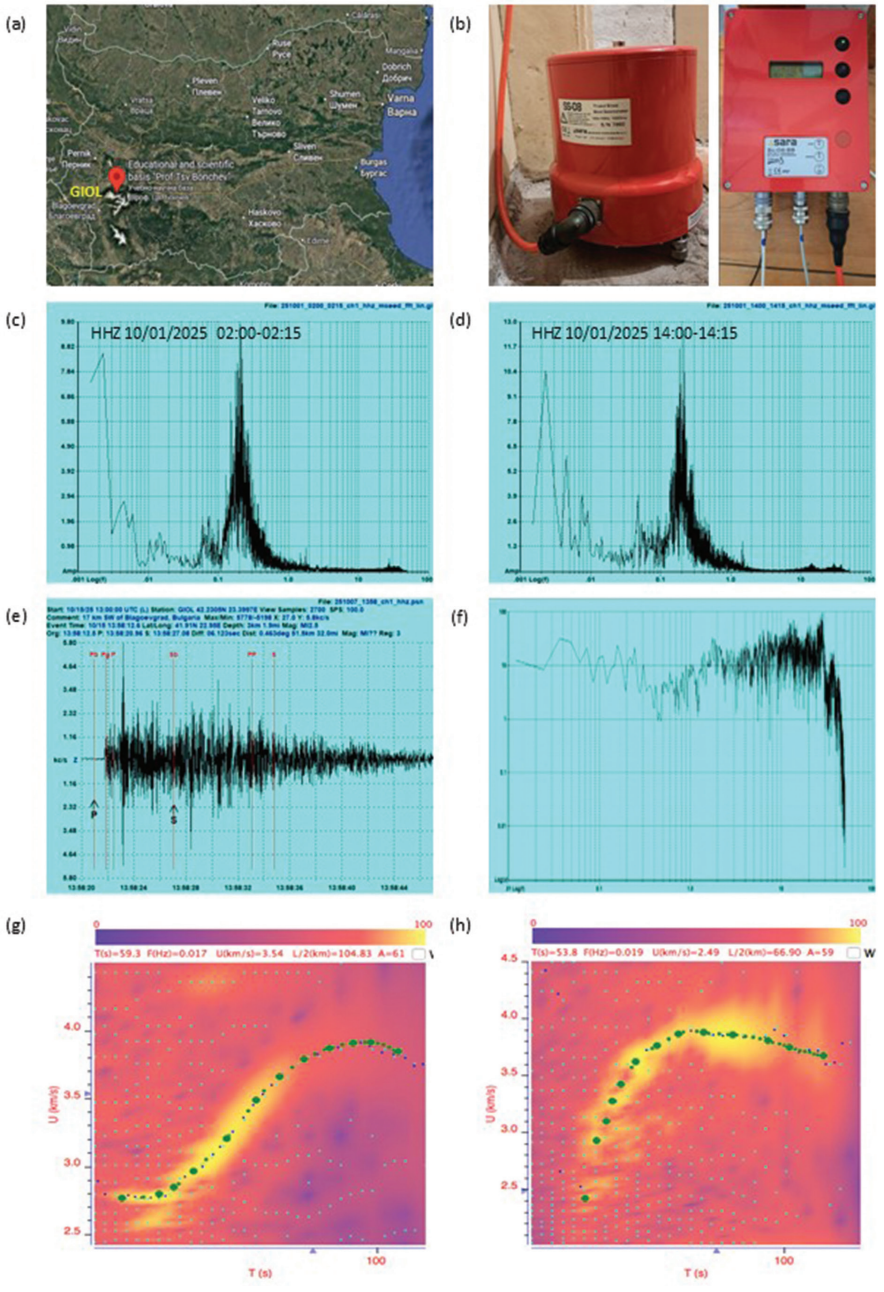


Fig. 1. (*a*) Location of GIOL station; (*b*) equipment installed at GIOL station – SS08 seismometer (100Hz – 120s) and SL06 digitizer; (*c–d*) 15-minute averaged amplitude spectrum of seismic noise during working day (*c*) component HHZ night; (*d*) component HHZ day; (*e*) seismogram of component HHZ and theoretical seismic phases for a registered earthquake (15.10.2025 13:58:12.6, Ml2.5, Bulgaria – data from www.emsc-csem.org); (*f*) FFT spectrum of the earthquake with logarithmic amplitude representation on the Y-axis; (*g*) frequency-time diagram of the Kamchatka earthquake (9.10.2025 13:28:44.2) and traced dispersion curve (green circles); and (*h*) frequency-time diagram of the Drake-Passage earthquake (10.10.2025 20:29:22.0) and traced dispersion curve (green circles).

and low power consumption. A Linux-based operating system and a small screen allow direct communication with the digitizer. There is also an option to configure the system via web-based user-friendly software. The time and exact location of the seismic records are guaranteed by a GPS receiver connected to the digitizer.

The data from the instrument are transferred in near-real time via ethernet connection to a server at the Faculty of Physics in Sofia. The software used for data transferring, SEISMOLOG, is developed by the producer SARA. The digitalization frequency of the data is 100 samples per second.

Seismic data from the station are stored in the MiniSEED format on the server's hard disks as well as on an external disk as a backup copy. By default, the organization of the data is in continuous one-hour files for each channel. A procedure to archive the station GIOL data at the international data center SAGE (www.iris.edu) is in progress.

Seismic noise analysis

Seismic noise spectra were analyzed to evaluate the quality of the seismic records. Frequency spectra were calculated for several 15-minutes intervals during the night and day (between 02:00 and 02:15 and between 14:00 and 14:15). Fast Fourier transform was used to calculate the frequency spectra of 15-minutes records. The station is located far from settlements and industrial infrastructures; therefore, the noise is not correlated to working and holiday days. The day and night noise spectra are influenced mainly by weather conditions and the number of visitors in the building. The spectral amplitudes are comparable during the night and day and the shapes of the two spectra are very similar (Fig. 1c, d). For comparison, the amplitude of the noise in the SOFSU station during the night is almost twice as low as the noise amplitude during the day. For station, SRKO amplitude of the daily noise is much higher than the night noise (Pandourska et al., 2025). Seismic noise level of the station GIOL is the lowest in respect to the other two stations of BUSN.

Seismic phase identification

Identification of the seismic phases generated by an earthquake is crucial for the building of a comprehensive 3D model of the Earth, but it is not a trivial task. The theoretical seismic phases are used as a guide to identify the exact time of arriving of specific seismic phases at the station GIOL. However, theoretical phases are calculated assuming radially symmetrical Earth and a specific global velocity model (as PREM, Dziewonski, Anderson, 1981; IASP91, Kennett, Engdahl, 1991; ak135, Kennett et al., 1996). The arrival times of a specific phase calculated using different global models may differ by a few seconds. The deviation of the real structure from the global model may result in travel-time difference of tens of seconds. Additional complication is the error in the estimated origin time that varies in the solutions from various data centers and sometimes exceeds 10 s.

We identify the seismic phases of several earthquakes (listed in Table 1) and estimate the arrival times of clear seismic phases that are close to the

Table 1. Parameters of the analyzed events

Date	Time (UTC)	Latitude	Longitude	Region name	Depth (km)	Magnitude Type	Magnitude
9/28/2025	9:59:16	39.222	28.994	WESTERN TURKEY	9	Mw	5.3
9/29/2025	23:10:50	41.81	22.754	REPUBLIC OF NORTH MACEDONIA	11	ML	2.7
10/7/2025	2:33:36	43.573	21.804	SERBIA	1	M	2.7
10/7/2025	11:05:17	–6.721	146.823	EASTERN NEW GUINEA REG. P.N.G.	98	Mw	6.6
10/9/2025	13:28:44	51.655	158.245	NEAR EAST COAST OF KAMCHATKA	49	Mw	6.1
10/10/2025	20:29:22	–60.182	–61.879	DRAKE PASSAGE	10	Mw	7.6
10/15/2025	13:58:12	41.91	22.95	BULGARIA	3	ML	2.5
10/16/2025	2:45:37	–58.727	–62.216	DRAKE PASSAGE	10	Mw	5.2

theoretical estimates. Apart from P and S, usually well distinguished phases are: Pg, Sg for local earthquakes; PP, SS, PS for regional earthquakes; and PKP for teleseismic events. Figure 1e shows the seismogram of the vertical component of the station GIOL with a recording of an earthquake in Bulgaria (15.10.2025 13:58:12.6, Ml 2.4). The record is very complicated, the S phase is not visible, and the waveform may be composed of several very close in time events. In order to better identify, the phase analysis of records from several stations with different back-azimuth to the epicenter should be considered.

Earthquake spectrum

The seismic spectrum of specific events is related to the moment magnitude M_W, with the corner frequency decreasing as magnitude increases. The average amplitude of the flat low-frequency part of the spectrum of an event is related to the scalar value of the seismic moment. The relation between this value and the M_W should be tuned by accumulating a statistically significant number of event spectra. We should also keep in mind that each seismic zone has peculiarities reflected in the spectrum of the earthquakes that lead to the increase in the number of required events (e.g., Munafo et al, 2015). A database of spectra of each identified event is created in order to accumulate the necessary quantity of data. The spectrum of a Bulgarian event is shown in Figure 1f. The corner frequency of the spectrum is about 20 Hz. Flat low-frequency level is well distinguished.

Dispersion curve analysis

Dispersion curves of seismic surface waves give the relation between the velocity of wave propagation and the wave period. The waves with a longer period penetrate deeper in the solid Earth. In this way, knowing the velocity at a certain depth range, we can obtain some information about the physical properties of the material at these depths. Thus, dispersion curves indicate the structure along the wave propagation path. To obtain dispersion curves from seismograms, recorded at the station GIOL, we use Frequency-Time analysis (Keili-Borok, Levshin, 1989) that represents one-dimensional time record (seismogram) in two-dimensional space (frequency and time). Period of the waves is used instead of frequency of the waves for regional and teleseismic events. Group velocity (equal to the ratio between the epicentral distance and the wave packet travel time) is used instead of time. We used a software realization of FTAN, developed at University of Trieste (https://dstxwg.units.it/dstxpub/Ftan/ftan.html). Surface waves have the higher amplitudes among the various seismic phases and because of this, they can be identified on the FTAN diagram. Figures 1g and 1h illustrate the FTAN diagrams and traced dispersion curves of two teleseismic events located: in Kamchatka (9.10.2025 13:28:44.2 Mw6.1, data from emsc-csem.org) and in the Drake Passage (10.10.2025 20:29:22.0, Mw7.6, data from emsc-csem.org). The dispersion curve of the Kamchatka event indicates typical continental wave path with a relatively thick crust. Drake Passage event has typical dispersion curve for the predominantly oceanic wave path with a very thin crust.

The accumulation of dispersion curves from local, regional, and global earthquakes will be used in seismic tomography to recover the structure at local, regional, and global scale.

Seismic database

A database with seismic records from the seismic stations of the BUSN is constructed. Continuous data from all three seismic stations are collected in near-real time by the software SEISMOLOG at a server in the Faculty of Physics of Sofia University. Continuous seismic records will be used for noise spectra analysis, seasonal characteristics of the noise, and further for cross correlation analysis of the records from the stations SRKO and GIOL. Additionally, the analyzed earthquake records will be saved along with seismic phase arrival times; spectra of the earthquakes; and dispersion curves. The accumulation of data analyzed will enable to resolve different scientific problems such as seismic moment calculation, determination of the focal mechanisms, and velocity structure of the Earth.

Conclusions

Seismic station GIOL was recently established, as a part of the Bulgarian University Seismic Network, operated by Faculty of Physics of Sofia University. Noise analysis shows that the station GIOL is the quietest station among the stations from BUSN. A database with continual analysis of the seismic records was created and is upgraded continuously. Accumulated results of the analyses will be a base for future more comprehensive studies.

***Acknowledgments*:** This study is financed by the European Union – NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project SUMMIT BG-RRP-2.004-0008-C01, internal project number 70-123-265/19.02.2024; NSF of SU project number 80-10-157/03.06.2025.

References

Dimova, L., R. Raykova. 2024. Earthquake focal mechanism analysis using data from seismic station SRKO. – *Rev. Bulg. Geol. Soc*., *85*, 3, 273–276; https://doi.org/10.52215/rev.bgs.2024.85.3.273.

Dimova, L., L. Dimitrova, R. Raykova. 2023. First station from the Sofia University Seismic Network. – *Rev. Bulg. Geol. Soc*., *85*, 3, 337–340; https://doi.org/10.52215/rev.bgs.2023.84.3.337.

Dragomirov, D., L. Dimova, R. Raykova. 2021. Parameters related to earthquake-early-warning system for some seismically active areas in the Balkan Peninsula Region. – In: *11th Congress of the Balkan Geophysical Society 2021*, European Association of Geoscientists & Engineers, 1, 1–5.

Dziewonski, A. M., D. L. Anderson. 1981. Preliminary reference Earth model. – *Phys. Earth Planet. Int*., *25*, 4, 297–356; https://doi.org/10.1016/0031-9201(81)90046-7.

Keilis-Borok, V. I., A. L. Levshin (Eds.). 1989. *Seismic Surface Waves in a Laterally Inhomogeneous Earth*. 9, Springer Netherlands, 304 p.

Kennett, B.L., E.R. Engdahl. 1991. Traveltimes for global earthquake location and phase identification. – *Geophys. J. Int.*, *105*, 2, 429–465; http://dx.doi.org/10.1111/j.1365-246X.1991.tb06724.x.

Kennett, B. L., E. R. Engdahl, R. Buland. 1995. Constraints on seismic velocities in the Earth from traveltimes. – *Geophys. J. Int.*, *122*, 1, 108–124; https://doi.org/10.1111/j.1365-246X.1995.tb03540.x.

Munafo, I., L. Malagnini, L. Chiaraluce, L. Valoroso. 2015. Moment magnitude, local magnitude and corner frequency of small earthquakes nucleating along a low angle normal fault in the Upper Tiber valley (Italy). – *In: AGU Fall Meeting Abstracts, 2015*, S51A-2667.

Pandourska, E., L. Dimova, R. Raykova. 2025. Performance of the stations from the Seismological Network of Sofia University. – In: *Book of Abstracts, XII National Conference of Geophysics*, Sofia, Bulgaria, 1–4.

Raykova, R. B., G. F. Panza, D. S. Yosifov. 2018. Mapping the lithosphere and asthenosphere in the Balkan Peninsula region. – In: *Proceedings of 9th National Geophysical Conference*, Sofia, Bulgaria.

The published material was presented at the National Conference with international participation GEOSCIENCES 2025.