THE INTERNATIONAL CONFERENCE ON THE 120TH ANNIVERSARY OF THE BULNAY EARTHQUAKE:
ADVANCES IN ASTRONOMY AND GEOPHYSICS

Analysis of the behavior of soils of various structures and conditions for the territory of Irkutsk based on earthquake registration data

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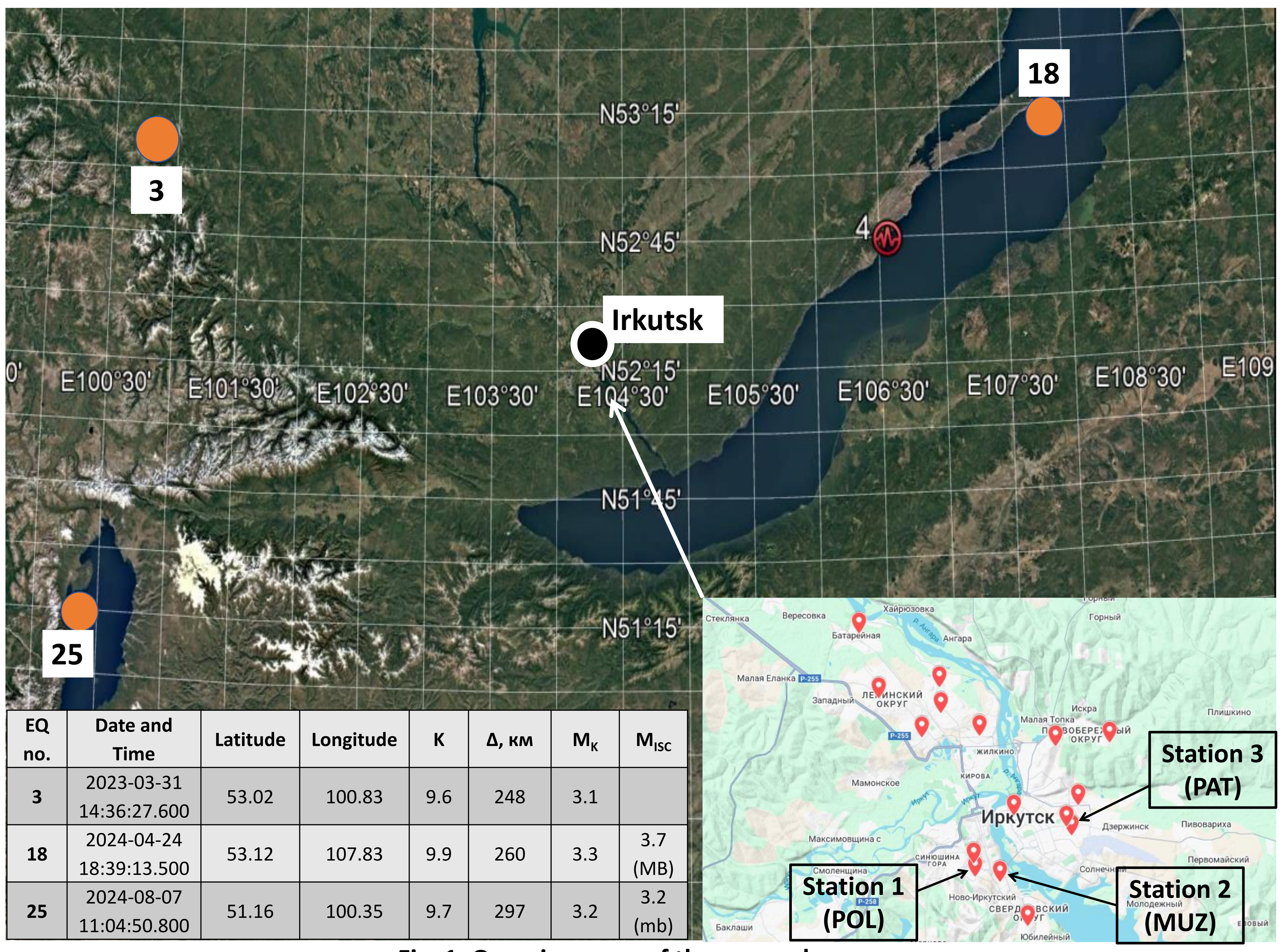
Introduction and Problem Statement

The seismicity and seismotectonics of Irkutsk are determined by its location on the southwestern activated margin of the Siberian platform. The city's territory is characterized by baseline seismic intensities of 8, 9, and 9 points for three seismic hazard levels of 10%, 5%, and 1% probability of exceedance within 50 years. Depending on soil conditions at the foundations, seismic hazard may vary by 1–2 points. It is necessary to refine the baseline seismicity and predict the seismic impacts of potential large earthquakes in the southwestern part of the Baikal seismic zone (Fig. 1) on the soil foundations of buildings in the Irkutsk city.



EQ no.	Date and Time	Latitude	Longitude	K	Δ, км	M_K	M_{ISC}
3	2023-03-31 14:36:27.600	53.02	100.83	9.6	248	3.1	
18	2024-04-24 18:39:13.500	53.12	107.83	9.9	260	3.3	3.7 (MB)
25	2024-08-07 11:04:50.800	51.16	100.35	9.7	297	3.2	3.2 (mb)

Fig. 1. Overview map of the research area.

Red circles – selected earthquakes; the insets show parameters of the selected earthquakes (on the left) and the location of seismic stations in the city of Irkutsk and their numbers (on the right).

Research Methodology

Since 2023, engineering-seismological monitoring of Irkutsk has been conducted. Geophysical parameters were studied at 16 potential registration points, that will form a local seismic observation network in the future. Three stations cover soils of categories I, II, and III and are equipped with permanent Baikal seismic stations (Fig. 1, inset):

№1 (POL): category I soils, fractured sandstones, longitudinal wave velocity (Vp) 1910 m/s, shear wave velocity (Vs) 900 m/s;

№2 (MUZ): loose, unsaturated soils of category II, Vp ~600 m/s, Vs 300 m/s;

№3 (PAT): upper 4 m are unsaturated category II soils, below are water-saturated category III soils, Vp 1630 m/s, Vs 460 m/s.
The network will be expanded as data accumulates.

Table 1. Distribution of seismic wave velocities with depth at the sites of station locations.

Station no. and its code	Layer thickness (in meters)	Vp (m/sec)	Vs (m/sec)
1. POL	4	400	**240**
	>6	1910	**900**
2. MUZ	3	300	**160**
	6	560	**280**
	>7	860	**420**
3. PATR	**4**	**340**	**170**
	>5	**1630**	**460**

Results and Initial Analysis

48 earthquakes have been recorded with energy class K from 8 to 13, epicentral distances of 60–752 km, magnitudes calculated from energy class 2.7–5.0, and ISC magnitudes 2.5–5.2. For analysis, earthquakes with magnitudes 3.1–3.3 and epicentral distances of 248–297 km were selected from three probable focal zones: Khubsugul (№25), Eastern Sayan (№3), and Middle Baikal (№18) (Fig. 1).

Comparative spectral analysis (Fig. 2), frequency characteristic calculations (Fig. 3), and parameter assessment (Table 1) were performed for three components NS, EW, and Z.

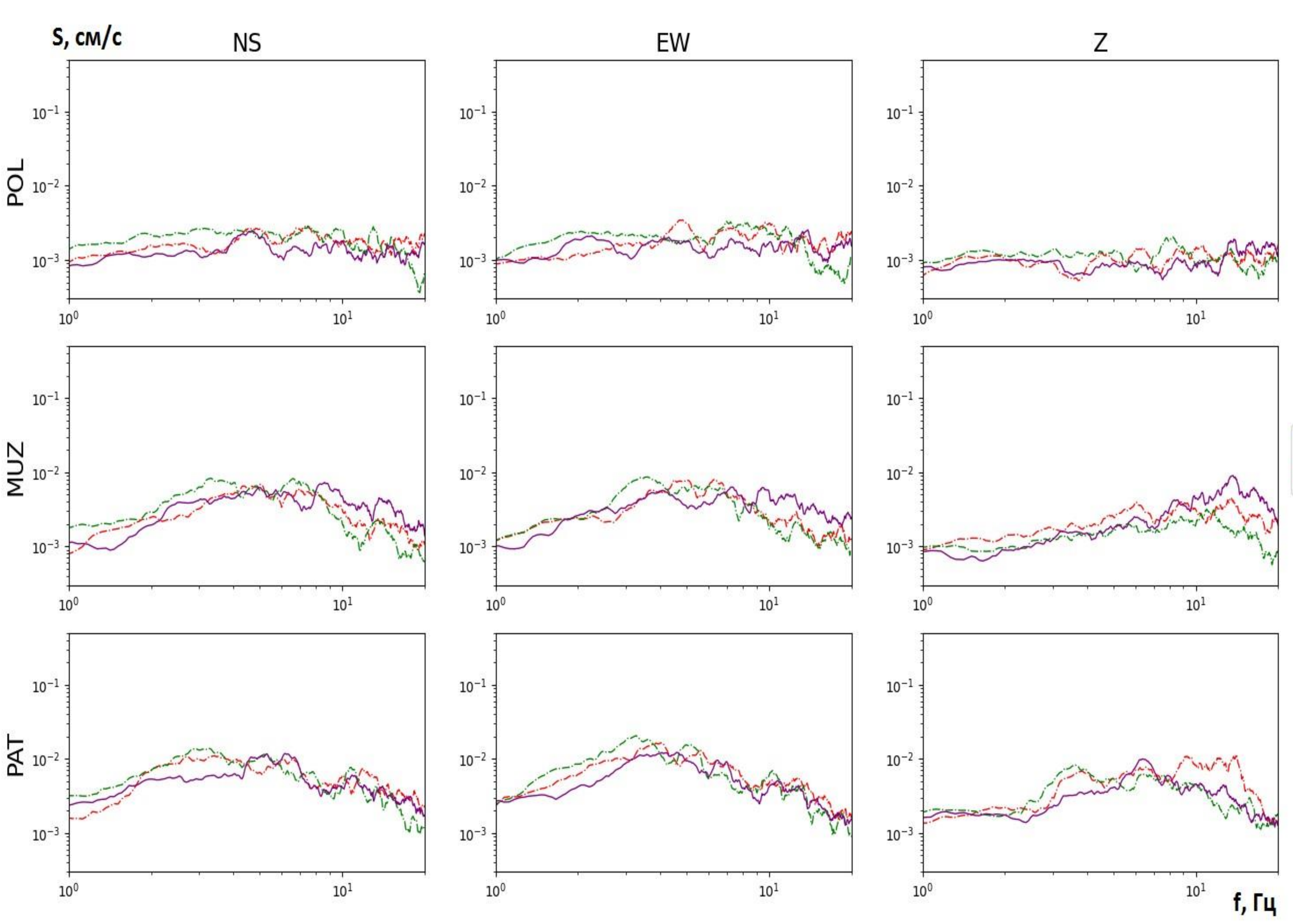


Fig. 2. Spectra of earthquakes №3, 18, 25 for NS, EW, and Z components; the names of the seismic stations.

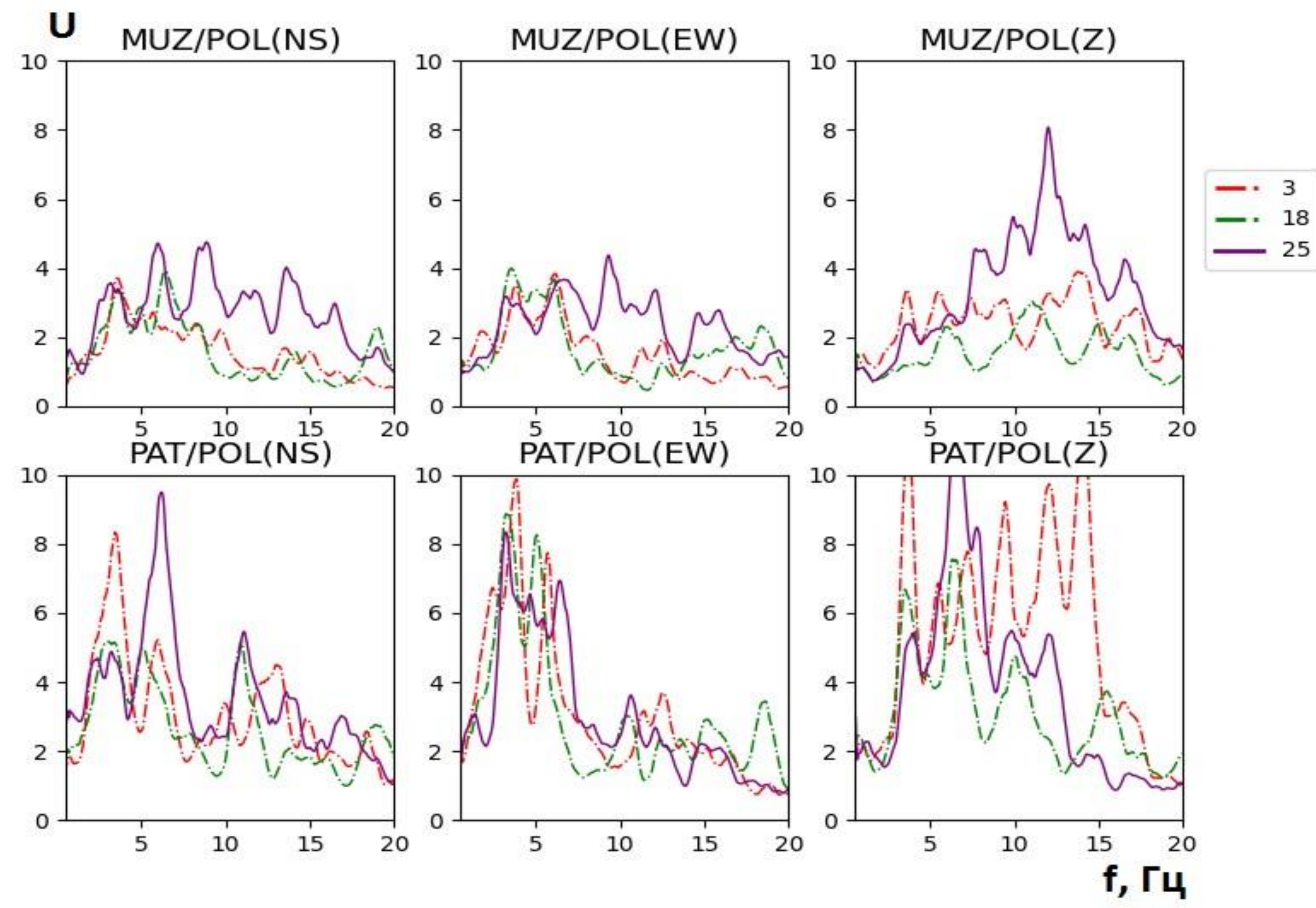


Fig. 3. Experimental frequency characteristics for earthquake recording points №2 (MUZ) and №3 (PAT).
MUZ/POL – relative frequency characteristic obtained as the ratio of the spectra of the second station to the first (Fig. 1) for the NS, EW, and Z components respectively (indicated in parentheses);
PAT/POL – relative frequency characteristic obtained as the ratio of the spectra of the third station to the first, also for the NS, EW, and Z components respectively (indicated in parentheses) for earthquakes № 3, 18, and 25.

Table 2. Main parameters of frequency characteristics for each registration point, calculated based on the data from recordings of three selected earthquakes.

EQ no.	Frequency characteristics	Umax	f(Umax)	f(0.7·Umax)
3	MUZ/POL(EW)	3.85	6.15	3.47–6.74
	MUZ/POL(NS)	3.71	3.56	3.12–5.81
	MUZ/POL(Z)	3.9	13.77	3.32–17.43
	PAT/POL(EW)	9.88	3.86	3.27–5.86
	PAT/POL(NS)	8.34	3.42	2.64–3.96
	PAT/POL(Z)	11.24	14.16	3.32–14.55
18	MUZ/POL(EW)	3.99	3.56	2.98–6.45
	MUZ/POL(NS)	3.9	6.35	3.17–7.23
	MUZ/POL(Z)	3.03	11.08	5.76–15.38
	PAT/POL(EW)	8.87	3.27	2.73–5.47
	PAT/POL(NS)	5.17	2.93	2.2–11.38
	PAT/POL(Z)	7.56	6.35	3.27–7.03
25	MUZ/POL(EW)	4.37	9.33	3.08–12.3
	MUZ/POL(NS)	4.75	8.84	2.93–14.36
	MUZ/POL(Z)	8.08	12.01	11.38–12.84
	PAT/POL(EW)	8.34	3.22	2.88–6.88
	PAT/POL(NS)	9.51	6.2	5.42–6.74
	PAT/POL(Z)	11.52	6.54	6.01–7.96

The spectra maxima for NS and EW components ranged 0.003–0.01 cm/s at frequencies 3–10–12 Hz. NS and EW spectra rapidly decrease after the peak with increasing frequency, unlike the Z component, which increases up to 18 Hz (stations №2 and №3) and above 20 Hz (№1).

Maximum spectral values are comparable per station, but agreement decreases as frequency rises, especially for the Z component.

Of particular interest are the curves obtained by the ratio of the spectra of the studied soils (points №2 and №3) to the reference soil (№1), followed by the comparison of their parameters for selected earthquakes close in magnitude and epicentral distance (Table №1). Such analysis is necessary because the obtained values of the spectral ratio are directly used to assess the relative change in seismic hazard of the compared soils in the studied areas, including with consideration of the source zones.

Frequency characteristics of points №2 and №3 relative to the reference №1 show significant amplitude amplification, especially at point №3.

Discrepancies, mainly in Z, may be due to microseismic noise and require further data.

Maxima of frequency characteristics for horizontal components lie within 2.9–9.3 Hz and vertical components 6.3–14.6 Hz. Frequency intervals at 0.7 of maxima are broad but comparable for horizontal components, mostly up to 10 Hz.

Calculations using seismic stiffness and amplitude-frequency methods indicate seismic hazard increments of 0, 0.9, and 1.6 points for stations 1 (POL), 2 (MUZ), and 3 (PAT) respectively.

The data support the use of earthquakes from different source zones for hazard assessment in Irkutsk. However, frequency and amplitude differences require further data considering earthquake mechanisms and focal depth.

Conclusion

At the initial monitoring stage, spectral analysis and preliminary estimates of relative changes in amplitude-frequency characteristics of soils were performed for three registration points considering hazardous source zones of the Baikal region. A comparative analysis of earthquakes close in magnitude and epicentral distance from Khubsugul, Eastern Sayan, and Middle Baikal zones was conducted. Spectra maxima for NS, EW, and Z are comparable, but agreement decreases with frequency, most notably for the vertical component. Differences up to 10–12 Hz are minor but grow at higher frequencies, necessitating more data including larger magnitude and closer earthquakes.

The results are important for predicting seismic effects of large Baikal earthquakes and seismic zoning of Irkutsk.