Journal of the Georgian Geophysical Society, e-ISSN: 2667-9973, p-ISSN: 1512-1127
Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v. 28(2), 2025, pp. 13-18

Seismic Surveys and Seismicity Refinement in Kvibisi Village, Borjomi District, Considering Local Parameters

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ABSTRACT

To obtain objective information about the engineering-geological properties of rock massifs, it is necessary to conduct a wide range of studies, including geological, geotechnical, hydrogeological, geophysical and, above all, seismoacoustic studies. The physical basis of engineering seismic acoustics is the close dependence of the parameters of elastic waves on the features of the structure, properties and condition of the investigated rock massifs.
This work is devoted to the role of engineering geophysics, particularly seismic, in the construction of significant structures. As an example, specific projects and methods used for their implementation are given.

Key words: *engineering geophysics, seismicity, rock massifs.*

Introduction

The works carried out by us included the construction of seismic profiles and refinement of seismicity [1-15], taking into account local parameters, in Kvibisi village, Borjomi district, within the territory of Borjomi Plant No. 2.

Experimental Studies: Construction of Soil Seismic Profiles

Seismic profiling (using the refraction method) was conducted, relevant seismogeological cross-sections were constructed, and the propagation velocities of elastic longitudinal (P-waves) and transverse (S-waves) were determined. Additionally, the values of the corresponding physical–mechanical parameters were assessed.

The report presents cross-sections of four seismic profiles with a total length of 276 m, each 69 m long (Fig. 1.1). Table 1.1 provides the starting and ending coordinates of the seismic profiles in the UTM system, together with absolute elevations.

Table 1. Starting and ending coordinates of seismic profiles

№1 indicates the first geophone, i.e., the beginning of the profile, while №24 denotes the 24th geophone, i.e., the end of the profile. H represents absolute elevations.

GPH №2	X	Y	H, m
1-1	368867.43	4636255.37	777
1-24	368875.56	4636200.80	777
2-1	368859.34	4636266.63	777
2-24	368927.52	4636272.03	777
3-1	368929.15	4636270.89	777
3-24	368994.94	4636281.90	778
4-1	368925.21	4636192.11	780
4-24	368993.39	4636197.52	780

Fig. 1. Study area and schematic layout of seismic profiles.

Geophysical Investigations (Seismic Profiling)

In the study area, seismic profiling was conducted using the refraction wave method, on the basis of which the propagation velocities of elastic longitudinal and transverse waves were determined, and the corresponding cross-sections were constructed.

The refraction wave method makes it possible to determine the thicknesses of both near-surface and deeper layers, as well as the propagation velocities of elastic waves within them. The method is based on determining the arrival times of longitudinal and transverse wave fronts from an elastic wave source to geophones arranged along a single line.

The following physical–mechanical parameters were determined:

Table 2.

Vp m/sec	Longitudinal wave velocity
Vs m/sec	Transverse wave velocity
Vs/Vp	Velocity ratio
ρ gr/cm^3	Density
μ	Poisson's ratio
Ed Mpa	Young's dynamic modulus
Gd MPa	Shear dynamic modulus
Kd Mpa	Dynamic modulus of universal compression
D Mpa	Total deformation modulus
τ Mpa	Tensile strength limit

Parameters 1–3 and 5–8 were calculated based on well-established theoretical relationships, while parameters 4, 9, and 10 were derived using available empirical correlations.

Seismic Profiling Methodology:

Seismic profiling was carried out using 10 Hz geophones spaced at 3-meter intervals. Seismic wave generation was achieved by striking a special plastic plate with a 10 kg hammer.

The measurements were conducted in both Z-Z and Y-Y orientations. A five-shot point system was used, which included:

- Two shots at the beginning and end of the profile,
- One shot in the middle of the profile,
- Two shots positioned off the ends of the profile.

Wave registration was performed using a 24-channel engineering seismic station manufactured by **GEOMETRICS**. Data processing and interpretation were conducted using the licensed **SeisImager** software from the same company.

Subsequently, the recorded data were analyzed, and the corresponding seismic sections were constructed (see Figs. 2–5).

Analysis of Conducted Works and Results

Seismic profiling (using the refraction wave method) was conducted in the study area, and corresponding seismogeological cross-sections were constructed. The propagation velocities of elastic longitudinal (P-wave) and transverse (S-wave) waves were determined. Additionally, the values of the relevant physical-mechanical parameters were assessed.

The report presents cross-sections of 4 seismic profiles, each 69 meters in length, with a total length of 276 meters (see Fig. 1.1). Table 1.1 shows the starting and ending coordinates of the seismic profiles in the UTM system along with absolute elevations.

Based on the values of the geophysical parameters, three distinct layers with different properties were identified on the seismic profiles. In our assessment, and considering the geological data from the surrounding areas and the elastic wave velocity values, these correspond to:

- **Layer 1** – Clay and clayey soils of varying consistency, occasionally containing hard pebbles, gravel, and cobble inclusions. The range of longitudinal and transverse wave velocities is: **V_p = 221–377 m/s; V_s = 148–252 m/s**. This layer corresponds to layers SGE1 to SGE5 described in the geological investigation report.
- **Layer 2** – Pebbly-gravelly deposits with a firm clay-sand matrix. The range of longitudinal and transverse wave velocities is: **V_p = 728–985 m/s; V_s = 287–377 m/s**.

This layer corresponds to layer SGE6 in the geological investigation report.

- **Layer 3** – Weathered and fractured alternation of foliated and thin-bedded argillites and medium-bedded sandstones. The range of longitudinal and transverse wave velocities is: **V_p = up to 2776 m/s; V_s = 1364–1423 m/s**.

This layer corresponds to layer SGE7 in the geological investigation report.

The resulting seismic cross-sections are shown in Figures 2 through 5, and the relevant physical-mechanical parameters have been calculated accordingly.

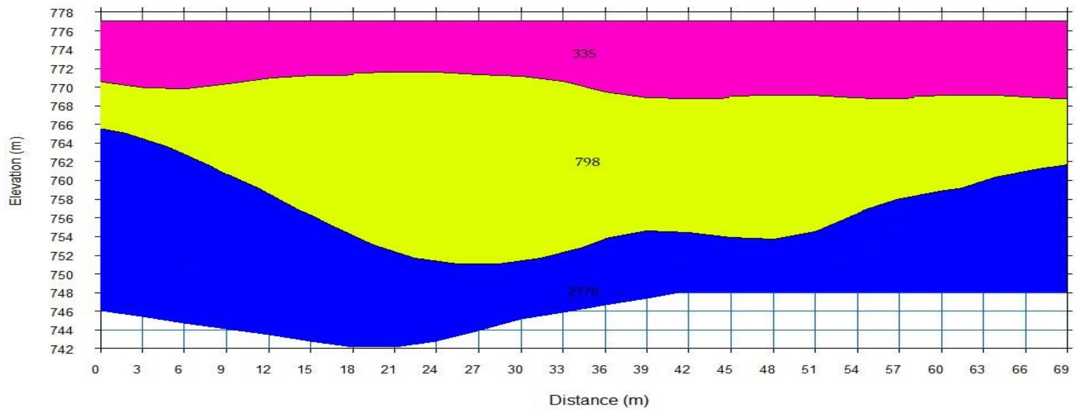

Fig. 2. Seismic section №1.

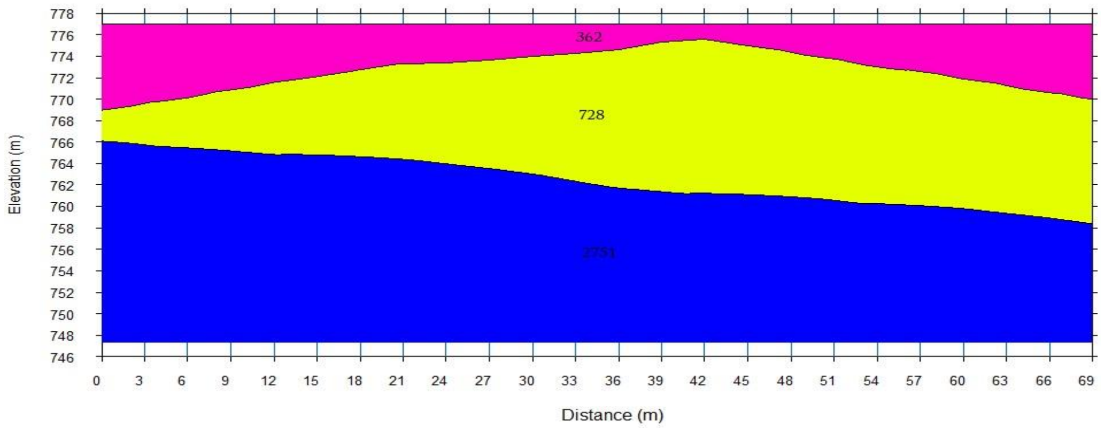

Fig.3. Seismic section №2.

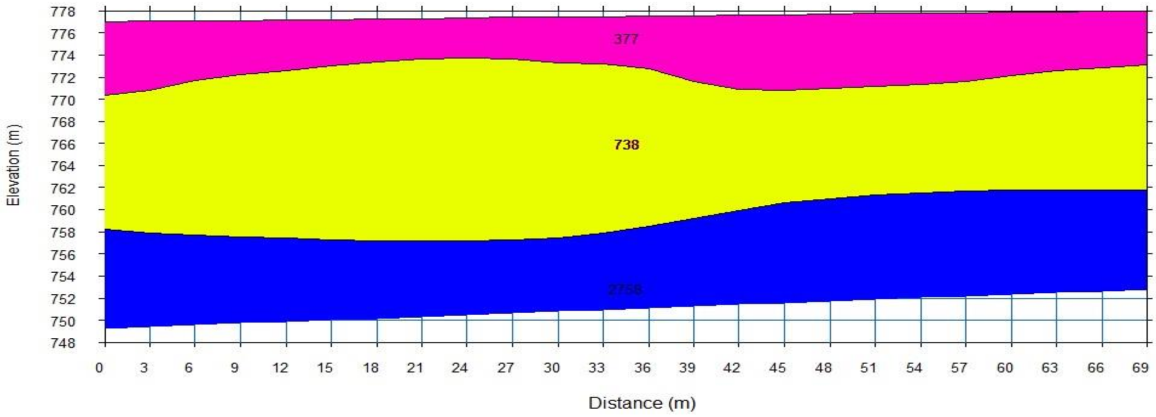

Fig.4. Seismic section №3.

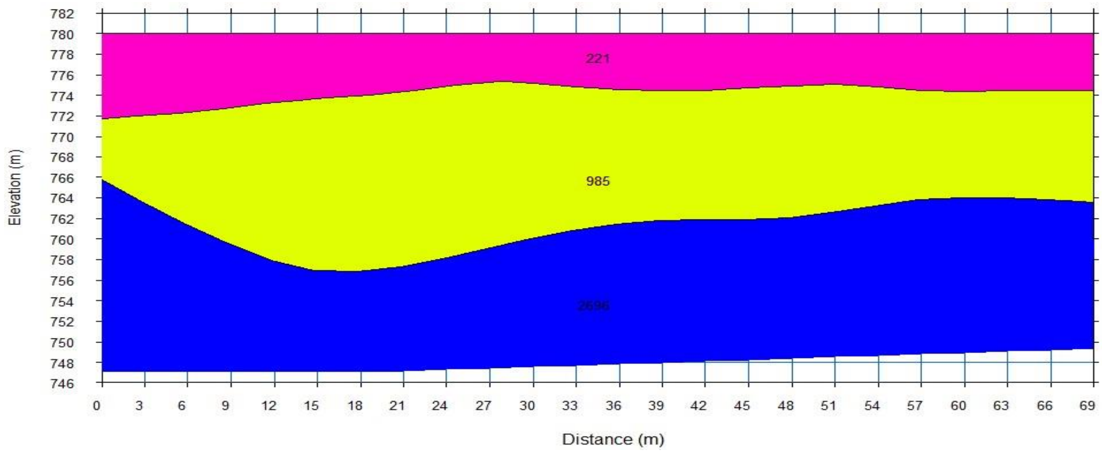

Fig. 5. Seismic section №4

Based on geophysical surveys, soil categories were assessed using the average shear-wave velocity in the upper 30 meters of the ground (Vs30). Averaged shear-wave velocities were obtained for the study area, and the corresponding soil categories were determined according to both Georgian national standards and international standards (IBC2006, Eurocode 8, ASCE7). For this area, the average shear-wave velocity in the upper 30 meters (Vs30) was found to be 382 m/s.

According to the national standards of Georgia, each profile area corresponds to Soil Category II, while under international standards, the classification is as follows: Eurocode 8 – Class B, IBC2006 and ASCE7 – Class C.

The detailed velocity values and corresponding soil categories for each profile area are presented in Table 2.

Table 2.

Prof. N	Vs30 (m/s)	DN 01.01-09 (Georgian Standard)	IBC2006 (International Standard)	ASCE (American Standard)	Eurocode 8 (European Standard)
1	365	II	D	D	B
2	401	II	C	C	B
3	401	II	C	C	B
4	361	II	D	D	B

Clarification of the Seismicity of the Study Area

The seismicity of the construction site was determined using the method of seismic stiffness, which involves adjusting the seismicity by comparing the acoustic stiffness of the reference soil to that of the investigated soil. The calculation is performed using the following formulae [2.2, 2.3, 2.4]: I=I0+ΔI, Where: **I** is the adjusted seismic intensity, $\mathbf{I_0}$ is the intensity of the reference soil, determined by seismic microzonation, **ΔI** is the intensity increment, calculated by the formula:

ΔI=1.67·log(V0·ρ0Vi·ρi)+exp(−0.04·h2), Where: $\mathbf{V_0}$ and $\boldsymbol{\rho_0}$ are the velocity of shear (or longitudinal) waves and density of the reference soil, $\mathbf{V_i}$ and $\boldsymbol{\rho_i}$ are the respective values for the investigated soil, **h** is the depth of groundwater below the foundation level.

According to the engineering-geological report, groundwater was detected and stabilized in five geological boreholes:

- Borehole #3 – stabilized at 12.0 m,
- Borehole #4 – 12.2 m,
- Borehole #7 – 13.3 m,
- Borehole #9 – 9.3 m,
- Borehole #11 – 13.7 m.

Groundwater was not detected in the remaining boreholes. The average groundwater depth across the construction site is **h = 12.1 m** (minimum **h = 9.3 m**).

Taking these values into account, the intensity increment is calculated as:

ΔI=1.67·log[(600±100)·(1750±50)/((429±64)·(1911±61))]+exp(−0.04·9.32) =0.3517±0.1324≈0 intensity)

Conclusions

Based on the method of acoustic stiffness used on the construction site, the obtained increment in seismic intensity is: For reference intensity $\mathbf{I_0 = 8}$, ΔI = 0.3517 ± 0.1324 (maximum value 0.48 < 0.50), 0 intensity, no full additional intensity grade is added, **Final adjusted seismic intensity** for the construction site is **I = 8**.

Using this method, the **calculated design horizontal acceleration** on the construction site is **0.274 g** (**2.688 m/s²**).

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ბორჯომის რაიონში სოფ. ყვიბისში სეისმური კვლევები და სეისმურობის დაზუსტება ლოკალური პარამეტრების გათვალისწინებით

მ. გიგიბერია, ვ. არაბიძე, ჯ. ქირია, ნ. ღლონტი

რეზიუმე

ქანების კლდოვანი მასივების სანჟინრო-გეოლოგიური თვისებების შესახებ ობიექტური ინფორმაციის მისაღებად საჭიროა კვლევების ფართო კომპლექსის ჩატარება, რომელშიც შედის გეოლოგიური, გეოტექნიკური, ჰიდროგეოლოგიური, გეოფიზიკური და უპირველეს ყოვლისა სეისმოაკუსტიკური კვლევები. საინჟინრო სეისმოაკუსტიკის ფიზიკურ საფუძველს წარმოადგენს დრეკადი ტალღების პარამეტრების მჭიდრო დამოკიდებულება საკვლევი კლდოვანი მასივების აგებულების, თვისებებისა და მდგომარეობის თავისებურებებთან.
ეს ნაშრომი შეეხება საინჟინრო გეოფიზიკის, კერძოდ სეისმიკის როლს მნიშვნელოვანი ნაგებობების მშენებლობაში. მაგალითის სახით მოვიყვანთ კონკრეტულ პროექტებს და მათი განხორციელებისათვის გამოყენებულ მეთოდებს.

საკვანძო სიტყვები: საინჟინრო გეოფიზიკა, სეისმურობა, კლდოვანი მასივები.

Сейсмические исследования и уточнение сейсмичности с учетом локальных параметров в селе Квибиси, Боржомский район

М. Гигиберия, В. Арабидзе, Д. Кириа, Н. Глонти

Резюме

Для получения объективной информации о инженерно-геологических свойствах скальных массивов необходимо проведение широкого комплекса исследований, включающего геологические, геотехнические, гидрогеологические, геофизические и, прежде всего, сейсмоакустические исследования. Физической основой инженерной сейсмоакустики является тесная зависимость параметров упругих волн от особенностей строения, свойств и состояния исследуемых скальных массивов.
Настоящая работа посвящена роли инженерной геофизики, в частности сейсмики, в строительстве значимых сооружений. В качестве примера приведены конкретные проекты и методы, использованные для их реализации.

Ключевые слова: инженерная геофизика, сейсмичность, скальные массивы.