RESULTS OF COMPLEX NEAR SURFACE GEOPHYSICAL INVESTIGATION BEFORE CONSTRUCTION OF WALKING AREA AT THE NEVA BRIDGEHEAD

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Summary

The Neva Bridgehead is a symbol for a small area on the banks of the Neva River. This place is known from the time of The battle for Leningrad of the Second World War. At present, the territory of the Bridgehead is partially occupied by memorial zones (Museum “Breakthrough of the Siege of Leningrad”), and also partially built up with private buildings. At the same time, most of the Bridgehead is undeveloped, funnels and trenches are still visible and a lot of war artefacts are kept in the ground.

In 2021, we carried out a set of geophysical investigations on the territory of the Neva Bridgehead. The goals were to study the structure of the near surface and to detect military artefacts before carrying out construction works announced as part of the expansion of the memorial zone. In this abstracts we present the results of magnetic exploration, geological description of pits and rock outcrops, ground penetrating radar (gpr) and engineering seismic surveys at the site of the proposed promenade area construction on the bank of the Neva River.

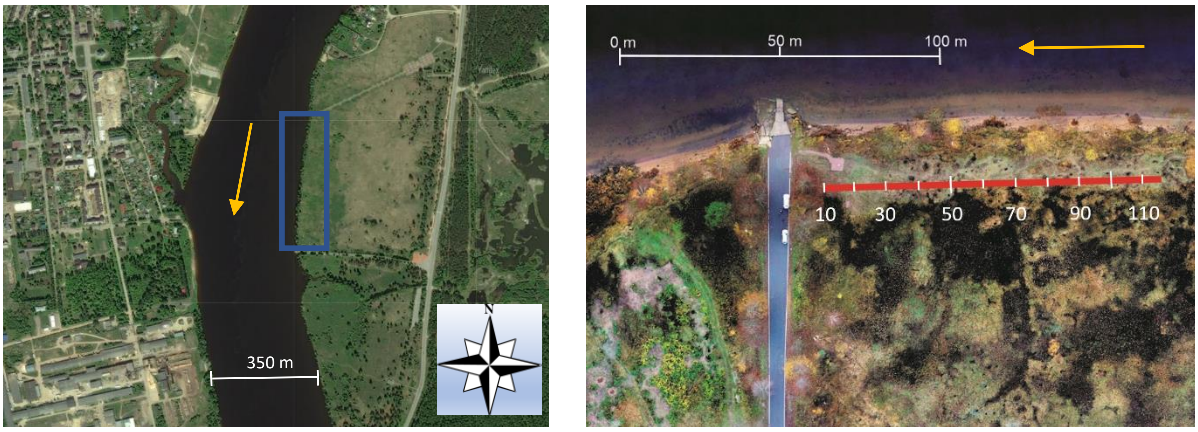
Results of complex near surface geophysical investigation before construction of walking area at the Neva Bridgehead

Introduction

The Neva Bridgehead is a symbol for a small area on the bank of the Neva river. This place is known from the time of The battle for Leningrad of the Second World War (WW II). Soviet troops tried to break the Siege of Leningrad through this place, where the Neva river is relatively narrow; tens of thousands of soldiers died in the small bridgehead, the remains of many of which have not been raised yet. At present, the territory of the Bridgehead is partially occupied by memorial zones (Museum-reserve "Breakthrough of the Siege of Leningrad"), and also partially built up with private buildings. At the same time, most of the Bridgehead is undeveloped, funnels and trenches are still visible and a lot of wartime artefacts are kept in the ground.

In 2021, the Museum-reserve “Breakthrough of the Siege of Leningrad” announced the expansion of the memorial zone, and the team of scientists and students from St. Petersburg State University was involved in complex geophysical investigations before the construction works. The goals were to study the structure of the near surface and to detect wartime artefacts both directly in the area of the proposed works and in the adjacent water area of the Neva river (see Figure 1).

In this abstract we present the results of complex geophysical investigation at the part of the site of the proposed promenade area construction on the bank of the Neva river.



(a) (b)

Figure 1 *(a) The satellite map of the Neva Bridgehead and (b) orthomosaic of the part of the proposed promenade area. The whole site for investigations is marked with blue (a), the considered profile is depicted in red (b) with coordinate ticks in meters (the profile coordinate axis starts at the paved road); yellow arrows show the direction of the Neva river flow; small compass (a) points north direction.*

The considered site and the methods for complex geophysical investigation

The proposed promenade area lies on the high bank of the Neva river between the paved road crossing the central territory of the Neva Bridgehead (from the main memorial on the highway to the Neva river) and the walking road in the northern part of the Bridgehead. We conducted the complex geophysical investigation in the southern part of the area along the 100-meter profile shown in Figure 1 (b). The complex of near surface geophysical investigations included ground penetrating radar (GPR) study, ground magnetic exploration coupled with metal detection using the Minelab X Terra 505 metal detector, and engineering seismic surveys. Also the geological description of pits and rock outcrops was conducted by M.V. Shitov from VSEGEI Institute, and we show below the geological description of the terrace rock outcrop.

Ground penetrating radar (GPR) study

GPR study was carried out using the OKO-2 georadar with a pulse central frequency of 250 MHz. Processing was carried out in the GeoScan32 software. Based on the diffracting objects, the dielectric constant of the soil was determined as equal to 5. The result for the whole profile is shown in Figure 2. The reflecting horizons can be traced just on the several parts of the profile because the medium down to depth of 4-5 m is highly heterogeneous due to the very intensive hostilities on the Neva Bridgehead. The fragment of another radargram acquired slightly to the north of the profile compared with the geological description of the terrace rock outcrop on the high bank on the Neva river is shown in Figure 3; the top of peat is the first marking reflecting horizon in GPR data due to its greater moisture saturation. The boundary of the interlayer of paleosols with underlying clays and clay siltstones is also distinguished. These boundaries are also can be partly traced on the whole profile (Figure 2).

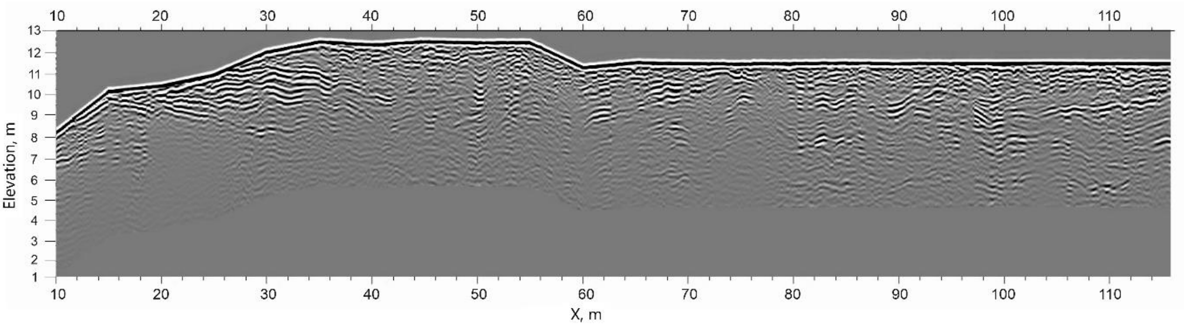


Figure 2 *The GPR data for the whole profile.*

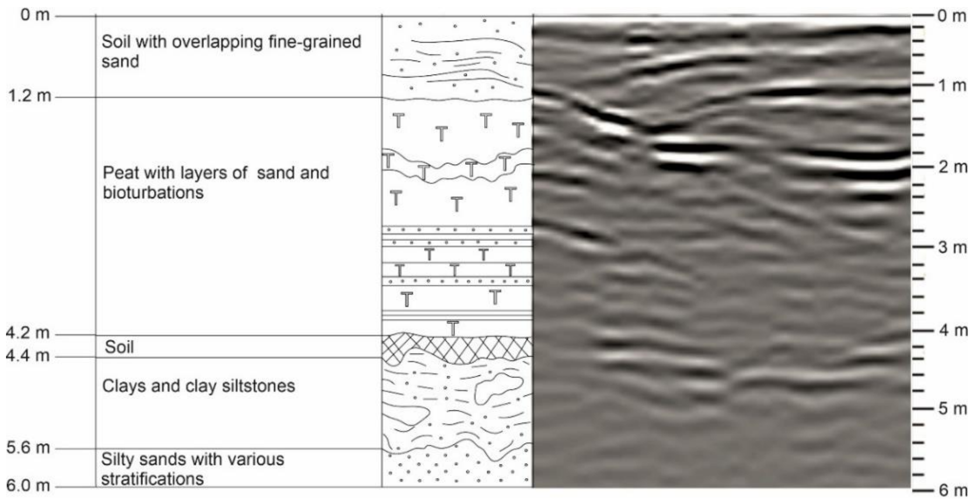


Figure 3 *The geological description of the terrace rock outcrop, left (courtesy of M.V. Shitov* from *VSEGEI Institute) and the fragment of radargram with several reflecting horizons, right.*

Magnetic exploration

Magnetic exploration was carried out using an MMPOS-1 magnetometer along the profile with a measurement step of 1 m. Data processing was carried out in the Oasis Montaj software. Figure 4 shows the result: the graph of the anomalous magnetic field and the result of the depth inversion performed in the ZondGM2D software. According to the graph of the anomalous magnetic field, several positive and one significant negative peaks are observed. The positive peak at 15±1 m of the profile coordinate axis corresponds to the steel frame of the temporary monument (just up of the profile in Figure 1, b). The positive peaks at 42±1 m and 61±2 m are caused by some anomalous objects buried at the depth of 1.5-3 m, presumably since the wartime. The significant negative peak can be caused by ravine or trench, buried during the hostilities, and which is observed at the orthomosaic (Figure 1, b) and should cross the profile approximately at 70 m. The positive peak at 113±2 m is caused by anomaly lying out of the profile.

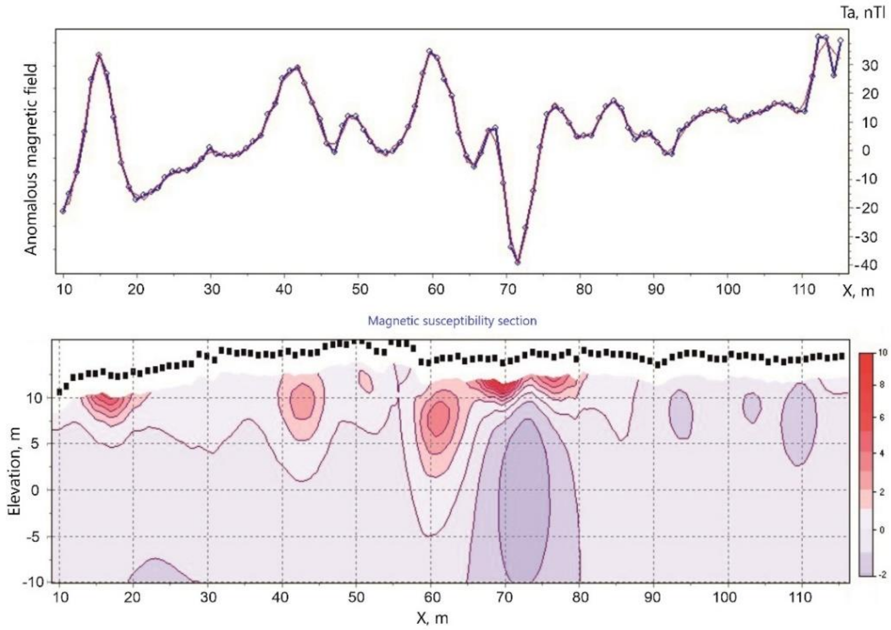


Figure 4 *The result of the magnetic exploration along the considered profile: the graph of the anomalous magnetic fields (nT), acquired (blue) and inverted (red); and the inverted magnetic depth section (redundant magnetic susceptibility, in SI). The black markers show the positions of measurement points.*

The metal detection along the same profile shows the presence of many small objects in the very uppermost part of the near surface (down to ~0.3 m). These objects are mainly steel wartime artefacts.

Seismic surveys

Seismic surveys on the same profile were carried out with the GSX nodal cableless system as receiving equipment. The impact of a 10-kg sledgehammer on a metal substrate was used as a source. The scheme of sources and receivers is shown in Figure 5. We use 5 number of accumulation for each shot point.

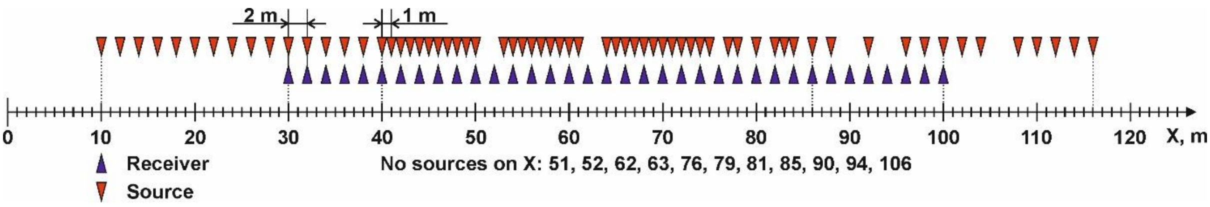


Figure 5 *The scheme of sources and receivers positions used for seismic data processing.*

Firstly, we performed picking of the first arrivals in the RadExPro software. The resulting picks were then processed in the XTomo-LM software to perform 2D seismic tomography method. The result of the tomography is V_P velocity model (Figure 6, up). The uplift of the high-velocity media is observed in the left part of the section (10-60 m of profile coordinate axis) and slight lower velocity anomaly can be detected at 56-78 m at the approximate depths of 8-18 m below the surface. This anomaly correlates with deeper contrast negative anomaly of the magnetic depth section (see Figure 4) and also can be explained as ravine or trench filled with low-velocity medium and buried under the present surface.

Data processing by the MASW method (Park et al., 1999) was also performed in the RadExPro software. The result of the inversion is V_S velocity model (Figure 6, down). The uplift of the high-velocity media is also observed in the left part of the section which is correlate with V_P model (Figure 6, up), but low velocity anomaly is not visible explicitly in V_S velocity model. This can be explained by the presence of a medium with increased porosity relative to the surroundings, while maintaining the elastic properties of the skeleton. Such explanation correlates with the assumption of buried trench.

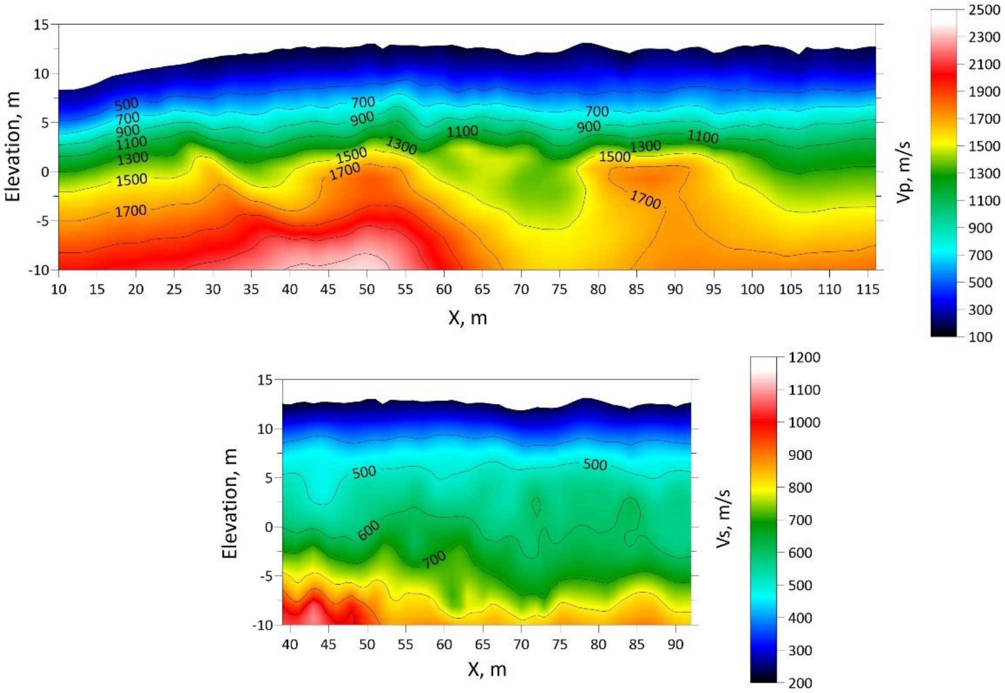


Figure 6 *Velocity model (V_P) from 2D first arrivals tomography (up) and velocity model (V_S) from the MASW method (down). The images were smoothed with slipping windows.*

Conclusions

We presented the results of complex geophysical investigation at the site of the proposed promenade area construction at The Neva Bridgehead. GPR study allowed to identify several reflecting horizons: top of peat and the boundary of the interlayer of paleosols with underlying clays and clay siltstones. Also this study approved that the uppermost part of the geological section (down to depths of 4-5 m) is highly heterogeneous due to the very intensive hostilities. The magnetic exploration showed several anomalies. Two of them can be explained with buried steel wartime artefacts (at depths of 1.5-3 m) and significant negative one can be explained with buried ravine or trench. The metal detection with metal detector showed the presence of many small steel wartime objects down to 0.3 m from the surface. The V_P and V_S velocity models as the result of seismic surveys both shows the general uplift of the high-velocity media in the left part of the section. The V_P velocity model shows low velocity anomaly which is correlated with negative anomaly of the magnetic depth section and can be explained as buried trench.

We conclude that before construction of walking area it is worth paying more attention to the areas: at 42±1 m and 61±2 m of profile coordinate axis where the anomalies are distinguished by the results of magnetic exploration; at 56-78 m, where the low velocity anomaly and the negative magnetic anomaly (72±2 m) related to buried trench are determined.

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References

Park, C., Miller, R. and Xia, J. [1999] Multichannel analysis of surface waves. Geophysics, 64(3), 659-992, https://doi.org/10.1190/1.1444590.