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Determination of the subsurface geological regime and geotechnical characteristics at the area of Goudi (Athens, Greece) derived from geophysical measurements

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Research Highlights

- Seismic velocity and density calculations for the estimation of the elastic moduli of the *Athens schist* formation.

In this paper we present the results of the near-surface geophysical survey for the investigation of the geological and geotechnical characteristics at the construction area of the new building of the Dental School of National and Kapodistrian University of Athens (Fig. 1). Three sampling boreholes, carried out during January of 2022, have also been taken into consideration for the interpretation of the geophysical measurements.

The area is covered with post-alpine sediments and more specifically with diluvial deposits (Fig. 1), formed from the weathering products of the surrounding rocks. Underlying, the *Schists of Athens* are expected to be found. The boreholes have verified their existence at depths 11-13 meters. It is a complex mélange without internal geometry, comprised of unmetamorphic clastic sediments, such as sandstones, pelites, clays, sandstone marls, greywackes, tuffs and argillic schists (Papanikolaou *et al.*, 2002). Based on the results of the sampling boreholes the study area is structured by 8,5 meters of anthropogenic coarse-grained materials, probably due to the fact that the area had been excavated on 2010 up to 7,25 meters and then was refilled. The water table level during the period of the measurements was defined at almost 10 meters depth. The shallow aquifer presents alterations, which may affect the building and for that reason we monitor its level from two boreholes.

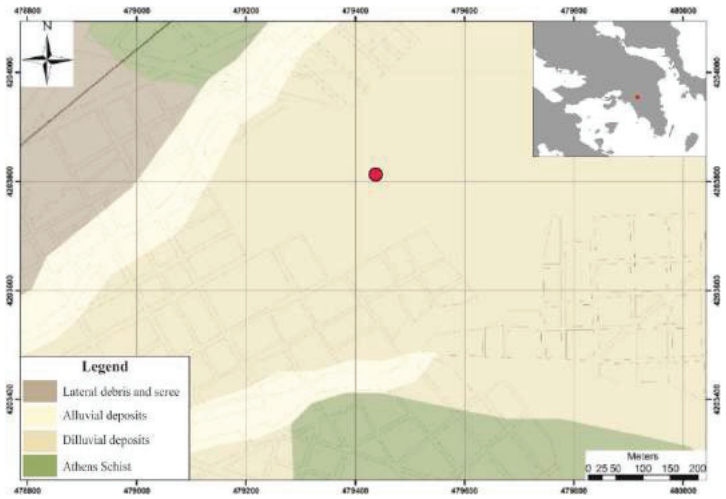

Figure 1. Geological map of the study area indicated with the red circle (Papanikolaou et al., 2002)

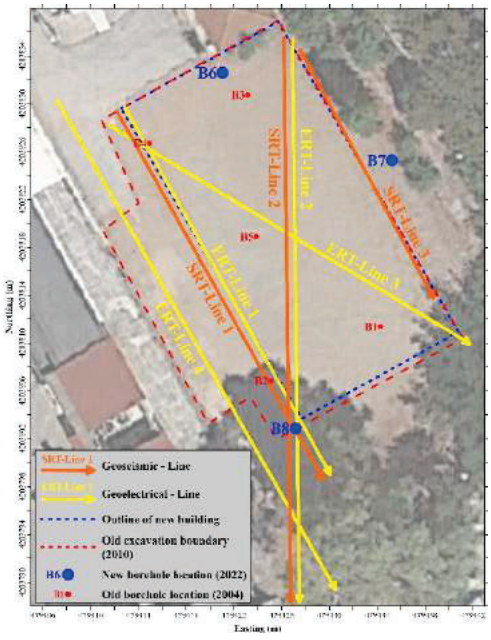

Figure 2. Location of ERT-SRT measurements, boreholes and the outline of the new building

Methodology

In the context of the geophysical investigation of the subsurface at the building site, three (3) different geophysical techniques have been applied in order to have a multi-disciplinary approach (Al-Heety *et al.*, 2021). More specifically (Fig. 2), we carried out i) four (4) electrical resistivity tomography (ert) sections, of totally 165 meters length, using the *IRIS Syscal Pro* unit, ii) three (3) seismic refraction and MASW sections, of totally 105 meters length, using the *Geometrics Strata View* unit. For the generation of seismic waves, a 6kg sledgehammer was used and the seismic energy was detected by 48 geophones of 4,5 Hz arranged in a linear deployment. iii) 52 GPR sections on a 1x1 meter grid, with dimensions 20x30 meters. The geophysical measurements were positioned based on the RTK-NTRIP technique,

providing horizontal and vertical accuracy of 8 mm and 15 mm, respectively. Additionally, we carried out density laboratory measurements for the geological formations of borehole samples.

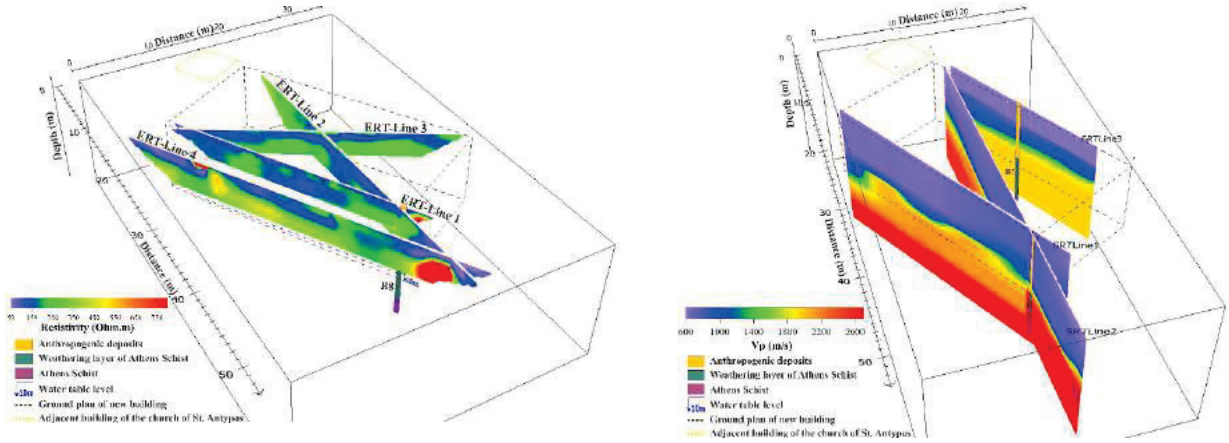

Figure 3. 3-D view of the Electrical Resistivity Tomography Sections (left) and the Seismic Refraction Tomography Sections (right). The dashed line represents the volume of the excavation

In Figure 3 (left), a 3-D presentation of the ert technique results is illustrated (processed with *Res2Dinv*), where we can observe a conductive zone (<100 Ohm.m) located up to the first 2 meters depth. On the other hand, a relatively resistant formation (>600 Ohm.m) has been adumbrated at the southeast part, at depths between 2-4 meters. The investigation depth from the ert measurements is practically the same with the lower level of the building (~8,6 meters). Due to the restricted available area for the geophysical measurements the investigation depth was limited.

Regarding the seismic refraction sections, the processing results, carried out with *SeisImager/2D*, are illustrated in a 3-D presentation in Figure 3 (right). We can observe an upper seismic layer with V_P = 600-1.000 m/s and thickness 8 meters and an underlying one with V_P = 1.200-2.000 m/s and thickness 5 meters. As basement, there is a third seismic layer with V_P > 2.200 m/s, located at depth >13 meters. According to the borehole cores, the first layer seems to be the anthropogenic deposits, the second one the weathering layer of *Athens schists* while the third one the compact formation of *Athens schists*. The corresponding V_S values were calculated from the MASW processing technique, with *SeisImager/SW*. Unfortunately, the GPR measurements hadn't penetrate deep enough to provide information due to the high percentage of clay in the anthropogenic materials of the area that caused the high attenuation of the electromagnetic waves.

Conclusions

Due to the restricted available area for resistivity measurements, we weren't able to investigate the *Athens schists* compact formation. Instead, a resistant formation (>600 Ohm.m) has been delineated at the southeast area, just 4,5 meters out of the excavation boundaries. Its geometry could be interpreted as an old subsurface small tunnel, possible connecting the older buildings. On the other hand, the seismic measurements reached greater depths of investigation, up to almost 15 meters, allowing us to identify the uppermost part of the compact *Athens schists* formation. In Table 1 we present the elastic moduli of the geological formations, calculated after the laboratory determination of their densities. At this point we have to mention that the V_S values of *Athens schists* are affected due to the acquirer's existence.

Table 1. Seismic velocity, density and elastic moduli determination

Geological formations	*Vp (m/s)*	*Vs (m/s)*	*Density (g/cm^3)*	*Poisson's Ratio (σ)*	*Shear modulus G (GPa)*	*Young's modulus E (GPa)*	*Bulk modulus k (GPa)*
Anthropogenic materials	800	400	2,51	0,33	0,40	1,07	1,31
Weathering layer of *Athens schists*	1.600	680	2,66	0,39	1,23	3,42	5,88
Athens schists	2.600	1.300	2,67	0,33	4,52	12,05	14,68

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