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GEOPHYSICALLY - ARCHAEOLOGICAL SURVEY AT THE HRADČANY SQUARE IN PRAGUE

GEOFYZIKÁLNĚ – ARCHEOLOGICKÝ PRŮZKUM HRADČANSKÉHO NÁMĚSTÍ V PRAZE

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Abstract

In cooperation with the Institute of Archaeology of the Czech Academy of Science the G IMPULS Praha company carried out a complex geophysical survey of the Hradčany square in Prague. The non-destructive geophysical survey aimed to cover a whole area (if possible) of the square and according to the complex geophysical methodology to describe in detail the bedrock state-of-manner and to try to define and localize any archaeological structures´ indications. The square area has not been exposed to any construction or research activities in contemporary era. Excluding the rescue archaeological 1944 research in the central part, no significant spatial outcrops have been made, only the linear trenches´ documentation of the engineering networks and small extent excavations. Chosen methodology aimed mainly to identify assumed north-south trenches going across the square.

Abstrakt

Ve spolupráci s Archeologickým ústavem Akademie věd České republiky provedla společnost G IMPULS Praha komplexní geofyzikální průzkum Hradčanského náměstí v Praze. Průzkum nedestruktivními geofyzikálními metodami měl za cíl pokrýt pokud možno celou plochu Hradčanského náměstí a na základě komplexní geofyzikální metodiky detailně popsat stav podloží a pokusit se definovat a lokalizovat jakékoliv indikace archeologických struktur. Plocha náměstí nebyla v novodobých dějinách vystavena výrazné stavební a badatelské aktivitě. Kromě záchranného archeologického výzkumu v centrální části v roce 1944 zde neproběhly žádné rozsáhlejší plošné odkryvy, ale pouze dokumentace liniových výkopů inženýrských sítí a sondáže menšího rozsahu. Zvolená metodika vycházela především ze zadání lokalizovat předpokládané příkopy ve směru S – J, jdoucí napříč náměstím.

Keywords

Hradčany, Prague castle, geophysics, ERT, GPR, gravimetry, magnetometry, archaeology

Klíčová slova

Hradčany, Pražský hrad, ERT, geologický radar, gravimetrie, magnetometrie, archeologie

1 Introduction

The Hradčany square is a natural centre of the Hradčany district lying in the western vicinity of the Prague Castle and, since the 14th century, of a mediaeval city. Since the 80th of the 20th century the Hradčany district is being extensively researched by archaeologists. The original conception of a less important area in the shade of a nearby state centre (Prague Castle) was slowly suppressed by large fortified area´s hypothesis. Such an area might have been a forecastle working as a direct part of the Castle´s area (Blažková et al., 2015; Frolík 2017, p. 230–231, 238–244). The largest archaeological excavation at the square so far was a rescue excavation during fire water reservoir´s sinking in 1944 (Frolík*,* 1988), which has proven an existence of remarkable house objects (Romanesque stone house of 12th century). The remains of the house were transferred into the archaeological area at the 3rd Castle Courtyard. Destination of the water reservoir, which might have not been used for its original purpose, is not clear in the post-war era. Discovery of the Romanesque house supports a possibility of another presence of Early Mediaeval architecture. This assumption was proved in 2011 as another Romanesque wall was discovered in front the frontage of the Salm Palace 184/IV (Mašterová, 2018).

Discovering an early mediaeval fortification on the southern side of the Hradčany promontory opened a theory of a transition between the Castle fortifications and newly identified outer ward. The early mediaeval dating of the trench, making a promontory in front the 1st Courtyard, was casted doubt – proven state of manner is dated into modern history. A terrain depression under the Salm Palace on the southern side of the square was pointed out - that depression could be a part of searched trench (Blažková et al., 2015*)*. Confirmation of its further continuation to the northern side, i.e. into the square, or discovery of another linear object, would be a remarkable discovery.

A closer look into the subsurface structures may be done by geophysical measurements identifying another buried walled objects and confirming assumed trench´s shape in the eastern part of the square. To match this goal, we chose a complex methodology consisting of ground penetrating radar (GPR), seismics, magnetics, gravimetry, electrical resistivity tomography (ERT) and dipole electromagnetic profiling (DEMP).

2 Methodology and measurements network

Geophysical measurements at the Hradčany square lasted about two months as they were strongly influenced especially by vehicles traffic and high number of tourists passing the square by almost 24/7 as the square and nearby Prague Castle belong to most visited sites in Prague. Therefore, the main part of the works had to be shifted into early morning hours, typically between 4–8 AM. The project itself was divided into several phases:

- research of the engineering networks and previous archaeological works,
- fast spatial geophysical measurements around the whole square (GPR, magnetics, DEMP),
- according to the spatial methods results detailed measurements on several geophysical lines (seismics, gravimetry, ERT).

As expected, the engineering network on the spot is rather complicated but fortunately we had access to detailed plans documenting them as seen in fig. 1. We are not able to describe them in particular due to license policy of the owner. Methods of DEMP and magnetometry were carried out across the whole space of the square. The GPR method was carried on the 19 lines in total, leading across the square in its entire length from west to east. ERT and seismics were measured on two geophysical lines and gravimetry on four (see fig. 2).

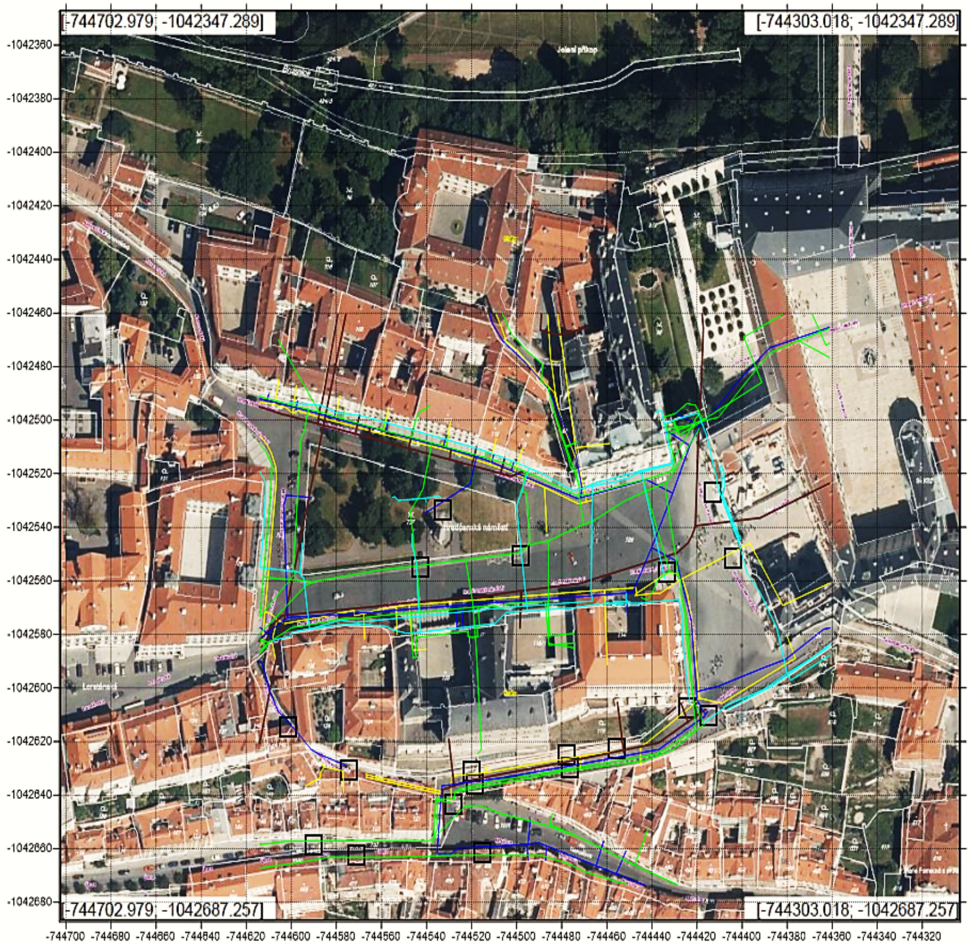

Fig. 1 Map of engineering networks at the Hradčany square.

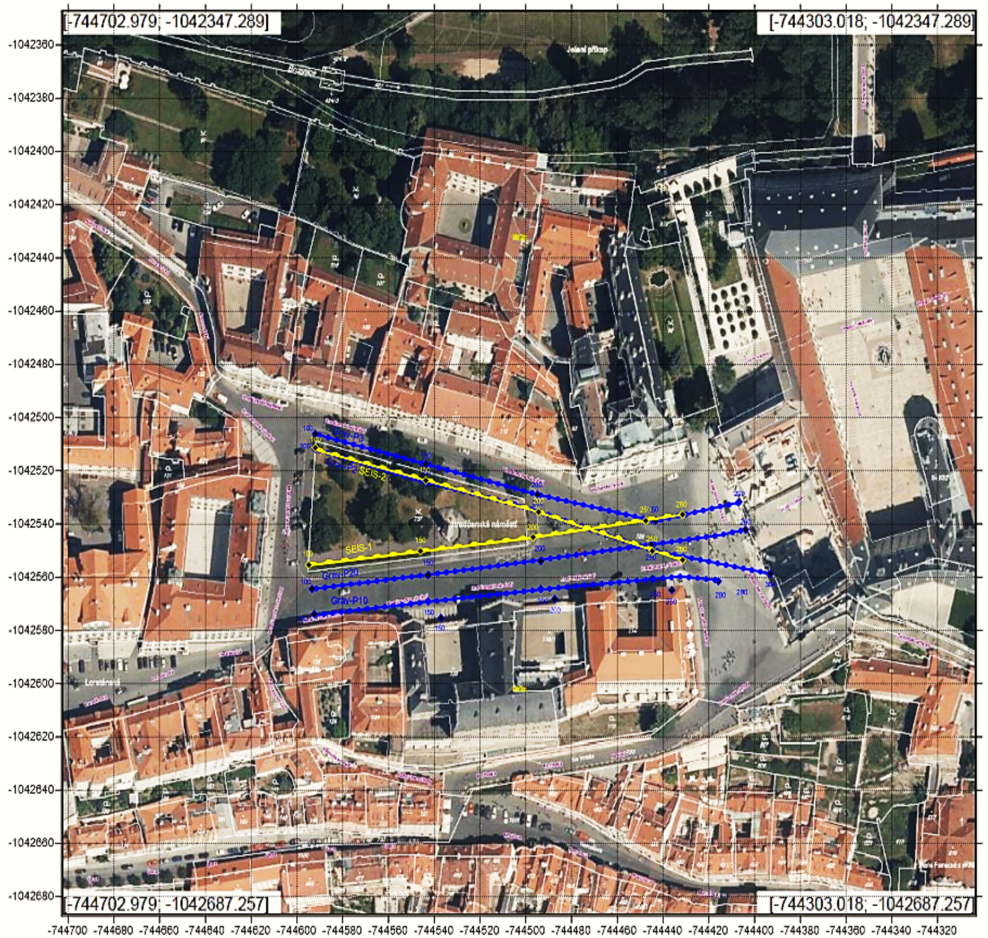

Fig. 2 Lines of gravimetry (blue), ERT and seismics (in yellow) at the Hradčany square.

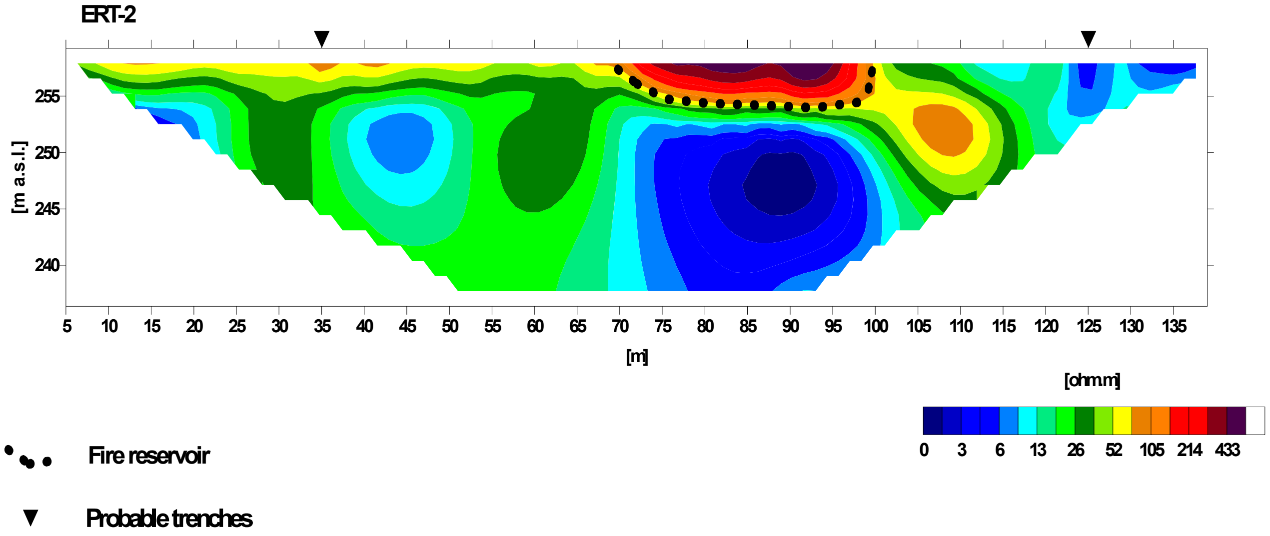

Fig.3 ERT- layout at the Hradčany square with interpretation.

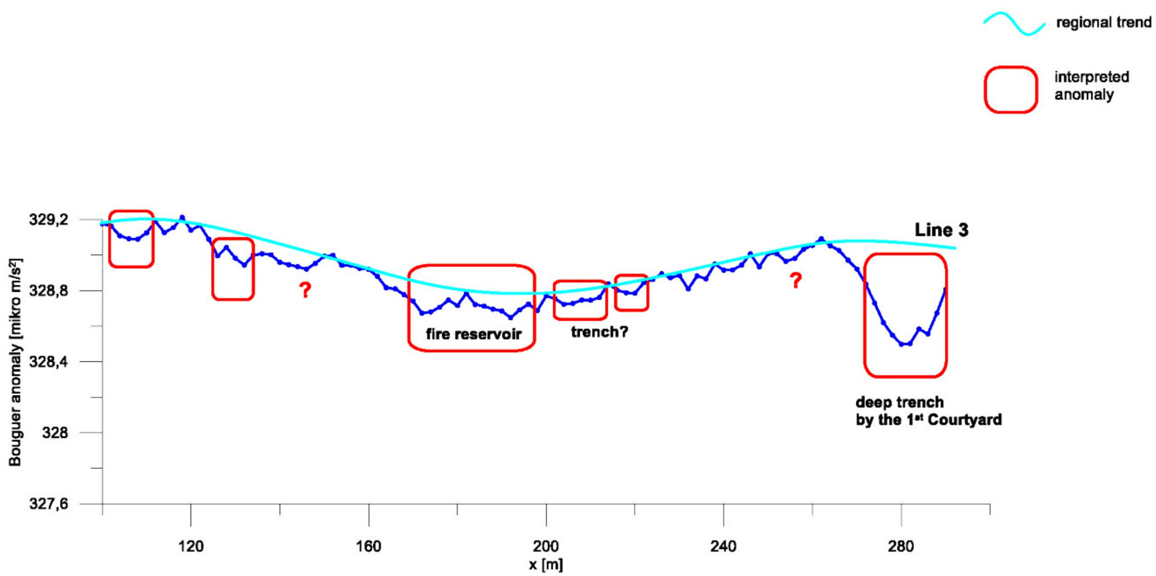

Fig. 4 Results of the gravimetry – line 3 at the Hradčany square.

2.1 Used geophysical methods

The first choice is usually the magnetometry as described in the (Almutari, 2015) or (Brion, 2012). Magnetic survey is one of a number of methods used in archaeological geophysics. Magnetic surveys record spatial variation in the Earth's magnetic field. In archaeology, magnetic surveys are used to detect and map archaeological artefacts and features. Magnetometers used in geophysical survey may use a single sensor to measure the total magnetic field strength or may use two (sometimes more) spatially separated sensors to measure the gradient of the magnetic field (the difference between the sensors). In most archaeological applications the latter (gradiometer) configuration is preferred because it provides better resolution of small, near-surface phenomena.

Among the electromagnetic methods, the DEMP method belongs to the ones using an active source of the alternate current. It also belongs to so called inductive methods, i.e. the EM signal spreads as an all-directional field without any grounded transmitters (electrodes etc.). The principle is usually based on using two or more couples of the coils – the first is the transmitting one and the other ones work as receivers. The EM field spreads through the geological environment and interacts with it. Resulting signal (based on so called eddy currents) is furtherly evaluated and interpreted. The depth of investigation of such measurements is based both on the coils separation (direct relation) and on the frequencies (thousands to tens of thousands kHz) of

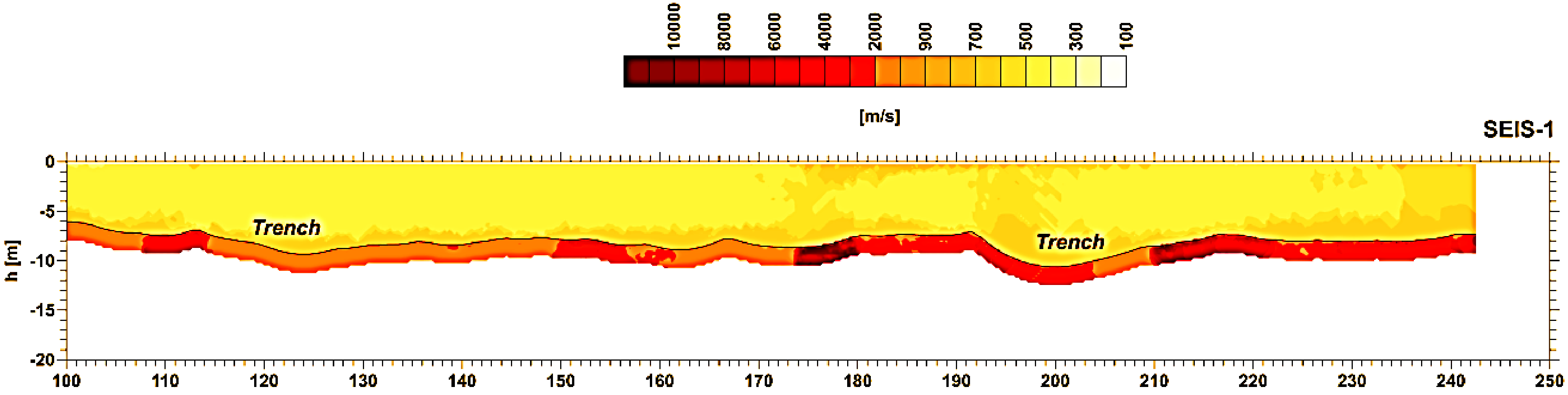

Fig.5 Seis-1 line, preliminary refraction model with values of velocities in m/s and marked positions of trenches.

the transmitter. We used the CMD – MiniExplorer instrument by GF Instruments with three pairs of coils, i.e. three theoretical calibrated depths of investigation 0.5, 1 and 1.8 meters (we display here the deepest theoretical depth as this usually is less influenced by man-made noise).

Ground-penetrating radar (GPR) is a geophysical method that uses radar pulses to image the subsurface. This non-destructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures. GPR can have applications in a variety of media, including rock, soil, ice, fresh water, pavements and structures. In the right conditions, practitioners can use GPR to detect subsurface objects, changes in material properties, and voids and cracks. GPR uses high-frequency (usually polarized) radio waves, usually in the range 10 MHz to 2.6 GHz. A GPR transmitter emits electromagnetic energy into the ground. When the energy encounters a buried object or a boundary between materials having different permittivity, it may be reflected or refracted or scattered back to the surface. A receiving antenna can then record the variations in the return signal. In the conditions of the Czech Republic the depth of investigation (DOI) can be strongly limited by electrically conductive clay layers causing attenuation of the signal and further drop in the DOI down to several meters below the surface. In this case we used the SIR-20 instrument mounted onto a self-made carrier.

Seismic, namely refraction here, is a geophysical principle governed by Snell's Law. Used in the fields of engineering geology, geotechnical engineering and exploration geophysics, seismic refraction traverses (seismic lines) are performed using a seismograph(s) and/or geophone(s), in an array and an energy source. The seismic refraction method utilizes the refraction of seismic waves on geologic layers and rock/soil units in order to characterize the subsurface geologic conditions and geologic structure. The method depends on the fact that seismic waves have differing velocities in different types of soil (or rock): in addition, the waves are refracted when they cross the boundary between different types (or conditions) of soil or rock. The methods enable the general soil types and the approximate depth to strata boundaries, or to bedrock, to be determined. We used ABEM Terraloc Mk6 with 48 active channels (2.5m spacing) and a seismic blow hammer as a source.

Electrical resistivity tomography (ERT) is a geophysical technique for imaging sub-surface structures from electrical resistivity measurements made at the surface, or by electrodes in one or more boreholes. If the electrodes are suspended in the boreholes, deeper sections can be investigated. It is closely related to the medical imaging technique electrical impedance tomography (EIT), and mathematically is the same inverse problem. We used the ARES II, device of GF Instruments on two geophysical lines with 3-meter spacing between electrodes. Due to cobblestones we were limited in placing the electrodes only in between the pavement.

Gravimetry is the measurement of the strength of a gravitational field. Gravimetry may be used when either the magnitude of gravitational field or the properties of matter responsible for its creation are of interest. An instrument used to measure gravity is known as a gravimeter, or gravinometer. For a small body, general relativity predicts gravitational effects indistinguishable from the effects of acceleration by the equivalence principle. Thus, gravimeters can be regarded as special-purpose accelerometers. The resulting measurement may be made in units of force (such as the newton) but is more commonly made in units of gals. When measuring the Earth's gravitational field, measurements are made to the precision of microgals to find density variations in the rocks making up the Earth. Several types of gravimeters exist for making these measurements, including some that are essentially refined versions of the spring scale described above. These measurements are used to define gravity anomalies. We used the CG-5 by Scintrex gravimeter, with 2-meter spacing between stations.

Fig.6 DEMP results with cross-interpretation of three interpreted trenches.

3 Results and interpretation

Selected results are displayed in the figures 3 – 6. As expected in the urban area, some of the methods did not show promising results due to strong industrial noise and anthropologic artefacts in the field, as lamps, sewage, fences etc. On the other hand, some other methods worked surprisingly well and brought us to a reasonable result. First, as expected, the position of the old fire reservoir was confirmed via GPR data, ERT data and particularly as a strong negative anomaly of the gravimetry, fig. 4. Historically, the reservoir worked as an open fire reservoir in the end of the 2nd World War, but probably was finished as a secret underground system in early 1950th. By cross-correlation of the ERT (fig. 3) and DEMP (fig. 6) results several anomalies that might equal to trench bodies have been identified. Three identified trenches (expected by archaeologist) were interpreted as a boundary between places with different resistivity (see fig. 6, DEMP). They cross the Hradčany promontory from South to North, as was expected. The middle trench corresponds with the find excavated under the Salm Palace and it could be dated to the early mediaeval period. The western depression needs to be verified in the future by excavation to prove it´s of anthropogenic origin. The big trench in the East between the 1st Courtyard and the square (fig. 4) was also detected very intensively as a negative gravity anomaly. In the fig. 5 the preliminary seismic model of the SEIS-1 line is showed (refraction boundary by the Reflex W software). The depression around the point of 200 can be the eastern trench. The depression around the 130 can be of geological origin. We would like to continue with our research also in the area of the 1st Courtyard, but currently we do not have entry permission for such activities.

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