Misiewicz, Krzysztof

Geophysical surveys of the Crimean sites carried on as the project NYMPHAION in 1997

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Krzysztof Misiewicz

Geophysical surveys of the Crimean sites carried on as the project NYMPHAION in 1971 (Pl. 41-47)

Geoelectrical measurements carried on the Crimean sites in the frame of the Nymphaion project in 1997 were done with the purpose to obtain additional information to the data collected on the base of field survey and the analysis of aerial photographs. Results of previous geophysical measurements, made here by Tomasz Herbich (HERBICH, 1994) in 1993 and 1994 were used for planning the survey. Having data on the geological situation we knew theoretically what kind of anomalies in resistivity could produce the archaeological remains we were looking for and which measuring system could be the most effective in their detection. All operations in the field were the same as in the case of rescue surveys. We tried to cover with the measurements the biggest surface in the shortest possible time. The preliminary elaboration of obtained data was made already in the field. Thanks to that we could change the method of survey and measuring systems due to the depth and kind of filling of prospected remains. The surveys were made in different places **(pl. 41)** in different geological conditions and it was necessary to adjust operations in the field to the specificity of the site.

Three main purpose were posed before the survey:

- verification of the presence of remains of defence system detected thanks to the remote sensing analysis;
- estimation of site extent on the site „Tobečk – 9";
- localisation of the possible archaeological objects on the site „Èltigen Zapadnyj".

Additionally we try to localise the remains of water pipe system partly detected accidentally in the sand quarry.

Method of survey

The method of survey depended on the problem we have to solve. A system of vertical soundings was used for location of the remains of defence system. The measurements in the field were taken with symmetrical Schlumberger array of current and potential probes arranged as follows: MN/2 = 0. 15 m with AB/2 = 0. 5, 0. 8,1.05, 1. 2, 1. 6, 2, 2. 5, 3. 5, 4. 5 m; for potential probes MN/2 = 1. 5 m distances of current ones – AB/2 were calculated in 6, 8, 10. 5 and 14 m. This system of measurements allowed to collect data on the apparent resistivity of the levels laying from 0.15 to ca.5 meters under the modern surface of the ground. The sounding were done on 5 lines, 2.5 m apart. That way 65 soundings were carried on the surface of ca. 300m^2.

Obtained data were collected in the separate files. That allowed us to present the result of survey both as the maps of vertical **(pl. 42,1)** and horizontal **(pl. 42.2, 43.1)** distribution of the apparent resistivity. Having 12 maps for different depth of prospection we have found as sufficient to present the changes of resistivity in each 0.5 m increasing from 0.5m beneath the modern surface to the depth of 5 m. The last maps present changes in geology e.g. levels of appearance of the natural limestone bedrock.

The Twin-probe array were used for location of the architectural remains laying beneath the modern surface of the ground at the site of „Tobečk-9" and „Èltigen-Zapadnyj". Disposition of the current and potential probes AM = 1m and BN = 5 m (in infinity) gave us the possibility to prospect the layers up to the depth of 1 -1.2 m. Line of 14 vertical soundings were completed at the site „Tobečk-9" for recognising the real depth of detected structures.

Finally we tried to locate the remains of water pipe line by observation of the changes of apparent resistivity measured with the Middle Gradient system.

We present the result of survey on colour and black and white maps and 3-D models of the distribution of the apparent resistivity of the ground.

Over 90 vertical geoelectrical soundings and ca. 8000 measuring points on the profile lines were carried out on the surface of ca. 1 ha at 4 sites.

Results of survey

Defensive constructions

The surveyed field was located on the base of remote sensing analysis. There were straight lines slightly visible on the satellite pictures in this place. These could be interpreted as the remains of defence system, consisted of ditch with possible attached palisade. A vertical geoelectrical sounding was chosen as the main method of survey.

[1] The paper was presented on the Nymphaion conference in the Institute of Archaeology and Ethnology of the Polish Academy of Sciences in October 1998.

We traced the lines of sounding in the place where they should cut vertically the archaeological structures possibly preserved in surveyed field. It could give a chance of detecting and strictly limiting the registered anomalies in resistivity. The changes of resistivity in the range of 25 – 120 omm were registered as the result of measurements and presented on vertical cross-sections of the disposition of apparent resistivity **(pl. 42.1)**. One could observe horizontal layer with the values of apparent resistivity in the range of 25 – 30 omm on the depth 2 – 2.5 m, visible on all prepared cross-sections. This layer we interpreted as the limit of anthropogenic and natural differentiation of resistivity. There were only a little changes resulted mainly from the different humidity of the ground, registered beneath this layer. Such changes are typical for virgin soils.

The arrangement of the levels above the last horizon was more complicated, but still one could not observe narrow, low resistivity anomalies characteristic for ditches or register increases of resistance caused by the presence of stones used for the construction of possible ramparts.

Neither on the map of vertical disposition of apparent resistivity **(pl. 42.1)** nor in figures presenting horizontal distribution of resistivity on different levels of prospection **(pl. 42.2, 43.1)** there were no anomalies typical for the structures we were looking for. In such situation, having in mind, that the constructions we were looking for could be destroyed by natural erosion or deep ploughing, we must prepare the detail analysis of the picture of resistance of subsurface layers. Thanks to that, we could detect the changes of resistivity resulted from different water transpiration in the places where natural lay-out of layers was destroyed by human activity. There were changes of that kind, visible in **(pl.42.1)**. Most of them were accompanied additionally by decreasing of thickness of direct subsurface, high resistance stratum. The most suspicious was the anomaly detected on metres 19 – 21 because of increasing of the values of resistivity in beneath. A trial pit made there (metres 19 – 21 on line 4) shown, that the anomaly could not be explained by the human activity. In this place existed a natural cavity field up by the eroded topsoils of high resistance. The obtained picture of the distribution of apparent resistivity was almost the same as in the case of filling of artificial ditch. In such conditions it was extremely difficult to differentiate anomalies having natural reasons from these of artificial ones.

Site Tobčk – 9

Area of 40 x 50 m, what makes almost 1/4 of the supposed surface of the site, was prospected there. Measurements, taken with Twin-probe system, allowed to recognise the arrangement and resistance characteristic of the layers up to the depth of ca. 1 m. The results of survey were presented on maps **(pl. 43.2)** and 3-D models **(pl. 44.1)** of the distribution of apparent resistivity. Values of resistivity in the range 25 – 100 omm were registered in prospected field. Resistance of 25 – 45 omm is characteristic for the natural soil – here formed by humus and loess mixed with clay. Values of resistivity above 45 omm correspond to the archaeological objects i.e. stone walls and their foundations. High resistivity anomalies were disposed irregularly in western part of prospected field. The shape of anomalies could suggest, that most of them were caused by solid structures surrounded by rubbish material. Line of vertical soundings, made in central part of surveyed site – on the distance of 30 m on the line E 20, gave us the information on possible depth of detected objects. The soundings were made 2 m apart, what allowed to present the result of measuring in form of the map of vertical disposition of resistivity **(pl. 44.2)**. As it is visible on the map, the supposed depth of disturbances is not bigger than 1 m. The concentration of high resistivity material was observable on meters 2-4 – zone 1 and meters 22-26 – zones 2 and 3. Such picture of the distribution of resistivity could suggest, that observed anomalies were caused by the remains of partly destroyed walls. It is not excluded, that solid, intact structures are still preserved under the ground in some part of the site. It is visible in the best way on 3 – D model **(pl. 44.1)**. Basing on these data we marked 8 zones of disturbances, with anomalies having regular – narrow, linear character and right angels **(pl. 45.1)**.

The trial pit, in most distinctive zone 4 (metres S 12 – S 13; E 22 – E 24), was opened to verify our suppositions. The remains of stone wall on the depth of ca. 0,4 m were excavated here **(pl. 45.2)**. Upper part of the wall was destroyed. Stones used originally for their construction, lied on both sides of the wall. The lower part of the wall, on the depth of ca. 0,7 m, is still well preserved and could give the data on time and type of masonary.

Though only the eastern and northern border of the architectural complex erected there were detected in surveyed field, obtained data seems to be sufficient for planning the large scale archaeological excavation in that part of the site.

Site Èltigen Zapadnyj

The area of 30 x 70 meters in proximity to the possible main road leading to ancient Nymphaion was surveyed on this site. The Twin-probe system was used for measurements in the field. Obtained results were very similar to that we had have on the site Tobèk – 9. Registered changes of resistivity, in the range 10 – 100 omm, could suggest, that also on that site most of the high resistivity anomalies were caused by the architectural remains laying not deeper then 1 m under the modern surface of the ground. The site was situated on a slight slope **(pl. 47.3)**. Taking the measurements on soundings in such conditions we had have to calculate the influence of the factor of levelling of surface on the real depth of prospection.

The calculations of these kind are too complicated and time-consuming. Obtained result not always corresponds to the reality in the field. In that situation we have found extremely difficult the using of vertical sounding for determination of the real depth of prospected remains. We limited our activity only to the profiling and present their results on maps **(pl. 47.1)** and 3-D models **(pl. 46.1)** of distribution of the resistivity. The zones of higher resistance that their surroundings are visible both on the maps and 3-D models. Linear character of anomalies could suggest that stone walls or their foundations caused most of the disturbances. Some of anomalies were rather slight (anomaly 1 and 2, **pl. 47.1**), some were large and distinctive – anomalies 3, 4, 5 and especially anomaly 6. This anomaly is also the most interesting because one could observe here enlargement of disturbed zone in their south – eastern part, typical for the case. The remains of corners of buildings were preserved there under the ground (HERBICH et al, 1997). However, the most distinctive increasing of the values of resistance was registered in zone 4. It could suggest, that the remains, being the cause of anomaly in resistivity are better preserved, or lie closer to the surface. We decided to open the trial pit within zone 4 to answer the question. The solid, good preserved stone wall, build with large, well elaborated limestone slabs, was found in the trench **(pl. 46.2)**.

Basing on the result of excavation we could interpret our map of the disposition of resistivity. It allowed us to limit the extent of the site from eastern and southern side and to find the places, where the architectural remains could be accessible for direct archaeological intervention. Data obtained on this site are sufficient both for limiting the zone of special protection and for planning the excavation.

Water-pipe line

The survey on that site, situated near modern sand quarry, was done to check the possibilities of tracing a course of water-pipe system by observation of the changes of resistivity. Surveyed remains lied on rather big depth 2 – 2.5 m, as it was visible in the quarry, where the part of water pipe was discovered accidentally.

The Middle Gradient measuring system was used in the field with current probes AB – 20 m and measuring ones MN – 1 m apart. It allowed to prospect the layers up to the depth of ca. 3 m. In normal operation in the field with Middle Gradient system it is necessary to repeat the measurements with current probes AB situated parallel and perpendicular to the possible surveyed structure. In our case we knew theoretically the supposed course of the water pipe and it was possible to place the current probes perpendicular to the structures. This position gave the biggest chance to register anomalies of resistivity caused by surveyed structures, if they caused any. We knew, that it would be extremely difficult to detect anomalies caused by the pipe itself. Preserved parts of terracotta pipes have rather small diameter of ca. 30 cm. In such conditions neither material nor the dimensions of surveyed features could produce distinctive anomalies in resistivity detectable by geoelectrical measurements. However, we have to check, if it is possible to detect a contrast between the filling of ditch made for placing the pipe and their surrounding – natural limestone bedrock. For this purpose area of ca. 2500 sq. m was surveyed between two cavities, visible in the field and interpreted as the remains of shafts for de-aeration and conservation of water pipe system.

Resistivity values in the range 20 – 600 omm were registered in the prospected field. The result of survey was presented on the map of disposition of resistivity **(pl. 47.2)**. The zone of high resistivity, visible in the northern part of surveyed area, with sharp borders from western and eastern side, corresponds to the limits of ploughed field. Single, linear anomalies in the range 120 – 150 omm, laying to the North of this zone could be caused by deep ploughing, but could be also the result of so called „slope effect". In the last case the difference in levels in the field could create long, linear higher resistivity anomalies when Middle Gradient system is used for measurements. These anomalies are, like in our case, parallel to the profiles – lines of measurements (CRUCIANI et al., 1990). This effect could be also observed in the zone between metres N 29 – N 30; W 20 – W 40, but because of higher values of resistance in this zone, is not so good visible as in the western part of prospected field. We have here the classical situation, when the noise, caused by natural sources and limits of the possibilities of measuring system, makes impossible certain interpretation of the reason of observed anomalies (WEYMOUTH, 1986, p. 329).

It is clear, that in such situation we could not distinguish and interpret possible anomalies created by the presence of the remains of water pipe system.

Unfortunately we could not answer at all the questions posed before geophysical survey at the *chora* of Nymphaion. Complicated geological conditions, different moisture of the subsurface soils and watering which could change rapidly many times made the interpretation of the results of measurement very difficult. Processes connected with natural erosion and the presence of natural bedrock, in many places directly under the surface, were also not favourable for the geophysical survey. In such conditions estimation of the site extent on the site Èltigen Zapadnyj or location of archaeological structures and determination of their depth on the site Tobečk could be treated as succes. I hope that the results of survey presented above will help in full reconstruction of the history of human activity on this terrain in antiquity.

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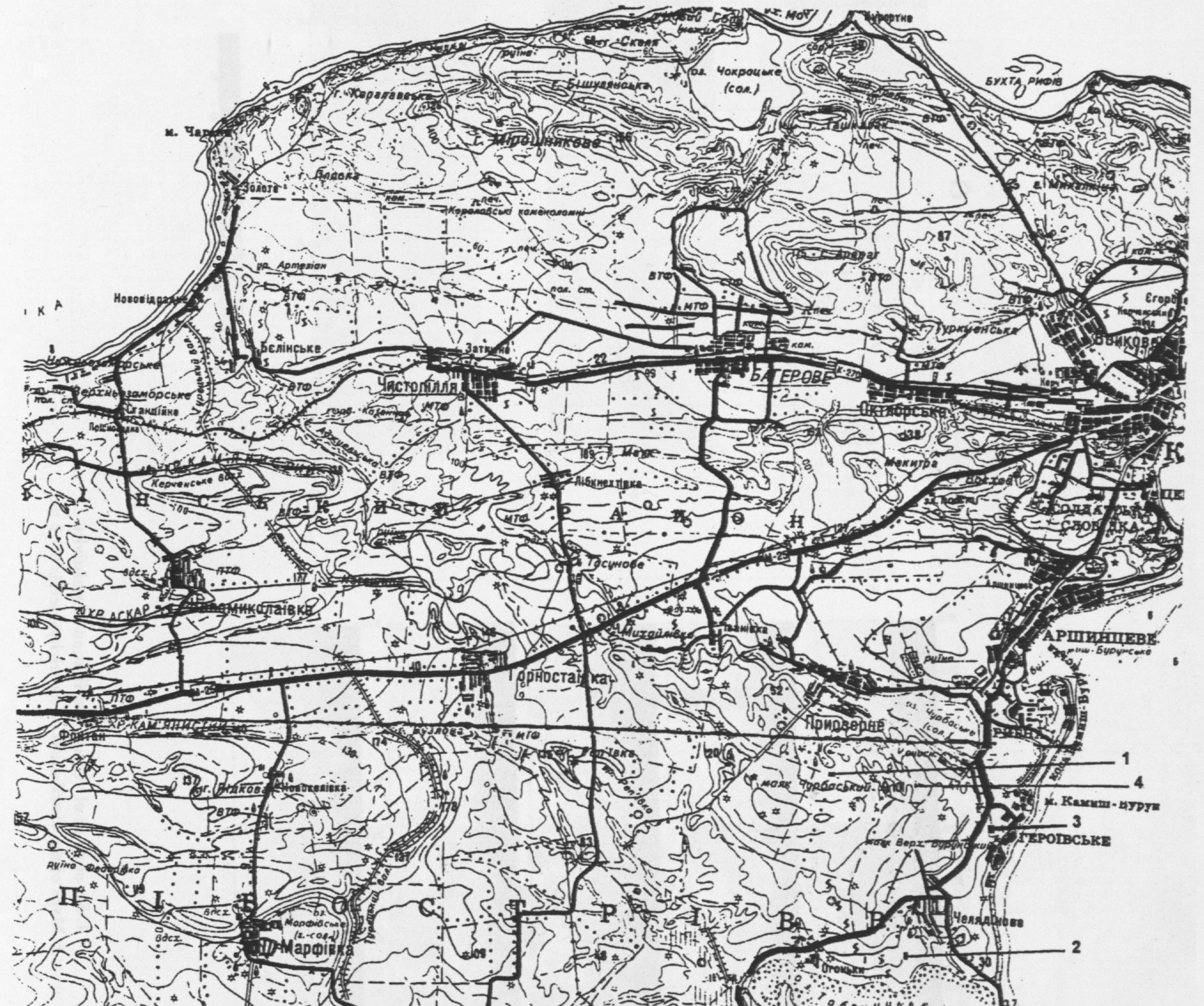
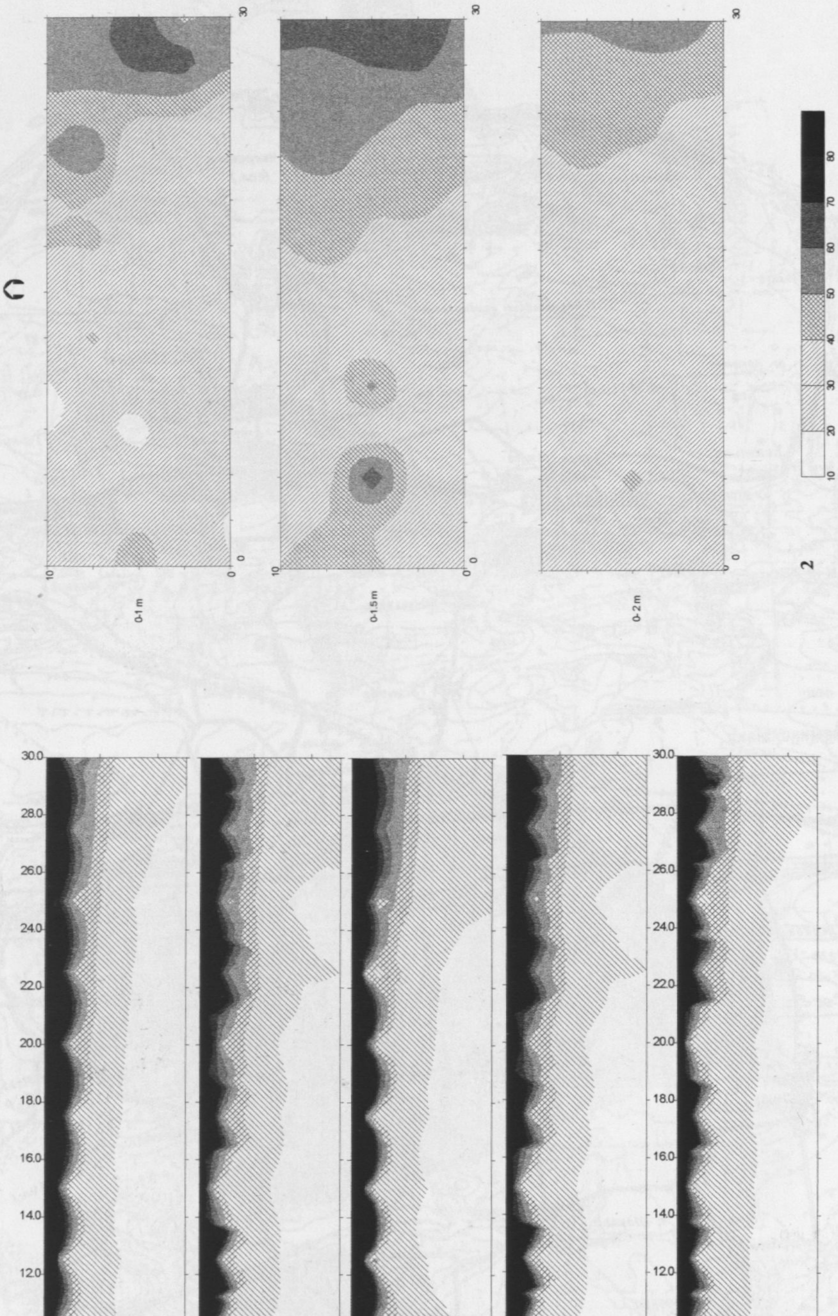
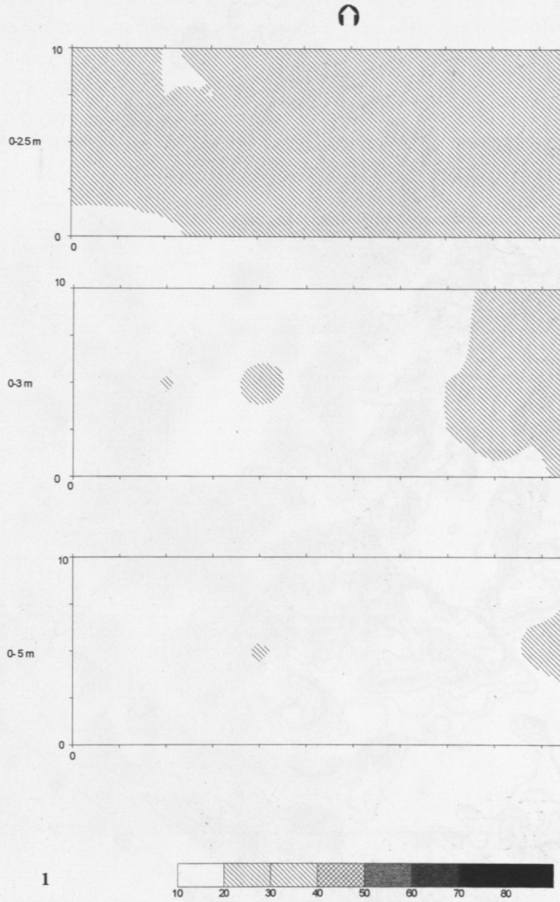


Localisation of geophysical surveys.



1. Set of maps of vertical distribution of resistivity.
2. Maps of the distribution of resistivity - levels 0 - 2 m.



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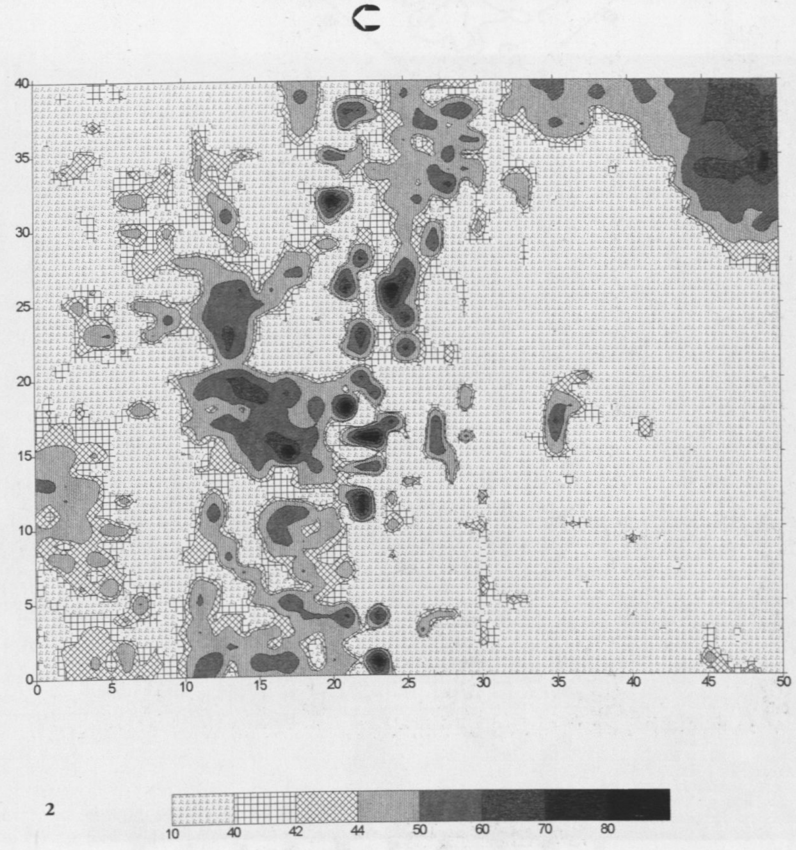

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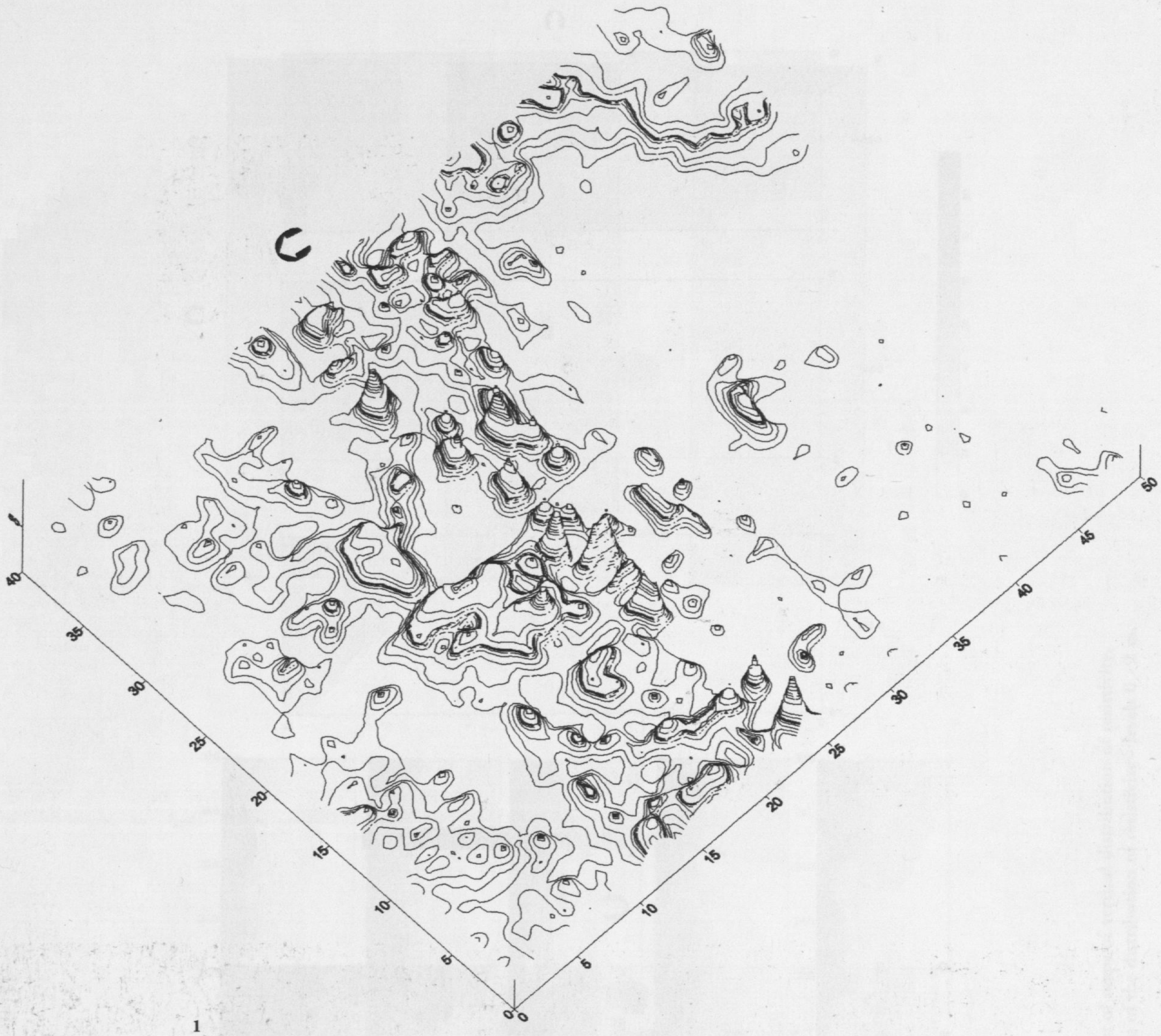
1. Maps of the distribution of resitivity - levels 2,5 - 5 m.
2. Tobečk - 9. Map of the distribution of resistivity.



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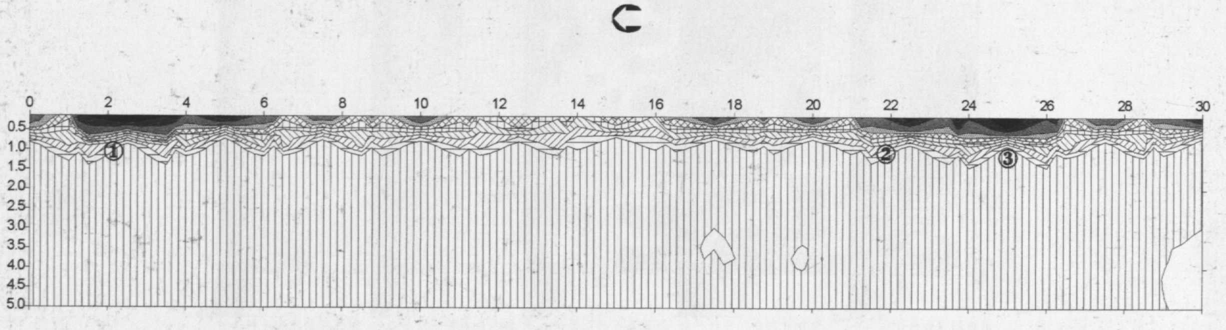
TOBEČK-9



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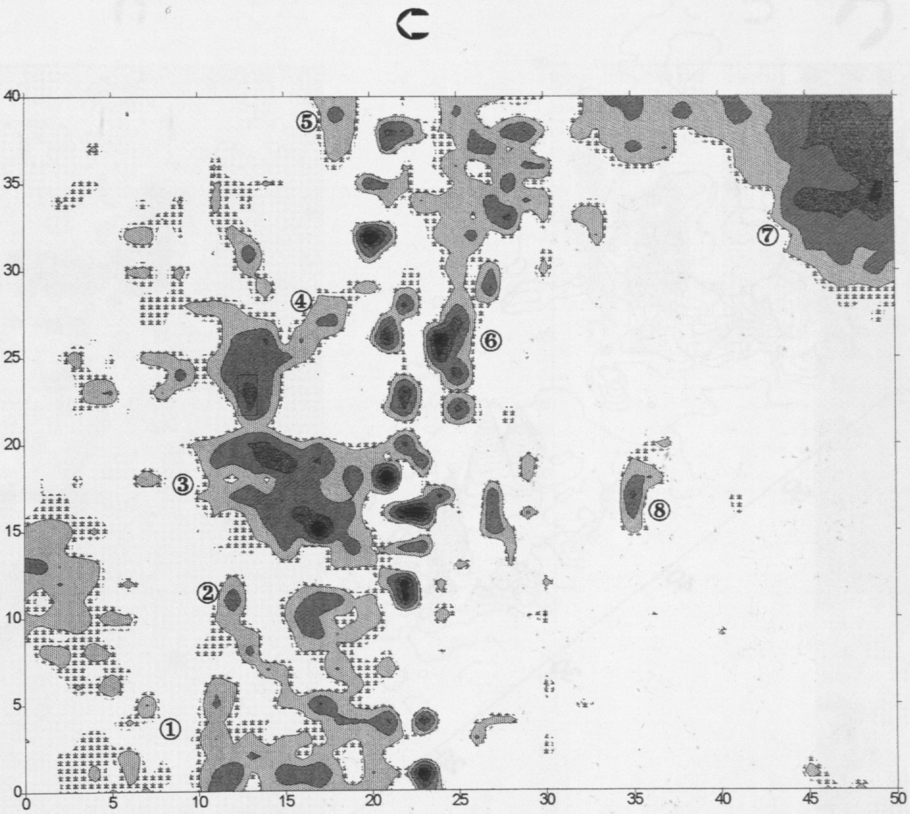
1. Tobečk - 9. 3-D model of the distribution of resistivity.
2. Tobečk - 9. Map of the vertical distribution of resistivity.



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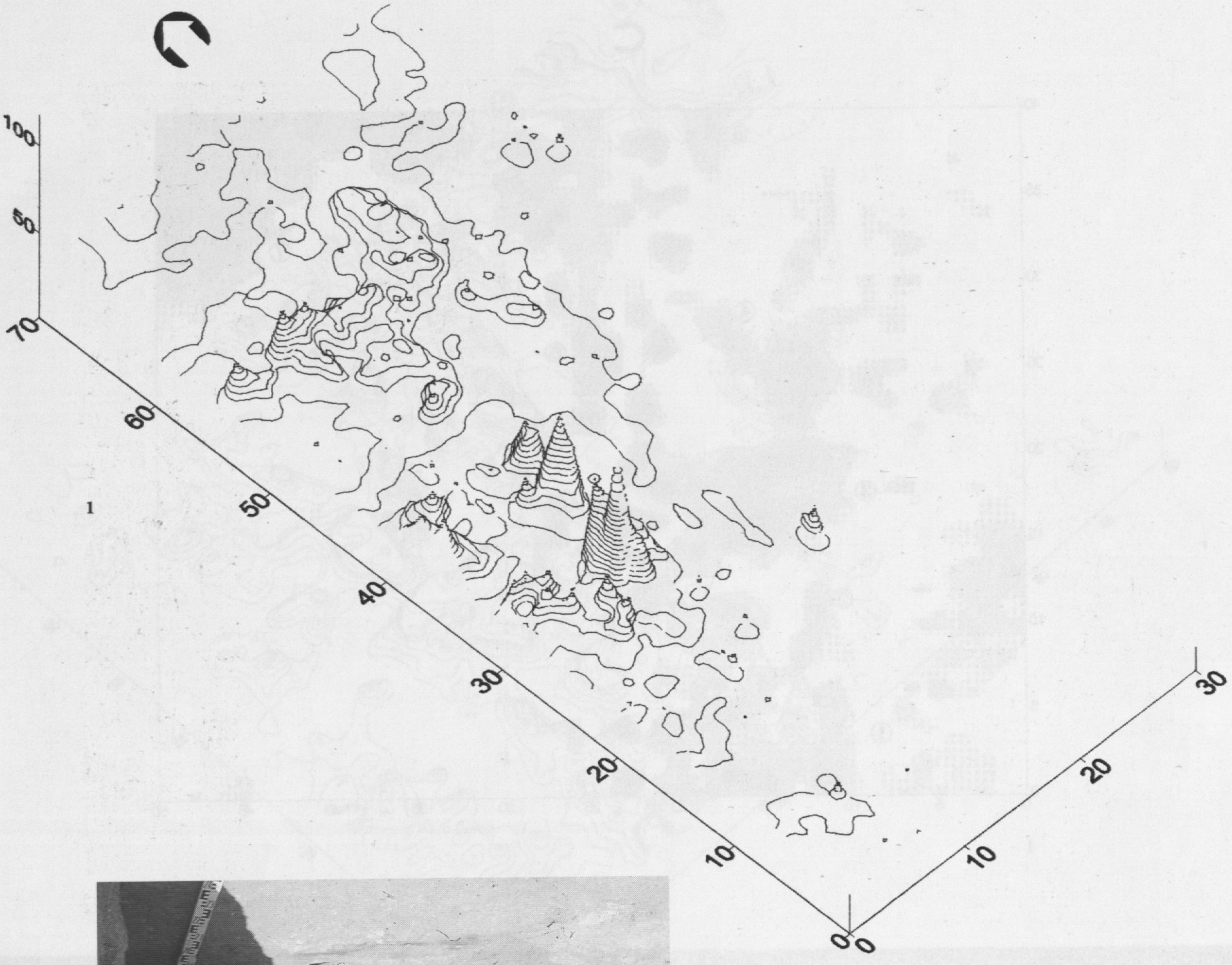
2

1. Tobečk - 9. Zones of anomalies of resisivity.
2. Tobečk - 9. Remains of stone wall in the trial pit.

PLANSZA 46



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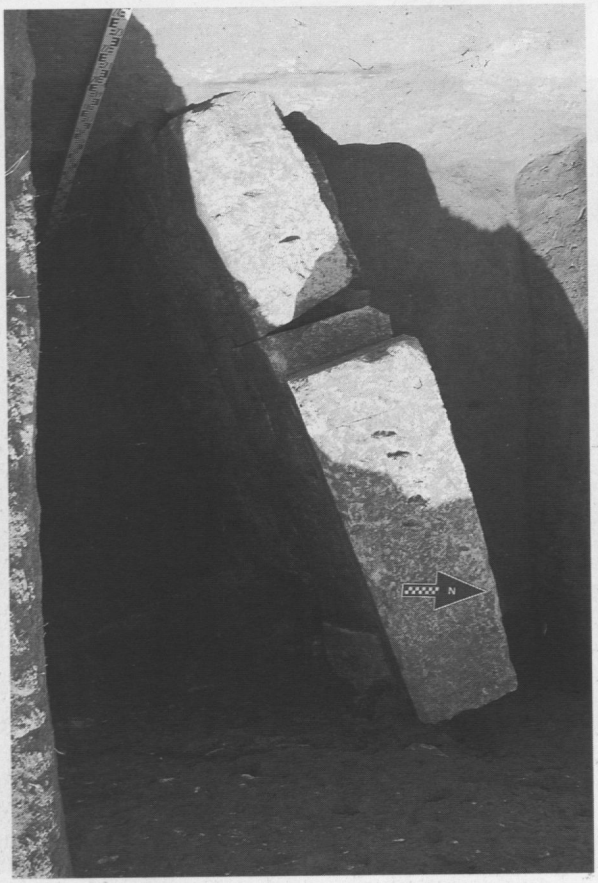
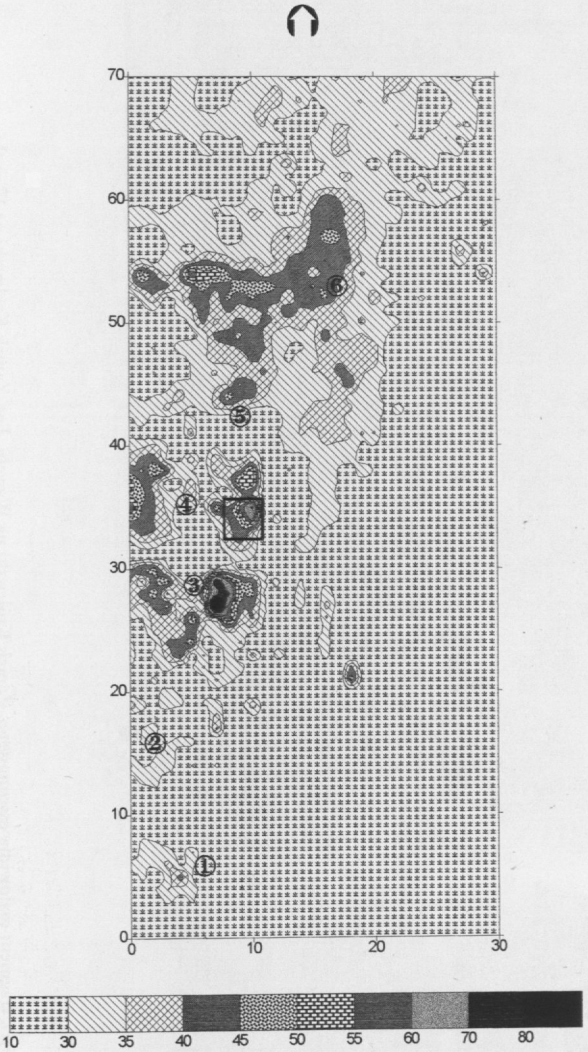


2

1. Èltigen Zapadnyj. 3-D model of the distribution of resistivity.
2. Èltigen Zapadnyj. Wall excavated in the trial pit.



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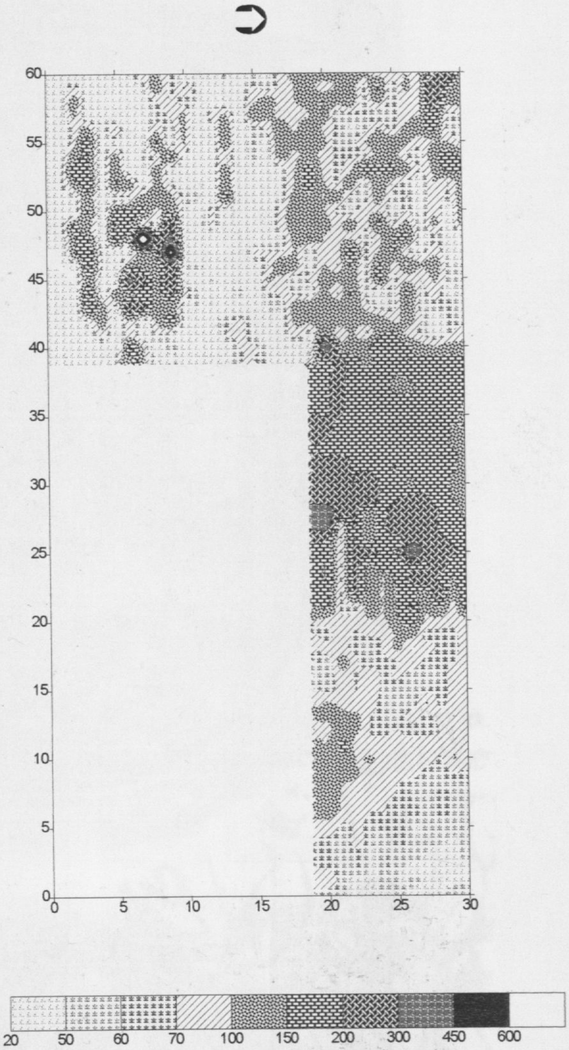

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3

1. Èltigen Zapadnyj. Map of the distribution of resistivity.
2. Map of the distribution of apparent resistivity measured with Middle Gradient system on the site "Water - pipe".
3. Èltigen Zapadnyj. General view of the site.