THE GIS OF THE ANCIENT CITY OF SALONA NEW TECHNOLOGIES AND METHODOLOGY IN ARCHAEOLOGICAL RESEARCH – GEOPHYSICAL INVESTIGATION

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In 1997, experts from the Ministry of Culture / Conservation Department in Split started protective archaeological work and conservation works on the northern walls of Salona, the capital of the Roman province of Dalmatia. The city walls, long-neglected, overgrown and mostly buried, once again saw the light of day. A stretch of ramparts fortified with towers north of Porta Andetria was revealed, all the way up to a joint where the direction of it went of at an angle towards Porta Caesarea, for a distance of about 800 m; Don F. Bulic had made a promenade on top of this way, covering it over mostly up to about half the height, so that some segments of them remained visible, and preserved almost in their original dimensions.

Images of these unique monuments of fortification architecture were made by experts from the Photogrammetry Institute of the Geodetic Faculty in Zagreb photogrammetrically, and a geodetic grid was laid out from Porta Andetria to Porta Caesarea. After this basic documentation, filled out with classical architectural and photographical imaging, the parts of the city walls most at risk were preventatively conserved. Then experts from the Archaeological Department of the Ljubljana Faculty of Philosophy carried out geophysical research of the northern ramparts of Salona, and in this way the whole stretch of the northern walls of the new part of the city, Urbs orientalis, was documented.

The excellent results led to the making of a database for ancient Salona – the city of Solin – in order to facilitate the planning of protective archaeological research and the conservational guidelines for the making, in cooperation with the city, of detail town planning maps of individual city zones. For this reason, a start was made in the eastern part of Salona, on top of which today's city of Solin came into being. In this context, the Photogrammetry Institute of Zagreb's Geodetic Faculty made a polygonal grid for the eastern part of Salona, which covered the triangle between the main roads, i.e., between Zvonimirova ulica and Ulica Stjepana Radica; then the Solin cadastre was scanned and transferred to CD, so that it should be accessible for the entry of data relating to new discoveries arrived at during the protective archaeological research that is being carried out in the protected city core and for the entry of the documentation of previous investigations. That is, this database should contain all the archaeological findings about ancient Salona made to date. On each cadastral plot would be entered data about the kind of land, with details of who owns it, descriptions of particular investigations including archival documents, and a list of the literature, architectural finds would be drawn in, and the movable archaeological finds would be indicated, with reference to where they are held today.

Also involved in this developmental research project into the GIS of Salona were experts from the surveying firm Kipregel d.o.o., of Split, who are recording in the field the new archaeological finds discovered during the protective archaeological research and entering them into the cadastral base. They are also unifying and entering the documentation of the previous archaeological research onto the cadastral plots.

The city of Solin has employed for this long-term and valuable project of the future GIS of Salona an archaeologist with a university degree, so that the basic database to serve for the joint planning of the protection and the presentation of the archaeological monuments of Salona should be made as soon as possible; a particular value of this lies in its being able to be used in the drawing up of detailed maps of individual zones of the city of Solin.

The city of Solin, which arose on the eastern part of Salona, the largest ancient city on the Croatian shores of the Adriatic, is an exceptional example of a complex historical image of a continuity existing since ancient times in coexistence with a contemporary city. The series of relevant elements unified on the single database will contribute to the simpler solution of the needs of Solin's everyday life.

From this point of view, one illustrative example is of the most recent archaeological research carried out along the lines of the sewage mains and the sewage network on the main roads, where segments of the city walls and towers by the side of the eastern city gate, Porta Andetria, and the gate itself, have been uncovered.

Experts of the Split Conservation Department, during municipal works along the line of the construction of the sewage main in the area of Bilankusa, where the ancient ramparts of Salona extend, carried out protective archaeological research. And precisely along this direction go important routes in the direction of Klis, and further into the interior; hence, research has never been able to be carried out before into this part of ancient Salona.

Parts of the eastern city walls, about 8 m long, were discovered, as well as a city tower built of large stone blocks, among which were incorporated some tombstones, used as building material, or spolia as it is called, which belonged to the eastern city necropolis. That is, from the oldest city gate, Porta Caesarea, a road led that forked into two basic directions, eastern and southern, and alongside it the necropolises were formed. When the city expanded outside this most ancient city centre (Urbs vetus), in an eastern and a western direction, creating the so-called Urbs orientalis and Urbs occidentalis, which were formed by the raising of new city walls in the third quarter of the 2nd century, during the time of Marcus Aurelius, the tombstones were gradually moved from the city, and where largely used as building material, right at the time when the city walls and towers were built.

Two tomb inscriptions were built into the newly discovered tower, the first one from the eastern city gate, Porta Andetria.

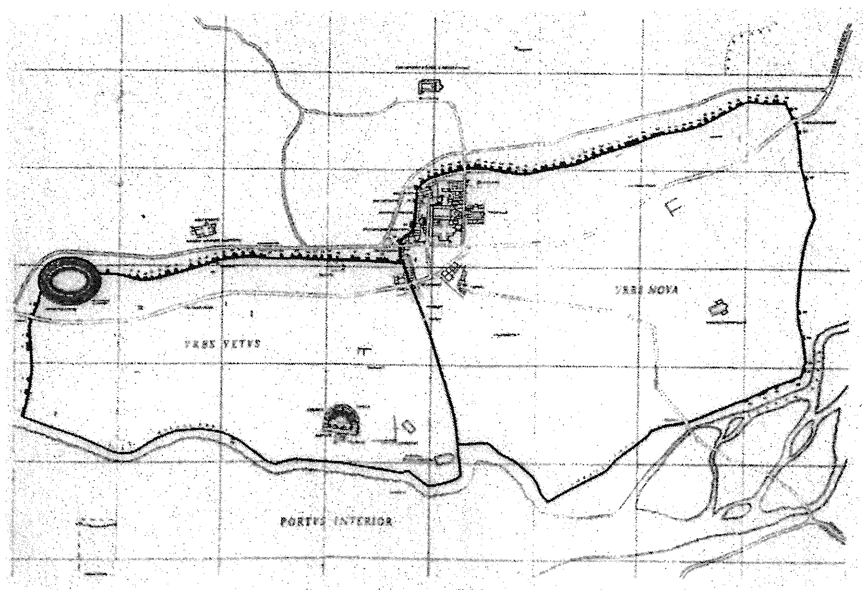
The first inscription related to the soldier Titus Flavius Lucilius, who from being the vexillary, or standard bearer of a Roman military unit, became a centurion of the 8th cohort, the Voluntariorum. On one side of the monument is a soldier, a centurion, and on the other side is the standard of a Roman legion. The other monument had its inscription chipped off even in ancient times, which is frequently the case with ancient imperial inscriptions.

Further along the direction of the trench, parts of the eastern city gate were discovered; this, the Porta Andetria, as it is called, was partially uncovered by F. Carrara in the mid-19th century. The gate lay at the end of the main city street (deumanus maximus) and must have been the grandest and most highly decorated, fitting the importance of their position. Carrara revealed the western part of the gate, the street paving with deep wheel tracks, flanked by two smaller towers. From here led important routes to the interior, to the north, in the direction of Andetrium, after which the gate was actually named.

Thanks to the protective research along the line of the construction of the sewage main (collector), for the first time it was possible to investigate one of the most important entrances into the ancient city of Salona. The eastern part of the gate was revealed; it consists of two square towers reinforced with a triangular superstructure. A metal portcullis dropped between the towers, the grooves for which are clearly cut into the side wall of the northern tower. In this way the towers, with the towers earlier revealed, closed off the internal courtyard, the propugnacle, defending the most vulnerable part of the city walls, the entry into the city. The eastern city gate, the Porta Andetria, was created in the 2nd century, when the eastern suburbs were protected by the building of a new ring wall.
Archaeological investigations carried out at an extremely complex point of transition, at the interface between today's Solin and ancient Salona, have revealed an eastern part of the gate that was connected with Carrara's finds of the western parts. The new archaeological understanding has been given body from geophysical research carried out by experts from Ljubljana, the Archaeological Department of the Faculty of Philosophy, and the firm Zorty. The outstanding results of the application of a new technology and methodology, presented here for the first time, are an invaluable contribution in the handling of complex urban archaeological research. It is the application of various methods of research, adapted to the demands of the contemporary city, that has advanced our understandings and provided more information for the database that is necessary for the construction of the Salona GIS.

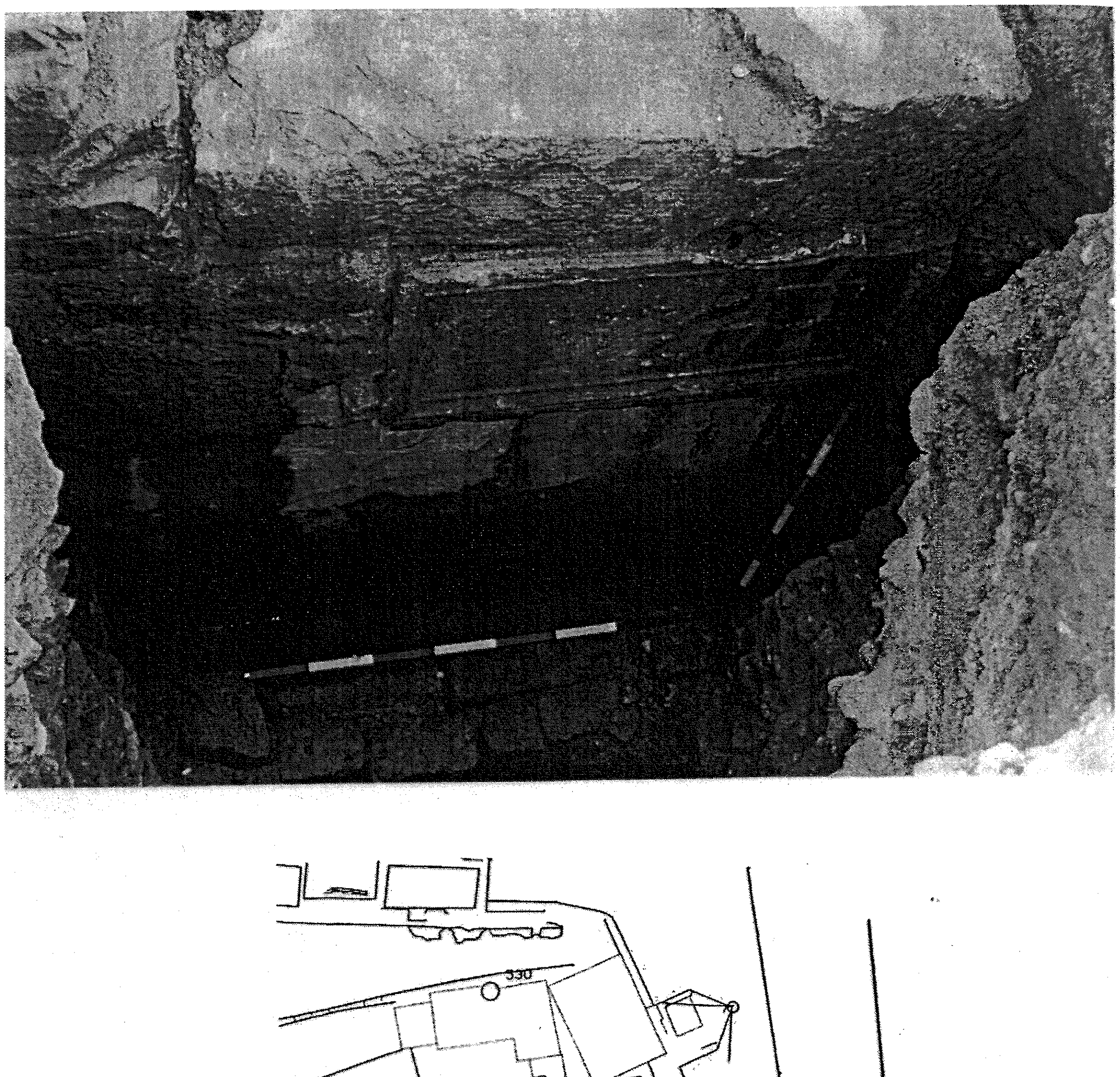
Experts of the Split Conservation Department of the Ministry of Culture, those leading the Salona GIS project, in cooperation with surveyors of the Photogrammetry Institute of the Geodetic Faculty, Zagreb, and surveyors from Kipregel d.o.o, as well as experts from Ljubljana, the Archaeological Department of the Faculty of Philosophy and the firm Zorty, and in exceptionally close cooperation with the city of Solin, will bring together all the results of the joint investigations and the archaeological findings. A database created in this way is the very basic foundation for the making of the Salona GIS, for the sake of fostering a living continuity between the modern city of Solin and the ancient city of Salona.

Photograph captions

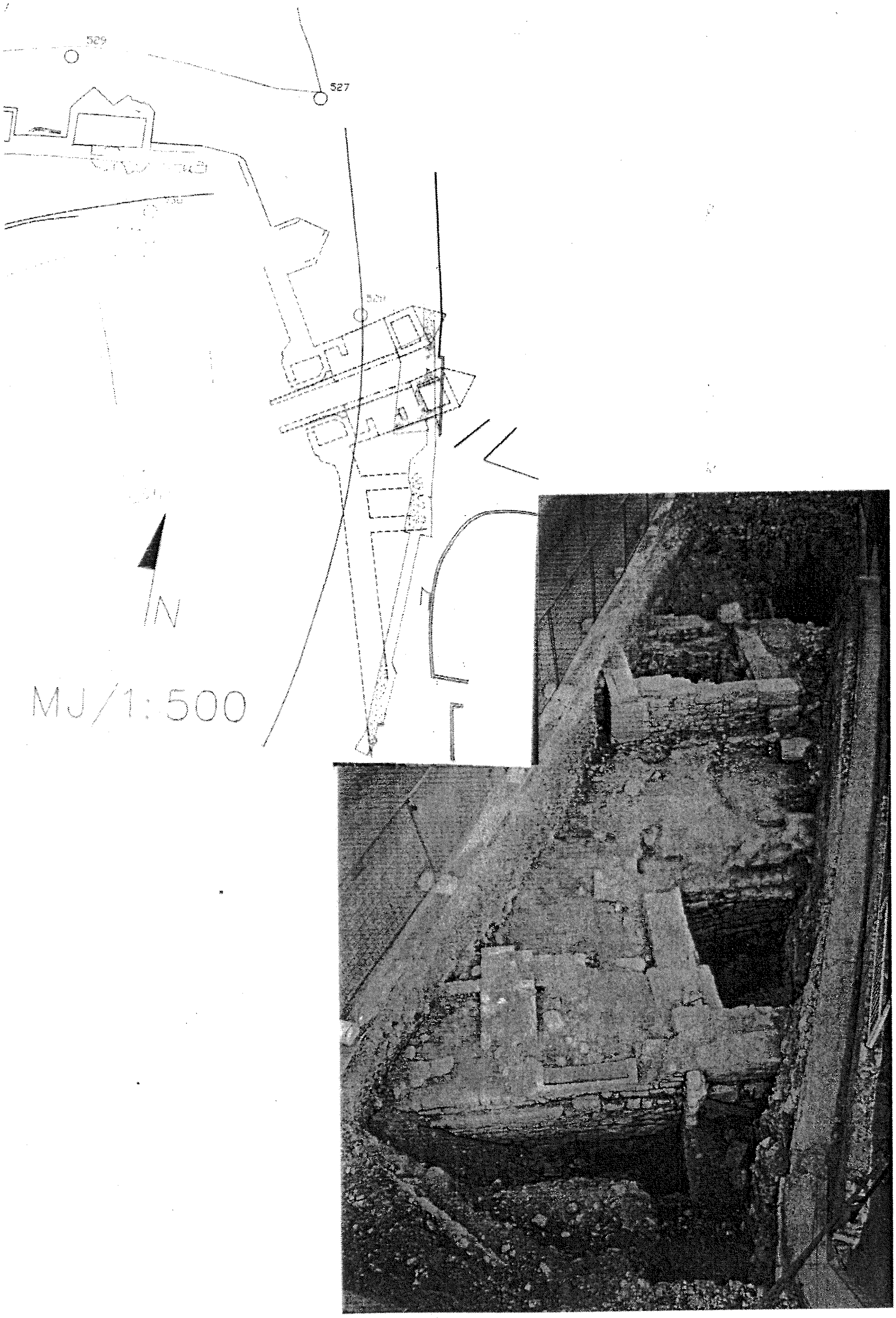


Tlocrt grada Salone (E. Dyggve)

1.Ground plan of the city of Salona (E. Dyggve)



2. Tower with the tombstone of a Roman centurion built in, discovered during archaeological research along the line of the sewage main.



3. A view of the eastern part of the city gate, Porta Andetria, during archaeological research along the line of the sewage main.

INTRODUCTION INTO THE GEOPHYSICAL PROSPECTING

Geophysical investigations for archaeological purposes at the Department of Archaeology, the University of Ljubljana, have produced a series of useful information for academic archaeological analyses as well as for the protection of the archaeological cultural heritage from construction intervention. One of the main problems with archaeological prospecting is still the evaluation of the suitability of individual techniques with regard to the various natural and urban environments and the types of archaeological remains. We shall illustrate my thoughts on this theme with the results of selected investigations on the site of Salona, which describe the possibilities provided by geophysical prospecting on the sites which are situated in somehow different urban environments.

The research strategy, from the outset of independent geophysical prospecting at the Department of Archaeology in 1990, was primarily directed towards collecting data on anomalies in physical fields resulting from archaeological remains that are situated in various natural and urban environments.

One of the basic principles of geophysical prospecting is to apply a variety of geophysical techniques at the same archaeological site, wherever possible. Current applications include magnetometry using a fluxgate gradiometer (Geoscan FM36), a proton magnetometers (Geometrics G816 and GemSystem GSM19), cesium magnetometer (Geometrics G-858), measuring the magnetic susceptibility (Kappameter KT-5), the apparent resistivity (Geoscan RM15) and self potentials (Digital multimeter Protec 506), as well as conductivity (Geonics EM38) and georadar measurements (GSSI SIR 3 main unit; 200 and 500 MHZ antenna). Such an approach procures more data, which consequently enables a better interpretation even in difficult urban conditions.

In this way it is possible to determine the “critical” or “border” values for physical fields (=anomalies) for each geophysical technique applied (see Mušič and Slapšak 1998, 81-93; Mušič, Slapšak and Perko 1999, 132-146). It is an empirical or statistically determined value which represents the lower limit of a significant anomaly characteristic for a particular type of archaeological remain in specific environment. Basically, it is a matter of distinguishing the signal to noise ratio and the value span, which is a result of noise, must be established first. On the basis of so-called “critical” values the boundaries between varying activity areas can be also determined. This procedure was first time explained for the resistivity method by Carr (1982).

To employ an approach similar to combining multi-channel satellite images into a composite picture we can replace the satellite images with a data series from different geophysical techniques (see Ladefoged et al. 1995, 471-481).

THE GIS DATABASE FOR GEOPHYSICAL PROSPECTING

Much attention has been dedicated to national archaeological databases, in the past few years, that also incorporate results from geophysical survey (see i.e. Linford and Cottrell 1994a, 133-134: 1994b, 133-134). This could be an indication that archaeological prospecting, and consequently also geophysical survey, have sufficiently asserted themselves throughout the academic world serving for archaeological settlement analyses, as well as for the everyday protection of the cultural heritage.

Newer databases are created in program packages that serve as tools for examining extensive databases for geographic information systems (i.e. ArcView, Esri). The primary advantage of these databases is that they enable a link between the textual part of the database and the graphic foundations composed of georeferential information on geophysical investigations and aerial photography (see i.e. Doneus and Neubauer 1998, 29-56). I also chose this type of database structure as it enables the combination of diverse types of information concerning archaeology, archaeological prospecting and the natural environment.

The trends in geophysical investigations in archaeology indicate that the phase of "filtering" raw data has, having experienced its culmination at the end of the 1980's and the beginning of the 1990's, finally expired. At that time, such an extensive selection of investigations was not yet available considering that they only came into full swing with the development of microcomputers. Initially the trend was to present and process the data in the foreground with the intention of emphasizing the significant anomalies in the physical fields, which result from the presence of archaeological structures against the various noise in the background.

Bevan (Geosight, USA) chose a different approach to geophysical prospecting in archaeology. His prospecting results are sumarized in three unpublished reports (Bevan 1996a; 1996b and 1996c). Relying on the basis of numerous investigations at very diverse sites, he was the first to provide an reliable evaluation of the suitability of various geophysical techniques in dependence of characteristics of the natural environment and the types of archaeological remains.

While establishing our database for geophysical prospecting, the fundamental principles of the English Heritage Geophysical Survey Database (SDB), proposed by the Ancient Monuments Laboratory in 1994, were taken into consideration. As the national database for archaeological sites (ARKAS) (see Tecco-Hvala1992, 62-63) is a project underway already at the Institute of Archaeology, Scientific Research Center of Slovenian Academy of Sciences and Arts, the particularities of this database were also considered.

The quotient of success and consequently also the evaluation of the suitability of geophysical investigations was determined relevant to the results of archaeological excavations. The estimated suitability of individual prospecting techniques were recorded for those sites not yet excavated, based upon comparisons with similar archaeological sites wherever justification by excavation was possible.

Information cited in the literature may be helpful to some degree when determining the potential of geophysical techniques, although it is insufficient for a more precise evaluation. The most evident limitation is that predominantly results from "successful" geophysical investigations are cited in the literature, that is, the majority of cases were executed on archaeological sites with well preserved archaeological remains and various other favorable natural characteristics. Noticeably fewer publications are more research oriented and deal with the effectiveness of geophysical techniques under various working conditions (see Bevan 1996a, 1996b and 1996c; Car 1982). An extensive investigation was organized in which numerous various geophysical techniques were tested, for example, within the region of the Selinunte archaeological park, Sicily (Finetti 1992, 83-232). Publications concerning geophysical investigations that failed to produce the anticipated results are even more rare (see Nishimura and Kamai 1990, 757-765).

Ideally, selection of the most suitable geophysical techniques is dictated only by the targeted archaeological objects. In reality, the targeted archaeological objects account for only a larger or smaller part in determining the most appropriate geophysical techniques. Correspondingly, an anomaly in the physical field, resulting from the presence of an archaeological object, is termed a signal, while all other irregularities in the physical fields, resulting from various other factors, are termed noise. The most suitable selection of the instrument is not in the case when the expected amplitude of the signal is the greatest, but rather when the ratio of the signal versus noise is the greatest.

Better results are usually attained in the instance that the anticipated type of archaeological remain is at least approximately known. The most effective strategy for geophysical prospecting is selected on the basis of the evaluated "contrast" of particular physical parameters (e.g. conductivity, dielectric constant, susceptibility ...), a type of archaeological remain, the noise from the surroundings, the surface condition, as well as the geological, pedological or modern urban composition of the terrain.

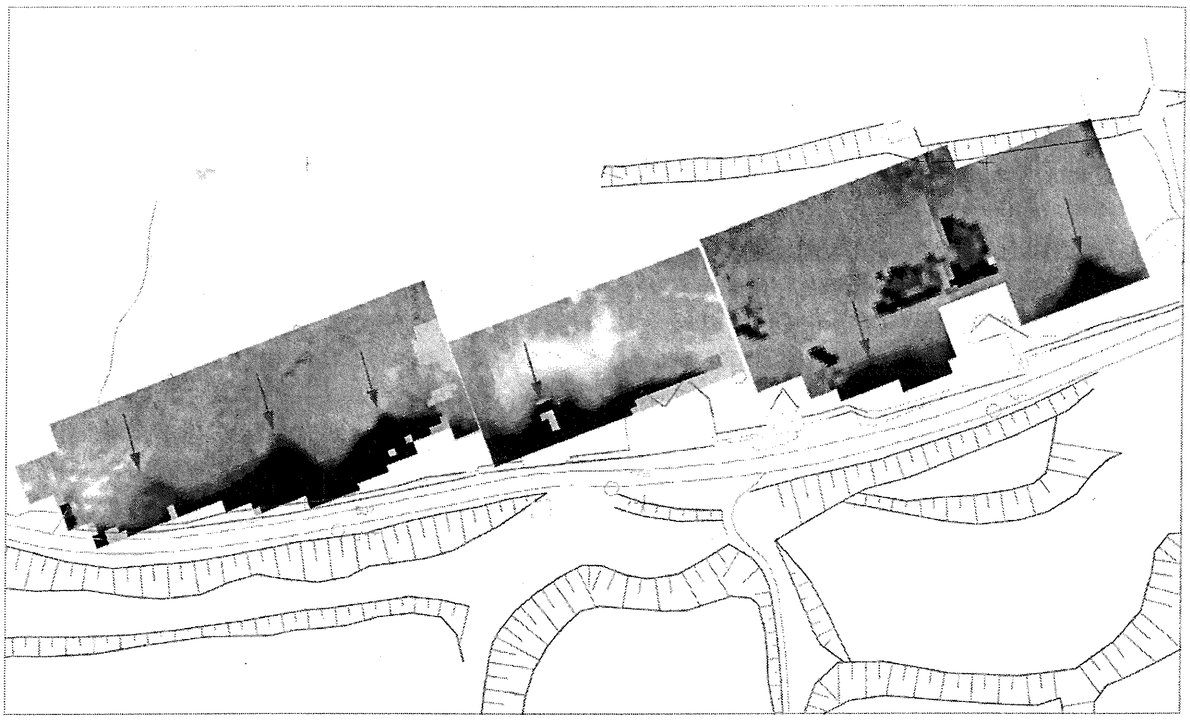


Fig. 1: Results of resistivity measurements on the direction of northern fortifications of Salona. High resistivity values represents efficiency of triangular deffence towers.

Fig. 2: Results of resistivity measurements on the direction of northern fortifications of Salona. High resistivity values represents efficiency of deffence tower of rectangular shape.

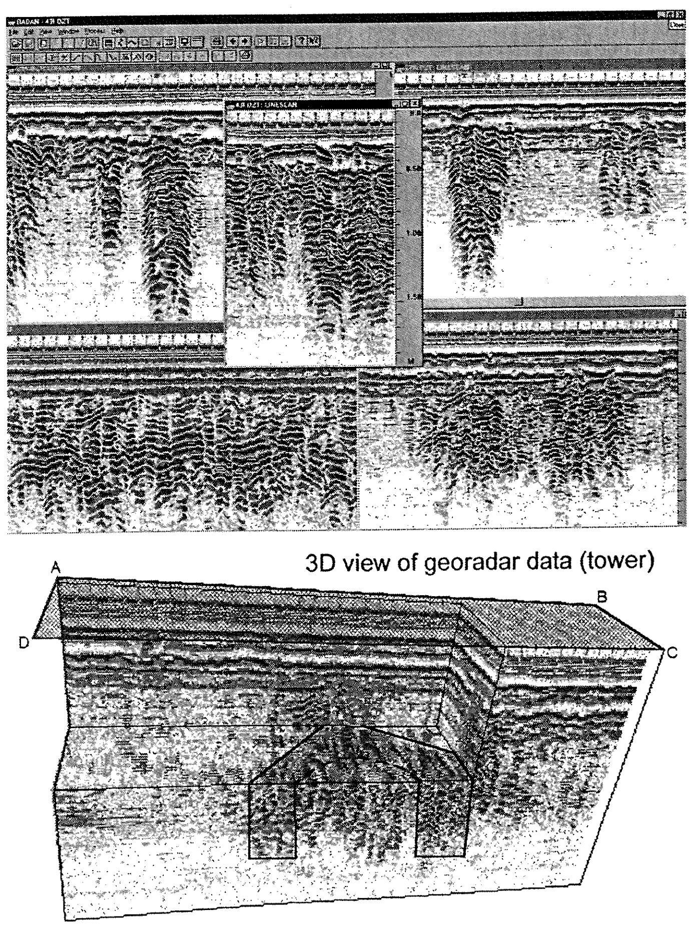


Fig. 3: Characteristic georadar reflections from archaeological architectural remains.

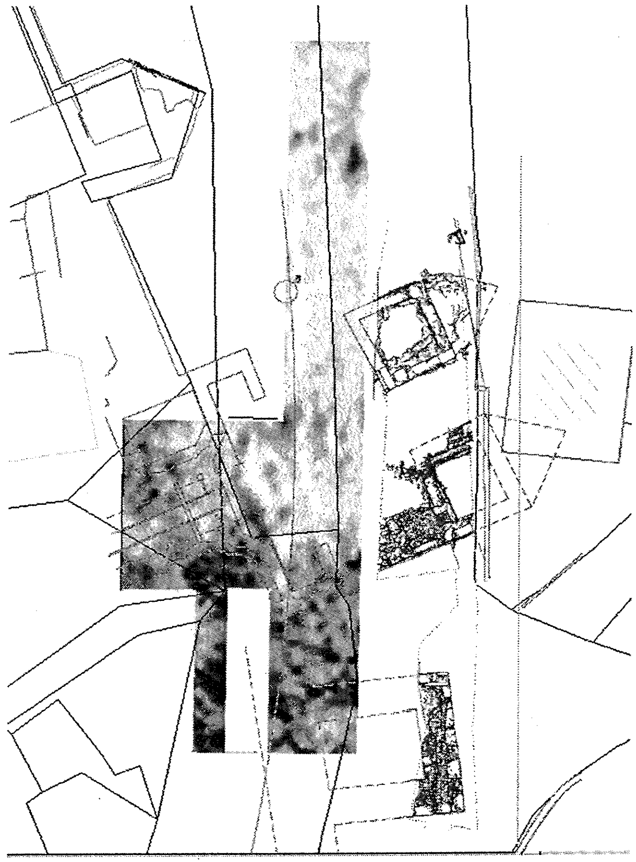


Fig. 4: Time slice (horizontal view) of georadar reflections on the depth off 1 m on the eastern entrance to the city of Salona. Continuation of structures discovered during excavation is clearly visible.

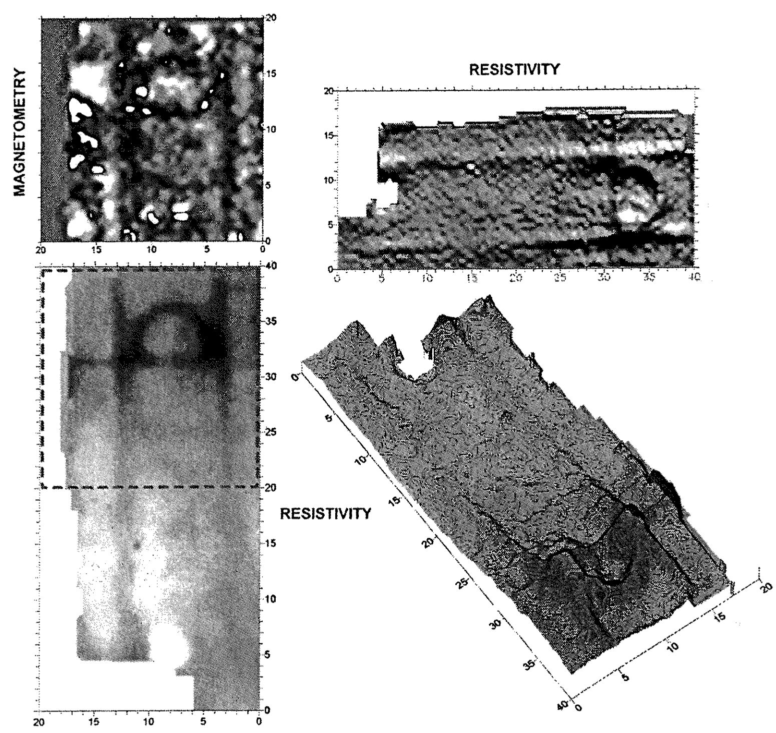


Fig. 5. Results of resistivity and magnetometry on the location of chatedral inside city of Salona. Results of resistivity are showing high resistivity anomalies producd by walls of chatedral. The same structures but less clear are wisible also on the results of magnetometry.

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