

Workshop 1





PRAGUE, 30/SEP - 01/OCT 2019

COST Action CA17131

The Soil Science & Archaeo-Geophysics Alliance: going beyond prospection



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Programme MONDAY, 30 September 2019 Presentations = 13' + 2' min for questions FLASH poster presentations = 2'

TOPIC 1: DEVELOPING A COMMON GROUND Chair: Jörg FASSBINDER 09:30 Carmen CUENCA-GARCÍA, Norwegian "An Update On COST Action SAGA" University of Science and Technology (NTNU), NORWAY 09:45 "Soil-Archaeology-Instrumentation: A **Michel DABAS** Deep Interrelationship" Centre National de la Recherche Scientifique (CNRS), FRANCE 10:00 "Interpreting Archaeological Subsurface **Roderick SALISBURY** Anomalies With A Minimally Invasive Department of Prehistoric and Historical Combined Geophysical, Archaeology, University of Vienna, Geoarchaeological, And Geochemical AUSTRIA Approach" 10:15 **Roman PAŠTEKA** "Transformations Of Archaeomagnetic Maps By Means Of Higher Derivatives Faculty of Natural Sciences, Comenius Evaluation" University, SLOVAKIA 10:30 **COFFEE BREAK & POSTER EXHIBITION** 11:00 Neli JORDANOVA "Employing Mineral Magnetic Signature Of Iron Oxides In Soils And National Institute of Geophysics, Archaeological Remains Of Burnt Clay Geodesy and Geography, Bulgarian In Archaeological Prospection Planning" Academy of Sciences, BULGARIA 11:15 "Representative Grid Point Values For Simo SPASSOV Surface Soil Susceptibility Mapping" Laboratory for Environmental Magnetism, Royal Meteorological Institute of Belgium, BELGIUM 11:30 "Archaeomagnetism: The Geophysical **Elina AIDONA** Tool For Dating Archaeological Department of Geophysics, School of Structures" Geology, Aristotle University of Thessaloniki GREECE Eduard PETROVSKÝ 11:45 "Magnetic Susceptibility: What Is It?" Institute of Geophysics of the Czech

Acad. Sci., CZECH REP



TOPIC 2: INTEGRATED APPROACHES COMBINING GEOPHYSICS AND SOIL SCIENCE AT ARCHAEOLOGICAL SITES Chair: Neli JORDANOVA				
12:00	"Twelve Centuries Long Iron Smelting Pollution Record – A Unique Archive Of Mining And Industrial History At Moravian Karst"	Milan GAZDIC University of Belgrade SERBIA		
12:15	"The Evolution Of Relict Phaeozems Related To Chalcolithic Settlements From Eastern Romania"	Andrei ASANDULESEI "Alexandru Ioan Cuza" University ROMANIA		
12:30	"New Geophysical And Geochemical Data At The Archaeological Site Of Zaldua (Auritz/Burguete, Navarre)"	Ekhine GARCIA-GARCIA Society of Science BASQUE COUNTRY-SPAIN		
12:45	"Combining Geochemical, Isotopic And Microscopic Methods To Distinguish Technogenic Materials In Soils"	Luke BEESLEY The James Hutton Institute SCOTLAND-UK		
13:00	LUNCH			
TOPIC 6: HANDS-ON SESSION ON "GEOPHYSICAL METHODS AND INSTRUMENTATION"				
14:30	STATION ROTATION (4 rotation groups, 30 minutes per station) Location: to be confirmed by the LO Stations:			
	 (Transient Technologies LLC, UKRAINE) 2. Gravimetry CG-6 Autograv, SCINTREX 3. Seismograph Terraloc Pro 2, ABEM 4. Electromagnetic sensor Gem 2, Geophex Ltd. 			
15:30	COFFEE BREAK & POSTER EXHIBITION			
16:	STATION ROTATION (cont.)			
16:00	GPR DATA PROCESSING AND INTERPRETATION by Volodymyr IVASHCHUK (Transient Technologies LLC, UKRAINE)			
17:30	GROUP PHOTO			



	Programme TUESDAY, 01 October 2019					
TOPIC 3: CHALLENGING SURVEY ENVIRONMENTS AND/OR DATA Chair: Armin SCHMIDT						
09:15	"Initial Archae	Geophysical Surveying Of eological Sites In Armenia''	Jaroslav JIRKU G IMPULS Praha, CZECH REP			
09:30	"Geop At The	physical - Archaeological Survey Hradčany Square In Prague"	Jaroslav BARTA G IMPULS Praha, CZECH REP			
09:45	"Integi And Ai Hittite S	rated Geophysical Investigations rchaeological Excavations In A State City (Šapinuwa)"	Mahmut Göktuğ DRAHOR Engineering Faculty Department of Geophysics, Dokuz Eylül University, TURKEY			
10:00	"Direct Testing And Vi Mappi	t Push Electrical Cone Penetration ŋ, Electrical Conductivity Logging ideo Imaging For (Deep) Paleosol ing"	Jeroen VERHEGGE Ghent University, BELGIUM			
10:15	"Envira Prospe Prospe Landsa Serbiaj	onmental And Archaeological action By Coring And Magnetic action In The Prehistoric cape Of Pusta Reka (Leskovec,)"	Cornelius MEYER CMP Cornelius Meyer Prospection, GERMANY			
10:30	COFFE	E BREAK & POSTER EXHIBITION				
11:00	FLASH	FLASH Poster presentation on TOPIC 3				
	1.	 "Forested environment: opportunities to survey (a case of Jakšiškis prehistoric settlement site)" by Andra STRIMAITIENĖ, Lithuanian history institute, LITHUANIA 				
	2.	 "A Complex Geophysical Survey At The Old Town Square In Prague" by Jaroslav BARTA, G IMPULS Praha, CZECH REP 				
	3.	 "GPR Investigations In The Church Of St. Elias -Bohdan Khmelnytsky Burial Vault" by Kseniia BONDAR, Taras Shevchenko National University of Kyiv, UKRAINE 				
	4.	 "Mapping The German Nazi Extermination Camps Of "Aktion Reinhardt" – Problems And Challenges For Archaeological Prospection" by Sebastian ROZYCKI, Warsaw University of Technology, POLAND 				
	5.	 "Elemental Composition Of Soil At Burial Sites" by Ladislav ŠMEJDA, Faculty of Environmental Sciences, Czech University of Life Sciences Prague, CZECH REP 				
	6.	6. "A Newcomer To Archaeo-geophysics, With Seismic Modelling And Imaging Experience From The (Dirty) O&G World - Turning Towards Teaching And Using GPRAnd Really Keen To Learn While Hoping To Contribute" by Isabelle LECOMPTE, University of Bergen, NORWAY				



TOPIC 4: Experimental/Monitoring projects (conducted at archaeological sites or related to archaeo-geophysics) Chair: Kseniia BONDAR				
11:15	"Co-operation Between Archaeological And Geophysical Research: Expedition Apostolus And Localities In Prague"	Jan FROLIK Institute of Archaeology of the Czech. Acad. Sci., CZECH REP		
11:30	"Identification Of Archaeological Soils By Vis-nir Reflectance Spectra	Yoon Jung CHOI Max Planck Institute For Chemistry, GERMANY		
11:45	Predicting The Contrast In Earth Resistance Data From Weather Observations"	Armin SCHMIDT GeodataWIZ, GERMANY		
12:00	"Investigating The Influence Of Environmental Factors On GPR Surveys: The Borre Monitoring Project"	Petra SCHNEIDHOFER Vestfold fylkeskommune, NORWAY		
12:15	"Innovation In Near-surface Geophysics: How Could Time-lapse Geophysics Help In Archeology"	Frédéric NGUYEN University of Liège, BELGIUM		
12:30	"Diagnostic And Monitoring Of Cultural Heritage: Heracles Project Experience"	Ilaria CATAPANO Institute for Electromagnetic Sensing of the Environment, ITALY		
12:45	"Human-rock Interaction And The Burial Practice In The Necropolis Of The Early Roman Era Jerusalem"	Nurit SHTOBER-ZISU Department of Israel Studies, University of Haifa, ISRAEL		
13:00	FLASH Poster presentation on TOPIC 4 1. "Edge Detection On Magnetic Data Interpretation By Using Tilt Angle Method: Amasya Oluz-boyuk Archaeological Field Example"			
	by Hazel Deniz TOKTAY , Istanbul University Cerrahpasa, TURKEY			
	 "Misinterpretation Of Geoelectrical Anomalies: A Case Study From Stavros- rafina, Greece" by George VARGEMEZIS, Department of Geophysics, School of Geology, Aristotle University of Thessaloniki, GREECE 			
13:05	LUNCH			
TOPIC 5: Multivariate proxy data analysis and/or forward modelling Chair: Mercedes SOLLA				
14:30	"Compositional Data Analysis And Its Applications"	Karel HRON Palacky University, CZECH REP		
14:45	"Characterization Of Archaeological Sites Using Gpr Signal Forward Modelling"	Mercedes SOLLA Defense University Center, Escuela Naval Militar, SPAIN		



15:00	"Machine Learning For Archaeo- geophysics Interpretation"	Abir JRAD Faculté des Sciences de Gabès, Gabes University, TUNISIA			
TOPIC 6	TOPIC 6: Hands-on sessions on "METHODS FOR SOIL ANALYSIS"				
15:15	STATION ROTATION 5 stations/ 4 rotation groups, 20 minutes per station				
	Location: to be confirmed by the LO				
	 Stations: Magnetic susceptibility by the SM 400 and SM 30 - ZH Instruments MS under different frequencies by the SM 150L(H) - ZH Instruments and MFK1 Multifunction Kappabridge - AGICO Temperature variation of MS - KLY5 Kappabridge with CS4 - AGICO Element analyses by the Niton XRF analyser - Thermo Scientific Soil reaction by portable pH meter Hanna Instruments 				
15:30	COFFEE BREAK & POSTER EXHIBITION				
16:00	STATION ROTATION (cont.)				
17:00	Closure of the WORKSHOP 1				
19:30	SOCIAL DINNER @ the restaurant PETŘÍNSKÉ TERASY				



SOIL-ARCHAEOLOGY-INSTRUMENTATION: A DEEP INTERRELATIONSHIP

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Keywords: Detectability; Erodability; Noise; Contrast; Soil

A geophysical map represents the variations of a physical signal that can be measured, most of the time an electrical voltage, and whose variations are hoped to be correlated with the structures that one wishes to highlight. This electrical voltage at the sensor output is related to the spatial and temporal variations of the electromagnetic fields measured, whether natural or induced.

Beyond the technical choices related to instrumentation, it is more interesting to ask the question under what conditions an archaeological structure will be detectable or not. This detection then raises a double question that of absolute values and measured relative values.

If the absolute values measured are too low, the structures will not be measurable. This will be the case, for example, of structures of small volume, at great depth or whose physical parameters have amplitudes too low to be measured by our sensors. In this case, the physical modelling (simulation) make it possible to define quite easily the criteria of detectability. But by pushing further the reasoning, one could imagine that any structure would be detectable if one could amplify the signal sufficiently to be measurable.

At this point, we have to introduce the statistical notion of noise. There are different definitions of noise, but we will give a very pragmatic one: noise is the portion of the signal that is not connected to what we want to detect. This leads to the notion of relative value. The measured absolute voltage should be compared to the absolute voltage that could be measured in the absence of archaeological structures - which could be equated with "noise". If this contrast is too low, the structure will not be detectable.

But this noise usually has several components: an instrumental origin (no sensor is perfect) and a 'ground' origin. If it is generally possible to know precisely the noise related to a sensor (signal / noise ratio as a function of frequency), the ground noise is generally not known or poorly understood. Thus, the detectability of archaeological structures becomes uncertain (Fig. 1). This ground noise may have a distant origin (case of diurnal variations in magnetic prospecting) or most of the time a local origin and we can associate it to a 'soil' noise.





Figure 1. Magnetic simulation of the effect of post-holes at different depths, of different size and magnetic susceptibility without (A) and with noise (B) (from Hulin G., 2007, Ing. Diploma, Strasbourg, 47 p.).

The soil as a matrix in which archaeological structures are included then becomes as important as the structures themselves.

Geophysicists know that beyond the absolute values of the contrast between soil and structures, it is the spatial variability of soil parameters that will determine the detectability of structures. The quantification of this heterogeneity that is not yet done will then allow better predictability. Several archaeological examples will be shown based on several detection methods. Finally, this variability is also a seasonal variability depending again on soil characteristics and we will show some examples in electrical prospecting (Fig. 2).



Figure 2. Time-variation of apparent electrical resistivity of a 10ha plot (April 2004 – August 2004 – August 2005) (data courtesy of Géocarta[®], Paris).

Beyond the detection problem, we will show that knowledge of soils can lead to other interesting maps like erodibility maps.

As a conclusion, knowing soil characteristics enable both a better prediction of detectability and the possible state of preservation of archaeological assets.



INTERPRETING ARCHAELOGICAL SUBSURFACE ANOMALIES WITH A MINIMALLY INVASIVE COMBINED GEOPHYSICAL, GEOARCHAELOGICAL, AND GEOCHEMICAL APPROACH

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Keywords: coring; magnetometry; soil chemistry; interdisciplinary

Geophysical prospection is now standard for most regional scale archaeological projects. When working at the scale of regions or landscapes, geophysical methods can be employed over several geological, cultural and topographic contexts. For example, a survey might move from low-lying alluvium over colluvium to better drained surfaces, while also moving from pasturage to plowed fields, over an area containing several cultural periods or components. Geoarchaeological methods, including coring, soil chemistry and soil analyses can aid interpretations of geophysical anomalies and subsurface variability within these settings.

The main part of this presentation will focus primarily on several projects, periods and sites within the Körös Region of eastern Hungary. This region, with a complex geography of paleochannels, former wetlands, low-lying meadows, and slightly elevated ridges, was intensively occupied from the earliest Neolithic onwards. Archaeologically, the landscape is somewhat unique for its excellent preservation of prehistoric settlements and burials and the density of prehistoric remains. The projects employ the same methodology as much as possible, including magnetometry over whole sites and targeted GPR, as well as intensive surface collections. Coring and soil chemistry are employed both as a prospection method to augment other datasets, and to check interpretations of magnetic and radar anomalies. Moreover, these combined methods contribute strongly to archaeological interpretations, by providing evidence for differences between cultural components and preservation of subsurface material. The integration of different prospection data into one overall interpretation involves the translation of data between disciplines and the transitions between multiple analytical scales. The results are being used in small-scale excavations intended to target intact occupation surfaces to collect short-lived datable material and diagnostic ceramics. Results also are used to justify proposed excavations and research.



A second point to be made is the importance of developing a database of soil chemical/physical signatures that is particular to Europe. The correspondence between archaeological geophysical and geochemical anomalies suggests that SAGA is well situated to be central to this project.

Acknowledgments

The following people and projects contributed support and data for this presentation. William Parkinson, Attila Gyucha, Richard Yerkes and Apostolos Sarris (Körös Regional Archaeological Project, KRAP), Danielle Riebe and Apostolos Sarris (Prehistoric Interactions on the Plain Project PIPP); Christopher Sevara, Michael Doneus, Klaus Löcker and Ralf Totschnig (Prospecting Boundaries Along the Mazaro).



TRANSFORMATIONS OF ARCHAEOMAGNETIC MAPS BY MEANS OF HIGHER DERIVATIVES EVALUATION

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Keywords: magnetometry; potential fields transformation

High definition magnetometry is one of the most important acquisition methods in archaeogeophysics - due to its high acquisition velocity and high data sampling rate. During the high definition magnetometric datasets interpretation it is very important to recognize and emphasize low-amplitude anomalies from archaeological objects and natural sources (geological and soil structures). Among the recognition of low-amplitude anomalies an important role is played by edge mappers, which are based on higher derivatives (enhances derivatives filters), numerically computed from the originally acquired magnetic field (or gradient). Majority of enhanced derivatives methods are based on the evaluation of various ratios of derivatives of different kind – mostly horizontal and total derivatives and their components. During the numerical evaluation of derivatives it is important to smooth them properly, because these have the tendency to emphasize errors and noise from the original data (in the term of mathematical physics called as instable or incorrect problem).

In our department the concept of so called regularized derivatives was introduced (Pašteka et al., 2009) and is widely applied (e.g. Pašteka et al., 2015). In this contribution, we try to show properties of different enhanced derivatives filters on various archaeomagnetic datasets and suggest the best of them for future application. The mostly used transformations are: vertical and horizontal gradient, tilt angle and balanced horizontal gradient (TDX), theta transformation and so called TDXAS transformation (good overview is given in Stampolidis and Tsokas, 2012). Of course that these methods can not directly distinguish between anomalies of anthropogenic and natural (geology, soil) origin of interpreted anomalies, but can contribute to its joint interpretation.

References

Pašteka, R., Richter, F. P., Karcol, R., Brazda, K. And Hajach, M. 2009. Regularized derivatives of potential fields and their role in semi-automated interpretation methods. Geophysical Prospecting 57: 507–516.



Pašteka, R., Milo, P., Kušnirák, D., Wunderlich, T., Wilken, D., Putiška, R., Urminský, J., Papčo, J., Murín, I., 2015. Role of regularized derivatives in magnetic edge mappers evaluation. Archaeologia Polona 53: 567-571.

Stampolidis, A., Tsokas, G.N., 2012. Use of edge delineating methods in interpreting magnetic archaeological prospection data. Archaeological Prospection 19: 123–140.



Figure 1. Comparison of measured magnetic field (left) and transformation based on tilt angle plus balanced horizontal gradient summation (right).



EMPLOYING MINERAL MAGNETIC SIGNATURE OF IRON OXIDES IN SOILS AND ARCHAEOLOGICAL REMAINS OF BURNT CLAY IN ARCHAEOLOGICAL PROSPECTION PLANNING

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Keywords: soil; burnt clay; iron oxides; mineral magnetism

Iron oxides in soils are sensitive proxies of changes in environmental conditions, related to climate, natural hazards (like wildfires) and anthropogenic influence. Environmental magnetic methods provide powerful tool for revealing the concentration, grain size and type of iron oxides present in soils (Evans and Heller, 2003; Jordanova, 2016) and in particulates from anthropogenic emissions (Petrovsky and Elwood, 1999). Importantly, natural soil magnetic minerals and their magnetization behaviour are essential components in archaeological prospection methods (Fassbinder, 2015). Furthermore, linking mineral magnetic signature of various soil types to the concentration and characteristics of magnetic iron oxides in archaeological materials of burnt clay could provide valuable background for application of field prospection strategies. This task is addressed in our contribution through summary analysis of excessive data on variations of a range of mineral magnetic parameters with depth for different soil types and topsoils, on one hand, and archaeological materials of burnt clay, on the other.

The different trends in the changes of mineralogy and magnetic grain size fractions along the depth of the various soil groups will be discussed as useful indicators of the soil chemistry and the dynamics of the main soil forming processes. In addition, an extract of the national magnetic data base for the magnetic properties of topsoils (upper 0-20 cm depth) including 6 major soil types (Chernozems, Phaeozems, Luvisos, Cambisols, Planosols, Vertisols) is used for obtaining histograms of distribution of magnetic susceptibility for each soil class. These data are compared against analogous histograms obtained for large collections of archaeological materials from various sites and ages of: (i) burned clay, ii) ovens, hearths, kilns; iii) bricks; iv) pottery). Histograms of magnetic susceptibility (X) displayed on Fig. 1 evidence certain differences among the distribution patterns for particular materials. Most probable reason for these variations will be discussed in the light of parent material (clay, soil) mineralogy, firing temperature, age, etc.





Figure 1. Histograms of distribution of magnetic susceptibility (X) for various types of archaeological materials of burnt clay. Measurements were done on individual samples of ~10 cm³ each from 105 archaeological sites from Bulgaria.

Comparison between magnetic susceptibility distributions for burned clay archaeological remains and natural soils of different type shows that in certain cases of strongly magnetic soils overlap between the maxima of magnetic susceptibility distributions of archaeological remains and soils may arise and therefore, be a cause of ambiguity in interpretation of field magnetic prospection data. Thus, prior knowledge about mineral magnetic properties of dominant soil type(s) and possible magnetic enhancement caused by various archaeological materials of burnt clay may add valuable information for planning and performing field prospection.

Acknowledgments

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Fassbinder, 2015. Seeing beneath the farmland, steppe and desert soil: magnetic prospecting and soil magnetism. Journal of Archaeological Science 56, 85-95.

Topic 1: Developing a common ground



REPRESENTATIVE GRID POINT VALUES FOR SURFACE SOIL SUSCEPTIBILITY MAPPING

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Keywords: soil, magnetic susceptibility, fractals, random, grid point mean

Soils are often inhomogeneous because cavities, stones and roots cause density differences, which influence *in-situ* soil magnetic susceptibility measurements and cause significant deviations. In addition, the non-uniform distribution of soil minerals and organic matter accumulation may be The cause of local outliers in the order of some centimetres. The determination of a mean value is hence difficult as inhomogeneities may occur at all length scales. When dealing with mapping larger areas, the distance between each grid point is of course also much larger, and it is therefore important that the susceptibility at each grid point represents a well-established mean, that close to the true but unknown value.

The aim of this presentation is to test if a random measurement or sampling scheme is more appropriate for the determination of a well-established mean or if a scaled measurement scheme, taking into account the fractal signal nature, seems better. The philosophy of scaled sampling will be illustrated, based on artificial and measured magnetic susceptibility data. The results of random and scaled sampling will be compared.



ARCHAEOMAGNETISM: THE GEOPHYSICAL TOOL FOR DATING ARCHAEOLOGICAL STRUCTURES

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Keywords: geomagnetic field variation; magnetic properties; dating

Archaeomagnetism is a discipline of Palaeomagnetism which combines magnetic methods with Archaeology in order to determine the geomagnetic field elements (the angles of inclination and declination, and the strength or intensity) in historic and prehistoric times. By comparing the archaeomagnetic direction and intensity registered by an archaeological artefact with well-established reference curves (SVCs) for the same area, it is possible to determine the age of the studied structure. By the inverse procedure, well-dated by independent methods such as ¹⁴C or Thermoluminescence/Optical Luminescence, artefacts can be used for the construction of the reference curves for a certain geographical area. Archaeological structures or artefacts that can be used for an archaeomagnetic investigation are mainly kilns, bricks, tiles, ceramics and generally all clay structures that have been heated in antiquity to high temperatures and subsequently cooled down to ambient temperatures.

During the last decades, Archaeomagnetism has considerably developed especially in Europe but also in other continents. Archaeomagnetic studies in Greece were initiated around the 1980s but a systematic development in obtaining new archaeomagnetic data is observed during the last decade. Several studies have been performed covering the data acquisition from archaeological burnt artefacts from the Neolithic (Aidona and Kondopoulou 2012; Fanjat et al. 2013) up to the Byzantine (Evans 2006; De Marco 2007; Kondopoulou et al. 2015) period, providing abundant archaeointensity and fewer directional data, which allowed for the construction of reference SVCs for Greece.

In this study the fundamental principles of the archaeomagnetic method will be presented. Additionally, the application of this technique for the dating of several Greek archaeological sites will be discussed, emphasizing on the importance of the method when compared to other dating techniques.



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MAGNETIC SUSCEPTIBILITY: WHAT IS IT?

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Keywords: environmental magnetism

Magnetic susceptibility is the primary magnetic parameter used in wide range of environmental magnetism studies, from atmospheric dust through soils to sediments and rocks, as a measure of concentration of iron oxides. The fact that it can be easily obtained, both in field and in laboratory, makes it very popular and commonly used even by non-experts in rock magnetism. However, its interpretation is by far not straightforward. In our contribution physical principles, meaning and interpretation potential of magnetic susceptibility will be reviewed in a "friendly" way. The effects affecting the obtained value will be explained and wide range of environmental applications will be presented. The aim is not to distract the user from the use of magnetic susceptibility, but to elucidate the advantages and limitations of this physical parameter.



TWELVE CENTURIES LONG IRON SMELTING POLLUTION RECORD – A UNIQUE ARCHIVE OF MINING AND INDUSTRIAL HISTORY AT MORAVIAN KARST

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Keywords: magnetic susceptibility; magnetism; soil pollution

Aims of the study are: (i) to examine pollution record, (ii) to explain native human impacts to the local environmental, and (iii) to explain human impacts to the local environment. The study is focused on multidisciplinary assessment of pollution record related to the iron ore smelting at the Moravian Karst. The earliest intense smelting activities started in the 8th century and continued till the 19th century in this area. Both surface (soil sections) and subsurface sedimentary archives accumulate pollution particles including specific microspherules formed during the smelting processes. The pollution record is examined in detail using magnetic and non-magnetic analytical approach namely mineral magnetic techniques combined with geochemical, mineralogical, and sedimentological methods. In magnetic extract we found industrial magnetic spherical particles, both magnetite and glass, produced of iron smelting. In material from Medieval iron smelting place the presence of alass particles in a larger quantity indicates probably more primitive smelting technology. Magnetite is dominating in magnetic extracts. Sediments in the studied section were heated during the iron smelting which is documented by increased value of frequency-dependent magnetic susceptibility.

Acknowledgments

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THE EVOLUTION OF RELICT PHAEOZEMS RELATED TO CHALCOLITHIC SETTLEMENTS FROM EASTERN ROMANIA

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Keywords: soil elements concentration; geophysics; Chalcolithic sites; Eastern Romania)

In this study we investigate the potential usefulness of integrated geophysical and soil prospection to recognize ancient patterns of human occupation and their impact on soil evolution within an area located in the north-eastern part of Romania. The research was focused on the relationship between soil cover characteristics and spatial distribution of prehistoric sites within Ruginoasa-Strunga saddle, where the dominant presence of relict cambic phaeozems is still insufficiently understood. Soils with similar properties, considered as relict chernozems/phaeozems, are also found in significant areas ofCentral Europe. Although there is a relative consensus on the taxonomic classification and the relict character of these soils, hypotheses about their genesis and age are often contradictory.

Preliminary research conducted in these areas aim to integrate soil parameters derived from several pedological studies, at 1: 10,000 scale, with geophysical data. Correlations between morphological features of soil profiles and the associated analytical data with the results of geophysical prospections will be established. Mapping the distribution of soil element concentrations, will enable the locations of human settlements to be determined with a reasonable accuracy. This is especially the case with potassium and phosphorus, which present significantly higher concentrations within and in proximity to archaeological sites. Nevertheless, in order to accurately discriminate between anthropogenic input and geogenic loadings, it was found that the computation and mapping of the vertical variation coefficients standardized by profile depth, can better reveal the soils that preserve ancient characteristics.

The geophysical surveys carried out at specific locations with a very high content of mobile phosphorus and potassium revealed the presence of prehistoric settlements, some previously unknown (e.g. Ruginoasa, *Dealul Ruginii*, Cucuteni, *Cetățuia* – external habitation). The results show that the distribution of the cambic phaeozems is not contingent on the lithology or

Topic 2: Integrated approaches combining geophysics and soil science at archaeological sites



landform, and that some of their properties do not reflect present-day climatic conditions. Moreover, by analysing the spatial distribution of the neoeneolithic settlements in relation to the soil, we found that most of the prehistoric sites are located at the contact area between the cambic phaeozems and the soils specific to forested areas, an optimal position for exploiting both forest vegetation and agricultural lands. Accordingly, we assume that the anthropogenic factor played an important role in evolution of these soils, by preserving their properties.



NEW GEOPHYSICAL AND GEOCHEMICAL DATA AT THE ARCHAELOGICAL SITE OF ZALDULA (AURITZ/BURGUERE/NAVARRE)

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Keywords: Training School; SAGA; Geophysical survey; Geochemical survey

Between the 29th July and the 2nd August the First SAGA Training School, Introduction to the Use of Geophysical & Soil Science Methods in Archaeology, has been held at the Roman site of Zaldua (Auritz/Burguete, Navarre). The scope of this abstract is to present the new data acquired during the hands-on sessions.

The Roman site of Zaldua is located in the north-east of Navarre, on the southern side of the Pyrenees range, in a natural pass through the mountains. After its discovery in 2012, geophysical and geoarchaeological methods have been extensively used to delimit and characterise this Roman town (Garcia-Garcia et al. 2016; Garcia-Garcia et al. 2017).

During the training school new data has been acquired. In an area where the existence of a building without magnetic contrast has been proven by GPR and earth resistance surveys, an electromagnetic Induction survey has been conducted. Three cores were also drilled to compare the stratigraphy and the nature of sediments within the building and in the surrounding area. The preliminary results suggest that sediments have low magnetic susceptibility values in comparison with other areas of the settlement, maybe because of a leaching or depletion of magnetic minerals due to the persistent waterlogging in winter. The samples extracted from the cores will be analysed

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in the laboratory to better characterize the variability of magnetic properties with depth.

Other complementary geophysical data has been acquired in areas where the archaeological investigation needed more information. Electrical tomography profiles were performed in two particular locations to provide complementary information about the section of some linear anomalies previously detected. GPR was also applied in an area next to the excavation, in order to investigate the continuation of the thermal building excavated this year.

In addition to geophysical surveys, geochemical data were also collected. Superficial magnetic susceptibility has been measured each 5 m in a line of 500 m that traverses the settlement from south to north. Magnetic susceptibility and the elementary composition through portable-XRF have also been used to analyse the open sections of the excavation. In that case the purpose was didactic and no data has been stored, excepting in a vertical profile of the north section. There, the profile has been sampled and in situ magnetic susceptibility data could be compared to frequency dependent magnetic susceptibility measured in the laboratory.

The combination of geophysical surveys, the analyses of sediment cores and the geochemical measurements has been useful to better understand the geophysical responses obtained in the previous campaigns.

Acknowledgments

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COMBINING GEOCHEMICAL, ISOTOPIC AND MICROSCOPIC METHODS TO DISTINGUISH TECHNOGENIC MATERIALS IN SOILS

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Keywords: technosols; micro-plastics; stable isotopes; pore water; soils

Soils containing exogenous materials can be distinguished from those composed primarily from *in-situ* parent materials by geochemical, isotopic and microscopic methods. We compared trace elements in extracted soil solutions (pore waters), stable nitrogen isotopes in vegetation material (ryegrass and reed canary grass) and micro-plastic fragments in soils, to identify whether technogenic soils [technosols] composed of construction and demolition residues (C&D) and green waste compost (GWC) were clearly distinguishable from 'natural' soil using this suite of methods.

Concentrations of total organic carbon, P and K in pore waters, as compared to Ca, Mg, Na and SO₄, reflected the composition of technosols, in terms of organic: mineral ratio. For example, highly soluble calcium was a marker of construction residues (ie gypsum), whereas soluble K was derived from compost (Figure 1).



----- Ratio of C&D/compost -----

Figure 1. Contrasting solubility of potassium (derived from compost) compared to calcium (derived from construction residues; C&D) in technosols.

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Microplastic fibres were abundant in 'natural' soils and technosols alike, but the latter contained distinct irregularly sized and shaped fragments not seen the 'natural' soil (Figure 2). By type and count, both fibres and fragments clearly originated from both C&D and GWC. In 'natural' soils fibres were assumed to have been deposited aerially and/or via previously applied fertilisers. Distinct $\delta 15N$ signatures were measured in both grass species grown on technosols, distinguishing these substrates from their 'natural' counterparts.



Figure 2. Distinct micro-plastic fragments present in technogenically derived soils (photo b; technosols) contrasting with fibres only in ,natural' soil (photo a.).

Our study demonstrates that combining diverse methods can provide complementary data indicating the likely composition of recent technogenic deposits in soils. These methods are herein applied to completely manufactured technosols versus 'natural' soil; further testing will now be applied to technosols with a component of 'natural' soil, to determine sensitivity of the methods under conditions more analogous to archaeological prospection.



INITIAL GEOPHYSICAL SURVEYING OF ARCHAEOLOGICAL SITES IN ARMENIA

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Keywords: Armenia; geophysics; archaeology

Within the Apostolus expedition the geophysical measurements were carried out at four archaeological sites in Armenia. These measurements aimed, together with the methods of field archaeology, to gathering information about hidden archaeological features at the sites. At each site particular areas of interest were chosen. These areas were subsequently covered with detailed geophysical survey. The areas of interest were chosen according to the needs of the Archaeological Institute of the Academy of Science of the Czech Republic employees (in cooperation with the experts of the Institute of Archaeology and Ethnography of the National Academy of Sciences of Armenia). The Apostolus project aimed mostly to cognizance of selected archaeological sites, which were concentrated into the Armavir region (gubernia). The Armavir region lies on the southwestern Armenian borders with Turkey. The main task at the sites was evaluating thickness of the historical sediments and describing overall archaeological features situation.

Using geophysical methods in the fields of archaeology is relatively well described. The priority goes to those methods, which use fast and easy field procedures and are not too expensive. The first choice is usually the magnetometry as described in the ALMUTARI, M. (2015) or BRION, C. (2012, see also Fig. 1. Very often the method of ground penetrating radar (GPR) is being used; see BERSENEVA, N., A. (2016) for instance. Regarding the direct current (DC) physical fields we can find especially the method of the resistivity tomography (ERT), based on the multielectrode geoelectrical instruments controlled via computer programs – see EKINCI, Y., L. (2007). To economically more demanding methods are micro gravimetric or seismic survey.

With respect to relatively short stay in Armenia the quickness of the field works was the crucial parameter, i.e. possibility of covering selected areas in detail and reasonable amount of time, together with high quality data demands. Therefore, two geophysical methods were chosen – magnetometry and dipole electromagnetic profiling (or DEMP, conductometry or slingram).

Overall results of the DEMP and magnetometry showed that either of these methods are viable for quick archaeological survey and bring valuable results even in non-favourable conditions of highly resistive volcanic rocks. Compering to the DEMP results the magnetometry described deeper

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structures at the sites and was not that sensitive to the noise sources. In the future we would like to do quantitative (modelling) interpretation of several magnetic anomalies. It would be interesting to uncover some of the geophysical anomalies. We believe that the Apostolus project may illuminate some of the future archaeological sites and will help in their future protection.



Figure 1. Depiction of magnetic gradients registered at the Lernamerdz archaeological locality.

Acknowledgments

We would like to express our thanks to the Chironium Ltd. Company for the financial support of the Apostolus project. We also thank to our colleagues from the Institute of Archaeology in Prague for reasonable cooperation, technical advising and selflessness

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A COMPLEX GEOPHYSICAL SURVEY AT THE OLD TOWN SQUARE IN PRAGUE

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Keywords: geophysics; archaeology; complex; Old Town Square

An initial complex survey campaign was carried out in 2018 at the Old Town Square in Prague (see Fig. 1). The place of interest is under strong transportation and public exposure hence we worked in early times (around 4AM) only and in cooperation with the Municipal Police of Prague. We split the project into several consequent parts – initial spatial measurement within the entire square via an electromagnetic method, followed by the GPR measurement (see Fig. 2 and finally the seismic and detailed gravimetric surveying. The data were continuously being processed as we went along. To nail down correct interpretation, we were making regular working briefings with contractors' experts. The results of the measurements confirmed original assumptions about historical building objects' distribution at the site but also brought several geophysical anomalies that one will have to inspect (including dug pits) together with archaeologists and sights experts.



Figure 1. The area of interest in the centre of the old Prague (marked area)

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Figure 2. GPR equipment SIR 20. Geophysical prospection in the night.

Acknowledgments

We would like to express our thanks to TSK Praha a. s. (Road Authority Prague) for actual technical information about the Old Town Square.



INTEGRATED GEOPHYSICAL INVESTIGATIONS AND **ARCHAEOLOGICAL EXCAVATIONS IN A HITTITE STATE CITY** (ŠAPINUWA)

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Keywords: integrated geophysics; archaeological excavation; modelling; Šapinuwa

Šapinuwa located in Ortaköy region of Çorum was one of the capital cities of the Hittite state. The geophysical and archaeological studies at Šapinuwa are currently focused in Tepelerarası area, which a location central to the city, is the area where all of the excavated monumental buildings of Šapinuwa are found. The integrated geophysical surveys (magnetic gradiometry, GPR, ERT, IPT, SRT, MASWT and SP) have been continued since 2012 on this site (Drahor et al., 2015; 2017). In this study, the results obtained from an area named as H which is determined by geophysical results and revealed by archaeological excavations are presented. The investigation site (area H) is 10 m x 30 m in dimensions and the overall area was investigated using the above-mentioned geophysical techniques with the aid of the eleven N-S oriented profiles. In order to display the results of different geophysical methods in the study area, magnetic gradiometry image, SP curves and depth slice images of ERT, IPT, GPR, SRT, MASWT results were compared in detail. In the magnetic image, there are high positive traces in the middle of the area. According to the previous excavation in the Šapinuwa archaeological site, we think that this kind of high magnetization should be characterized with burned structures. Besides this magnetic variation in the gradiometry image, especially white (negative) coloured traces have regular orientation that might represent a buried architecture of the area (Figure 1a). According to the ERT result of the depth slice between 0.54 and 0.75 m, high resistivity values correspond to one to one the traces displayed in the magnetic image (Figure 1b). Thus, we defined the buried structures as stone walls. The structure determined according to the ERT results continues to a depth of approximately 1.3 m. Surprisingly, the GPR results of the same measurement area did not yield very clear results. Thus, a direct relationship between magnetic and ERT method with the GPR could not be established in the context of the archaeological subsurface. The high chargeability values in the IPT depth slices of the field are characterized by the resistive structures defined by the ERT and the high burned fields in the magnetic results. This is an Topic 3: Challenging survey environments and/or data 24



important result related to IP in archaeological sites. The SP results of the field have also generally positive voltage values, indicating traces of burned structures. SRT and MASWT studies in the field also showed important results related to buried structures. The results of the preliminary excavations conducted according to geophysical studies are given in Figure 1c. Excavations have been very consistent with the geophysical results. It is thought that the results of analysis of soil, burnt material, metal and other material samples taken from the excavations will be caused a more detailed geophysical interpretation.

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Figure 1. (a)Magnetic image, (b)ERT depth slice and (c) preliminary excavation result of area H in the Šapinuwa archaeological site.

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DIRECT PUSH ELECTRICAL CONE PENETRATION TESTING, ELECTRICAL CONDUCTIVITY LOGGING AND VIDEO IMAGING FOR (DEEP) PALEOSOL MAPPING

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Keywords: Prehistoric landscapes; paleosols; Cone Penetration Testing; Camera CPT; Electrical Conductivity logging

Prospecting prehistoric archaeology depends profoundly on reconstructing the natural paleolandscapes. Invasive sampling methods such as test pitting and coring are widely used to this aim. These methods rely on direct observations of the sediments by physical exposure and by bringing soil samples to the surface respectively. Therefore, non-invasive paleolandscape survey methods such as remote sensing, marine or near surface geophysics have been developed over the past decades. However, these techniques are characterized by a decreasing spatial resolution as the burial depth of the targeted paleolandscape increases and often fail when the targets do not consist of contrasting lithologies but rather subtle paleopedological subsoil variations.

Rapid and minimally invasive, direct push sensing contributes to mapping the subtler soil traces of deeply buried prehistoric landscapes, where fully non-invasive methods are not successful. As such, direct push sensing provides some of the advantages of both coring and near surface geophysics, respectively the high vertical spatial resolution and data collection speed.

Geotechnical cone penetration testing was used in combination with direct current electrical conductivity logging and in situ camera imaging and compared with outcrops, coring or near surface geophysics. Three case studies will be demonstrated from the polder (embanked estuarine floodplain) region, the sand belt and the loess belt of Belgium. These studies have revealed Holocene, Late Weichselian Glacial and Eemian to Weichselian Glacial prehistoric paleosols respectively. As such, direct push sensing deserves a place in the soil science- and archaeo-geophysical toolbox, somewhere between non-invasive and invasive survey methods.

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ENVIRONMENTAL AND ARCHAELOGICAL PROSPECTION BY CORING AND MAGNETIC PROSPECTION IN THE PREHISTORIC LANDSCAPE OF PUSTA REKA (LESKOVEC, SERBIA)

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Keywords: Neolithics; coring; magnetic prospection; landscape; Balkan

An Austrian-Serbian cooperation has been initiated to investigate the Leskovac Basin at the Southern Morava that will focus on the identification of potential early farming communities in the region. Additional analyses of the later prehistoric sites, dating to the Copper and Bronze Ages, seek to provide an insight into the long-term landscape use by prehistoric communities in the area. The first systematic survey campaign of the new Pusta Reka Project in 2017 provided new data regarding the prehistory in the region and a first insight into the landscape and the environmental conditions.

The Leskovac Basin and its low elevations between the tributary rivers to the Southern Morava River, form a settlement area presumably attractive to prehistoric communities. Extensive and intensive archaeological surveys formed the basis for geophysical surveys and corings in the selected areas. GIS analyses, material studies and radiocarbon dating of core samples have been conducted to gain a broad spectrum of new primary data about the prehistory in the region.

Magnetic surveys were conducted on three prehistoric sites in the Pusta Reka region. Based on prior archaeological research and recent surveys, the two sites of Čuka and Čekmin were identified as possible early farmers' settlements. A 7-probe fluxgate gradiometer array was used to investigate a total surface of approximately 8 ha. Several indications of buried archaeological structures are evident in the magnetic data (Figure 1).

The objectives of the geographical-geoarchaeological work were the exploration of the potential of the landscape in the environment of Neolithic sites for landscape reconstruction, the localisation and demarcation of culture layers, and the extraction of datable material from the culture layers for Radiocarbon analysis. A total of 13 corings were realized at the Čuka site, the results of which are compared with the magnetic data and the results of the intensive archaeological surveys.



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Figure 1: Čuka: Magnetic survey and interpretation of the magnetic data in the central part with drilling points (Horejs et al., 2018)

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FORESTED ENVIRONMENT: OPPORTUNITIES TO SURVEY (A CASE OF JAKŠIŠKIS PREHISTORIC SETTLEMENT SITE)

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Keywords: forested area; prehistoric settlement site; lab-based magnetic susceptibility; phosphate analysis; eastern Lithuania

The forested environment in Eastern Lithuania limits the use of a range of potential methods, e.g., surface survey or systematic magnetometry. Under these circumstances, manual coring could be applied as an alternative way to evaluate stratigraphy and the distribution of anthropogenic sediments. At the same time, soil samples might be taken for laboratory tests to determine the nature and intensity of human activity by measuring different soil properties. In this poster we consider how specific aspects of the built environment might be visible in datasets produced by coring and lab-based geophysical and geochemical analyses and apply these methods to the Jakšiškis prehistoric settlement site of first millenium AD.

The integrated strategy included coring, soil sampling, lab-based Magnetic Susceptibility and Phosphate analysis, as well as the excavation of test units. The research was carried out for over 800 soil bulk samples from 250 cores which cover the territory of approximately 4 ha (Fig.1). Sampling was not confined only to visually apparent anthropogenic sediments ("cultural layer") but targeted both topsoil and subsoil. 12 test units were excavated to evaluate the effectiveness of the integrated strategy.

The applied strategy allows to monitor the dynamics of properties in relation to stratigraphy. Data from each sampled horizon displayed somewhat different spatial patterns due to a range of anthropogenic loadings, postdeposition processes, and the underlying geology. It was determined both vertically and horizontally that neither the thickness of the cultural layer nor its presence was the main cause for the high measurement values. It was established that the territory of the site stretched further than it had been assumed by the incidence of the cultural layer alone. Furthermore, surveys of measured properties demonstrated only a slight correlation. Most likely the areas of separate activities were defined by different techniques. The big challenge was to get some seemingly obvious readings disapproved by subsequent archaeological excavations. One solution for the future might be employing small-scale magnetic gradiometry surveys to cover the adjacent area of unproven anomalies.

The investigation performed has shown that applied field and labprocedures have the potential to contribute to understandings of a site's



overall size and approximate structural arrangement in a forested area beyond the archaeological remains and extensive geophysical field surveys.



Figure 1. Sampling pattern at Jakšiškis settlement site. The distribution and thickness of anthropogenic sediments ("cultural layer")



GEOPHYSICALY - ARCHAELOGICAL SURVEY AT THE HRADČANY SQUARE IN PRAGUE

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Keywords: geophysics; archaeology; complex; square

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's state-of-manner and to try to define and localize any archaeological structures' indications. The Hradčany square has not been exposed to any strong construction or research activities in contemporary era. Excluding the rescuing archaeological 1944 survey in the central part no significant spatial outcrops have been made, only the linear trenches' documentation of the engineering networks. Chosen methodology aimed mainly to identify assumed north-south trenches going across the square.

As expected in the urban area, some of the methods (mainly magnetometry, see field work in Fig. 1) did not show simple results due to 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 big negative anomaly of the gravimetry (see Fig. 2). Historically, the reservoir worked as the open fire reservoir on the end of second war, but probably was finished as a kept secret underground system round 1950 year. By cross-correlation of the ERT and DEMP results several anomalies that might equal to trench bodies have been identified. The magnetometry map is filtered of contemporary anomalies and analysis of anomalies of archaeological relevance will be then executed.

The geophysical measurement at the Hradčany square demonstrates possibilities of co-operation between archaeological and geophysical teams. The chance for good results is better if we can use a wide complex of geophysical methods. Studying of geophysical results from the Hradčany square are just at the beginning and we hope it may bring new historical information.





Fig. 1 MAGNETO multi-channel magnetometer (in the front) and gravimeter CG-5 (back) in the field (Hradčany square)



Fig. 2 Results of the gravimetry – line 3 at the Hradčany square.

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GPR INVESTIGATIONS IN THE CHURCH OF ST. ELIAS -BOHDAN KHMELNYTSKY BURIAL VAULT

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Keywords: ground penetrating radar; church; crypt

Ground penetrating radar investigations were performed in winter of 2019 in Illvinska (St. Elias) Church located in Subotiv village. The church is known as the family burial vault of Bohdan Khmelnytsky, the Hetman of Ukraine (1648-1657). The area of the church was partially excavated in 1970, 1971 and 2006, but Khmelnytsky's burial was never found. Since 1971, a pit near the southern wall of the church has been considered his burial place, and was thought to have been destroyed in 1664 by Polish soldiers. GPR survey was performed over western half of the nave of the church using a VIY-3 (Transient technologies) georadars equipped with 300 and 500 MHz antennas. The data were collected in continuous mode along parallel profiles stretching N-S and E-W. The profiles acquired with 500 MHz antenna were 0.25 m apart and with 300 MHz antenna 0.5 m apart. The data were subsequently processed using standard two-dimensional processing techniques: zero level setting; wavelet filtering; manual gain and Hilbert transform. The average electromagnetic wave velocity was estimated as 90 m/µs from the known depth of gas pipe located 20 m from the church. By means of 'Planner' software, the transformed data were subsequently merged together into three-dimensional volumes and visualized in various ways in order to enhance the spatial correlations of anomalies of interest. An anomalous zone at a time 51-61 ns (depth of 2.1-2.6 m) was traced in the centre of the western half of the nave with the help of 500 MHz antenna (Fig. 1A,B). It is a layer up to 50 cm thick, probably filled with air. In the plan view it is a linear anomaly approx. 1.3 m wide, extending over 3 m towards the altar. Sections acquired with 300 MHz antenna show clearly two reflectors at 62 and 92 ns (Fig. 1C,D). Data from both antennas can be interpreted as the arch and floor of an underground construction with area 3 x 2 m, probably faced inside with bricks and partly infilled with soil. The construction could be considered a burial crypt. In the near-entrance area of the church, between the pillars supporting the choirs, inclined reflections are visible – probable marks of the entrance tunnel to the crypt (Fig. 1E). Fig. 1F shows the possible shape of the crypt. Our assumption is supported by the Metrics of the Church composed in 1888, soon after restoration (1869), which contains an indication of Bohdan Khmelnytsky's crypt, as a burial construction. Although in 1970 the area above the crypt was excavated to the depth 1,77 m, the construction was not unearthed because it was located deeper and had been dug in loess from underground.

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Figure 1. GPR results from the Church of St. Elias. Time-slice at 54 ns (A) and selected section (B) acquired with 500 MHz antenna, showing anomalous zone, which was assumed to be air-filled. Scheme of profiles measured with 300 MHz antenna (C) and selected sections showing predicted crypt (D,E). The shape of the crypt reconstructed from GPR data (F).

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MAPPING THE GERMAN NAZI EXTERMINATION CAMPS OF "AKTION REINHARDT" – PROBLEMS AND CHALLENGES FOR ARCHAEOLOGICAL PROSPECTION

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Keywords: extermination camps; GIS; Archaeology; non-invasive investigation

Issues relating to archaeological research and mapping of Nazi extermination camps cause a major challenge for researchers of the Holocaust. Our goal is to combine geophysical methods, analysis of historical sources and spatial analysis into a coherent research methodology.

The primary problem of the archaeological investigations of the many Nazi death camps, i.a. Treblinka II, Sobibór, and Bełżec, is the Halakhic ban for any violation of human remains. This rule defines a specific methodology that should be used for the investigation of these extermination camps. The first step is the location and delineation of gravesites as precise as possible. Because of Halacha, we can use non-invasive techniques only, allowing them to locate places without serious interference in the ground.

The next problem is the camp topography. In all camps Nazis were very meticulous in removing all the traces of their perfect "death machines". Huts, buildings as well as gas chambers were precisely demolished and the former camp area has been transformed into an innocent-looking object, e.g. natural-looking farm was created in place of Treblinka II extermination camp. Due to the lack of camp plans, researchers must be based on witness testimonies mostly.

Our preliminary proposition comprises a methodology for integrating and harmonizing multi-source data for the research on the functioning of the "Aktion Reinhardt" extermination camps. The research was conducted and based on an innovative method using the technology of Geographic Information Systems (GIS) that allows the connection of the witnesses' testimonies with the available and newly obtained geographic data and noninvasive geophysical results.



ELEMENTAL COMPOSITION OF SOIL AT BURIAL SITES

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Keywords: human graves; soil chemistry; pXRF

Burial sites are important components of historic landscapes. In our contribution we address the problem of human-induced chemical change in sediments and soils affected by burial of the deceased. While the decomposition of dead bodies may be seen as a very natural process, cultural customs of most human societies often dictate the establishment of formal funerary areas where human remains accumulate for decades and centuries. What is the long-term ecological legacy of former places of intensive burial has been little studied so far. Phosphate analysis used to be the most frequently applied method for geoarchaeological detection of past human impact on soils. It has also been used in research aimed at human araves. To overcome the inherent limits of this method, we focus mainly on a multielemental analysis of necrosols based on X-ray fluorescence spectroscopy (XRF). In this contribution, we discuss selected observations made in typologically and chronologically distinct localities, covering a spectrum of burial customs practiced since prehistory to the recent period, namely inhumation, cremation, and (through animal proxies) also excarnation.

We aim to demonstrate that mortuary areas are a quite specific and complex class of sedimentary archives. Chemical signals of decomposed human remains can frequently be well distinguished against the natural background values. We have found increased concentrations of P, S, Ca, Fe, and Zn in our varied case studies. These chemical signatures may remain persistent for a very long time, in timescale of centuries to millennia. Attention must be paid to ethical concerns towards human remains and methodological aspects of taphonomic and diagenetic effects on measured data. From an ecological point of view, mortuary sites (even abandoned ones) represent landscape patches significantly enriched with various nutrients compared to the surrounding region, with unavoidable impact on local biota. This emergent research area produces knowledge that can be utilised in archaeology, soil science, ecology, and landscape management.

Acknowledgments

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CO-OPERATION BETWEEN ARCHAELOGICAL AND GEOPHYSICAL RESEARCH: EXPEDITION APOSTOLUS AND LOCALITIES IN PRAGUE

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Keywords: geophysical measurements; archaeology; Armenia; Czech Republic

The largest joint project of the Institute of Archeology of the Academy of Sciences of the Czech Republic, Prague and company G IMPULS Praha was the geophysical measurements carried out in Armenia from 2016 to 2018 project "APOSTOLUS". Partner in Armenia is The Institute of Archeology and Ethnography of the National Academy of Sciences of the Republic of Armenia in Yerevan. The selection of sites in the Armavir region for geophysical measurements was made by the Armenian side. Surveys intended to detecte the presence of archaeological objects (at Argishtichinili – stone structures, probably buildings), the extent of the archaeological site (at sites Aygeshat and Ghanjyan Blur) or the thickness of archaeological terrains (at Ghanjyan Blur and Aghvesi Grer sites) were conducted. At the Ghanjyan Blur site, rectangular structures were detected, most notably stone prehistoric buildings. Geophysical measurements were performed by magnetometry and DEMP. The extent of prehistoric archaeological structures was examined by the ERT method at the prehistoric site of Lernagog in 2018. Furthermore, the original shape of the riverbed was found on the bank of which the excavated site is located.

Two projects were implemented in the Czech Republic. The first concerned geophysical measurements in the area of the deserted wing of the Town Hall in the Old Town Square in Prague. The extent of the preserved masonry was managed to identify very difficult terrain and it was compared with the preserved plans. The geophysical survey on Hradčanské Square focused on the identification of the supposed extinct moats of the Prague Castle fortifications and early medieval stone buildings. The measurement was carried out by six methods and confirmed the anomaly at the site of the supposed moat and found anomalies (buildings?) along the road leading to the entrance to Prague Castle.

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IDENTIFICATION OF ARCHAEOLOGICAL SOILS BY VIS-NIR REFLECTANCE SPECTRA

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Keywords: Soil spectroscopy; VIS-NIR spectra; topsoil; soil mark

Soils influenced by buried archaeological remains tend to have distinctive colour compared to the surrounding soils due to changes in specific soil compounds. These soil colour differences in the topsoil are a strong indicator for archaeologists to identify buried remains. Spectral information of soil from the visible to near infrared region contains detailed information of the archaeological soil. This study introduces a statistical method to identify whether a spectrum is measuring an archaeological feature or not.

This method uses principal component analysis to calculate whether a measured spectrum contains the spectral characteristics of archaeological features. To do this, it calculates how different the measured spectrum is compared to the spectra of surrounding soils. The difference is quantified by a value R. When this R value is larger than 1, then the measured spectrum likely represents a soil influenced by ancient anthropogenic activities.

In this study, soil spectra were measured in the range from 400 to 1000 nm by an ASD spectrometer (Malvern Panalytical, Malvern) with an artificial halogen light source. Five archaeological sites were selected from Italy and Hungary to test the method. Two sites were prehistoric kitchen formation, another two sites were ditch formations and one site was a prehistoric rubbish pit. For the sites with the kitchen formation, R values larger than 3 were found indicating clear distinction between the spectra of archaeological and non-archaeological soils. Pit feature also produce R values larger than 1.7, since the remains contain high amounts of organic matter compared to the adjacent soils. However, ditch features showed varying R values. For the ditch features the R value varies depending on how the ditch has been infilled with collapsed surrounding soils which are not influenced by anthropogenic activities.

Overall, the method introduced in this study showed positive results for the five archaeological sites investigated. The spectra of archaeological remains showed R values larger than 1. It would be advantageous to apply the method to various archaeological sites to identify the different soil properties between archaeological and non-archaeological soils.



PREDICTING THE CONTRAST IN EARTH RESISTANCE DATA FROM WEATHER OBSERVATIONS

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Keywords: earth resistance, weather, contrast, prediction

The successful detection of archaeological features through electrical methods of survey requires a contrast in electrical resistivity between these features and their surrounding soil matrix. The major soil property governing this is moisture content, which varies depending on weather and vegetationcover. Despite several studies it has been difficult to establish a model that can use such external parameters for the prediction of electrical contrast from buried archaeological features. In particular, actual evapotranspiration and downward percolation are difficult to estimate; a general model that describes all relationships in detail is, therefore, hard to formulate. Instead we have developed a simplified model that can predict broad trends as a practical and workable alternative.

Taking porosity as well as soil-water salinity into account the model describes several situations encountered in real field surveys. For example, even on a site where the saturation of a ditch and its surrounding soil are the same (e.g. fully saturated after prolonged rain), the lower-resistivity response of the ditch does not disappear entirely, due to the usually larger pores of its fill.

It is often mentioned by practitioners that the best time for detecting a ditch in earth resistance data is after a dry period preceded by considerable rain. To quantify this, a precipitation ratio p(d) was defined as the ratio of the average daily rainfall in the last d days prior to a survey date, and the average daily rainfall over the last 30 days. To test its usefulness, linear correlation with the resistivity contrast from a series of measurements was determined using nine case studies from the UK and Ireland. For a large Roman ditch at the Roman Town of Caistor (Norwich, UK) a twin-probe pseudosection was measured across the ditch and the resistivity contrast calculated from the topmost layer. For each survey date the precipitation ratio was calculated for a range of prior days d, and the correlation with the resistivity contrast tested. It was found that for this site the best correlation was obtained for 24 prior days. Similar results were found in the grounds of the University of Bradford, UK, where Topic 4: Experimental/Monitoring projects 39



a former waste pit was monitored over more than one year. The correlation between the resistivity contrast (from a 0.75 m square array) and the precipitation ratio was strongest for 15 prior days.

Overall, based on the results from eight of the seasonal series it was found that the newly introduced precipitation ratio calculated for the preceding fortnight is a good predictor for the strength of a resistivity contrast in earth resistance measurements. Calculated using records of daily rain data it allows predicting the strength of resistivity responses from buried ditches. However, there will be sites on which such a generalised predictor is not suitable. For example, in the ninth site of this study the correlation between the resistivity contrast and the precipitation ratio was found to be negative, which was attributed to the extremely well-draining site conditions, both for the ditch and its surrounding soil matrix.



INVESTIGATING THE INFLUENCE OF ENVIRONMENTAL FACTORS ON GPR SURVEYS: THE BORRE MONITORING PROJECT

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Keywords: Ground penetrating radar; soil science; monitoring; archaeological prospection; Norway

In 2015, motorised GPR surveys at the Late Iron and Viking Age site Borre (Tonning et al. 2019) using a 400 Mhz 16-channel Måla MIRA System failed to depict archaeological features detected by earlier GPR surveys in 2007, 2008 and 2013. This result was as surprising as it was alarming for the use of GPR in cultural heritage management, where unreliable results can result in legal consequences.

Provisional investigations pointed to limited contrast between archaeological features and surrounding subsurface material caused by a sudden increase in soil moisture. In response to these findings, the Borre Monitoring Project (BMP) was initiated in 2016 by the Vestfold County Council, in collaboration with the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology and the Norwegian Institute for Cultural Heritage Research. The project aimed to better understand the influence of environmental factors such as local precipitation rates and soil and sediments types present at the survey area onto the quality of the GPR data.

Three test areas covering parts of two known Late Iron Age halls were measured once a month during a period of 14 months. Three monitoring stations (Fig. 1) recorded soil moisture, electrical conductivity and temperature in-situ. A weather station collected data on local precipitation rates, solar radiation and snow heights.

Preliminary results (Schneidhofer et al. 2017) show a tentative trend of increased contrast in the data sets acquired between September and January when compared to data collected in June, July and August. This becomes particularly apparent through the postholes of hall building 2, which are much more discernible during autumn and winter. Real seasonality,



however, is not the case: The lowest contrast occurred in the data set from January, while the highest was measured just a month later in February.

In this paper, we will present the preliminary findings of BMP as well as a critical review about the monitoring approach applied. We will also discuss future research avenues and introduce the newly funded Vestfold Monitoring Project.



Figure 1. Monitoring station 3 targeted the contrast between the posthole of a Late Iron Age hall building and the surrounding subsurface material

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INNOVATION IN NEAR-SURFACE GEOPHYSICS: HOW COULD TIME-LAPSE GEOPHYSICS HELP IN ARCHAEOLOGY

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Keywords: geophysics; time-lapse; monitoring; archaeogeophysics

Geophysical methods have gained in popularity in a wide range of applications with the increasing simplicity and availability of multi-channel data acquisition systems and imaging softwares. With the increased survey speed, larger areas and 3D imaging are now readily available with standard equipment. The advances in hardware has also led to higher temporal resolution that has allowed to monitor complex systems ranging from in-situ tracer or amendments injection to moisture content monitoring at various scales. As a result, this has led to new developments and challenges in terms of fundamental understanding of "rock-physics" opening new multidisciplinary research areas, multi-modal data assimilation and uncertainty quantification, all in which geophysics may play a key role in providing insights on subsurface processes.

An important area of research is the domain of archaeology, or archaeogeophysics. In this framework, imaging and mapping surveys have proven to be informative and useful for exploration. In this contribution, we examine how monitoring or time-lapse geophysical survey could potentially bring further information in archaeological projects. A first line of study considers the use of active tracers to highlight structures in the subsurface that may be hidden in a static geophysical survey. A second axis consists in the natural monitoring of subsurface systems which may yield information complementary to known structures, such as the presence of a groundwater resurgence or the presence of biological hotspots. Finally, a third axis will consider the non-invasive monitoring of the built environment to improve the characterization and evolution of the studied structures.



DIAGNOSTIC AND MONITORING OF CULTURAL HERITAGE: HERACLES PROJECT EXPERIENCE

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Keywords: Remote Sensing; Material Characterization; Cultural Heritage

The H2020 project HERACLES - HEritage Resilience Against Climate Events on Sites (GA No 700395), ended in April 2019, aimed at proposing a holistic multidisciplinary and multi-sectorial approach devoted to provide an operative system and eco-solutions able to innovate and to promote a strategy and vision of the future of the CH resilience.

One of the main goals of the HERACLES project was a multi-temporal and spatial situational awareness of the considered site as element of a more general context, including also territories where the CH is located. This challenge was faced by collecting and integrating data provided by different novel and state of art technologies operating at different spatial scale (from wide area to the single structure and its elements) and on different observation platforms, i.e. satellite, airborne and on site.

Specifically, the general diagnostic protocol depicted in Figure 1 was initially designed and then specialised for each one of the HERACLES test beds, i.e. the *Consoli Palace* and the *Town Walls* in Gubbio, Italy, and the *Knossos Palace* and the *Koules Fortness* in Heraklion, Greece, according to their specific criticalities, such as structural issues and material degradation.

The designed protocols involve the use of the following technologies.

- Synthetic aperture radar (SAR) analysis and interferometric approaches to provide surface deformation maps.
- Visual and thermographic surveys to map indoor/outdoor issues, f.i. crack patterns.
- Ground Penetrating radar analysis, enhanced by microwave tomographic approaches, to perform subsurface inspection and infer information about the construction modalities as well as to detect, localize and characterize surface and subsurface anomalies, for example cracks and fractures.



- Long-term static and vibration-based Structural Health Monitoring to track in time natural frequencies of structures, as well as the amplitude of the major cracks. In this frame, environmental (temperature) effects on the monitored parameters have been characterized and removed.
- In situ and ex-situ (laboratory) analysis performed by means of different techniques, such as Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS), Polarized light Microscopy (PLM), X-ray Diffraction (XRD) devoted to characterize mortars, black crusts and biological colonization phenomena, with the final aim to define the building materials weathering state.
- Satellite and in-situ meteo-climatic technologies in order to obtain a localscale characterization of meteorological conditions and climate change effects, including increased pollution levels and phenomena having a potential impact on conservation of historical/archaeological structures.

Acknowledgments

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Figure 1. General HERACLES protocol for cultural heritage.



HUMAN-ROCK INTERACTION AND THE BURIAL PRACTICE IN THE NECROPOLIS OF THE EARLY ROMAN ERA JERUSALEM

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Keywords: Rock-cut tombs; weathering; Schmidt Hammer; geoarchaeology; necrogeography

During the last 150 years, various archaeological excavations and surveys undertaken in and around ancient Jerusalem revealed approximately 900 rock-cut tombs in the extensive necropolis surrounding the city. This large number of tombs has been archaeologically dated to the last 150 years before the destruction of the city by the Romans in 70 CE. The study of the distribution of tombs surrounding the city provides valuable knowledge of adjoining agricultural systems, quarries, roads, villages, burial customs and practices during the late Hellenistic and Early Roman period (Figure 1)

The research goals are to examine the human-environment interaction in relation to the lithological units and rock hardness and to examine the diverse methods by which the ancient masons solved various lithological defects they encountered during excavation.

Jerusalem is located north of the structural saddle between the NE–SWorientated Judea and Hebron anticlines. Following these structures, a succession of softer Senonian age carbonate rocks (chalk and marl) with inherent crystallinity and fossil content were deposited in the synclines and overlapped the flanks of the anticlines. Thus, the distribution and exposure of rocks of various ages in the Jerusalem area are the result of the stratigraphic order of the layers and their position. Under the present Mediterranean climate, karst processes prevail.

We used field observations and Schmidt Hammer tests to determine the rock hardness and the lithological properties. Our study demonstrates that the substrate played a crucial role in the establishment of the city and the residents' living conditions and that the presence or absence of caves in certain areas can be explained lithologically. Most tombs found west of the city were excavated in the dolomitic Weradim Formation (13.7%); those found north of the city were mainly hewn into the well-bedded limey Nezer Formation (20.7%); the tombs hewn east or south of the ancient city were mainly within the soft chalk and marl of Menuha Formation (56%) (Figure 2). Excavating the hard limestone of the Shivta Formation required substantial



effort and funding, and therefore, the number of tombs is limited (3%). In some cases, owners of estates located in soft lithologies granted burial rights to additional families, as proven by the large number of tombs and the clusters of burial systems in the Menuha Formation.

The rock surfaces are mostly decayed by chemical dissolution, which is enhanced by structural fissures in the rock. Condensation corrosion and excess moisture were observed on the ceilings of some structures, in addition to bio-erosion. Two types of defects are common in the local rock: (a) major defects endangering the stability of the rock-cut chamber that required complementary building with ashlar stones and (b) superficial defects that required only aesthetic solutions.



Figure 1. The ancient necropolis of Jerusalem during the Hellenistic and early Roman periods; (a) Tombs are marked black over the geological map; (b) Distribution of tombs by geological formation





Figure 2. Rock-cut tombs into the chalk of Menuha Formation. (a) Mechanical and biogenic decay at the Dominus Flevit site; (b) Kokhim and ossuaries hewn in chalk at Dominus Flevit site; (c) Destruction and collapse of loose material from beneath stable calcrete layers; (d) Destruction of a rock-cut tomb system during infrastructure constructions, Jabel Muqaber area.

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EDGE DETECTION ON MAGNETIC DATA INTERPRETATION BY USING TILT ANGLE METHOD: AMASYA OLUZ-HOYUK ARCHAEOLOGICAL FIELD EXAMPLE

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Keywords: Archaeogeophysics; Edge Detection; Magnetic Prospection; Tilt Angle Method

In archaeological prospection surveys it is crucial to identify and determine the limits of buried archaeological structures. Magnetic method is one of the most applied method in archaeological surveys in order to plan excavation process. It is aimed to identify the buried temples, graves, walls and similar structures by interpreting the data obtained from magnetic measurements, which is one of the non-destructive geophysical exploration methods. In the process of interpretation of magnetic data, many derivative based algorithms have been developed such as Horizontal Gradient Magnitude, Analytical Signal, Theta Map, Tilt Angle methods which can generate information about the horizontal locations and depths of potential subsurface features. The main theme of these methods is the rapid attenuation of the magnetic field with increasing distance between source and observation. By analyzing the gradients of the magnetic field data, inferences can be made to determine the edges of subsurface potential archeological structure distributions.

In this research, by using archaeogeophysical methods through monitoring subsurface on projecting of archaeological surveys are provided from different perspective. In order to determine the horizontal boundaries of the buried structures by using the magnetic anomaly maps formed by the subsurface potential archeological structure distributions causing magnetic anomalies, program codes were prepared of Tilt Angle and Automatic Gain Control algorithms. The applicability of the programs prepared for these algorithms on synthetic models created with appropriate geometric parameters was tested and successful results were obtained.

In order to discover the historical remanents on archaeological sites nondamaged, a model shed light on the planning of archaeological excavation has designed and it tested on synthetic and field data. It was concluded that

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the prepared programs could be used to determine the subsurface potential archeological structure distributions causing land data and these programs were applied to the total magnetic anomaly maps which are belongs to excavation area of Oluz Hoyuk (Mound) region which settled in Amasya -Turkey as field application.

In conclusion, the findings obtained are acceptable and it is suggested that the methods applied for the determination of buried archaeological structures that have higher historical values which for this purpose can be used.



MISINTERPRETATION OF GEOELECTRICAL ANOMALIES: A CASE STUDY FROM STAVROS-RAFINA, GREECE

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Keywords: Geoelectrical mapping; ghost anomalies

A common geophysical method applied in survey for remains of ancient structural elementshosted in the top soil, such as walls or roads, is the horizontal mapping of the geoelectrical resistance at a certain depth. The main indices for the anthropogenic origin of features detected as low or high resistivity bodies is their shape. The geometrical characteristics of the anomalies in relation with the relative resistivity contrast between the detected anomaly and the host earth material, lead to conclusions about the nature of the target. In most of the cases, geophysical survey results to successful excavations, although in several cases, the interpretation based in these criteria proved to be misled, since, the excavation results did not verify the conclusions of the resistivity survey.

In the present case study, we are trying to highlight this problem, based on the results of the geophysical investigation and the excavations that followed for the construction of the Stavros-Rafina highway in Greece. The twin probe array has been used in the geoelectrical prospection while the gradient of the vertical component of the magnetic field has been measured in areas covering several hectares along the highway.



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The values of the electric resistance of the top soil range from 20 to 150 Ohm. Features of resistance higher than 50 Ohm have been interpreted as possible archaeological targets. A number of possible targets have been proposed for the following phase of excavation. Some of these have been verified and ancient constructions have been discovered. In certain areas, resistive anomalies proved to be outcropping limestone at a depth between 0.5 and 1 meter.

In the area between 3500 and 3700 meters of the highway, a very interesting featured appeared, suggesting the existence of a very big structure in a very characteristic rectangular shape, forming an angle of 90 degrees (Fig. 2). In addition, it was very promising that this feature was measured in a number of continuous grids of 20 x 20 meters. Given the fact that this was a flat cultivated plot, the presence of a rectangular feature led to the suggestion of a possibly very important archaeological structure. The excavations results were very disappointing since nothing similar to ancient ruins revealed.

Resistive features were proved to be lateral changes of the earth material (from clay to calcareous fecal pellets or to gravel) or to oxides concentration especially surrounding roots of plants. In several points old beds were noticed.



Figure 2. Resistance map of the area between 3520 and 3700 meters of the highway Sravros-Rafina

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COMPOSITIONAL DATA ANALYSIS AND ITS APPLICATIONS

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Keywords: relative information; concentrations; logratios; statistical analysis

Compositional data are multivariate observations that carry relative information. They are measured in units like proportions, percentages, mg/l, mg/kg, ppm, and so on, i.e., as data that might obey (or not) a constant sum of components. Due to their specific features, the statistical analysis of compositional data must obey the geometry of the simplex sample space. In order to enable processing of compositional data using standard multivariate statistical methods like the principal component analysis, regression or classification, compositions should be conveniently expressed by means of real vectors of logratio coordinates. Their meaningful interpretability is of primary importance in practice. Aim of the contribution is to introduce the logratio methodology of compositional data and to outline its possible applications.



CHARACTERIZATION OF ARCHAEOLOGICAL SITES USING GPR SIGNAL FORWARD MODELLING

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Keywords: GPR; dielectric properties; FDTD modelling; 3D visualization

The interpretation of GPR data can be complex due to the coexistence of several disturbing factors, namely: ringing noise, reflection multiples and diffraction events. Numerical modelling allows for the simulation of different scenarios of the subsurface. In this framework, Finite-Difference Time-Domain (FDTD) modelling has been widely used as an assistant tool for helping to understand radar-wave propagation phenomena through media. Realistic and large-scale models can be created using data obtained from complementary geophysical and/or geomatic techniques in two different ways: (1) geometry (e.g. photogrammetry or laser scanning) and (2) zonification and/or characterization (electrical resistivity tomography, magnetic, gravimetry, thermography). The technique enables the prior creation of different sections or XZ imaging (models) from a 3D virtual model and next, their elaboration in a Matlab environment, to simulate different media (with different soil properties) and heterogeneity. Furthermore, these models can be simulated using dielectric soil properties obtained from analysis or inversion modelling, as well as using back calculation, in which the synthetic data produced is compared to the field data until the best correlation match is achieved (using an iterative process). Additional information on FDTD modelling using complementary geophysical and geomatic data can be found in [1-3].

As an example, Figure 1 presents a basic case study of a rectilinear structure simulating both dry (a) and wet (b) conditions. The GPR survey was simulated using a Gaussian signal, with an antenna frequency of 500 MHz, 5 cm in traceinterval and time window of 60 ns. To create the 3D model, a constant distance of 10 cm between consecutive GPR lines was considered. Table 1 describes the soil properties assumed for simulation. The synthetic data were produced using the GprMax simulator and then exported into a format compatible with ReflexW, which is commercial software used for GPR signal processing and 3D visualization. The results obtained in Figure 1 demonstrate the capabilities of the FDTD modelling as an additional tool for GPR data interpretation. Further research should be focused on the development of more advanced modelling through the combination of additional geophysical methods and accurate soil properties data.





Figure 1. Synthetic data: a) dry model, b) wet model (red square) and c, d) 3D cube

Media	Dielectric constant	Conductivity (S/m)
Dry filling	9.0	0.0001
Wet filling	17.0	0.005
Dry stone	12.0	0.0001
Wet stone	15.0	0.001

Table 1. Media characterization assumed for simulation

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Topic 5: Multivariate proxy data analysis and/or forward modelling



MACHINE LEARNING FOR ARCHAEO-GEOPHYSICS INTERPRETATION

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Keywords: Machine Learning; geophysics; archaeological features; magnetic anomalies

Machine learning (ML) is a cross-disciplinary approach which combines computer science and artificial analysis with maths and statistics applied on data of certain domain knowledge; allowing software applications to become more accurate in predicting outcomes without being explicitly programmed. The last decade showed an explosion of ML approaches in areas from the image classification to self-driving cars. But its application in geosciences remains underdeveloped. The area of geophysics, which employs this technique the most, is the petrochemical industry with the interpretation of seismic data for reliable results (Huang et al., 2017). The transfer of this technique to near surface geophysics and especially for archaeological prospection will assist in the production of objective interpretations, with both processes; supervised and unsupervised learning of artificial neural networks. Several techniques could be applied; such as classification, regression, cluster analysis and association analysis. In general, the interpretation of geophysical data depends on the ability of the geophysicist and the familiarity of their eyes with the characteristic anomalies encountered in archaeological prospection. The machine learning program will perform as an artificial geophysical eye helping the geophysicist to unveil the nature of the buried archaeological remains. At first, the algorithm will analyse the magnetic anomalies generated by archaeological features. Afterwards, the compilation of different geophysical parameters will be analysed to reach a better constrained interpretation.

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THE USE OF MODERN GPR TECHNOLOGIES IN ARCHEOLOGY

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Keywords: non-invasive methods; geophysical; ground penetrating radar

Geophysical non-invasive methods of preliminary study of the archaeological site can significantly reduce the volume of excavations and speed up the work. The round penetrating radar (GPR) research method is distinguished by the greatest amount of the useful information and high level of the detalization.

During the workshop, GPR hardware and software tools for archaeological research will be demonstrated, as well as methodological recommendations on the use of this type of equipment.