New Technologies for Safeguarding Cultural Heritage – A State of the Art Report of Applied Research and Practice in Germany

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1. Abstract

To preserve and restore our cultural heritage more and more modern technologies have been applied. In Germany there are a lot of institution dedicating to the development of these technologies. First part of the paper is a listing of some outstanding institutions and their research focuses. In the second part tendences in archeometry and non-destructive testing methods are pointed out. The third part is dedicated to the application of geophysical methods in the field of preservation of monuments and archeology. The most useful methods, geomagnetics, geoelectrics and GPR are outlined. To illustrate the power of geophysical investigation methods some examples, above all the complex prospection at the Terme Stabiane in Pompei are presented.

2. General

In Germany the protection of monuments is organized on a regional level. All 12 countries, the two free cities of Hamburg and Bremen and the capital Berlin have their own monument authorities. Number and conditions of the monuments vary from country to country. Especially in the former East Germany there is a lot of unique monuments but in bad conditions. Outstanding examples are the medieval town centres of Görlitz, Quedlinburg and Wismar, the castles and parks of Potsdam, the Bauhaus ensemble of Dessau as well as the industrial monuments in Saxony and Saxony-Anhalt. All this is a large field for scientists and preservators to look for sensitive and efficient ways of preservation including the application of new technologies.

But safeguarding means also the monuments beneath the floor, the archaeological sites. Evidences of prehistoric times are often not visible like erected monuments, but they contain the main information about the early history of a country and its peoples. Sometimes it is difficult to localize and estimate them, it is much easier to destroy them by agricultutral or construction works. For that reason the need of well-organized and responsible institutions dedicating to the preservation of archaeological monuments is obvious. Archaeological field work and preservation are structured like the preservation of monuments, on the level of the countries. In the last ten years both, archaeologists and preservators, started to apply new technologies in their work and often they use the same techniques, p.e. archaeometrical methods and geophysical prospection.

3. New technologies for preservation

3.1 Main focus

A lot of institutions and working groups at universities is dealing with the development and application of new technologies in preservation techniques. Special interests are in the preservation of materials like wood, glass or bricks, in the investigation of building damages and in laser technologies.

3.2 Main players

In Germany especially the institutes of the Fraunhofer Society (FHG) are the main players in the investigation of materials. The Fraunhofer Society is the upholding organization of the German institutions of applied science.

Fraunhofer Institute for Material and Beam Technology

Wittenbergstr. 28, D-01277 Dresden

Tel. 0049-351–2583-251, Fax. 0049-351- 2583-440

Email: günter.wiedemann@iws.fhg.de, www.fhg.de

- Laser cleaning of artworks, wood preservation

Fraunhofer Institute for Integrated Circuits (X-ray center)

Am Weichselgarten 3, D-91085 Erlangen

Tel. 0049-911–9703721

Email: bsr@iis.fhg.de, www.fhg.de

- X-ray tomography for testing of archeological artefacts and artworks

Fraunhofer Institute for Silicate Research (Bronnbach Branch)

D-97877 Wertheim-Bronnbach

Tel. 0049-931–4100703, Fax. 0049-931-4100799

Email: roemich@isc.fhg.de, www.fhg.de

- Characterization and conversation of archeological and historical glasses, outdoor weathered glazed ceramics: degradation and conversation

Fraunhofer Institute for Wood Research

Bienroder Weg 54E, D-38108 Braunschweig

Tel. 0049-531–2155-448, Fax. 0049-531- 351587

Email: johann.herlyn@wki.fhg.de , www.fhg.de

- Application of weathering simulation and non-destructive inspection methods on the preservation of monuments

4. New technologies in archeometry and geophysical prospection

4.1 Main focus

In the last years archeometry has become an irreplaceable part of archaeological work and preservation of monuments. Archeometrical methods cover a wide range of applications:

- investigation of paintings and artefacts
- provenance analysis of metals
- dating of artefacts
- C14-analysis

- authenticity analysis of artefacts
- geophysical prospection

In the last decade has increased the number of universities and institutes playing in this field. Although the funds are always limited there is a wide range of funding possibilities by federal and regional authorities and foundations like ministeries of culture and science or the Deutsche Forschungsgemeinschaft (DFG) as well as by industrial foundations, p.e. the Volkswagen Foundation and the Gerda Henkel Foundation. Some of the most important institutions and their objectives follow.

4.2 Main players

Institut für Archäometrie (Institute of Archeometry)

TU Bergakademie Freiberg

Gustav-Zeuner-Straße 5, D-09596 Freiberg

Tel. 0049-3731–393353, Fax. 0049-3731-392489

Email: pernicka@ww.tu-freiberg.de, http://www.am.tu-freiberg.de

- Copper metallurgy, origin of tin-bronze technology, provenance of gold artefacts, ceramics classification, provenance and processing technologies of Pre-Roman iron artefacts, material properties of early copper alloys, geochemistry of obsidian, authenticity of archaeological finds

Forschungsstelle Archäometrie der Heidelberger Akademie der Wissenschaften

(Department of Archeometry of Heidelberg Academy of Science)

am Max-Planck-Institut für Kernphysik

Saupfercheckweg 1, D-69117 Heidelberg

Tel.0049-6221 – 516 289/335, Fax. 0049-6221-516 633

Email: g.wagner@mpi-hd.mpg.de, www.mpi-hd.mpg.de/archaeometry/

- dating of pottery, sediments and surfaces by luminiscence, particle trace dating, geoarcheology, landscape reconstruction

Arbeitsgruppe Archäometrie (Research group archeometry)

Institut für Chemie, Freie Universität Berlin

Fabeckstraße 34-36, D-14195 Berlin

Tel. 0049-330-838 52417, Fax. 0049-30-838 52424

Email: schnarch@chemie.fu-berlin.de,

http://userpage.chemie.fu-berlin.de/fb_chemie/iac/agsimon/analhome.html

- Geochemical, petrological and technological analysis of archeological pottery: classification of mass finds, provenance of raw material, reconstruction of technological processes, determination of ceramic and using properties. Analysis of glazes, glass, pigments, wall paintings, stucco and stone

Arbeitsgruppe Archäometrie (Archeometry group)

Institut für Mineralogie (Institute of Mineralogy)

Universität Würzburg

Am Hubland, D-97074 Würzburg

Tel. 0049-931-888-5422, Fax. 0049-931-888-4620

e-mail: uli.schuessler@mail.uni-wuerzburg.de

- Ancient and medieval glasses; Roman Kameo glass; medieval glassworks, furnaces; ancient coins; stone artefacts: Neolithic stone axes, garnet in medieval jewellery; pottery glazes, ancient beads

Institut für Anorganische und Analytische Chemie

(Institute of Anorganic and Analytic Chemistry)

Technische Universität Clausthal

Paul-Ernst-Strasse 4, D-38678 Clausthal-Zellerfeld

Tel.: 0049-5323-722656, Fax: 0049-5323-722995

Email: Wolfgang.Brockner@tu-clausthal.de, www.iaac.tu-clausthal.de/abtc

- Archeometallurgy, precious metal processes

Fachgebiet Chemische Analytik (Department of Chemical Analytics)

Technische Universität Darmstadt

Petersenstr. 23, D-64287 Darmstadt

Tel.:0049-6151-166382, Fax:0049-6151-16637

Email: dg7j@hrzpub.tu-darmstadt.de

- Ancient European, Arabic and Georgian glass beads, ancient and medieval glass, ancient counterfeiting of coins, ink of medieval documents, inks of islamic documents

Fachbereich Archäometallurgie (Archeometallurgy group)

Deutsches Bergbau-Museum Bochum (German Mining Museum)

Hernerstraße 45, D-44787 Bochum

Tel.: 0049-234 968 4031/4041, Fax: 0049-234 968 4040

Email: andreas.hauptmann@bergbaumuseum.de, www.bergbaumuseum.de

- Technology of copper and iron mining and processing in the Old World, early pyrotechnology in Anatolia

Arbeitsgruppe Archäometrie (Archeometry group)

Institut für Strahlen- und Kernphysik (Institute of Radiometry and Nuclear Physics)

Universität Bonn

Nussallee 14-16, D-53115 Bonn

Tel.: 0049-228 – 732534, Fax: 0049-228 – 732505

Email: mommsen@iskp.uni-bonn.de,

http://www.iskp.uni-bonn.de/gruppen/mommsen/top.html

- Provenance analysis of pottery, geomagnetic prospection

Landesamt für Denkmalpflege Rheinland-Pfalz (Monument service of Rheinland-Pfalz)

Abteilung Archäologie, Amt Mainz (Archeological department, Mainz branch)

Große Langgasse 29, D-55116 Mainz

Tel. 0049-6131 – 20 16 300 / 302, Fax. 0049-6131 - 20 16 333

- Archeological and archeometrical investigation of building material of Roman constructions (stones, stucco and bricks), ancient history of brickworks, reconstruction of Roman brick technology, brick marks

Institut für Geophysik (Institute of Geophysics)

Technische Universität Clausthal

Arnold Sommerfeld Str. 1, D-38678 Clausthal-Zellerfeld

Tel. : 0049-5323 722233, Fax: 0049-5323 722320

Email: Norbert.Schleifer@tu-clausthal.de, Andreas.Weller@tu-clausthal.de,

http://www.ifg.tu-clausthal.de

- Archeological prospection by geophysical methods, investigation of phsical properties of construction materials

Institut für Meteorologie und Geophysik (Institute of Meteorology and Geophysics)

J. W. Goethe-Universität Frankfurt am Main

Feldbergstr. 47, D-60323 Frankfurt am Main

Tel. : 0049-69 798 24 90 8, Fax. : 0049-69 798 23 28 0

Email: N.Schleifer@geophysik.uni-frankfurt.de, Junge@geophysik.uni-frankfurt.de

http://www.geophysik.uni-frankurt.de

- Geomagnetic and geoelectric prospection

Arbeitsgruppe Ingenieurgeophysik und Archäometrie

(Engineering geophysics and archaeometry group)

Institut für Geowissenschaften

Christian-Albrechts-Universität Kiel

Otto-Hahn-Platz 1, D-24118 Kiel

Tel 0049-431-8803903, Fax 0049-431-8804432

- Geophysical prospection

4.3 Scientific organizations

In 1999 a special organization for researchers and generally interested in the field of archeometry was founded:

Society for Scientific Arqueology ARCHAEOMETRIE (Gesellschaft für Naturwissenschaftliche Archäologie ARCHAEOMETRIE)

Chairman: Prof. Dr. G. A. Wagner

Forschungsstelle Archäometrie der Heidelberger Akademie der Wissenschaften am Max-Planck-Institut für Kernphysik

PF 103980, D-69029 Heidelberg

Tel: 0049-6221 518289,

g.wagner@mpi-hd.mpg.de

4.4 The part of small and medium enterprises (SME)

Small and medium enterprises exist in almost all areas of the preservation of cultural heritage:

- Trades for building conservation
- Construction and renovation materials
- Conservation and restoration of works of art and the moveable heritage
- Preservation and restoration materials
- Instruments and tools for restorers
- Preservation and repair of cultural monuments
- Archeological conservation of sites and remains
- Garden and landscape conservation
- Town and village renewal
- Security technology and protective measures
- Computer systems and software, documentation, inventory, scientific methods of examination
- Non-destructive methods of examination like geophysical prospection

The best place to get in touch with these enterprises is the biennial European Fair for Cultural Heritage, Conservation and Urban Renewal in Leipzig. The fair is a wide forum for scientists, engineers, restorers, craftsmen and officials to inform about new technologies, tendences and outstanding examples concerning all kinds of monuments and their preservation. Next fair will take place in November, 2002

(http://www.leipziger-messe.de/LeMMon/denkmal_web_ger.nsf?OpenDatabase)

5. Geophysics in the preservation of monuments

Geophysical investigation methods are useful tools for the examination of monuments and the localization of hidden structures. In the last 10 years geophysical prospection became part of standard archeological and preservation fieldwork. Recent applications in urban context have also shown its efficiency and usefulness under apparently unfavourable conditions. Successful and comparable working requieres the observance of some methodological rules.

5.1 General remarks

Geophysical methods form an integral part of modern fieldwork in the preservation of monuments and archeological works today. For example magnetic and electrical mapping of subsurface structures became standard procedures for the survey of extensive archaeological places. But these techniques may not be sufficient in case of complex stratigraphy and/or three-dimensional archaeological structures. Especially at excavations in urban context or in the reinvestigation of excavated areas there is a huge need of high-resolving and non-destructive prospection methods yielding three-dimensional presentations of hidden archaeological structures.

For curators of monuments and archaeologists it seems often difficult to see the complete bandwidth of geophysical methods clearly. The following questions always arise: When do I use which method? Which results can provide the different methods? So the users must be well acquainted with the possibilities and limits of geophysical prospection methods. In the same way geophysicists have to open their minds for typical archaeological problems to be able to offer an efficient and good value investigation program. Limited funds are often the main obstacle for a successfull geophysical prospection. The problem is obvious since archaeologists have used more and more the offers of the private sector in geophysical prospection. The reason is that there have been a change of looking at the situation. Curators and archaeologists considerate geophysical prospection more as a service with immediate results than as scientific work lasting months or years. It is the same development like p.e. in scientific dating methods of archaeological remains.

5.2 Geophysical prospection methods

5.2.1 Geomagnetics

Geomagnetic prospection is the fastest and less expensive prospection method. It is the classic mapping method and yields usually 2D-images of the subsurface.The most useful application is the investigation of big and entire areas at single-layer archaeological sites. Sometimes it is possible to distinguish different layers or phases of sites, but only considerating archaeological excavation results.

Fig. 1: Geomagnetic prospection, left: Roman site in Luxembourg, right: Slavic fortification in Mecklenburg-Vorpommern (Germany)

Geomagnetic prospection always should be performed using Caesium or fluxgate probes arranged in multi-probe arrays (4 to 8 probes, fig. 1). A gradient mode with a vertical probe distance of about 0.5 m is mostly the best choose. Data loggers should have a ADC resolution of at least 24 bit and a sampling rate of 20/sec or more. The profil distance mustn't extend 0.5 m. The optimal inline distance of measuring points is less than 0.2 m. An efficient geomagnetic prospection should be yield at least a daily prospection area of 1.5 ha up to 4 ha depending by the field conditions (fig. 2).

5.2.2 Geoelectrics

Geoelectric prospection is very useful in the investigation of certain archaeological structures especially in an urban context. Its parameter the specific electrical resistivity has a very large bandwith. So there is a big contrast between stone foundations and the surrounding, often water-saturated soil. Depending by the physical conditions of a archaeological site it is possible to apply 2D- or 3D-measurements. In the two-dimensional case the results are usually vertical profiles of the underground while three-dimensional investigations (ERT – Electrical Resistivity Tomography, fig. 3) yields presentations of entire blocks of the subsurface. These blocks can be imaged by horizontal slices, vertical cuts or their sequences just as the archaeologist wishes.

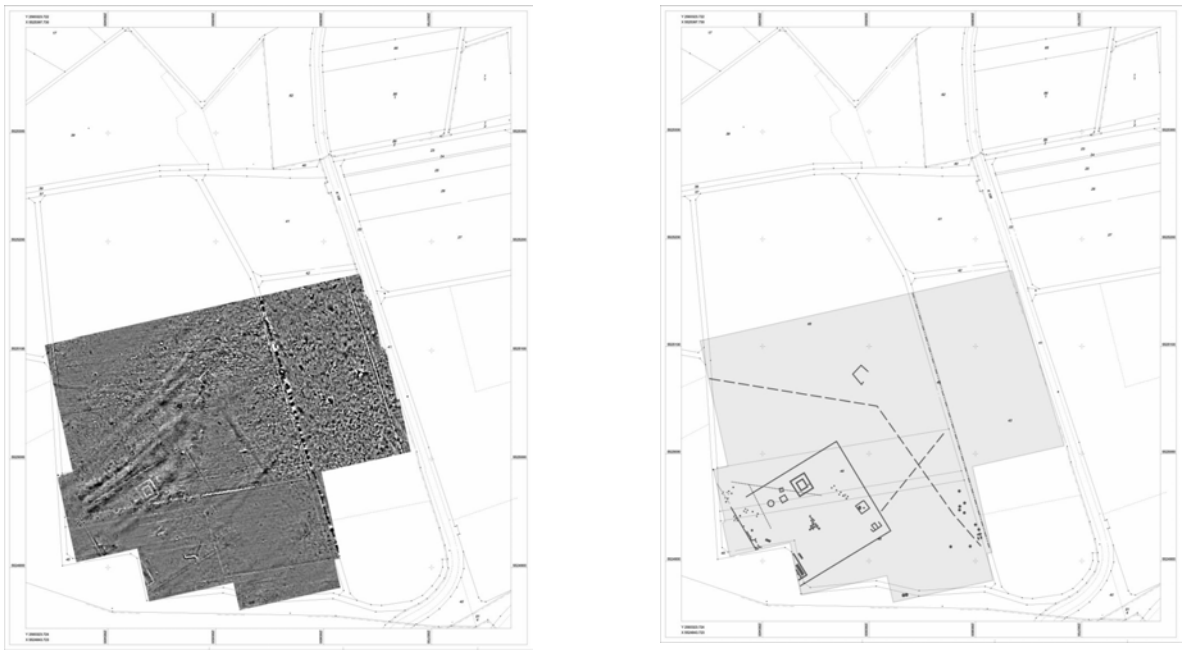

Fig. 2: Left: Greyscalemap of a geomagnetic prospection at a Celtic-Roman site in southwestern Germany (about 8 ha), right: Interpretation of archeological structures.

For fast and effective prospection should be used always multi-electrode and multi-channel systems. These systems should offer the possibilty to apply different measuring frequences to enhance the measuring accuracy. The inversion of geoelectrical data in the field of archaeology must not be performed by commercial software developped for exploration purposes because of the need of very high resolution in archaeology. The necessary software should offer the possibilty to change all parameters like grid distances and fitting coefficients.

Fig. 3: Electrical resistivity tomography (ERT) at the medieval castle of Useldingen (Luxembourg), field display with multi-electrode array RESECS.

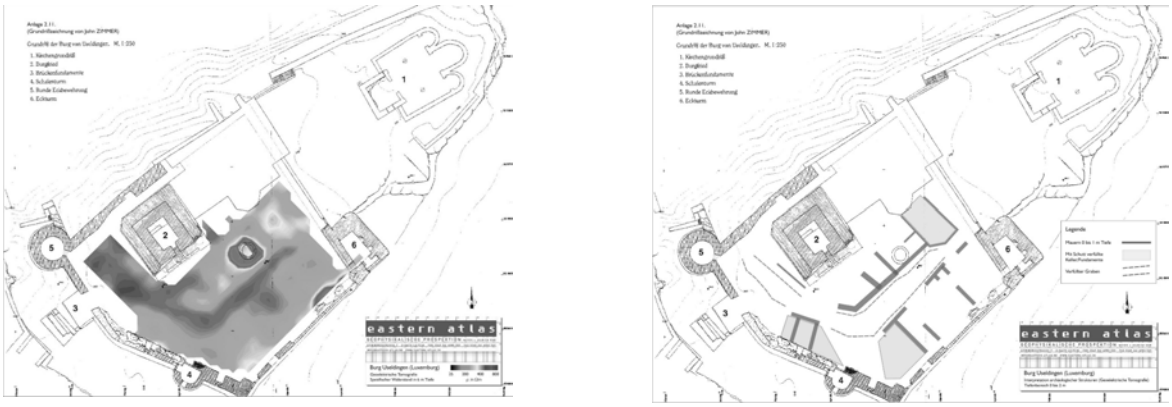

Fig. 4: Castle Useldingen (Luxembourg), left: Geoelectrical Tomography, specific electrical resistivity in a depth between 0 and 1 m, right: interpretation of hidden foundations

5.2.3 Ground Penetrating Radar

The Ground Penetrating Radar (GPR) is a electro-magnetic prospection method combining high spherical resolution and speed. Like geoelectrics it can be applied in 2D- or 3D-mode. But usually the spherical resolution of GPR is better. The main limitation of GPR applications is caused by the water content of the soil and the occurence of clay minerals which contain bound water. In cases of complex and massive 3D structures there is the possibility to apply cross-hole tomographic measurements. It is not absolutely non-destructive but in some special cases like artificial hills (p. e. Tells in Middle East) is this the only way to get information about hidden structures without excavating.

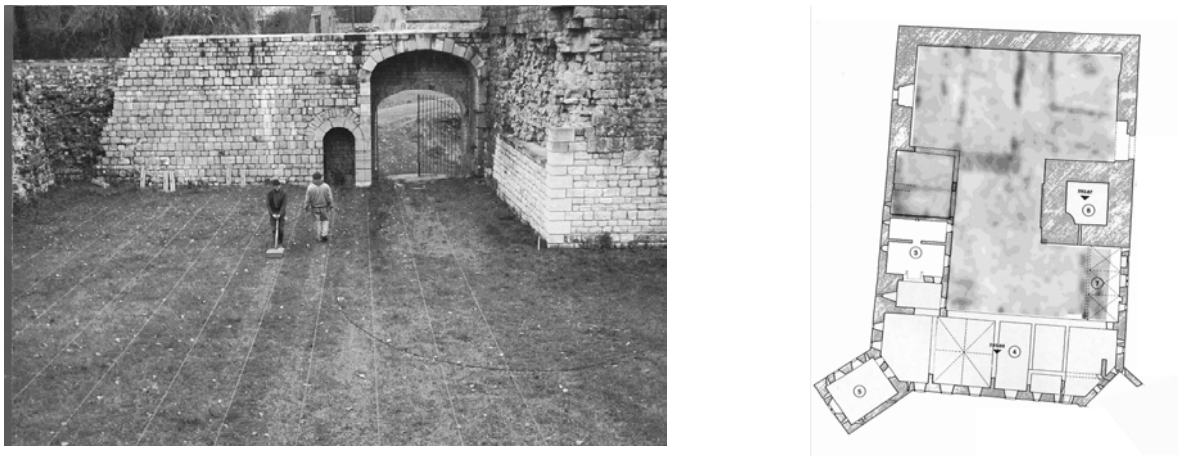

Fig.5: Left: Ground Penetrating Radar (GPR), field display, right: GPR horizontal depth slice showing hidden building structures (medieval castle of Koerich, Luxembourg)

A lot of useful GPR systems is available at the market. The main focus of the enhancement of the GPR results is the further development of processing and imaging software, especially for tomographic reconstruction of the underground.

5.2.4 Combination of the methods

The need of combination of different prospection methods is obvious. Only one method can't solve archaeological problems just as geophysical prospection always is only one part of comprehensive archaeological fieldwork as well as aerial photography and close collaboration with the excavators and restorers.

The following example of a complex prospection in Pompeji shows that geoelectrics is better than GPR in the detection of water-saturated fillings of ditches and pits while GPR measurements yields clearer images of massive foundations and small installations like sewers. In Pompeji geomagnetics seemed to be useless because of the ubiquity of high-magnetized volcanic rocks in the ground and in the buildings. But nevertheless geomagnetics yielded some interesting details for better understanding of the archaeological structures.

5.3 Example: complex geophysics in Pompeji

In view of the progressive dilapidation of the world-famous ruins of Pompeji Italian and foreign restorers and archaeologists have forced up the investigation, documentation and conservation of the excavated areas in the last years. The German Archaeological Institute (DAI) have participated in two concerning projects since 1997. One of them is the investigation of the development, face and function of a building complex, the Casa dei Postumii and the Terme Stabiane in its neighourhood. It was excavated in 1861 and it is a typical, medium-sized, residential building in the centre of Pompeji.

In Pompeji the complete spectrum of high-resolution non-destructive geophysical methods, including high resolution geomagnetic measurements, electrical mapping an profiling, GPR and electrical resistivity tomography were applied at the same object, the Terme Stabiane (fig. 1) and the Casa dei Postumii. The measured parameter distributions are presented in horizontal slices, vertical cuts or sequence of individual slices (films). This allows the comparison of geophysical parameters and the imaged archaeological structures and yields new insight into the complex structure of archeological sites.

5.3.1 Geophysical prospection results

The geophysical measurements in the Terme Stabiane yielded a lot of astonishing insights (fig. 6): A ditch with 6 m width and 4 m depth was detected in the area of the palaestra. It is probably a part of the “Old Pompeji” fortification which was later built over. This is an important fact concerning the urbanistic context of the area and the historical genesis of the Casa dei Postumii and the whole town. The subsurface of the palaestra also contains well-preserved remains of sewers belonging to the installations of the baths. For the first time the course of the sewers was exactly detected. The investigation of the Casa dei Postumii using GPR, geoelectric mapping and ERT allowed insights in the construction of the plumbing under the building. Excavation and geophysical prospection show that the Casa dei Postumii had been a permanent and amateurish construction site until the disastrous eruption of the Vesuv volcano in 79 AD.

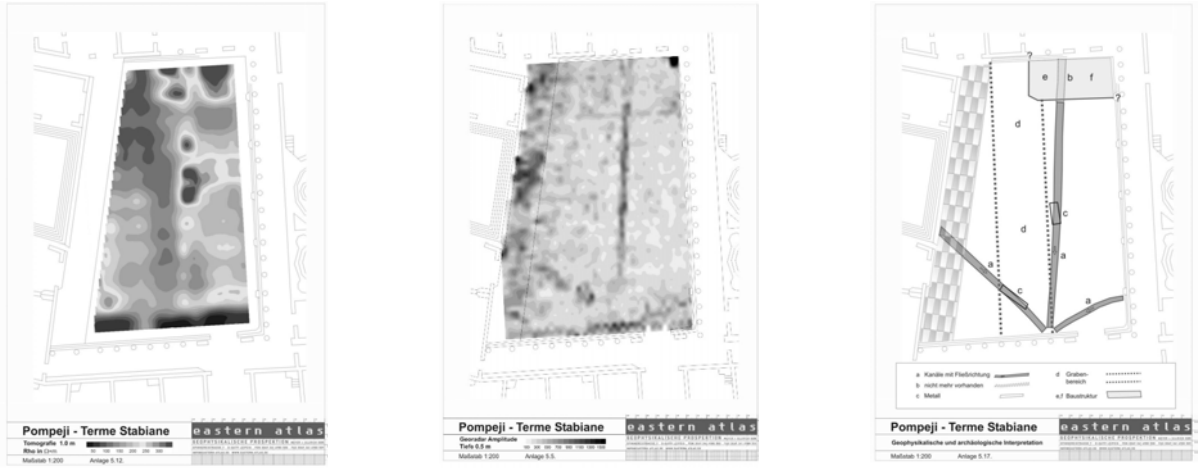

Fig 6: Complex geophysical prospection at Terme Stabiane (Pompei), left: geoelectrical tomography horizontal slice, center: GPR depth slice, right: complex interpretation with sewers (a,b,c) ditch (d) and foundations (e,f)

6. Conclusions

In spite of a lot of doubts complex geophysical prospection can be very useful for archeologists and restorers of monuments even under very complicated and apparently unfavourable conditions. Examples like the Pompeji campaign should open the door for more applications of geophysical prospection in urban context, at multi-layer sites and inside of buildings. Because of its efficiency advanced geophysical prospection has become a irreplaceable tool for investigation and conservation of our cultural heritage.

7. Reference

[1] Gesellschaft für Naturwissenschaftliche Archäologie ARCHAEOMETRIE (Ed.): Archäometrisches Nachrichtenblatt 2002/1, Heidelberg 2002.

[2] J.-A. Dickmann, F. Pirson: Wohnen und Arbeiten im antiken Pompeji. Antike Welt 1, 2002, 81-94.