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**PROCEEDINGS OF THE EEC  
CHINA WORKSHOP ON  
PRESERVATION OF CULTURAL HERITAGES**



**Xian, Shaanxi, P.R. of China  
September 25-30, 1991**

*Non Destructive archaeological and geophysical surveying methods for  
evaluation and preservation of buried cultural remains*

XI'AB; Workshop on Preservation of Cultural Heritage; Sept. 91

Dr. M. Dabas works in a CNRS laboratory (National Center for Scientific Research) in France. In this laboratory, his team has been involved for more than thirty years in the development of new geophysical surveying techniques for archaeological targets. Another team, closely linked to the first, surveys archaeological sites on behalf of archaeologists and the state's ministry of culture.

He has been concerned in (i) the development of high speed acquisition technics in electrical surveying (RATEAU)(ii) characterization of the magnetic behaviour of archaeological soils either in time domain electromagnetism (em magnetic viscosity) or in frequency domain em (frequency dependence of magnetic susceptibility). His researches now focuses on the applicability of sub-surface radar for the detection of archaeological targets and on the possibility of 3D inversion using multi probe devices in electrical surveying.

ABSTRACT

Most of our cultural heritage lies in the first three metres below the ground surface. Preservation of this hidden heritage should begin by a precise location of possible archaeological sites. Geophysical methods can be useful in assessing possible archaeological areas. They could even give some insights about the space organization within the site.

We discuss the definition of "site" and the different threats acting on them. An history of archaeology in France is taken as an example to show how we deal nowadays with the problem of destruction of sites.

The last part deals with the different geophysical methods we use on archaeological sites. The first to be considered is satellite imaging and air-born visible or IR pictures. Through different examples, we show the applicability of electrical, magnetic and electromagnetic surveys on archaeological targets.



I) Introduction

Apart from vestiges above the ground surface, most of our heritage lies within the first three metres below the ground surface. Preservation of this heritage should begin with a precise knowledge of the extension of possible sites.

If in Europe or in Middle East countries, past civilizations have left a lot of remains above the ground surface despite of the different wars and destructions, it does not seem to be the case, at least from a foreign point of view, in China where paradoxically the past is perhaps more present in people's mind than in Europe. Let me quote Victor Segalen who visited China at the end of the last empire. In a poem dating from 1912, he makes the opposition between the barbarians (roman or greek) and the people from China :

" These barbarians, ignoring wood and brick and clay, build with stone in order to build eternal!

They adore tombs whose glory is still to exist; bridges celebrated for their ancientness and temples of too hard stones of which no foundation could fail (...)

You, Han's sons, whose wisdom is ten thousand and hundreds of thousands years old, keep away from this treachery.

Nothing which is motionless will escape from the starving teeth of ages. Long continuance is not the destiny of solid. Immovability is not in your walls, but in you, low men, men of continuity.

If time does not threaten the work, time will threaten to beat the worker. (...)

No rebellion: let us honour the ages in their continuous falls and the time with its voracity "(V. Segalen , Steles, 1912).

Most of our past lies hidden into the ground. Most of your heritage too, but it is not solid.

The knowledge of the underground could be brought by archaeological prospecting: site seeing or surface gathering for example and by geophysical prospecting. We will see some examples of archaeological, thermal, electrical, magnetic and electromagnetic surveys.

II) Definition of the notion of site and threats acting upon them

First, what do we mean exactly by "site"? One definition among others is that a site could be defined by its content. More precisely,

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any place which could bring us some information about our past is a possible site. Consequently, a direct link exists between the notion of site and our present state of knowledge. This link makes the notion of site a subjective one. The number of sites is becoming larger and larger through the years not only as the consequence of new discoveries through urban development for example but also as a consequence of our increasing consciousness of our archaeological heritage.

This notion of site becomes even more confused since we discovered that "off-site" information, that is information which is collected out of the geographical area of the site, could be essential to the comprehension of this site.

Geophysical exploration will have to be sensitive to the physical content of a site compared to the "off-site" content. That is the definition in geophysics of "anomalous" structures. The anomaly could be the result of differences in properties such as thermal conductivity or diffusivity in thermal surveying; electrical resistivity or conductivity in electrical or EM prospecting; magnetic susceptibility in magnetic or EM surveying and finally dielectrical properties in radar surveying.

Among these different methods, we would like to stress that none of them could be used alone. The knowledge of the site arises from the combination of different surveying technics. We will make that point clearer through two examples of kiln surveys in Poland and in France.

Because it is impossible for us to preserve all the sites, we will have to make a choice between them :

(i) This choice is partly the result of the state's heritage preservation policy. It could then be driven by the results of the non-destructive methods we are using. For the remains above the ground surface, preservation is done through a direct purchase or a "classification" of the remains which prevents the owner from modifying the remains without notification to the state. For remains under the ground surface, the preservation policy acts through different laws which oblige one to take into account the so-called "archaeological risk". Considering the view-point of developers, this risk is lessened by the geophysical surveys undertaken on possible sites.

(ii) On the other hand, the choice is also the result of the cultural "value" of the site. None of our methods could give an answer to that particular point.

(111) Because all sites are threatened, we will have to know precisely the different threats, both human (urbanism for example) and natural (terrace erosion for example). That is the third point which should be taken into consideration in the state's heritage preservation policy. Projects such as the general "archaeological map" undertaken in France since 1978 and other countries from the EEC are very important. They should act as a tool for concentrating and unifying the different sources of our archaeological knowledge. For developers, they will be in the future one of the most important data bases to consult in order to take the archaeological risk into consideration either by changing their original plans or by considering a modified time-table for the intervention of field archaeologists.

### III) Types of archaeology in France, management of the archaeological heritage

In the following lines, I have tried to summarize the recent developments of archaeology in France. The first application of an archaeological law which shows the important and necessary role of the government in France dates back to 1945. Reconstruction after the 2nd world war rarely took archaeology into consideration. It is only in the 1960's that archaeology in France grew during a period of both economic expansion and interest in human sciences. Consequently, the awareness of an archaeological risk is relatively new in France compared to other countries.

The great motorway-making plan began in 1953 and has been followed by development of high-speed railways, expansion of underground parking and trains in cities and by regrouping of land and deep-ploughing in the country. Archaeology and the different sciences applied to archaeology had to face these different threats in a very short time period. As a consequence of the lack of appropriate laws and the heaviness of state organizations, a lot of sites have disappeared. For example during fifteen years, it is estimated that 1500 sites have been destroyed by motorways. It was only in 1977 that environmental laws appeared. In 1980, for the first time, the law mentioned "land which contains archaeological remains" and not only visible remains. After a period where archaeologists operated only very belatedly, that is during the earth works, they now operate at an earlier stage that is during

planning. At present, funding becomes very important with the developers contributions. The demand for more efficient and quicker tools for archaeology is growing rapidly. Geophysical prospection is one of these methods. The counterpart for archaeologists is (i) the strict application of a time table, (ii) diggings dictated only by the earth works.

The new process of management of archaeological heritage within the frame of this rescue archaeology tends now to be separated in four different points :

- 1- Early discussions, which is surely the time where most of the preservation policy takes place;
- 2- Evaluation through all known types of documents;
- 3- Mitigation strategy with the developers;
- 4- Planning application;
- 5- Implementation (surveys and digging).

During evaluation, not only the excavation time-table must be specified but also the different post-excavation works: scientific analyses, preservation of the finds and scientific or mass-media publications. We insist that preservation is both an intellectual preservation through publications (cf. Ren Caiyun's and Koch's papers) and a material preservation.

The work of the geophysicist comes very early namely during stage 1 or 2. Some complementary work could be done during stage 5 and is necessary to the comparison of the geophysical results with the digging.

Beside this ever-growing archaeology often called "rescue-archaeology", I want to mention the place of a more academic archaeology named in France "program-based archaeology". Its role is fundamental as a research tool for evaluating new instruments or techniques when there is no time to do so in rescue archaeology. Moreover, the choice of the sites is the result of long term programs which could bring some insights on specific problems. We are presently working on such sites to test new developments of geophysical apparatus. In France, this archaeology is done by universities or state organizations. The number of these authorized diggings is lessening as the result of more and more accurate work performed on these carefully chosen sites.

IV) Geophysical methods, examples

Before going directly to the survey examples, I should recall the different ways one can use for representing graphically numerical data. The most simple way, at least for the computer..., is the use of dot density plots: the higher the numerical value, the higher the number of points per unit surface and consequently the darker (the opposite convention could also be valid). Another way is to use different colors. But in general, we prefer black and white (gray scale) where the dynamic is higher. Another type of representation is isovalues like contours on a topographical map i.e. equal values are connected by a curve. It is more time consuming for the computer but more information can be extracted from the data set.

We are using routinely a lot of geophysical methods for surveying archaeological targets. We will begin by satellite imaging. We don't think that nowadays the resolution of satellite images can be compared to photographs taken from a plane. Even the best actual resolution available which is around 1 meter is not enough. But a global image can be brought by these photographs, specially in remote areas. If we use for example a typical image from satellite SPOT and compare it to photos taken from a plane, it is very easy to see the poor resolution of the SPOT image. But this necessary schematisation allows a better understanding of large areas. We think that the use of such a document is useful only for regional studies or in remote areas.

Surveying by plane either by taking photographs in the visible or IR spectrum is actually one of the only possibility for studying large areas. The visible marks on the soil over the archaeological remains are strongly dependent upon the time of flight. What can be seen are: microtopography, visible remains or difference in the overlying crops (retarded or advanced growth). We are using also in our laboratory an air-borne device which enables us to measure the ground temperature (ARIES radiometer). It measures the thermal IR emitted by the soil in the range between 10 and 13  $\mu\text{m}$ . We do not obtain a surface temperature like in the ordinary IR but a temperature which reflects the thermal history of the soil up to a certain depth. Flight at low altitude enables a good spatial resolution of the images (1m) and a temperature resolution of 0.1 C. On figure 1, it is possible to see a buried ditch with a local increase of the temperature compared to the cold surrounding gravel. Data are corrected by different computer programs to take into



account the geometrical distortions due to the flight path. Image analysis can also be used. But the different indices of the photo-interpretation must be compared to the field for checking. This is a tremendous work because of the large amount of anomalies found.

When a potential site is found, a surface gathering can be done. Classification, either by hand or multivariate statistics, could be performed and bring some insights on a possible chronology and area repartition. But to obtain what is deep in the ground, other methods must be used.

Electrical surveying is the most widespread method. This success is the result of both performing instruments and results which are easily interpretable. The principle is fairly simple: injection of current into the soil and measurement of how this current flows (potential). A wall or a cavity will scatter the lines of current, a wet ditch will concentrate the lines of current: its electrical resistivity is low. In the past, current was injected in the soil manually, point by point, by means of electrodes. It was lengthy. We have developed a continuous system (RATEAU) for the injection of the current and the measure of the potential. Electrodes are mobile and roll on the ground. A tractor or a car tow the apparatus. Compared to the manual procedure, we can now survey large areas, several hectares a day, and have a continuous measure of resistivity. On figure 2, we can see the map obtained on a neolithic ditch (Balloy, France) where the ditch is clearly visible (low resistivity in dark).

The second method uses the earth's magnetic field. Bricks, volcanic rocks, slags or even the superficial layer of the soil have their own magnetization, we call it magnetic susceptibility. One way to measure it, is through the earth's magnetic field (cf. Zhang Zhitian article). This measure is very quick since the discovery of the free precession magnetometer and the flux-gate magnetometer or gradiometer. We insist that measurements are difficult in interpreting. But the information brought by a magnetic map on an archaeological site is different and complementary from the information of the electrical map. We have applied this technique to pre- and protohistoric sites, to metallurgical sites and pottery sites.

We want to finish this very quick overview with em methods. Instead of using a natural magnetic field as in magnetic surveys, an artificial field is created. It induces a secondary magnetic field and currents

which we will measure. One of the advantages is that we control all the parameters of the inducing field. With these methods, it is possible to measure at the same time the electrical resistivity and magnetic susceptibility. In theory, em methods supercede the two previous methods. But the investigation depth is low (<50cm) for the portable instruments we are using. We are using the EM15 from Geonics as a very light apparatus for quick surveys of the apparent magnetic susceptibility of the top soil layers. The SH3, built in our laboratory, can measure at the same time the electrical resistivity and magnetic susceptibility. Interpretation of a site with these two data is important as can be seen in the example of the site on figure 3. It is an iron melting site in Poland (Milanovek). The mass of iron slags and the kilns can be located in the northern part of the site (high susceptibilities). But the map of conductivity brings some different information about a linear conductive structure (ditch?) which comes into the kiln area.

We will finish by a promising method: the SIR, sub-surface interface radar. It is not the aim of this paper to get into the theory of the SIR (see for ex. P. Ulriksen, Application of impulse radar to civil engineering, Thesis, 19821, Univ. of Lund, Sweden) which is quite different from the one at low frequencies. High frequencies above 200MHz are used. People first were thinking that they could obtain images as clear as X-ray images but it proved rapidly to be false. The images obtained, which are basically vertical sections of the soil, are subject to diffraction processes and absorption especially in wet conductive soils. Images obtained are promising but complicated to interpret. We should say that radar surveying is but one of the methods applicable to surveys in urban areas. It has, I am sure, a great potential of development. Finally, we would like to mention the application of radar as a very powerful tool for investigation of masonry: It is used very often for detection of pipes in stone or concrete, detection of fractures and voids in walls, detection of reinforcing bars in concrete or old stones. Its fields of application is widening each day.

As a conclusion, we would like to say that, in the present state of the art, none of these methods could substitute for manual digging. But they give an invaluable help to archaeologists in the discovery and the orientation of digging. They can be considered as one tool in our policy of heritage preservation.

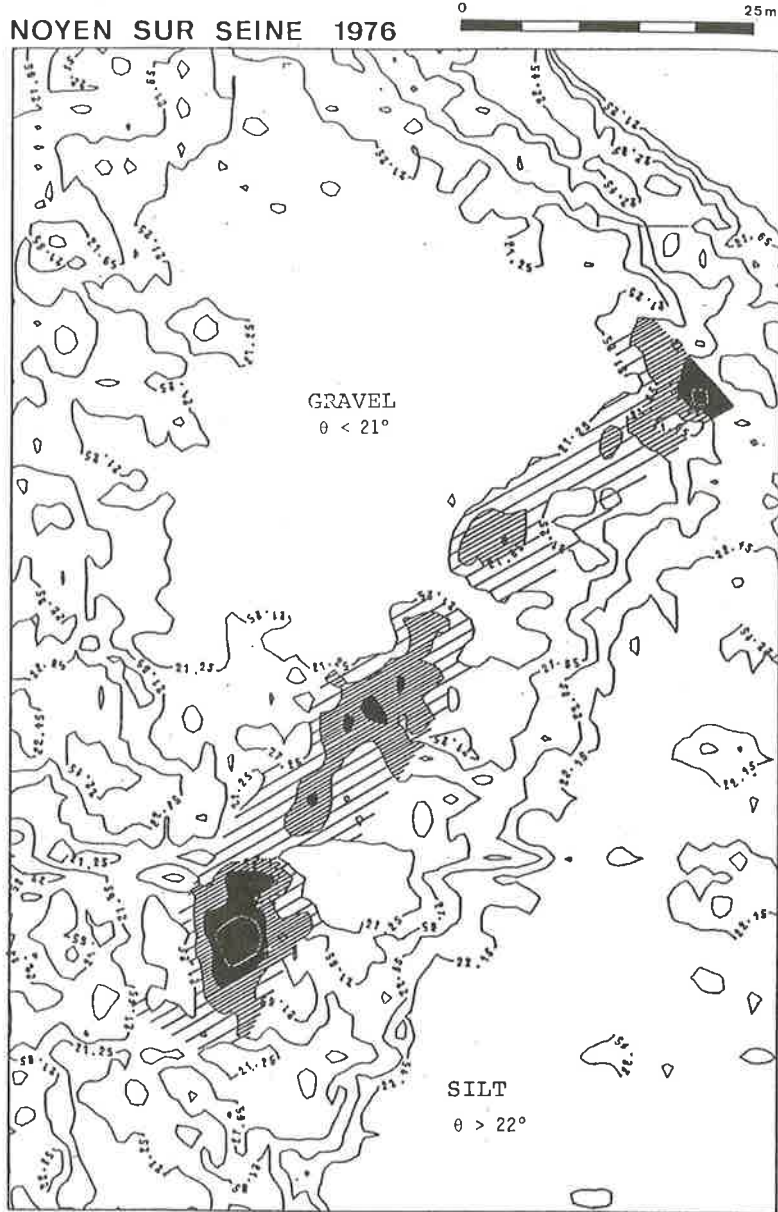


FIG. 1

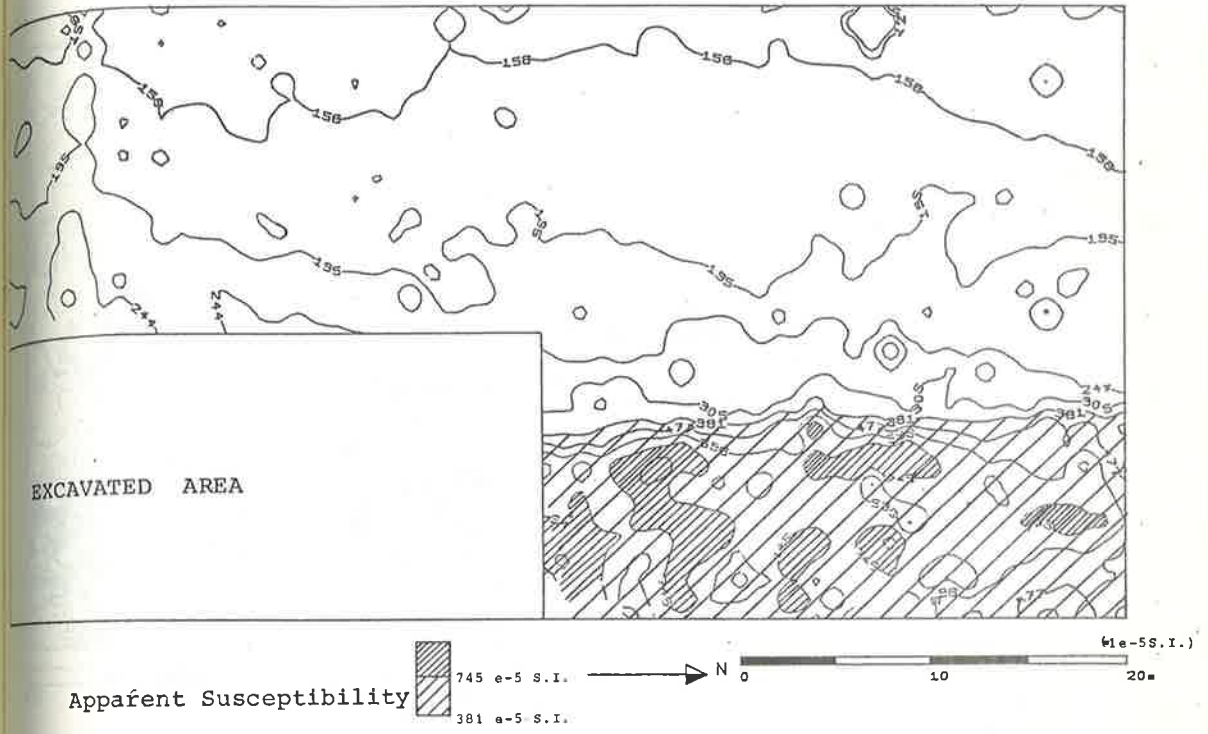


FIG. 2



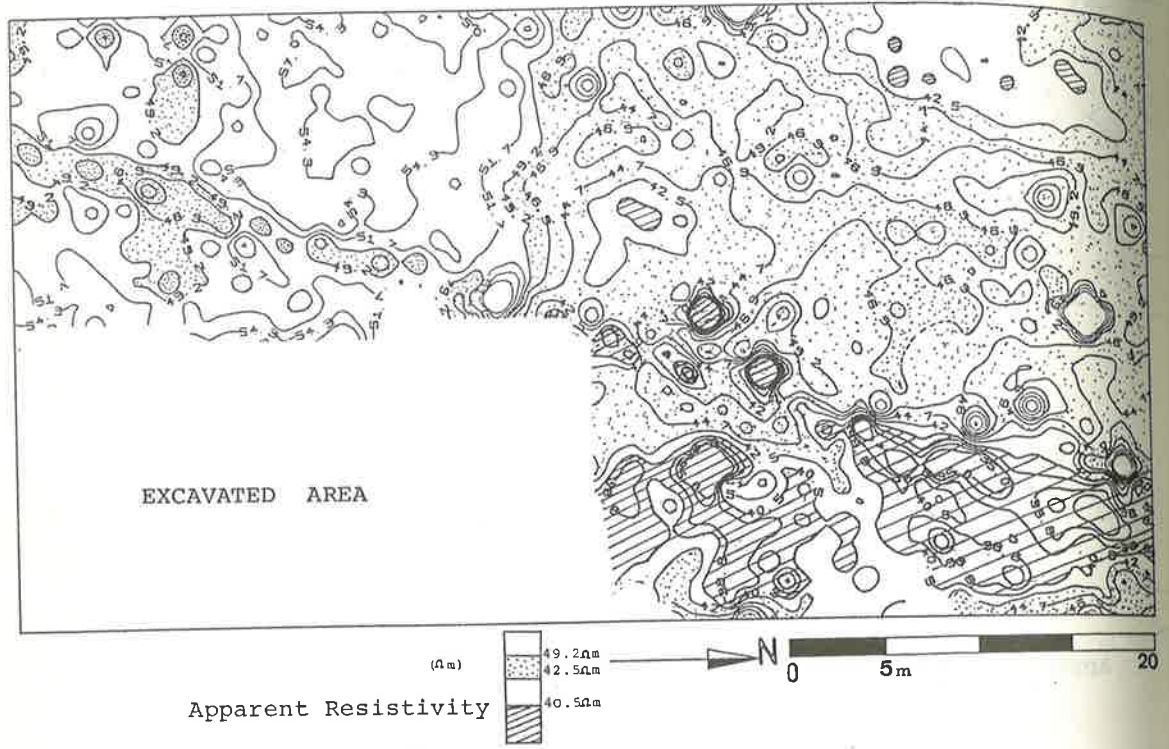


FIG. 3



Apparent 500.0  
Resistivity( $\Omega m$ )

350.0

244.9

171.4

120.0

0 10 20m

Balloy, France: Neolithic enclosure

FIG. 4