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Subject: Contributions of Physics to Archaeological Salvage

Author: R. E. Linington, B. A., Research Associate, Techniques Laboratory, University Museum, University of Pennsylvania, Philadelphia

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This paper aims to discuss the difficulties of the application of physical methods of locating archaeological structures, rather than describing the actual methods.

Most archaeologists are uncertain about the use of the methods, and unfortunately several misconceptions about the possible applications exist. This situation is mainly due to the relatively recent date of the first uses of such methods in archaeology.

At the present only two methods have been used to any extent on archaeological sites. These are resistivity surveying, which measures the electrical resistance at points across the given archaeological site; and proton magnetometer surveying, which measures magnetic field strengths. The main problem is then that of interpreting the physical readings in terms of archaeologically meaningful features.

In order to show the possible use of these methods three examples of surveys undertaken by the author are given. It should be stressed that any success obtained was mainly due to the organization of the survey apart from normal archaeological direction.

The difficulties of interpretation partly arise from the different viewpoints of archaeologist and physicist; in particular, the archaeologist normally considers his site in terms of rationalized features rather than the basic physical elements. To attempt any interpretation one must reconsider the possible archaeological features in terms of their physical properties. Such a process is not too difficult in practice, many of the problems are relatively simple.

In conclusion it was stated that much basic work remains to be done, particularly on the interpretive methods used. Also it is to be expected that further methods will be developed. Owing to the nature of the methods any survey work will have to be undertaken by special teams, under the direction of people with sufficient scientific training. These teams have to be in addition to the normal archaeological staff.

It is to be hoped that research and training centers will be set up to undertake this work, as for example the existing laboratory at Oxford, England, or the new development at the University Museum, Philadelphia. Given these conditions, most of which ultimately depend on adequate financial support, the contributions of physics to archaeological salvage should be of increasing importance.

As sent to Mrs Whinhery

Contributions of Physics to Archaeological Salvage R.E. Linington

In this paper the only contributions to be considered are the new methods for locating buried archaeological features. Full details of the theory and practical use of these methods will not be given for I have felt that in connection with this symposium a more general discussion of their application would be of greater value.

It is probably wise to start by considering the attitude of archaeologists to the idea of using scientific methods. Whilst one can find those who decry the value of such methods, most people seem to agree that much useful information can be gained. In fact sometimes belief in the almost miraculous properties associated with scientific instruments can be rather embarrassing, especially if one is unable to provide the detailed results expected. A more common attitude, however, does seem to be one of relatively cautious support for the methods. Often the harrassed director in the field, especially under the strain of salvage conditions, feels that there is no time for the complexities of scientific surveys. Also there are still many who are convinced that such surveys are basically unnecessary, and that just as much information can be obtained, as quickly, by digging a few test holes. This I hope to show is a mistaken view, generally based on ignorance of the methods concerned. However, it is true that, unless very close cooperation is maintained between the survey team and the archaeologists, much of the survey work can be wasted. It is also very important to have the survey undertaken by people with sufficient time from other duties, and sufficient scientific knowledge to interpret the results. This means in practice that all survey work, especially under salvage conditions, should be separate from the normal archaeological direction of the excavation. Given these conditions under most circumstances a survey is likely amply to repay the effort involved. However it must be expected that several types of situation will be found where the present methods are not applicable.

Although it is probably partly due to the complexity of the methods, and to the somewhat mistaken ideas of the time and labour involved, the fact that so very little work has been done in this country is mainly due to the very recent date of the first use of the main methods. In particular one of the most satisfactory methods, that using the proton magnetometer, has until recently mainly been used by a group at Oxford where an instrument has been developed in a form suitable for archaeological use. One notable exception to this is the work of Dr. Glenn Black at Angle Mounds, Indiana; however, even so he has mainly used the Oxford-designed instrument. It is thus probably not out of place to mention the main methods, and to give a few examples of their application. For some people may have been wondering exactly what are the methods so conveniently covered by the general term scientific.

A wide variety of possible methods have been suggested, and even tested; however, up to the present only two methods have received sufficient use to enable a judgement of their capabilities to be made. It is probably worth stressing that the very recent development of these methods has, in itself, limited the number of applications, and thus of knowledge about the conditions of use of the instruments.

The first method, that of resistivity surveying, has been in use in commercial geophysical exploration for several years. The original archaeological application of the method also occurred some time ago. Since then the use of the method has been somewhat neglected, and it is only in the last few years that any number of surveys have been attempted. The method consists basically of the measurement of the electrical resistance between metal rods inserted into the soil. A sample set of equipment is shown set up ready for use in fig. ...; the use of four metal rods, or probes, is necessary in order to obtain a meaningful resistance measurement. Details of the operation and theory of the instrument will not be given here as they can be found elsewhere. In general the spacing used between the probes depends on the nature of the survey to be attempted; for normal archaeological work the probes are usually equally spaced as shown. In a survey a whole series of measurements is taken across the given archaeological site. This enables the pattern of the variation of the soil resistance across the site to be found. The problem then becomes one of interpreting the measured resistance variation in terms of archaeologically meaningful features.

The second method is that of magnetic surveying. A very high degree of accuracy in the measurements taken is necessary in order to observe the type of difference caused by archaeological features. Because of this the main instrument used, the proton magnetometer, is far more complex, and thus more expensive, than the resistivity equipment mentioned above. A sample set of equipment is shown in fig. .... . Again it is not possible to mention the theory of operation of one instrument other than that it is used to discover the pattern of the magnetic variations across the area to be surveyed. One then has the problem of interpreting this pattern in terms of possible archaeological features.

Finally, a third method should be mentioned; this is seismic surveying. For although at present the existing geophysical instruments are not in a form suitable for archaeological work, there is great hope that practical instruments will soon be developed. A sample set of seismic equipment for near surface surveying is shown in fig. .... . This equipment was used with encouraging results by the writer in recent tests on sites in Arizona.

It can be seen that none of the existing methods yield any direct information on the nature of the buried archaeological features. This is of course true of any possible scientific survey method. One is always faced with the difficulty of interpretation and correlation. However, before turning to these problems a few examples of the use of these methods may show that the position is not as hopeless as might appear. I apologise for using examples from my own surveys, however this has the advantage that I can be certain about the details involved.

Firstly, as an example of a rapid, small scale survey for the location of a single group of archaeological features, there is the case of a Romano-British ditched enclosure in northern Oxfordshire. This enclosure was only about 80 feet in internal measurement, and had been completely leveled leaving no surface indications. Its existence was revealed by air photography nearly thirty years ago, however subsequent changes in the area made it impossible to be certain of the position of the enclosure ditches without errors of at least twenty feet. In order to locate these ditches somewhat more accurately a proton magnetometer survey was undertaken; this took just over three hours, and involved a working force of three people. From the results of the survey it was possible to plot the position of the enclosure ditches with an error of less than one foot, as shown by subsequent excavation.

Secondly, another example of the use of the proton magnetometer, this time on a much larger scale. A site of a minor Romano-British town, again in north Oxfordshire, was surveyed with a total area of nearly 200,000 square feet being covered in five working days, with a working force of from two to three people. The major part of this survey is shown in colour in fig. .... . The magnetic readings have been presented as a contour diagram with the colour code chosen so that the normal readings for the area fall in the green. Areas of high magnetic strength are then shown as the blues and violets, whilst areas of low strength are the yellows and reds. The survey was carried out using a grid system of fifty foot squares, with readings being taken every five feet; the grid is marked on the diagram. One area within the survey was subsequently tested by excavation by the Oxford University Archaeological Society under the direction of J. May, from whose plan fig. ... has been prepared to show the major archaeological features discovered. A full discussion of the results can not be given here, however it can be pointed out that in general one would expect to find the areas of higher magnetic strength than normal as being over the sites either of heavily burnt areas, kilns and hearths, or of occupation deposits, such as refuse pits, ditches and middens. Areas of low strength in this case would probably be due to the presence of quantities of non-magnetic material, for example stone paving or even walling.

As can be seen by comparing the two figures, quite good correlation was obtained between the archaeological features and the magnetic anomalies. In fig. ... the major excavated features are shown within the limits of the excavation trenches, whilst their probable continuation into unexcavated areas, as deduced from the magnetometer results, fig. ... , is shown in dotted outline. Apart from the excavated features two other possible buildings are in order to show the general alignment of the settlement. This pattern is bourne out by the change in direction of the main road through the town.

Thus in summary the main advantages obtained from the survey were that it not only gave an indication of suitable areas in which to excavate, but also showed both the extent of the main occupation area and the probable position and alignment of major features within it. In this case there had been no previous evidence, other than a few surface finds, of either the extent or the nature of the site.

Finally, an example of a resistivity survey. This was undertaken on the site of two overlapping Neolithic camps in south-western France. The area available for excavation was greatly limited by the presence of modern vineyards, with the result that it was impossible to discover the plan of the intersection of the two camps by direct excavation. As it was particularly important to establish the relative dates of the two camps, an extended survey of the area of intersection was undertaken. This survey took just over a week and involved up to four people at any one time. The results of the survey not only showed the exact form of the intersection, but also enabled the point of intersection to be located to within 50 centimeters. In view of this a special small trench was placed in the vineyard. From this trench evidence of the relative dating of the two camps was obtained. Without the scientific survey this important evidence could not have been obtained.

These three brief examples should give a slight indication of the use, and the speed at which these surveys can be made. However it must be stressed that the success achieved was very greatly due to the fact that the surveys were undertaken by a special group under scientific supervision and independent of the main archaeological site direction, but working in close cooperation with it.

Having, one hopes, shown that scientific surveys can be of use, the important, but difficult, subject of the interpretation and correlation of the results should be considered. Here there tends to be an immediate difficulty, for the archaeologist is so prone to thinking of his site in terms of archaeology, that it seems to be difficult for him to consider it in terms of purely physical properties. By this one does not mean that the archaeologist lacks objectivity when considering an excavated site, only that he is inevitably, and of necessity, biased in his approach. Thus on viewing an excavation the archaeologist will always tend to rationalise the observed phenomena in terms both of his past experience, and in the light of any working hypotheses that he may have formed. Such rationalization is of course essential, for without it the interpretation of the site is likely to be impossible. That some form of synthesis and rationalization of the information presented by the soil occurs is obvious if one considers the physical elements that make up an archaeological site. In terms solely of earth and rock particles, of mud, stone, brick or even concrete building materials, and of the assorted artifacts and other objects, an archaeological site becomes almost impossible complex. However, despite the complexity, it is in terms of even more basic elements that the site must be considered when one attempts any method of survey involving physical measurements.

At this point an example may clarify the situation. If an archaeologist on excavating his site comes across a mass of stones, or a patch of burnt material, it is fairly easy for him to decide whether these are significant features. Thus it is possible that he may interpret the stones as forming part of a badly damaged wall, and the burnt material as the remains of a hearth. However when one considers the interpretation of the results of a scientific survey the problem becomes more difficult. Much of the point of the survey is that it is undertaken over areas where excavation has not commenced, or is not possible. Thus one has to infer the nature and position of the buried features purely from the physical measurements taken along the modern surface of the ground. In our example, even if it is possible to identify the presence of the stones, or of the burnt material, it is likely to remain completely uncertain as to whether they are deliberate or accidental features. Only if one found readings which could be interpreted as several masses of stones in a line could one postulate the existence of a wall, whilst the hearth is likely to remain problematical. The difficulties are greatly magnified, of course, if stray stones, or patches of burnt material, have a pronounced effects on the physical properties measured. It should perhaps also be stressed that the very identification of the existence of the features may not be possible. For instance a loosely built wall may contain as much earth in its construction as there is in the rubble layers at each side of the wall. In this case it is quite possible that the physical properties of both wall and rubble would be identical.

In order not to over-emphasize the difficulties one can consider the great success of aerial photography. If stated purely in terms of the basic physical elements the problem would appear to be rather complex. However in practice aerial photography has proved to be one of the most useful methods of locating archaeological sites. For, under satisfactory conditions, markings in the vegetation cover can reveal details of both the plan and the nature of buried archaeological features. The observed crop marks are not, in any way, direct manifestations of the archaeology, but rather are due to variations produced by the buried features in the moisture distribution and soil depth, which in turn affect the crop. In terms of the moisture distribution or soil depth the problem would seem to be very formidable, and it is rather remarkable that the results of these phenomena do give such valuable information on the archaeology. Of course even here the final amount of information produced from a given air photograph will still depend on the interpretive methods used. It is convenient for the archaeologist that these methods are almost always relatively simple. This probably explains in part the acceptance of the evidence from aerial photography by archaeologists who are more sceptical about the more complex scientific techniques.

Finally on the question of interpretation, it is of course possible to interpret any given set of data at several levels of increasing complexity. Thus in some cases it may be sufficient just to choose outstanding readings from the norm in order to spot worthwhile archaeological features. However in many cases, in order to gain enough information to warrant undertaking a survey, relatively complicated methods must be used. Such an example, where the contouring proved to be necessary, was given above in fig. .... . It is in cases where these more complex methods have to be used that the question of interpretation becomes critical, and also, one fears, that of the person attempting the interpretation.

In conclusion one should consider briefly what actually can be the contributions to salvage archaeology. These can be divided into three catagories; first the discovery of new sites, secondly the investigation of known sites before, or instead of, excavation, and finally the use in conjunction with actual excavation. As for the first use it must be admitted that at the present none of the methods is completely suitable for the type of rapid location sought for by most salvage archaeologists. When the area of survey can be more limited, for example in terms of acres rather than square miles, then the instruments can be of much more use. Often it is possible to suggest, not only where it should be most profitable to excavate, but also as to whether it is worth excavating at all. Of course great care must be taken over the use of negative evidence, as it is always possible that the type of site concerned just does not have the requisite physical nature to respond to the method used. Finally, great value can often be found for the use of surveys actually during the progress of an excavation. This is particularly true for cases where features can be only partially excavated, or where it is not desirable to undertake complete excavation. An example of this would be the excavation of an extensive ditch system. It should also be mentioned that often it may prove cheaper to use a survey team rather than to undertake the removal of overlying earth layers from large areas of the site.

As to actual use of the survey methods, I feel that to expect the archaeologists themselves to undertake the surveys in addition to their normal duties is not the final answer to the problem. Despite this it is unfortunately probable that for some time, mainly in view of practical and financial considerations, much of the field use of these new instruments will have to be done by the archaeologists. However, I personally hope that full consideration will be given to the situation, and that it will be possible not only to establish courses in the use of the instruments, and in the interpretive methods, but also, particularly in connection with salvage archaeology, it will be possible to establish sufficient financial support to allow of a more satisfactory use to be made of these exciting new developments. Meanwhile it is to be hoped that the research laboratories, as for example the one at Oxford, or the new centre we are trying to set up in Philadelphia, will continue to develop new methods, and to improve our understanding of the existing ones.

Given these conditions, most of which ultimately depend on adequate financial support, then the contributions of physics to archaeological salvage, and to archaeology in general, will be of increasing importance in the years to come; and it would be a great loss to archaeology if the fullest advantage were not taken of these new techniques.