An electrical resistance survey over a Romano-British villa site

by

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Introduction

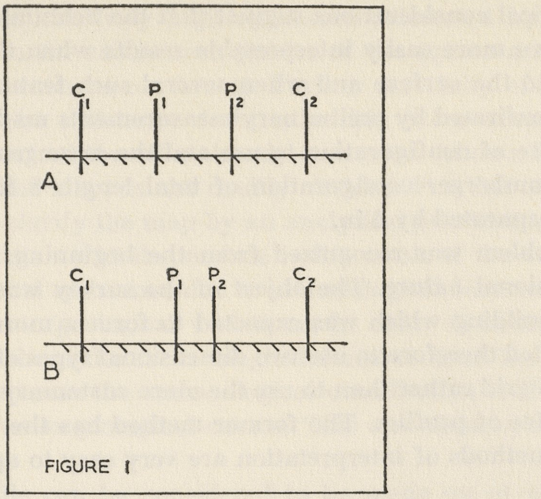
An electrical resistance survey was made during the summer of 1961 at the Romano-British site in Barnsley Park, Gloucestershire, where casual finds made a few years previously had strongly suggested the presence of a villa.

It is intended to excavate this site completely during the next few years, and the aim of this survey was to find whether it is feasible to use electrical methods to produce a ground plan of at least the major constructional features. Such a plan would be of assistance to the excavator in planning his work, or, in the absence of excavation, would be useful in giving a general idea of the type of structure present.

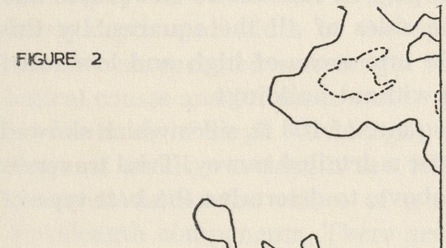
The lower courses of a number of walls were known to reach nearly to the surface, and this, together with the clay-like nature of the soil, made it probable that resistivity contrasts would be good and that it would be relatively easy to distinguish between upstanding walls and the distribution of debris which surrounded them.

The resistance of the ground to the passage of electric current varies according to the nature and the water content of the material forming it. A local concentration of material noticeably different from its surroundings will cause an anomalously high or low resistivity. The sub-surface resistivity is estimated by means of measurements made at the ground surface, the most usual method being with a line of four steel pegs which act as electrodes. Alternating or commutated current is fed into the ground by means of the two outer electrodes and the magnitude of this current is compared potentiometrically with the magnitude of the potential difference between the inner pair. The ratio of these quantities is called the resistance of the ground. When lateral inhomogeneities, such as those produced by archaeological features, are present the exact meaning of the resistance value is very complex, but for the purpose of the archaeologist it is sufficient to say that it is an approximation to the resistance of a roughly equidimensional body of the ground extending between the inner potential electrodes.

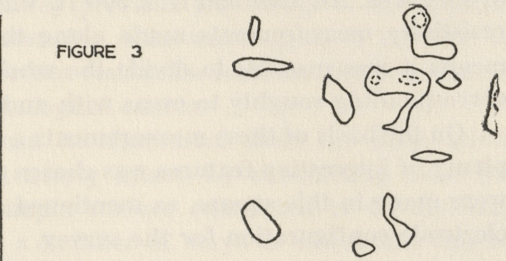
Two ways of arranging the electrodes are in common use. In both, the electrodes are spaced along a line but in the Wenner configuration the electrodes are spaced equally (Figure 1) while in the Schlumberger configuration the potential electrodes which form the inner pair are separated by only a small fraction of the total length of the spread.



Schematic representation of A-Wenner and B-Schlumberger configurations.
C - current electrodes, P - potential electrodes.



Resistance contour map showing combined values of two sets of readings at right angles and their relationship with known wall footings.



Contour map of the residual values found from the combined resistance readings.

Theoretical considerations suggest that the Schlumberger configuration is likely to give more easily interpretable results when the buried features are very close to the surface and when several such features are close together. This was confirmed by preliminary measurements made to establish the best type and size of configuration to use and the arrangement finally employed was a Schlumberger configuration of total length 8 ft. 6 in. with potential electrodes separated by 6 in.

The problem was recognized from the beginning to be essentially of a two dimensional nature. The object of the survey was to recover a ground plan of a building which was expected to form a more or less regular grid. It was decided therefore to use two dimensional types of survey with readings spaced on a grid rather than to use the more customary method of measuring along a series of profiles. The former method has the added advantage that analytical methods of interpretation are very easy to apply.

Preliminary Measurements

Surface indications suggest that the site extends over a considerable area and the first step was to obtain a general picture of the electrical properties of this area. An area 500 ft. x 300 ft. was pegged out into 50 ft. squares and resistivity measurements made along the sides of all the squares. By this means it was possible to divide the whole into areas of high and low relief corresponding roughly to areas with and without buildings.

On the basis of these measurements a square of 100 ft. sides which showed plenty of interesting features was chosen for a detailed survey. Trial traverses were made in this square, as mentioned above, to determine the best type of electrode configuration for the survey.

The Survey

The survey of the 100 ft. square was made, using a constant electrode separation, at intervals of 3 ft. along traverses 3 ft. apart so that the measurements fell on a rectangular grid. Two measurements were made at each point with the configuration alternately parallel and at right angles to the line of traverse.

Since this involved well over 2000 measurements it was necessary to adapt the apparatus for rapid use. The total length of the configuration used for the survey was 8 ft. 6 in. and the length of each traverse 100 ft. This made it possible to mount the configuration on a hinged board which removed the need for measuring the spacing of the electrodes for each measurement and to work with the instrument fixed at the centre of the traverse. The instrument was mounted waist high and long electrodes were used to eliminate bending. Whith these adaptations the survey was completed by two men in four days.

Analysis of the Measurements

The measurements from the two sets of traverses were combined and then plotted on a map and contoured (Figure 2). From this map it is clear that there are two areas or relatively high resistance delineated by the 6 ohm contour. One area is in the south-west quarter of the square and the other, a smaller area, in the extreme north-east. Further scrutinity of the contour map shows there to be resistance features within these areas, but their relationship to that part of the villa already excavated (shown in the lower right hand corner of the map) is not readily obvious. For this reason it was decided to attempt to clarify the map by an analytical procedure.

The measured resistance at the surface is the result of the superposition of anomalies in the local resistance due to archaeological features, and those on a larger scale due to geological variations. In order to extract the most information possible about the archaeological features from the map it was found necessary to separate the archaeological contribution to the resistance map from the part due to geological causes. This was done by a method of frequency analysis.

A resistance profile can be considered to be made up of a number of various wavelengths. The length of feature will be an indication of the extent of the anomalous body along the line of measurement and will be dependent on the depth of the body below the surface and its relation to the spacing of the electrodes. In this survey previous knowledge of the approximate depth and width of the upstanding villa walls made it possible to estimate an excepted wavelength for the resistance features due to archaeological causes and for those due to geological causes.

Features of large wavelength can be eliminated from the map, while those of small wavelength are left nearly intact, by subtracting from the observed values the values of a simple surface calculated to fit the long wavelength components. There are a number of ways in which this can be done, the theory of the simple method used here being discussed by Griffin (1949)[1].

The residual resistance ($\triangle$ R) at a point was defined as the measured value (R_0) at that point less an average value ($\overline{R}_r$) at a radial distance r from that point

$$\text{i. e.} \qquad R = R_0 - \overline{R}_r$$

The distance r is called the filter spacing. The residual resistance ($\triangle$ R) may be a positive or negative quantity depending on whether or not the value R_0 at the point under study is greater than or less than the average background value $\overline{R}_r$.

R_0 should, strictly speaking, be the most typical value of a resistance at the point under consideration. As a resistance measurement is directional however, the most typical value is a function of measurements made in all possible directions about the point. In this particular survey resistance had to be measured at over a thousand points, and so it was decided to take, as an approximation to R_0, the average of measurements made first with the electrode spread in one direction and then in a perpendicular direction.

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[1] W. R. Griffin, Geophysics 14, 1949, 1, 39.

The average value ($\bar{R}_r$) was the arithmetic mean of four points about the circumference of a circle of radius r.

$$\text{i. e. } \bar{R}_r = \frac{R_{1r} + R_{2r} + R_{3r} + R_{4r}}{4}$$

By filtering the combined values and contouring them to produce a residual map (Figure 3) the detail of the features within the high resistance areas has been made more clear. Several other filter spacings were tried, but $r = \sqrt{2}s$ (where s = grid spacing of 3 ft.) proved to be the most successful. On this residual map the features are seen to have a rectangular plan and the same orientation as the already known walls. The 1 ohm contour shows within the SW high resistance area many linear features two or three feet wide which appear to correspond to the foundation of villa walls.

Thus by filtering resistance measurements and contouring the resulting residuals it has been possible to draw a ground plan of part of the villa. The plan, though showing only the major structural features, should nevertheless prove useful to the archaeologist in his future excavation of the site.

Conclusion

This approach should prove fruitful on sites similar to Barnsley Park provided suitable resistivity constrasts exist. With the exception of the work of Scollar (1959)[2] no very serious attempt has been made to use the resistivity method in areas of complex archaeology. It has now been shown to be practicable to attempt this type of two dimensional survey in a small area and to interpret the results analytically without the automation that is, of course, necessary in large scale surveys such as those at Xanten. This puts the method within the reach of amateur groups working on a small scale. It is hoped to continue the work at Barnsley Park in the near future.

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[2] I. Scollar, Bonner Jahrb. 159, 1959, 284 ff.

Acknowledgements

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