An experiment on the effect of rainfall on electrical resistivity anomalies in the near surface

by

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During the last few years there has been an increased interest in the use of geophysical methods to find buried archaeological features. In one such method measurements of apparent electrical resistivity are made at the surface, variations in sub-surface soil conditions causing variations in the apparent resistivity which may be interpreted in terms of buried features.

The ability of rocks to conduct electric current is largely due to the presence in the rock pores of interstitial water, and the degree of conductivity depends on the amount of water present and its salinity. Variations in apparent resistivity caused by variations in sub-surface conditions will depend therefore on differences in the water holding properties of the various soil types present and on the total amount of water present in the ground.

If the ground is saturated with water any differences in electrical resistivity between soil types will be due largely to differences in the geometry of arrangement of their particles while, if the ground is relatively dry, variations may also be caused by differences in the water retaining properties of different materials. It cannot be decided a priori whether this will mean that resistivity variations will be more or less marked when the ground is relatively dry, but, since resistivity variations caused by archaeological features are often fairly slight, it is important to have some criterion for deciding the best climatic conditions for field measurements to be made.

This question can only be answered in full for any given site after a prolonged investigation of that site. This will not usually be practicable, but it is possible to give some general guidance on the subject by making available the results of a number of studies of typical sites. The results of one such study are given here.

This work was carried out during the investigation (Chalabi 1961) of the Roman military defences at Wall in Staffordshire[1]. The site is a complex one, a section through the defences showing at least seven ditches, some

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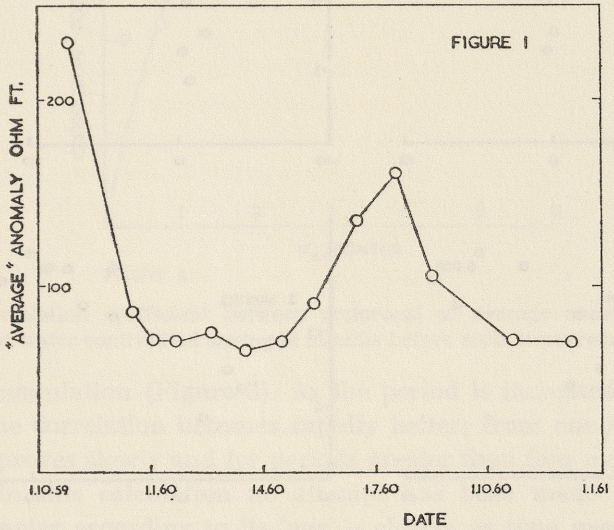
[1] M. M. Al Chalabi, Unpublished M. Sc. Thesis, University of Birmingham (1961).

overlapping, cut into the soft Triassic sandstone[2]. The ditches, the deepest of which extends eleven feet below present ground level, were nearly all filled soon after their cutting with a mixture of sand, clay and turf and much later the whole area was covered with two or three feet of pebbly sand, probably in fact in the seventeenth century. The site may well have been under pasture since this last filling and is now covered with rough grass.

As part of the study of this site a resistivity traverse was made using a Wenner configuration (a = 5ft.) parallel and fairly close to a previously cut section. Measurements along this traverse were made, during the period



Variation of 'average' anomaly over the period of measurement.

October 24. 1959 to December 6. 1960 at intervals of approximately a month. Daily precipitation figures from April 1959 to December 1960 were obtained from the South Staffordshire Waterworks station at Little Hay, about two miles from the site, and the monthly estimates of evaporation and transpiration for this part of the Midlands from the Ministry of Agriculture, Fisheries and Food.

An estimate of the effect of contributed water on the quality of the resistivity anomalies was arrived at as follows. The resistivity profile when plotted out appears as a train of peaks and troughs due to various features passed over during the traverse. Several features were involved and these were taken to be a representative sample from the site. A representative value, the 'average anomaly' of apparent resistivity, statistically related to the average difference between peak and trough, was obtained by taking the average difference regardless of sign between adjacent measurements spaced at intervals of two feet along the traverse. This value is not in any strict sense an average amplitude of the variations along the profile, but since the procedure was not varied results from measurements made on different days

[2] F. H. Lyon and J. J. Gould, Richfield Arch. and Hist. Soc. Trans. 2, 1960, 31–37.

can be compared. Figure 1 shows the variation of the average anomaly over the period of measurement.

This average anomaly was correlated with the nett contributed water (precipitation – evaporation) for periods of various duration immediately before the date of measurement. It has been found[3] that the relationship

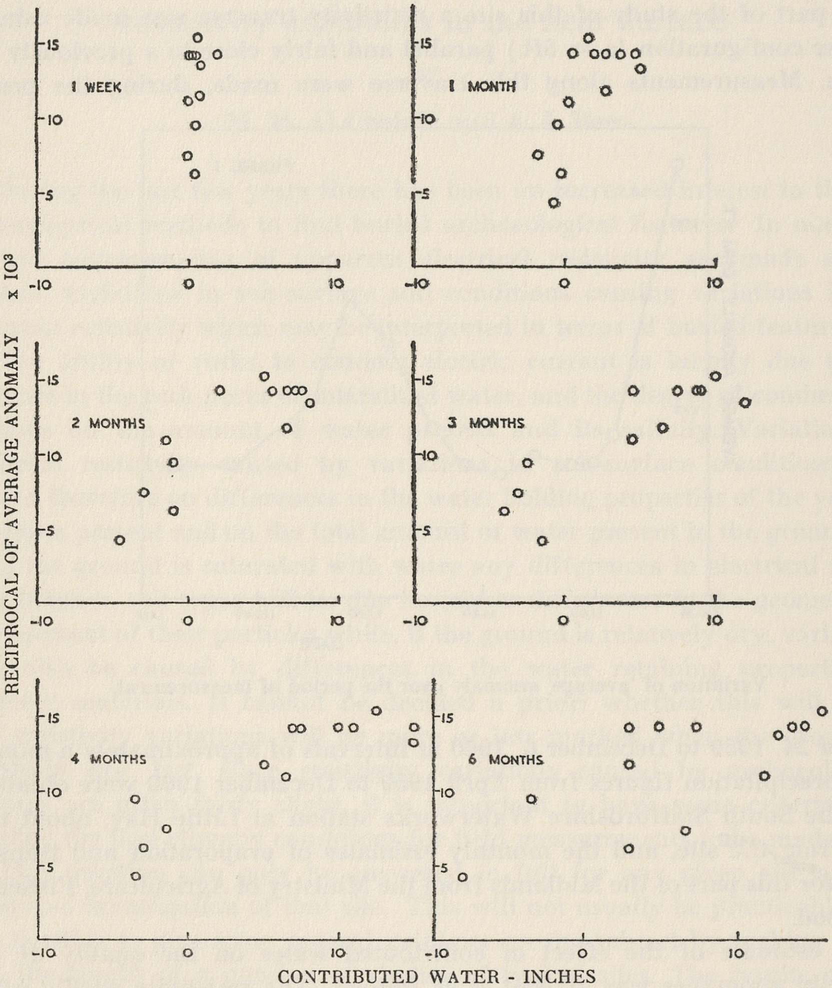


FIGURE 2

Correlation between reciprocal of average anomaly and water contributed during various periods before each measurement.

between the conductivity of a rock and its water content is usually a hyperbolic one, and for this reason the correlation was made not between the nett contributed water and the average anomaly but between the contributed water and the reciprocal of the average anomaly. Figure 2 shows the correlations between the reciprocal anomaly and the nett water contributed during periods varying from one week to six months before the date of each

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[3] J. J. Jakosky and R. H. Hopper, Geophysics 2, 1937, 33–35.

measurement. It will be seen that correlation appears to be best when the contributed water is taken into account for a period from two to four months before the date of measurement. This was confirmed by calculating correlation coefficients between the two variables for a range of values of the

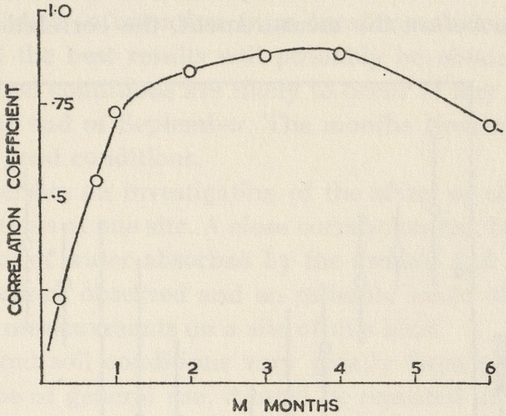


FIGURE 3

Correlation coefficient between reciprocal of average anomaly and water contributed during M months before each measurement.

period of accumulation (Figure 3). As the period is increased from zero to one month the correlation becomes rapidly better; from one month to four months it improves slowly and for periods greater than four months it begins to fall off. In this calculation no attempt has been made to weight the contributed water according to its 'age' – clearly as time passes water will tend to diffuse downwards and be lost – and it might be supposed that if a correct weighting could be achieved the correlation coefficient would rise asymptotically to unity.

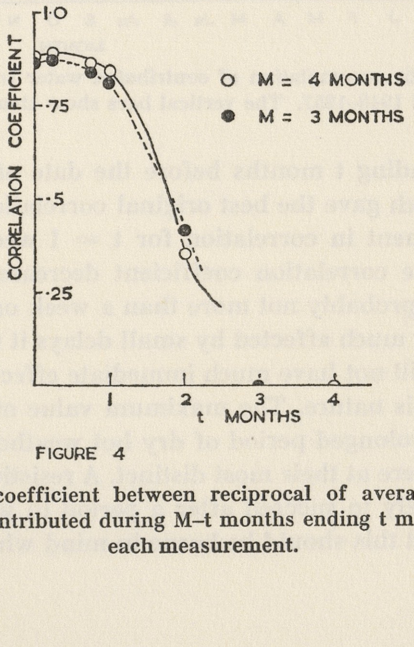
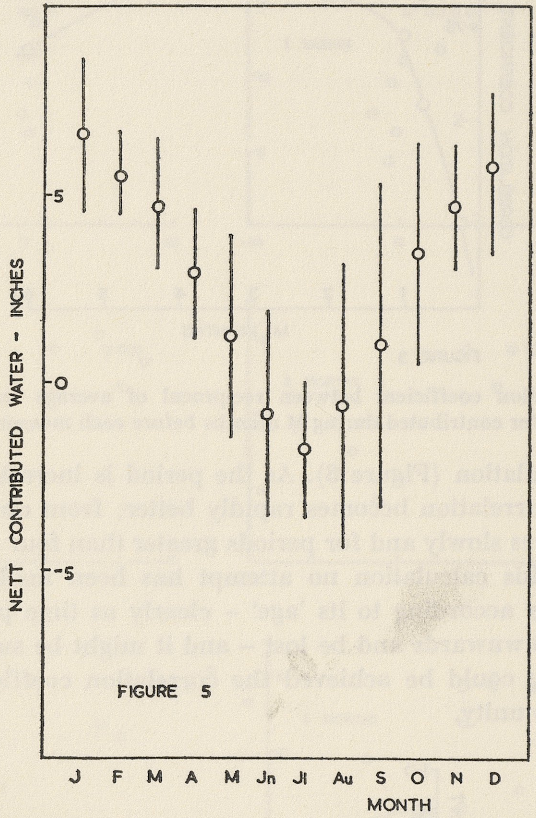


FIGURE 4

Correlation coefficient between reciprocal of average anomaly and water contributed during M–t months ending t months before each measurement.

It has been suggested that there might be a time lag during which water entering the ground might not be effective in producing anomalies. The suggestion is that the water will take some time to percolate down to the level where the anomalies are produced. Figure 4 shows an attempt to find out whether this is so. Correlation coefficients have been calculated for periods ending some time before the measurement, the correlation being made for



Mean three months accumulation of contributed water (rainfall evaporation) for the period 1948–1957. The vertical bars show standard deviations.

the M - t months ending t months before the date of measurement for the two values of m which gave the best original correlation. In both cases there is a slight improvement in correlation for t = 1 week but for values of t greater than this the correlation coefficient decreases. This means that if there is a delay it is probably not more than a week or two at this site. Since the correlation is not much affected by small delays it means also that a brief but heavy rainfall will not have much immediate effect on the measurements made on a site of this nature. The maximum value of the average anomaly was found after a prolonged period of dry hot weather, and at this time the resistivity features were at their most distinct. A resistivity survey on a site of this type is most likely to succeed after a period in which there has been a nett loss of water and this should be borne in mind when planning a season's field work. It is not possible, of course, to predict that, at any given time of year, the best conditions will apply, but a study of weather statistics suggests that certain times will be better than others.

Figure 5 shows the monthly mean, for the years 1948–1957, of the nett contributed water for a three month period of accumulation. These figures are based on published information from local measuring stations[4]. From this it is clear that the best results will probably be obtained in the month of July, but that good conditions are likely to occur at any time between the end of May and the end of September. The months November to March are least likely to give good conditions.

This report describes an investigation of the effect of climatic conditions on resistivity variations at one site. A close correlation has been demonstrated between the amount of water absorbed by the ground and the magnitude of the resistivity variations observed and an estimate made of the best time of year for resistivity measurements on a site of this kind.

Both climatic and soil conditions vary greatly from place to place and, if this work is to be of general use, it must be repeated under a wide range of conditions. Our results lead us to think that this is both practicable and desirable.

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[4] British Rainfall 1948–57. H. M. Stationery Office, London.