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GEOPHYSICAL INVESTIGATION OF ARCHEOLOGICAL SITES

INVESTIGATION GÉOPHYSIQUE DE SITES ARCHÉOLOGIQUES

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Summary:

Rapid loss of archeological sites as a consequence of population expansion and industrial, urban, and rural development in the United States necessitates the expeditious assessment of the importance of particular sites within a region. Tailored to different scales of archeological phenomena, two alternative interpretation techniques for the use of resistivity surveying methods have proven effective for this purpose. Where features are large, tend to have linear boundaries, and/or contrast well with their matrices relative to the local level of noise, individual features can be investigated. Where features are small, round, have low contrast profiles, and are clustered in activity areas, these areas should be characterized by the statistical and spatial patterning of their collective resistivity values. Trend surface analysis of resistivity survey data works well when applied to house foundations, wells, and burials in historic sites in North Carolina. The Barnes Layer method of resistivity data interpretation and frequency analysis is effective in locating clusters of artifacts, earthen pits, midden deposits, hearths, and post molds as demonstrated at a prehistoric Indian village in Illinois.

Résumé:

La perte rapide de sites archéologiques à cause de l'accroissement de la population et à cause du développement industriel, urbain et rural aux États-Unis nécessite l'évaluation prompte de l'importance de certains sites dans une région. Consacrées aux différentes dimensions de phénomènes archéologiques, deux techniques alternatives d'interprétation au service de la méthode de résistivité électrique se sont montrées efficaces à cet égard. Si les matériaux archéologiques sont grands, s'ils ont des limites linéaires, s'ils contrastent bien avec le sol à l'égard des courants vagabonds voisinants, on pourra considérer des objets individuels. Si les matériaux sont petits ou ronds, s'ils contrastent mal et s'ils sont réunis dans des secteurs d'activité, ces secteurs devront posséder une résistivité caractéristique. La mèthode "Trend Surface Analysis" appliquée aux données de résistivité fonctionne bien lorsqu'elle s'applique aux fondations, aux puits et aux tombes des sites historiques dans la Carolina du nord. On a démontré pour une petite ville préhistorique en Illinois que la Mèthode "Barnes Layer" d'interprétation de résistivité et d'analyse de fréquence ("Frequency analysis") produit son effet à repérer les groupes de matériaux archéologiques, de fosses, de débris, de foyers et de traces de poteaux.

Introduction

Rapid loss of potentially significant archeological sites is an unfortunate consequence of population expansion and industrial, urban, and rural development. To minimize the adverse impact on nonrenewable cultural resources caused by these pressures, massive legislation has been enacted in the United States requiring assessment of the archeological importance of an affected area prior to the start of any ground-disturbing activities. The result is that the number of archeological sites which must be rapidly and thoroughly surveyed and examined far exceeds the capability of available professional manpower using traditional subjective and unreliable site reconnaissance techniques (Schneider and Noakes, 1970).

Two alternative techniques for obtaining and interpreting resistivity survey data are applicable to archeological problems. The choice between the two depends upon the nature and scale of the archeological features to be investigated. Where the features are fairly large relative to the electrode spacing and the distance between survey stations, where they have well defined linear boundaries, and where they produce a significant resistivity contrast with the surrounding soil matrix, a resistivity survey may be designed to locate the individual features of the site. House foundations, wells, and graves in historic sites surveyed in North Carolina fit these conditions and produce recognizable anomalies in the electrical data. On the other hand, where archeological features are small, without sharp boundaries, and do not produce a strong resistivity contrast with their soil matrices, a resistivity survey may be designed and interpreted to characterize statistically the anomalies indicative of human activity areas within larger, intra-site, geographic zones, rather than to delineate the individual features. This type of "zone identification" has been used in Illinois on a prehistoric Indian site to define geographic areas in which specific human activities occurred.

In the decade following Palmer's assessment of resistivity surveying techniques (Palmer, 1960), theoretical principles were explored (Scollar, 1962) and instruments were designed to rectify basic problems and to increase both the speed and efficiency of electrical resistivity surveying (Schwarz, 1961). In addition, the utility of electrical resistivity and other prospecting techniques in locating pits, ditches, walls and related subsurface cultural phenomena over a wide terrain and broad time span was explored (Hesse, 1962; Dabrowski and Stopinski, 1962; Dabrowski, 1963; Tite and Mullins, 1970). It became clear that, under given conditions and in search of specific sets of cultural phenomena, resistivity surveying was a powerful tool.

In the United States, Leith and Schneider conducted a study of the applicability of resistivity surveying in historic site investigations (Leith and Schneider, 1975). Their choice of sites was determined by a need to establish baselines, temporal and cultural, against which resistivity measurements could be compared prior to and following excavation. The sites selected were properties of once prominent people and ranged in time from the 17th to the 20th century. The nature of structures and dependencies, wells, and outhouses through time were documented through chains of title, court records of business transactions, marriage and death records, and other modes of historical research. The sites tested were scheduled for excavation, though this work has not been completed.

North Carolina: Trend surface analysis

Generally speaking, the common minerals of rocks and soils are non-conductive so the rock or soil porosity, and in particular, the amount and character of the electrolyte dissolved in the pore water, is a dominant factor in determining the degree of success of an electrical resistivity survey. At two North Carolina sites the soils were porous, granular, well drained, and derived from middle Tertiary and younger marine and nonmarine Coastal Plain sediments. At the time the surveys were attempted the moisture content of these soils was so low that no measurable current flowed between the electrodes and readable data could not be obtained. Good data were recorded at other Coastal Plain sites, where the soils were moist.

For the North Carolina surveys the Wenner electrode configuration was used, with constant 1.524 m (5 foot) spacing. An additional electrode was placed at the center of the spread (Lee partitioning arrangement) to allow measurement of potential differences through half the Wenner interval. The spread was moved forward at 1.524 m increments along parallel survey lines spaced 3.048 m (10 feet) apart, closed with cross lines at each end.

High frequency "noise" was filtered arithmetically by 3-point averaging of the data along the profile lines. Trend surfaces through the fifth order were generated by least squares polynomial regression analysis of the smoothed data and the deviations of the smoothed data from these trend surfaces were recorded as residual anomalies. Based on the computed correlation coefficients and the F statistics, the fourth order trend surfaces generally produced the closest fit to the original data, and were used to make the residual maps for interpretative purposes.

Interpretations of Survey Results:

Three of the North Carolina Surveys are used to illustrate the applicability of trend surface analysis of archeological site resistivity investigations. Two are located on the Coastal Plain; the third (Old Salem) is in the North Carolina Piedmont, where the thick residual soil is micaceous and clayey, derived by long and intense weathering of the underlying Paleozoic igneous and metamorphic rocks.

Wheeler House, Murfreesboro, North Carolina (Figs. 1 and 2). The present property includes a 2-story brick house and an adjacent structure. Surviving records suggest that these buildings were constructed before 1832. The object of the survey was to locate evidence of other structures mentioned in early records, including stables and a kitchen; lumber, log, carriage and smoke house; and a well.

Archeological excavation was in progress when the resistivity survey was made, but was terminated prior to the processing and interpretation of the electrical data. Based on the raw data obtained as the survey progressed, new excavation was started along the southern base line (80 N), between 115 W and 130 W, on what appeared to be a high point on the electrical profile. The excavation extended to 90 N and exposed rubble from an early 19th Century fireplace, sherds of porcelain dating from 1790 to 1825, and tableware dating between 1775 and 1820.

The linear anomaly extending along 120 N, from 50 W to 130 W is of interest, possibly indicating the presence of a buried foundation. A large pecan tree on line 110 N between 140 W and 150 W probably accounts for the saddle shaped anomaly at that location. The large negative anomaly near the southwest corner of the map remains unexplained.

Lot 39, Site OS 39–74, Old Salem, North Carolina (Figs. 3 and 4).

Historical records suggest that lot 39 was once a site of at least one pottery kiln associated with a mid-18th Century Moravian trade and craft center. Excavation prior to the survey had failed to locate them; there are indications that portions of the property had been removed for use as fill material.

The survey was started near the southwest corner of the lot, at the east edge of an excavation in which a brick foundation was exposed. The north-south anomaly along line 325 E proved, during subsequent excavation, to be another brick foundation wall.

Harmony Hall, Kinston, North Carolina (Figs. 5 and 6). Harmony Hall dates to the mid-18th Century and with the exception of recent additions, the original structure remains intact. Other buildings and facilities such as stables, wells, and outhouses have been razed.

The electrical survey was conducted in the open area to the rear of the house, and beyond a hedgerow and fence, in a small area to the east, in which three 19th Century grave markers are located. It is believed that ancillary structures previously were present behind and perhaps to the side of the single remaining house.

A pier from an old foundation is located at 40 S, 40 E. Presumably a small kitchen was located in this general area, and a well defined broad positive residual anomaly extends across this part of the map, reaching a maximum at 60 E, with a secondary maximum at 20 E. The areas of relatively high residual resistivity may represent compacted and consolidated, and thus drier, areas in otherwise uniform soil, and this condition could result from the presence of a building or other structure at some time in the past. The foundation pier at 40 S, 40 E tends to support this interpretation.

Another well defined positive residual anomaly extends east-west across the area, generally along the line 110 S. The maximum values, between 30 E and 40 E, coincide with patches of light color tonality on aerial photographs of the area; a building may have been located there at some time in the past. A stable and/or carriage house, as suggested from historical records, may be the cause of this residual anomaly.

Illinois: Barnes layer interpretation

Once an archeological site has been located, a resistivity survey may, in some circumstances, yield additional insights into former human activities. Such is the case at a prehistoric Indian site in Illinois.

In 1974 Carr performed a resistivity survey on the Crane Site (Fig. 7), a Middle Woodland (300 B.C. – A.D. 200) village located on the floodplain of the Macoupin Creek tributary of the lower Illinois River. The soil matrix for the archeological features on the

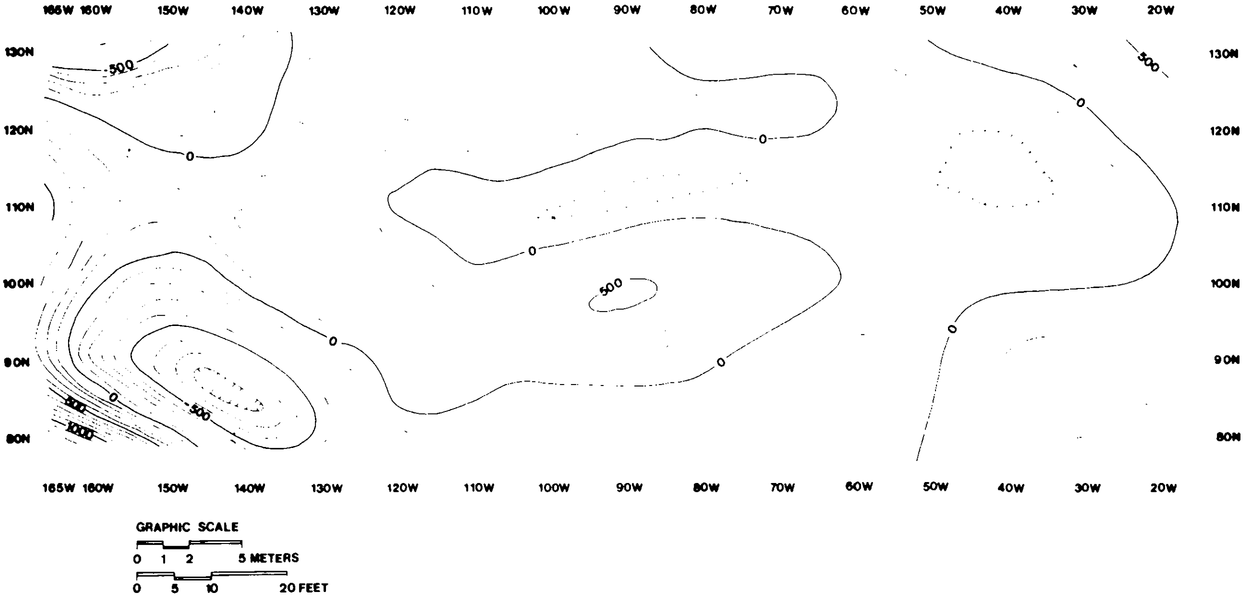

Fig. 1 : Fourth order trend surface residual map, Wheeler House, Murfreesboro, North Carolina.

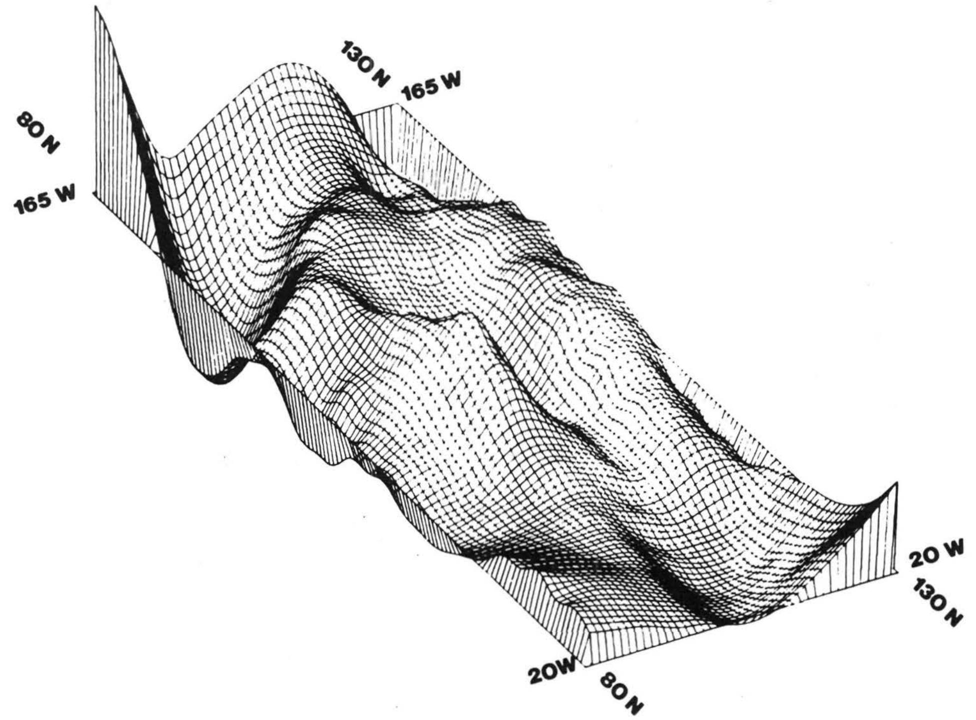

Fig. 2 : Computer generated fourth order trend surface residual diagram, Wheeler House, Murfreesboro, North Carolina.

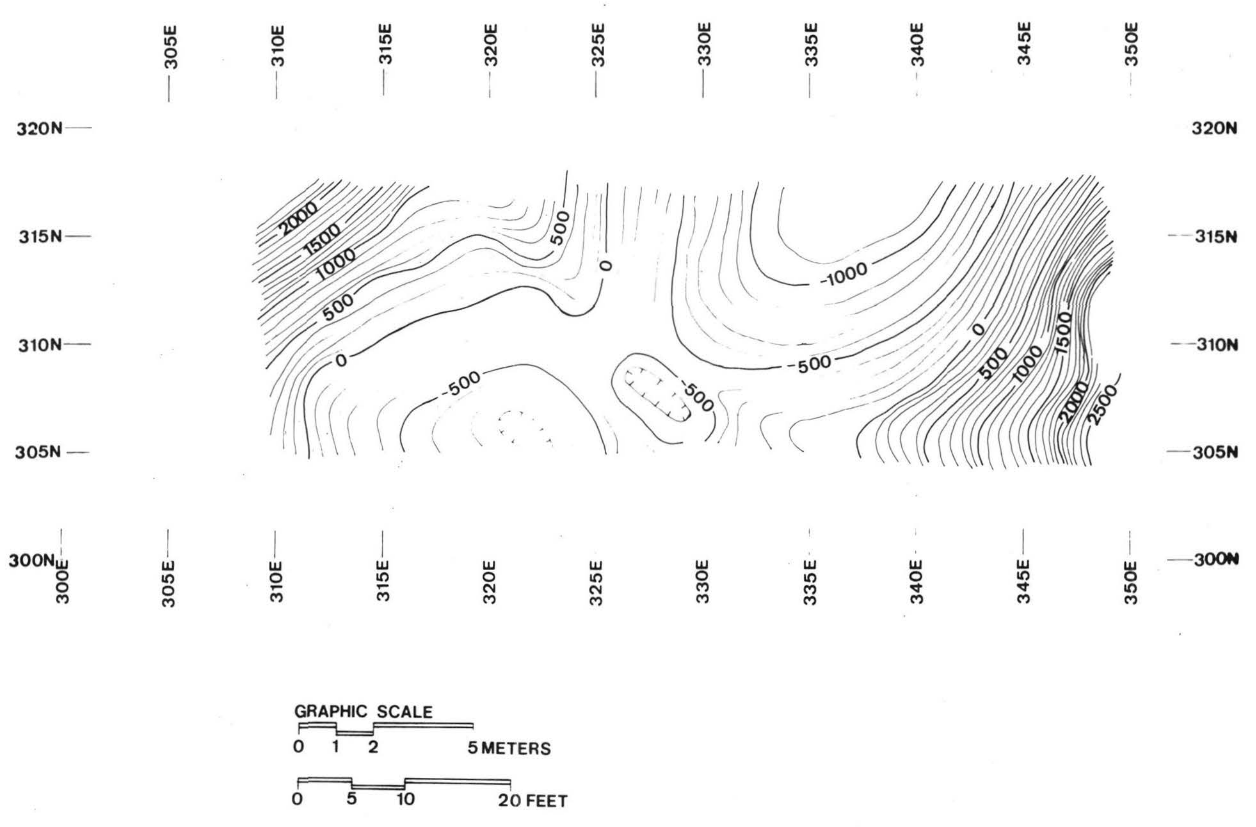

Fig. 3 : Fourth order trend surface residual map, Lot 39, Old Salem, North Carolina.

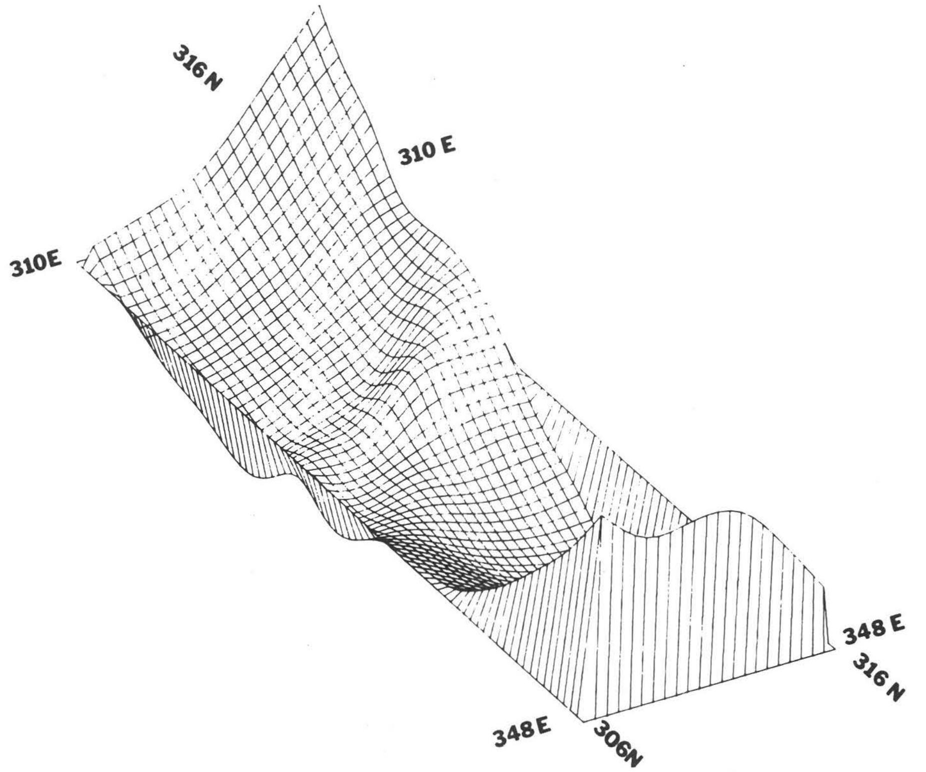

Fig. 4 : Computer generated fourth order trend surface residual diagram, Lot 39, Old Salem, North Carolina.

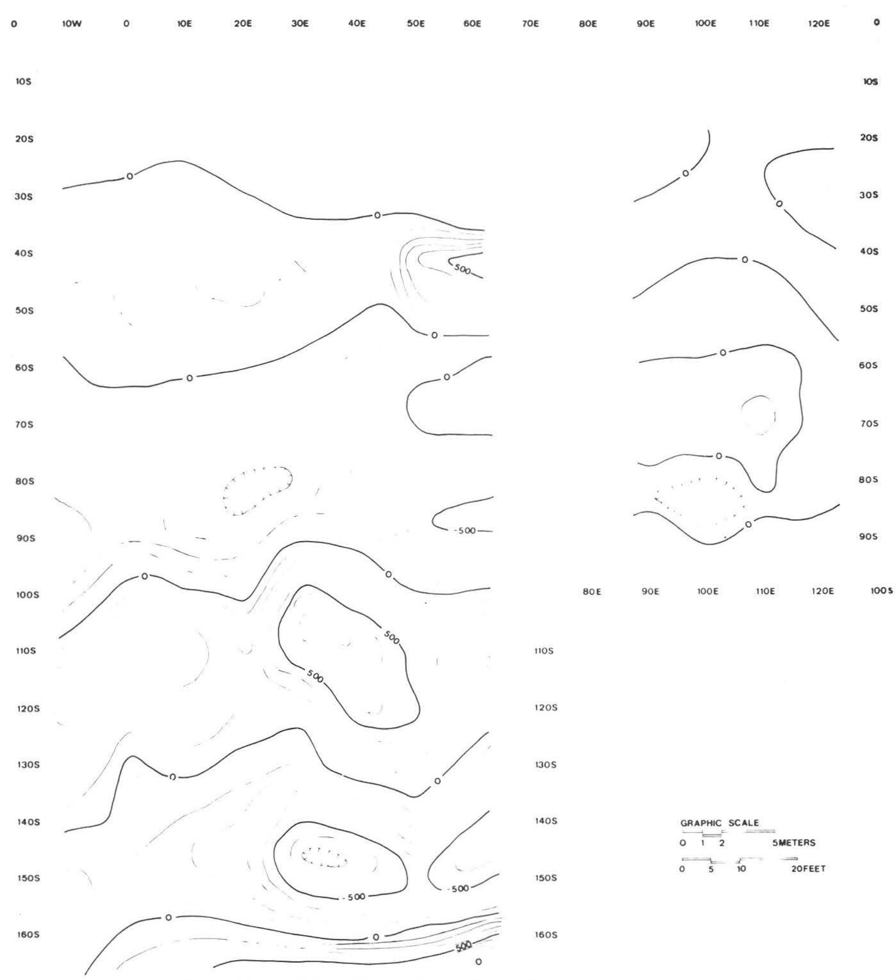

Fig. 5 : Fourth order trend surface residual map, Harmony Hall, Kinston, North Carolina.

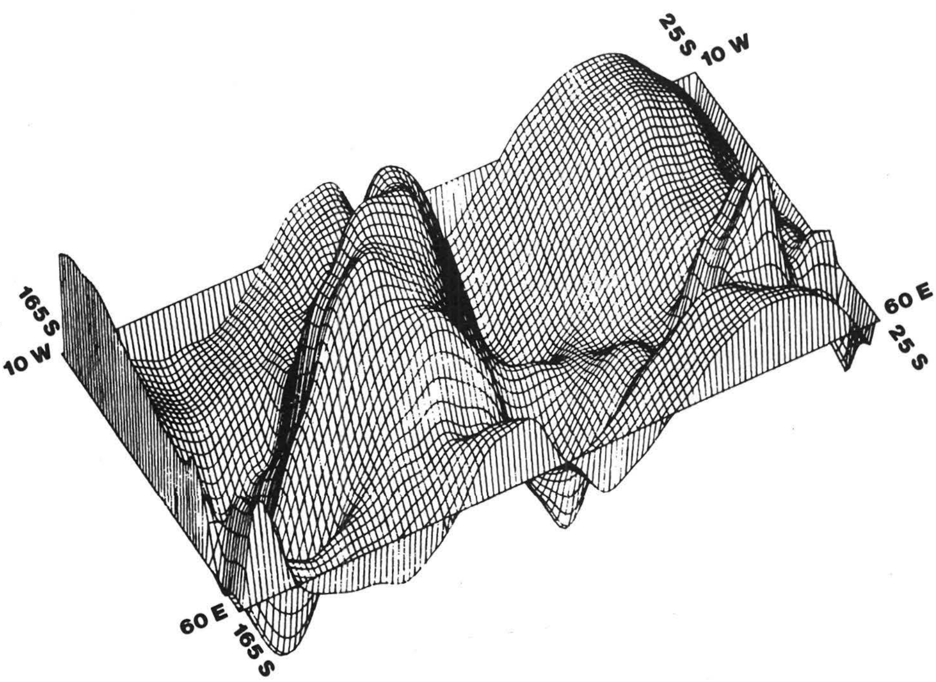

Fig. 6 : Computer generated fourth order trend surface residual diagram, Harmony Hall (western area only), Kinston, North Carolina.

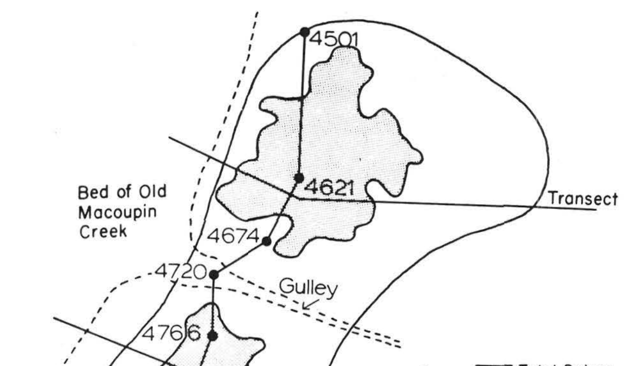

Fig. 7 : Crane site, prehistoric Indian village, southern Illinois. Numbers along Transect 4 are locations shown on Fig. 8.

site is alluvially redeposited Wisconsin age loess, upon which has developed a forest soil. Various portions of the site have been farmed since 1819, but subplowzone middens (up to 40 cm. deep), pits, hearths, and post molds remain intact.

The objective of this survey was to identify "activity areas," those larger geographic zones in which particular human activities, such as flint knapping and food processing, occurred. The particular magnitudes and patterns of soil resistivity values from different activity areas should be distinguishable.

On the basis of the stratigraphy determined from 32 cores, five depths of investigation, allowing the generation of five Barnes Layers, were selected. The first layer, (0–26.4 cm below surface) was the plowzone, with its high frequency resistivity noise. The second layer (26.4–33.7 cm) was defined to include only archeological features, where present, and to monitor the archeological resistivity component. The third layer (33.7–42.5 cm) included deeper midden deposits and the uppermost subsoil zone. It did not include any midden intrusions, only pits. The fourth (42.5–64.2 cm) and fifth (64.2–75.5 cm) layers were chosen so as to monitor the areal density of pits of two distinct Middle Woodland types, shallow and deep. The natural, low spatial frequency soil variations in those locations where pits were very dispersed were also monitored.

Resistivity soundings, using the Wenner electrode array, were made every .5 m along transects crosscutting several major concentrations of surface debris, and were extended off the site. Transect 4 (Fig. 7), used as an example, crosscuts two areas having high densities of debris and artifacts on the surface, as well as a gulley 2 m deep.

To aid in the examination of the data, a 21 location smoothing interval for arithmetic averaging was used to locate areas having generally low mean resistivity and low variability. Three were evident, one corresponding to the gulley, and two to the zones recognized as activity areas from high surface debris densities and subplowzone midden deposits (Fig. 8). There is a strong tendency for the borders of activity areas to be demarked by high local resistivity variances. This border effect might be explained as the Barnes Layer manifestation of the phenomenon of "subsidiary peaking" (Chalabi, 1969) which occurs as a Wenner array passes over a vertical discontinuity. Also, locations at which several activity areas coterminate are associated with higher peaks than locations where singular activity areas terminate. Thus, zones of multipurpose activity (such as areas of household activity within the village proper, in the southern high debris density zone) are distinguishable from more special-purpose activity areas (zones where butchery and hide processing possibly occurred, in the northern high debris density zone) by the magnitude of the peaks at their borders.

Activity areas of different types, whether or not distinguished by subsidiary peaks, can be differentiated by frequency analysis. The high frequency component of resistivity for the archeological layer may be found by subtracting an arithmetically smoothed series from the original data series. The degree of local continuity between

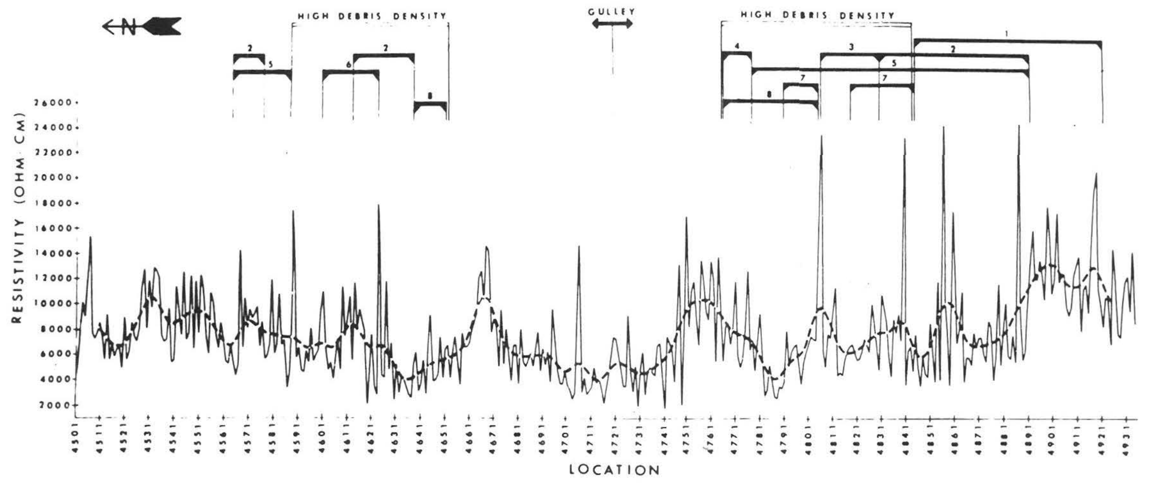

Fig. 8 : Apparent resistivity along Transect 4, second (archeological) Barnes Layer. Averaged data using a 21 location (10.5 m) smoothing interval are shown as the smoothed curve.

adjacent points within activity areas can be evaluated from such a plot, but local magnitudes of variance cannot.

If a battery of plots of resistivity values of bands of different spatial frequencies (different averaging or filtering intervals) are examined, each activity area, can be distinguished by the magnitude and patterning of the variability of its resistivity signature.

Conclusion

Resistivity surveys provide a feasible and efficient method for evaluating areas threatened by industrial, urban, or other types of development.

In selecting an appropriate field and analytical resistivity survey technique, the size, shape, and distinctiveness of the archeological disturbance should dictate the electrode configuration, separation, and sampling spacing, and the scale at which the analysis should proceed. The North Carolina design is effective for locating foundations, wells, and other features associated with historic human occupation. The Illinois design is effective for outlining prehistoric intra-site activity areas at the statistical level.

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