This document has been checked for information on Native American burials. No images considered to be culturally insensitive, including images and drawings of burials, Ancestors, funerary objects, and other NAGPRA material were found.



Department of Anthropology

 $Laboratory \, of Archaeology$ 

UNIVERSITY OF GEORGIA LABORATORY OF ARCHAEOLOGY SERIES REPORT NUMBER 20

# INTRA-SITE PHOSPHATE ANALYSIS: A TEST CASE AT COLD SPRINGS

ELIZABETH CRABILL SHIRK



Wallace Reservoir Project Contribution No. 2

UNIVERSITY OF GEORGIA LABORATORY OF ARCHAEOLOGY SERIES REPORT NUMBER 20

INTRA-SITE PHOSPHATE ANALYSIS: A Test Case at Cold Springs

by

ELIZABETH CRABILL SHIRK Department of Anthropology

> University of Georgia Athens, Georgia

WALLACE RESERVOIR PROJECT CONTRIBUTION NUMBER 2

Athens 1979

#### ACKNOWLEDGEMENTS

Many persons helped make this report possible. It is with sincere appreciation that I acknowledge their contributions.

First, I would like to thank Suzanne K. Fish, principal investigator at the site of Cold Springs, for her assistance, especially in the planning and analysis stages of this study. She also read the manuscript and provided helpful criticisms. My major professor, Dr. Paul R. Fish, and reading committee members, Dr. David J. Hally and Dr. Stephen A. Kowalewski, provided criticisms and comments. Dr. Fish, particularly, provided both guidance and encouragement. I also wish to acknowledge the contribution of Gisela Weis, who drafted Figures 1 - 9. This study was part of the Wallace Reservoir Archaeological Project, sponsored by Georgia Power.

# TABLE OF CONTENTS

|         |  |    |   |         |      |        |    |   |   |   |   |   |  |   |     |              |    | Page |
|---------|--|----|---|---------|------|--------|----|---|---|---|---|---|--|---|-----|--------------|----|------|
| ACKNOWL | EDGEMENTS  | •  |   |         |      | •      | •  |   | • | • | • |   |  |   | •   |              | •  | iii  |
| LIST OF | TABLES   |    |   |         |      |        |    |   |   |   |   |   |  | • | •   | 12           |    | vi   |
| LIST OF | FIGURES  |    |   |         |      |        |    |   |   |   |   |   |  |   | × . | <br>1. 1. K. |    | vii  |
| CHAPTER | s de la militaria de la companya de |    |   |         |      |        |    |   |   |   |   |   |  |   |     |              |    |      |
| 1.      | INTRODUCTION   |    |   |         |      |        |    |   |   |   |   |   |  |   |     |              |    | 1    |
|         | History of Soil Phosph   | at | е | An      | al   | ys     | is |   | - |   | • | • |  |   |     | and the low- | 10 | 3    |
|         | Focus of Present Study   |    |   | •       |      |        |    |   |   |   |   |   |  |   |     |              |    | 6    |
| п.      | BACKGROUND MATERIAL .  |    | • |         |      | •      | -  | 1 |   |   |   |   |  |   |     |              |    | 8    |
|         | Cold Springs (9Gel0) .   |    |   |         |      |        |    |   |   |   |   |   |  |   |     |              |    | 9    |
| III.    | FIELD METHODS  |    |   |         |      |        |    |   |   |   | • | • |  |   |     |              |    | 11   |
|         | Introduction   |    |   |         |      |        |    |   |   |   |   | • |  |   |     |              |    | 12   |
|         | Sampling Design  |    |   | •       |      |        |    |   |   |   |   |   |  |   |     |              |    | 13   |
|         | Collection of Samples  |    |   |         |      |        |    |   |   |   | 5 |   |  |   |     |              |    | 18   |
| IV.     | LABORATORY METHODS   |    | • | N. C.F. |      | - ANNE | 1  |   |   |   |   |   |  |   |     |              |    | 22   |
| v.      | RESULTS  |    |   | in Mart | . 10 |        |    | • |   |   |   |   |  |   |     |              |    | 22   |
|         | Background Values  |    |   |         |      |        |    |   |   |   |   |   |  |   |     |              |    | 23   |
| 1       | Systematic Coverage .  |    |   |         |      |        |    | • |   |   |   |   |  |   |     |              |    | 29   |
|         | Activity Areas   |    |   |         |      |        |    |   |   |   |   |   |  |   |     |              |    | 31   |
|         | Structural Features .  |    |   |         |      |        |    |   |   |   |   |   |  |   |     |              |    | 35   |
| . 1     | Non-Structural Features  |    |   |         |      |        |    |   |   |   |   |   |  |   |     |              |    | 37   |

| VI.   | CONCLUSIONS                            | . 37 |
|-------|--|------|
|       | Analysis Results: Cold Springs         | . 37 |
|       | Analysis Results: General Applications | . 39 |
| VII.  | REFERENCES                             | 42   |
| VIII. | APPENDIX                               | 55   |

Page

# LIST OF TABLES

Table

Page

vi

# LIST OF FIGURES

| Fi | gur      | re internet in the second s | Page      |
|----|----------|---|-----------|
|    | 1.       | Plan of Excavation at Cold Springs  | 46        |
|    | 2.       | Contour Map of Cold Springs Based on Plain Sherd<br>Surface Density   | 47        |
|    | 3.       | Contour Map of Cold Springs Based on Biface Surface<br>Density  | <u>48</u> |
| 4  | 4.       | Distribution of Phosphate Values of all Samples from<br>Cold Springs  | 49        |
| -  | 5.       | Phosphate Values from Structure 4Prov. 12   | 50        |
| e  | 5.       | Phosphate Values from Structure 2Prov. 10   | 51        |
| 7  | <i>.</i> | Phosphate Values from Structures 1 and 11Prov. 2  | 52        |
| 8  | 3.       | Phosphate Values from Structure 7 Prov. 22  | 53        |
| 9  | •        | Phosphate Values from Structure 5Prov. 18   | 54        |

# CHAPTER I

# INTRODUCTION

The use of soil phosphate analysis in archaeology is possible because past human occupation and activities resulted in the addition of sizeable quantities of phosphorus, in the form of phosphate, to the soil of occupied areas. Phosphate accumulation is caused by the deposition of human and animal waste products and organic refuse. The accumulated phosphate, which remains stable in location through time, is measurable by soil sampling and chemical analysis, thus providing archaeology with a valuable tool. One such method of soil phosphate analysis is a qualitative spot test, recently revised by Robert C. Eidt (1973). The subject of this thesis is an application and evaluation of Eidt's phosphate method as a technique in archaeological investigations. More specifically, the test will be evaluated as a tool in intra-site analyses in which the main emphasis is determination of the extent of the site and delineation of the features within it.

Additions to the soil which result from human and animal activities include various compounds of calcium, nitrogen and phosphorus. Phosphorus is the substance most often tested for anthropic soil development because, of all the materials produced by the breakdown of animal material and human wastes, phosphates are the most readily fixed, usually surviving as the calcium salt (Shackley 1975:68). In

addition, unlike the other products of human and animal activities, phosphates are not easily dispersed by soil action, weathering or leaching even over archaeological time spans (Cornwall 1958:196). Also, the natural phosphorus content of most soils is relatively low (Berger 1965:188).

The amount of phosphorus in an area may be increased by deposition of plant and animal matter. This increase in phosphorus is a result of the concentration of both human and animal excrement and organic residues consisting of cadavers and garbage or rejected plant and animal material which accompanies human habitation of an area (Woods 1975:27). Bones are the most important source of phosphate deposited by humans and plant material is the least important (Cornwall 1958:70). Human and animal excrement also contains significant quantities of phosphorus. The relatively high phosphorus content is due to the fact that phosphorus is a major component of man's foods, a by-product of protein catabolism, and is secreted into the digestive tract to aid digestion (Waggaman 1969:17).

Human occupation of an area results in dramatic increases in phosphate, which become extraordinary if the settlement is intense or of long duration (Woods 1975:27). It has been computed that a model living group of one hundred persons will produce each year in body wastes alone 137 pounds of phosphorus and, from this, it can be assumed that similar chemical enrichment of soil occupied by aboriginal peoples occurred (Hole and Heizer 1973:230). Cook and Heizer (1965:9) estimated annual soil increments of phosphate from human occupation of

an area to be in the range of 0.495% to 9.91% of the phosphorus already present in the soil.

As a result of the high phosphate enrichment caused by man around his settlements and the fact that phosphates rapidly bond to soil particles when they are deposited and are stable in location over archaeological time spans, soil samples taken from undisturbed contexts produce readings consistent with their depositional history. Therefore, abandoned settlements can be located and activity zones identified through the chemical analysis of areally varying phosphate concentrations (Woods 1975:1).

# History of Soil Phosphate Analysis

The idea of using chemical tests to indicate the enrichment of soil by human and animal contaminants has long been the principle behind methods developed in Europe and used by European settlement geographers as well as archaeologists (Eidt 1973:206). The use of phosphate testing in subsurface analyses dates from laboratory methods devised in the 1920's and 1930's by 0. Arrhenius. Arrhenius, a Swedish soil scientist, using data from extensive studies in Sweden, was the first to point out that the content of phosphorus was unusually high in the soil of old village sites (1929, 1931). He realized its potential value in detecting abandoned settlements, and used soil phosphate analysis to locate Stone Age, Viking and other settlements in northern Europe (1931). Between 1930 and 1950, this technique was applied in Indochina (Castagnol 1939), Thailand (Pendleton 1943) and Uganda (Thomas 1947).

Lorch, a German geographer, simplified the laboratory procedure for phosphate determination in 1939. Lorch (1940) summarized his method, colorimetric determination of phosphate by a molybdenum blue reaction, and tested it at sites in the Middle East and Europe. He established horizontal phosphate profiles of samples collected at uniform depths along transects through settlements of different economies, ranging from hunting and gathering through early agricultural settlements. The sites varied in rates of phosphate increase along the sampling line. Based upon the accumulation of phosphorus, Lorch developed models explaining different types of subsistence. Lorch's method was also successfully used by H. Bandi (1945) to locate a medieval site.

4

Prior to 1950, soil phosphate analysis was not used in the United States despite its application in archaeological investigations in Europe and elsewhere. R. Solecki's (1951) use of phosphate analysis on soil samples from a late Adena mound at Natrium, West Virginia was the first in the United States. Features which were believed to be burial pits, but in which all skeletal material had disintegrated, were shown to have at one time contained burials due to their high phosphate content.

Confirmations of Arrhenius' initial correlation between human habitation and increased phosphate content continued in the United States in the 1950's and 1960's. Lutz (1951), in an investigation of two Alaskan village sites, noted that human occupancy of one of the village sites resulted in a tremendous increase in phosphate content of the soil. Dietz (1957) utilized phosphate analysis in an investigation of a habitation site in Wisconsin. Cruxent (1962) interpreted the absence of phosphate as evidence against occupation by man of the Texas Street site in San Diego, California. Arrhenius (1963), using the same method he devised in 1929, reported on the phosphate content of 31 archaeological sites in the southern and western United States. Cook and Heizer (1965) found surface indications varied from 0.072% off site to 0.148% phosphorus on the site in California and Mexico, with maximum phosphorus retention 20-40 inches below the surface.

Laboratory methods used in the above studies or investigations were based on agricultural techniques designed to reveal available phosphate (Eidt 1977:1328). Most experiments with anthrosols have continued in the laboratory despite the fact that procedures for determination of soil phosphate content have been simplified sufficiently to allow testing in the field. Tedious laboratory work as well as a well-equipped laboratory is involved in the quantitative determination of phosphate, and, usually, archaeologists must rely on outside laboratories for testing of the soil samples.

In 1961, Gundlach simplified the procedure for phosphate testing and a true field method resulted. Schwartz (1967) successfully used Gundlach's method of phosphate determination along with resistivity surveying to locate archaeological sites in southern Switzerland. This qualitative spot test which required only two minutes per sample and very little laboratory equipment was not publicized in the United States until the article by Eidt (1973) in which he revised Gundlach's

procedure, substituting hydrochloric acid for nitric acid for better extraction results. According to Eidt (1977:1333), since 1976, spot phosphate tests have been used in rapid site surveys in Arizona, Arkansas, California, Illinois, New Mexico and Texas.

The most detailed study of the Eidt phosphate method is that of W. I. Woods (1975). Woods' study is primarily concerned with the development and techniques of the test, but it also includes examples of instances in which the Eidt phosphate method can be successfully applied. Baker (1975) experimented with Eidt's method in testing surface distribution of artifacts against phosphate values at two sites in Arkansas. Gregg (1975) also demonstrated the value of soil phosphate analysis using Eidt's spot test as a surveying tool. His investigation at a site in Illinois demonstrated that the high phosphate readings conformed to the prehistorically inhabited portion of the study area. Overstreet (1974) applied and evaluated Eidt's field test at a site in Wisconsin. The site boundaries as determined by the phosphate content of the soil were checked by excavation of the site. Overstreet's study is the only one prior to the present one which checked phosphate results against excavation results.

# Focus of Present Study

The main focus of this study is an evaluation of the Eidt phosphate method as to its applicability in intra-site analyses, a topic not previously investigated. The site of Cold Springs (9Gel0) in the Wallace Dam Reservoir was used as a control in an experiment to evaluate the accuracy and utility of soil phosphate analysis in intra-site

analyses. The major concern was determination of the extent of the overlapping group of components which constitute the site and delineation of features within them. As the site has been thoroughly investigated archaeologically, a comparison of test and excavation results was possible. This study goes beyond others in that it is a detailed comparison of phosphate results with features, artifact distribution and other results of excavation.

The intent of this thesis is not merely reconfirmation of Arrhenius' findings that soil phosphate analysis works. In addition to evaluation of the qualitative spot test as a method of delimiting site boundaries and identifying features within the site, soil phosphate analysis is used as a tool to aid interpretation of excavation results from the site. Test results are used as a further indication that site boundaries are correct and that the probability of undiscovered structures on the site is low, an important consideration in the correct estimation of the population inhabiting the site at any one time.

# CHAPTER II

# BACKGROUND INFORMATION

The main source of information about the area used in the study was Suzanne K. Fish, principal investigator of the site of Cold Springs. Details concerning the site cited here are taken from "Site Plan at Cold Springs," a paper presented by S.K. Fish at the 1978 Southeastern Archaeological Conference. The sampling strategy employed was based on information obtained from excavation of the site. The grid was already present, backhoe trenches crossed the site at regular intervals and features were known (see Fig. 1). These prior findings greatly facilitated the collection of samples at the site.

Also important in this study are possible factors affecting interpretation of the phosphate values. It is necessary to know the background level of phosphate in the soil, the erosional history of the area, economic systems used to exploit the area, and any modern construction or post-occupational disruptions which have occurred at the site. In addition, factors relating to human use of the area must be known. Background knowledge of the cultures that inhabited the area is necessary, including an idea of the arrangement of settlements, the internal structure and size of settlements, types of houses, land use and soil disruptions through excavation, construction and cultivation of the site (Woods 1975).

# Cold Springs, 9Ge10

The site of Cold Springs is located less than 16 kilometers from Greensboro, Georgia, in the Wallace Dam Reservoir. The site which overlooks the floodplain is on the east side of the Oconee River, about 1.5 kilometers upstream from its confluence with Town Creek. Consisting of two mounds and a surrounding village area, the site covers 43,700 square meters. About one-third of the site lies under a 35-40 year old forest stand. The remainder of the site is located in a recently cultivated field.

Techniques for archaeological investigation of the site included surface pick-up of artifacts in five meter squares from the non-wooded portion of the site, test pits and trenches, and broad horizontal exposures. Surface collection indicating artifact density decline and cessation, as well as artifact distribution in the trenches, was used to determine the areal extent of the site. Surface distributions of various artifact categories were plotted in contours (see Fig. 2 and 3).

The site consists of multiple components from Archaic through Lamar periods. The major occupations as evidenced by structural remains date to Swift Creek and Etowah times, and secondarily to Cartersville. There are two radiocarbon Swift Creek dates of A.D.  $290 \pm 70$  (UGA 2384) and A.D.  $445 \pm 55$  (UGA 2364). There is a single radiocarbon Etowah date of A.D.  $905 \pm 95$  (UGA 1878). A suggested Cartersville range is A.D. 1-500 (Caldwell 1958:38). Lamar period in the reservoir dates from A.D. 1375-1600 (Marvin T. Smith, personal communication).

There are 10 certain and three "probable" structures on the site (S.K. Fish, personal communication). Four are depressed-floor, dishshaped structures which are filled with dark debris. The other six are surface structures consisting of post-hole patterns with no intact floor. Structure 5, which is located under the larger of the two mounds, is the only one which appears, at a preliminary stage of analysis, to be non-domestic.

Although the site of Cold Springs was occupied over a long time span, it never underwent significant sedimentary deposition or erosion. Except for artificial superpositioning of soil layers through mound construction and a few instances of intrusive burials, almost no vertical stratification was encountered during excavation of the site. There was, in all probability, little erosion because sub-surface features were found on the highest elevations at the site where erosion would have been most likely to have occurred.

# CHAPTER III

# FIELD METHODS

Two types of investigations are possible using the Eidt phosphate method: inter-site and intra-site analyses. In inter-site analysis, the main concern is locating and identifying abandoned settlements within a region, whereas intra-site analysis concentrates on defining the extent of a single settlement or compact group of settlements and identifying activity areas and features found within them (Woods 1975: 14).

Sampling designs vary according to which type of analysis is undertaken. In an inter-site analysis, samples are taken about every 100 meters. When an increase in phosphate is detected, samples are taken at smaller intervals around the station which registered the increase. These samples, when tested, should show the relative extent of settlement (Woods 1975:14).

In an intra-site analysis, the primary consideration is location. The vertical and horizontal position of each sample must be accurately recorded. A combination of horizontal and vertical sampling is used, depending on the main emphasis of the investigation. Horizontal sampling is used if the primary interest of the study is determining site boundaries and activity areas within the site. Vertical sampling is most applicable if intensity, duration or subsistence of continuous

settlements on a stratified site is the main interest of the investigation (Sjoberg 1977:449).

# Sampling Design

Samples were taken at the intersection of grid lines, and the entire site was systematically covered in an attempt to define the site boundaries and activity areas within the site. This sampling was facilitated by the presence of the backhoe trenches which crossed the site at regular intervals, as soil samples could be taken using the natural stratification rather than at an arbitrary depth. Also, the location of features along the trenches was known and results of phosphate testing could be checked.

Samples were also collected approaching known features in order to determine the distance at which a feature could be detected by an increase in soil phosphate. Samples were taken approaching pits as well as structures to determine if there was a difference in the distance at which they could be detected by an increase in phosphate. Samples were also taken from the features themselves to determine if structure and pit types could be distinguished by differences in the resulting phosphate values.

Since this project was undertaken after the initial phase of excavation at the site, the non-structural features were sampled from the soil taken for pollen and flotation samples. Testing of these samples determined whether or not the results produced were comparable to those from the structures, which were sampled in the field. In an attempt to detect activity areas, additional samples were taken from areas of high and low surface artifact densities. Samples were taken from what was the ground level during occupation and not from the soil above it. Areas sampled had been horizontally stripped so it was possible to determine how accurately phosphate values reflected the presence or absence of sub-surface features.

Areas of high densities of specific artifact categories were also sampled. Areas of high surface sherd densities were chosen to sample because of their relation to activities involving features. Since one area of interest of this study was the potential of the technique to reveal information about activities which did not involve features, areas of high surface biface density were also sampled. Bifaces were selected because of their involvement in such activities as butchering.

# Collection of Samples

The field procedure described by Eidt (1973:206-210) was used as the basic experimentation procedure. The major exception was that samples were tested in the laboratory instead of in the field. As the major focus of this study was a comparison of test and excavation results rather than an evaluation of the field application itself, this divergence in procedure was deemed reasonable. By testing the samples later in the laboratory, fewer people and less time were involved in the collection of the soil samples.

Several tools were used in collecting the samples. In the backhoe trenches, trowels were used to scrape the profiles before samples were taken. Trowels were also used in collecting samples from the features.

A hand auger was used to collect samples in the wooded area of the site where there were no trenches.

The quantity of soil removed varied, but only a small amount--50 milligrams--is needed for the phosphate test (Eidt 1973). Larger samples were collected in order to allow retesting of a sample and as a reference to soil color, particle size, etc.

Samples were collected in plastic bags. Very wet soil samples were allowed to air dry for several days to prevent the growth of mold. An experiment with the procedure was conducted in which samples were placed in envelopes instead of plastic bags so that air drying of wet soil samples would not be necessary. A series of samples was taken from a trench profile with two samples taken from each layer. One was placed in a plastic bag and the other in an envelope. The pairs of samples (samples 94-105) produced the same results whether in plastic bags or envelopes (see Appendix). However, most samples were still placed in plastic bags to avoid possible contamination by the paper. Each bag was labeled and the sample recorded as to horizontal and vertical location.

In order to determine the natural phosphate content of the soil at the site, a series of samples was collected from an area adjacent to, but not included in, the habitation zone. The area sampled for this purpose was one south of the creek which, according to excavation results, formed the southern boundary of the site. A hand auger was used to collect these samples which were taken from two locations outside of the occupied area. In order to determine the highest natural phosphate readings of the soil, samples were collected from unusual areas near the site. The areas sampled included a swampy area

and an old cattle feeder, both north of the site. It was thought that readings from the two areas might be high because of decaying plant material in the swampy area and a concentration of animal wastes around the old cattle feeder.

Samples were collected at 20 meter intervals along the backhoe trenches. The interval used was primarily a practical consideration due to the size of the site. The vertical position of the samples ranged from 30 to 50 centimeters beneath the surface. Samples were also collected along the grid lines of seven of the trenches projected 60 meters beyond trench ends into the woods east of the field on which the site is located. This area was sampled in order to verify the eastern site boundary since the trenches had had to terminate at the edge of the woods because this land is privately owned. The samples, also taken at 20 meter intervals, were collected using a hand auger and they ranged in depth from 15 to 30 centimeters.

The only features sampled in the field were the structures known at the end of the 1978 field season. More structures were found later, but these were not sampled. Samples from the structures were taken close to the surface, and, as such, were primarily from the house floors. Samples from pits were tested using the flotation and pollen samples taken durnig excavation of the features. It was found that use of soil carefully collected for other purposes did not affect the phosphate results.

Four areas were sampled in the field, two low artifact density areas and two high artifact density areas. Samples were taken using a trowel at an average depth of 25 centimeters. The main emphasis in the literature is in the field application of this method. Being rapid, this spot test can be used in a great variety of field situations. The basic equipment remains the same for each situation as does the accuracy of the test if contamination of the samples is avoided (Woods 1975).

In collecting the samples, certain practices are necessary in order to prevent either contamination of the soil or interference with the test results. Post-occupational disruptions, natural conditions as well as the method of collecting the samples are all possible complicating factors (Woods 1975).

The primary post-occupational disruptions at the site of Cold Springs stem from farming with the use of fertilizer, construction of a road and excavation of the site. Samples were taken below the plow zone to avoid effects of plowing and fertilizer. In order to prevent interference by such modern cultural features as roads, samples were ideally taken no closer to them than 10 meters. According to Woods (1975), this distance is sufficient to avoid any possible effects this feature might have on the soil samples. Also, excavation of an area disturbs the sedimentary sequence. As excavation of the site was in progress when the samples were collected, at least 20 centimeters were scraped from the trench walls before samples were taken.

The natural condition forseen as a possible complicating factor was the frequent flooding of the area west of the site. Floodwaters of the Oconee River presently inundate the river edge of the site several times a year (Fish 1978). The area subject to flooding corresponds to

the area west of the 1.50 contour. Often certain soils of marine origin contain organisms whose shells are rich in phosphate (Eidt and Woods 1974:63). This possible source of interference was recognized and taken into account when the test results were interpreted. Sampling beneath the plow zone avoided possible effects of weathering and vegetation or organic material.

# CHAPTER IV

# LABORATORY METHODS

Several methods for phosphate analysis have been used in an archaeological context, among them, ones developed by Arrhenius (1929), Lorch (1939), Gundlach (1961) and Eidt (1973). The methods differ in the reducing agent utilized to develop the blue color in the chemical process and in which phosphates are dissolved because of this use of different reagents. Another way these methods differ is in the way the phosphorus content of the soil is determined. The group of methods, which includes those developed by Arrhenius and Lorch, involves quantitative analysis through the use of colorimetry. The other group, which includes the methods developed by Gundlach and Eidt, involves the qualitative determination of the phosphate content through comparison with standard color scales (Sjoberg 1977:451).

Most experiments with anthrosols have utilized quantitative determination of soil phosphate content (Eidt 1977:1328). Total phosphate is best measured by colorimetric methods, using the molybdenumblue reaction (Shackley 1975:69). A spectrometer or photometer is required. The light absorbance of the test solution is measured and compared to a graph prepared by initially measuring absorbance of solutions of known phosphate content (Sjoberg 1977:451).

The method used in this study is a qualitative determination of the total phosphorus content of soil samples. It was first developed

by Gundlach (1961) and then modified by Eidt (1973). In this method, results are ranked as to phosphate content using a color scale based on several criteria.

The soil phosphate test is a simple qualitative one involving two reagents. Reagent "A" consists of 35 milliliters of 5 N hydrochloric acid mixed with 5.0 grams of ammonium molybdate dissolved in 100 milliliters of distilled water. Reagent "B", the reducing agent, is prepared by dissolving 0.5 grams ascorbic acid in 100 milliliters of distilled water. Two drops of Reagent "A" are placed on 50 milligrams of soil on ashless (phosphate-free) filter paper. Thirty seconds later, two drops of Reagent "B" are placed on the soil. If any phosphate is present in the soil, a blue color will appear around the sample within two minutes (Eidt 1973).

When "A" is applied to the soil, the hydrochloric acid releases the bound phosphate compounds and converts them to phosphoric acid. The phosphoric acid then reacts with the molybdate compound, also within "A", and forms phosphor molybdate. When "B" is applied, the phosphor molybdate is reduced to molybdenum blue compounds. The amount of phosphate in a soil sample is shown by the quantity of molybdenum blue formed and its time of appearance.

Eidt's intensity table, as cited in Woods (1975), was used to judge the quantity of phosphate present in the soil samples (Table 1). At least four qualities vary with the amount of phosphate present, and these qualities determine the classes or ranks into which the results are ordered. The samples are assigned phosphate values of one to six dependent upon the following four qualities: the time elapsed before appearance of the blue coloration, the percentage soil circumference surrounded by the blue color, the length of the rays emanating from the sample and the intensity of the blue coloration. There is some overlap of classes or ranks within a quality, but usually if three of the four criteria of a class are met, the sample is assigned to that class. In testing the samples from Cold Springs, often the time of appearance of the blue coloration and the intensity of that coloration were relied upon more than the other two qualities, especially the smaller the amount of phosphate in the sample.

The color characteristics must be read after precisely two minutes because a continuous reaction is produced and, after two minutes, the blue color spreads over the entire filter paper and any interpretable pattern is obliterated (Eidt 1977:1329).

There are several limiting factors in this method of soil phosphate analysis. The scale is neither linear nor logarithmic and, as such, values cannot be quantified or treated statistically. Therefore, the phosphate intensities revealed cannot be compared as the values are relative rather than absolute and may change with location depending upon sample size, color perception, temperature and unequal extraction of soil phosphate types. Also, using this method one cannot distinguish between soils that possess sizeable amounts of native phosphate and anthrosols whose phosphate is derived primarily from settlement activities (Eidt 1977:1329).

Sjoberg (1977:451) regards this method as "a step backwards" in its use of "vague class limits" based on visible inspection when there are sophisticated methods for the quantitative determination of phosphorus

available. The ranking of soil as to phosphate content using the Eidt spot test method is not quite so shaky and unscientific as Sjoberg would lead one to believe. Qualitative results are inherently more limited in the amount of information one can obtain. However, there are advantages, in particular the rapidity and inexpensiveness of the test, which may outweigh its lack of precision. All in all, the limitations of this method do not seem sufficiently important to warrant complete disregard of qualitative methods of soil phosphate analysis as an archaeological technique.

# CHAPTER V

#### RESULTS

A primary means of interpretation of the results was by evaluating the distribution of phosphate values over the site. These values were plotted in numerical form on a large-scale map of the site on artifact density contour maps (Fig. 2 and 3), and on maps of each structure (Fig. 6 through 9). Assessing the accuracy with which the site boundaries and features were determined by the phosphate values was the major concern in interpretation of the results.

# Background Values

A first step in evaluating the results was determination of the natural phosphate content of the soil at the site. All seven samples (samples 1-7) taken from an area approximately 50 meters south of the southernmost trench (860N), produced phosphate readings of one or two. This was further supported by the values of one and two from samples taken on the northernmost trench (1100N), most of which was outside of the site boundary. Values of three and above were considered indications of past human or animal activity as values of one and two could not be differentiated as to whether they were from natural or human sources. Values of three and four were interpreted as indications

of moderate phosphate concentration and values of five and six as indications of high phosphate concentration.

Values of soil taken from the surface and plow zone (samples 59, 60, 64, and 65), were high--fives and sixes. However, the aluminum, iron and calcium retaining elements usually found in soils hold fertilizerderived phosphate so strongly that downward movement is at most several centimeters (Eidt 1973:210). As a result, previous fertilization of the field did not affect soil samples taken below the plow zone. The marsh sampled was located approximately 125 meters north of the site, and the old cattle feeder was approximately 200 meters north of the site. The soil samples taken from these areas yielded only moderate values--threes. Because of this, an attempt was made to explain culturally all values of four and above.

# Systematic Coverage

Three of the trenches (860N, 900N and 920N) were in the wooded portion of the site, and the remaining seven were in the part of the site located in a field. A total of 176 samples were collected along the 10 backhoe trenches. The phosphate values of these samples ranged from one to five.

The most southern trench, 860N, had consistently high phosphate values which decreased at the ends of the trench. The samples ranged in phosphate value from one to five (samples 8-19). Archaeological investigation of a 10 meter square (Prov. 14) which corresponded to the location of the samples ranked five did not support the high readings as no subsurface features were encountered. However, the surface

distribution of artifacts was dense in this area and some type of activity involving organic material but not features could be represented by the artifacts and high phosphate values.

The next trench, 900N, intersects one of the structures, Structure 2. Sixteen samples were taken along the trench (samples 20-35). Phosphate values were low at each end of the trench, but increased dramatically in the samples taken approaching Structure 2. This increase occurred at a distance of seven meters from the western edge of the structure (900N/940W). The phosphate value at 900N/947W was a five and that at 900N/943W, a six. Going away from the structure, the values decreased to four and then to three. Therefore, a progression of rankings from three to six was encountered approaching the structure from the west.

The 920N trench yielded, for the most part, low and moderate phosphate values (samples 36-42). There was only one exception. The higher readings at 920N/935W were the result of taking the samples from one of two small features located on the trench at 920N/940W. Also, the only reading of four occurred 20 meters east of these features. It was discovered that this sample was taken less than 10 meters from a road present on the site. Even though it is only a dirt road used by logging trucks, it may have interfered with an accurate reading of the phosphate content of soil at this location. Low values occurred at the eastern end of the trench.

The phosphate values of samples taken along the 960N trench ranged from two to four (samples 43-58). There were five readings of four, two of which corresponded to the location of features. A

value of four at 960N/940W occurred on the trench where it intersected Structure 4. A value of four at 960N/960W was an indication of Feature 149,a pit bisected by the trench, in Provenience 9. The other three areas that produced readings of four were harder to interpret. Two, those at 960N/910W and 960N/1100W, were interpreted as indications of the site boundaries because of the increase from preceding low phosphate readings. The other value of four, which occurred at 960N/970W, did not correspond to an area of high artifact density and, as the area was not investigated archaeologically, it was difficult to make a positive interpretation of the reading except that it indicated an area of some type of past human or animal activity.

The 980N trench was characterized by low to moderate phosphate readings (samples 59-75). The highest value from these samples was a four, and there were three areas which produced readings of four. They were located at 980N/970W, 980N/910W and 980N/840W. The first two locations corresponded to high artifact density areas of the site. The last location was from the wooded area along the projected trench line. As there were no surface artifact distribution or excavation results from this part of the site, interpretation of this reading was difficult. It probably did not reflect an extension of the site in this direction, as it was an isolated value of four after several low values which were also along the projected trench line.

The 1000N trench (samples 76-115) showed a rise in phosphate values at the two locations sampled closest to the end of the trench as it was projected beyond the point of termination into the woods. Since the values of the samples approaching the eastern end of the trench were

consistent, these were interpreted as an indication of the extension of the site in this direction. There was a reading of four at the eastern end of the trench, however, this sample was taken less than 10 meters from the dirt road on the site which would make the value obtained somewhat suspect. The rest of the values from samples along the trench were twos and threes, except for samples taken approaching Mound B, the smaller of the two mounds on the site. Values of four were determined for samples taken at 1000N/1062W and 1000N/1064W. These samples were taken 50 centimeters below the surface, from the same layer which was one of the occupation layers of the mound. Activity around the mound was probably being reflected by these values, although the distributions of values do not reveal the kinds of human activities responsible for the values. Samples taken west of the mound followed the trench line, with samples collected at 20-meter intervals. The phosphate values were mainly twos and threes, but two values of four occurred at 1000N/1110W and 1000N/1150W. The exact depth of the samples was not known, as the samples were taken with a hand auger, but both were from the second layer from the surface--from orange clay beneath brown clay and above gray clay--so it was assumed that they were taken at approximately the same depth. These readings may reflect past human activity of some type since this area was not excavated. There were few artifacts in this area, however, and it is more likely that the phosphate values were a result of the frequent flooding of this part of the site.

Phosphate values on the 1020N trench (samples 116-132) were twos and threes, with values of four at 1020N/960W, 1020N/1040W, 1020N/1060W,

1020N/1080W and 1020N/1125W. The sample taken at 1020N/960W was from an area of high artifact density which, when excavated, revealed the absence of subsurface features. It is possible that some other type of activity not involving features was indicated by the phosphate value. The next three values of four could represent activity around both mounds as the trench runs between the mounds. The value of four at the western end of the trench, after consistently lower values, probably was due to the flooding which occurs in this part of the site.

The 1040N trench (samples 133-142) is a short one which approaches Mound A, the larger of the two mounds on the site, from the east. It also was projected into the woods, the three samples producing low phosphate values. The values from the field were primarily threes, with one four and one two. The sample which yielded a phosphate value of four was located approximately five meters from the post-hold structure in Provenience 22, Structure 7. A sample was also taken from the 1046N trench which goes through Mound A. The sample, which had a phosphate value of five, was from the structure located at the eastern end of the mound. This structure was discovered after the 1978 field season, so it was not one of the structures purposely sampled.

The phosphate values along the 1060N trench (samples 142-157) were primarily threes, with an occasional two. Along the trench line projected into the woods, there was an increase from two at 1060N/870W to three at 1060N/990W. This increase could possibly reflect extension of the site in this direction. However, in the field there was an increase in phosphate values from two at 1060N/930W to three at 1060N/950W which corresponded to the surface and trench distribution of artifacts.

It was not surprising that the values along this trench were low as no known structures or features were intersected by the trench, and there were no areas of high artifact densities.

Parts of the 1080N trench appeared to be beyond the site boundaries as only a few readings in the field were even as high as three (samples 158-172). The three samples taken in the woods east of the point of termination of the trench yielded higher readings, two were fours and the other was a three. The increase in phosphate values beginning at 1080N/1090W after previously low values on the western end of the trench are probably due to the frequent flooding of the area as all samples were taken from sand layers.

The values from the 1100N trench (samples 173-183), the northernmost trench, were similar to those from the 1080N trench. In the field and along the projected trench line in the woods, the values were consistently low, with values of three at 1100N/1060W and 1100N/940W the only exceptions. The trench appeared to be almost entirely beyond the site boundaries, a conclusion supported by the artifact distribution.

To aid interpretation of the phosphate results from the trenches, the values were placed on a grid corresponding to that of the site. Lines were drawn to indicate the extent of the site as determined by the phosphate values. These compared favorably with the site boundaries as determined by the surface and trench artifact distribution.

The distribution of phosphate values of all samples tested is shown in Fig. 4. In general, values for the site as a whole contrast
with background values. Out of 80 samples taken within the site boundaries only 14 were ones and twos. As a rule, values outside the site gave no higher readings than one or two. The main points of divergence were in the northeastern and northwestern parts of the study area. These samples were retested with the same values resulting.

Values indicated the site might have extended further to the east than the artifacts in the trenches indicated. On the eastern part of the site, as the trenches did not extend as far as samples were taken, the phosphate values were unsupported by excavation. A possible factor involved in these readings was the method of collection of the samples. Because of the hard ground and the use of an auger, collection of the samples was difficult. Also, some samples were taken not more than 15 centimeters below the ground surface which is close enough to the surface to involve interference in the test results. Whether these methodological complications affected the results or the values actually indicated an extension of the site boundaries, it was difficult to determine solely by the phosphate values.

There was actually little divergence between the two boundary lines in the northwestern portion of the site. A major factor involved was the frequent flooding which occurred, and still occurs, in this part of the site.

## Activity Areas

Another means used to aid interpretation of the phosphate values was plotting the values on contour maps of the site which were based on plain sherd and biface artifact densities (Fig. 2 and 3). It was hoped

that the readings of four from the trench samples which were not associated with features might correspond to areas of high artifact density. A comparison of phosphate distributions and artifacts collected from the surface of the site could reveal a great deal about the kinds and intensity of activities conducted in different parts of the site. For example, work areas not involving organic products may have a lot of cultural debris, but relatively low phosphate readings (Woods 1975:39). Conversely, activities involving organic products but not features would have higher phosphate readings.

The site was revisited after the initial collection of samples, and samples were recovered from areas of varying artifact densities. The highest density areas were already sampled because they were over features, but the next order of density was sampled as well as areas of low density.

High density areas, based on plain sherd and biface surface distributions, were sampled. The results of this resampling were mixed. Of the five samples taken from the plain sherd high artifact density areas, three were ranked three and two were ranked four. Of the eight samples taken from biface high density areas, there was one value of six, two fours, three threes and two twos. These areas were not archaeologically investigated so it is not known whether or not there were any subsurface features. In general, most readings from the high artifact density area sampled were moderate.

Of the areas of high and low artifact density which were horizontally stripped, the phosphate values corresponded well with the excavation results. In the high artifact density area in which a structure was

found (Prov. 22), the phosphate values were threes and fours. In the other high density area sampled (Prov. 25), which yielded no postmolds or features upon excavation, the phosphate values were low (twos). In the low artifact density areas sampled (Prov. 24 and 26), which yielded no features or postmolds upon excavation, the phosphate values also were low (ones and twos). At least in these four instances, the phosphate values corresponded to the presence or absence of subsurface features. Also, in the high artifact density area in which no subsurface features were encountered, phosphate values would have revealed this and excavation would not have been necessary.

# Structural Features

All but two of the structures sampled were located on trenches, and these could be detected by an increase in phosphate in the samples taken nearest to the structures. Usually, these samples were ranked four, with rankings of five and six only from within the structures themselves. The structures detected in the trenches were Structure 2 on the 900N trench, Structure 4 on the 960N trench, Structure 5 on the 1046N trench and Structure 7 on the 1040N trench. There was also an increase approaching the other two structures, Structures 1 and 11.

Although the presence of a structure was in every case detected by an increase when approaching it, it was only possible in a few cases to differentiate an area inside the walls from that immediately outside. This seems reasonable because people would presumably throw as much garbage outside their house as inside.

The structure best delineated by phosphate values was an Etowah wall-trench house, Structure 4. Samples were taken at two meter intervals, crossing the structure from north to south and east to west. To the north, east and west, samples were taken at least four meters beyond the structure boundaries. As determined by the phosphate values, the limits of the structure corresponded well with excavation results (see Fig. 5).

One of the areas of highest phosphate concentrations was Structure 2. This was not surprising since the structure fill was rich in bone (Fish, personal communication). Twenty-nine samples were taken from the two 10 meter squares in which the structure was located. Samples were collected at two meter intervals along four transects. All the values were high so it was not possible to distinguish the structure boundaries (see Fig. 6).

Two of the structures in Prov. 2 were sampled, one which was dish-shaped with a depressed floor (Structure 1) and one a circular post-hole structure (Structure 11). Samples were taken along a transect beginning at the eastern edge of Structure 11 and ending west of Structure 1 (see Fig. 7). The values within Structure 11, lacking an intact floor above the post-holes, were moderate. There was a slight decrease in phosphate content of the soil sample taken outside of Structure 11, then an increase when Structure 1 was encountered. The values from Structure 1 were quite high, correlating with the presence of bone recovered during excavation.

A structure known from a post-hole pattern rather than a preserved floor (Structure 7), located in Prov. 22, was also sampled. Samples

were taken along north-south and east-west transects at three meter intervals. The phosphate values did not reveal the boundary of the structure (see Fig. 8), possibly because most of the house floor had been plowed away. The samples may have been taken as much as 20 centimeters below the original floor. The structure was detected in the trench, however.

A rectangular burned structure of Swift Creek affiliation beneath Mound A (Structure 5), was approached from the south and the west (see Fig. 9). Samples were taken from the 1046N trench on the western side of the mound, approaching the structure at two meter intervals. Seven meters from the boundary of the house as determined by excavation, the phosphate values were low. However, there was an increase in phosphate value beginning five meters from the house and continuing until the house boundary was reached. Moderate to high values continued in the trench opposite the house and in samples from the house floor. Approaching the house from the south, there was an increase in phosphate value four meters from the south, there was an increase in phosphate value four meters from the southern boundary of the structure. Precise mapping of the structure based on phosphate values was not possible, but a good approximation of the extent of the structure was revealed.

A depressed-floor structure directly east of Mound A was located and excavated after the 1978 field season ended. As a result, the structure itself was not sampled in the field. However, the trench sample taken nearest Mound A from the 1046N trench happened to be from within the structure. The sample showed a high concentration of soil

phosphate, and, as such, the structure was detected in the trench by the high phosphate value.

The structures were detected by a relative increase in soil phosphate and no characteristic number could be associated with structures in general. As far as distinguishing house "types" by phosphate values, the site of Cold Springs was not conducive to such a problem. As house types have been defined in the archaeological literature, a case could be made that each structure at Cold Springs was actually a different house "type." For purposes of this study, the structures could be divided into two broad categories--surface structures and depressed-floor structures. Only in the depressed-floor structures were values of five and six regularly produced. Surface structures yielded values of four and, sometimes, three.

The two depressed-floor structures (1 and 2) produced higher phosphate values than the surface ones (4, 5, 7, and 11). One possible explanation of this is that the surface structures were more subject to post-occupational disturbances, such as plowing and weathering. However, Structure 5 which was protected by the mound shows a case in which disturbance was not a factor. The non-domestic function of the structure may be the reason for its moderate phosphate values. These two "types" of structures were distinguishable, at least at Cold Springs, by the soil phosphate content. Perhaps the higher values in depressed-floor structures reflect differences in function during occupation. Alternatively, the higher values in them may indicate use of the abandoned structures for garbage disposal prior to their collapse, in which case plant and animal food waste (garbage) would be the main contributor.

#### Non-Structural Features

Samples from non-structural features, all pits except for one hearth, were tested using soil collected for pollen analysis and flotation at the time the features were excavated. The features sampled were primarily pits of unknown functions except for three burial pits. The values from the features ranged from three to six (samples 285-338).

The three burials (samples 308, 309 and 328) all produced readings of six. If after artifact analysis a pit is suspected of having contained a burial, the phosphate value could be used as supporting evidence.

There were no values of one or two from the pits, and, of the 50 pits sampled, all but 10 yielded values of four or above. Other pits had readings as high as the burials, but only nine of the 50 pits produced readings of six. As a result, burials could not be distinguished solely by the phosphate value, but rather phosphate analysis would be one line of evidence which could be used to check suspected burials.

An attempt could be made to distinguish pits with functions involving particular animal substances versus those which did not. High phosphate values from pits could be interpreted in this manner. One must keep in mind, however, that high values may not reflect a primary function, but rather a secondary one if debris is thrown in after the pit is no longer required for its original purpose.

An interesting observation concerning the stability of deposited phosphate over archaeological time spans can be made using the results

from Prov. 18 (samples 326-332). Soil samples were tested from seven pits ranging in location from the top to the bottom of Mound A. The same range of values was produced despite the age of the feature.

#### CHAPTER VI

#### CONCLUSIONS

## Analysis Results: Cold Springs

Using soil phosphate analysis, the areal extent of intensive habitation at the site was confirmed. The limits based on phosphate values corresponded well with those determined by excavation of the site. It also proved a quick and inexpensive means of checking beyond excavation limits.

Most areas which produced high or moderate concentrations of phosphate were associated with known distribution of cultural debris and/or archaeological features (structures, pits, postmolds). Values from the systematic coverage of the site did not give indications of any large areas of low phosphate values. However, this is understandable because of the nature of the site. Cold Springs consists of many overlapping components. On the other hand, some portions of the site were known to have had the densest occupations during several periods. These areas (Prov. 2 and 10) consistently produced high phosphate readings. At the same time, a number of the areas with low surface densities of artifacts also gave the lower range of site phosphate values.

Based on the range of values, pits and structures could not be differentiated as groups at Cold Springs. Detection of structures was

possible as much as seven meters from the actual feature. This pattern was not observed in samples collected approaching pits (samples 339-345). Values of samples nearest the pits did not reflect the presence of these features, probably because of a lack of garbage surrounding the pits. It appears detection of pits would require a much smaller grid than would be necessary to detect structures.

Known structures could always be detected by an increase in phosphate, not so much by an absolute value, but by a relative increase in phosphate. The approximate range at which a structure could be detected was at a distance of five to seven meters. Since structures at Cold Springs range from five to twelve meters in diameter, a grid spacing phosphate values at wide intervals would still have detected increased values associated with structures. With a few localized exceptions, the entire site was sampled with a grid 20 meters on a side and, even at this scale, the chances of missing a structure are relatively small. From the results, it appears that a depressedfloor structure could not have been missed at the site. The only values of five not directly associated with known structures were tested archaeologically and yielded no features. Surface structures are not as clear as a few instances of moderate values occurred where no structural remains were detected. The results of soil phosphate analysis supported the assumption that most of the structures present at the site were detected. A confirmation of this assumption from an unrelated line of information is important in reliable estimation of the population at the site.

Because features of known cultural affiliation were involved, it was possible to assess the retention of phosphate deposited over a long period of time. For example, some Swift Creek features dating between A.D. 200 and 500 had values as high as the most recent burials on the site dating to the Lamar period (A.D. 1375-1600). An interesting comparison is the two depressed-floor structures--one Swift Creek (A.D.  $445 \pm 55$ ) and one Etowah (A.D. 905 \pm 95). These two structures had similar readings despite five hundred years difference. At Cold Springs, the liklihood of detecting early features by this method seems as good as the liklihood of detecting late features.

# Analysis Results: General Applications

The distributions of phosphate values within a site would be much easier to interpret at sites which were not occupied intensely for a long period of time. The most unambiguous case would be a single component site with a minimum of feature superpositioning. Further information about activity areas and the function of such areas would be revealed if one knew the component to which areas belonged.

There is a real need for experimental archaeology in soil phosphate analysis. Results from specific experiments still could not be transferred directly to a site, but the relative contribution of phosphate of different activities could certainly be weighed. Cook and Heizer (1965) and Hole and Heizer (1973) are the only examples in the literature of attempts to determine how much phosphate different activities would add to the soil.

If the relative contribution to the soil of plant detritus versus animal detritus were known, precision in interpretation would be greatly enhanced. For instance, the one hearth sampled produced a reading of three. Does fire have something to do with the moderate reading? Very basic questions for interpretation remain to be answered.

The ideal situation to gain the most information from soil phosphate analysis would be a multi-stage investigation in which there is time available for feedback from analysis to plan further. An idealized version of a multi-stage research design of excavation employing soil phosphate analysis in addition to more conventional excavation techniques would include site location, limited testing, intensive investigation of particular areas within the site and interpretation of excavation results.

First, soil phosphate analysis could be used to locate an area or areas of higher density within a large grid. A smaller grid could then be used to determine the site limits.

In the stage of limited testing, a still finer grid could be used within the site to delimit areas of high and low phosphate density. These areas would be checked against high and low artifact densities on the surface. Various values could then be tested by excavation to determine what they mean in terms of subsurface features. If these results were profitable, areas of differing phosphate values could be used to stratify your random samples into more culturally meaningful units.

During intensive investigation of particular areas within the site, soil phosphate analysis would be used to test for activity areas not

associated with visible features. These could be checked against activity areas defined on artifacts rather than features.

As an aid in interpretation of excavation results, soil phosphate analysis could be used to distinguish feature function in terms of the presence of organic debris. Post-hole patterns could be tested to see if a higher concentration of phosphate is present. The phosphate content of a pit suspected of being a burial on other grounds such as shape, size or content could be tested as a means of confirming a burial function. There are many instances in which soil phosphate analysis could be used to confirm something which is suspected on another line of information.

This study demonstrated that soil phosphate analysis is not only suitable for locating and delimiting sites, but that is can also serve as a valuable tool in the interpretation of intra-site relationships. It can add valuable planning data at all stages of investigation as well as information about cultural activities within the site not readily available by other means. Results from soil phosphate analysis can be added to other archaeological evidence for a clearer picture or better argument about what is going on at a site.

#### REFERENCES

#### Arrhenius, 0.

- 1929 Die phosphatfrage. Zeitschrift für Pflanzenernährung, Düngung, und Bodenkunde Teil A. 10:185-194.
- 1931 Die bodenanalyse im dienst der archäologie. Zeitschrift für Pflanzenernährung, Düngung, und Bodenkunde Teil B. 10:427-439.
- 1963 Investigation of soil from old Indian sites. Ethnos 28:122-136.

# Baker, C. M.

1975 Experimentation with soil phosphate analysis. In C. M. Baker, ed. <u>Arkansas Eastman Archeological Project</u>. <u>Arkansas</u> Archeological Survey, Research Report No. 6:67-82.

#### Bandi, H.

- 1945 Archäologische erforschung des zukunftigen staiseagebretes Rossens--Broc. Jahrbuch der Schweiz, Gesellscheft für Urgeschichte 36:100-106.
- Berger, Kermit C. 1965 Introductory soils. The Macmillan Company, New York.
- Caldwell, Joseph R.
  - 1958 Trend and tradition in the prehistory of the eastern United States. American Anthropological Association, Memoir 88.

Castagnol, E. M.

1939 Methode d'analyse du sol appliquee a la recherche des emplacements anciennement habites. <u>Institut-Indochinois</u> pour l'etude de l'homme, Bulletins et Travaux 2:191-203.

Cook, S. F. and R. F. Heizer

1965 <u>Studies on the chemical analysis of archaeological sites</u>, 2. University of California Press, Berkeley.

Cornwall, I. W.

<sup>1958</sup> Soils for the archaeologist. Phoenix House, Ltd., London.

Cruxent, J. M.

1962 Phosphorus content of the Texas Street 'hearths'. <u>American</u> Antiquity 28:90-91.

Dietz, E. F.

- 1957 Phosphorus accumulation in soil of an Indian habitation site. American Antiquity 22:405-409.
- Eidt, R. C.
  - 1973 A rapid chemical field test for archaeological site surveying. American Antiquity 38:206-210.
  - 1977 Detection and examination of anthrosols by phosphate analysis. Science 197:1327-1333.

Eidt, R. C. and W. I. Woods

- 1974 Abandoned settlement analysis--theory and practice. Field Test Associates, Milwaukee.
- Fish, S. K.
  - 1978 Site plan at Cold Springs. Paper presented at the 1978 Southeastern Archaeological Conference, Knoxville.
- Gregg, Michael L.
  - 1975 Two sites in northwestern Illinois. <u>The Wisconsin</u> Archaeologist 56:174-200.
- Gundlach, H.
  - 1961 Tüpfelmethode auf phosphat, angewandt in prähistoricher forschung (als feldmethode). Mikrochimica Acta. 5:735-737.
- Hole, Frank and R. F. Heizer
- 1973 <u>An Introduction to Prehistoric Archaeology</u>. 3rd ed. Hole, Rinehart and Winston, New York.
- Lorch, W.
  - 1939 Neue methoden der siedlungsgeschicte. <u>Geographisches</u> Zeitschrift 45:294-305.
  - 1940 Die siedlungsgeographische phosphatmethode. <u>Die</u> Naturwissenschaften 28:633-640.
- Lutz, H. J.
  - 1951 The concentration of certain chemical elements in the soils of Alaskan archaeological sites. <u>American Journal of Science</u> 249:925-928.

Overstreet, D.

1974 A rapid chemical field test for archaeological site surveying: An application and evaluation. <u>The Wisconsin</u> Archaeologist 55:262-276. 44

Pendleton, R. L. 1943 Land use in northeastern Thailand. <u>Geographical Review</u> 33:15-41.

Schwartz, G. T.

- 1967 A simplified chemical test for archaeological field work. Archaeometry 10:57-63.
- Shackley, M. L.
  - 1975 Archaeological sediments: A survey of analytical methods. John Wiley and Sons, New York.
- Sjoberg, Alf
  - 1976 Phosphate analysis of anthropic soils. Journal of Field Archaeology 3:447-454.
- Solecki, R. S.
  - 1950 Notes on soil analysis and archaeology. <u>American Antiquity</u> 16:254-256.
- Thomas, A. S.
  - 1947 The vegetation of some hillsides in Uganda. <u>The Indian</u> Forester 73:130-136.
- Waggaman, William H.
  - 1969 Phosphoric acid, phosphates and phosphatic fertilizers. 2nd ed. Hafner, New York.

Woods, W. I.

1975 The analysis of abandoned settlements by a new phosphate field test method. The Chesopeian 13:1-45.

| Rating  | 1    | 2            | 3      | 4              | 5    | 6            |
|---|------|--------------|--------|----------------|------|--------------|
| Time of Appearance<br>of Rays (seconds)                   | 120+ | 90-120       | 50-100 | . 20–60        | 5-30 | 0-10         |
| Approximate Ring<br>Closure<br>Around Sample<br>(percent) | 0    | 0-50         | 50     | 75             | 100  | 100          |
| Length of Rays<br>(mm)                                    | 0    | 0-2          | 2-3    | 3–5            | 5-8+ | 5-8+         |
| Intensity of Blue<br>Coloration                           | none | very<br>pale | pale   | medium<br>dark | dark | very<br>dark |

# Table 1. Spot Test Phosphate Values<sup>a</sup>

<sup>a</sup>From William I. Woods' "The Analysis of Abandoned Settlements by a New Phosphate Field Test" (1975)









Figure 3. Contour Map of Cold Springs Based on Biface Surface Density



Figure 4. Distribution of Phosphate Values of all Samples from Cold Springs



Figure 5. Phosphate Values from Structure 4--Prov. 12



Figure 6. Phosphate Values from Structure 2 - Prov. 10



Figure 7. Phosphate Values from Structures 1 and 11--Prov 2



Figure 8. Phosphate Values from Structure 7--Prov. 22





# APPENDIX: SAMPLE PHOSPHATE RESULTS

| ample F                                | 1<br>s            | l<br>s            | 2<br>8                | 3<br>8<br>0           | 4                 | S                 | 6<br>S<br>S           | 7. c              | 8              | 9 8        | 10 8       | 11 8       | 12 8      | 13 8       | 8              |
|--|-------------------|-------------------|-----------------------|-----------------------|-------------------|-------------------|-----------------------|-------------------|----------------|------------|------------|------------|-----------|------------|----------------|
| Feature<br>10., etc.                   | control<br>sample | control<br>sample | control<br>sample     | control<br>sample     | control<br>sample | control<br>sample | contro,l<br>sample    | control<br>sample | 860N<br>Lrench | 860N       | 860N       | 860N       | 860N      | 860N       | 36.0M          |
| Sample grid<br>reference               | south of<br>site  | south of<br>site  | south of<br>site      | south of<br>site      | south of<br>site  | south of<br>site  | south of<br>site      | south of<br>site  | M0T01/N098     | M066/N098  | 860N/970W  | 860N/950W  | 860N/930W | 860N/935W  | BEDN / DOGU    |
| Sample<br>description                  | brown sand        | brown sand        | reddish-brown<br>sand | banded orange<br>sand | brown clay        | orange sand       | mottled brown<br>clay | brown sand        | brown sand     | brown sand | brown sand | brown sand | tan sand  | brown sand | Terrer believe |
| Sample<br>depth                        |                   |                   |                       |                       |                   |                   |                       |                   |                |            | 28         | 60         | 47        | 24         | 00             |
| Phosphate<br>rating                    | 1                 | 1                 | 2                     | 1                     | 2                 | 2                 | 2                     | 2                 | 2              | 2          | 4          | 4          | 5         | S          |                |
| Time of<br>appearance<br>of rays (sec) | 120               | 120               | 06                    | 120                   | 06                | 100               | 06                    | 06                | 100            | 105        | 50         | 35         | 15        | 20         |                |
| %<br>ríng                              | 0                 | 0                 | 25                    | 0                     | 25                | 25                | 25                    | 25                | 25             | 25         | 75         | 75         | 100       | 100        | 36             |
| Length of<br>rays (mm)                 | 0                 | 0                 | I                     | 0                     | 2                 | 0                 | I                     | 0                 | 1              | 2          | 3          | 4          | 1         | 5          | u              |
| Intensity of<br>coloration             | none              | none              | very pale             | none                  | very pale         | very pale         | very pale             | very pale         | very pale      | very pale  | med. dark  | med. dark  | dark      | dark       | and doub       |

| ample grid Sa<br>reference des | 0 0               | mple<br><u>cription</u> | Sample<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | %<br>ring | Length of<br>rays (mm) | Intensity of<br>coloration |
|--------------------------------|-------------------|-------------------------|-----------------|---------------------|--|-----------|------------------------|----------------------------|
| 60N/885W reddish-br<br>sand    | eddish-br<br>und  | UMO                     |                 | 4                   | 50                                     | 75        | e                      | med. dark                  |
| 60N/865W reddish-bro<br>sand   | eddish-bro<br>ind | UM                      |                 | 4                   | 30                                     | 75        | 5                      | med. dark                  |
| 60N/845W brown sand            | town sand         |                         |                 | 4                   | 45                                     | 75        | 4                      | med. dark                  |
| 60N/845W mottled bro<br>sand   | uttled bro        | แพ                      |                 | 4                   | 60                                     | 75        | 4                      | med. dark                  |
| 60N/835W mottled brow<br>sand  | ttled bround      | UM                      |                 | 1                   | 120                                    | 0         | 0                      | none                       |
| 00N/1025W mottled yell<br>clay | sttled yell       | MO                      | ۴               | 2                   | 90                                     | 25        | 2                      | very pale                  |
| 00N/1005W mottled yell<br>clay | sttled yell<br>ay | MO                      |                 | 4                   | 60                                     | 75        | £                      | med. dark                  |
| 00N/1005W mottled yell<br>clay | sttled yell       | MO                      |                 | 4                   | 30                                     | 75        | 2                      | med. dark                  |
| 00N/990W tan sand              | m sand            |                         |                 | 3                   | 75                                     | 50        | Э                      | pale                       |
| 00N/965W mottled brow<br>sand  | sttled brow       | u,                      |                 | e                   | 75                                     | 50        | 2                      | pale                       |
| 00N/965W brown sand            | own sand          |                         |                 | e                   | 60                                     | 50        | Э                      | pale                       |
| 00N/965W brown sand            | town sand         |                         |                 | e                   | 70                                     | 50        | 2                      | pale                       |
| 00N/947W mottled orar<br>sand  | uttled oran<br>md | ige                     | 42              | S                   | 10                                     | 100       | 5                      | dark                       |
| 00N/943W mottled oran<br>sand  | ttled ora         | oge                     |                 | 9                   | 5                                      | 100       | 7                      | very dark                  |

| Sample | Feature<br>no., etc. | Sample grid<br>reference | Sample<br>description  | Sample<br>Gepth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | z<br>ring | Length of<br>rays (mm) | Intensity of<br>coloration |
|--------|----------------------|--------------------------|------------------------|-----------------|---------------------|--|-----------|------------------------|----------------------------|
| 29     | N006                 | M076/N006                | mottled brown<br>sand  | 27              | 9                   | 1.0                                    | 100       | 9                      | very dark                  |
| 30     | N006                 | M0%6/N006                | mottled orange<br>sand | 32              | 2                   | 10                                     | 100       | 9                      | dark                       |
| 31     | N006                 | M068/N006                | mottled brown<br>clay  | 30              | 4                   | 50                                     | 75        | 3                      | med. dark                  |
| 32     | N006                 | 900N/870W                | orange clay            | 32              | £                   | 60                                     | 50        | 3                      | pale                       |
| 33     | N006                 | 900N/870W                | brown clay             | 05              | Э                   | 80                                     | 50        | 3                      | pale                       |
| 34     | N006                 | 900N/850W                | mottled orange<br>clay | 22              | 2                   | 90                                     | 25        | 2                      | very pale                  |
| 35     | N006                 | M0E8/N006                | brown clay             | 38              | 2                   | 06                                     | 25        | I                      | very pale                  |
| 36     | 920N<br>trench       | 920N/935W                | mottled brown<br>clay  | 40              | 4                   | 45                                     | 75        | 3                      | med. dark                  |
| 37     | 920N                 | 920N/935W                | mottled orange<br>clay | 60              | s                   | 15                                     | 100       | S                      | dark                       |
| 38     | 920N                 | 920N/900W                | mottled orange<br>clay | 05              | 4                   | 40                                     | 75        | Ч                      | med. dark                  |
| 39     | 920N                 | 920N/880M                | brown sand             | 43              | 3                   | 60                                     | 75        | 3                      | pale                       |
| 40     | 920N                 | 920N/860W                | mottled orange<br>sand | 36              | 2                   | 06                                     | 25        | 2                      | very pale                  |
| 15     | 920N                 | 920N/840W                | brown clay             | 68              | 2                   | 100                                    | 25        | T                      | very pale                  |
| 42     | 920N                 | 920N/840W                | brown clay             | 06              | I                   | 120                                    | 0         | 0                      | none                       |
| 43     | NO 96                | M0E L1/NO96              | reddish-brown<br>clay  |                 | 2                   | 60                                     | 50        | 3                      | pale                       |

| Intensity of<br>coloration             | med. dark  | med. dark  | pale                  | dark                  | pale                  | pale       | med. davi              | med. dark             | very pale              | very pale             | med. dark             | none                   | very pale | very pale |
|--|------------|------------|-----------------------|-----------------------|-----------------------|------------|------------------------|-----------------------|------------------------|-----------------------|-----------------------|------------------------|-----------|-----------|
| Length of<br>rays (nm)                 | 2          | 4          | £                     | 5                     | 2                     | 2          | 4                      | 4                     | 1                      | 2                     | 4                     | 0                      | 2         | T         |
| %<br>ring                              | 75         | 75         | 50                    | 100                   | 50                    | 50         | 75                     | 75                    | 10                     | 25                    | 75                    | 0                      | 25        | 25        |
| Time of<br>appearance<br>of rays (sec) | 45         | 20         | 90                    | 20                    | 80                    | 75         | 55                     | 40                    | 011                    | 06                    | 45                    | 120                    | 110       | 100       |
| Phosphate<br>rating                    | 4          | 4          | e                     | 4                     | Э                     | Э          | 4                      | 4                     | 2                      | 2                     | 4                     | I                      | 2         | 2         |
| Sample<br>depth                        | 40         |            | 14                    | 14                    | 42                    | 20         | 50                     | 25                    | 18                     | 22                    | 50                    | 40                     | 20        | 20        |
| Sample<br>description                  | tan clay   | brown clay | mottled brown<br>clay | mottled brown<br>clay | banded orange<br>sand | brown sand | mottled orange<br>sand | mottled brown<br>saud | mottled orange<br>sand | mottled brown<br>sand | mottled brown<br>clay | mottled orange<br>sand |           |           |
| Sample grid<br>reference               | MOTIT/N096 | MOTIL/NO96 | M060T/N096            | MOL 0T/N096           | M0101/N096            | M066/N096  | 960N/970W              | M096/N096             | M0E9/N096              | M0E6/N096             | M0T6/N096             | M016/N096              | 960N/890W | 960N/870W |
| Feature<br>no., etc.                   | N096       | N096       | N096                  | N096                  | 960N                  | N096       | N096                   | 960N                  | N096                   | N096                  | N096                  | N096                   | N096      | N096      |
| Sample                                 | 44         | 45         | 46                    | 4.7                   | 48                    | 49         | 50                     | 51                    | 52                     | 53                    | 54                    | 55                     | 56        | 57        |

|                  |                      |                          |                        |                 |                     | Jo on pr                    |           |                        |                            |
|------------------|----------------------|--------------------------|------------------------|-----------------|---------------------|-----------------------------|-----------|------------------------|----------------------------|
| Sample<br>number | Feature<br>no., etc. | Sample grid<br>reference | Sample<br>description  | Sample<br>depth | Phosphate<br>rating | appearance<br>of rays (sec) | %<br>ring | Length of<br>rays (mm) | Intensity of<br>coloration |
| 58               | N096                 | 960N/850W                |                        | 20              | 2                   | 115                         | 25        | 1                      | very pale                  |
| 59               | 980N<br>trench       | MOTOT/NO86               | surface                |                 | 5                   | 5                           | 100       | 5                      | dark                       |
| 60               | 980N                 | MOTOT/N086               | plow zone              | 12              | 4                   | 60                          | 75        | 3                      | med. dark                  |
| 61               | 980N                 | 980N/1010W               | orange sand            | 27              | 3                   | 70                          | 50        | 2                      | pale                       |
| 62               | N086                 | MOTOT/NO86               | mottled brown<br>sand  | 44              | 3                   | 75                          | 50        | в                      | pale                       |
| 63               | 980N                 | MOTOT/NO86               | brown clay             | •               | 2                   | 06                          |           |                        | very pale                  |
| 64               | 980N                 | M066/N086                | surface                |                 | 4                   | 55                          | 75        | 4                      | med. dark                  |
| 65               | 980N                 | M066/N086                | plow zone              | 12              | 9                   | 5                           | 100       | 9                      | very dark                  |
| 99               | 980N                 | M066/N086                | mottled orange<br>sand | 29              | 3                   | 60                          | 50        | £                      | pale                       |
| 67               | 980N                 | M066/N086                | mottled brown<br>sand  | 0%              | £                   | 06                          | 50        | 2                      | pale                       |
| 68               | N086                 | M066/N086                | orange sand            |                 | Э                   | 70                          | 50        | 2                      | pale                       |
| 69               | N086                 | M0197086                 | orange sand            | 45              | 3                   | 85                          | 50        | 2                      | pale                       |
| 70               | N086                 | 980N/950W                | mottled orange<br>sand | 29              | 4                   | 55                          | 75        | 4                      | med. dark                  |
| 11               | N086                 | 980N/930M                | dark gray clay         | 45              | 2                   | 105                         | 25        | 2                      | very pale                  |
| 72               | N086                 | M016/N086                | mottled brown<br>sand  | 16              | 4                   | 55                          | 75        | 5                      | med. dark                  |

| Sample<br>number | Feature<br><u>no., etc.</u> | Sample grid<br>reference | Sample<br><u>description</u> | Sample<br>depth. | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | z<br>r1ng | Length of<br>rays (mm) | Intensity of<br>coloration |
|------------------|-----------------------------|--------------------------|------------------------------|------------------|---------------------|--|-----------|------------------------|----------------------------|
| 73               | 980N                        | 980N/880N                | reddish-brown<br>sand        | 25               | £                   | 70                                     | 50        | 3                      | pale                       |
| 14               | 980N                        | 980N/860W                | brown sand                   | 20               | 3                   | 80                                     | 50        | 3                      | pale                       |
| 75               | 930N                        | 980N/840W                | brown sand                   | 25               | 4                   | 50                                     | 75        | 4                      | med. dark                  |
| 76               | 1000N<br>trench             | 1000N/1150W              | reddish-brown<br>clay        |                  | 3                   | 70                                     | 50        | 2                      | pale                       |
| 11               | 1000N                       | 1000N/1150W              | orange clay                  |                  | 4                   | 55                                     | 75        | 4                      | med. dark                  |
| 78               | 1000N                       | 1000N/1150W              | gray clay                    |                  | 2                   | 105                                    | 25        | 2                      | very pale                  |
| 79               | 1000N                       | 1000N/1150W              | reddish-brown<br>cLay        |                  | 3                   |  | 50        | 2                      | pal.e                      |
| 80               | 1000N                       | 1000N/1150W              | gray clay                    |                  | £                   | 55                                     | 50        | 2                      | pale                       |
| 81               | 1000N                       | 1000N/1150W              | orange sand                  |                  | 3                   | 06                                     | 60        | 3                      | pale                       |
| 82               | 1000N                       | 1000N/1150W              | reddfsh-brown<br>clay        |                  | e                   | 70                                     | 50        | 2                      | pale                       |
| 83               | 1000N                       | M0E11/N0001              | mottled orange<br>clay       |                  | 2                   | 90                                     | 25        | 2                      | very pale                  |
| 84               | 1000N                       | M0111/N0001              | orange clay                  |                  | 4                   | 05                                     | 75        | e                      | med. dark                  |
| 85               | 1000N                       | M0111/N0001              | mottled brown<br>clay        |                  | 3                   | 06                                     | 50        | 2                      | pale                       |
| 86               | 1000N                       | 1000N/1090M              | yellow clay                  |                  | 3                   | 40                                     | 75        | 3                      | pale                       |
| 87               | 1000N                       | 1000N/1090M              | brown sand                   |                  | 2                   | 120                                    |           |                        | very pale                  |

| Intensity of coloration                | very pale        | med. dark    | very pale    | pale                   | pale                  | med. dark   | med. dark   | med. dark   | pale        | pale        | pale                  | pale                  | very pale            | very pale            | very pale             |
|--|------------------|--------------|--------------|------------------------|-----------------------|-------------|-------------|-------------|-------------|-------------|-----------------------|-----------------------|----------------------|----------------------|-----------------------|
| Length of<br>rays (mm)                 | 2                |              | 2            | 2                      | 2                     | 3           | 4           | 5           | 2           | 2           | 3                     | £                     | 2                    | I                    | 2                     |
| %<br>ring                              | 25               |              | 30           | 50                     | 50                    | 75          | 75          | 80          | 50          | 50          | 50                    | 50                    | 25                   | 25                   | 25                    |
| Time of<br>appearance<br>of rays (sec) | 06               | 60           | 100          | 70                     | 06                    | 60          | 35          | 40          | 50          | 60          | 60                    | 75                    | 100                  | 106                  | 06                    |
| Phosphate<br>rating                    | 2                | 4            | 2            | 3                      | e                     | 4           | 4           | 4           | 3           | 3           | 3                     | 3                     | 2                    | 2                    | 2                     |
| Samp le<br>dep th                      | 38               |              |              |                        |                       |             | 58          | 58          | 53          | 53          | 45                    | 45                    | 38                   | 38                   | 30                    |
| Samp.le<br>description                 | mottled tan sand | brown clay   | orange sand  | mottled orange<br>sand | mottled brown<br>sand | brown sand  | brown clay  | brown clay  | tan clay    | tan clay    | mottled brown<br>clay | mottled brown<br>clay | mottled gray<br>clay | mottled gray<br>clay | mottled brown<br>clay |
| Sample grid<br>reference               | 1000N/1064W      | 1.000N/1064W | 100001/1040M | 10000/1040M            | 100001/1040M          | 1000N/1040M | 1000N/1062W | 1000N/1062W | 1000N/1062W | 1000N/1062W | 1000N/1062W           | 1.000N/1062W          | 1000N/1062W          | 1000N/1062W          | 1000N/1062W           |
| Feature<br>no., etc.                   | 1000N            | 1000N        | 1.000N       | 1000N                  | 1000N                 | 1000N       | 1.000N      | 1000N       | 1.000N      | TOOON       | 1000N                 | 1000N                 | 1000N                | 1000N                | 1000N                 |
| Samp.le<br>number                      | 88               | 89           | 06           | 16                     | 92                    | 93          | 1/6         | 95          | 96          | 1.6         | 98                    | 66                    | 100                  | 101                  | 102                   |

| Sample<br>number | Feature<br>no etc. | Sample grid<br>reference | Sample<br>description  | Sample<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | %<br>ring | Length of<br>rays (mn) | Intensity of<br>coloration |
|------------------|--------------------|--------------------------|------------------------|-----------------|---------------------|--|-----------|------------------------|----------------------------|
| 103              | 1000N              | 1000N/1062W              | mottled brown<br>clay  |                 | 2                   | 90                                     | 25        | 2                      | very pale                  |
| 104              | 1000N              | 1000N/1062W              | brown clay             | 1.9             | 4                   | 30                                     | 75        | 5                      | med. dark                  |
| 105              | 1000N              | 1000N/1062W              | brown clay             | 19              | 4                   | 50                                     | 75        | 5                      | med. dark                  |
| 106              | 1000N              | 1000N/1020M              | mottled orange<br>sand | 35              | 2                   | 120                                    | 25        | 2                      | very pale                  |
| 107              | 1000N              | M0001/N0001              | mottled brown<br>sand  | 28              | 3                   | 70                                     | 50        | 2                      | pale                       |
| 108              | 1000N              | M0001/N0001              | mottled orange<br>sand | 42              | 4                   | 50                                     | 75        | £                      | med. dark                  |
| 109              | 1000N              | 1000N/980N               | mottled orange<br>clay | 21              | C                   | 60                                     | 50        | £                      | pale                       |
| 110              | 1000N              | 1000N/960W               | mottled orange<br>clay | 26              | 4                   | 60                                     | 75        | 4                      | med. dark                  |
| 111              | 1000N              | M0%6/N000T               | brown clay             | 28              | £                   | 70                                     | 50        | 2                      | pale                       |
| 112              | 1000N              | 1000N/920W               | brown clay             | 42              | 4                   | 60                                     | 75        | 3                      | med. dark                  |
| 113              | 1000N              | 1000N/890W               | orange sand            |                 | 2                   | 110                                    | 10        | 1                      | very pale                  |
| 11.4             | 1000N              | 1000N/870W               | orange sand            |                 | 4                   | 60                                     | 75        | 3                      | med. dark                  |
| 115              | 1000N              | 1000N/830W               | brown sand             |                 | 4                   | 50                                     | 75        | 5                      | med. dark                  |
| 911              | 1020N<br>trench    | 1020N/1155W              | reddish-brown<br>clay  |                 | 4                   | 50                                     | 75        | 4                      | med. dark                  |
| 11.7             | 1020N              | 1020N/1125W              | mottled brown<br>clay  | 45              | 3                   | 75                                     | 50        | 3                      | pale                       |

| tensity of<br>loration                 | pale        | pale                  | d. dark                | d. dark     | d. dark     | ry pale     | pale        | pale                   | d. dark               | ry pale                | pale                  | ery pale              | ery pale    | ery pale    | pale                  |
|--|-------------|-----------------------|------------------------|-------------|-------------|-------------|-------------|------------------------|-----------------------|------------------------|-----------------------|-----------------------|-------------|-------------|-----------------------|
| Int                                    |             |                       | me                     | me          | me          | ve          |             |                        | me                    | ve                     |                       | ve                    | >           | >           |                       |
| Length of<br>rays (mm)                 | £           | 9                     | 3                      | 3           | 4           | 1           | 3           | 2                      | 5                     | 1                      | 2                     | I                     | 2           | T           | 2                     |
| %<br>r1.ng                             | 50          | 50                    | 75                     | 75          | 75          | 25          | 50          | 50                     | 75                    | 25                     | 50                    | 25                    | 30          | 25          | 50                    |
| Time of<br>appearance<br>of rays (sec) | 60          | 60                    | 45                     | - 09        | 60          | 06          | 70          | 80                     | 55                    | 110                    | 65                    | 90                    | 100         | 06          | 55                    |
| Phosphate<br>rating                    | 3           | 3                     | £                      | 4           | 4           | 2           | З           | £                      | 4                     | 2                      | £                     | 2                     | 2           | 2           | 3                     |
| Sample<br>depth                        | 37          |                       | 28                     | 17          | 35          | 35          | 25          | 30                     | 30                    | 30                     | 15                    |                       |             |             |                       |
| Sample<br>description                  | brown sand  | mottled brown<br>sand | mottled orange<br>clay | brown sand  | tan sand    | brown sand  | orange sand | mottled orange<br>clay | mottled brown<br>clay | mottled orange<br>clay | mottled brown<br>clay | reddish-brown<br>clay | orange clay | orange clay | mottled brown<br>sand |
| Sample grid<br>reference               | 1020N/1105W | 1020N/1093W           | 1020N/1080W            | 1020N/1060W | 1020N/1040W | 1020N/1020W | 1020N/1000W | 1020N/980W             | 1020N/960W            | 1020N/940W             | 1020N/920W            | 1020N/900W            | 1020N/880W  | 1020N/860W  | 1.020N/860W           |
| Feature<br>no., etc.                   | 1020N       | 1020N                 | 1020N                  | 1020N       | 1020N       | 1020N       | 1020N       | 1020N                  | 1.020N                | 1020N                  | 1020N                 | 1020N                 | 1020N       | 1020N       | 1020N                 |
| Sample<br>number                       | 118         | 119                   | 120                    | 121         | 122         | 1.23        | 124         | 125                    | 126                   | 127                    | 128                   | 129                   | 130         | 131         | 132                   |

| ample | Feature         | Sample grid  | Sample<br>description  | Samp.l.e<br>dep.t.h | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | %<br>rlng | Length of<br>rays (ma) | Intensity of<br>coloration |
|-------|-----------------|--------------|------------------------|---------------------|---------------------|--|-----------|------------------------|----------------------------|
| 133   | 1040N           | 1040N/1010W  | brown sand             | 43                  | 3                   | 06                                     | 50        | 3                      | pale                       |
|       | trench          |              | weld wellow            |                     | 2                   | 100                                    | 25        | 2                      | very pale                  |
| 134   | N0401           | M066/N0501   | mottled brown          | 29                  | £                   | 70                                     | 50        | 2 .                    | pale                       |
| c6.1  | NUPOT           | M026/N0701   | sand<br>mottled orange | 30                  | 4                   | 55                                     | 75        | 4                      | med. dark                  |
| 137   | NOPOT           | 1040N/950W   | clay<br>mottled orange | 28                  | 3                   | 06                                     | 25        | 2                      | pale                       |
| 138   | N0401           | 1040N/930W   | clay<br>mottled orange | 40                  | 3                   | 06                                     | 50        | £                      | pale                       |
| 139   | 1040N           | 1040N/905W   | reddish-brown<br>sand  | 15                  | 2                   | 100                                    | 15        | I                      | very pale                  |
| 071   | N0401           | 1040N/885    | brown sand             | 15                  | 2                   | 06                                     | 25        | 2                      | very pale                  |
| 141   | 1040N           | 1040N/865W   | reddish-brown<br>clay  | 32                  | 3                   | 60                                     | 50        | 2                      | pale                       |
| 142   | 1060N<br>trench | 1060N/1150W  | orange-black<br>sand   | 80                  | C                   | 80                                     | 50        | £                      | pale                       |
| 143   | 1060N           | 1060N/11.30W | brown clay             | 43                  | 3                   | 65                                     | 50        | £                      | pale                       |
| 144   | 1060N           | M0111/N0901  | banded orange<br>sand  | 73                  | 2                   | 105                                    | 25        | 2                      | very pale                  |
| 145   | 1060N           | MOTIT/NO901  | mottled orange<br>sand | 25                  | 2                   | 95                                     | 25        | T                      | very pale                  |
| continued) |
|------------|
| RESULTS (  |
| PHOSPHATE  |
| SAMPLE     |
| :XIUN:     |

|         |                 |             | VPPENDLX: SA                   | MPLE PHOS       | PUATE RESULT        | S (continued)                          |           |                        |                            |
|---------|-----------------|-------------|--------------------------------|-----------------|---------------------|--|-----------|------------------------|----------------------------|
| Samp Je | Feature         | Sample grid | Sample<br>description          | Sample<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | %<br>ring | Length of<br>rays (mm) | Intensity of<br>coloration |
| number  | 100., ELC.      | 10001/1020M | brown clay                     | 25              | Э                   | 90                                     | 50        | 2                      | pale                       |
| 147     | N0901           | 1060N/1070W | mottled orange                 | 20              | £                   | 80                                     | 50        | 2                      | pal.e                      |
|         |                 | 10101110000 | cray<br>hours cand             | 36              | 2                   | 06                                     | 25        | 2                      | very pale                  |
| 148     | 1060N           | M066/N0901  | mottled brown                  | 25              | 3                   | 75                                     | 50        | 2                      | pale                       |
| 150     | 1060N           | M010/N0301  | sand<br>mottled orange<br>clay | 36              | 3                   | 70                                     | 50        | 3                      | pale                       |
| 151     | 1060N           | 1060N/950W  | mottled orange<br>clay         | 27              | 9                   | 70                                     | 50        | e                      | pale                       |
| 152     | 1060N           | M0C6/N090T  | mottled orange<br>sand         | 28              | 2                   | 06                                     | 25        | 1                      | very pale                  |
| 153     | 1060N           | M016/N0901  | reddish-brown<br>sand          | 10              | £                   | 80                                     | 50        | 7                      | pale                       |
| 154     | 1060N           | M01910W     | brown sand                     | 20              | Э                   | 60                                     | 50        | 2                      | pale                       |
| 155     | 1060N           | M0T6/N090T  | 11ght brown<br>sand            | 27              | 3                   | 80                                     | 50        | £                      | pale                       |
| 156     | 1060N           | M068/N090T  | reddish-brown<br>clay          |                 | 3                   | 90                                     | 50        | 2                      | pale                       |
| 157     | 1060N           | 1060N/870W  | reddish-brown<br>clay          |                 | 2                   | 06                                     | 25        | I                      | very pale                  |
| 1.58    | 1080N<br>trench | 1080N/1150W | mottled brown<br>clay          | 30              | 2                   | 100                                    | 25        | 2                      | very pale                  |

| Sample<br>number | Feature<br>no., etc. | Sample grid<br>reference | Sample<br>description  | Sample<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | %<br>ring | Leugth of<br>rays (mm) | Intensity o<br>coloration |
|------------------|----------------------|--------------------------|------------------------|-----------------|---------------------|--|-----------|------------------------|---------------------------|
| 159              | 1080N                | 1080N/1150W              | orange-black<br>sand   | 52              | e<br>F              | 80                                     | 50        | 3                      | pale                      |
| 160              | 1080N                | 1080N/1130W              | orange sand            | 25              | 1                   | 120                                    | 0         | 0                      | none                      |
| 161              | 1080N                | 1080N/1130W              | banded gray<br>sand    | 26              | £                   | 70                                     | 50        | £                      | pale                      |
| 162              | 1080N                | 1080N/1090M              | orange sand            | 09              | 3                   | 60                                     | 50        | 3                      | pale                      |
| 163              | 1080N                | 1080N/1070W              | orange sand            | 14              | 1                   | 120                                    | 0         | 0                      | none                      |
| 164              | 1080N                | 1080N/1050W              | banded orange<br>sand  | 38              | 2                   | 06                                     | 25        | T                      | very pale                 |
| 165              | 1080N                | 1080N/1030W              | brown clay             | . 33            | Э                   | 75                                     | 50        | 2                      | pale                      |
| 166              | 1080N                | 1080N/1010W              | tan sand               | 39              | Э                   | 75                                     | 50        | 2                      | palle                     |
| 167              | 1,080N               | M066/N0801               | mottled brown<br>sand  | 42              | 2                   | 100                                    | 25        | 2                      | very pale                 |
| 168              | 1080N                | M079/N0801               | mottled brown<br>sand  | 35              | 2                   | 95                                     | 25        | 1                      | very pale                 |
| 169              | 1.080N               | 1080N/950W               | mottled orange<br>sand | 25              | I                   | 120                                    | 0         | 0                      | none                      |
| 1.70             | 1080N                | 1080N/930W               | reddish-brown<br>sand  |                 | £                   | 70                                     | 50        | 3                      | pale                      |
| 171              | 1.080N               | N010/N0801               | reddish-brown<br>sand  |                 | 4                   | 45                                     | 75        | 4                      | med. dark                 |
| 172              | 1080N                | 1080N/890W               | reddi.sh-brown<br>sand |                 | 4                   | 40                                     | 75        | ŝ                      | med. dark                 |

| 60N/945N         4         60         75         4         media dark           60N/943N         3         60         50         3         pale           96N/947N         4         45         75         5         medi dark           96N/947N         4         45         75         3         medi dark           96N/947N         4         60         75         3         medi dark           96N/947N         3         66         50         3         medi dark           96N/947N         3         65         50         2         pale           96N/947N         3         65         50         2         pale           96N/947N         3         65         50         2         pale           96N/94N         4         6         6         7         3         medi dark           96N/94N         3         65         50         2         pale         fark           96N/94N         4         6         6         7         3         medi dark           96N/94N         4         6         7         6         fark         fark           90N/94N         5 <th>rre<br/>etc.</th> <th>Sample grid<br/>reference</th> <th>Sample<br/>description</th> <th>Sample<br/>depth</th> <th>Phosphate<br/>rating</th> <th>Time of<br/>appearance<br/>of rays (sec)</th> <th>2<br/>ring</th> <th>Length of<br/>rays (mm)</th> <th>Intensity of<br/>coloration</th> | rre<br>etc. | Sample grid<br>reference | Sample<br>description | Sample<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | 2<br>ring | Length of<br>rays (mm) | Intensity of<br>coloration |
|--|-------------|--------------------------|-----------------------|-----------------|---------------------|--|-----------|------------------------|----------------------------|
| My 94.7W         3         60         50         3         palle           My 94.7W         4         45         73         5         med. dark           My 94.7W         4         40         75         5         med. dark           My 94.7W         4         40         75         3         med. dark           My 94.7W         3         60         75         3         palle           By 94.7W         3         60         75         3         palle           By 94.7W         3         65         50         2         palle           By 94.7W         3         65         50         2         palle           By 94.7W         3         66         75         3         med. dark           By 94.7W         3         67         75         3         med. dark           By 94.7W         3         66         75         3         med. dark           By 94.7W         3         67         75         3         med. dark           By 94.7W         4         60         75         5         med. dark           Gy 94.5W         4         7         60         75  | 960         | N/945W                   |                       |                 | 4                   | 09                                     | 75        | 4                      | med. dark                  |
| N/947N         4         45         75         5         med. dark           M/947N         4         60         75         3         med. dark           M/947N         3         60         75         3         med. dark           M/947N         3         60         75         3         med. dark           M/947N         3         65         50         2         pale           M/947N         3         65         50         2         pale           M/947N         3         65         50         2         pale           M/947N         4         60         75         3         med. dark           M/947N         4         60         75         3         med. dark           M/947N         6         65         75         3         med. dark           M/947N         6         65         75         3         med. dark           M/947N         6         75         7         7         7           M/944.5N         6         75         7         7         7           M/944.5N         5         100         5         1         1   | 96          | W643W                    |                       |                 | 3                   | . 09                                   | 50        | Э                      | pale                       |
| 4// 947 (4)     4     40     75     3     med dark       6// 947 (4)     3     60     50     3     pale       6// 947 (4)     3     65     50     2     pale       6// 947 (4)     3     65     50     2     pale       6// 947 (4)     3     65     50     2     pale       6// 947 (4)     3     65     50     7     pale       6// 947 (4)     4     60     75     3     med dark       6// 947 (4)     4     60     75     3     med dark       6// 943 (5)     6     75     100     5     med dark       6// 943 (5)     6     75     100     5     med dark       6// 943 (5)     6     75     100     5     med dark       6// 943 (5)     7     6     75     7     10       6// 943 (5)     100     100     6     10     10       6// 943 (5)     100     10     6     10     10       6// 943 (5)     10     10     6     10       6// 943 (6)     10     10     6     10       6// 943 (6)     10     10     6     10       6//  | 96          | W/ 94 7W                 |                       |                 | 4                   | 45                                     | 75        | 5                      | med. dark                  |
| 66N/947N         3         60         50         3         pale           68N/947N         3         65         50         2         pale           68N/947N         3         65         50         2         pale           68N/947N         3         65         50         2         pale           68N/947W         3         65         50         2         pale           68N/947W         4         60         75         3         pale           60N/941W         6         75         5         pale         4xf           60N/934.5W         6         75         5         pale         4xf           60N/934.5W         5         20         100         5         dark           06N/934.5W         5         20         100         5         dark           07N/934.5W         5         20         100         6         dark           07N/934.5W         5         100         5         dark           07N/934.5W         5         100         6         5         dark           05.5N/936W         5         100         6         5         dark   | 6           | W7494N46                 |                       |                 | 4                   | 40                                     | 75        | 3                      | med. dark                  |
| 68N/947U         3         65         50         2         pale           70N/947U         3         65         50         2         pale           70N/947U         4         60         75         3         pale           60N/941U         4         60         75         3         pale           60N/941U         4         60         75         3         pale           60N/934.5W         4         60         75         3         pale           00N/934.5W         5         20         100         5         dark           00N/934.5W         5         20         100         5         dark           00N/934.5W         5         20         100         6         dark           00S.N/934.5W         5         100         5         dark           00S.N/934.5W         5         100         6         dark           00S.SN/936W         5         100         6         dark           00S.SN/936W         5         100         6         dark           00S.SN/936W         6         10         10         6         dark           00S.SN/936W         6  | 6           | WL46/N99                 |                       |                 | 3                   | 09                                     | 50        | 3                      | pale                       |
| JON/947W         3         65         50         2         Pale           960N/941W         4         60         75         3         medi. dark           960N/934.5W         4         60         75         3         medi. dark           960N/934.5W         6         75         5         medi. dark           906N/934.5W         5         25         100         5         medi. dark           906N/934.5W         5         25         100         5         dark           906N/934.5W         5         20         100         5         dark           906N/934.5W         5         20         100         5         dark           905N/934.5W         5         20         100         6         very dark           905.5N/930W         5         15         100         6         very dark           905.5N/930W         5         100         6         very dark           905.5N/930W         5         100         6         very dark           905.5N/930W         6         10         6         very dark           905.5N/930W         6         10         6         very dark  |             | ML 96/N896               |                       |                 | Э                   | 65                                     | 50        | 2                      | pale                       |
| 60N/941W         4         60         75         3         med. dark           908N/934.5W         4         40         75         5         med. dark           908N/934.5W         4         40         75         5         med. dark           908N/934.5W         5         25         100         5         dark           905N/934.5W         5         20         100         5         dark           902N/934.5W         5         20         100         6         dark           902N/934.5W         5         20         100         6         dark           902N/934.5W         5         20         100         6         dark           905N/934.5W         5         15         100         6         very dark           905.5N/930W         5         10         6         10         6         dark           905.5N/930W         5         10         6         10         6         dark           905.5N/930W         6         10         10         6         10         6           905.5N/930W         6         10         6         10         6         10           905.   |             | W196/N016                |                       |                 | 3                   | 65                                     | 50        | 2                      | pal.e                      |
| 908N/934.5W         4         40         75         5         med. dark           906N/934.5W         5         25         100         5         dark           906N/934.5W         5         25         100         5         dark           906N/934.5W         5         20         100         5         dark           904N/934.5W         5         20         100         6         dark           902N/934.5W         5         20         100         6         dark           902N/934.5W         5         20         100         6         dark           905N/934.5W         5         15         100         6         very dark           905.5N/936W         6         15         100         6         dark           905.5N/936W         6         05         100         6         very dark           905.5N/932W         6         10         6         very dark           905.5N/930W         6         100         6         very dark   |             | W146/N096                |                       |                 | 4                   | 60                                     | 75        | 3                      | med. dark                  |
| 906N/934.5W         5         23         100         5         dark           904N/934.5W         5         20         100         5         dark           904N/934.5W         5         20         100         5         dark           902N/934.5W         5         20         100         6         dark           902N/934.5W         5         15         100         6         dark           902N/934.5W         5         15         100         6         very dark           905.5N/940W         6         05         10         6         very dark           905.5N/936W         6         15         100         6         dark           905.5N/936W         6         05         10         5         very dark           905.5N/932W         6         05         10         5         very dark           900N/940W         6         10         10         5         very dark   |             | 908N/934.5W              |                       |                 | 4                   | 40                                     | 75        | 2                      | med. dark                  |
| 904N/934.5W         5         20         100         5         dark           902N/934.5W         5         20         100         6         dark           902N/934.5W         5         20         100         6         dark           902N/934.5W         5         15         100         6         very dark           905.5N/936W         6         05         15         100         6         very dark           905.5N/936W         5         15         100         6         very dark           905.5N/936W         6         05         10         6         very dark           905.5N/932W         6         10         5         very dark           905.5N/932W         6         10         5         very dark  |             | 906N/934.5W              |                       |                 | 5                   | 25                                     | 100       | 5                      | dark                       |
| 902N/934.5W         5         20         100         6         dark           900N/934.5W         5         15         100         8         very dark           905.5N/940W         6         05         15         100         6         very dark           905.5N/930W         6         05         100         6         very dark           905.5N/930W         5         10         6         very dark           905.5N/930W         5         10         6         very dark           905.5N/930W         5         10         5         very dark           905.5N/930W         6         10         5         very dark           900N/940W         6         10         10         5         very dark  |             | 904N/934.5W              |                       |                 | 5                   | 20                                     | 1.00      | 5                      | dark                       |
| goon/934.5W         5         15         100         8         very         dark           g05.5N/940W         6         05         100         6         very         dark           g05.5N/938W         5         15         100         6         very         dark           g05.5N/938W         5         10         6         very         dark           g05.5N/938W         5         10         6         very         dark           g05.5N/938W         5         10         5         very         dark           g05.5N/936W         6         05         100         5         very         dark           g05.5N/932W         6         10         10         5         very         dark           g00N/940W         6         10         10         6         very         dark   |             | 902N/934.5W              |                       |                 | 5                   | 20                                     | 100       | 9                      | dark                       |
| 905.5N/940W     6     05     100     6     very dark       905.5N/938W     5     15     100     6     dark       905.5N/936W     5     10     6     dark       905.5N/936W     6     05     10     6     very dark       905.5N/930W     6     05     100     5     very dark       900N/940W     6     10     100     6     very dark   |             | 900N/934.5W              |                       |                 | 5                   | 15                                     | 100       | 8                      | very dark                  |
| 905.5N/938W     5     15     100     6     dark       905.5N/936W     5     10     6     0     dark       905.5N/932W     6     05     100     5     very dark       900N/940W     6     10     100     6     very dark  |             | W049/N2.209              |                       |                 | 9                   | 05                                     | 100       | 9                      | very dark                  |
| 905.5N/936W     5     10     6     dark       905.5N/932W     6     05     100     5     very dark       900N/940W     6     10     100     6     very dark  |             | W8E6/N5.206              |                       |                 | 5                   | 21.5                                   | 100       | 9                      | dark                       |
| 905.5N/932W 6 05 100 5 very dark<br>900N/940W 6 10 100 6 very dark   |             | 905.5N/936W              |                       |                 | 5                   | 10                                     |           | 9                      | dark                       |
| 900N/940W 6 10 100 6 very dark   |             | 905.5N/932W              |                       |                 | 9                   | 05                                     | 100       | 5                      | very dark                  |
|  |             | M049/N006                |                       |                 | 9                   | 10                                     | 1.00      | 9                      | very dark                  |

-

| Intensity o<br>coloration              | dark      | med. dark | very dark | very dark | very dark | very dark | dark      | dark      | med. dark | dark      | very dark | dark      | med. dark | very dark | very dark  | dark      | very dark | med. dark |  |
|--|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|-----------|-----------|-----------|--|
| Length of<br>rays (mm)                 | 9         | 5         | 5         | 7         | 8         | 8         | 9         | 9         | 4         | 5         | 2         | 9         | 4         | 7         | 9          | 9         | 5         | 4         |  |
| %<br>ring                              | 100       | 75        | 100       | 100       | 100       | 100       | 100       | 100       | 75        | 100       | 100       | 100       | 75        | 100       | 100        | 100       | 100       | 75        |  |
| Time of<br>appearance<br>of rays (sec) | 1.5       | 30        | 10        | 01        | 05        | 02        | 10        | 20        | 30        | 25        | 05        | 20        | 20        | 05        | 10         | 15        | 05        | 60        |  |
| Phosphate<br>rating                    | 5         | 4         | 9         | 9         | 9         | 9         | 9         | 9         | 4         | 5         | 9         | 5         | 4         | 9         | 9          | 5         | 9         | 4         |  |
| Sample<br>depth                        |           |           |           |           |           |           |           |           |           |           |           |           |           |           |            |           |           |           |  |
| Sample<br>description                  |           |           |           |           |           |           | :         |           |           |           |           |           |           |           |            |           |           |           |  |
| Sample grid<br>reference               | 898N/940W | 896N/940W | 894N/940W | 900N/935W | 898N/935W | 896N/935W | 894N/935W | 892N/935W | 895N/932W | 895N/934W | W9E6/N568 | W049/N268 | 895N/942W | 900N/938W | W9E 6/N006 | W469/N006 | 900N/932W | MLL6/N556 |  |
| Feature<br>no., etc.                   | struc. 2   | struc. 2  | struc. 2  | struc. 11 |  |
| Sample<br>number                       | 205       | 206       | 207       | 208       | 209       | 210       | 21.1      | 212       | 213       | 214       | 215       | 216       | 217       | 21.8      | 21.9       | 220       | 221       | 222       |  |

| Sample<br>umber | Feature<br>no etc.   | Sample grid<br>reference | Sample<br>description | Sample<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | %<br>ring | Length of<br>rays (mm) | Intensity of<br>coloration |
|-----------------|----------------------|--------------------------|-----------------------|-----------------|---------------------|--|-----------|------------------------|----------------------------|
| 223             | struc. 11            | W879/NE46                |                       |                 | 4                   | 50                                     | 75        | Э                      | med. dark                  |
| 224             | struc. 11            | 942N/980W                |                       |                 | 4                   | 4.0                                    | 75        | 4                      | med. dark                  |
| 225             | struc. 11            | M186/N146                |                       |                 | 4                   | 60                                     | 75        | 4                      | med. dark                  |
| 276             | struc. 11            | 940N/982W                |                       |                 | 4                   | 50                                     | 80        | 4                      | med. dark                  |
| 227             | struc. 11            | WE86/N6E6                |                       |                 | 3                   | 70                                     | 50        | 2                      | pal.e                      |
| 228             | struc. 11            | 938N/984W                |                       |                 | 4                   | 45                                     | 75        | 5                      | med. dark                  |
| 229             | struc. 11            | 937.5N/985W              |                       |                 | 3                   | 06                                     | 50        | 2                      | pale                       |
| 230             | west of<br>struc. 11 | M286/N766                |                       |                 | 5                   | 100                                    | 25        | 1                      | very pale                  |
| 231             | east of<br>struc. 1  | 937N/988W                |                       |                 | ų                   | 01                                     | 75        | 4                      | med. dark                  |
| 232             | struc. 1             | 935N/989W                |                       |                 | 9                   | 05                                     | 100       | 80                     | very dark                  |
| 233             | struc. 1             | M066/N9E6                |                       |                 | 9                   | 02                                     | 100       | 1                      | very dark                  |
| 234             | struc. 1             | 933N/991.5W              |                       |                 | 9                   | 08                                     | 100       | 8                      | very dark                  |
| 235             | struc. 1             | 932N/993W                |                       |                 | 9                   | 1.0                                    | 100       | 1                      | very dark                  |
| 236             | struc. 1             | M966/NTE6                |                       |                 | 9                   | 20                                     | 100       | 5                      | dark                       |
| 237             | west of<br>struc. 1  | N266/N066                |                       |                 | 4                   | 45                                     | 75        | £                      | med. dark                  |
| 238             | struc. 5             | 1047N/1057W              |                       |                 | 9                   | 70                                     | 50        | e                      | pale                       |
| 2.39            | struc. 5             | N6501/N2501              |                       |                 | 4                   | 50                                     | 75        | 4                      | med. dark                  |

| Sample<br>number | Feature<br>no., etc. | Sample grid<br>reference | Sample<br>description | Sample<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | %<br>ring. | Length of<br>rays (mm) | Intensity of<br>coloration |
|------------------|----------------------|--------------------------|-----------------------|-----------------|---------------------|--|------------|------------------------|----------------------------|
| 240              | struc. 5             | M1901/N7401              |                       |                 | 4                   | 45                                     | 75         | 3                      | med. dark                  |
| 241              | struc. 5             | NE 901/N/ 106 3M         |                       |                 | 4                   | 35                                     | 75         | 5                      | med. dark                  |
| 242              | struc. 5             | 1047N/1065W              |                       |                 | 4                   | 30                                     | 75         | 4                      | med. dark                  |
| 243              | struc. 5             | M2901/N2901              |                       |                 | 5                   | 10                                     | 100        | 1                      | dark                       |
| 244              | struc. 5             | 1035N/1061W              |                       | ł               | 2                   | 1.00                                   | 25         | 2                      | very pale                  |
| 245              | struc. 5             | 1037N/1061.51            | 3                     |                 | 3                   | 50                                     | 50         | Э                      | pale                       |
| 246              | struc. 5             | 1039N/1062W              |                       |                 | 4                   | 50                                     | 80         | 5                      | med. dark                  |
| 247              | struc. 5             | 1040N/1062W              |                       |                 | 5                   | 15                                     | 1.00       | 9                      | dark                       |
| 248              | struc. 5             | WE901/N5401              |                       |                 | 4                   | 35                                     | 75         | 4                      | med. dark                  |
| 249              | struc. 5             | M1901/N4401              |                       |                 | 4                   | 55                                     | 50         | 3                      | med. dark                  |
| 250              | struc. 5             | 1042N/1063W              |                       | ·               | 4                   | 30                                     | 75         | 4                      | med. dark                  |
| 251              | struc. 5             | 1042N/1061W              |                       |                 | 4                   | 35                                     | 75         | 3                      | med. dark                  |
| 252              | struc. 5             | 1041N/1063W              |                       |                 | 9                   | 10                                     | 100        | 8                      | very dark                  |
| 253              | struc. 5             | M1901/N1501              |                       |                 | 4                   | 01/                                    | 75         | 3                      | med. dark                  |
| 254              | struc. 7             | prov. 22                 |                       |                 | T                   | 120                                    | 0          | 0                      | none                       |
| 255              | struc. 7             | prov. 22                 |                       |                 | 4                   | 40                                     | 75         | 3                      | med. dark                  |
| 256              | struc. 7             | prov. 22                 |                       |                 | 2                   | 60                                     | 30         | 2                      | very pale                  |
| 257              | struc. 7             | prov. 22                 |                       |                 | 4                   | 50                                     | 75         | 4                      | med. dark                  |
|                  |                      |                          |                       |                 |                     |  |            |                        |                            |

| Samp1 | le grld | Sample<br>description | Sample<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | z<br>ring | Length of<br>rays (mm) | Intensity of<br>coloration |
|-------|---------|-----------------------|-----------------|---------------------|--|-----------|------------------------|----------------------------|
|       | 22      |                       |                 | г                   | 120                                    | 0         | 0                      | none                       |
|       | 22      |                       |                 | 3                   | 06                                     | 50        | 3                      | pale                       |
|       | 22      |                       |                 | 2                   | 105                                    | 25        | 1                      | very pale                  |
|       | 22      |                       |                 | 3                   | 06                                     | 50        | 3                      | pale                       |
|       | 22      |                       |                 | 2                   | . 06                                   | 30        | 1                      | very pale                  |
| ÷     | 25      |                       |                 | e                   | ,<br>50                                | 50        | E                      | pale                       |
| 2     | 25      |                       | e.              | 2                   | 95                                     | 25        | 2                      | very pale                  |
|       | 25      |                       |                 | 2                   | 100                                    | 25        | T .                    | very pale                  |
|       | . 24    |                       |                 | 2                   | 01.1                                   | 25        | I                      | very pale                  |
|       | 24      |                       |                 | 2                   | 100                                    | 25        | 1                      | very pale                  |
|       | 24      |                       |                 | 2                   | 06                                     | 25        | 2                      | very pale                  |
| 2.    | 26      |                       | ÷               | 3                   | 60                                     | 50        | £                      | pale                       |

| Intensity of<br>coloration             | pale                                | pale                                | med. dark                            | med. dark                            | pale                                 | pale                                 | pale                                 | very pale                            | pale                                 |
|--|-------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Length of<br>rays (mm)                 | 2                                   | 2                                   | S                                    | 4                                    | 2                                    | e.                                   | 7                                    | T                                    | £                                    |
| %<br>ring                              | 25                                  | 25                                  | 75                                   | 75                                   | 50                                   | 50                                   | 50                                   | 25                                   | 50                                   |
| Time of<br>appearance<br>of rays (sec) | 06                                  | 100                                 | 30                                   | 45                                   | 55                                   | 80                                   | 70                                   | 115                                  | 80                                   |
| Phosphate<br>rating                    | 2                                   | 2                                   | 4                                    | 4                                    | e                                    | e                                    | £                                    | 2                                    | m                                    |
| Samp.Le<br>depth                       |                                     |                                     | 20                                   | 25                                   | 30                                   | 30                                   | 20                                   | 20                                   | 30                                   |
| Sample<br>description                  |                                     |                                     |                                      |                                      |                                      |                                      |                                      |                                      |                                      |
| Sample grid<br>reference               | prov. 26                            | prov. 26                            | N086/N086                            | N086/N086                            | 980N/980N                            | N086/N086                            | 980N/980N                            | - 975N/995W                          | N266/NST6 -                          |
| Feature<br>no., etc.                   | low arti-<br>fact den-<br>sity area | low arth-<br>fact den-<br>sity area | high arti-<br>fact den-<br>sity area |
| Sample<br>number                       | 270                                 | 271                                 | 272                                  | 273                                  | 274                                  | 275                                  | 276                                  | 277                                  | 278                                  |

| Sample<br>number | Feature<br>no., etc.                 | Sample grid<br>reference | Sample<br>description | Samp.Le<br><u>dep.th</u> | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | r<br>r Ing | Length of<br>rays (mm) | Intensity of<br>coloration |
|------------------|--------------------------------------|--------------------------|-----------------------|--------------------------|---------------------|--|------------|------------------------|----------------------------|
| 279              | high arti-<br>fact den-<br>sity area | . 1025N/955W             |                       | 25                       | 4                   | 30                                     | 75         | 4                      | med. dark                  |
| 280              | high arti-<br>fact den-<br>sity area | · 1025N/955W             |                       | 30                       | 4                   | 40                                     | 75         | S                      | med. dark                  |
| 281              | high arti-<br>fact den-<br>sity area | - 1025N/955W             |                       | 35                       | ñ                   | 55                                     | 50         | e                      | pale                       |
| 282              | high arti-<br>fact den-<br>sity area |                          |                       | 25                       | 9                   | 10                                     | 100        | S                      | very dark                  |
| 283              | high arti-<br>fact den-<br>sity area | . W2101/N2101            |                       | 30                       | 2                   | 06                                     | 25         | 2                      | very pale                  |
| 284              | high arti-<br>fact den-<br>sity area | - 1015N/1015W            |                       | 20                       | 3                   | 60                                     | 50         | 'n                     | pale                       |
| 285              | F. 8                                 | prov. 2                  | pit                   |                          | 4                   | 35                                     | 75         | 4                      | med. dark                  |
| 286              | F. 9                                 | prov. 2                  | pit                   |                          | 4                   | 40                                     | 75         | 3                      | med. dark                  |
| 287              | F. 10                                | prov. 2                  | pit                   |                          | 9                   | 1.0                                    | 100        | 9                      | very dark                  |
| 288              | F. 11                                | prov. 2                  | plt                   |                          | 9                   | 10                                     | 100        | 7                      | very dark                  |
| 289              | F. 12                                | prov. 2                  | pit                   |                          | 9                   | 10                                     | 100        | 7                      | very dark                  |
| 290              | F. 13                                | prov. 2                  | pit                   |                          | 5                   | 15                                     | 100        | 9                      | dark                       |

| Sample<br>number | Feature<br>no., etc. | Sample grid<br>reference | Sample<br>description | Sample l<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | %<br>ring | Length of<br>rays (mm) | Intensity of<br>coloration |
|------------------|----------------------|--------------------------|-----------------------|-------------------|---------------------|--|-----------|------------------------|----------------------------|
| 791              | F. 14                | prov. 2                  | pit                   |                   | 9                   | 05                                     | 100       | 1                      | very dark                  |
| 292              | F. 15                | prov. 2                  | plt                   |                   | 4                   | 20                                     | 75        | 3                      | med. dark                  |
| 293              | F. 16                | prov. 2                  | pit                   |                   | 5                   | 25                                     | 100       | 5                      | dark                       |
| 294              | F. 17                | prov. 2                  | pit                   |                   | 4                   | 45                                     | 75        | 4                      | med. dark                  |
| 295              | F. 19                | prov. 2                  | pit                   |                   | ,<br>3              | 75                                     | 50        | 2                      | pale                       |
| 296              | F. 20                | prov. 2                  | pit                   |                   | 4                   | 20                                     | 75        | 3                      | med. dark                  |
| 297              | F. 22                | prov. 2                  | pit                   |                   | 3                   | 09                                     | 50        | ß                      | pale                       |
| 298              | F. 23                | prov. 2                  | pit                   |                   | 3                   | 60                                     | 50        | 2                      | pale                       |
| 299              | F. 24                | prov. 2                  | plt                   |                   | 3                   | 80                                     | 50        | 2                      | pale                       |
| 300              | F. 28                | prov. 2                  | pit                   |                   | 4                   | 35                                     | 75        | 5                      | med. dark                  |
| 301              | F. 29                | prov. 2                  | pit                   |                   | 5                   | 20                                     | 1.00      | 9                      | dark                       |
| 302              | F. 30                | prov. 2                  | pit                   |                   | 3                   | 50                                     | 50        | 2                      | pale                       |
| 303              | F. 31                | prov. 2                  | plt                   |                   | 5                   | 20                                     | 100       | 5                      | dark                       |
| 304              | F. 44                | prov. 2                  | plt                   |                   | 4                   | 40                                     | 75        | ß                      | med. dark                  |
| 305              | F. 81                | prov. 10                 | pit                   |                   | 4                   | 60                                     | 75        | 4                      | med. dark                  |
| 306              | F. 82                | prov. 10                 | pit                   |                   | 9                   | 05                                     | 100       | 8                      | very dark                  |
| 307              | F. 83                | prov. 10                 | pft                   |                   | 9                   | 04                                     | 100       | 9                      | very dark                  |
| 308              | F. 80                | prov. 10                 | burial pit            |                   | 9                   | 02                                     | 100       | 8                      | very dark                  |
|                  |                      |                          |                       |                   |                     |  |           |                        |                            |

| Sample<br>number | Fea | ature<br>., etc. | Samp L<br>refe | e grid<br>rence | Sample<br>description | Sample<br>depth | Phosphate<br>rating | Time of<br>appearance<br>of rays (sec) | %<br>ring | Length of<br>rays (mm) | Intensity of<br>coloration |
|------------------|-----|------------------|----------------|-----------------|-----------------------|-----------------|---------------------|--|-----------|------------------------|----------------------------|
| 309              | ч.  | 85               | prov.          | 10              | burial pit            |                 | 9                   | 05                                     | 100       | 1                      | very dark                  |
| 310              | 5   | 84               | prov.          | 10              | pit.                  |                 | 4                   | 30                                     | 75        | 4                      | med. dark                  |
| 311              | Ρ.  | 36               | prov.          | 10              | pit                   |                 | Ś                   | 20                                     | 100       | 9                      | dark                       |
| 312              | н.  | 12               | prov.          | 9               | pit                   |                 | 4                   | 45                                     | 75        | 2                      | med. dark                  |
| 313              | ч.  | 1.3              | prov.          | 9               | plt                   |                 | 5                   | 70                                     | 50        | 9                      | pale                       |
| 314              | Υ.  | 99               | prov.          | 12              | plt                   |                 | ۲                   | 60                                     | 50        | 3                      | pale                       |
| 315              | F.  | 65               | prov.          | 12              | hearth                |                 | 3                   | 60                                     | 50        | 3                      | pale                       |
| 316              | Г.  | 67               | prov.          | 12              | pit                   |                 | 4                   | 30                                     | . 75      | 4                      | med. dark                  |
| 31.7             | Ρ.  | 20               | prov.          | 12              | pit                   |                 | 5                   | 20                                     | 100       | 9                      | dark                       |
| 318              |     | 72               | prov.          | 12              | pit                   |                 | 4                   | 45                                     | 75        | 4                      | med. dark                  |
| 319              | Ч.  | 74               | prov.          | 12              | pit                   |                 | 9                   | 20                                     | 100       | 5                      | dark                       |
| 320              | Ε.  | 35               | prov.          | 13              | pit                   |                 | 4                   | 50                                     | 75        | 4                      | med. dark                  |
| 321              | Γ.  | 36               | prov.          | 13              | pit                   |                 | 9                   | 05                                     | 1.00      | 9                      | very dark                  |
| 322              | ч.  | 37               | prov.          | 13              | pit                   |                 | 'n                  | 15                                     | 100       | 3                      | dark                       |
| 323              | Υ.  | 39               | prov.          | 13              | pit                   |                 | 4                   | 50                                     | 75        | 4                      | med. dark                  |
| 324              | Ρ.  | 40               | prov.          | 13              | pit                   |                 | 4                   | 20                                     | 75        | 4                      | med. dark                  |
| 325              | Ψ.  | 41               | prov.          | 13              | pit                   |                 | 4                   | 45                                     | 75        | 5                      | med. dark                  |
| 326              | 5   | 55               | prov.          | 18              | plt                   |                 | 4                   | 05                                     | 75        | 3                      | med. dark                  |